Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

# GEOTECHNICAL EVALUATION
# PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS
# NEDERLAND, COLORADO

**PREPARED FOR:**
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April 29, 2013
Project No. 500651001

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Huitt-Zollars, Inc.
Attn: Mr. Brian McClaren
4582 South Ulster Street, Suite 240
Denver, Colorado 80237

Subject: Geotechnical Evaluation
Pedestrian Enhancement and Storm Water Improvements
Nederland, Colorado

Dear Mr. McClaren:

In accordance with your request and authorization, Ninyo & Moore has performed a geotechnical evaluation for the proposed Pedestrian Enhancement and Storm Water Management Improvement project in Nederland, Colorado. The attached report presents our methodology, findings, and geotechnical engineering recommendations for the proposed improvements.

We appreciate the opportunity to be of service to you during this phase of the project.

Sincerely,
**NINYO & MOORE**

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## 1. INTRODUCTION

In accordance with your request and authorization, we have performed a geotechnical evaluation for the proposed Pedestrian Enhancement and Storm Water Improvement project located in Nederland, Colorado. The approximate location of the project alignment is depicted on Figure 1.

The purposes of our study were to evaluate the subsurface conditions and to provide design and construction recommendations regarding geotechnical aspects of the proposed project. This report presents the findings of our subsurface exploration, results of our laboratory testing, conclusions regarding the subsurface conditions at the site, and geotechnical recommendations for design and construction of this project.

## 2. SCOPE OF SERVICES

The scope of our geotechnical services for the project generally included:

- Review of referenced background information includes aerial photographs, published geologic and soil maps, in-house geotechnical data, and available topographical information pertaining to the project site and vicinity.
- Mark out of the boring locations at the site based on proposed boring locations drawing provided by your office and notifying Utility Notification Center of Colorado (UNCC) of the boring locations prior to drilling.
- Drilling, logging, and sampling of eight small-diameter exploratory borings along the project alignment to depths ranging between approximately 2 and 14 feet below ground surface (bgs). The boring logs are presented in Appendix A.
- Performance of laboratory tests on selected samples obtained from the borings to evaluate engineering properties including in-situ moisture content and dry density, Atterberg limits, No. 200 sieve and gradation analyses, Proctor density, resistance value (R-Value), and soil corrosivity characteristics (including water soluble sulfates and chlorides). The results of the laboratory testing are presented on the boring logs and in Appendix B.
- Preparation of this report presenting our findings, conclusions, and geotechnical recommendations regarding design and construction of the project.

## 3. SITE DESCRIPTION

The approximate location of the project alignment is depicted on Figure 1. The alignment spans across the town of Nederland in an east-west direction along State Highway 72/Second Street to the terminus of Second Street at East Street, then continues northward along East Street to the intersection with State Highway 119. The majority of the project alignment is comprised of asphalt-paved roadway. However, approximately 865 linear feet of East Second Street, between Snyder Street and East Street exists as a dirt road. Beaver Creek crosses underneath the unpaved East Second Street through a corrugated metal culvert approximately 250 west of East Street. The project alignment generally slopes from west to east at grades of approximately 2 to 4 percent draining toward Baker Reservoir, with the exception of East Street.

## 4. PROPOSED CONSTRUCTION

The proposed project includes design and construction of:

- Bike lanes and new sidewalks along a portion of State Highway 72, Second Street and East Street.
- Improvements to the existing roundabout at the Second Street, Bridge Street and State Highway 119 intersection.
- Replacement of an existing culvert where Beaver Creek crosses under East Second Street
- Placement of asphalt concrete pavement on the dirt portion of East Second Street from Snyder Street extending east to East Street C
- Construction of a masonry landscape wall along the southeast corner of the intersection of East Street and State Highway 119.

## 5. FIELD EXPLORATION AND LABORATORY TESTING

On April 4, 2013, Ninyo & Moore conducted a subsurface exploration at the project site to evaluate the existing subsurface conditions and to collect soil samples for laboratory testing. Our evaluation consisted of drilling, logging, and sampling of eight small-diameter borings using a truck-mounted drill rig equipped with 4-inch diameter solid stem augers. Two of the borings were drilled along the north side of Second Street west of the roundabout to depths of approximately 2 feet bgs, four borings were advanced along East Second Street between Snyder Street and East Street to depths of approximately 5 feet bgs. The remaining two borings were advanced along the southeast corner of the intersection of East Street and State Highway 119 to depths between approximately 13 and 14 feet bgs. Bulk and relatively undisturbed soil samples were collected at selected intervals. A grab sample was excavated with hand tools from one foot below the surface approximately 100 feet west of the roundabout. The approximate locations of the borings and the grab sample are presented on Figures 2A, 2B, and 2C.

