# PRELIMINARY GEOTECHNICAL ENGINEERING REPORT WESTMINSTER WATER 2025 PRELIMINARY DESIGN PROJECT WESTMINSTER, COLORADO

**Prepared For:**

CDM Smith
Denver, Colorado

October 9, 2020
Revised March 4, 2021

Olsson Project No. 019-1378

olsson®

March 4, 2021

CDM Smith
Attn: Brian O'Connor, PE, CFM
555 17th Street, Suite 500
Denver, CO 80202

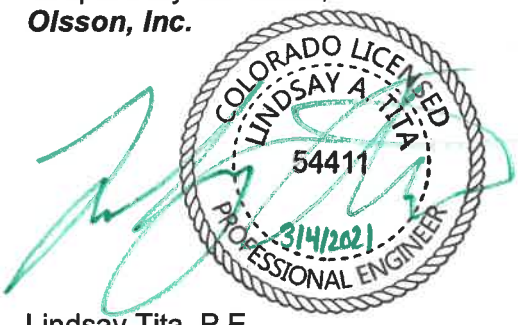
Re: Preliminary Geotechnical Engineering Report
Westminster Water 2025 Preliminary Design Project
Westminster, Colorado
Olsson Project No. 019-1378

Dear Mr. O'Connor,

***Olsson*** has completed the preliminary geotechnical engineering report for the above referenced project. The enclosed report summarizes our understanding of the project at the time of our investigation, presents the findings of the borings and laboratory tests, discusses the observed subsurface conditions, and based on those conditions, provides preliminary geotechnical engineering recommendations for this project.

We appreciate the opportunity to provide our geotechnical engineering services for this project. If you have any questions or need further assistance, please contact us at your convenience.

Respectfully submitted,
***Olsson, Inc.***

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# 1. PROJECT UNDERSTANDING

## 1.1. GEOTECHNICAL SCOPE

This preliminary geotechnical engineering report presents the results of the subsurface exploration completed for the proposed new water treatment facility located east of Westminster Boulevard and north of West 98th Avenue in Westminster, Colorado. Twelve (12) borings were drilled to approximate depths of 50 feet below ground surface (bgs) across the site area and three (3) piezometers were installed at select boring locations at the time of drilling. The purpose of this exploration was to evaluate the subsurface and groundwater conditions, and based on the encountered conditions, provide preliminary geotechnical design recommendations for the proposed water treatment plant, including foundations, pavements, earthwork, and other geotechnical considerations associated with the project. Approximate locations of the borings are shown on the Boring Location Plan in *Appendix A*, and boring logs are provided in *Appendix B*.

## 1.2. SITE INFORMATION

The project is an approximately 40-acre area located along the east side of Westminster Boulevard, from around 650 feet to 2200 feet north of West 98th Avenue in Westminster, Colorado (Figure 1.1). Based on the draft Topographic Exhibit prepared by Flatirons, Inc., draft dated July 8, 2020; the site typically slopes down from the south site bound to the northwest site corner, with a maximum elevation of 5379 feet near the middle of the south property boundary to the minimum elevation of 5326 feet in the northwest corner. The site is currently undeveloped and covered by native grasses, scattered deciduous trees, and shrubs. The site is currently inhabited with a large prairie dog colony and several burrow entrances are visible at the ground surface.

From our review of readily available historical aerial images obtained from Google Earth dating back to 1993, the project site and surrounding areas appear to have remained largely unchanged since in or around September 2002, following the construction of Westminster Boulevard and demolition of the residential and farming property immediately south of the project site that took place sometime between October 1999 and September 2002.


**Figure 1.1: Site Location**

## 1.3. PROJECT INFORMATION

We understand the proposed construction will be built during multiple phases and may include sludge lagoons, filters, sedimentation basins, flocculation basins, a chemical building, storage tanks, associated treatment facilities and pipelines. Construction will also include site pavements and landscaping. We further understand that the construction of the proposed facilities will take place over multiple phases with the Phase I storage anticipated to accommodate approximately 10-percent of the total planned capacity and increase with additional phases. Based on the topography of the site and the nature of the proposed construction, we anticipate cuts on the order of 10 to 25 feet may be necessary to accommodate below-grade construction of the planned structures and ponds, and fills on the order of 5 to 10 feet may be desired to balance the project site and reduce the volume of spoil material.

At the time of this report, design of the facility is currently underway. The intent of our investigation was to drill widely spaced borings across the site in order to characterize the

subsurface conditions at the project area, identify any potential geotechnical concerns, and provide preliminary geotechnical design parameters. Final structural loads, final building configurations, and site grading plans were not available at the time of this report. A final geotechnical exploration and engineering report should be completed later in the design process to verify the recommendations discussed in this report and to provide more detailed geotechnical design information and recommendations for the planned construction.

Preliminary structural loads and traffic loads are provided in the tables below. The preliminary counts were provided by CDM Smith (O'Connor, email correspondence, October 2, 2020). These traffic counts were further refined based on discussions with the City of Westminster and CDM Smith (T. Rynders, email correspondence, February 3-4, 2021).

**Table 1.1. Preliminary Structural Loads**

| Building Name | Shallow Foundations | | Deep Foundations | |
|---|---|---|---|---|
| | Maximum Loads (psf) | Minimum Loads (psf) | Maximum Loads (kips) | Minimum Loads (kips) |
| Sludge Lagoons | 1500 | 100 | 338 | 23 |
| Washwater EQ Basin and Pump Station | 2000 | 350 | 450 | 79 |
| Chemical Building | 2000 | 225 | 450 | 51 |
| Lime Silo Building | 2000 | 225 | 450 | 51 |
| High Service Pump Station | 2000 | 150 | 450 | 34 |
| Electrical Room | 1500 | 400 | 338 | 90 |
| 1.5 MG Storage Tank | 2500 | 75 | 563 | 17 |
| Admin Building | 2000 | 75 | 450 | 17 |
| Flocculation Basin | 2000 | 300 | 450 | 68 |
| Sedimentation Basin | 2000 | 300 | 450 | 68 |
| Ozone | 2000 | 300 | 450 | 68 |
| Filters | 2000 | 900 | 450 | 203 |

**Table 1.2. Preliminary Traffic Loads**

| Vehicle Type | Standard Duty | | Heavy Duty | |
|---|---|---|---|---|
| | Count | Frequency | Count | Frequency |
| Personal Vehicles | 12 | Daily | 18 | Daily |
| Chemical Delivery Trucks (HS-20) | N/A | N/A | 10 | Monthly |
| Drying Bed Waste Trucks (HS-20) | N/A | N/A | 32 | Quarterly |
| Miscellaneous HS-20 Trucks* | 1 | Weekly | 1 | Weekly |
| Dumpster/Trash Truck* | N/A | N/A | 1 | Weekly |
| Fire Truck Loading* | N/A | N/A | 3 | Monthly |

*Values assumed by ***Olsson***, not explicitly provided by CDM Smith or the City of Westminster

The preliminary geotechnical recommendations presented herein are based on the available project information, proposed project location, and the subsurface conditions described in this report. If any of the noted information is incorrect, please inform ***Olsson*** so that we may amend the recommendations presented in this report if appropriate.

# 2. EXPLORATORY AND TEST PROCEDURES

## 2.1. FIELD EXPLORATION

Twelve (12) borings were drilled by ***Olsson*** across the site with an ATV-mounted drill-rig using either hollow-stem or solid-stem, continuous flight augers to approximate depths of 50 feet below the ground surface (bgs). The ***Olsson*** boring locations were selected during the proposal phase and reviewed by CDM Smith prior to mobilization. A portion of the boring locations were selected based loosely on the site plan sketch provided by CDM Smith (Rynders, email correspondence January 31, 2020) then additional boring locations were scattered throughout the site with the understanding that the site features may shift. Borings were located using a hand-held GPS device and adjusted in the field based on available drilling equipment access and positions of underground and overhead utilities. The locations should be considered accurate only to the degree implied by the methods used to obtain them. True coordinates could vary. Approximate final locations of the borings are shown on the Boring Location Plan in *Appendix A* and the ***Olsson*** Boring Logs are provided in *Appendix B*.

Soil samples were obtained at selected intervals in the borings using a standard split-spoon sampler during the Standard Penetration Tests (SPT; “SS” on the boring logs) or a ring lined barrel sampler (“MC” on the borings logs). The standard split spoon sampler was driven in three 6-inch intervals and the ring lined barrel sampler was driven in two 6-inch intervals into the substrata with blows from a 140-pound automatic hammer free-falling 30 inches. Penetration resistance (blow counts) was recorded for each 6-inch drive. Penetration resistance of the final 12 inches is considered SPT “N” values for the SS sampler. The blow counts and SPT “N” values are shown on the boring logs at the respective depths the samples were taken. The blow counts shown for the MC sampler are not equivalent to the blow counts obtained from the SS sampler.

An ***Olsson*** field technician prepared field logs of the material encountered in each boring during the drilling operation. The field logs include the technician’s and driller’s interpretation of the conditions between samples and approximate elevations of each stratum change. The boring logs presented in *Appendix B* have been modified to represent the project engineer’s interpretation of the field logs based on visual classification and laboratory tests of the samples.

Site cross-sections showing the borings and materials encountered within the borings are included in *Appendix D* to assist the project design team and potential contractor in visualizing the subsurface conditions across site. Additionally, a surficial soil zones plan has been included in *Appendix D* showing where, based on the borings and laboratory tests, surficial soil materials and transition zones are most likely located.

## 2.2. LABORATORY TESTING

The samples obtained from the borings were sealed and returned to the laboratory for testing and classification. All recovered soil samples were visually classified using the Unified Soil Classification System (USCS). The moisture contents of all samples were measured in the laboratory. In addition, Atterberg limits, grain size distribution, in-situ density, and percent passing the #200 sieve tests were performed on selected samples. One dimensional swell/consolidation tests were performed on five (5) selected ring lined barrel samples to evaluate the tendency of the materials to expand with moisture changes and consolidate/settle with loading changes. Hydraulic conductivity tests were performed on two (2) selected ring lined barrel samples to evaluate the ability for water to move through the soil in the approximate planned area of the retention ponds and to provide permeability information of the onsite materials to assist with the development of a dewatering plan, as necessary.

One (1) Standard Proctor compaction test and one (1) R-value test was performed on a bulk sample obtained from materials in the upper 5 feet near the center of site at boring B-6. The R-value test result was less than 5, which correlates to a resilient modulus value of approximately 2500 psi (CDOT 2020).

The laboratory test results are presented on the respective boring logs, and in the laboratory test result graphics in *Appendix C*.

## 2.3. SOIL CORROSIVENESS

Laboratory testing was also performed by ***Olsson*** on two (2) bulk soil samples to determine pH, water-soluble sulfate content, water soluble chloride content, and electrical resistivity to evaluate the corrosiveness of the material. The results are presented in *Appendix C* and summarized in the following table.

**Table 2.1: Soil Corrosion Series Test Results**

| Test/Sample Location | Soil Type | Water Soluble Sulfate (% mass) | Water Soluble Chloride (% mass) | pH | Soil resistivity (ohms-cm) |
|---|---|---|---|---|---|
| B-3, 9 to 15.5 feet | Claystone | 0.01 | 0.023 | 7.22 | 357 |
| B-10, 3.5 to 7.5 feet | Sandy clay | 0.09 | 0.019 | 7.63 | 457 |

The resistivity values indicate that the onsite sandy clay soils and claystone bedrock from the bulk samples are considered severely corrosive to buried metal objects. The onsite soils and rock classify as S0 exposure class indicating no specific cement type is required per ACI 318,

based on sulfate levels less than 0.1 percent by mass. An experienced designer should review these results and evaluate corrosiveness in developing the design for this project.

# 3. SUBSURFACE CONDITIONS

## 3.1. SITE GEOLOGY

The following sections describe the geology and potential hazards associated with the project location.

### 3.1.1. REGIONAL PHYSIOGRAPHY

The project site is located in the Colorado Piedmont Subprovince of the Great Plains Province of Colorado. The Colorado Piedmont Subprovince lies between the High Plains and the Front Range of the Rockies, at elevations distinctly lower than the High Plains. The area consists of a series of river terraces which represent former floodplain levels of the South Platte and Arkansas Rivers and their principal tributaries (Wishart 2011). The Colorado Piedmont Subprovince is bordered by the Raton Basin to the south, the High Plains to the east and north, and the Southern Rocky Mountains to the west.

### 3.1.2. LOCAL GEOLOGY AND SOILS

The surficial geology, as mapped by Machette (1977) consists of Pinedale-Bull Lake Interglaciation and Late Bull Lake Aged loess. Thickness of the loess is commonly 3 to 5 feet thick with local areas up to 10 feet thick. The loess is described as light-gray-brown to light-brown nonstratified fine sand and silt, and forms a mantle covering bedrock and alluvium.

The USDA soil survey maps the entire project site within the Nunn-Urban land complex (0 to 2 percent slopes), which is comprised of 65 percent Nunn soil unit, 20 percent Urban Land soil unit, and 15 percent minor soil units. The Nunn unit is noted as clay loam, clay, and loam extending from 0 to 60 inches in depth and is hydrologic group C. Depth to bedrock and depth to water table are both indicated as greater than 60 inches.

Bedrock geology, as mapped by the Tweto (1979), includes Tertiary-Cretaceous aged Denver and Arapahoe Formations. These sedimentary bedrock formations include sandstone, mudstone, claystone, and conglomerate bedrock materials.

### 3.1.3. GEOLOGIC AND GEOTECHNICAL HAZARDS

***Olsson*** has reviewed the project area, geologic conditions, and published information with regard to site conditions and potential geologic and geotechnical hazards. The following sections discuss commonly considered hazards and the anticipated potential for these to affect development of the project.

#### 3.1.3.1. Seismicity and Faulting

There are no active folds or faulting in the vicinity of the project area (USGS Quaternary Fault Database, 2020). The nearest fault line appears to be the Golden Fault in Golden, Colorado, approximately 10 miles from the project site.

Overall, the seismicity and faulting risks in the vicinity of the site appear low. Seismicity for project design is further discussed in *Section 6.6*.

#### 3.1.3.2. Collapse and Swell Potential

Clays and claystone bedrock across the Rocky Mountain Front Range are known to have variable swell potential, which has been extensively mapped by Hart (1974). The project area, as identified by Hart, lies in an area of moderate swell potential and notes that special foundations are generally necessary to prevent foundation damages.

Soils with moderate to high plasticity are considered to have shrink/swell potential. In general, soils with liquid limit values less than 50 and a plasticity index less than 25 are considered to have low shrink-swell potential. Soils with liquid limit values of 50 to 60 and a plasticity index of 25 to 35 are considered to have moderate shrink-swell potential. Soils with liquid limit values greater than 60 and a plasticity index value greater than 35 are considered to have high shrink-swell potential (Das, 2010).

Sand and silt soils generally have low plasticity and are not considered susceptible to significant swell potential. Lean clay soils (low to moderate plasticity) are generally anticipated to have a liquid limit value less than 50 and a plasticity index value less than 25 and exhibit low to moderate swell potential. Fat clay soils (moderate to high plasticity) have a liquid limit value greater than 50 and a plasticity index value greater than 25 and exhibit high swell potential. Swell potential of the on-site soils is further discussed in *Section 4*.

#### 3.1.3.3. Subsidence from Oil and Gas Production

Oil and gas production is prevalent across the state of Colorado and is regulated by the Colorado Oil and Gas Conservation Commission (COGCC). From publicly available mapping through the COGCC website, it appears no oil and gas production facilities are in the vicinity of the project site. Groups of active production wells were noted to the west, north, and northeast of the project site, but appear to be more than 3 miles from the approximate project area. Subsidence risk due to oil and gas development is considered low.

#### 3.1.3.4. SLOPE STABILITY

The relief across the site is relatively flat, with approximately 55 feet of grade change across the entire 40-acre project area, with an approximate slope on the order of 2.7 percent. Global slope instability issues are not anticipated for the site due to the relatively flat grades.

#### 3.1.3.5. FLOODING

A review of mapped flooding potential from the FEMA flood mapping website indicate there are regulatory floodways located approximately 330 feet east of the east project boundary and approximately 1000 feet north of the northwest site corner. There are also localized areas of Zone AE (1% annual chance flood) and Zone X (0.2% annual chance flood), primarily northwest of the site.

Within the site boundaries, there are no flooding plains mapped and there should be low potential for flooding.

## 3.2. SOIL STRATIGRAPHY

Specific conditions at each ***Olsson*** boring location are shown on the boring logs in *Appendix B*. The logs represent subsurface conditions at each specific boring location. Stratification boundaries shown on the boring logs represent the approximate depth of changes in soil types. The changes are more gradual in-situ. The boring logs do not reflect variations that may occur between borings or across the project site. The nature and extent of such variations may not become evident until construction.

The subsurface conditions ***Olsson*** encountered in the borings generally consisted of stiff to very stiff clay with lesser amounts of sand overlying claystone and sandstone bedrock. In some borings, a thin layer of clayey sand was encountered between the surficial clay and underlying bedrock materials. The surficial material at the boring locations consisted of a thin root zone layer of organic-rich clay approximately 3 to 6 inches deep. Below is a further description of the materials encountered during ***Olsson's*** subsurface exploration. The specific descriptions within each boring can be found on the boring logs in *Appendix B*.

**CLAY:** Within all twelve (12) borings, clay was encountered immediately underlying the surficial material/root zone. The clay ranged from low plasticity (lean) to high plasticity (fat), with the higher plasticity soils encountered in the northern portion of the site. Our index testing generally exhibited a trend of decreasing plasticity in surficial clays the further southeast the samples were obtained. The clay soils have varying sand content, with up to 49.2 percent sand. The onsite clays classify as USCS CL and CH soils based on liquid limits ranging from 37 to 56 percent and plasticity indices between 21 and 36 percent. Three one-dimensional swell-

consolidation tests were run on clay soil samples obtained from borings across the site; these materials exhibited swell potentials ranging from 2.1 to 3.2 percent under surcharge pressures of 500 psf and 6.2 percent under a surcharge pressure of 150 psf, indicating moderate to high swell risk potential (CDOT 2020). Laboratory testing performed on the clay soil samples resulted in unconfined compressive strengths of 7.9 and 10.6 tons per square foot. One flexible wall permeability test run on overburden clay materials resulted in a hydraulic conductivity of approximately 5.4 X $10^{-6}$ (cm/s).

**SANDS:** In borings B-2 and B-10, a layer of clayey sand (4.5 and 3.0 feet thick, respectively) was encountered underlying the surficial clays and immediately overlying bedrock. The sand materials were typically medium dense and contained fine grained sand with fines on the order of 43.6 percent. The sand soils were categorized as USCS classification SC (clayey sand).

**BEDROCK:** Bedrock was encountered within all borings underlying the surficial soils at depths ranging from 4.8 to 9.5 feet below the existing grade. Bedrock consisted of interbedded sandstone and claystone with some minor lenses of siltstone, as typical of the Arapahoe and Denver bedrock formations. The bedrock was relatively soft and was penetrated using standard auger drilling methods. Rock coring was not required to reach the boring termination depths. The anticipated excavation efforts of the bedrock materials are further discussed in *Section 5.1*.

SANDSTONE**:** Poorly to moderately cemented sandstone bedrock was encountered in significantly thick layers within all borings except B-12 as was typically interbedded with claystone throughout the explored depth. The sandstone had a fines content on the order of 35.4 percent and tested unconfined strengths ranging from 2.6 to 3.8 tons per square foot.

CLAYSTONE**:** Claystone bedrock was encountered in all borings at various depths throughout the bedrock materials and varied from slightly to highly weathered. The claystone was typically described in the field as moderately plastic; one Atterberg limits test run on claystone resulted in a liquid limit of 40 percent and plasticity index of 25 percent and had relatively high sand content, up to 35.9 percent sand in the one tested sample. One-dimensional swell-consolidation tests were run on 2 claystone samples and exhibited swell potentials of 3.4 percent under a 500 psf surcharge pressure and 1.2 percent under a 1000 psf surcharge pressure. Laboratory unconfined compressive strength performed on one sample of slightly weathered claystone resulted in a strength of 8.2 tons per square foot. One flexible wall permeability test run on claystone bedrock and resulted in a hydraulic conductivity of approximately 2.8 X $10^{-7}$ (cm/s).

## 3.3. GROUNDWATER OBSERVATION

Water levels were observed and recorded at the boring locations during drilling and immediately upon completion. Water was encountered in 8 of the 12 borings, with water levels varying from approximately 7.0 to 30.0 feet bgs. The depths to water in the borings are shown in the respective boring logs and summarized in *Table 3.1*. The boring elevations were interpolated from the Draft Topographic prepared by Flatirons, Inc. and dated July 8, 2020. The elevations provided below should be considered approximate.

**Table 3.1: Groundwater Levels – Observations During and Immediately After Drilling**

| Boring No. | During Drilling | | Immediately After Drilling | |
|---|---|---|---|---|
| | Depth (bgs, feet) | Approximate Elevation (feet) | Depth (bgs, feet) | Approximate Elevation (feet) |
| B-1 | Not encountered | Not encountered | Not encountered | Not encountered |
| B-2 | 17.0 | 5328.5 | 34.2 | 5311.3 |
| B-3 | 34.0 | 5306.0 | Not encountered | Not encountered |
| B-4 | 34.0 | 5308.5 | 33.5 | 5309.0 |
| B-5 | 40.0 | 5310.5 | 38.6 | 5311.9 |
| B-6 | 40.0 | 5312.0 | 47.6 | 5304.4 |
| B-7 | 19.0 | 5334.0 | 33.7 | 5319.3 |
| B-8 | 36.4 | 5320.1 | 47.4 | 5309.1 |
| B-9 | 35.0 | 5325.0 | 34.6 | 5325.4 |
| B-10 | Not encountered | Not encountered | Not encountered | Not encountered |
| B-11 | Not encountered | Not encountered | Not encountered | Not encountered |
| B-12 | Not encountered | Not encountered | Not encountered | Not encountered |

*Note: Elevations were interpolated from the draft Topographic Exhibit dated July 8, 2020.*

During our investigation, three monitoring wells (piezometers) were installed to depths of 50 feet at boring locations B-1, B-6, and B-12 to allow for periodic long-term monitoring of the groundwater levels across the project site. The monitoring wells were installed with a 20-feet screen from approximately 30 to 50 feet bgs and solid riser pipe extending to the ground surface. Based on the water level elevations encountered during our exploration and our understanding of the subsurface materials encountered within our borings, it appears that groundwater is generally encountered either within sandy claystone lenes or within interbedded sandstone layers.

At the time of this report, one reading had been taken approximately a week following installation of the piezometers. Seasonal groundwater measurements are planned through summer 2021. The depths and approximate elevations observed are summarized in Table 3.2.

**Table 3.2: Groundwater Levels – Monitoring Well Observations**

| Boring No. | Date of Measurement | Approximate Ground Surface Elevation (feet) | Depth to Groundwater (bgs, feet) | Approximate Elevation of Groundwater (feet) |
|---|---|---|---|---|
| B-1 | 8/31/2020 | 5334.0 | 12.4 | 5321.6 |
| B-6 | 8/31/2020 | 5352.0 | 17.4 | 5334.6 |
| B-12 | 8/31/2020 | 5373.0 | 21.4 | 5351.6 |

*Note: Elevations were interpolated from the draft Topographic Exhibit dated July 8, 2020.*

Based on the water level elevations encountered variations and uncertainties exist with the relatively short-term water levels observed and recorded during this exploration and in the monitoring wells to date. Water levels can and should be anticipated to vary between boring locations as well as with time within a specific boring. Water also tends to be present near the soil and bedrock interface and can flow through joints in the bedrock. Groundwater levels may be expected to fluctuate with precipitation, site grading, drainage and adjacent land use. **Excavations that extend below the water elevation will need to be adequately dewatered for proper subgrade preparation and other construction activities**.

# 4. GEOTECHNICAL CONSIDERATIONS

## 4.1. EXPANSIVE SOILS AND BEDROCK

The onsite soils selected for swell potential testing were determined to have moderate to high swell potential based on the laboratory one dimensional swell/consolidation tests and bedrock materials exhibit low to moderate swell potential. The resulting magnitude of volume change for these expansive materials depends on various factors including soil composition, in-situ moisture content, in-situ density, and the change in moisture content. The test results are summarized in the table below:

**Table 4.1: Summary of expansion potential based on one-dimensional consolidation/swell tests**

| Test/Sample Location | Material | In-situ moisture (%) | In-situ dry density (pcf) | Inundation Pressure (psf) | Percentage swell (%) | Swell pressure (psf) |
|---|---|---|---|---|---|---|
| B-3 @ 3.5’ | Fat clay with sand | 15.2 | 103.9 | 500 | 3.16 | 5,200 |
| B-3 @ 9.0’ | Claystone | 22.9 | 99.6 | 1,000 | 1.21 | 4,200 |
| B-6 @ 3.5’ | Lean clay with sand | 10.0 | 110.1 | 500 | 2.13 | 3,500 |
| B-7 @ 1.0’ | Lean to fat clay with sand | 12.9 | 115.3 | 150 | 6.15 | 6,900 |
| B-7 @ 6.0’ | Claystone | 17.0 | 104.9 | 500 | 3.41 | 7,000 |

Based on an assessment of slab performance risk at the site, conducted in general conformance with local industry guidelines (CAGE, 1996), it is our opinion that moderate to potentially high slab performance risk exists at the site. Slab-on-grade movements of 2.25 to 3.4 or more inches, were calculated for various assumed depths-of-wetting. Slab movements of that magnitude could result in associated slab cracking on the order of ¼-inch width or more for slabs constructed directly on the native clays and claystone. Further, the laboratory swell pressures all exceed the anticipated shallow foundations loads which could lead to intolerable movements and distress to foundations elements constructed directly on the expansive soils and/or rock at the site. Therefore, we recommend subgrade mitigation at the proposed foundation footprints, and critical floor slabs, as discussed in *Section 6* This will be especially important for basins or other structures which will be required to contain fluids on poured concrete slabs.

To reduce soil movement due to swell and to provide uniform support below pavements, overexcavation of the in-situ soil or bedrock underlying pavements is recommended as discussed in *Section 7.1*. Overexcavated soils or bedrock should be backfilled or replaced with controlled structural fill per *Section 5.2*.

## 4.2. GROUNDWATER

At the time of ***Olsson's*** exploration, groundwater was encountered in eight of the twelve borings at depths ranging from approximately 17.0 feet to 47.6 feet. When checked approximately a week after drilling, the water levels were measured from 12.4 to 21.4 feet within the piezometers (B-1, B-6, and B-12). At these depths, groundwater or saturated soil conditions may impact site grading and earthwork operations if cuts on the order of 10 to 20 feet are required to level the site or construct ponds or basins. Groundwater may also be encountered during utility and/or below grade structure installation. Excavations that extend below the water elevation will need to be adequately dewatered for proper subgrade preparation. The design, operation, and maintenance of the dewatering system during construction is the responsibility of the contractor. Additionally, perimeter underdrain systems are recommended for buildings and tanks to protect below grade foundations and reduce potential settlement of fill materials.

## 4.3. DEPTH OF WETTING

The client should understand that some potential risk of movement exists for the use of shallow foundations on sites underlain by soils and bedrock with swelling potential within the depth of wetting zone. The depth of wetting will also dictate the recommended length of deep foundations. Several factors can affect the depth of wetting which can vary from site to site. There is no absolute method to determine the depth of wetting however, Walsh et. al (2009) provide a probability study for the depth of wetting in the Denver metropolitan area. Their findings are presented in the table below.

**Table 4 2: Walsh et. al (2009) Probability of Depth of Wetting in the Denver Metropolitan Area**

| Assumed Depth of Wetting (Feet bgs) | Probability that the Actual Depth of Wetting will Exceed the Assumed Depth of Wetting |
|---|---|
| 15 feet | 60% |
| 20 feet | 30% |
| 25 feet | 6% |
| 30 feet | 1% |
| 35 feet | 0.1% |

The amount of potential heave is dependent on the depth of wetting. Estimated heave amounts will increase as the depth of wetting increases. It is our opinion that an assumed depth of wetting of 25 feet is appropriate for this site. However, to further reduce potential risk, the assumed depth of wetting could be increased.

# 5. SITE PREPARATION

## 5.1. General Site and Subgrade Preparation

All topsoil, vegetation, major root systems, organic soils, and any loose, soft, or otherwise unsuitable or deleterious material should be stripped and removed from the entire construction area. These materials should be carefully separated to avoid incorporation into structural fill. Based on our observations in the borings, the topsoil/root zone where present was approximately 3 to 6 inches thick across the site; however, the contractor should be prepared for areas with deeper root zones across the project site.

Site clearing, grubbing, and stripping should be completed during periods of dry weather. Operating heavy equipment on the site during periods of wet weather could result in excessive pumping and rutting of the subgrade soils.

As previously discussed, the site is currently inhabited with a large population of prairie dogs. To reduce potential settlement of the proposed structures due to burrow collapse, the prairie dog tunnels should be excavated and thoroughly compacted during construction.