The soil samples collected during drilling activities were transported to the Ninyo & Moore laboratory for geotechnical laboratory analyses. The analyses included in-situ moisture content and dry density, Atterberg limits, No. 200 sieve and gradation analyses, Proctor density, resistance value (R-Value), and soil corrosivity characteristics (including water soluble sulfates and chlorides). The results of the in-situ moisture content and dry density testing are presented on the boring logs in Appendix A. Descriptions of laboratory test methods and the remainder of the test results are presented in Appendix B.

## 6. GEOLOGY AND SUBSURFACE CONDITIONS

Based on our field observations, subsurface exploration, and review of referenced geologic and soils maps, the subject alignment is underlain primarily by areas of relatively shallow fill material, which are in turn underlain by Quaternary-age alluvium (native soil). The geology and subsurface conditions at the site are described in the following sections.

### 6.1. Geologic Setting

The project site is located within the central foothills portion of the Colorado Rocky Mountains Front Range physiographic province. The foothills are generally composed of Pre-Cambrian age granitic rock and igneous rock of the Pikes Peak Batholith. The terrain consists of mountain and valley topography with streams and rivers including Coal Creek, Boulder Creek, and Ralston Creek. The granitic rocks contain Laramide-age igneous intrusions and old fault zones. Surficial geology of the site is mapped by Gable (2000) as *Qa*. *Qa* is defined as alluvium, colluvium, and glacial deposits (Holocene and Late Pleistocene).

## 6.2. Subsurface Conditions

Our understanding of the subsurface conditions along the project alignment is based on our field exploration and laboratory testing, review of published geologic maps, historic aerial photographs, and our experience with the general geology of the area. The following sections provide a generalized description of the subsurface materials encountered. More detailed descriptions are presented on the boring logs in Appendix A.

### 6.2.1. Fill

Fill was encountered in our shallow borings along the north side of Second Street west of the roundabout. Encountered fill in this area extended to a depth of 2 feet or more. Fill was also encountered in our borings on East Street. Encountered fill in this area extended to depths of between 7 and 9 feet bgs. Fill material generally consisted of light brown to dark brown, damp to moist, medium dense to dense, silty sand with varying amounts of gravel. Based on the results of the subsurface exploration and laboratory testing, the fill encountered is non-plastic. Test results performed on a sample of the fill material indicates an in-place moisture content of 4.9 percent and a dry density of 116.3 pounds per cubic foot (pcf).

### 6.2.2. Alluvium

Alluvium (native soil) was encountered at the surface in Borings B-3 through B-6 and underlying undocumented fill in Borings B-7 and B-8. The alluvium extended to the maximum depth explored of 14 feet bgs. The alluvium generally consisted of light to dark brown, grayish brown, or reddish brown, damp to saturated, medium dense to dense, silty sand with varying amounts of gravel and silty gravel with few cobbles. Boulders although not encountered may be present within the alluvium.

Based on the results of the subsurface exploration and laboratory testing, the alluvium encountered is non-plastic with in-place moisture contents between 3.5 and 15.7 percent. Selected samples had in-place dry densities between 112.2 and 144.7 pcf.

### 6.3. Groundwater

Groundwater was encountered in Boring B-5 at a depth of 5 feet bgs. Boring B-5 was drilled approximately 10 feet west of Beaver Creek. As seasonal fluctuations in groundwater levels and surface water flow occur in and adjacent to the creek, we anticipate potentially elevated groundwater levels above the measured depth depending on the time of year of construction.

## 7. FAULTING AND SEISMICITY

Historically, several minor earthquakes have been recorded near the Nederland area. Based on our field observations and our review of readily available published geological maps and literature, there are no known active faults underlying or adjacent to the subject alignment. The closest Quaternary-age fault to the site is the Golden Fault, located approximately 20 miles to the southeast (USGS & CGS, 2013). The fault is considered to be late Quaternary in age and has not shown displacement in Holocene time. Therefore, the probability of damage at the site from seismically induced ground surface rupture is considered to be low.