The results of the geotechnical exploration indicate shallow bedrock consisting of weak sedimentary rock (claystone and sandstone). Conventional excavation machines are anticipated to be suitable for excavation of most of the foundations; however, heavy excavation equipment may be needed for areas of planned deep excavations or where hard cemented sandstone is encountered. The contractor should review the boring logs included in *Appendix B* to determine where heavy equipment may be necessary based on materials and SPT “N” values

After grubbing, stripping, demolition, site grading, and any required excavation, but prior to placement of structures, pavements, or fill in areas below design grade, the exposed soil subgrades should be prepared by scarifying, moisture conditioning and recompacting at least the upper 12 inches of exposed surface as recommended in *Table 5.1*. If excavations or site grading exposes bedrock materials, these materials should be surface compacted using a fully weighted smooth drum roller to confirm the stability of the bedrock surface. Any localized zones of soft materials should be excavated and replaced with approved structural fill as recommended in *Section 5.2*. At the time of placement, the areas to receive fill should not be frozen and any ice, snow, or standing water should be removed. The use of a smooth cutting edge on the excavation bucket will help reduce subgrade disturbance at the base of foundation trenches.

Options and considerations for overexcavation of the different project elements, including shallow foundations, mat foundations, slabs-on-grade, and pavements, are discussed in *Sections 6* and *7* of this report. These recommendations are based on the subsurface information available as part of our preliminary field investigation and may be revised following the final geotechnical engineering investigation later in the design process. Overexcavated areas should be backfilled with controlled and engineer approved structural fill, in accordance with *Section 5.2* of this report. In addition, following moisture treatment and compaction the prepared subgrade should be proofrolled with a fully loaded, tandem-axle dump truck or other wheeled equipment with minimum gross weight of 20 tons, wherever access for the equipment is feasible. Proofrolling aids in delineating soft or loose areas that may exist below subgrade level. Unsuitable areas identified by visual observation or proofrolling should be improved by compaction in-place or by overexcavation and replacement of the unstable soil with compacted structural fill.

We recommend an ***Olsson*** geotechnical engineer, or their authorized representative, evaluate the base of new construction excavations prior to the placement of any new fill soils or pavements. We further recommend that an ***Olsson*** representative be on-site to observe and document uniform and stable subgrade conditions prior to placing new structural fill, structures, or pavement.

## 5.2. Structural Fill

The on-site lean clays are suitable for reuse as structural fill provided the higher plasticity soils are blended with lower plasticity soils such that their resulting liquid limit is less than 45, plasticity index less than 20, and have a swell potential that is less than 1% under an inundation pressure of 500 psf. Laboratory plasticity and swell documentation of blended materials should be provided to ***Olsson*** for review and approval prior to placement. Excavated claystone bedrock materials are not suitable for reuse as structural fill and should be removed from the site. Excavated sandstone may be reused as fill provided the material is free of claystone fragments and processed to have a maximum particle size of 3 inches.

During excavation, we recommend that apparent fat clay materials be separated and stockpiled away from apparent lean clay materials. A geotechnical engineer or geologist from ***Olsson*** should be onsite during excavation to visually classify excavated materials and collect samples for laboratory testing to confirm the field classifications.

Fat clays are not appropriate for use as structural fills or as retaining wall backfill but may be placed as general site landscaping fill in areas that are not intended for future facility expansions.

Imported fill materials, if required, should be low plasticity, cohesive acting, non-expansive, sandy clays or clayey sands with a liquid limit less than 45, a plasticity index less than 20, have at least 25 percent passing the #200 sieve, and have a swell potential that is less than 1% under an inundation pressure of 500 psf. If alternate borrow materials are considered, we recommend the contractor provide supplier gradation and/or laboratory plasticity and remolded swell documentation to ***Olsson*** for review and approval prior to site delivery. ***Olsson*** should be onsite to provide regular monitoring of either import or blended materials during earthwork activities to document consistency with the soil parameters recommended in this report.
The figure below provides preliminary boundaries assumptions for where lean clays verses fat clay surficial materials may be encountered. The boundaries were estimated based on the materials encountered within ***Olsson's*** widely spaced boring locations. We categorized lean-to-fat clays with moderate or higher swell potential as fat clays for the purpose of our structural fill recommendations. These areas are subject to change following the final investigation and other inter-boring location variability may also be encountered. A more detailed surficial zone plan is provided in *Appendix D*.

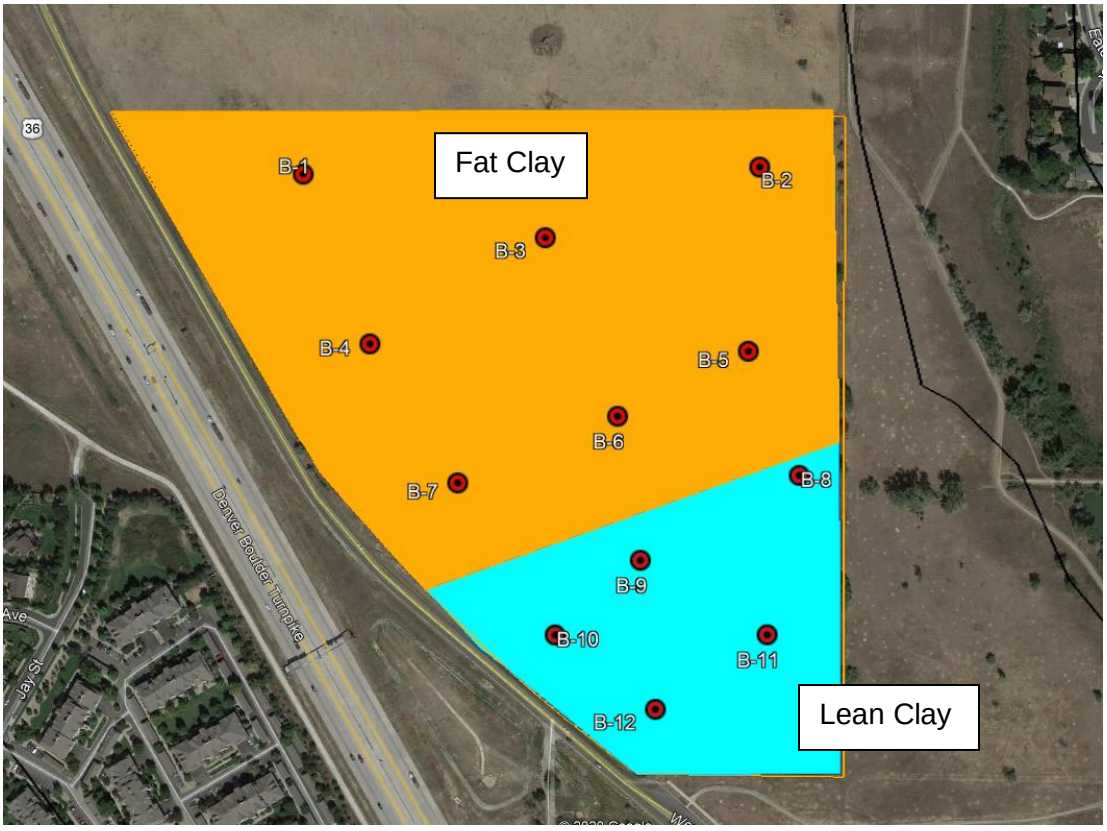


**Figure 5.1: Approximate Preliminary Lean Clay vs Fat Clay Boundaries**

All structural fill soils should be free of debris, organics, and other unsuitable materials, and should not be frozen or include ice at the time of placement.

New fill should be placed in maximum loose lift thicknesses of 8 inches and compacted as recommended in *Table 5.1*. The lift thicknesses should be limited to 4 inches when compacting in small areas requiring hand-operated equipment such as vibrating plate compactors, walk behind trench rollers, or jumping jacks.

An ***Olsson*** representative should be on site full time throughout placement of fill materials to observe and monitor the excavation and grading operations and perform field density tests to document that recommended moisture and compaction requirements are being achieved.

**Table 5.1: Fill Placement Guidelines**

| Areas of Fill Placement | Material | Minimum Compaction Recommendation | Moisture Content (% of Optimum) |
|---|---|---|---|
| General subgrade preparation, overexcavation backfill underlying pavements, and trench backfill | Onsite excavated or imported low plasticity predominantly sandy soils (SC, SC/SM) | 95% Standard Proctor (ASTM D698) | -2 to +2 percent |
| | Onsite excavated, onsite blended, or imported low plasticity, non-expansive, cohesive predominantly clay soils (CL, CL/ML) | 95% Standard Proctor (ASTM D698) | -1 to +3 percent |
| Overexcavation backfill or site fill underlying structures | Onsite excavated or imported low plasticity predominantly sandy soils (SC, SC/SM) | 98% Standard Proctor (ASTM D698) | -2 to +2 percent |
| | Onsite excavated, onsite blended, or imported low plasticity, non-expansive, cohesive predominantly clay soils (CL, CL/ML) | 98% Standard Proctor (ASTM D698) | -1 to +3 percent |
| Immediately below floor slabs | Non-cohesive granular fills (No. 57 stone meeting ASTM C-33 specifications) | 95% Standard Proctor (ASTM D698) | Necessary Moisture Content to reach compaction |

| Areas of Fill Placement | Material | Minimum Compaction Recommendation | Moisture Content (% of Optimum) |
|---|---|---|---|
| Aggregate Base Course | Non-cohesive granular fills (CDOT Class 6 material) | 95% Modified Proctor (ASTM D1557) | -2 to +2 percent |
| Utility trench | Granular bedding | 95% Standard Proctor (ASTM D698) | Necessary moisture content to reach compaction |

The moisture content for the structural fill at the time of compaction should generally be maintained between the ranges specified above. More stringent moisture limits may be necessary with certain soils and some adjustments to moisture contents may be necessary to achieve compaction in accordance with project specifications.

## 5.3. Drainage Considerations

The long-term performance of the structures is dependent on reducing or eliminating moisture infiltration into the subgrade materials. Water should not be allowed to collect at the ground surfaces near foundations, critical project elements, or areas of new pavement, either during or after construction. Provisions should be made to quickly remove accumulating seepage water or storm water runoff from excavations. Undercut or excavated areas should be sloped toward one corner to allow rainwater or surface runoff to be quickly collected and gravity drained or pumped from construction areas. Subgrade soils that are exposed to precipitation or runoff should be evaluated by ***Olsson*** prior to the placement of new fill, reinforcing steel, or concrete to determine if corrective action is required.

To minimize concerns related to improper or inadequate drainage away from foundation bearing subgrades or from cohesive backfill materials used in utility trenches, we recommend the following:

- Provide for efficient drainage of rainfall or surface runoff away from new structures. Water should not be allowed to pond near foundation elements.
- Underdrain systems are recommended for below grade construction to help protect and prevent hydrostatic pressure buildup of foundation walls and to reduce the potential settlement of fill materials. Underdrains should be installed around all building foundation systems and tank foundation systems to collect water runoff and redirect moisture away from areas of structural fill. Moisture should be gravity drained to daylight or collected in

a sump and pump system, the drain outlet should be directed away from the foundation area and discharged well beyond the limits of the backfill zone.

- In addition, as a part of structure maintenance, we recommend that the finished grade slopes be periodically inspected and reestablished, as necessary.
- Depending on the depths of excavations and foundations, a permanent dewatering system may need to be considered. Site grading was not available at the time of this report. Further discussion of potential dewatering concerns based on the groundwater table should be included in the final geotechnical engineering report following development of a site grading plan and completion of additional monitoring well water level observations.
- Any drainage swales or outlets should be located at least 10 feet away from any foundation elements or other critical structures.
- Roof run-off should be collected and discharged directly to the storm sewer system or directed to a location with positive and rapid drainage away from new structures and well beyond the foundation backfill extents.
- External hose connections in unpaved areas should incorporate splash blocks to prevent accidental flooding of foundation bearing or backfill soils. External hose connections should have cut-off valves inside the building to prevent accidental or unauthorized use.
- Site grading should provide for efficient drainage of rainfall or surface runoff away from new structures and pavements.
- Pavement run-off should be collected and discharged directly to the storm sewer system or directed to a location with positive and rapid drainage away from new structures and pavements.
- Landscape irrigation amounts could be reduced with the use of xeriscaping. Xeriscape rather than traditional landscaping is recommended near buildings and other critical structures.

## 5.4. Temporary Slopes and Excavations

Construction site safety is the responsibility of the general contractor. The contractor shall also be solely responsible for the means, methods, techniques, sequencing, and operations during construction. ***Olsson*** is providing the following information solely as a service to our client. Under no circumstances should ***Olsson***'s provision of the following information be construed to mean that we are assuming responsibility for construction site safety or the contractor's activities. Such responsibility is not implied and should not be inferred.

The contractor should be aware that slope height, slope inclination, and excavation depths (including utility trench excavations) should in no case exceed those specified in local, state, or federal safety regulation; e.g., *OSHA Health and Safety Standards for Excavations, 29 CFR*

*Part 1926,* or successor regulations. Such regulations are strictly enforced and, if not followed, the owner, contractor, or earthwork or utility subcontractor could be liable for substantial penalties.

Temporary slopes exceeding 5H:1V should be properly benched prior to placement of new fill to reduce the potential for slippage between existing slopes and fills. Benches should be wide enough to accommodate compaction and earth moving equipment, and to allow placement of horizontal lifts of fill. As an alternative to flatter and benched temporary slopes, vertical excavations can be temporarily shored. The contractor should be responsible for the design of temporary shoring in accordance with applicable regulatory requirements.

Permanent fill and cut slopes at the site should not exceed 3H:1V. Where steeper slopes are planned, additional analysis should be performed once grading plans have been developed.

If excavations, including utility trenches, are extended to depths of more than 20 feet, OSHA requires that the side slopes of such excavations be designed by a professional engineer registered in the state where construction is occurring. Utility trench shoring may also be necessary in areas constrained by existing structures or infrastructure. ***Olsson*** is available to provide supplemental design recommendations for shoring systems.

## 5.5. UTILITIES

We recommend the subgrade supporting utility pipes should be prepared as recommended in *Section 5.1*. Granular pipe bedding is acceptable and should be placed over the prepared subgrade and compacted per *Section 5.2*. In accordance with the City of Westminster, utility trench backfill material shall be deposited in uniform horizontal layers which may not exceed six inches (6") (compacted depth).The remaining trench should be backfilled using the soils originally removed from the trench excavations as long as these soils meet the structural fill requirements and have a compatible gradation with the granular bedding material below such that this backfill does not migrate into the granular material causing unexpected settlement. On the other hand, if the gradation of this backfill is not compatible, we recommend a separating fabric be installed between the granular bedding material below and this backfill. The trenches should be backfilled with properly compacted structural fill placed in accordance with *Section 5.2* of this report. In places where proper compaction of the backfill cannot be achieved, the utility trenches should be backfilled with flowable fill or controlled low-strength materials (CLSM) and the material should completely surround the utility line.

To restrict water infiltration into the trenches, the utility trenches not covered with pavement or concrete flatwork should be capped with at least 1 foot of low permeability clay soils extending

at least 3 feet outside of the perimeter of the trench. In addition, where utilities will penetrate the footprint of the building, it is recommended that a utility trench "plug" be constructed around the utilities that extends at least 5 feet beyond the perimeter of the structure. The trench plug should consist of non-expansive cohesive backfill materials having at least 50 percent passing the #200 sieve, to provide a moisture barrier within the influence zone of the new structure. Further flexible utility connections should be considered where possible and openings within foundation walls should be oversized by a couple inches.

Water should be prevented from entering utility trenches before and during construction. While in service, the utility designer should consider the potential impact of groundwater on the utilities depending on its depth. Extended excavations should not remain open if rain and/or snow is anticipated. Excavations should be backfilled as soon as possible with approved structural fill to reduce the potential for moisture infiltration or sidewall sloughing. Depending on the final planned pipe elevations, consideration of an underdrain system may be warranted.

We understand that both raw and treated water pipes are planned throughout the distribution system as part of the City of Westminster's 2025 Process Plans. The above discussion and the recommendations in this report do not address any utilities planned outside the bounds of the water treatment facility project area. Separate investigation(s) should be performed to develop design and construction recommendations for pipelines throughout the distribution network.

## 5.6. Construction Equipment Mobility

The onsite subgrade soils consisting of significant amounts of clay are anticipated to be susceptible to degradation under repeated construction equipment traffic and may be unstable and cause excessive pumping and rutting when exposed to high moisture levels under repeated traffic loads. Therefore, necessary precautions should be made to avoid excessive degradation of the subgrade soils, including use of lightly loaded track mounted equipment in lieu of heavy rubber-tired equipment. Temporary stabilization techniques may be required depending on severity of the degradation or weather conditions.

Some general guidelines for reducing equipment mobility problems and addressing potential soft and wet surface soils are as follows:

- Optimize surface water drainage at the site during construction.
- Whenever possible, wait for dry weather conditions to prevail, and do not operate construction equipment on the site during wet conditions. Temporarily recompact loose subgrade soils if rain is forecast to promote site drainage and reduce moisture

infiltration. Ruts caused by construction vehicle traffic will accelerate subgrade disturbance.

- Disc or scarify wet surface soils during periods of favorable weather to accelerate drying.
- Use construction equipment that is well suited for the intended job under the existing site conditions. Heavy rubber-tired equipment typically requires better site conditions than lightly loaded track-mounted equipment.

It may be necessary to take steps to aggressively improve equipment mobility if construction must proceed during unfavorable conditions. In our experience, sheepsfoot rollers are likely the best suited compaction equipment based on the subsurface materials encountered.

# 6. STRUCTURES

We understand that design of the facility is currently underway and in preliminary stages. A range of expected structural loads has been provided to ***Olsson*** by CDM Smith, as noted in *Section 1.3*; however, grading plans and final maximum structural loads were not available at the time of this report. The discussions below presents a range of options for consideration by the project team which may further be refined in the final geotechnical engineering report.

## 6.1. SHALLOW FOUNDATION DESIGN

Provided the subsurface modifications in this section are followed, the site appears suitable for supporting the facility structural loads on conventional shallow spread or trench type foundations. As previously discussed in *Section 4*, moderate to high swell potentials were encountered in subsurface soils across the site in the clay soils and claystone bedrock. To reduce potential movement due to soils with moderate to high swell potential, we have provided the following options for overexcavation and support of the footings.

Shallow Foundation Option 1: Footings will be supported by a minimum 6 feet of approved structural fill, placed in accordance with *Section 5.2*, either by overexcavating and replacing the native materials or by raising the existing site grade. Prior to placement of structural fill, the exposed soil or bedrock materials should be prepared per *Section 5.1*.

Shallow Foundation Option 2: Foundations with minimum dead loads supported on a minimum 3 feet of approved structural fill, placed in accordance with *Section 5.2.* We recommend that the footing foundations be designed for a minimum loading of at least 1/3 of the final allowable net bearing pressure to resist some of the uplift due to potential swelling. If there are difficulties attaining the recommended minimum loads, an isolated perimeter pad foundation may be considered. The minimum void height below the foundation stem wall and between isolated perimeter pads has not been estimated at this time due to various project unknows however, based on our preliminary subsurface information we anticipate voids of approximately 3 to 5 inches will be required. The structural fill depths may be accomplished either by overexcavating and replacing the native materials with approved structural fill or by raising the existing site grade with approved structural fill. Prior to placement of structural fill, the exposed soil or bedrock materials should be prepared per *Section 5.1.* Extra caution during construction should be taken to ensure that void cartons are not punctured and filled with concrete, if this occurs the damaged cartons should not be allowed to remain in place and should be replaced.

Depending upon final building elevations, foundation depths, and quantity of cut and fill, the net allowable soil pressure may vary significantly. Based on our limited field exploration, we

anticipate a maximum allowable net bearing pressure on the order of approximately 3,000 to 4,000 pounds per square foot (psf) for a shallow foundation system bearing on structural fill placed to the depths recommended in this section and placed in accordance with *Sections 5.1 and 5.2*. The net allowable bearing capacity can be increased by 1/3 for transient loadings (short term loading such as wind load or seismic load) when used with the alternative basic load combinations of Section 1605.3.2 of IBC 2015.

Total and differential settlement amounts were not estimated at this time due to the variability of loads, subgrade soils, and footings depths and should be evaluated during the final geotechnical investigation and report. Differential settlement on the order of 1-inch total and 0.5-inches differential is generally tolerable for typical structures. Based on the soils encountered, it is anticipated that these settlement limits can be achieved with shallow spread foundations at this site, however, it should be noted that the anticipated allowable net bearing pressures indicated above may need to be modified if settlement controls the design.

For either option, building footings should have minimum dimensions in accordance with local building codes. ***Olsson*** recommends minimum dimensions of 18 inches for continuous footings and 24 inches for isolated column footings to minimize the potential for localized bearing failure. Perimeter footings and footings in unheated areas should bear at a minimum depth of 36 inches below the lowest adjacent final ground surface for frost protection per City of Westminster requirements. Interior footings in heated areas can bear as shallow as 12 inches below the floor slab.

The use of the recommended design bearing pressure is contingent on having prepared foundation subgrades observed by an ***Olsson*** geotechnical engineer or their authorized field representative prior to placing new structural fill, reinforcing steel, or concrete to document that the subgrade soils and conditions are consistent with the bearing subgrade requirements of this report. Additionally, we recommend bearing subgrades be proofrolled or hand probed before placing reinforcing steel or concrete to identify soft, loose, or otherwise unsuitable conditions. Proofrolling should be performed using a fully loaded, tandem-axle dump truck or other wheeled equipment with minimum gross weight of 20 tons wherever access for the equipment is feasible.

Lateral resistance of the foundation will be achieved through a combination of base shear resistance mobilized at the footing-subgrade interface and passive earth pressure acting on the vertical faces of the footings at right angles to the direction of applied load. A friction coefficient value of 0.4 can be used between the structural fill and the foundation concrete for base shear and sliding resistance. Passive earth pressure resistance within the frost penetration depths should be ignored. If foundations are extended below frost penetration depths, lateral resistance

for foundations extending below frost depth can be calculated using a drained nominal passive equivalent fluid pressures provided in *Section 6.5*. The design engineer should select the appropriate lateral pressures based on the material and groundwater conditions encountered. The design engineer should also use a suitable factor of safety. For foundations that extend below the water table, buoyant forces should be considered for foundation design.

## 6.2. Deep Foundations

Deep foundation systems are another suitable option for supporting facility structural loads across the project site. During drilling in our preliminary investigation, the borings appeared to remain open while drilling and immediately upon completion of drilling. While we do not anticipate sidewall sloughing during drilled shaft construction, it is likely shafts, if used, will extend below the water table. We recommend that the installation contractor review this report and the final geotechnical report, when published, to evaluate the soils encountered and select their means and methods for drilled shaft installation accordingly.

If designing lateral capacity of drilled shaft foundations using LPILE (by Ensoft Inc.) or similar programs, the following parameters are applicable for this project site. The design parameters are based on the results of our laboratory testing program and information obtained from the preliminary geotechnical borings. Depths and properties shown in the table below represent general parameters for the different encountered materials within ranges of depth. Specific preliminary design values for the structures should use the values below in combination with the boring logs in *Appendix B* to evaluate capacities at each specific boring location. Deep foundation design parameters should be verified for each individual structure during the final geotechnical engineering report if a deep foundation system is desired.

**Table 6.1. Preliminary Design Parameters for Deep Foundations**

| Soil Type | Approximate Formation Depths (ft) | Moist Unit Weight (pcf) | Ultimate Skin Friction (psf) [3,4] | Ultimate End Bearing (psf) [3] | Cohesion/ Friction Angle | Soil Modulus $k_h$ (pci) | Strain Factor E50 |
|---|---|---|---|---|---|---|---|
| CL (Frost) | 0 – 3 | 110 | Ignore | Ignore | Ignore | Ignore | Ignore |
| CL, CL/CH, CH[1] | 3 – 10 | 120 | -225 | N/R | 1,500 psf | Static – 500<br>Cyclic – 200 | 0.007 |
| SC | 5 – 10 | 120 | Ignore | N/R | 32 degrees | Static – 90<br>Cyclic – N/A | N/A |
| Upper Sandstone[2] | 6 – 25 | 125 | 400 | N/R | 35 degrees | Static – 125<br>Cyclic – N/A | N/A |
| Upper Claystone[1] | 6 – DOW[5] | 120 | -700 | N/R | 4,000 psf | Static – 2000<br>Cyclic – 800 | 0.004 |
| Lower Sandstone[2] | 25 – 50 | 125 | 600 | 50,000 | 40 degrees | Static – 125<br>Cyclic – N/A | N/A |
| Lower Claystone[1] | DOW[5]– 50 | 120 | 2,000 | 25,000 | 4,000 psf | Static – 2000<br>Cyclic – 800 | 0.004 |

[1] Clay soils with cohesion more than 1,000 psf should be modeled as "Stiff Clay with Free Water (Reese)".
[2] Sandy soils should be modeled as "Sand (Reese)".
[3] These are ultimate or nominal values and do not include any factor of safety or resistance factors. When using allowable stress design method, we recommend using a minimum factor of safety 3 for end bearing and 2.5 for side friction against axial resistance with 3/4$^{th}$ of the allowable skin friction for uplift resistance.
[4] The upper 10 feet of the shafts should be cased, and skin friction should be ignored within the seasonal zone of moisture variation. Negative values indicate uplift pressure due to swell of claystone materials, as directed by CAGE (1999).
[5] DOW is the assumed depth of wetting, as discussed in *Section 4.3*.
N/A = Not Applicable; N/R = Not Recommended

For the values above to be valid, the following considerations should be included in the design:

- The values above assume that proper drainage is provided around the foundations to avoid moisture changes in the subgrade soils.
- Friction should be ignored within the seasonal zone of moisture variation; however, negative skin friction or uplift should still be considered.
- Permanent sleeves or casing within the seasonal zone of moisture variation or deeper may be considered as an option to reduce negative skin frictions due to swelling.
- Olsson recommends that drilled shaft foundations be a minimum of 18 inches in diameter and be designed in accordance with the soil parameters provided above. It is our opinion that the overturning moment will be the controlling loading condition and as such will govern the total depth of the shaft; however, the shaft should be embedded at least 2 feet or 1 diameter into competent bedrock to achieve the ultimate end bearing

value associated with the bedrock as shown in Table 6.1. The final shaft diameter and tip depth should be provided by the structural engineer based on their review of this report, the final geotechnical engineering report, the final grading plan, and the soil conditions encountered at the time of installation.

- The drilled shafts should extend a minimum of 5 feet beyond the assumed depth of wetting, or deeper as necessary to counter act pier uplift
- An uplift capacity of 75 percent of the allowable skin friction can be used in combination with the overall pile weight for the design of a steel reinforced pile to resist uplift loads. The structural capacity of the piles should be determined using applicable local building codes.
- Drilled shafts required to resist uplift forces must be reinforced over their entire length. It is common for drilled shaft foundations to be designed with sufficient reinforcing steel to accommodate incidental bending moments and transient lateral loads.
- The contractor should be prepared for drilling with temporary casings if required. Where temporary casings are used, the casing should be extracted at a slow, uniform rate, with the pull in line with the center of the shaft. Where groundwater is encountered, concrete should be brought up at least to the external level of groundwater before any casing lifting commences to prevent infiltration of water, caving soils, or creation of voids in shaft concrete.
- Groundwater was encountered up to a depth of approximately 12.4 feet below the existing ground surface. If water is encountered during drilling it should be removed or prevented from entering the hole with temporary casing and/or dewatering equipment prior to placement of concrete, the tremie method should be used after the hole has been cleared. Concrete should not be placed in more than 3 inches of water unless placed through an approved tremie method.
- Construction specifications for drilled shafts should include a concrete mix designed to limit bleeding of installed shafts and the pile contractor's responsibility to increase individual or group shaft lengths, the installation of additional shafts to compensate for any soil disturbance created by the contractor's means and methods during construction. The concrete or grout mix, at a minimum, should be designed to sufficient strength to support the structures.
- An ***Olsson*** field technician should be on-site to observe the shafts as they are drilled and during concrete and reinforcing steel placement.
- The base of the drilled shaft boring should be clean and free of debris or loose soil prior to placing concrete or reinforcing steel. Concrete for the drilled shaft foundation should be placed promptly to reduce exposing the subsoil to rain, surface runoff, or drying conditions. If foundation bearing soils are subjected to such conditions, the soils should be reevaluated by ***Olsson*** prior to reinforcing steel or concrete placement.

- We recommend that concrete for drilled shaft foundations have a slump of 5 to 7 inches at the time of placement.
- Free-fall concrete placement is not recommended unless approved by the structural engineer. The use of a bottom dump hopper or tremie pipe could be considered to prevent potential aggregate segregation or sidewall disturbance.

## 6.3. BUILDING FLOOR SLABS

Due to the documented swell of the native soils, we have provided two options for building floor slabs for consideration by the project team.

Floor Slab Option 1: Structural slab or slab-on-void with at least 4 inches of void space between the bottom of slab and final subgrade surface. The slab loading will be transferred directly to the shallow or deep foundation system and suspended above the subgrade soils which allows the soils to swell within the void space below the slab. Void spaces could be established with cardboard void boxes (such as SureVoid® or similar) or by constructing a crawlspace. Soils below the voided floor slab system that are not supporting or in contact with the building elements do not need to be excavated and replaced, or moisture treated. However, the surface should be sloped to drain and surface compacted to reduce moisture infiltration. Structural design of the structural slab or slab-on-void should be completed by the project structural engineer.

Floor Slab Option 2: Slab-on-grade floors supported by a minimum 6 feet of approved structural fill, placed in accordance with *Section 5.2*, either by overexcavating and replacing the native materials or by raising the existing site grade. Prior to placement of structural fill, the exposed soil or bedrock materials should be prepared per *Section 5.1*. Additionally, the floor slab subgrade should be evaluated by proofrolling (if feasible) with an ***Olsson*** representative present, during the site grading or earthwork stages prior to placement of crushed rock, reinforcing steel, or concrete. If unstable soils are encountered which cannot be adequately densified in place, these soils should be removed and replaced with structural fill in accordance with the recommendations of this report. A minimum of 4 inches of clean, crushed rock similar to No. 57 stone should be placed directly underlying concrete slab in order to provide a capillary break and leveling surface. The stone should be compacted as discussed in *Section 5.2*.

If the recommendations of Option 2 are followed and the subgrade soils are prepared and compacted as recommended, the building floor slab may be designed using a subgrade modulus ("$k_v$" value) of 100 psi/in.

Interior partition walls should not be supported directly on the slab on grade floor, and instead should be supported by the building super-structure and a void space should be left between the bottom of the wall and slab-on-grade surface. This separation will allow any minor movement of the slab and prevent damage to interior finishes.

It may be appropriate to provide a sealed polyethylene vapor barrier between the new floor slab and granular drainage materials to reduce moisture infiltration. The decision to place a vapor barrier in direct contact with the slab or beneath the layer of granular fill should be made by the design engineer after considering the moisture sensitivity of new flooring materials or finishes and installed per the current American Concrete Institute standards and recommendations. Because the long-term performance of the slab-on-grade will greatly depend on the minimizing moisture variations in the subgrade soils, the recommendations provided in *Section 5.3* should be followed.

## 6.4. MAT FOUNDATIONS

If desired for the treatment ponds or water storage tank(s), the subsurface conditions appear suitable for supporting proposed facility elements on a mat foundation system provided recommendations in this preliminary report are followed and verification of these design parameters is included in the final geotechnical engineering report.

Mat foundations should be founded on a minimum of 4 feet of structural fill placed in accordance with *Section 5.2*, either by overexcavating and replacing the native materials or by raising the existing site grade. Prior to placement of structural fill, the exposed soil or bedrock materials should be prepared per *Section 5.1*. The mat should be designed to uniformly distribute the applied building loads across the entire mat foundation. The mat foundation should be designed for a maximum net allowable soil bearing pressure of approximately 2,000 to 3,000 psf.

Mat foundations tend to experience more settlement than lightly loaded isolated foundations due to the larger influence zone associated with mat foundation. However, mat-type foundation systems tie the multiple structure elements together in one reinforced concrete mat which will typically reduce the differential settlement potential across the structural pad.

If the structural designer would prefer this design using this methodology, ***Olsson*** should be contacted for additional recommendations and these recommendations should be verified as part of the final geotechnical engineering report.

## 6.5. LATERAL EARTH PRESSURES

Below grade walls should be designed utilizing the lateral earth pressures provided in this section. The parameters below are based on the understanding that the retained soils will be similar in composition to the on-site soils encountered during this exploration.

Site retaining wall foundations should extend to below frost depth and should be founded on at least 3 feet of structural fill placed in accordance with *Sections 5.1 and 5.2*. Retaining wall foundations should be designed for a maximum net allowable soil bearing pressure of approximately 2,000 to 3,000 psf.

The "at-rest" condition assumes no wall rotation or deflection and would be applicable for walls which are rigidly restrained at the top, such as basement walls. Walls that are not restrained at the top and are free to deflect or rotate slightly may be designed for "active" earth pressure conditions. The "passive" earth pressure condition should be used to evaluate the resistance of soil to lateral loads. The table below presents recommended values of earth pressure coefficients and equivalent fluid density. The drained condition values provided assume that positive drainage is present to prevent hydrostatic forces from developing behind the wall.

**Table 6.1: Earth Pressure Parameters**

| Condition | Earth Pressure Coefficient | | Equivalent Fluid Density* | |
|---|---|---|---|---|
| | | | Moist Condition | Saturated Condition** |
| Active ($K_a$) | Low plasticity, cohesive soils | 0.36 | 45 pcf | 85 pcf |
| | Granular backfill material | 0.31 | 40 pcf | 80 pcf |
| At Rest ($K_0$) | Low plasticity, cohesive soils | 0.53 | 65 pcf | 95 pcf |
| | Granular backfill material | 0.47 | 60 pcf | 90 pcf |
| Passive ($K_p$) | Low plasticity, cohesive soils | 2.77 | 335 pcf | 235 pcf |
| | Granular backfill material | 3.25 | 390 pcf | 265 pcf |

*Assumed level backfill.

**Saturated conditions account for groundwater up to the top of the wall. If groundwater is expected to raise above the wall, adjustments will need to be made.

These design recommendations are based on the following assumptions:

- For active earth pressure, the wall must rotate out about its base with top lateral movements 0.002 Z to 0.004 Z (granular) or 0.010 Z to 0.020 Z (clays), where Z is wall height. This is necessary to allow the active condition to develop.

- For passive earth pressure, the wall must rotate in about its base with top lateral movements 0.020 Z to 0.060 Z (granular) or 0.020 Z to 0.040 Z (clays), where Z is wall height. This is necessary to allow the passive condition to develop.
- Drained conditions require the walls have a permanent drainage system behind the wall that will prevent hydrostatic pressure from developing. Moisture collected in the drain system should be collected in a sump pit and pumped away from the structure or daylight to a location that will gravity drain. If permanent drainage is not provided, undrained conditions and hydrostatic pressures should be used for design.
- The soil parameters provided above assume the backfill is level with the top of the wall. If a sloping backfill is utilized, the parameters will need to be reevaluated. In addition to a sloping backfill, the walls should be designed to resist surcharge loads, including nearby shallow foundations or other concentrated load components and traffic loads. Passive pressures are typically lower if the ground surface slopes downward away from the face of the wall.
- Backfill soils placed within the height of the retained wall should consist of well compacted selected granular soils or low-plasticity non-expansive cohesive soils. On-site overburden soils placed within the height of the retained wall consisting of non-expansive cohesive soils should be tested to verify these soils exhibit low plasticity and can achieve a minimum friction angle of 28 degrees and a unit weight of 120 pcf. Backfilled granular materials should have a minimum friction angle of 32 degrees and a unit weight of 120 pcf. For the granular values to be valid, the granular backfill must extend out from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, respectively. Fat clays and claystone fragments should not be used for retaining wall backfill.
- Passive resistance against horizontal movement within the frost zone of 3 feet should be ignored.
- Heavy equipment and other concentrated load components are not included. If heavy construction equipment is anticipated, the walls should be designed to resist surcharge loads, including any construction equipment load or traffic loads.
- Factor of safety is not included. The designer should use appropriate factor of safety for design.
- To calculate the resistance to sliding on native soil, a coefficient of friction value of 0.35 should be used where the footing is supported by engineer approved bearing soil.

To intercept infiltrating surface water behind the wall, we recommend a footing drain be installed at or slightly below the foundation level and/or weep holes be placed at regular intervals along the wall. The drain line invert should be below the finished subgrade elevation for the wall foundation. The drain line should be sloped to provide positive gravity drainage and should be

surrounded by free-draining granular material graded to prevent the intrusion of fines, or an alternative free-draining granular material encapsulated with suitable filter fabric. A minimum 2-foot wide section of free-draining granular fill should be used for backfill above the drain line and adjacent to the wall, and should extend to within 2 feet of final grade. The granular backfill should be capped with compacted cohesive fill to minimize infiltration of surface water into the drain system.

## 6.6. SEISMIC CLASSIFICATION

For this project site, we recommend using a Site Class "C" (Very Dense Soil and Soft Rock profile) according to ASCE 7-10. This recommendation is based on the soils and bedrock conditions encountered in the borings during the exploration and our assumption that the encountered bedrock continue beyond the drilled depth to the full 100 feet. A seismic survey to 100 feet depth should be performed to verify a better site class. Site coefficients and spectral acceleration parameters for structural design are provided in Table 6.2 below for Site Class "B" and should be converted to Site Class "C" by the foundation designer accordingly.

**Table 6.2: Seismic Design Parameters**

| Site | Latitude (North) | Longitude (West) | 2% in 50 Years | | ASCE-07 Site Class | $F_a$ | $F_v$ |
|---|---|---|---|---|---|---|---|
| | | | $S_S$ | $S_1$ | | | |
| Westminster WTP | 39.87857 | 105.06195 | 0.186 | 0.059 | C | 1.2 | 1.7 |

Notes: $S_S$ = 0.2 sec Mapped Spectral Acceleration (for Site Class B – foundation designer will need to adjust for class C)
$S_1$ = 1.0 sec Mapped Spectral Acceleration (for Site Class B – foundation designer will need to adjust for class C)
$F_a$ = Short Period Seismic Design Factors
$F_v$ = Long Period Seismic Design Factors
$S_{MS}$ = The maximum considered earthquake spectral response for short period = $F_a$ $S_S$
$S_{M1}$ = The maximum considered earthquake spectral response for 1-second period = $F_v$ $S_1$
$S_{DS}$ = Design spectral response acceleration for short period = 2/3 $S_{MS}$
$S_{D1}$ = Design spectral response acceleration for 1-second period =2/3 $S_{M1}$

# 7. PAVEMENTS

## 7.1. PAVEMENT SUBGRADE PREPARATION

As previously discussed, site grading plans were not available at the time of this report. The recommendations for pavements discussed should be verified during the final geotechnical investigation, in accordance with the City of Westminster *Standards and Specifications*, Chapter 6, following the completion of grading and rough cutting of subgrade.

As part of our preliminary investigation, an R-value test was performed on materials collected from the center of the site at boring B-6 from an approximate depth of 1 to 5 feet which resulted in an R-value of "< 5." The City of Westminster requires that subgrade soils underlying the pavements with an R-value less than 10 or Plasticity Index (PI) greater than 15 percent must be stabilized.

Additionally, expansive soils with plasticity indices ranging from 21 to 36 percent were encountered across site, as discussed in *Sections 3.2* and *4*. The Colorado Department of Transportation *2020 Pavement Design Manual* recommends that treatment of expansive soils with Plasticity Indices ranging from 30 to 40 percent should extend to depths of 4 feet below normal subgrade elevation to reduce probable swell damage risk.

In order help reduce the risk of distress associated with expansive soils we recommend pavement areas should be overexcavated at least 4 feet below planned aggregate base elevation and replaced with structural fill in accordance with *Section 5.2*. The base of the overexcavation should be prepared in accordance with *Section 5.1*. If overexcavation is required to improve unstable areas identified during proofrolling, aggregate base (CDOT Class 6 material) should be used as backfill instead of structural fill. We also recommend that the overexcavation and subgrade preparation extend a minimum of 2-feet outside the roadway surface to provide edge support.

Shallow claystone bedrock was encountered at various depths across the project site. If encountered during site grading or overexcavation of pavement areas, excavated claystone fragments are not suitable for reuse as fill and should be removed from site.

It is important that the subgrade support be relatively uniform, with no abrupt changes in the degree of support. Non-uniform pavement support can occur at the transition from cut to fill areas, as a result of varying soil moisture contents or soil types, or where improperly placed utility backfill has been placed across or through areas to be paved. Improper subgrade

preparation such as inadequate vegetation removal, failure to identify soft or unstable areas, and inadequate or improper compaction can also produce non-uniform subgrade support.

***Olsson*** should be present during subgrade preparation to observe, document, and test compaction of the materials at the time of placement. As recommended for all prepared soil subgrades, heavy, repetitive construction traffic should be controlled, especially during periods of wet weather, to minimize disturbance. The final prepared subgrade should be proofrolled with a loaded dump truck, or similar rubber-tired equipment with a total weight of at least 20-tons, immediately prior to placement of new pavements. Proofrolling operations should be observed and documented by ***Olsson***. Unstable or unsuitable soils revealed by proofrolling should be reworked to provide a stable subgrade or removed and replaced with structural fill.

## 7.2. PRELIMINARY PAVEMENT DESIGN

The pavement section recommended below has been developed using a minimum R-value of 10, corresponding to a resilient modulus ($M_R$)of 3,560 psi and modulus of subgrade reaction ($k_v$) of 100 pci, was used for the subgrade soils assuming the subgrade preparation discussed in *Section 7.1* is completed.

For the heavy-duty pavement section, ***Olsson*** used the 18-kip Equivalent Single Axle Load ($ESAL_{18}$) value of 134,000. For the standard duty pavement section, ***Olsson*** assumed an 18-kip Equivalent Single Axle Load ($ESAL_{18}$) value of 25,000. ESAL values were calculated assuming the Phase II service traffic loads that were provided by CDM Smith and the City of Westminster. These pavement sections are not designed to accommodate increased traffic beyond the loads assumed in *Table 1.2* which includes heavy construction traffic associated with future construction of the facility. If the pavement sections below are exposed to traffic loads beyond those listed in *Table 1.2*, additional deflections, potentially significant cracking, and a decreased service life of the pavement should be expected.

$ESAL_{18}$ values calculated by ***Olsson*** were based on the respective traffic loadings referenced in *Table 1.2*, a personal vehicle split of half cars and half vans or trucks, a growth rate of 0.5%, AASHTO 1993 axle load equivalency factors, and a pavement design life of 20 years.

**Table 7.1: Summary of Pavement Design Value Assumptions**

| Design Assumptions | Westminster WTP |
|---|---|
| Equivalent Single Axle Loads (ESAL) – Heavy Duty | 134,000 |
| Equivalent Single Axle Loads (ESAL) – Standard Duty | 25,000 |
| Serviceability Index – Heavy Duty | 2.5 |
| Serviceability Index – Standard Duty | 2.0 |
| Reliability (percent) – Heavy Duty | 90 |
| Reliability (percent) – Standard Duty | 85 |
| Standard deviation, $S_o$ | 0.40 |
| Aggregate Base Course (ABC) Material | CDOT Class 6 |
| ABC Minimum R-Value | 70 |
| AASHTO Design Subbase Material Classification | A-4 or A-6 |
| Minimum R-Value – Subbase Soils Replaced as Structural Fill | 10 |
| Subbase Design Resilient Modulus $M_R$ (psi) | 3,560 |
| PCCP compressive strength of concrete (psi) | 4,000 |
| PCCP concrete elastic modulus, $E_c$ (psi) | 3,600,000 |
| PCCP concrete modulus of rupture, $S'_c$ (psi) | 569 |
| PCCP load transfer coefficient, J standard/heavy duty | 4.0/2.7 |
| Drainage coefficient for PCCP | 0.8 |

**Table 7.2: Preliminary Minimum Pavement Sections**

| **Standard Duty Pavement** | |
|---|---|
| Hot Mix Asphalt (HMA) | Portland Concrete Cement Pavement (JPCP) |
| 4.0 inches HMA | 4.5 inches PCCP |
| 7 inches Aggregate Base Course | 4 inches Aggregate Base Course |
| Structural Fill per *Sections 5.2* and *7.1* | Structural Fill per *Sections 5.2* and *7.1* |
| Prepared Subgrade per *Section 5.1* | Prepared Subgrade per *Section 5.1* |
| **Heavy Duty Pavement** | |
| Hot Mix Asphalt (HMA) | Portland Concrete Cement Pavement (PCCP) |
| 6 inches HMA | 6 inches PCCP |
| 6 inches Aggregate Base Course | 4 inches Aggregate Base Course |
| Structural Fill per *Sections 5.2* and *7.1* | Structural Fill per *Sections 5.2* and *7.1* |
| Prepared Subgrade per *Section 5.1* | Prepared Subgrade per *Section 5.1* |
| Note: The aggregate base should consist of well graded sand and gravel conforming to CDOT Class 6 Aggregate Base material compacted per the *Section 5.2*. | |

***Olsson*** recommends that rigid concrete pavement be used in areas designated for heavily loaded trucks, lanes, or concentrated lanes of repetitive traffic, or in non-designated areas that could experience turning truck traffic.

The preliminary pavement sections provided above represent typical minimum thicknesses assuming routine maintenance. Routine maintenance of HMA (Hot Mix Asphalt) pavement typically consists of periodic seal coats and possibly one intermediate mill in addition to regular crack maintenance. Routine maintenance of PCCP (Portland Cement Concrete Pavement) typically involves regular crack maintenance. The performance of pavements will be dependent upon several factors, including subgrade conditions at the time of paving, rainwater runoff, and traffic.

Rainwater runoff should not be allowed to seep below pavements from adjacent areas. The thickness of the aggregate base (compacted Class 6 material) should be uniform, and the pavement subgrade should be graded to provide positive drainage of the granular base section. The granular section should be graded to adjacent storm sewer inlets and provisions should be made to provide drainage from the granular section into the storm sewer. Pavement surfaces should be sloped approximately 1/4 inch per foot to provide rapid surface drainage. Proper drainage below the surface layer helps prevent softening of the subgrade and has a significant impact on pavement performance.

# 8. LIMITATIONS

The conclusions and recommendations presented in this preliminary report are based on the information available regarding the proposed construction, the results obtained from our soil test borings and sampling procedures, the results of the laboratory testing program, and our experience with similar projects. The soil test borings represent a very small statistical sampling of subsurface soils and it is possible that conditions may be encountered during the final geotechnical investigation or during construction that are substantially different from those indicated by the soil test borings. In these instances, adjustments to design and construction may be necessary. This preliminary geotechnical report is based on the site plan and information provided to ***Olsson*** and our understanding of the project as noted in this report. Changes in the location or design of new structures and/or pavements could significantly affect the conclusions and recommendations presented in this geotechnical report. ***Olsson*** should be contacted in the event of such changes to determine if the recommendations of this report remain appropriate for the revised site design.

This report was prepared under the direction and supervision of a Professional Engineer registered in the State of Colorado with the firm of ***Olsson***. The conclusions and recommendations contained herein are based on generally accepted professional geotechnical engineering practices at the time of this report within this geographic area. No other warranty is expressed, intended, or made. This report has been prepared for the exclusive use of **CDM Smith** and their authorized representatives for specific application to the proposed project.

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# CDM Smith – Westminster Water 2025 Preliminary Design Project

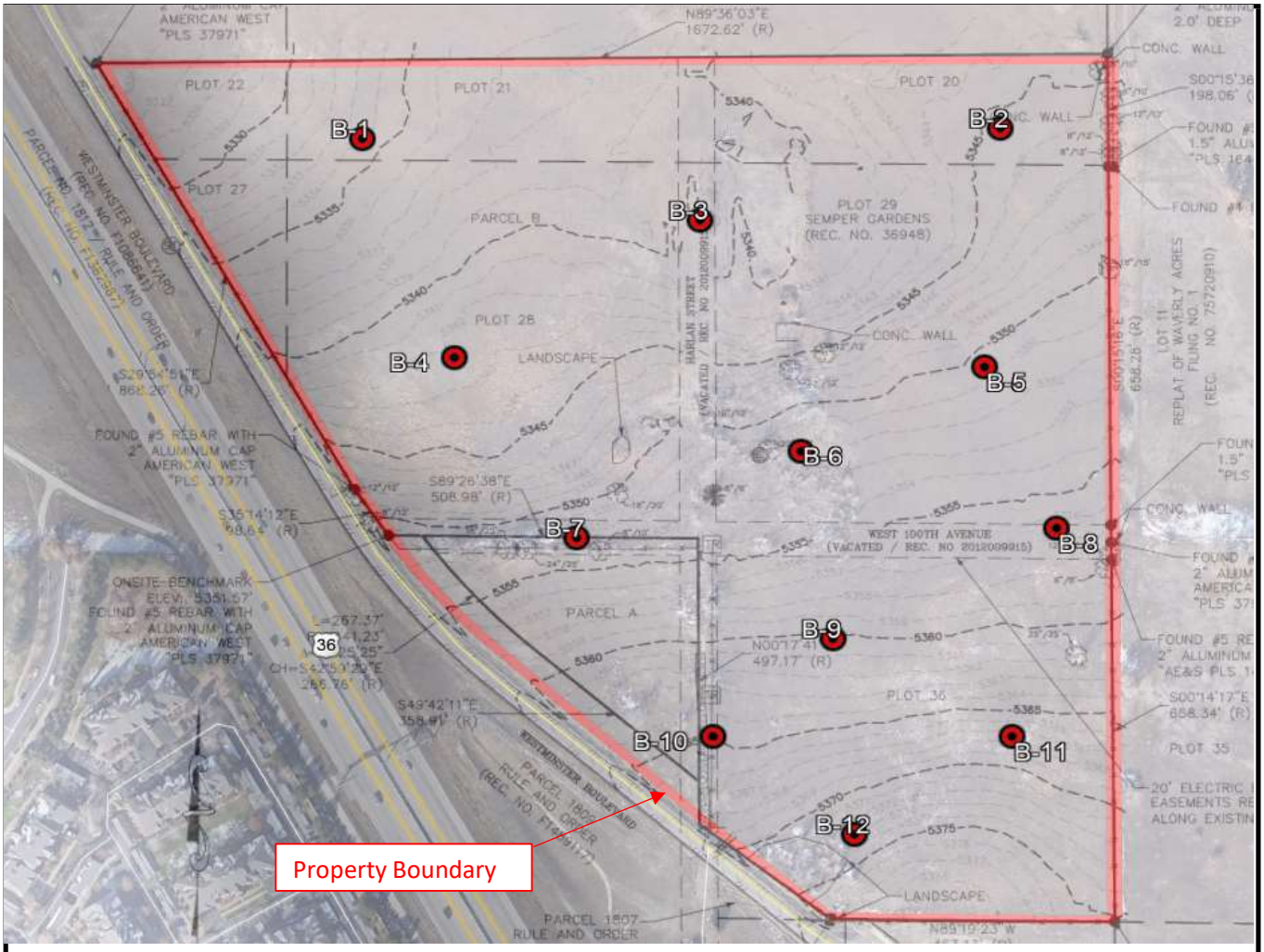
**Westminster, Colorado**

**March 4, 2021**

**Olsson Project No. 019-1378**

# APPENDIX A

Boring Location Map




| I.D. | Depth | Approximate Coordinates | | Pieozmeter |
|---|---|---|---|---|
| B-1 | 50 | 39.880094° N | 105.064531° W | X |
| B-2 | 50 | 39.880138° N | 105.060782° W | |
| B-3 | 50 | 39.879694° N | 105.062543° W | |
| B-4 | 50 | 39.879026° N | 105.063984° W | |
| B-5 | 50 | 39.878979° N | 105.060876° W | |
| B-6 | 50 | 39.878570° N | 105.061950° W | X |
| B-7 | 50 | 39.878151° N | 105.063263° W | |
| B-8 | 50 | 39.878198° N | 105.060458° W | |
| B-9 | 50 | 39.877664° N | 105.061763° W | |
| B-10 | 50 | 39.877194° N | 105.062463° W | |
| B-11 | 50 | 39.877195° N | 105.060722° W | |
| B-12 | 50 | 39.876726° N | 105.061640° W | X |

**Boring Location Plan**

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Scale: nts
Project: 019-1378
Approved by: LAT
Date: 03/01/2021

**Westminster 2025 Water Preliminary Design Project**
**Westminster Boulevard near W 98th Ave**
**Westminster, Colorado**

# APPENDIX B

Symbols and Nomenclature, Boring Logs

# SYMBOLS AND NOMENCLATURE

## *DRILLING NOTES*

### *DRILLING AND SAMPLING SYMBOLS*

| | | | | | |
|---|---|---|---|---|---|
| SS: | Split-Spoon Sample (1.375" ID, 2.0" OD) | HSA: | Hollow Stem Auger | NE: | Not Encountered |
| U: | Thin-Walled Tube Sample (3.0" OD) | CFA: | Continuous Flight Auger | NP: | Not Performed |
| CS: | Continuous Sample | HA: | Hand Auger | NA: | Not Applicable |
| BS: | Bulk Sample | CPT: | Cone Penetration Test | % Rec: | Percent of Recovery |
| MC: | Modified California Sampler | WB: | Wash Bore | WD: | While Drilling |
| GB: | Grab Sample | FT: | Fish Tail Bit | IAD: | Immediately After Drilling |
| SPT: | Standard Penetration Test Blows per 6.0" | RB: | Rock Bit | AD: | After Drilling |
| | | PP: | Pocket Penetrometer | CI: | Cave-In |

### *DRILLING PROCEDURES*

Soil samples designated as "U" samples on the boring logs were obtained in using Thin-Walled Tube Sampling techniques. Soil samples designated as "SS" samples were obtained during Penetration Test using a Split-Spoon Barrel sampler. The standard penetration resistance 'N' value is the number of blows of a 140 pound hammer falling 30 inches to drive the Split-Spoon sampler one foot. Soil samples designated as "MC" were obtained in using Thick-Walled, Ring-Lined, Split-Barrel Drive sampling techniques. Recovered samples were sealed in containers, labeled, and protected for transportation to the laboratory for testing.

### *WATER LEVEL MEASUREMENTS*

Water levels indicated on the boring logs are levels measured in the borings at the times indicated. In relatively high permeable materials, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels is not possible with only short-term observations.

## *SOIL PROPERTIES & DESCRIPTIONS*

Descriptions of the soils encountered in the soil test borings were prepared using Visual-Manual Procedures for Descriptions and Identification of Soils.

### *PARTICLE SIZE*

| | | | | | |
|---|---|---|---|---|---|
| Boulders | 12 in. + | Coarse Sand | 4.75mm-2.0mm | Silt | 0.075mm-0.005mm |
| Cobbles | 12 in.-3 in. | Medium Sand | 2.0mm-0.425mm | Clay | <0.005mm |
| Gravel | 3 in.-4.75mm | Fine Sand | 0.425mm-0.075mm | | |

### *COHESIVE SOILS*

| Consistency | Unconfined Compressive Strength (Qu) (tsf) |
|---|---|
| Very Soft | <0.25 |
| Soft | 0.25 – 0.5 |
| Firm | 0.5 – 1.0 |
| Stiff | 1.0 – 2.0 |
| Very Stiff | 2.0 – 4.0 |
| Hard | > 4.0 |

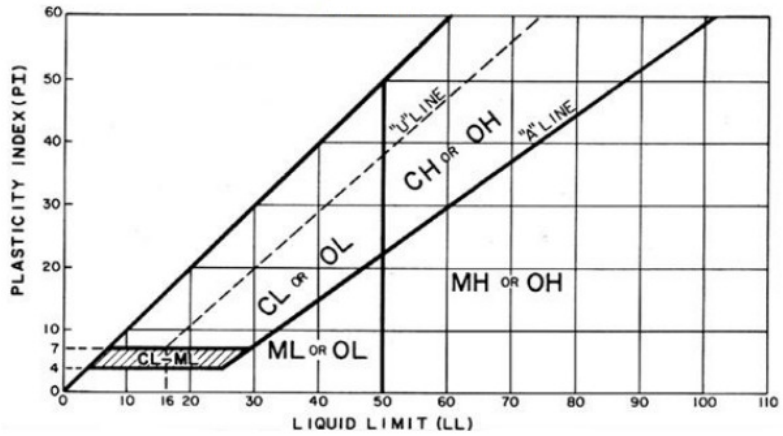
### *COHESIONLESS SOILS*

| Relative Density | 'N' Value |
|---|---|
| Very Loose | 0 – 3 |
| Loose | 4 – 9 |
| Medium Dense | 10 – 29 |
| Dense | 30 – 49 |
| Very Dense | ≥ 50 |

### *COMPONENT %*

| Description | Percent (%) |
|---|---|
| Trace | <5 |
| Few | 5 - 10 |
| Little | 15 - 25 |
| Some | 30 - 45 |
| Mostly | 50 - 100 |

### *PLASTICITY CHART*




### *ROCK QUALITY DESIGNATION (RQD)*

| Description | RQD (%) |
|---|---|
| Very Poor | 0 – 25 |
| Poor | 25 – 50 |
| Fair | 50 – 75 |
| Good | 75 – 90 |
| Excellent | 90 – 100 |

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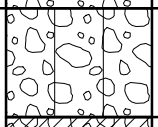
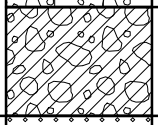
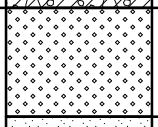
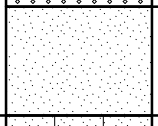
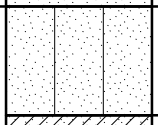
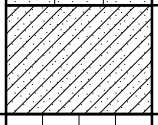
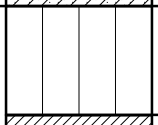
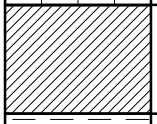
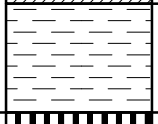
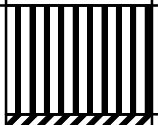
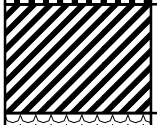
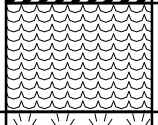
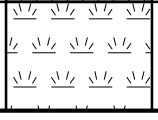
# SOIL CLASSIFICATION CHART

| MAJOR DIVISIONS | | | SYMBOLS | | TYPICAL DESCRIPTIONS |
|---|---|---|---|---|---|
| | | | GRAPH | LETTER | |
| COARSE GRAINED SOILS<br>MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE | GRAVEL AND GRAVELLY SOILS<br>MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE | CLEAN GRAVELS<br>(LITTLE OR NO FINES) |  | GW | WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES |
| | | |  | GP | POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES |
| | | GRAVELS WITH FINES<br>(APPRECIABLE AMOUNT OF FINES) |  | GM | SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES |
| | | |  | GC | CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES |
| | SAND AND SANDY SOILS<br>MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE | CLEAN SANDS<br>(LITTLE OR NO FINES) |  | SW | WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES |
| | | |  | SP | POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES |
| | | SANDS WITH FINES<br>(APPRECIABLE AMOUNT OF FINES) |  | SM | SILTY SANDS, SAND - SILT MIXTURES |
| | | |  | SC | CLAYEY SANDS, SAND - CLAY MIXTURES |
| FINE GRAINED SOILS<br>MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE | SILTS AND CLAYS | LIQUID LIMIT LESS THAN 50 |  | ML | INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY |
| | | |  | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS |
| | | |  | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY |
| | SILTS AND CLAYS | LIQUID LIMIT GREATER THAN 50 |  | MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS |
| | | |  | CH | INORGANIC CLAYS OF HIGH PLASTICITY |
| | | |  | OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS |
| HIGHLY ORGANIC SOILS | | |  | PT | PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS |

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

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# BOREHOLE REPORT NO. B-1



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon ☒ | Modified California Sampler ⋈

**APPROX. SURFACE ELEV. (ft):** 5334.0

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** 0.5' | | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | | SS 1 | | 7-10-12 N=22 | | | | | PP = >4.5 tsf |
| | ***FAT CLAY*** | | | | | | | | | | |
| 5330 | *with fine grained sand, very stiff, light brown with white lensing, moist (CH)* | | | MC 2 | | 10-19 | | | | | |
| | | | 5 | | | | | | | | |
| | | | | SS 3 | | 6-8-8 N=16 | | 21.6 | | 56/36 | PP = >4.5 tsf |
| 5325 | 9.0' | | | | | | | | | | |
| | ***SANDSTONE*** | | | MC 4 | | 10-32 | 3.6 | 12.7 | 113.3 | | PP = 3.5 tsf |
| | *moderately cemented, slightly oxidized, yellow brown, moist* | | 10 | | | | | | | | |
| | ▼ | | | | | | | | | | |
| 5320 | | | | SS 5 | | 50 | | | | | PP = >4.5 tsf |
| | | | 15 | | | | | | | | |
| 5315 | | | | | | | | | | | |
| | | | | MC 6 | | 21-50/3" | | | | | PP = >4.5 tsf |
| | | | 20 | | | | | | | | |
| 5310 | | | | | | | | | | | |
| | 25.0' | | 25 | SS 7 | | 12-14-24 N=38 | | 20.5 | | | PP = >4.5 tsf |
| | ***CLAYSTONE*** | | | | | | | | | | |
| | 27.0' | | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ 12.4 ft after 144Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/25/20 | FINISHED: | 8/25/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

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# BOREHOLE REPORT NO. B-1



| PROJECT NAME | CLIENT |
|---|---|
| **Westminster Water 2025 Preliminary** | **CDM Smith** |
| **PROJECT NUMBER** | **LOCATION** |
| **019-1378** | **Westminster, Colorado** |

Split Spoon ☒ Modified California Sampler ⋈

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5305 | ***CLAYSTONE*** *moderately weathered, sandy, grayish brown with oxidation lensing, moist* | | 30 | MC 8 | | 13-25 | | | | | PP = >4.5 tsf |
| 5300 | | | | | | | | | | | |
| | *grades to with small crystallization zones and organic lensing* | | 35 | SS 9 | | 10-12-24 N=36 | | 16.3 | | | PP = >4.5 tsf |
| 5295 | | | | | | | | | | | |
| | *grades to moderately to highly weathered* | | 40 | MC 10 | | 16-50/3" | | | | | PP = >4.5 tsf |
| 5290 | | | | | | | | | | | |
| | *grades to slightly weathered, with organic or lignite inclusions, gray* | | 45 | SS 11 | | 21-50 | | | | | PP = >4.5 tsf |
| 5285 | | | | | | | | | | | |
| | | | ***49.3'*** | MC 12 | | 50/4" | | 11.5 | | | |
| | *grades to highly weathered, increased sand content* | | | | | | | | | | |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

Note: Groundwater monitoring well installed following drilling.