Based on a Probabilistic Seismic Hazard Assessment for the Western United States, issued by the United States Geological Survey (USGS, 2012), the site is located in a zone where the peak ground accelerations that have a 10, 5, and 2 percent probability of being exceeded in 50 years are 0.04g, 0.06g, and 0.11g respectively. These ground motion values are calculated for "firm rock" sites, which correspond to a shear-wave velocity of approximately 2,500 feet per second in approximately the top 100 feet bgs. Different soil or rock conditions may amplify or de-amplify these values.

Using the referenced USGS seismic web application (USGS, 2012), estimated maximum considered earthquake spectral response accelerations for short (0.2 second) and long (1.0 second) periods were obtained for the project site. Based on the findings of our subsurface exploration program and the International Building Code developed by the International Code Council (ICC, 2012), a site-specific Seismic Site Class D is appropriate for the project site. The parameters in the following table are characteristic of the project site for design purposes.

**Table 1 – 2012 International Building Code Seismic Design Criteria**

| Seismic Design Factors | Value |
|---|---|
| Site Class | D |
| Site Coefficient, $F_a$ | 1.6 |
| Site Coefficient, $F_v$ | 2.4 |
| Mapped Spectral Acceleration at 0.2-second Period, $S_s$ | 0.249 g |
| Mapped Spectral Acceleration at 1.0-second Period, $S_1$ | 0.061 g |
| Spectral Acceleration at 0.2-second Period Adjusted for Site Class, $S_{MS}$ | 0.398 g |
| Spectral Acceleration at 1.0-second Period Adjusted for Site Class, $S_{M1}$ | 0.146 g |
| Design Spectral Response Acceleration at 0.2-second Period, $S_{DS}$ | 0.266 g |
| Design Spectral Response Acceleration at 1.0-second Period, $S_{D1}$ | 0.098 g |

## 8. CONCLUSIONS

Based on the results of our subsurface evaluation, laboratory testing, and data analysis, it is our opinion the proposed construction is feasible from a geotechnical standpoint, provided that the recommendations of this report are incorporated into the design and construction of the proposed project. Geotechnical considerations include the following:

- The project site is underlain by fill and alluvium. These materials generally consisted of light brown to dark brown, damp to saturated, medium dense to dense silty sand with varying amounts of gravel and cobbles. Boulders although not encountered may be present at the site.

- Groundwater was encountered at a depth of 5 feet bgs in Boring B-5 adjacent to Beaver Creek. At the time of our subsurface exploration water in the creek was less than 12 inches deep. Pumping and construction of earthen berms may be needed to divert water during culvert replacement, we recommend working during a dry time of year for ease of construction.

- The on-site soils should generally be excavatable to the anticipated removal depths with heavy-duty earthmoving or excavating equipment in good operating condition. Site soils generated from on-site excavation activities that are free of deleterious materials, and do not contain particles larger than 6 inches in diameter, can generally be used as engineered fill.

- The sulfate content of tested soils presents a negligible risk of sulfate attack to concrete. Corrosivity test results indicate that the subgrade soils at the site are generally non-corrosive to ferrous metals.

# 9. RECOMMENDATIONS

Based on our understanding of the project, the following sections present our geotechnical recommendations for design and construction. These recommendations were prepared based on preliminary information provided by Huitt-Zollars, Inc. It should be noted that we have not been provided with site grading plans or structural drawings for the proposed improvements, and our recommendations may need to be revised once final plans have been prepared.

## 9.1. Earthwork

The following sections provide our earthwork recommendations for this project. In general, CDOT Construction Standards & Specifications and/or project specific earthwork specifications are expected to apply, unless noted.

### 9.1.1. Site Grading

Prior to grading, proposed structure and improvement areas should be cleared of any pavements, surface and subsurface obstructions, debris, organics (including vegetation), and other deleterious material. Materials generated from clearing operations should be removed from the project site for disposal (e.g. at a legal landfill site). Obstructions that extend below finish grade, if present, should be removed and resulting voids filled with compacted soil or cement slurry, in accordance with the recommendations of the geotechnical consultant.

After the previously described removals have been made, the new pavements, exterior flatwork, and landscaping retaining walls should be placed on 12 or more inches of moisture conditioned and compacted fill.

The subgrade under paved surfaces should be proof rolled in order to locate and densify any areas of pumping soils. A fully-loaded dump truck, water truck, or a similar heavily-loaded piece of construction equipment should be used for planning purposes. Proof rolling operations should be observed by the Geotechnical Engineer or his representative to document subgrade condition and preparation.