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ 12.4 ft after 144Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/25/20 | FINISHED: | 8/25/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

# BOREHOLE REPORT NO. B-2



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon ☒ | Modified California Sampler ⋈

**APPROX. SURFACE ELEV. (ft):** 5345.5

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5345 | ***ROOT ZONE*** 0.5' | | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | | SS 1 | | 10-10-11 N=21 | | | | | PP = >4.5 tsf |
| | ***FAT CLAY*** | | | | | | | | | | |
| | *with sand, very stiff, brown, moist (CH)* | | | | | | | | | | |
| | *grades to with white lensing* 5.0' | | | MC 2 | | 8-11 | | | | | PP = >4.5 tsf |
| 5340 | ***CLAYEY SAND*** | | 5 | | | | | | | | |
| | *fine grained sand, fat clay, medium dense, brown, moist (SC)* | | | SS 3 | | 11-11-11 N=22 | | 9.5 | | | P-200 = 43.6% PP = >4.5 tsf |
| | 9.5' | | | MC 4 | | 15-27 | | | | | PP = >4.5 tsf |
| | ***CLAYSTONE*** | | 10 | | | | | | | | |
| 5335 | *highly to moderately weathered, with sand, light brown with heavy white lensing, moist* | | | | | | | | | | |
| | 14.0' | | | | | | | | | | |
| | ***SANDSTONE*** | | 15 | SS 5 | | 7-7-7 N=14 | | 10.4 | | | PP = 3.25 tsf |
| 5330 | *poorly cemented, with gravel inclusions, light brown, moist* | | | | | | | | | | |
| | ▽ | | | | | | | | | | |
| | 19.0' | | | | | | | | | | |
| | ***CLAYSTONE*** | | 20 | MC 6 | | 24-26 | | | | | |
| 5325 | *moderately weathered, dark brown with minor oxidation and organic lensing, moist* | | | | | | | | | | |
| | *grades to slightly weathered, blocky* | | 25 | SS 7 | | 12-28-36 N=64 | | | | | PP = 3.5 tsf |
| 5320 | 27.0' | | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 17.0 ft |
| IAD | ▼ 34.2 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-2



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***CLAYSTONE*** | | | | | | | | | | |
| | *slightly weathered, blocky, gray brown with minor oxidation and organic lensing, moist* | | 30 | MC 8 | | 16-50/2" | | | | | PP = >4.5 tsf |
| 5315 | | | | | | | | | | | |
| | | | 35 | SS 9 | | 18-50 | | 21.4 | | | PP = >4.5 tsf |
| 5310 | | | | | | | | | | | |
| | | | 40 | MC 10 | | 25-50 | | | | | PP = >4.5 tsf |
| 5305 | | | | | | | | | | | |
| | | | 45 | SS 11 | | 23-50/3" | | | | | PP = >4.5 tsf |
| 5300 | *moderately weathered, sandy texture, gray, moist* | | | | | | | | | | |
| | ***49.3'*** | | | MC 12 | | 50/3" | | | | | PP = >4.5 tsf |

***BASE OF BORING AT 49.3 FEET***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 17.0 ft |
| IAD | ▼ 34.2 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-3



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler | No Recovery

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5340 | **APPROX. SURFACE ELEV. (ft):** 5340.0 | | 0 | | | | | | | | |
| | ***ROOT ZONE*** 0.5' | | | | | | | | | | |
| | *6 inches of organic rich clay* | | | SS 1 | | 9-12-11 N=23 | | | | | PP = >4.5 tsf |
| | ***FAT CLAY*** | | | | | | | | | | |
| | *with sand, very stiff, brown with white lensing, moist (CH)* | | | MC 2 | | 12-16 | | 15.2 | 103.9 | | Swell (500 psf surcharge): 3.2%PP = >4.5 tsf |
| 5335 | | | 5 | | | | | | | | |
| | *grades to stiff, with trace gravel* | | | SS 3 | | 2-5-7 N=12 | | | | | PP = >4.5 tsf |
| | 9.0' | | | | | | | | | | |
| | ***CLAYSTONE*** | | | MC 4 | | 8-12 | | 22.9 | 99.6 | | Swell (1000 psf surcharge): 1.2%PP = 4.0 tsf |
| 5330 | *slightly weathered, yellowish light brown with small oxidation lenses, moist* | | 10 | | | | | | | | |
| 5325 | *grades to moderately weathered, with organic lesning* | | 15 | SS 5 | | 9-18-15 N=33 | | | | | PP = >4.5 tsf |
| 5320 | *grades to slightly weathered* | | 20 | MC 6 | | 9-18 | | | | | PP = >4.5 tsf |
| | 24.0' | | | | | | | | | | |
| | ***SANDSTONE*** | | | SS 7 | | 29-50/2" | | | | | PP = 2.0 tsf |
| 5315 | *poorly cemented, brownish yellow, moist* | | 25 | | | | | | | | |
| | 27.0' | | | | | | | | | | |

***CONTINUED NEXT PAGE***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 34.0 ft |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/28/20 | FINISHED: | 8/28/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-3



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler | No Recovery

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***SANDSTONE*** | | | | | | | | | | |
| | *poorly cemented, brownish yellow, moist* | | | | | | | | | | |
| 5310 | *grades to with large sandstone fragments in matrix* | | 30 | MC 8 | | 50/2" | | | | | |
| | ▽ *34.0'* | | | | | | | | | | |
| | ***CLAYSTONE*** | | | SS 9 | | 50 | | | | | PP = 4.0 tsf |
| 5305 | *moderately weathered, yellowish brown, wet* | | 35 | | | | | | | | |
| 5300 | *grades to slightly weathered* | | 40 | MC 10 | | 33-50/4" | | 22.6 | 94.4 | | PP = >4.5 tsf |
| | | | | SS 11 | | 50/2" | | | | | PP = 3.0 tsf |
| 5295 | *grades to highly weathered, sandy, bluish gray* | | 45 | | | | | | | | |
| | *49.1'* | | | | | | | | | | |
| | ***BASE OF BORING AT 49.1 FEET*** | | | NR 12 | | 50/1" | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 34.0 ft |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/28/20 | FINISHED: | 8/28/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-4



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⊠ Split Spoon ⊠

**APPROX. SURFACE ELEV. (ft):** 5342.5

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** 0.5' | | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | | MC 1 | | 6-10 | | | | | PP = >4.5 tsf |
| 5340 | ***LEAN TO FAT CLAY*** | | | | | | | | | | |
| | *with sand, medium dense, light brown with white lensing, moist (CL/CH)* | | | | | | | | | | |
| | | | 5 | SS 2 | | 8-9-8 N=17 | | | | | PP = >4.5 tsf |
| | 6.0' | | | | | | | | | | |
| | ***CLAYSTONE*** | | | MC 3 | CL | 3-9 | | 18.9 | | 40/25 | P-200 = 64.1% PP = >4.5 tsf |
| 5335 | *slightly weathered, brownish gray with oxidation lensing, moist* | | | | | | | | | | |
| | *grades to with white crystallization lesning* | | 10 | SS 4 | | 6-8-10 N=18 | | | | | PP = 4.5 tsf |
| 5330 | | | | | | | | | | | |
| | *grades to with black organic inclusions* | | 15 | MC 5 | | 12-17 | 8.2 | 17.2 | 110.3 | | PP = >4.5 tsf |
| 5325 | | | | | | | | | | | |
| | 19.0' | | | | | | | | | | |
| | ***SANDSTONE*** | | 20 | SS 6 | | 16-50/4" | | 15.8 | | | PP = >4.5 tsf |
| | *moderately cemented, slightly weathered, yellow brown, moist* | | | | | | | | | | |
| 5320 | | | | | | | | | | | |
| | | | 25 | MC 7 | | 23-27 | | | | | PP = >4.5 tsf |
| | 27.0' | | | | | | | | | | |

***CONTINUED NEXT PAGE***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 34.0 ft |
| IAD | ▼ 33.5 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/25/20 | FINISHED: | 8/25/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-4



| PROJECT NAME | CLIENT |
|---|---|
| **Westminster Water 2025 Preliminary** | **CDM Smith** |
| **PROJECT NUMBER** | **LOCATION** |
| **019-1378** | **Westminster, Colorado** |

Modified California Sampler ⊠ Split Spoon ⊠

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5315 | ***SANDSTONE***<br>*moderately cemented, slightly weathered, yellow brown, moist* | | 30 | SS 8 | | 23-50 | | | | | PP = >4.5 tsf |
| 5310 | ▽ | | 35 | MC 9 | | 50/5" | | | | | PP = >4.5 tsf |
| 5305 | | | | | | | | | | | |
| | ***39.0'*** | | | | | | | | | | |
| | ***CLAYSTONE***<br>*slightly weathered, blocky, dark gray, moist* | | 40 | SS 10 | | 18-50 | | 28.8 | | | PP = >4.5 tsf |
| 5300 | | | 45 | MC 11 | | 50 | | | | | PP = >4.5 tsf |
| 5295 | *grades to bluish gray* | | | | | | | | | | |
| | ***49.3'*** | | | SS 12 | | 50/3" | | | | | PP = >4.5 tsf |

***BASE OF BORING AT 49.3 FEET***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 34.0 ft |
| IAD | ▼ 33.5 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/25/20 | FINISHED: | 8/25/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-5



| | |
|---|---|
| PROJECT NAME: **Westminster Water 2025 Preliminary** | CLIENT: **CDM Smith** |
| PROJECT NUMBER: **019-1378** | LOCATION: **Westminster, Colorado** |

Modified California Sampler ⊠ Split Spoon ⊠

**APPROX. SURFACE ELEV. (ft):** 5350.5

| ELEVATION (ft) | MATERIAL DESCRIPTION | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 5350 | ***ROOT ZONE*** 0.5' | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | MC 1 | | 8-10 | | | | | PP = >4.5 tsf |
| | ***LEAN TO FAT CLAY*** | | | | | | | | | |
| | *with sand, very stiff, light brown with white lensing, moist (CL/CH)* | | | | | | | | | |
| | | 5 | SS 2 | | 8-8-10 N=18 | | 10.5 | | | PP = >4.5 tsf |
| 5345 | | | | | | | | | | |
| | *grades to with trace gravel* | | MC 3 | | 10-14 | | | | | PP = >4.5 tsf |
| | 9.0' | | | | | | | | | |
| | ***SANDSTONE*** | 10 | SS 4 | | 8-8-8 N=16 | | | | | PP = >4.5 tsf |
| 5340 | *moderately cemented, yellowish brown, moist* | | | | | | | | | |
| | *grades to whitish yellow* | 15 | MC 5 | | 18-22 | | 4.6 | | | PP = >4.5 tsf |
| 5335 | | | | | | | | | | |
| | 19.0' | | | | | | | | | |
| | ***CLAYSTONE*** | 20 | SS 6 | | 27-50 | | | | | PP = >4.5 tsf |
| 5330 | *moderately weathered, yellow brown, moist* | | | | | | | | | |
| | *grades to slightly weathered, with oxidation lensing and organic inclusions* | 25 | MC 7 | | 15-50/5" | | | | | |
| 5325 | | | | | | | | | | |
| | 27.0' | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 40.0 ft |
| IAD | ▼ 38.6 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-5



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⋈ Split Spoon ⊠

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***CLAYSTONE*** | | | | | | | | | | |
| | *slightly weathered, organish brown with oxidation lensing and organic inclusions, moist* | | | | | | | | | | |
| 5320 | | | 30 | SS 8 | | 8-14-23 N=37 | | 26.4 | | | PP = >4.5 tsf |
| | | | 35 | MC 9 | | 27-50/3" | | | | | PP = >4.5 tsf |
| 5315 | | | | | | | | | | | |
| | ▼ | | | | | | | | | | |
| | ▽ *grades to highly weathered, wet* | | 40 | SS 10 | | 50 | | | | | PP = >4.5 tsf |
| 5310 | | | | | | | | | | | |
| | | | 45 | MC 11 | | 50 | | 16.0 | 102.0 | | |
| | *grades to sandy, bluish gray, moist* | | | | | | | | | | |
| 5305 | | | | | | | | | | | |
| | *grades to moderately weathered* | | | SS 12 | | 27-50/3" | | | | | |
| | ***49.8'*** | | | | | | | | | | |

***BASE OF BORING AT 49.8 FEET***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 40.0 ft |
| IAD | ▼ 38.6 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-6



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon ☒ Modified California Sampler ⋈

**APPROX. SURFACE ELEV. (ft):** 5352.0

| ELEVATION (ft) | MATERIAL DESCRIPTION | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** *0.3'* | 0 | | | | | | | | |
| 5350 | *4 inches of organic rich clay*<br>***LEAN TO FAT CLAY***<br>*with sand and trace silt, stiff, light brown with white lensing, moist (CL/CH)* | | SS 1 | | 6-6-9 N=15 | | | | | PP = >4.5 tsf |
| | *grades to very stiff* | 5 | MC 2 | | 7-11 | | 10.0 | 110.1 | | Swell (500 psf surcharge): 2.1%PP = >4.5 tsf |
| | *6.0'* | | | | | | | | | |
| 5345 | ***SANDSTONE***<br>*moderately cemented, with trace gravel, yellow brown, moist* | | SS 3 | | 7-7-7 N=14 | | 8.2 | | | P-200 = 35.4% PP = >4.5 tsf |
| | | 10 | MC 4 | | 6-20 | 3.8 | 9.4 | 113.9 | | PP = >4.5 tsf |
| 5340 | | | | | | | | | | |
| | *14.5'* | | | | | | | | | |
| | ***CLAYSTONE***<br>*slightly weathered, with oxidation lensing, yellowish light brown, moist* | 15 | SS 5 | | 6-9-10 N=19 | | | | | PP = >4.5 tsf |
| 5335 | ▼ | | | | | | | | | |
| | *grades to gray* | 20 | MC 6 | | 5-15 | | 21.9 | | | PP = >4.5 tsf |
| 5330 | | | | | | | | | | |
| | *24.0'* | | | | | | | | | |
| | ***SANDSTONE***<br>*moderately cemented, yellow brown, moist* | 25 | SS 7 | | 10-50 | | 17.4 | | | PP = 3.0 tsf |
| 5325 | *27.0'* | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 40.0 ft |
| IAD | ▼ 47.6 ft after 0 Hrs |
| AD | ▼ 17.4 ft after 168Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

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# BOREHOLE REPORT NO. B-6



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon ☒ | Modified California Sampler ⋈

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5325 | ***SANDSTONE*** | | | | | | | | | | |
| | *moderately cemented, yellow brown, moist* | | 30 | MC 8 | | 50 | | | | | |
| 5320 | | | | | | | | | | | |
| | ***34.0'*** | | | | | | | | | | |
| | ***CLAYSTONE*** | | 35 | SS 9 | | 12-22-28 N=50 | | | | | |
| 5315 | *slightly weathered, brown with oxidation and organic or lignite lensing, moist* | | | | | | | | | | |
| | ▽ *grades to moderately weathered, gray, moist* | | 40 | MC 10 | | 50 | | | | | PP = 4.0 tsf |
| 5310 | | | | | | | | | | | |
| | *grades to slightly weathered* | | 45 | SS 11 | | 21-50 | | 18.8 | | | PP = >4.5 tsf |
| 5305 | ▼ | | | | | | | | | | |
| | ***49.3'*** | | | MC 12 | | 50/4" | | | | | PP = >4.5 tsf |
| | *grades to moderately weathered* | | | | | | | | | | |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

Note: Groundwater monitoring well installed following drilling.

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 40.0 ft |
| IAD | ▼ 47.6 ft after 0 Hrs |
| AD | ▼ 17.4 ft after 168Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

# BOREHOLE REPORT NO. B-7



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler | Split Spoon

**APPROX. SURFACE ELEV. (ft):** 5353.0

| ELEVATION (ft) | MATERIAL DESCRIPTION | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** — 0.5' | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | MC 1 | | 6-12 | | 12.9 | 115.3 | | Swell (150 psf surcharge): 6.2%PP = >4.5 tsf |
| | ***LEAN TO FAT CLAY*** | | | | | | | | | |
| 5350 | *with sand, very stiff, light brown with white lensing, moist (CL/CH)* | | | | | | | | | |
| | *grades to stiff* | 5 | SS 2 | | 6-7-7 N=14 | | | | | PP = >4.5 tsf |
| | 6.0' | | | | | | | | | |
| | ***CLAYSTONE*** | | MC 3 | | 11-17 | | 17.0 | 104.9 | | Swell (500 psf surcharge): 6.2%PP = >4.5 tsf |
| 5345 | *slightly weathered, yellowish gray with white lensing, moist* | | | | | | | | | |
| | *grades to with organic inclusions* — 10.0' | 10 | SS 4 | | 6-14-11 N=25 | | | | | PP = >4.5 tsf |
| | ***SANDSTONE*** | | | | | | | | | |
| | *moderately cemented, with gravel in matrix, yellow brown, moist* | | | | | | | | | |
| 5340 | | 15 | MC 5 | | 12-50/3" | | 16.2 | 107.9 | | PP = >4.5 tsf |
| 5335 | ▽ | | | | | | | | | |
| | *grades to with oxidation lensing, whitish yellow* | 20 | SS 6 | | 50 | | | | | PP = 3.0 tsf |
| 5330 | 24.0' | | | | | | | | | |
| | ***CLAYSTONE*** | 25 | MC 7 | | 11-17 | | | | | PP = >4.5 tsf |
| | *slightly weathered, grayish brown, moist* | | | | | | | | | |
| | 27.0' | | | | | | | | | |

***CONTINUED NEXT PAGE***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 19.0 ft |
| IAD | ▼ 33.7 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-7



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⊠ Split Spoon ⊠

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5325 | ***CLAYSTONE***<br>*slightly weathered, grayish brown with oxidation lensing and organic or lignite lensing, moist* | | | | | | | | | | |
| | | | 30 | SS 8 | | 10-12-16 N=28 | | 27.9 | | | PP = >4.5 tsf |
| 5320 | ▼ | | | | | | | | | | |
| | | | 35 | MC 9 | | 11-20 | | | | | |
| 5315 | | | | | | | | | | | |
| | | | 40 | SS 10 | | 10-12-16 N=28 | | | | | PP = >4.5 tsf |
| | ***40.0'*** | | | | | | | | | | |
| | ***SANDSTONE***<br>*moderately cemented, yellow brown, wet* | | | | | | | | | | |
| 5310 | ***44.0'*** | | | | | | | | | | |
| | ***CLAYSTONE***<br>*highly weathered, sandy, gray, wet* | | 45 | MC 11 | | 50/2" | | | | | PP = 3.0 tsf |
| 5305 | ***49.3'*** | | | SS 12 | | 50/3" | | | | | PP = 1.5 tsf |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 19.0 ft |
| IAD | ▼ 33.7 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-8



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

**APPROX. SURFACE ELEV. (ft):** 5356.5

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** 0.5' | | 0 | | | | | | | | |
| 5355 | *6 inches of organic rich clay* | | | SS 1 | | 12-16-16 N=32 | | | | 40/23 | PP = >4.5 tsf |
| | ***LEAN CLAY*** *with sand, hard, brown, moist (CL)* | | | MC 2 | | 12-17 | 10.6 | 7.3 | 118.3 | | PP = >4.5 tsf |
| | | | 5 | | | | | | | | |
| 5350 | 7.0' | | | SS 3 | | 3-2-5 N=7 | | | | | PP = 1.5 tsf |
| | ***CLAYSTONE*** *slightly weathered, yellow brown, moist* 9.0' | | | | | | | | | | |
| | ***SANDSTONE*** *moderately cemented, yellow brown, moist* | | 10 | MC 4 | | 8-50 | | | | | PP = >4.5 tsf |
| 5345 | 14.0' | | | | | | | | | | |
| | ***CLAYSTONE*** *moderately weathered, with sand, brownish gray with oxidation lensing and organic or lignite inclusions, moist* | | 15 | SS 5 | | 9-11-15 N=26 | | 23.5 | | | PP = >4.5 tsf |
| 5340 | | | | | | | | | | | |
| | | | 20 | MC 6 | | 18-32 | | 22.6 | 103.7 | | PP = >4.5 tsf |
| 5335 | | | | | | | | | | | |
| | | | 25 | SS 7 | | 8-9-13 N=22 | | | | | PP = >4.5 tsf |
| 5330 | 27.0' | | | | | | | | | | |

***CONTINUED NEXT PAGE***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 36.4 ft |
| IAD | ▼ 47.4 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-8



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***CLAYSTONE*** | | | | | | | | | | |
| | *moderately weathered, with sand, brownish gray with oxidation lensing and organic or lignite inclusions, moist* | | 30 | MC 8 | | 16-50/4" | | | | | PP = >4.5 tsf |
| 5325 | | | | | | | | | | | |
| | | | 35 | SS 9 | | 23-50/3" | | | | | PP = >4.5 tsf |
| 5320 | ▽ | | | | | | | | | | |
| | *grades to wet* | | 40 | MC 10 | | 21-28 | | | | | PP = >4.5 tsf |
| 5315 | | | | | | | | | | | |
| | *grades to dark gray, increased sand content* | | 45 | SS 11 | | 50 | | | | | PP = >4.5 tsf |
| 5310 | ▼ | | | | | | | | | | |
| | ***49.3'*** | | | MC 12 | | 50/4" | | | | | PP = >4.5 tsf |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 36.4 ft |
| IAD | ▼ 47.4 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/27/20 | FINISHED: | 8/27/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-9



| PROJECT NAME | CLIENT |
|---|---|
| Westminster Water 2025 Preliminary | CDM Smith |
| **PROJECT NUMBER** | **LOCATION** |
| 019-1378 | Westminster, Colorado |

Split Spoon ☒ Modified California Sampler ⋈

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5360 | **APPROX. SURFACE ELEV. (ft):** 5360.0 | | 0 | | | | | | | | |
| | ***ROOT ZONE*** 0.5' | | | | | | | | | | |
| | *6 inches of organic rich clay* | | | SS 1 | | 7-6-6 N=12 | | | | | PP = >4.5 tsf |
| | ***LEAN CLAY*** | | | | | | | | | | |
| | *with sand, stiff, light brown, moist (CL)* | | | MC 2 | | 9-11 | 7.9 | 12.8 | 108.0 | | PP = >4.5 tsf |
| 5355 | *grades to very stiff* | | 5 | | | | | | | | |
| | 6.0' | | | SS 3 | | 15-16-17 N=33 | | | | | PP = >4.5 tsf |
| | ***SANDSTONE*** | | | | | | | | | | |
| | *moderately cemented, orangish brown, moist* | | | MC 4 | | 12-50 | | | | | |
| 5350 | | | 10 | | | | | | | | |
| | | | | SS 5 | | 50 | | | | | PP = 3.25 tsf |
| 5345 | *grades to with small sandstone fragments in matrix* | | 15 | | | | | | | | |
| | | | | MC 6 | | 15-50/4" | 2.6 | 12.5 | 108.5 | | PP = >4.5 tsf |
| 5340 | 20.0' | | 20 | | | | | | | | |
| | ***CLAYSTONE*** | | | | | | | | | | |
| | *slightly weathered, with small oxidation lenses, yellow brown, moist* | | | SS 7 | | 7-10-15 N=25 | | | | | PP = >4.5 tsf |
| 5335 | *grades to with organic or lignite inclusions* | | 25 | | | | | | | | |
| | 27.0' | | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 35.0 ft |
| IAD | ▼ 34.6 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-9



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5330 | ***CLAYSTONE***<br>*slightly weathered, yellow brown with small oxidation lenses and organic or lignite inclusions, moist* | | 30 | MC 8 | | 14-26 | | | | | PP = >4.5 tsf |
| 5325 | *6 inch sandstone lense noted* | | 35 | SS 9 | | 50/5" | | | | | PP = 1.75 tsf |
| | ***39.0'*** | | | | | | | | | | |
| 5320 | ***SANDSTONE***<br>*poorly cemented, with oxidation lensing, orangish brown, moist* | | 40 | MC 10 | | 50 | | | | | |
| | ***44.0'*** | | | | | | | | | | |
| 5315 | ***CLAYSTONE***<br>*highly weathered, sandy, bluish gray, moist* | | 45 | SS 11 | | 50/2" | | | | | |
| | ***49.3'*** | | | MC 12 | | 50/4" | | | | | PP = >4.5 tsf |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ 35.0 ft |
| IAD | ▼ 34.6 ft after 0 Hrs |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-10



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5365 | **APPROX. SURFACE ELEV. (ft):** 5365.0 | | 0 | | | | | | | | |
| | ***ROOT ZONE*** 0.5' | | | | | | | | | | |
| | *6 inches of organic rich clay* | | | SS 1 | CL | 6-8-8 N=16 | | 11.7 | | 44/30 | P-200 = 50.8% PP = >4.5 tsf |
| | ***SANDY CLAY*** | | | | | | | | | | |
| | *very stiff, brown with white lensing, moist (CL)* | | | MC 2 | | 8-12 | | | | | PP = >4.5 tsf |
| 5360 | | | 5 | | | | | | | | |
| | 6.0' | | | | | | | | | | |
| | ***CLAYEY SAND*** | | | SS 3 | | 7-10-11 N=21 | | | | | PP = >4.5 tsf |
| | *medium dense, brown with white lensing, moist (SC)* | | | | | | | | | | |
| | 9.0' | | | | | | | | | | |
| 5355 | ***SANDSTONE*** | | 10 | MC 4 | | 9-18 | | 12.9 | | | |
| | *poorly cemented, with small oxidation lenses, whitish brown, moist* | | | | | | | | | | |
| | 14.0' | | | | | | | | | | |
| 5350 | ***CLAYSTONE*** | | 15 | SS 5 | | 6-9-13 N=22 | | 22.4 | | | PP = >4.5 tsf |
| | *slightly weathered, tan with oxidation and organic or lignite lensing, moist* | | | | | | | | | | |
| 5345 | | | 20 | MC 6 | | 10-29 | | | | | PP = >4.5 tsf |
| 5340 | *grades to yellowish brown* | | 25 | SS 7 | | 6-10-15 N=25 | | | | | PP = >4.5 tsf |
| | 27.0' | | | | | | | | | | |

***CONTINUED NEXT PAGE***

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

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# BOREHOLE REPORT NO. B-10



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Split Spoon | Modified California Sampler

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***CLAYSTONE***<br>*slightly weathered, yellowish brown with oxidation and organic or lignite lensing, moist* **29.0'** | | | | | | | | | | |
| 5335 | ***SANDSTONE***<br>*poorly cemented, yellow orange, with oxidation lensing, moist* | | 30 | MC 8 | | 50/5" | | 14.2 | | | |
| 5330 | *grades to moderately cemented* | | 35 | SS 9 | | 10-20-20 N=40 | | | | | PP = >4.5 tsf |
| 5325 | *grades to gray* | | 40 | MC 10 | | 50/5" | | | | | PP = >4.5 tsf |
| | **44.0'** | | | | | | | | | | |
| 5320 | ***CLAYSTONE***<br>*moderately to highly weathered, sandy, thinly bedded, gray, moist* | | 45 | SS 11 | | 21-50/5" | | | | | PP = >4.5 tsf |
| | **49.3'** | | | MC 12 | | 50/4" | | | | | PP = >4.5 tsf |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

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# BOREHOLE REPORT NO. B-11

Sheet 1 of 2

| PROJECT NAME | CLIENT |
|---|---|
| Westminster Water 2025 Preliminary | CDM Smith |
| **PROJECT NUMBER** | **LOCATION** |
| 019-1378 | Westminster, Colorado |

Modified California Sampler ⊠ Split Spoon ⊠

**APPROX. SURFACE ELEV. (ft):** 5367.5

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***ROOT ZONE*** — 0.5' | | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | | MC 1 | | 8-10 | | | | | PP = >4.5 tsf |
| 5365 | ***LEAN CLAY*** | | | | | | | | | | |
| | *with sand and gravel, very stiff, brown, moist (CL)* | | | | | | | | | | |
| | — 4.8' | | 5 | SS 2 | | 2-2-8 N=10 | | | | | |
| | ***SANDSTONE*** | | | | | | | | | | |
| | *poorly cemented, light brown, moist* — 6.0' | | | MC 3 | | 22-24 | | 14.7 | 108.5 | | PP = >4.5 tsf |
| 5360 | ***CLAYSTONE*** | | | | | | | | | | |
| | *moderately weathered, with gravel in matrix, brown, moist* | | | | | | | | | | |
| | — 9.0' | | | | | | | | | | |
| | ***SANDSTONE*** — 10.0' | | 10 | SS 4 | | 17-11-9 N=20 | | | | | PP = >4.5 tsf |
| | *poorly cemented, orangish brown, moist* | | | | | | | | | | |
| | ***CLAYSTONE*** | | | | | | | | | | |
| 5355 | *slightly weathered, gray brown with oxidation lensing, moist* | | | | | | | | | | |
| | — 14.5' | | 15 | MC 5 | | 18-32 | | | | | PP = >4.5 tsf |
| | ***SANDSTONE*** | | | | | | | | | | |
| | *moderately cemented, yellowish brown with oxidation lensing, moist* | | | | | | | | | | |
| 5350 | — 19.0' | | | | | | | | | | |
| | ***CLAYSTONE*** | | 20 | SS 6 | | 11-12-14 N=26 | | 24.9 | | | PP = >4.5 tsf |
| | *moderately weathered, brownish gray with oxidation lensing, moist* | | | | | | | | | | |
| 5345 | | | | | | | | | | | |
| | *grades to slightly weathered* | | 25 | MC 7 | | 15-50/4" | | | | | |
| | — 27.0' | | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

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# BOREHOLE REPORT NO. B-11



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⊠ Split Spoon ☒

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5340 | ***CLAYSTONE*** | | | | | | | | | | |
| | *slightly weathered, brownish gray with oxidation lensing, moist* | | | | | | | | | | |
| | *grades to moderately weathered* | | 30 | SS 8 | | 15-50/4" | | 18.4 | | | PP = 2.75 tsf |
| 5335 | | | | | | | | | | | |
| | | | 35 | MC 9 | | 15-50/5" | | | | | |
| 5330 | | | | | | | | | | | |
| | | | 40 | SS 10 | | 50 | | | | | |
| | *grades to highly weathered, sandy, gray* | | | | | | | | | | |
| 5325 | | | | | | | | | | | |
| | | | 45 | MC 11 | | 50/3" | | | | | PP = >4.5 tsf |
| 5320 | | | | | | | | | | | |
| | ***49.3'*** | | | SS 12 | | 50/4" | | | | | PP = >4.5 tsf |
| | ***BASE OF BORING AT 49.3 FEET*** | | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ Not Performed |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/26/20 | FINISHED: | 8/26/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: CONTINUOUS FLIGHT AUGER | | | |

# BOREHOLE REPORT NO. B-12



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⊠ Split Spoon ⊠

**APPROX. SURFACE ELEV. (ft):** 5373.0

| ELEVATION (ft) | MATERIAL DESCRIPTION | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***TOPSOIL*** 0.5' | 0 | | | | | | | | |
| | *6 inches of organic rich clay* | | MC 1 | | 9-9 | | | | | PP = >4.5 tsf |
| | ***LEAN CLAY*** | | | | | | | | | |
| 5370 | *with sand, trace silt and white lensing, very stiff, light brown, moist (CL)* | | | | | | | | | |
| | *grades to with trace gravel* | 5 | SS 2 | | 6-8-5 N=13 | | | | 37/21 | PP = >4.5 tsf |
| | 7.0' | | MC 3 | | 6-10 | | | | | PP = >4.5 tsf |
| | ***CLAYSTONE*** | | | | | | | | | |
| 5365 | *highly weathered, sandy, yellowish brown, moist* | | | | | | | | | |
| | *grades to with oxidation lensing* | 10 | SS 4 | | 7-11-13 N=24 | | | | | PP = >4.5 tsf |
| 5360 | | | | | | | | | | |
| | *grades to yellowish gray, blocky* | 15 | MC 5 | | 7-19 | | 22.1 | 100.9 | | PP = 4.0 tsf |
| 5355 | | | | | | | | | | |
| | *grades to moderately weathered, with trace organic or lignite lensing* | 20 | SS 6 | | 14-22-28 N=50 | | | | | PP = >4.5 tsf |
| 5350 | | | | | | | | | | |
| | | 25 | MC 7 | | 9-23 | | | | | PP = >4.5 tsf |
| | 27.0' | | | | | | | | | |
| | ***CONTINUED NEXT PAGE*** | | | | | | | | | |

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ 21.4 ft after 168Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

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# BOREHOLE REPORT NO. B-12



PROJECT NAME: **Westminster Water 2025 Preliminary**

CLIENT: **CDM Smith**

PROJECT NUMBER: **019-1378**

LOCATION: **Westminster, Colorado**

Modified California Sampler ⊠ Split Spoon ⊠

| ELEVATION (ft) | MATERIAL DESCRIPTION | GRAPHIC LOG | DEPTH (ft) | SAMPLE TYPE NUMBER | CLASSIFICATION (USCS) | BLOWS/6" N-VALUE | UNC. STR. (tsf) | MOISTURE (%) | DRY DENSITY (pcf) | LL/PI (%) | ADDITIONAL DATA/ REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5345 | ***CLAYSTONE*** *slightly weathered, sandy, yellowish gray, blocky texture, moist* | | 30 | SS 8 | | 21-20-50/1" | | | | | PP = >4.5 tsf |
| 5340 | | | 35 | MC 9 | | 14-34 | | | | | PP = >4.5 tsf |
| 5335 | *grades to grayish brown, slightly weathered* | | 40 | SS 10 | | 11-16-20 N=36 | | 20.5 | | | PP = >4.5 tsf |
| 5330 | *grades to light gray* | | 45 | MC 11 | | 50/4" | | | | | PP = 4.0 tsf |
| 5325 | *grades to highly weathered, increased sand content* | | | SS 12 | | 50/5" | | | | | PP = 2.75 tsf |
| | ***49.4'*** | | | | | | | | | | |

***BASE OF BORING AT 49.4 FEET***

Note: Groundwater monitoring well installed following drilling.

| WATER LEVEL OBSERVATIONS | |
|---|---|
| WD | ▽ Not Encountered |
| IAD | ▼ Not Encountered |
| AD | ▼ 21.4 ft after 168Hrs |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

| | | | |
|---|---|---|---|
| STARTED: | 8/24/20 | FINISHED: | 8/24/20 |
| DRILL CO.: | VINE LABS | DRILL RIG: | ATV |
| DRILLER: | VINE LABS | LOGGED BY: | M. ALMAND |
| METHOD: HOLLOW STEM AUGER | | | |

# APPENDIX C
Laboratory Test Results

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

# SUMMARY OF LABORATORY RESULTS



**PROJECT NAME:** Westminster Water 2025 Preliminary
**PROJECT NUMBER:** 019-1378
**CLIENT:** CDM Smith
**PROJECT LOCATION:** Westminster, Colorado

| BORING NUMBER | SAMPLE I.D. | SAMPLE DEPTH (ft) | MOISTURE CONTENT (%) | DRY DENSITY (pcf) | VOID RATIO | SATURATION (%) | UNCONFINED STRENGTH (tsf) | STRAIN (%) | ATTERBERG LIMITS | | | P-200 | USCS CLASS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | LIQUID LIMIT | PLASTIC LIMIT | PLASTIC INDEX | | |
| B-1 | SS-3 | 6.0 - 7.5' | 21.6 | | | | | | 56 | 20 | 36 | | |
| B-1 | MC-4 | 9.0 - 10.0' | 12.7 | 113.3 | 0.488 | 70.5 | 3.6 | 4.0 | | | | | |
| B-1 | SS-7 | 24.0 - 25.5' | 20.5 | | | | | | | | | | |
| B-1 | SS-9 | 34.0 - 35.5' | 16.3 | | | | | | | | | | |
| B-1 | MC-12 | 49.0 - 49.3' | 11.5 | | | | | | | | | | |
| B-2 | SS-3 | 6.0 - 7.5' | 9.5 | | | | | | | | | 43.6 | |
| B-2 | SS-5 | 14.0 - 15.5' | 10.4 | | | | | | | | | | |
| B-2 | SS-9 | 34.0 - 35.0' | 21.4 | | | | | | | | | | |
| B-3 | MC-2 | 3.5 - 4.5' | 15.2 | 103.9 | 0.622 | 66.0 | | | | | | | |
| B-3 | MC-4 | 9.0 - 10.0' | 22.9 | 99.6 | 0.692 | 89.3 | | | | | | | |
| B-3 | MC-10 | 39.0 - 39.8' | 22.6 | 94.4 | 0.785 | 77.6 | | | | | | | |
| B-4 | MC-3 | 6.0 - 7.0' | 18.9 | | | | | | 40 | 15 | 25 | 64.1 | CL |
| B-4 | MC-5 | 14.0 - 15.0' | 17.2 | 110.3 | 0.528 | 87.8 | 8.2 | 4.6 | | | | | |
| B-4 | SS-6 | 19.0 - 19.8' | 15.8 | | | | | | | | | | |
| B-4 | SS-10 | 39.0 - 40.0' | 28.8 | | | | | | | | | | |
| B-5 | SS-2 | 3.5 - 5.0' | 10.5 | | | | | | | | | | |
| B-5 | MC-5 | 14.0 - 15.0' | 4.6 | | | | | | | | | | |
| B-5 | SS-8 | 29.0 - 30.5' | 26.4 | | | | | | | | | | |
| B-5 | MC-11 | 44.0 - 44.5' | 16.0 | 102.0 | 0.653 | 66.3 | | | | | | | |
| B-6 | MC-2 | 3.5 - 4.5' | 10.0 | 110.1 | 0.531 | 50.9 | | | | | | | |
| B-6 | SS-3 | 6.0 - 7.5' | 8.2 | | | | | | | | | 35.4 | |
| B-6 | MC-4 | 9.0 - 10.0' | 9.4 | 113.9 | 0.480 | 52.6 | 3.8 | 3.6 | | | | | |
| B-6 | MC-6 | 19.0 - 20.0' | 21.9 | | | | | | | | | | |
| B-6 | SS-7 | 24.0 - 25.0' | 17.4 | | | | | | | | | | |
| B-6 | SS-11 | 44.0 - 45.0' | 18.8 | | | | | | | | | | |
| B-7 | MC-1 | 1.0 - 2.0' | 12.9 | 115.3 | 0.462 | 75.4 | | | | | | | |
| B-7 | MC-3 | 6.0 - 7.0' | 17.0 | 104.9 | 0.607 | 75.6 | | | | | | | |
| B-7 | MC-5 | 14.0 - 14.8' | 16.2 | 107.9 | 0.562 | 77.7 | | | | | | | |
| B-7 | SS-8 | 29.0 - 30.5' | 27.9 | | | | | | | | | | |
| B-8 | SS-1 | 1.0 - 2.5' | | | | | | | 40 | 17 | 23 | | |

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

# SUMMARY OF LABORATORY RESULTS



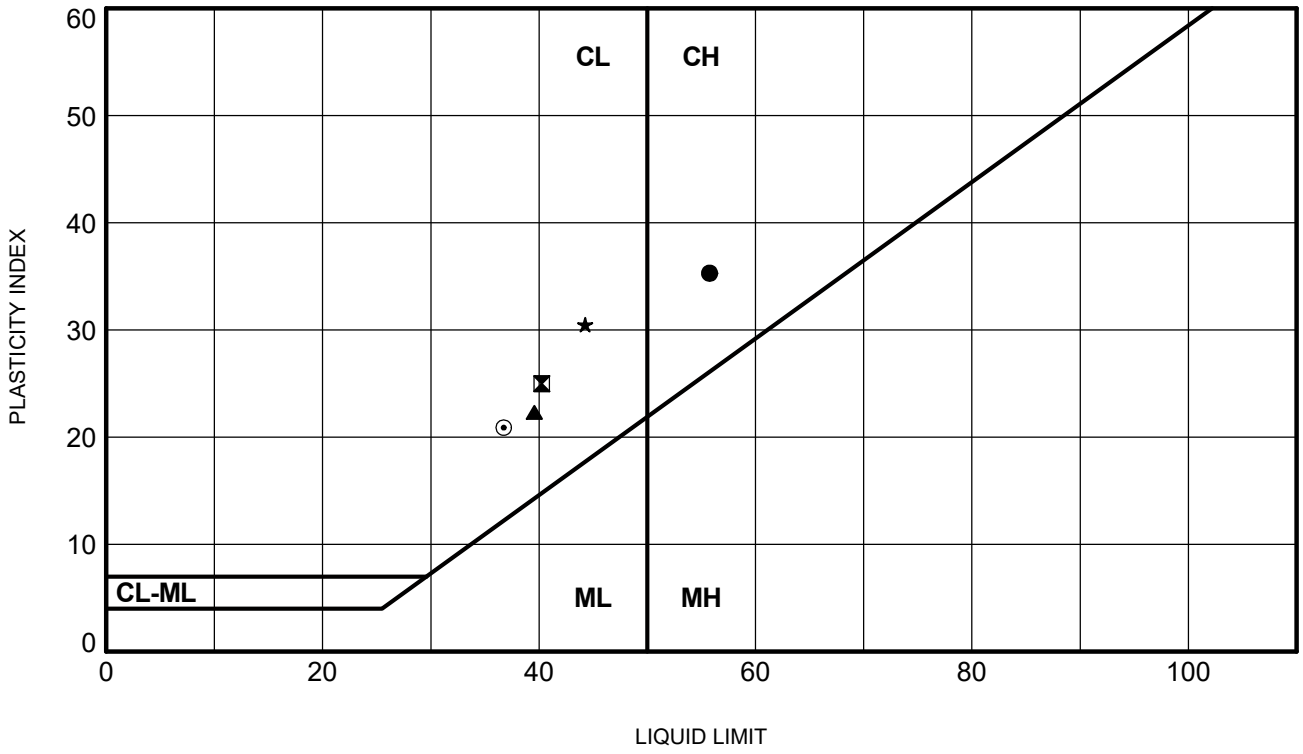
**PROJECT NAME:** Westminster Water 2025 Preliminary
**PROJECT NUMBER:** 019-1378
**CLIENT:** CDM Smith
**PROJECT LOCATION:** Westminster, Colorado

| BORING NUMBER | SAMPLE I.D. | SAMPLE DEPTH (ft) | MOISTURE CONTENT (%) | DRY DENSITY (pcf) | VOID RATIO | SATURATION (%) | UNCONFINED STRENGTH (tsf) | STRAIN (%) | ATTERBERG LIMITS | | | P-200 | USCS CLASS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | LIQUID LIMIT | PLASTIC LIMIT | PLASTIC INDEX | | |
| B-8 | MC-2 | 3.5 - 4.5' | 7.3 | 118.3 | 0.425 | 46.1 | 10.6 | 3.5 | | | | | |
| B-8 | SS-5 | 14.0 - 15.5' | 23.5 | | | | | | | | | | |
| B-8 | MC-6 | 19.0 - 20.0' | 22.6 | 103.7 | 0.625 | 97.8 | | | | | | | |
| B-9 | MC-2 | 3.5 - 4.5' | 12.8 | 108.0 | 0.561 | 61.7 | 7.9 | 2.3 | | | | | |
| B-9 | MC-6 | 19.0 - 19.8' | 12.5 | 108.5 | 0.554 | 60.7 | 2.6 | 2.8 | | | | | |
| B-10 | SS-1 | 1.0 - 2.5' | 11.7 | | | | | | 44 | 14 | 30 | 50.8 | CL |
| B-10 | MC-4 | 9.0 - 10.0' | 12.9 | | | | | | | | | | |
| B-10 | SS-5 | 14.0 - 15.5' | 22.4 | | | | | | | | | | |
| B-10 | MC-8 | 29.0 - 29.4' | 14.2 | | | | | | | | | | |
| B-11 | MC-3 | 6.0 - 7.0' | 14.7 | 108.5 | 0.554 | 71.9 | | | | | | | |
| B-11 | SS-6 | 19.0 - 20.5' | 24.9 | | | | | | | | | | |
| B-11 | SS-8 | 29.0 - 29.8' | 18.4 | | | | | | | | | | |
| B-12 | SS-2 | 3.5 - 5.0' | | | | | | | 37 | 16 | 21 | | |
| B-12 | MC-5 | 14.0 - 15.0' | 22.1 | 100.9 | 0.671 | 89.0 | | | | | | | |
| B-12 | SS-10 | 39.0 - 40.5' | 20.5 | | | | | | | | | | |

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

# ATTERBERG LIMITS RESULTS

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith
**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado



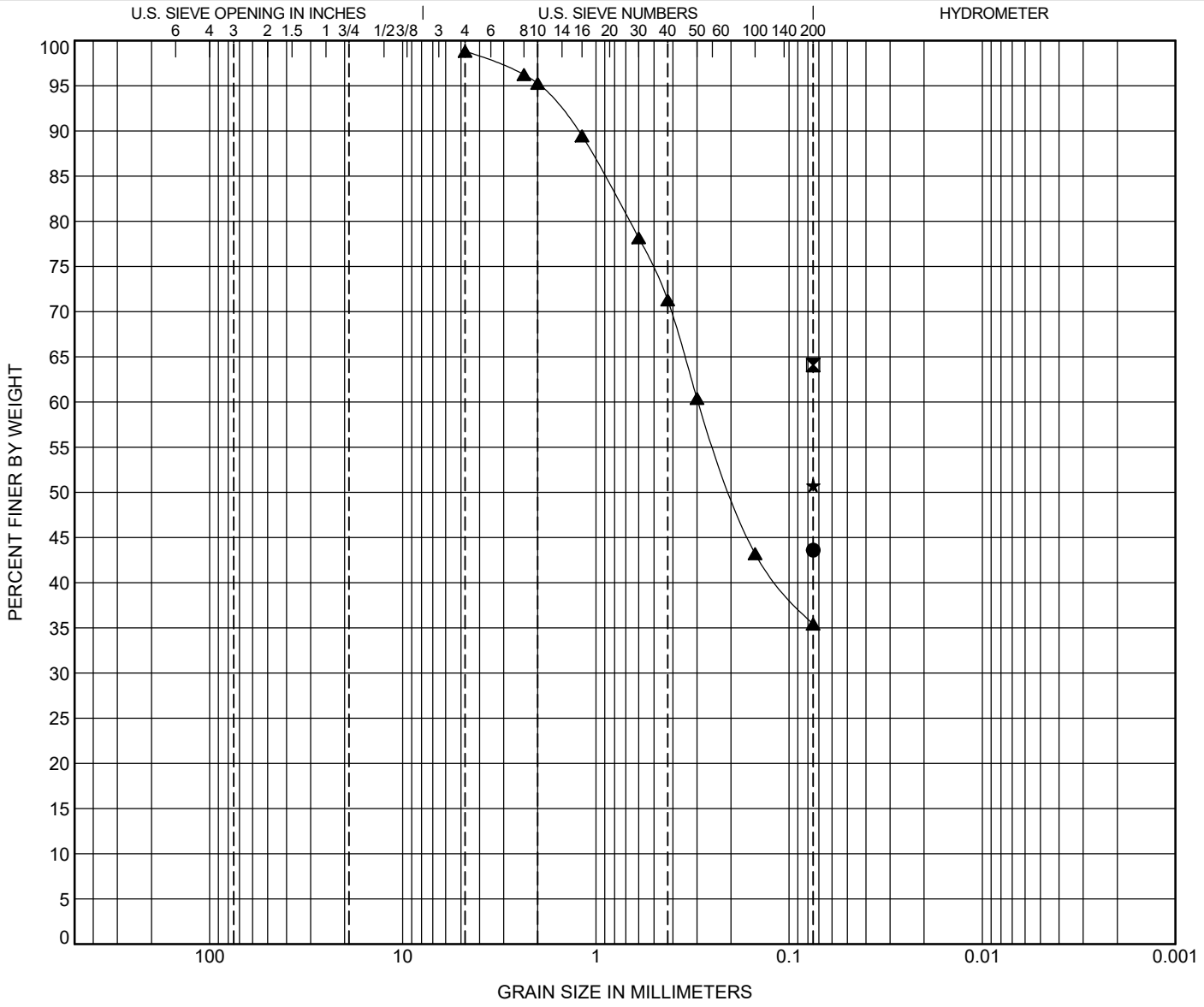

| Boring No. | Sample ID | Depth (ft) | Liquid Limit (%) | Plastic Limit (%) | Plastic Index (%) | Fines (%) | Classification (USCS) |
|---|---|---|---|---|---|---|---|
| ● B-1 | SS-3 | 6.0 - 7.5 | 56 | 20 | 36 | | |
| ⊠ B-4 | MC-3 | 6.0 - 7 | 40 | 15 | 25 | 64.1 | CL |
| ▲ B-8 | SS-1 | 1.0 - 2.5 | 40 | 17 | 23 | | |
| ★ B-10 | SS-1 | 1.0 - 2.5 | 44 | 14 | 30 | 50.8 | CL |
| ⊙ B-12 | SS-2 | 3.5 - 5 | 37 | 16 | 21 | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

# GRAIN SIZE DISTRIBUTION

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Boring No. | Sample ID | Depth (ft) | Classification | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● B-2 | SS-3 | 6.0 - 7.5 | Clayey sand (SC) | | | | | |
| ⊠ B-4 | MC-3 | 6.0 - 7.0 | Sandy Lean clay (CL) | 40 | 15 | 25 | | |
| ▲ B-6 | SS-3 | 6.0 - 7.5 | Clayey sand (SC) | | | | | |
| ★ B-10 | SS-1 | 1.0 - 2.5 | Sandy Lean clay (CL) | 44 | 14 | 30 | | |
| | | | | | | | | |

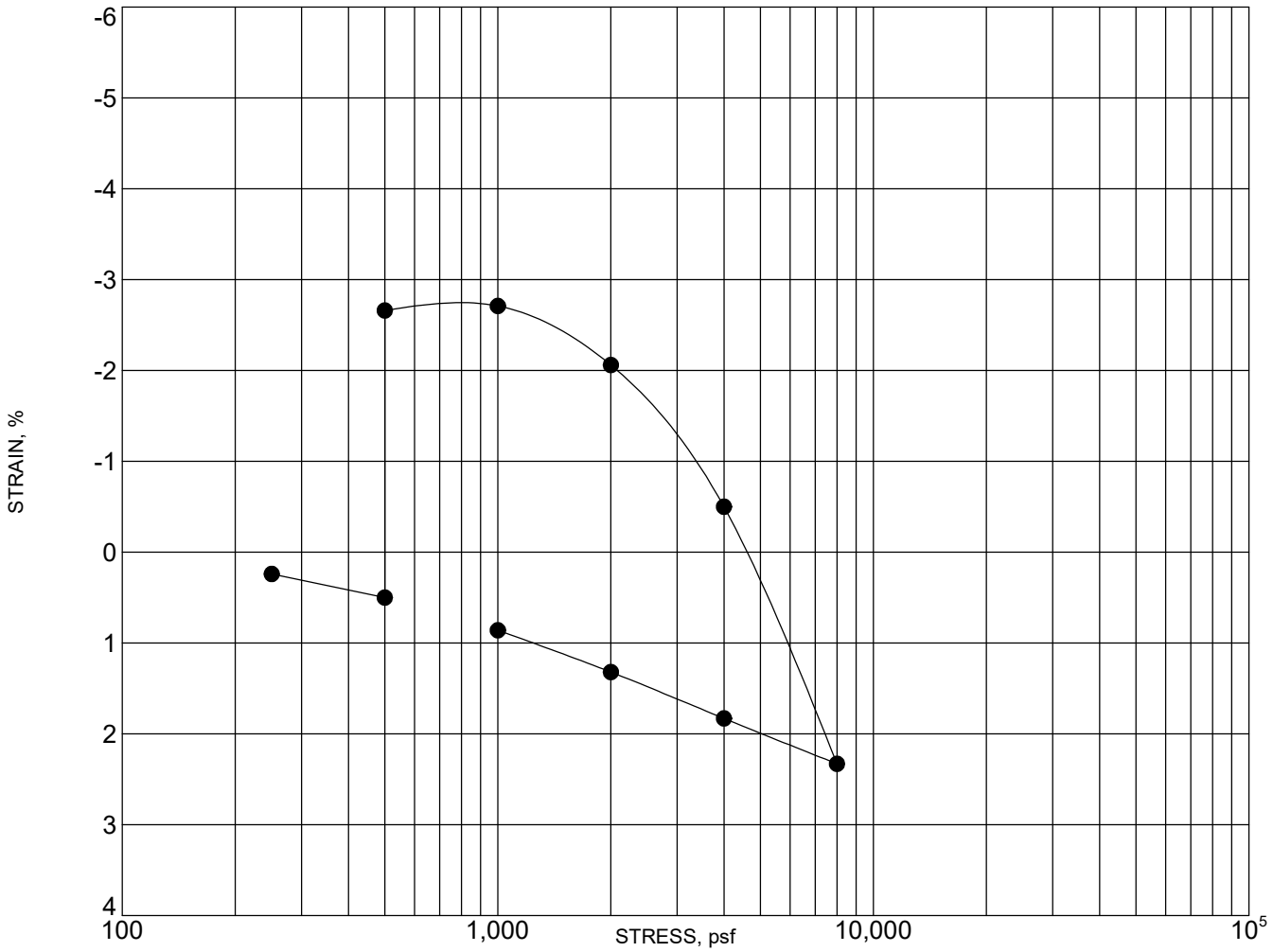
| Boring No. | Sample ID | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● B-2 | SS-3 | 0.075 | | | | | | 43.6 | |
| ⊠ B-4 | MC-3 | 0.075 | | | | | | 64.1 | |
| ▲ B-6 | SS-3 | 4.75 | 0.295 | | | | 63.4 | 35.4 | |
| ★ B-10 | SS-1 | 0.075 | | | | | | 50.8 | |
| | | | | | | | | | |