#### 9.1.2. Excavations

Our evaluation of the excavation characteristics of the on-site materials is based on the results of the subsurface exploration, our site observations, and our experience with similar materials. The on-site surface soils (fill and alluvium) may generally be excavated with heavy-duty earthmoving or excavation equipment in good operating condition. Although boulders were not encountered in our borings, they may be encountered in the excavations. Boulders, where encountered, will slow the excavation rate and increase wear and tear on the excavation equipment used. Depending on the size(s) of boulder encountered, the use of specialty-equipment may be needed to remove boulders.

Groundwater was encountered in Boring B-5 at a depth of 5 feet bgs. Based on the anticipated depths of earthwork and construction for the culvert replacement where Beaver Creek crosses East Second Street, groundwater may be encountered along with soft and wet conditions. Therefore, dewatering techniques may need to be implemented during the installation of the new culvert. Dewatering should be performed with care and so as not to cause harmful settlement of nearby foundations, utilities, or pavements. Loss of fines should be carefully monitored during dewatering operations at this site, due to the presence of fine-grained soils within the alluvial deposits encountered in the borings. Discharge of water from the excavations to storm water collection systems may entail securing a special permit.

#### 9.1.3. Engineered Fill and Backfill

Based on the laboratory test results and our general observations, it is our opinion the excavated site soils may be suitable for reuse as engineered fill and backfill provided that the excavated materials are processed (to remove material larger than 6-inches in nominal diameter and prevent nesting of cobble size material) and moisture conditioned in accordance with the recommendations provided herein.

Engineered fill and backfill soil should consist of coarse-grained material with less than 50 percent passing the No. 200 sieve. Engineered fill and backfill soils should not contain expansive soil, organic material, construction debris, rock particles, other deleterious matter, or rocks or hard chunks larger than approximately 6 inches nominal diameter unless advised by the geotechnical consultant.

Soils used as engineered fill and backfill should be moisture-conditioned to approximately optimum moisture content and placed and compacted in uniform horizontal lifts to a relative compaction of 95 percent, as evaluated by ASTM D 1557.

Fill should be compacted by appropriate mechanical methods using vibratory compaction equipment. The optimal lift thickness of fill will depend on the type of soil and compaction equipment used, but should generally not exceed approximately 8 inches in loose thickness. Fill materials should not be placed, worked, or rolled while they are frozen or thawing, and should not be placed during poor/inclement weather conditions.

Earthwork operations should be observed and compaction of engineered fill and backfill materials should be tested by the project's geotechnical consultant. Typically, one field test should be performed, per lift. Additional field tests may also be performed in structural and non-structural areas at the discretion of the geotechnical consultant. Compaction areas should be kept separate, and no lift should be covered by another until relative compaction and moisture content within the recommended ranges are obtained.

### 9.1.4. Imported Fill Material

Import soil should consist of coarse-grained material with less than 50 percent passing the No. 200 sieve, a low sulfate content (less than 0.1 percent), and a low swell potential (approximately 1 percent or less when wetted against a surcharge pressure of 200 psf), and a low plasticity index (approximately 10 or less). Import soil should not contain organic matter, clay lumps, bedrock (claystone, sandstone, etc.) fragments, debris, other deleterious matter, or rocks or hard chunks larger than approximately 6 inches nominal diameter.

We further recommend that proposed import material be evaluated by the project's geotechnical consultant at the borrow source for its suitability prior to importation to the project site. Import soil should be moisture-conditioned and placed and compacted in accordance with the recommendations in Section 9.1.3.

### 9.1.5. Temporary Cut Slopes

Temporary excavations will be needed for this project to construct new retaining walls and culverts. Based on the subsurface information obtained from our exploratory borings and our experience with similar projects, we anticipate that the site soils may slough or cave during excavation.

Appropriate slope inclinations should be evaluated in the field by an OSHA-qualified "Competent Person" based on the conditions encountered. Based on the results of our subsurface explorations and in accordance with Appendix A to Subpart P of the referenced Occupational Safety and Health Administration (OSHA) regulations (OSHA, 2005), Type C Soil is appropriate for the project site soils consisting of undocumented fill or alluvium. For Type C soil conditions, OSHA recommends a temporary slope inclination of 1.5H:1V or flatter for excavations 20 feet or less in depth. Steeper cut slopes may be utilized for excavations less than 4 feet deep depending on the strength, moisture content, and homogeneity of the soils as observed in the field. If construction materials, or stockpiled earth materials, are stored, or equipment is operated, near the top of construction excavation slopes, flatter slope geometry or shoring should be used during construction.