**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# SWELL / CONSOLIDATION TEST

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado




| | | | | | |
|---|---|---|---|---|---|
| Boring No: | B-3 | Initial Water Content (%): | 15.2 | Est. Preconsolidation Stress (tsf): | |
| Sample ID: | MC-2 | Final Water Content (%): | 21.7 | Laboratory Water Type: | Distilled |
| Sample Depth: | 3.5 - 4.5' | Initial Dry Density (pcf): | 103.9 | Test Procedure Method: | C |
| Start Date: | 9/9 | Initial Void Ratio: | 0.621 | Interpretation Procedure: | NA |
| Technician: | N. RASMUSSEN | Final Void Ratio: | 0.594 | Stress at Inundation (psf): | 500 |
| Apparatus: | DNV Swell A | Initial Degree of Saturation (%): | 66.2 | Specimen Trimming Method: | Ring Sampler |
| Specific Gravity: | 2.7 | Final Degree of Saturation (%): | 98.7 | **ATTERBERG LIMITS** | |

| LL | PL | PI | Classification |
|---|---|---|---|
| | | | |

Sample Description: Fat clay with sand, brown with white lensing

**Notes:** Swell Potential (500 psf surcharge): 3.16%
Swell Pressure: 5,200 psf

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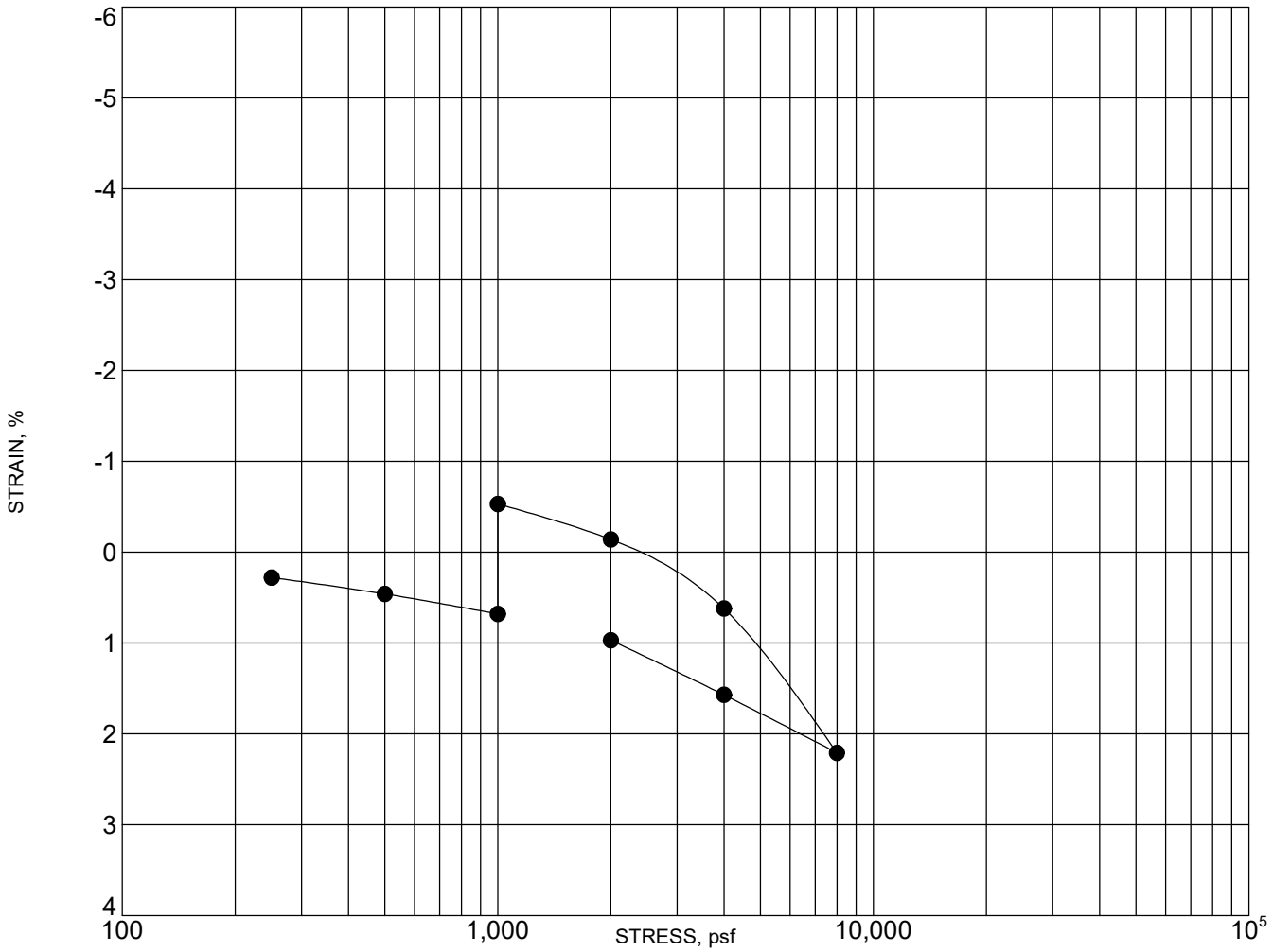
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# SWELL / CONSOLIDATION TEST

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado




Boring No: B-3

Sample ID: MC-4

Sample Depth: 9.0 - 10.0'

Start Date: 9/9/2020

Technician: N. RASMUSSEN

Apparatus: DNV Swell B

Specific Gravity: 2.7

Initial Water Content (%): 22.9

Final Water Content (%): 7.8

Initial Dry Density (pcf): 99.6

Initial Void Ratio: 0.691

Final Void Ratio: 0.446

Initial Degree of Saturation (%): 89.5

Final Degree of Saturation (%): 47.1

Est. Preconsolidation Stress (tsf):

Laboratory Water Type: Distilled

Test Procedure Method: C

Interpretation Procedure: NA

Stress at Inundation (psf): 1,000

Specimen Trimming Method: Ring Sampler

**ATTERBERG LIMITS**

| LL | PL | PI | Classification |
|---|---|---|---|

Sample Description: Claystone, yellowish light brown

**Notes:** Swell Potential (1,000 psf surcharge): 1.21%

Swell Pressure: 4,200 psf

**OLSSON, INC.**
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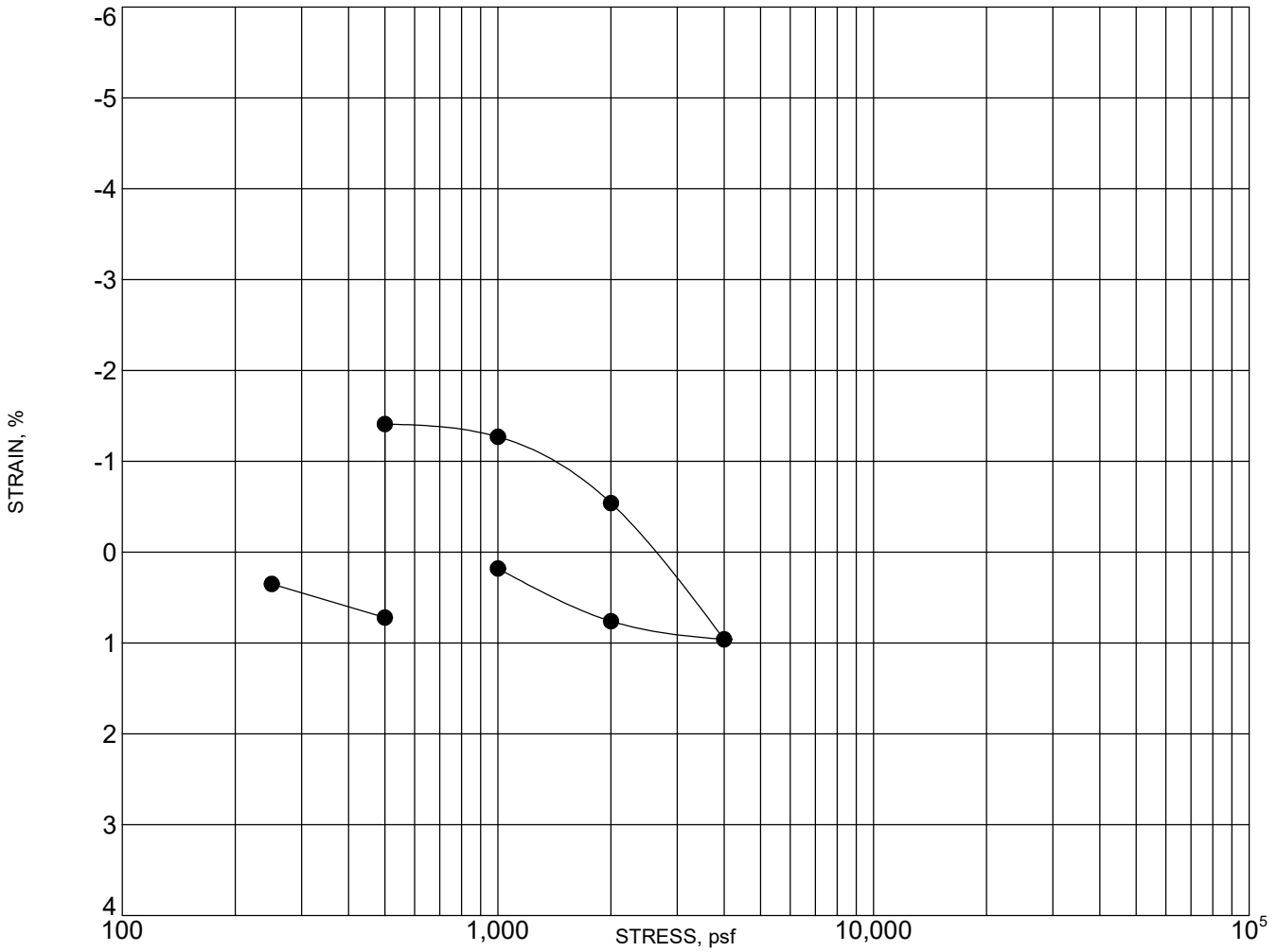
# SWELL / CONSOLIDATION TEST

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado




| | | | | | |
|---|---|---|---|---|---|
| Boring No: | B-6 | Initial Water Content (%): | 10.0 | Est. Preconsolidation Stress (tsf): | |
| Sample ID: | MC-2 | Final Water Content (%): | 19.2 | Laboratory Water Type: | Distilled |
| Sample Depth: | 3.5 - 4.5' | Initial Dry Density (pcf): | 110.1 | Test Procedure Method: | C |
| Start Date: | 9/9/2020 | Initial Void Ratio: | 0.531 | Interpretation Procedure: | NA |
| Technician: | N. RASMUSSEN | Final Void Ratio: | 0.526 | Stress at Inundation (psf): | 500 |
| Apparatus: | DNV Swell C | Initial Degree of Saturation (%): | 51.0 | Specimen Trimming Method: | Ring Sampler |
| Specific Gravity: | 2.7 | Final Degree of Saturation (%): | 98.7 | | |

**ATTERBERG LIMITS**

| LL | PL | PI | Classification |
|---|---|---|---|
| | | | |

Sample Description: Lean clay with sand, light brown with white lensing

**Notes:** Swell Potential (500 psf surcharge): 2.13%
Swell Pressure: 3,500 psf

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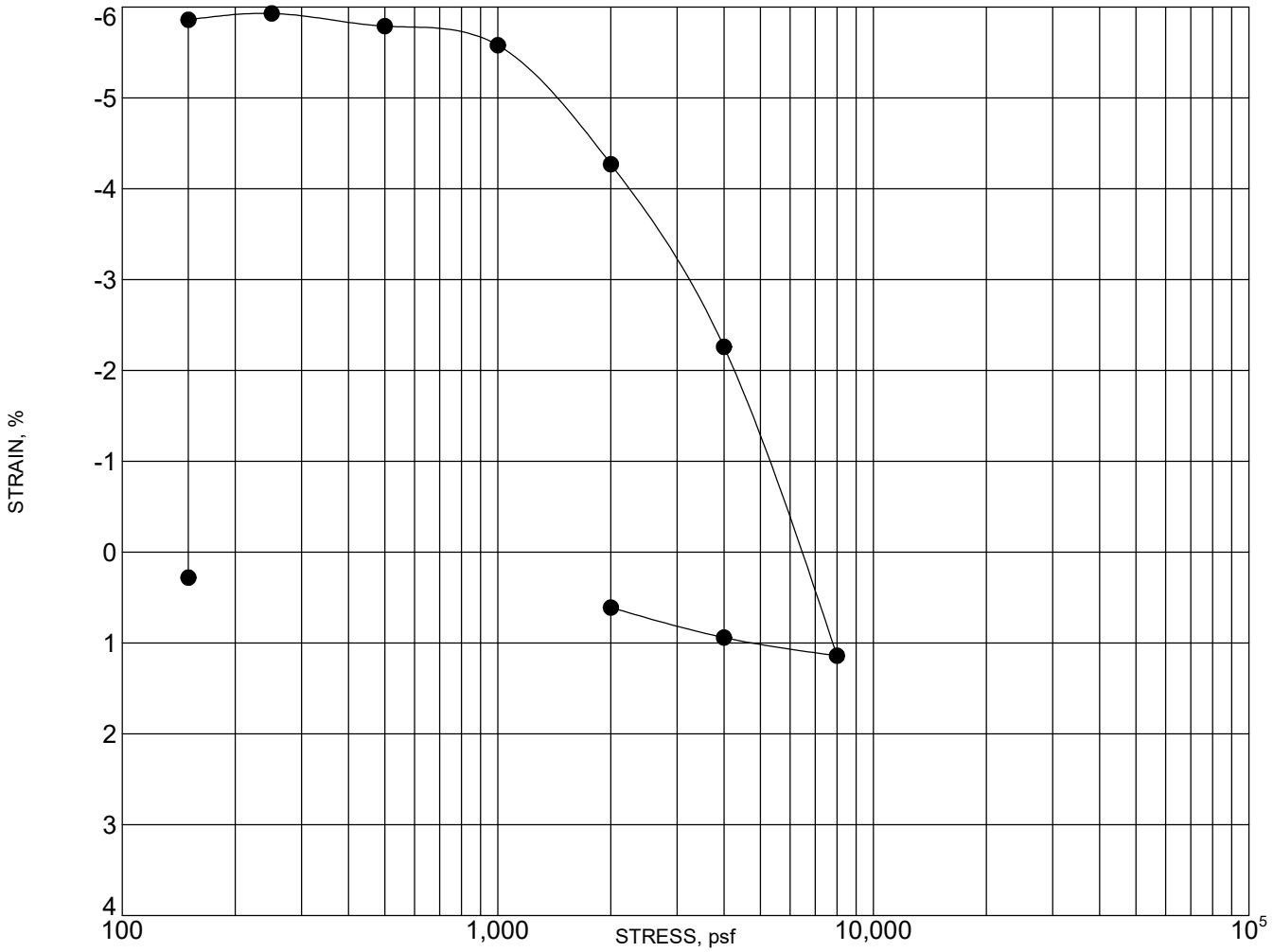
# SWELL / CONSOLIDATION TEST

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminister, Colorado




| | | | | | |
|---|---|---|---|---|---|
| Boring No: | B-7 | Initial Water Content (%): | 12.9 | Est. Preconsolidation Stress (tsf): | |
| Sample ID: | MC-1 | Final Water Content (%): | 24.1 | Laboratory Water Type: | Distilled |
| Sample Depth: | 1.0 - 2.0' | Initial Dry Density (pcf): | 115.3 | Test Procedure Method: | C |
| Start Date: | 9/9/2020 | Initial Void Ratio: | 0.461 | Interpretation Procedure: | NA |
| Technician: | N. RASMUSSEN | Final Void Ratio: | 0.491 | Stress at Inundation (psf): | 150 |
| Apparatus: | DNV Swell D | Initial Degree of Saturation (%): | 75.3 | Specimen Trimming Method: | Ring Sampler |
| Specific Gravity: | 2.7 | Final Degree of Saturation (%): | 100.0 | **ATTERBERG LIMITS** | |

| LL | PL | PI | Classification |
|---|---|---|---|
| | | | |

Sample Description: Lean to fat clay with sand, light brown with white lensing

**Notes:** Swell Potential (150 psf surcharge): 6.15%
Swell Pressure: 6,900 psf

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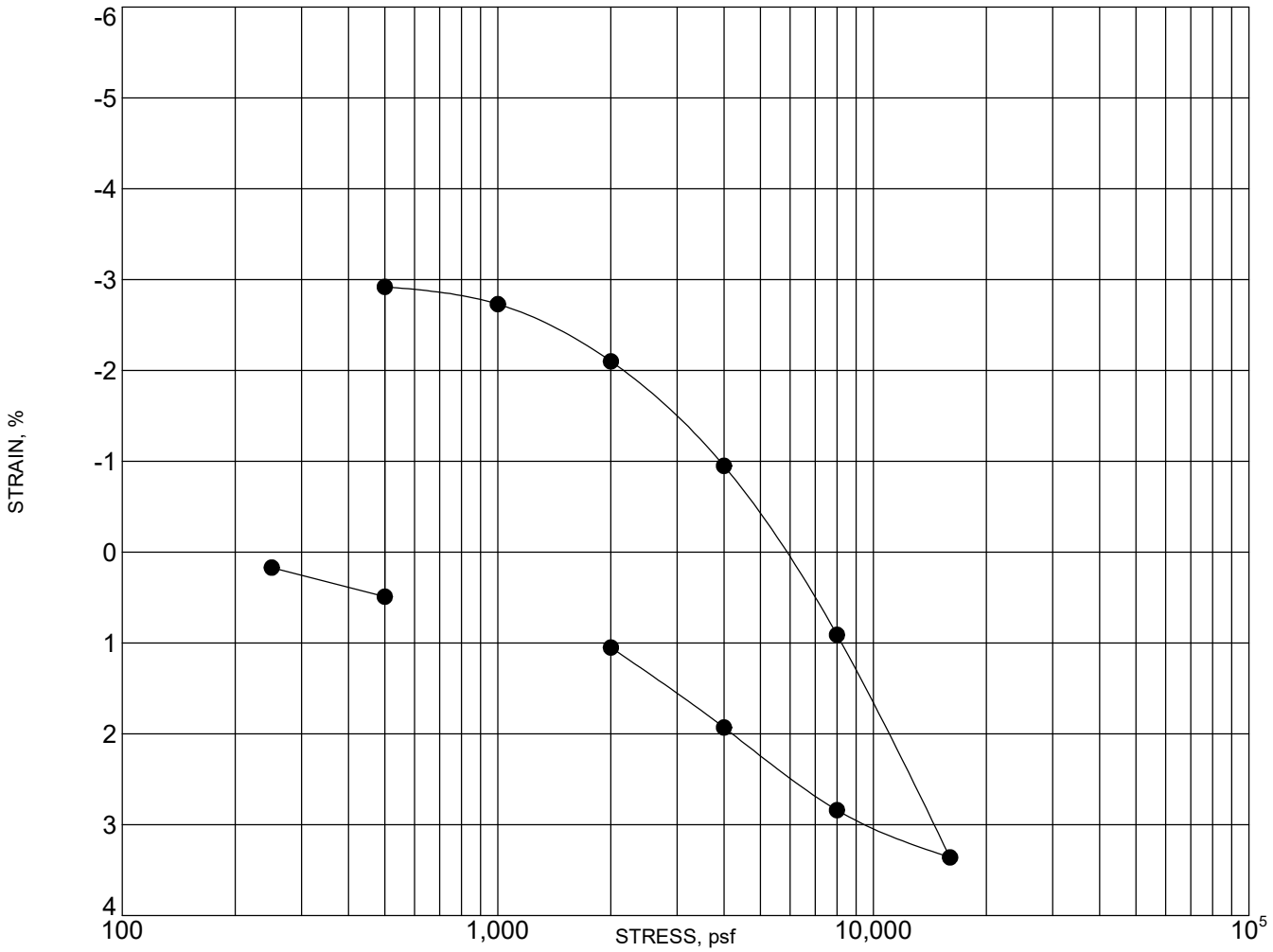
# SWELL / CONSOLIDATION TEST

**PROJECT NAME:** Westminster Water 2025 Preliminary **CLIENT:** CDM Smith

**PROJECT NUMBER:** 019-1378 **PROJECT LOCATION:** Westminster, Colorado




Boring No: B-7

Sample ID: MC-3

Sample Depth: 6.0 - 7.0'

Start Date: 9/9/2020

Technician: N. RASMUSSEN

Apparatus: DNV Swell E

Specific Gravity: 2.7

Initial Water Content (%): 17.0

Final Water Content (%): 21.5

Initial Dry Density (pcf): 104.9

Initial Void Ratio: 0.606

Final Void Ratio: 0.570

Initial Degree of Saturation (%): 75.6

Final Degree of Saturation (%): 100.0

Est. Preconsolidation Stress (tsf):

Laboratory Water Type: Distilled

Test Procedure Method: C

Interpretation Procedure: NA

Stress at Inundation (psf): 500

Specimen Trimming Method: Ring Sampler

**ATTERBERG LIMITS**

| LL | PL | PI | Classification |
|---|---|---|---|

Sample Description: Claystone, yellowish gray with white lensing

**Notes:** Swell Potential (500 psf surcharge): 3.41%

Swell Pressure: 7,000 psf

olsson

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# Soil Corrosion Suite

| Project Information | |
|---|---|
| **Project Name:** | Westminster Water 2025 Preliminary |
| **Project Number:** | 019-1378 |
| **Client Name:** | CDM Smith |
| **Project Location:** | Westminster, Colorado |
| **Sample and Test Information** | |
| **Sample Location:** | B-3, 9 to 15.5 feet |
| **Sample Description:** | Claystone, yellowish light brown with oxidation staining |
| **Laboratory Technician:** | N. Rasmussen |
| **Date Tested:** | 9/29/2020 |

## Test Results

**Water Soluble Sulfate (Colorado Procedure CP-L-2103)**

| Dilution | Reading | Concentration, mg/L | Concentration, % mass |
|---|---|---|---|
| 100:1 | 1 | 100 | 0.01 |

**Water Soluble Chloride (Colorado Procedure CP-L-2104)**

| Dilution | Concentration, ppm | Concentration, % mass |
|---|---|---|
| Second | 225 | 0.023 |

**pH (ASTM G51)**

| pH Meter Reading |
|---|
| 7.22 |

**Electrical Resistivity (ASTM G57)**

| Readings (ohm*cm) |
|---|
| 364 |
| 357 |
| 413 |

| Lowest Resistivity (ohm*cm) |
|---|
| 357 |

*Sample portion passing the #10 sieve used in testing. Each reading performed after additional water was added.*

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# Soil Corrosion Suite

| Project Information | |
|---|---|
| **Project Name:** | Westminster Water 2025 Preliminary |
| **Project Number:** | 019-1378 |
| **Client Name:** | CDM Smith |
| **Project Location:** | Westminster, Colorado |
| **Sample and Test Information** | |
| **Sample Location:** | B-10, 3.5 to 7.5 feet |
| **Sample Description:** | Sandy clay and clayey sand, brown with white lensing |
| **Laboratory Technician:** | N. Rasmussen |
| **Date Tested:** | 9/29/2020 |

## Test Results

**Water Soluble Sulfate (Colorado Procedure CP-L-2103)**

| Dilution | Reading | Concentration, mg/L | Concentration, % mass |
|---|---|---|---|
| 100:1 | 9 | 900 | 0.09 |

**Water Soluble Chloride (Colorado Procedure CP-L-2104)**

| Dilution | Concentration, ppm | Concentration, % mass |
|---|---|---|
| Second | 189 | 0.019 |

**pH (ASTM G51)**

| pH Meter Reading |
|---|
| 7.63 |

**Electrical Resistivity (ASTM G57)**

| Readings (ohm*cm) |
|---|
| 801 |
| 517 |
| 479 |
| 457 |
| 465 |

| Lowest Resistivity (ohm*cm) |
|---|
| 457 |

*Sample portion passing the #10 sieve used in testing. Each reading performed after additional water was added.*

ADVANCED TERRA TESTING

# R Value

## ASTM D2844

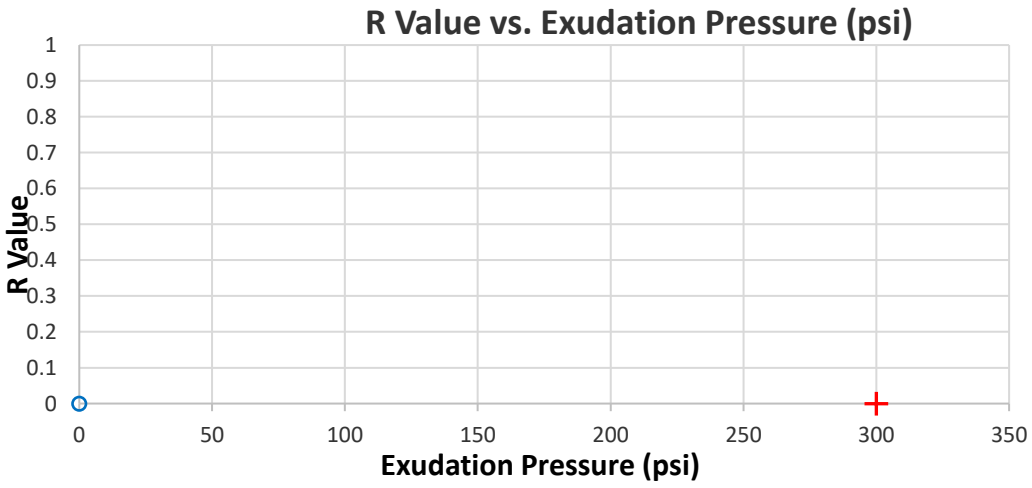
| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | Bulk (B-6) |
| JOB NO. | 2494-038 | DEPTH | 1-5' |
| PROJECT | Westminster WTP | SAMPLE NO. | -- |
| PROJECT NO. | 019-1378 | DATE SAMPLED | -- |
| LOCATION | Westminster, CO | SAMPLED BY | -- |
| DATE TESTED | 09/24/20 | DESCRIPTION | -- |
| TECHNICIAN | ALH | | |

### Sample Conditions

| | |
|---|---|
| Mass of Wet Soil & Pan (g): | |
| Mass of Dry Soil & Pan (g): | |
| Mass of Pan (g): | |
| Mass of Wet Soil & Mold (g): | |
| Mass of Mold (g): | |
| Sample Height (in): | |
| Wet Density (pcf): | |
| Dry Density (pcf): | |
| Wet Density (kg/m³): | |
| Dry Density (kg/m³): | |
| Moisture (%): | |

### R Value Data

| | |
|---|---|
| Exudation Pressure (lbs): | |
| Exudation Pressure (psi): | |
| 2000 lbs. Dial Reading (psi): | |
| Displacement Turns: | |
| Uncorrected R Value: | |
| Corrected R Value: | |




Corrected R Value at 300 psi Exudation Pressure

**<5**

NOTES: Specimen extruded from under the mold during the loading operation. This occured when the 5520-kPa [800-psi] point was reached and fewer than five lights were lite.

| | | | |
|---|---|---|---|
| Data entry by: | ALH | Date: | 09/25/20 |
| Checked by: | DPM | Date: | 09/25/20 |
| File name: | 2494038__R Value ASTM D2844_0.xlsm | | |

ADVANCED TERRA TESTING

# Constant Rate of Flow
# Flexible Wall Hydraulic Conductivity

## ASTM D 5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | B-12 |
| JOB NO. | 2494-038 | DEPTH | 14-15' |
| PROJECT | Westminster WTP | SAMPLE NO. | MC-5 |
| PROJECT NO. | 019-1378 | DATE SAMPLED | -- |
| LOCATION | Westminster, CO | SAMPLED BY | -- |
| DATE TESTED | 09/16/20 | DESCRIPTION | -- |
| TECHNICIAN | CAL | | |

### Sample Conditions

| | | | |
|---|---|---|---|
| Before Test Mass of Wet Soil (g): | 289.4 | Initial Wet Density (pcf): | 124.1 |
| After Test Mass of Wet Soil (g): | 302.1 | Initial Dry Density (pcf): | 101.5 |
| Mass of Dry Soil and Pan (g): | 353.6 | Initial Wet Density (kg/m³): | 1989 |
| Mass of Pan (g): | 117.0 | Initial Dry Density (kg/m³): | 1626 |
| Diameter (in): | 1.93 | Initial Moisture (%): | 22.3 |
| Initial Sample Height (in): | 3.05 | Final Wet Density (pcf): | 140.2 |
| Assumed Specific Gravity: | 2.650 | Final Dry Density (pcf): | 109.8 |
| | | Final Wet Density (kg/m³): | 2246 |
| Back Pressure (psi): | 38.0 | Final Dry Density (kg/m³): | 1759 |
| Cell Pressure (psi): | 44.9 | Final Moisture (%): | 27.7 |

Final density calculated using volume change method from ASTM D4767.