Temporary slope surfaces should be kept moist to retard raveling and sloughing. Water should not be allowed to flow over the top of excavations in an uncontrolled manner. Stockpiled material and/or equipment should be kept back from the top of excavations a distance equivalent to the depth of the excavation or more. Workers should be protected from falling debris, sloughing, and raveling in accordance OSHA regulations (OSHA, 2005). Temporary excavations should be observed by the project's geotechnical consultant so that appropriate additional recommendations may be provided based on the actual field conditions. Temporary excavations are time sensitive and failures are possible.

### 9.2. Culvert Installation

The Contractor should provide adequate mechanical compaction in the culvert trench backfills, particularly in the lower portions of the excavations. Culvert bedding materials, placement and compaction should meet the specifications of the culvert manufacturer and applicable municipal standards. Materials proposed for use as culvert bedding should be tested for suitability prior to use.

Special care should be exercised to avoid damaging the culvert during the compaction of the backfill. In addition, the underside (or haunches) of the culvert should be supported on bedding material that is compacted as described above. This may need to be performed with placement by hand or small-scale compaction equipment. Due to the presence of groundwater, subgrade stabilization at the base of the excavation for the culvert may be needed to achieve a firm, stable base for culvert and backfill placement. Such stabilization may include placement of crushed rock, geosynthetic reinforcement, etc. The geotechnical engineer should be consulted to provide additional recommendations in this regard.

### 9.3. Retaining Wall Foundations

Retaining wall foundations should be designed in accordance with the recommendations of the project's structural engineer. Prior to placement of reinforcement, the geotechnical engineer should observe the footing excavations.

#### 9.3.1. Rigid Walls

Footings should extend to 48 inches or more below the lowest exterior finished grade (for frost protection), and bear on medium dense to dense alluvial soils or on a zone of adequately placed and compacted engineered fill (reworked native or import soils), as described in Section 9.1.3 of this report. Continuous footings should have a width of 18 inches or more. Footings should be reinforced in accordance with the project structural engineer's recommendations.

An allowable bearing pressure of 3,000 pounds per square foot (psf) may be used for conventional spread footings bearing on undisturbed alluvial soils or on compacted engineered fill for the proposed retaining wall. These allowable bearing capacities were developed considering a factor of safety of 2.5.

The average footing bearing pressure should not exceed the allowable equivalent uniform bearing pressure presented above; however, peak edge stresses may exceed this value as long as the resultant passes through the middle third of the footing base. The allowable soil bearing pressure may be increased by one-third when considering total loads including transient loads such as wind or seismic forces. Lateral resistance for footings is presented in the following section. Seismic parameters for design of structures at the site are provided in Table 1 in Section 7.

#### 9.3.2. Mechanically Stabilized Earth Walls

Flexible-type retaining walls, such as "mechanically stabilized earth" (MSE) walls, may be supported on 12 or more inches of leveling coarse material underlain by 12 or more inches of moisture conditioned and compacted engineered fill. For design of the MSE wall system an angle of internal friction of 32 degrees and a moist unit weight of

125 pcf may be used for the foundation materials and the retained materials behind the reinforcing zone. Imported, granular, fill material, meeting the requirements of the wall design, should be used within the geotextile reinforcing zone. For estimation purposes, the length of the geotextile reinforcing zone can be taken as 0.7 to 0.8 times the wall height, but will depend on the final design provided by the contractor or wall designer.

MSE retaining walls bearing on 12 or more inches of moisture conditioned and compacted engineered fill may be designed for an allowable bearing pressure of 3,000 psf. This allowable bearing capacity is based on the assumption of well-drained foundation conditions. If foundation soils become wetted, the effective bearing capacity could be reduced. We estimate settlements from compression of the foundation soils under the imposed footing loads of 1-inch, for drained conditions.

MSE retaining walls should bear at least 48 inches below lowest adjacent grade to provide adequate soil cover above the bearing elevation to reduce the risk of frost heave, if that is a design concern.

### 9.4. Lateral Earth Pressures

Walls that are not restrained from movement at the top and have a level backfill behind the wall may be designed using an "active" equivalent fluid unit weight of 40 pcf as shown on Figure 3. These lateral earth pressure values assume compaction within about 5 feet of the wall will be accomplished with relatively light compaction equipment. These values also assume that retaining walls will have a height of approximately 12 feet or less. Unrestrained retaining walls should also be designed to resist a horizontal surcharge pressure of 0.35q. The value for "q" represents the pressure induced by adjacent light loads, such as traffic loads.