### Permeability Data

| Pump Setting | Percentage of Pump Setting | Rate of Flow (cc/s) | Pump Pressure (psi) | Head Loss (cm) | Gradient - i | Effective Stress (psi) - $\sigma_3$ | Effective Stress (kPa) - $\sigma_3$ | Temperature (°C) | Temperature Correction | Corrected Hydraulic Conductivity (cm/s) - k |
|---|---|---|---|---|---|---|---|---|---|---|
| 45 | -- | 9.47E-06 | 0.082 | 5.77 | 0.75 | 6.86 | 47.3 | 21.9 | 0.956 | 6.9E-07 |
| 45 | -- | 9.47E-06 | 0.133 | 9.36 | 1.22 | 6.83 | 47.1 | 21.9 | 0.956 | 4.2E-07 |
| 45 | -- | 9.47E-06 | 0.173 | 12.18 | 1.59 | 6.81 | 47.0 | 22.0 | 0.953 | 3.2E-07 |
| 45 | -- | 9.47E-06 | 0.199 | 14.01 | 1.83 | 6.80 | 46.9 | 22.1 | 0.951 | 2.8E-07 |
| 45 | -- | 9.47E-06 | 0.207 | 14.57 | 1.90 | 6.80 | 46.9 | 21.4 | 0.967 | 2.7E-07 |
| 45 | -- | 9.47E-06 | 0.200 | 14.08 | 1.84 | 6.80 | 46.9 | 21.4 | 0.967 | 2.8E-07 |
| 45 | -- | 9.47E-06 | 0.182 | 12.81 | 1.67 | 6.81 | 46.9 | 21.1 | 0.974 | 3.1E-07 |

### Test Results

Average Corrected Hydraulic Conductivity (cm/s): 2.9E-07

NOTES:

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 09/18/20 |
| Checked by: | KR | Date: | 09/23/20 |
| File name: | 2494038__Permeability Method D ASTM D5084_0.xlsm | | Page 1 of 2 |

ADVANCED TERRA TESTING

# Constant Rate of Flow
# Flexible Wall Hydraulic Conductivity

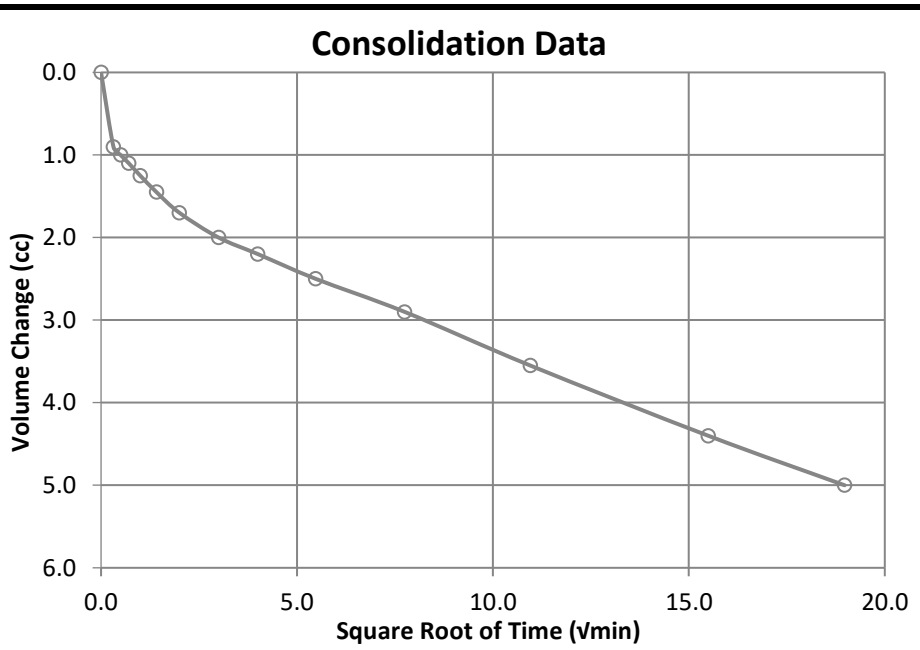
## ASTM D 5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | B-12 |
| JOB NO. | 2494-038 | DEPTH | 14-15' |
| PROJECT | Westminster WTP | SAMPLE NO. | MC-5 |
| PROJECT NO. | 019-1378 | DATE SAMPLED | -- |
| LOCATION | Westminster, CO | SAMPLED BY | -- |
| DATE TESTED | 09/16/20 | DESCRIPTION | -- |
| TECHNICIAN | CAL | | |

## Consolidation

| | | | |
|---|---|---|---|
| Initial Saturation (%): | 93.8 | Initial Volume of Sample (cc): | 145.5 |
| Final Saturation (%): | 100.0 | Final Volume of Sample (cc): | 134.5 |
| Cell Pressure (psi): | 44.9 | Volume Change After Consolidation (cc): | 17.8 |
| Back Pressure (psi): | 38.0 | Initial Dial Reading (in): | 0.200 |
| Effective Stress (psi): | 6.9 | Final Dial Reading (in): | 0.230 |
| Effective Stress (kPa): | 47.6 | Height Change (in): | 0.03 |
| Cell Expansion Correction (cc): | 6.80 | Initial Area (cm²): | 18.80 |
| Cell ID: | 3P | Final Area (cm²): | 17.55 |

| Elapsed Time (min) | Square Root of Time (√min) | Burette Reading (cc) | Volume Change (cc) |
|---|---|---|---|
| 0 | 0.00 | 15.40 | 0.00 |
| 0.1 | 0.32 | 16.30 | 0.90 |
| 0.25 | 0.50 | 16.40 | 1.00 |
| 0.5 | 0.71 | 16.50 | 1.10 |
| 1 | 1.00 | 16.65 | 1.25 |
| 2 | 1.41 | 16.85 | 1.45 |
| 4 | 2.00 | 17.10 | 1.70 |
| 9 | 3.00 | 17.40 | 2.00 |
| 16 | 4.00 | 17.60 | 2.20 |
| 30 | 5.48 | 17.90 | 2.50 |
| 60 | 7.75 | 18.30 | 2.90 |
| 120 | 10.95 | 18.95 | 3.55 |
| 240 | 15.49 | 19.80 | 4.40 |
| 360 | 18.97 | 20.40 | 5.00 |




## Saturation

| Cell Pressure (psi) | | Pore Pressure (psi) | | Burette Reading (cc) | | Back Pressure (psi) | Volume Change (cc) | Effective Stress (psi) | Δu (psi) | B |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial | Final | Initial | Final | Initial | Final | | | | | |
| 40.0 | 50.0 | 38.9 | 48.4 | 15.30 | 15.40 | 38.0 | 0.10 | 2.0 | 9.5 | 0.95 |

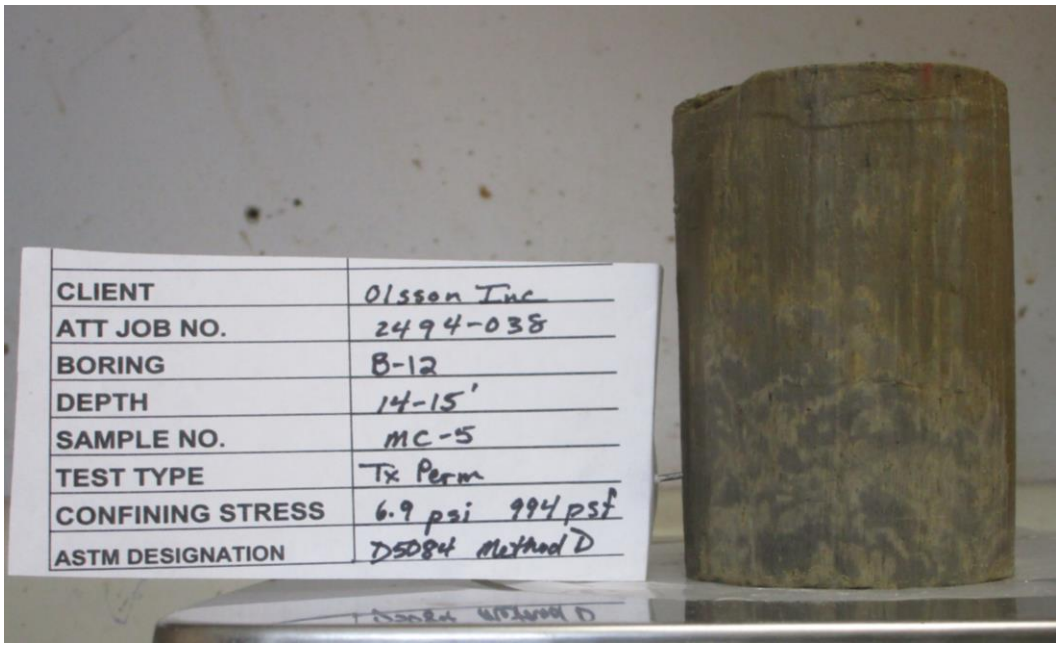


File name: 2494038__Permeability Method D ASTM D5084_0.xlsm

# Image Attachment

ADVANCED TERRA TESTING

| | | | |
|---|---|---|---|
| CLIENT | Tetra Tech | BORING NO. | B-12 |
| JOB NO. | 2592-052 | DEPTH | 14-15' |
| PROJECT | Wild Horse Reservoir | SAMPLE NO. | MC-5 |
| PROJECT NO. | 200-23365-20001 | DATE SAMPLED | |
| LOCATION | Hartsel CO | DESCRIPTION | cal. Liner |




NOTES

File name: 2494038_perm_MC-5_14-15.pdf

ADVANCED TERRA TESTING

# Constant Rate of Flow
# Flexible Wall Hydraulic Conductivity

## ASTM D 5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | B-12 |
| JOB NO. | 2494-038 | DEPTH | 6-7' |
| PROJECT | Westminster WTP | SAMPLE NO. | MC-3 |
| PROJECT NO. | 019-1378 | DATE SAMPLED | -- |
| LOCATION | Westminster, CO | SAMPLED BY | -- |
| DATE TESTED | 09/16/20 | DESCRIPTION | -- |
| TECHNICIAN | CAL | | |

### Sample Conditions

| | | | |
|---|---|---|---|
| Before Test Mass of Wet Soil (g): | 279.2 | Initial Wet Density (pcf): | 118.9 |
| After Test Mass of Wet Soil (g): | 299.9 | Initial Dry Density (pcf): | 97.3 |
| Mass of Dry Soil and Pan (g): | 352.0 | Initial Wet Density (kg/m³): | 1905 |
| Mass of Pan (g): | 123.5 | Initial Dry Density (kg/m³): | 1559 |
| Diameter (in): | 1.93 | Initial Moisture (%): | 22.2 |
| Initial Sample Height (in): | 3.05 | Final Wet Density (pcf): | 125.1 |
| Assumed Specific Gravity: | 2.650 | Final Dry Density (pcf): | 95.3 |
| | | Final Wet Density (kg/m³): | 2004 |
| Back Pressure (psi): | 78.0 | Final Dry Density (kg/m³): | 1526 |
| Cell Pressure (psi): | 81.5 | Final Moisture (%): | 31.3 |

Final density calculated using volume change method from ASTM D4767.

### Permeability Data

| Pump Setting | Percentage of Pump Setting | Rate of Flow (cc/s) | Pump Pressure (psi) | Head Loss (cm) | Gradient - i | Effective Stress (psi) - $\sigma_3$ | Effective Stress (kPa) - $\sigma_3$ | Temperature (°C) | Temperature Correction | Corrected Hydraulic Conductivity (cm/s) - k |
|---|---|---|---|---|---|---|---|---|---|---|
| -- | -- | 3.33E-04 | 0.320 | 22.53 | 2.91 | 3.34 | 23.0 | 21.4 | 0.967 | 5.7E-06 |
| -- | -- | 3.33E-04 | 0.320 | 22.53 | 2.91 | 3.34 | 23.0 | 21.5 | 0.965 | 5.7E-06 |
| -- | -- | 3.33E-04 | 0.344 | 24.22 | 3.12 | 3.33 | 22.9 | 21.7 | 0.960 | 5.3E-06 |
| -- | -- | 3.33E-04 | 0.341 | 24.01 | 3.10 | 3.33 | 23.0 | 21.7 | 0.960 | 5.4E-06 |
| -- | -- | 3.33E-04 | 0.335 | 23.59 | 3.04 | 3.33 | 23.0 | 21.8 | 0.958 | 5.4E-06 |
| -- | -- | 3.33E-04 | 0.336 | 23.66 | 3.05 | 3.33 | 23.0 | 21.7 | 0.960 | 5.4E-06 |

### Test Results

Average Corrected Hydraulic Conductivity (cm/s): 5.4E-06

NOTES:

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 09/22/20 |
| Checked by: | KR | Date: | 09/23/20 |
| File name: | 2494038__Permeability Method D ASTM D5084_1.xlsm | | Page 1 of 2 |

ADVANCED TERRA TESTING

# Constant Rate of Flow
# Flexible Wall Hydraulic Conductivity

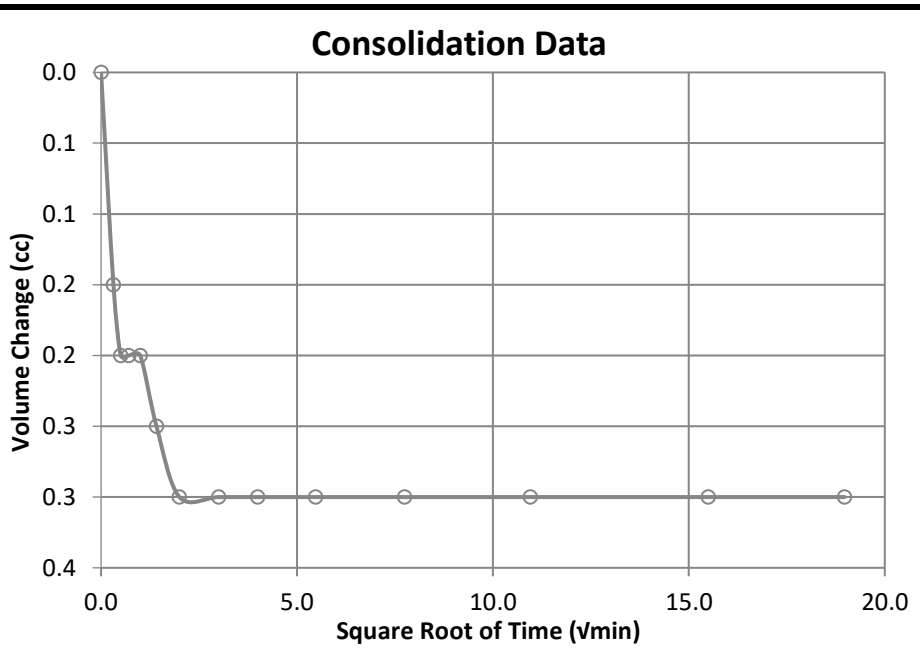
## ASTM D 5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | B-12 |
| JOB NO. | 2494-038 | DEPTH | 6-7' |
| PROJECT | Westminster WTP | SAMPLE NO. | MC-3 |
| PROJECT NO. | 019-1378 | DATE SAMPLED | -- |
| LOCATION | Westminster, CO | SAMPLED BY | -- |
| DATE TESTED | 09/16/20 | DESCRIPTION | -- |
| TECHNICIAN | CAL | | |

### Consolidation

| | | | |
|---|---|---|---|
| Initial Saturation (%): | 84.1 | Initial Volume of Sample (cc): | 146.6 |
| Final Saturation (%): | 100.0 | Final Volume of Sample (cc): | 149.7 |
| Cell Pressure (psi): | 81.5 | Volume Change After Consolidation (cc): | 10.9 |
| Back Pressure (psi): | 78.0 | Initial Dial Reading (in): | 0.200 |
| Effective Stress (psi): | 3.5 | Final Dial Reading (in): | 0.202 |
| Effective Stress (kPa): | 24.1 | Height Change (in): | 0.002 |
| Cell Expansion Correction (cc): | 13.99 | Initial Area (cm²): | 18.89 |
| Cell ID: | 4P | Final Area (cm²): | 19.31 |

| Elapsed Time (min) | Square Root of Time (√min) | Burette Reading (cc) | Volume Change (cc) |
|---|---|---|---|
| 0 | 0.00 | 1.00 | 0.00 |
| 0.1 | 0.32 | 1.15 | 0.15 |
| 0.25 | 0.50 | 1.20 | 0.20 |
| 0.5 | 0.71 | 1.20 | 0.20 |
| 1 | 1.00 | 1.20 | 0.20 |
| 2 | 1.41 | 1.25 | 0.25 |
| 4 | 2.00 | 1.30 | 0.30 |
| 9 | 3.00 | 1.30 | 0.30 |
| 16 | 4.00 | 1.30 | 0.30 |
| 30 | 5.48 | 1.30 | 0.30 |
| 60 | 7.75 | 1.30 | 0.30 |
| 120 | 10.95 | 1.30 | 0.30 |
| 240 | 15.49 | 1.30 | 0.30 |
| 360 | 18.97 | 1.30 | 0.30 |




### Saturation

| Cell Pressure (psi) | | Pore Pressure (psi) | | Burette Reading (cc) | | Back Pressure (psi) | Volume Change (cc) | Effective Stress (psi) | Δu (psi) | B |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial | Final | Initial | Final | Initial | Final | | | | | |
| 40.0 | 50.0 | 38.8 | 46.6 | 11.90 | 12.90 | 38.0 | 1.00 | 2.0 | 7.8 | 0.78 |
| 50.0 | 60.0 | 48.9 | 57.5 | 12.80 | 13.60 | 48.0 | 0.80 | 2.0 | 8.6 | 0.86 |
| 60.0 | 70.0 | 58.9 | 67.8 | 13.50 | 14.20 | 58.0 | 0.70 | 2.0 | 8.9 | 0.89 |
| 70.0 | 80.0 | 68.9 | 78.1 | 14.10 | 14.80 | 68.0 | 0.70 | 2.0 | 9.2 | 0.92 |
| 80.0 | 90.0 | 78.9 | 88.5 | 14.90 | 14.90 | 78.0 | 0.00 | 2.0 | 9.6 | 0.96 |

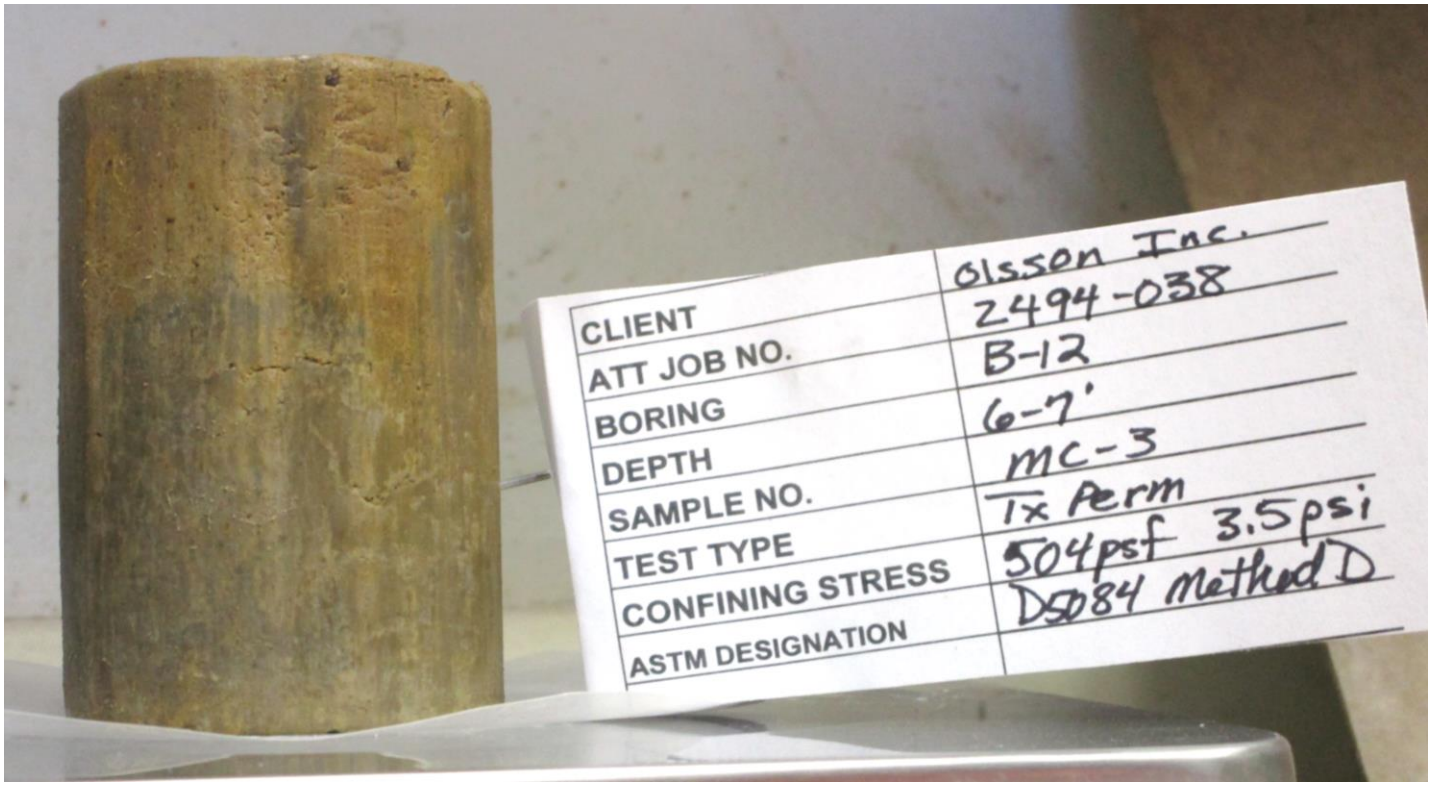


File name: 2494038__Permeability Method D ASTM D5084_1.xlsm

# Image Attachment

ADVANCED TERRA TESTING

| | | | |
|---|---|---|---|
| CLIENT | Olsson Associates | BORING NO. | MW-4 |
| JOB NO. | 2494-038 | DEPTH | 37-39' |
| PROJECT | Westminster WTP | SAMPLE NO. | |
| PROJECT NO. | 019-1378 | DATE SAMPLED | 8/13/20 |
| LOCATION | Westminster, CO | DESCRIPTION | soil |

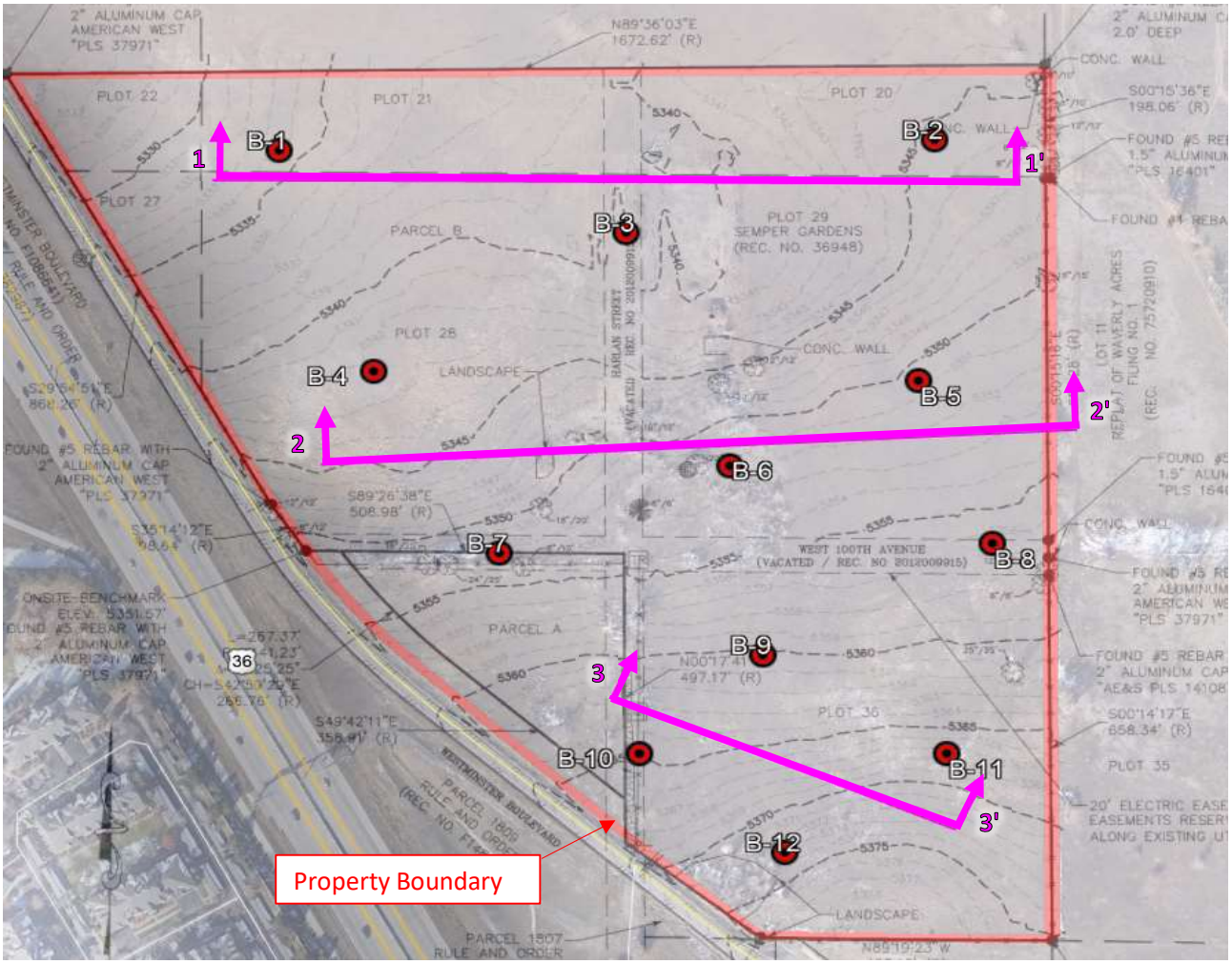



NOTES

File name: 2494038_PERM_B12_MC3.pdf

# APPENDIX D

Site Cross-Sections and Surficial Soil Zones



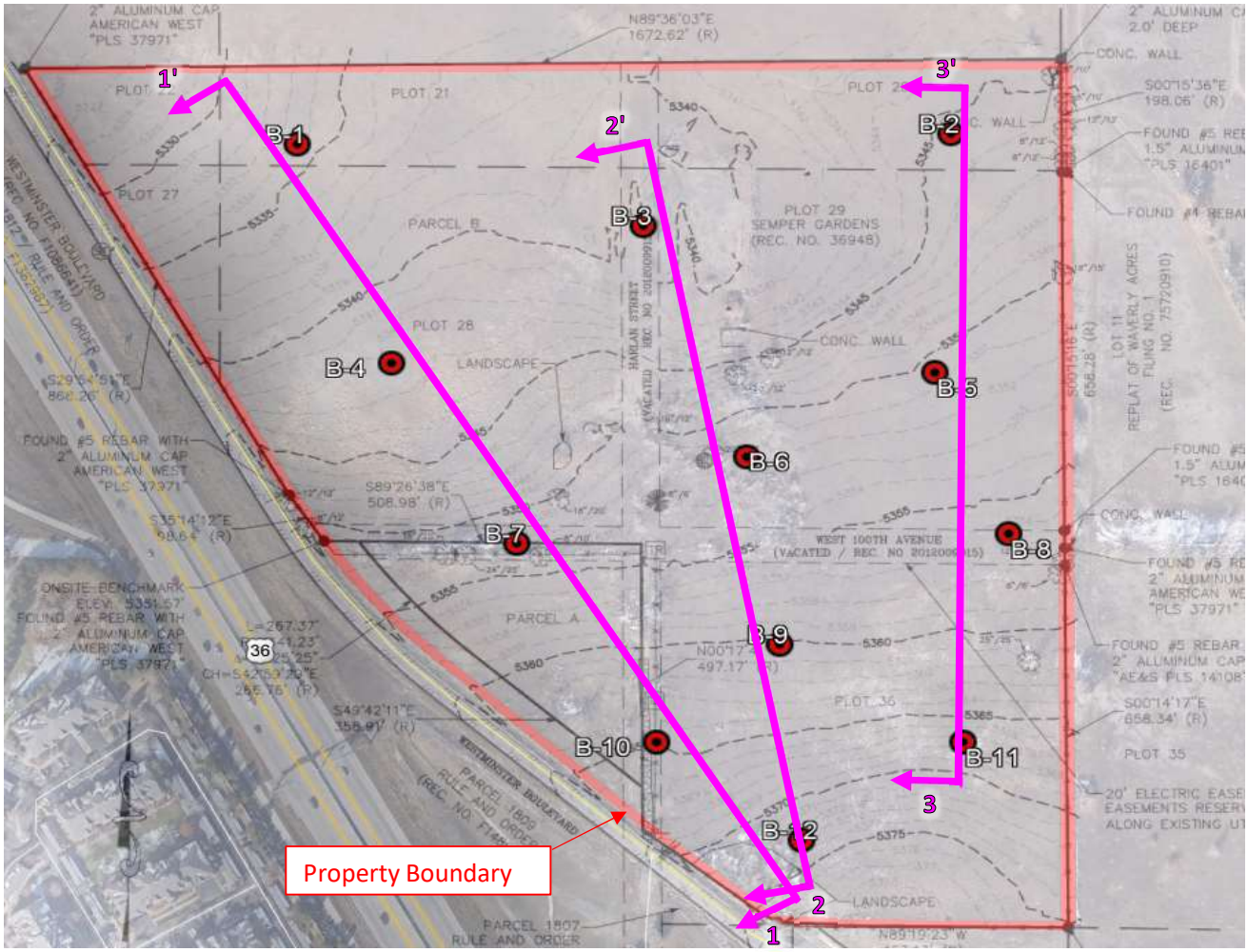

| I.D. | Depth | Approximate Coordinates | | Pieozmeter |
|---|---|---|---|---|
| B-1 | 50 | 39.880094° N | 105.064531° W | X |
| B-2 | 50 | 39.880138° N | 105.060782° W | |
| B-3 | 50 | 39.879694° N | 105.062543° W | |
| B-4 | 50 | 39.879026° N | 105.063984° W | |
| B-5 | 50 | 39.878979° N | 105.060876° W | |
| B-6 | 50 | 39.878570° N | 105.061950° W | X |
| B-7 | 50 | 39.878151° N | 105.063263° W | |
| B-8 | 50 | 39.878198° N | 105.060458° W | |
| B-9 | 50 | 39.877664° N | 105.061763° W | |
| B-10 | 50 | 39.877194° N | 105.062463° W | |
| B-11 | 50 | 39.877195° N | 105.060722° W | |
| B-12 | 50 | 39.876726° N | 105.061640° W | X |

**East-West Cross-Section Location Plan**

olsson

Scale: nts
Project: 019-1378
Approved by: LAT
Date: 03/01/2020

**Westminster 2025 Water Preliminary Design Project**
**Westminster Boulevard near W 98th Ave**
**Westminster, Colorado**




| I.D. | Depth | Approximate Coordinates | | Pieozmeter |
|---|---|---|---|---|
| B-1 | 50 | 39.880094° N | 105.064531° W | X |
| B-2 | 50 | 39.880138° N | 105.060782° W | |
| B-3 | 50 | 39.879694° N | 105.062543° W | |
| B-4 | 50 | 39.879026° N | 105.063984° W | |
| B-5 | 50 | 39.878979° N | 105.060876° W | |
| B-6 | 50 | 39.878570° N | 105.061950° W | X |
| B-7 | 50 | 39.878151° N | 105.063263° W | |
| B-8 | 50 | 39.878198° N | 105.060458° W | |
| B-9 | 50 | 39.877664° N | 105.061763° W | |
| B-10 | 50 | 39.877194° N | 105.062463° W | |
| B-11 | 50 | 39.877195° N | 105.060722° W | |
| B-12 | 50 | 39.876726° N | 105.061640° W | X |