For "passive" resistance to lateral loads, we recommend that an equivalent fluid weight of 300 pcf be used up to value of 3,000 psf. This value assumes that the ground is horizontal for a distance of 10 feet or more behind the wall or three times the height generating the passive pressure, whichever is more. We recommend that the upper 12 inches of soil not protected by pavement or a concrete slab be neglected when calculating passive resistance. A coefficient of friction of 0.41 may be used between soil and concrete contacts. If passive and frictional resistances are to be used in combination, we recommend that the passive resistance be limited to one-half of the ultimate lateral resistance. The passive resistance values may be increased by one-third when considering loads of short duration such as wind or seismic forces.

Measures should be taken so that moisture does not build up behind walls. Rigid retaining walls should be backfilled and provided with a drain. Drainage guidelines for rigid retaining walls are presented on Figure 4. Drainpipes should outlet away from retaining walls. Weep-holes may be used in lieu of drainage pipes. Drainage details for flexible walls should be developed by the wall design engineer.

Snow storage locations should be restricted to paved areas where positive surface drainage is maintained. Walls should be waterproofed in accordance with the recommendations of the project civil engineer or architect. To reduce the potential for water- and sulfate/salt-related damage to the retaining walls, particular care should be taken in selection of the appropriate type of waterproofing material to be utilized and in the application of this material.

## 9.5. Pavements

Pavement sections for East Second Street were developed in general accordance with the guidelines and procedures of the American Association of State Highway and Transportation Officials (AASHTO), the Colorado Department of Transportation (CDOT), and Boulder County.

### 9.5.1. Pavement Subgrade Support

The subgrade soils encountered in our borings typically consisted of silty sands and silty gravels that generally exhibit good pavement support characteristics. A Resistance value (R-Value) of 65 was calculated from a laboratory test performed on a composite soil sample representative of subsurface soils along the project alignment. For conservatism in design, an R-Value of 50 was utilized and correlated to a subgrade resilient modulus ($M_R$) of 13,400 pounds per square inch (psi). If during construction the subgrade is found to vary from the expected soil conditions, we should be contacted so we may re-evaluate our recommended resilient modulus value.

### 9.5.2. Design Traffic

Specific traffic loadings for the project were not available at the time of this report preparation. Equivalent 18-kip single axle load applications (ESAL's) of 36,000 were assumed for pavements over a 20 year design life. If design traffic loadings differ significantly from these assumed values, we should be notified to re-evaluate the pavement recommendations below.

### 9.5.3. Pavement Design

Pavement designs for the site were based on the "Guide for Design of Pavement Structures" by the American Association of State Highway and Transportation Officials (AASHTO, 1993).

The design of flexible pavements was based on the following input parameters:

| | |
|---|---|
| Initial Serviceability: | 4.5 |
| Terminal Serviceability: | 2.0 |
| Reliability | 80 % |
| Overall Standard Deviation: | 0.44 |
| Resilient Modulus: | 21,518 psi |
| Stage Construction: | 1 |

Boulder County specifies a composite pavement section for all new constructed pavements. Based on the Boulder County specifications, the above-mentioned design traffic and input parameters, and following the AASHTO method of pavement design (AASHTO, 1993), we recommend placement of 3 inches of asphalt concrete (AC) over 4 inches of aggregate base course (ABC).

The AC pavement shall consist of a bituminous plant mix composed of a mixture of high quality aggregate and bituminous material, which meets the requirements of a job-mix formula established by a qualified engineer. The geotechnical engineer should be retained to review the proposed pavement mix designs, grading, and lift thicknesses prior to construction.

The ABC placed beneath pavements should meet the criteria of CDOT Class 6 aggregate base. ABC materials should be compacted to 95 percent relative compaction, as evaluated by AASHTO T 180. Requirements for CDOT Class 6 aggregate base can be found in Section 703 of the current CDOT Standards and Specifications for Road and Bridge Construction.

#### 9.5.4. Porous Pavements

The climate of Nederland and most of Colorado presents a challenge to porous pavement design. These challenges include the following:

- De-icing salts and sand contain chlorides that could migrate through the porous pavement into groundwater. The de-icing salts, may also cause reduction in pavement material durability, especially for porous Portland cement concrete and porous concrete pavers. In addition, the sand used for snow and ice control or carried by traveling vehicles may plug the pores of the porous pavements and reduce permeability.
- Snow plow blades may damage the relatively rough surface of the porous pavement. If porous pavers are utilized, the plows could catch the edges of the pavers.
- Runoff may infiltrate below pavements and freeze causing frost heave and/or ice jacking.

These challenges do not imply that porous pavements cannot be used in cold climates. Porous pavements that are properly maintained and designed to reduce frost heave have been utilized in many parts of the country and in Colorado. The site soils, in their current condition are not considered rapidly draining, therefore, they will have to be replaced by more permeable subgrade material such as crushed aggregate to allow for the transfer of surface waters to an elevation that is below the frost depth. In addition, the subgrade materials may loose their subgrade support strength while they are saturated. Alternatively, underground detention or retention systems could be incorporated below the porous pavements that can rapidly collect the surface water runoff.

At this time we do not have sufficient project civil design details to develop recommendations for porous pavements. Ninyo & Moore is available to further discuss the consideration of porous pavements and provide addendum recommendations upon request.

#### 9.5.5. Pavement Subgrade Preparation

For the flexible pavement section recommended above, we recommend the underlying subgrade soils be prepared as described in Section 9.1.1 of this report.

The contractor should be prepared either to dry the subgrade materials or moisten them, as needed, prior to compaction. The prepared subgrade should be protected from the elements prior to pavement placement. Subgrades that are exposed to the elements may need additional moisture conditioning and compaction, prior to pavement placements.

Immediately prior to paving, the pavement subgrade should be proof rolled with a heavily loaded, pneumatic tired vehicle, and checked for moisture content. Areas that exhibit excessive deflection (as evaluated by the geotechnical engineer) during proof rolling should be excavated and replaced and/or stabilized.

#### 9.5.6. Alignment Drainage

The collection and diversion of surface drainage away from paved areas is vital to satisfactory performance of the pavements. The subsurface and surface drainage systems should be carefully designed to facilitate removal of the water from paved areas and subgrade soils. Allowing surface waters to pond on or adjacent to pavements will cause premature pavement deterioration. Any known natural or man-made subsurface seepage which may occur along the roadway at sufficiently shallow depths as to influence moisture contents within the subgrade should be intercepted by drainage ditches or below grade drains. Where topography, site constraints or other factors limit or preclude adequate surface drainage, pavements should be provided with edge drains to reduce loss of subgrade support.

#### 9.5.7. Pavement Maintenance

The standard care of practice in pavement design describes the recommended flexible pavement section as a “20-year” design pavement; however, many pavements will not remain in satisfactory condition without routine, preventive maintenance and rehabilitation procedures performed during the life of the pavement. Preventive pavement treatments are surface rehabilitation and operations applied to improve or extend the functional life of a pavement. These treatments preserve, rather than improve, the structural capacity of the pavement structure. In the event the existing pavement is not structurally sound, the preventive maintenance will have no long-lasting effect. Therefore, a routine maintenance program to seal joints and cracks, and repair distressed areas is recommended.

### 9.6. Concrete Flatwork

Exterior flatwork should be supported on improved subgrade as described in section 9.1.1 of this report. To reduce manifestation of distress to exterior concrete flatwork, we recommend placement of crack control joints at appropriate spacing as designed by the project civil engineer.

Ground-supported flatwork, such as walkways, may be subject to soil-related movements resulting from heave/settlement, frost, etc. Thus, where these types of elements abut rigid building foundations or isolated/suspended structures, differential movements should be anticipated. We recommend that 2 or more inches of clearance be provided where such elements abut structures to allow for differential movement at these locations.

Positive drainage should be established and maintained adjacent to flatwork. Water should not be allowed to pond on or adjacent to flatwork.

### 9.7. Corrosion Considerations

The corrosion potential of on-site soils to concrete and buried metal was evaluated in the laboratory using representative samples obtained from the exploratory borings. Laboratory testing was performed to assess the effects of sulfate on concrete and the effects of soil resistivity on buried metal. Results of these tests are presented in Appendix B. Recommendations regarding concrete to be utilized in construction of proposed improvements and for buried metal pipes are provided in the following sections.

#### 9.7.1. Concrete

Laboratory chemical tests performed on selected samples of on-site soils indicated negligible water-soluble sulfate contents. Based on the laboratory test results and the American Concrete Institute (ACI, 2008) requirements for soil exposed to sulfate containing soil, the on-site soils are considered to have a negligible sulfate exposure to concrete.