**North-South Cross-Section Location Plan**

olsson

Scale: nts
Project: 019-1378
Approved by: LAT
Date: 03/01/2020

**Westminster 2025 Water Preliminary Design Project**
**Westminster Boulevard near W 98th Ave**
**Westminster, Colorado**

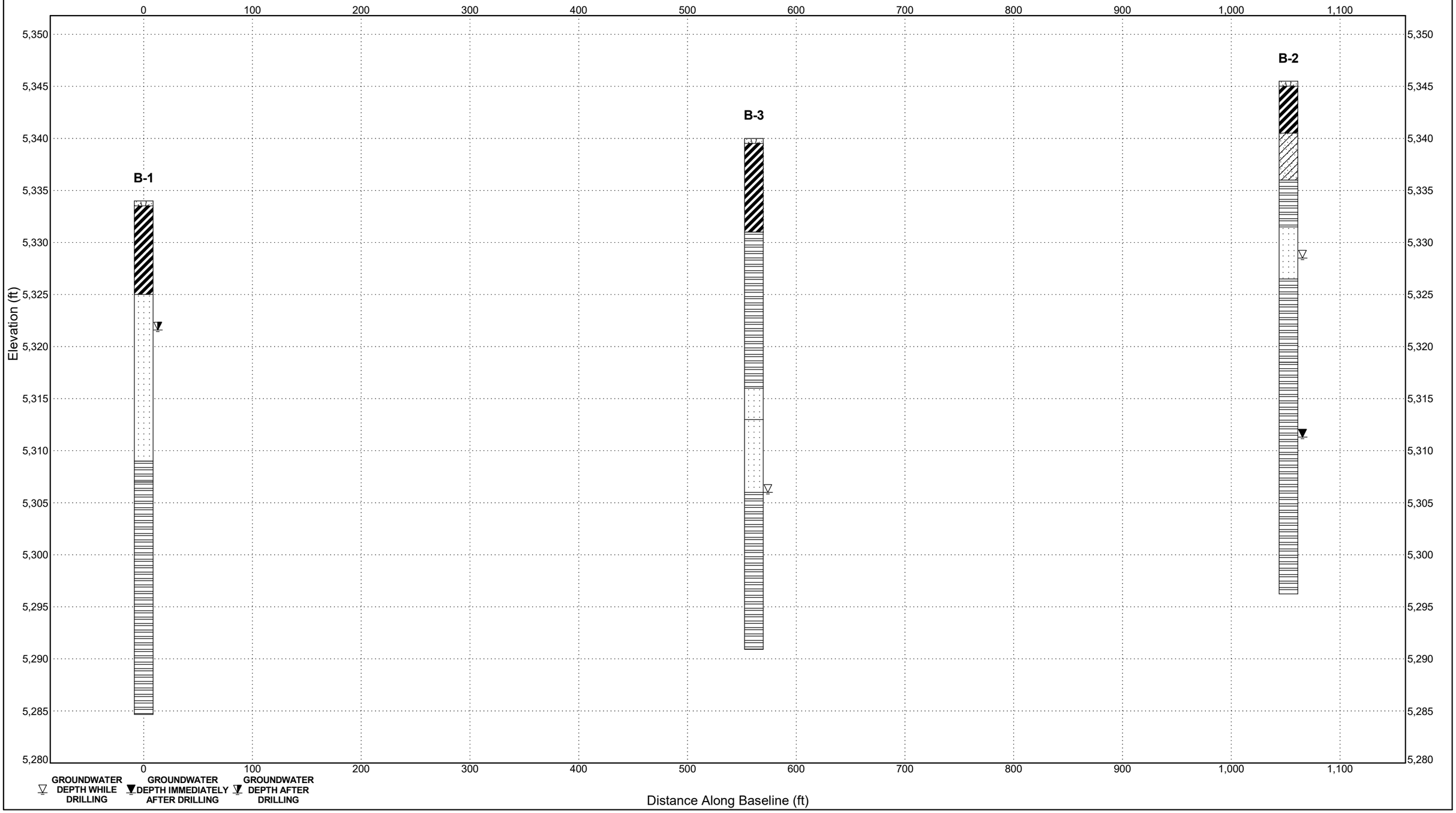
**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# GEOLOGIC PROFILE
# East-West Cross-Section 1

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Shale
USCS High Plasticity Clay
USCS Clayey Sand
Sandstone

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**



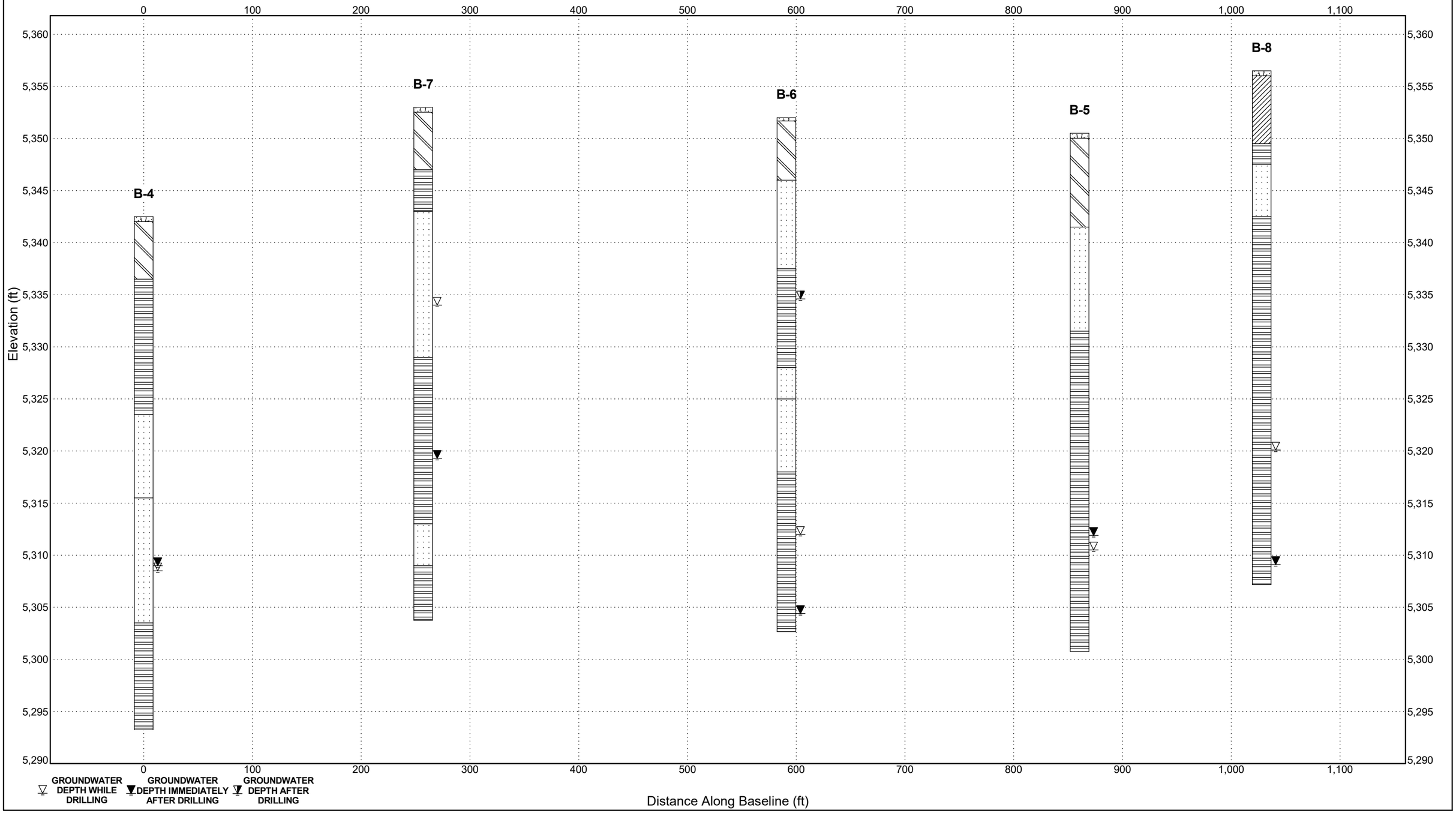
**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# GEOLOGIC PROFILE
## East-West Cross-Section 2

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Sandstone
USCS Low to High Plasticity Clay
USCS Low Plasticity Clay
Shale

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**



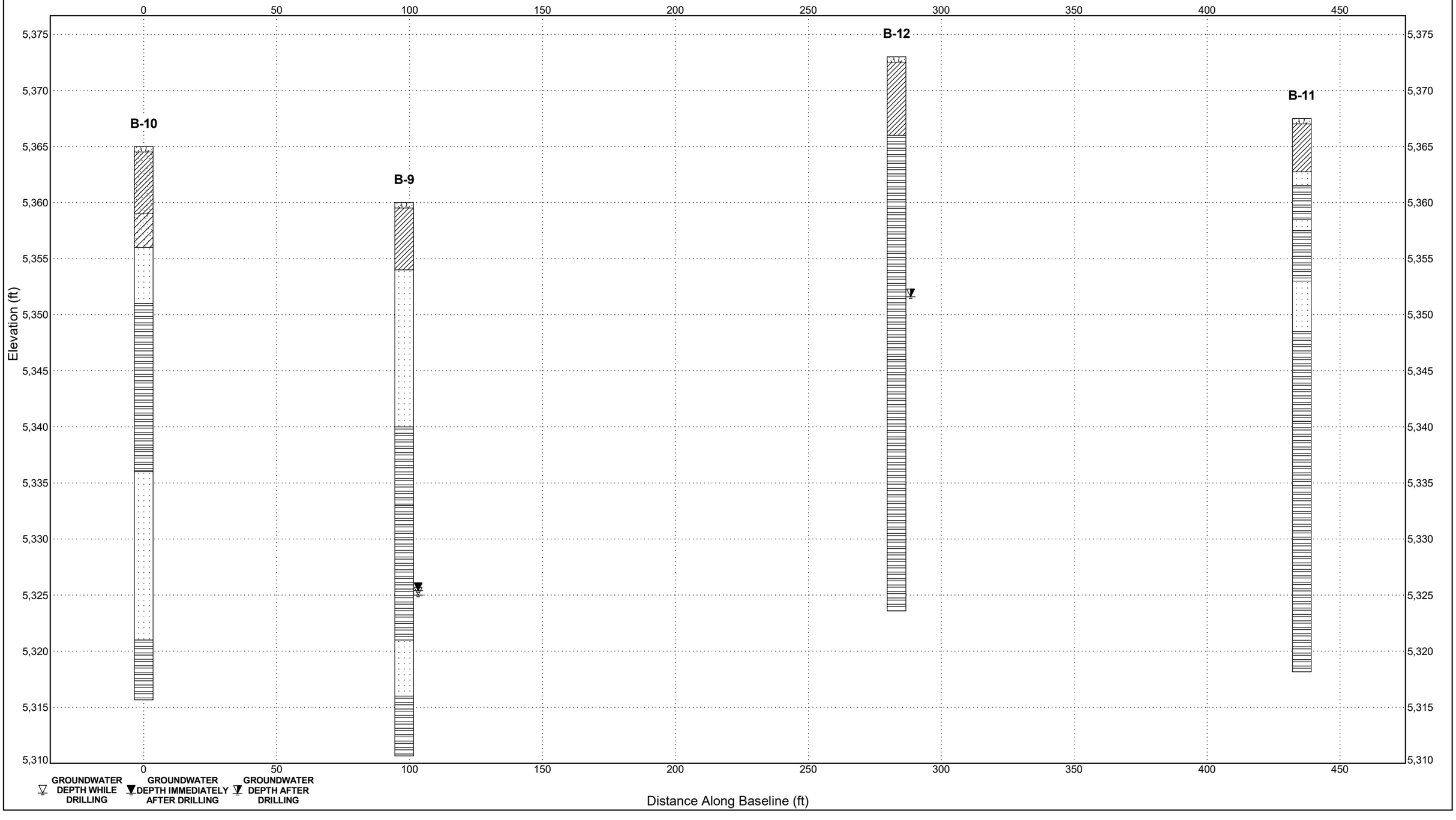
**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# GEOLOGIC PROFILE
## East-West Cross-Section 3

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Shale
USCS Low Plasticity Clay
USCS Low Plasticity Sandy Clay
Sandstone
USCS Clayey Sand

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**



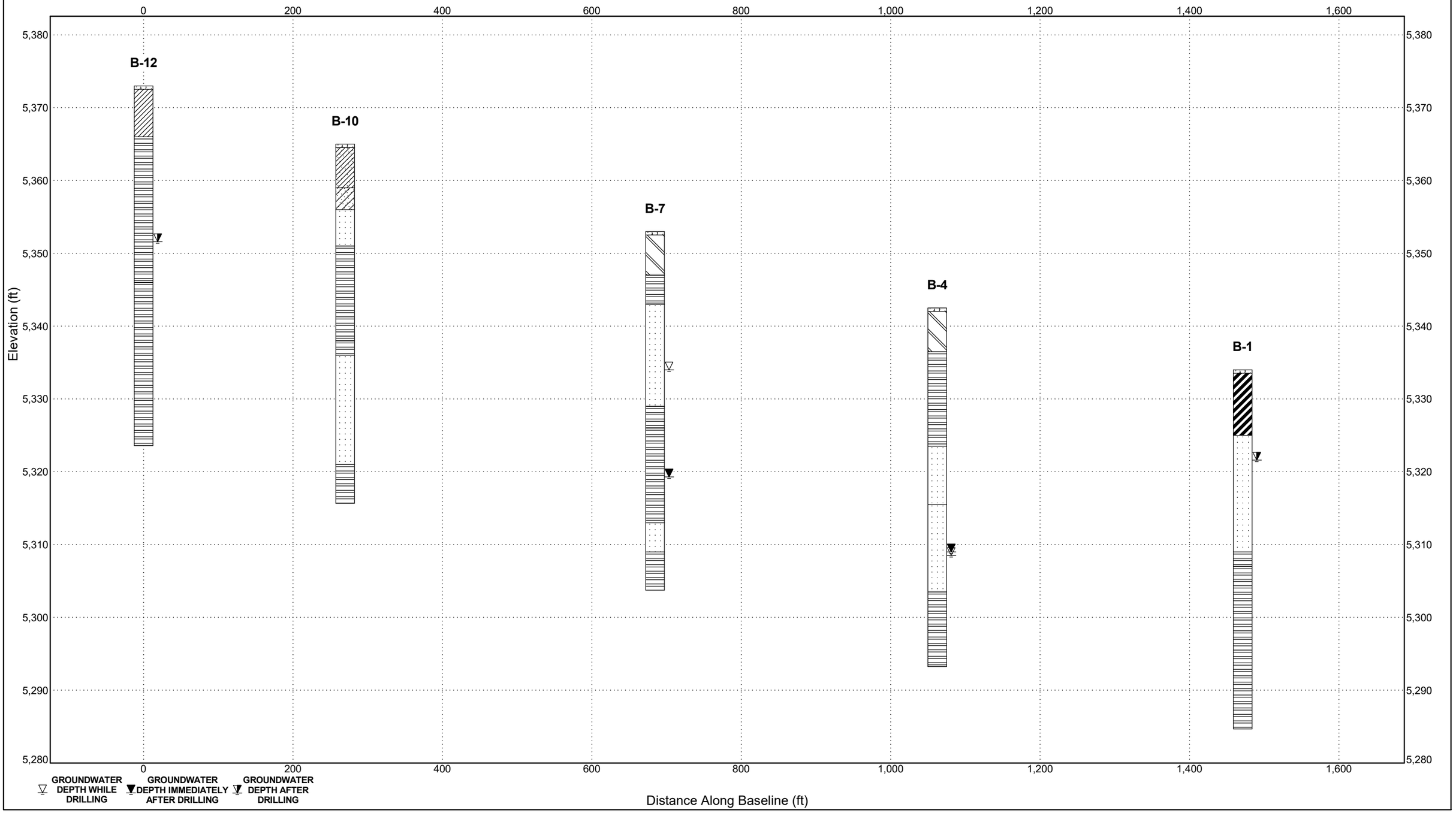
**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# GEOLOGIC PROFILE
## North-South Cross-Section 1

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Shale
USCS Clayey Sand
USCS High Plasticity Clay
USCS Low to High Plasticity Clay
USCS Low Plasticity Clay
Sandstone
USCS Low Plasticity Sandy Clay

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**



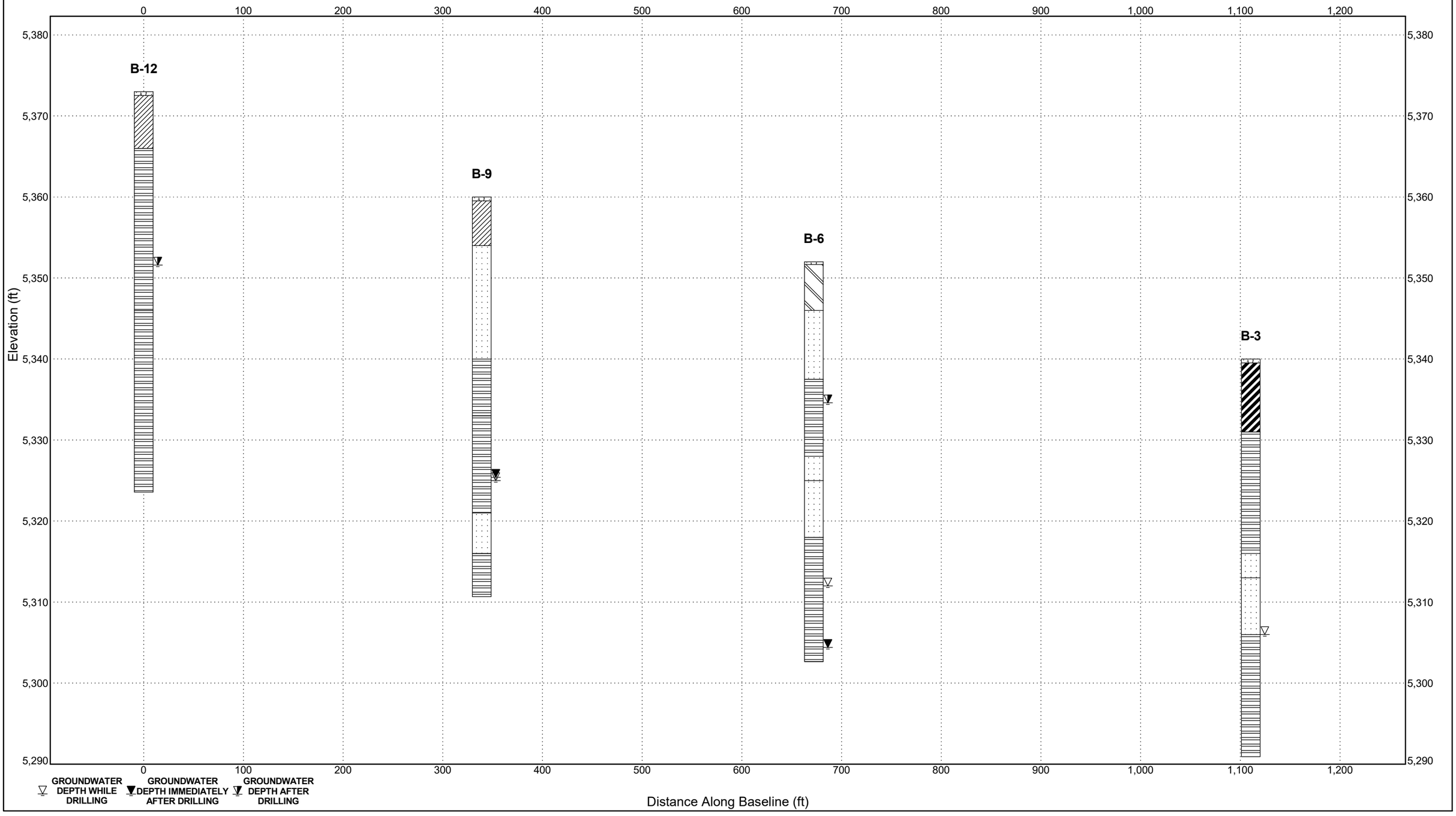
**OLSSON, INC.**
**3990 FOX STREET**
**DENVER, COLORADO 80216**

# GEOLOGIC PROFILE
## North-South Cross-Section 2

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Sandstone
USCS High Plasticity Clay
USCS Low to High Plasticity Clay
Shale
USCS Low Plasticity Clay

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**



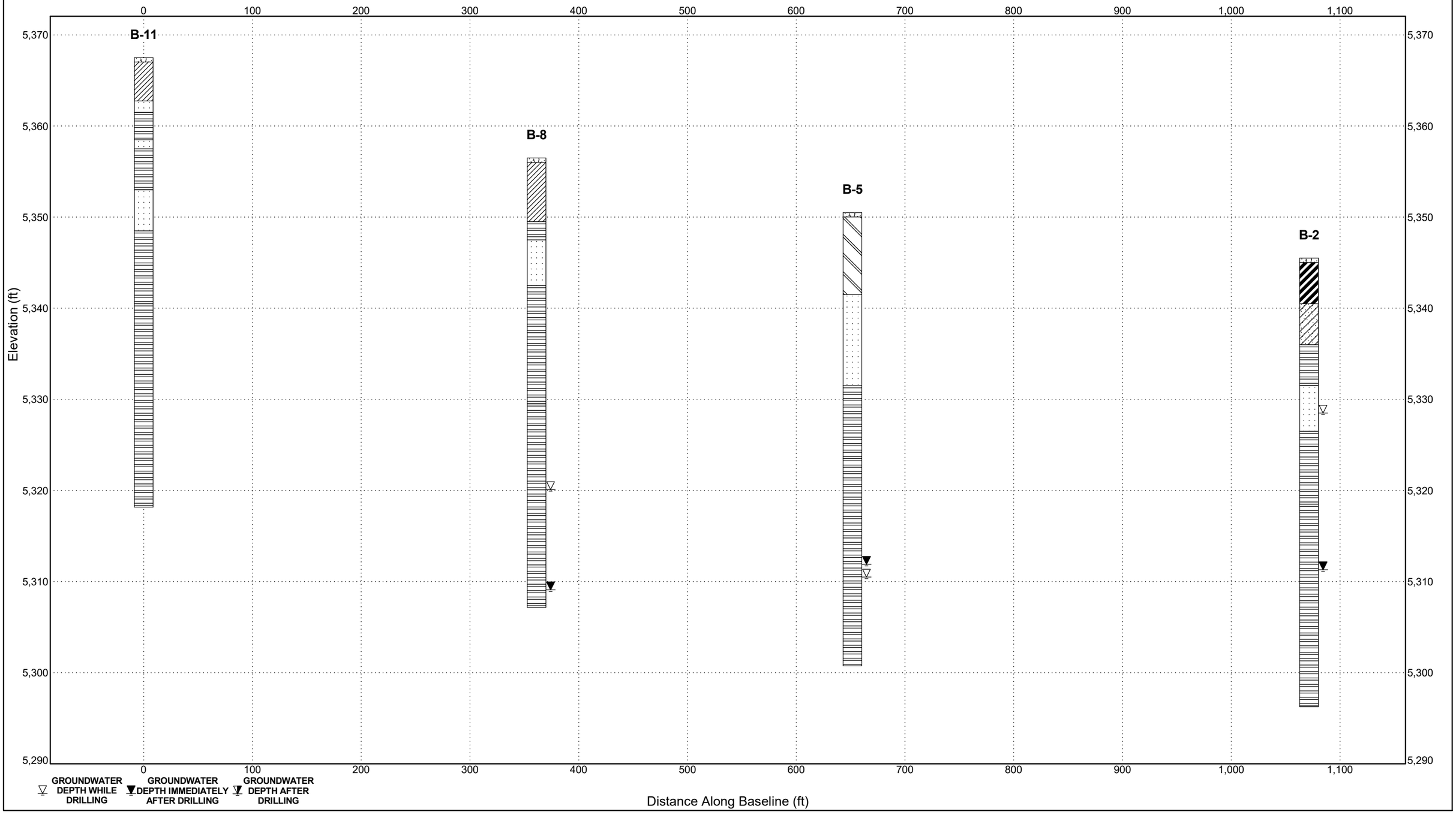
OLSSON, INC.
3990 FOX STREET
DENVER, COLORADO 80216

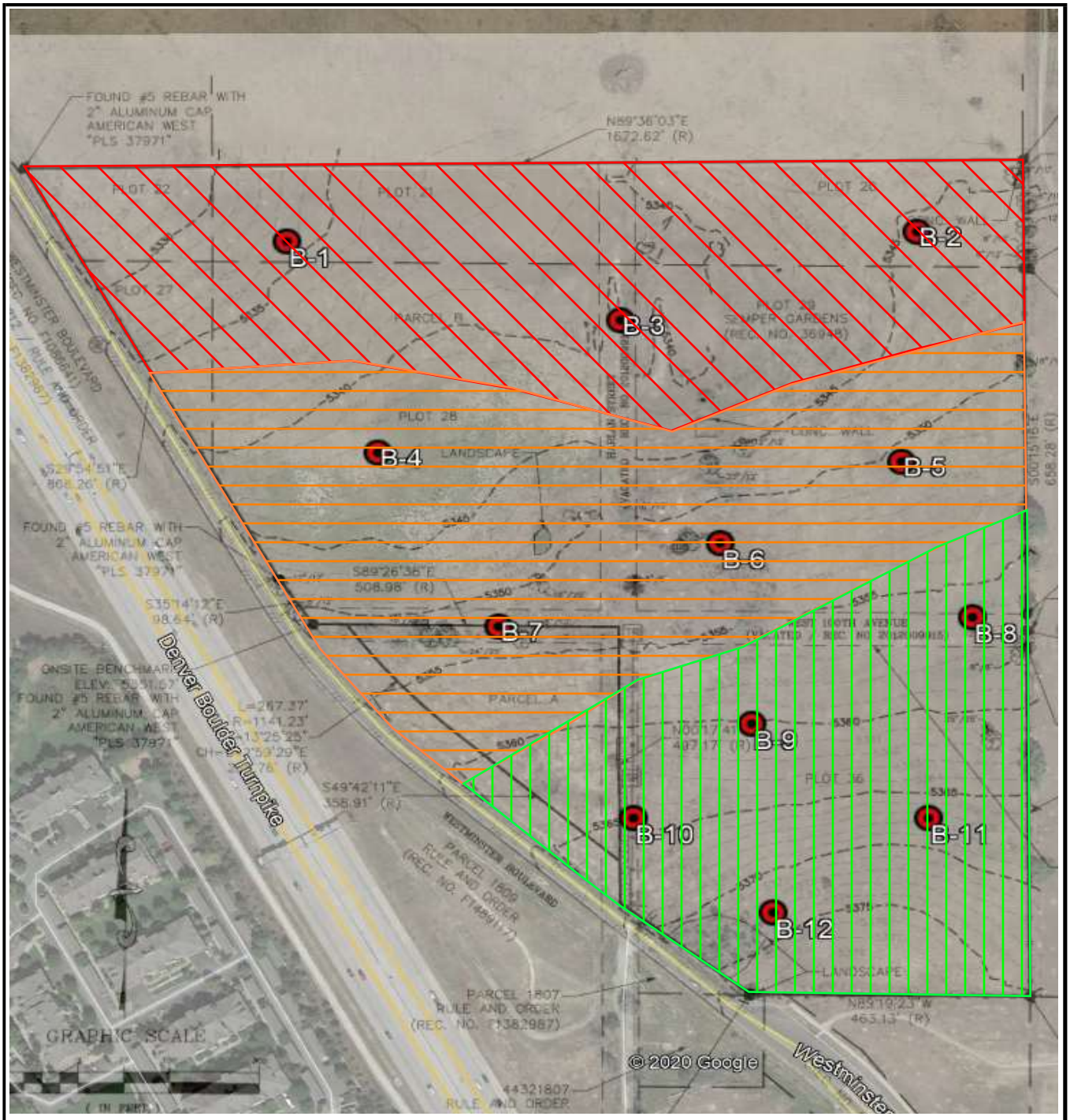
# GEOLOGIC PROFILE
## North-South Cross-Section 3

**PROJECT NAME** Westminster Water 2025 Preliminary
**PROJECT NUMBER** 019-1378
**CLIENT** CDM Smith
**PROJECT LOCATION** Westminster, Colorado

Topsoil
Shale
USCS Low Plasticity Clay
USCS High Plasticity Clay
Sandstone
USCS Clayey Sand
USCS Low to High Plasticity Clay

**NOTE: Soil stratification, as shown on the geologic profile, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations.**






Note: Surficial soil, as shown on this graphic, represents soil conditions at the boring locations: however, variations may occur between or around the boring locations

Higher plasticity, fat clay (CH)
Medium plasticity, lean to fat clay (CL/CH)
Lower plasticity, lean clay (CL)

**Surficial Soil Zones Plan**

olsson

| |
|---|
| Scale: nts |
| Project: 019-1378 |
| Approved by: LAT |
| Date: 03/03/2021 |

Westminster 2025 Water Preliminary Design Project
Westminster Boulevard near W 98th Ave
Westminster, Colorado