Notwithstanding the sulfate test results and due to the limited number of chemical tests performed, as well as our experience with similar soil conditions and local practice, along the project alignment. Due to potential uncertainties as to the use of reclaimed irrigation water, or topsoil that may contain higher sulfate contents, pozzolan or admixtures designed to increase sulfate resistance may be considered.

The concrete should have a water-cementitious materials ratio of no more than 0.50 by weight for normal weight aggregate concrete. The structural engineer should ultimately select the concrete design strength based on the project specific loading conditions. However, higher strength concrete may be selected for increased durability, resistance to slab curling and shrinkage cracking. We recommend the use of concrete with a design 28-day compressive strength of 4,000 psi or more, for flatwork at this site. Concrete exposed to the elements should be air-entrained.

### 9.7.2. Buried Metal Pipes

The corrosion potential of the on-site materials was analyzed to evaluate its potential effects on flatwork and structures. Corrosion potential was evaluated using the results of laboratory testing of samples obtained during the subsurface evaluation that were considered representative of soils at the subject sites. The results of the laboratory testing indicate the on-site materials have low soluble chloride contents indicative of a low corrosion potential to ferrous metals.

## 9.8. Scaling

Climatic conditions in the project area including relatively low humidity, large temperature changes and repeated freeze-thaw cycles, may cause surficial scaling and spalling of exterior concrete. Occurrence of surficial scaling and spalling can be aggravated by poor workmanship during construction, such as "over-finishing" concrete surfaces and the use of de-icing salts on exterior concrete flatwork, particularly during the first winter after construction. The use of de-icing salts on nearby roadways, which can be transferred by vehicle traffic onto newly placed concrete, can be sufficient to induce scaling.

The measures below can be beneficial for reducing the concrete scaling. However, because of the other factors involved, including workmanship, surface damage to concrete can develop even though the measures provided below were followed. The mix design criteria should be coordinated with other project requirements including the criteria for soluble sulfate resistance presented in Section 9.7.1.

- Curing concrete in accordance with applicable codes and guidelines.
- Maintaining a water/cement ratio of 0.45 by weight for exterior concrete mixes.
- Including Type F fly ash in exterior concrete mixes as 20 percent of the cementitious material.
- Specifying a 28-day, compressive strength of 4,500 or more psi for exterior concrete.
- Including 'fibermesh' in the concrete mix.

- Avoiding the use of de-icing salts through the first winter after construction.

### 9.9. Construction in Cold or Wet Weather

During construction, the site should be graded such that surface water can drain readily away from the building areas. It is important to avoid ponding of water in or near excavations. Water that accumulates in excavations should be promptly pumped out or otherwise removed and these areas should be allowed to dry out before resuming construction. Berms, ditches, and similar means should be used to decrease stormwater entering the work area and to efficiently convey it off site.

Earthwork activities undertaken during the cold weather season may be difficult and should be done by an experienced contractor. Fill should not be placed on top of frozen soils. The frozen soils should be removed prior to the placement of new engineered fill or other construction material. Frozen soil should not be used as structural fill or backfill. The frozen soil may be reused (provided it meets the selection criteria) once it has thawed completely. In addition, compaction of the soils may be more difficult due to the viscosity change in water at lower temperatures.

If construction proceeds during cold weather, foundations, slabs, or other concrete elements should not be placed on frozen subgrade soil. Frozen soil should either be removed from beneath concrete elements, or thawed and recompacted. To limit the potential for soil freezing, the time passing between excavation and construction should be minimized. Blankets, straw, soil cover, or heating could be used to discourage the soil from freezing.

### 9.10. Construction Observation and Testing

A qualified geotechnical consultant should perform appropriate observation and testing services during grading and construction operations. These services should include observation of removal of undocumented fill and soft, loose, or otherwise unsuitable soils, evaluation of subgrade conditions where soil removals are performed, evaluation of the results of any subgrade stabilization or dewatering activities, and performance of observation and testing services during placement and compaction of engineered fill and backfill soils.

The geotechnical consultant should also perform observation and testing services during placement of concrete, mortar, grout, asphalt concrete, and steel reinforcement. If another geotechnical consultant is selected to perform observation and testing services for the project, we request that the selected consultant provide a letter to the owner, with a copy to Ninyo & Moore, indicating that they fully understand our recommendations and that they are in full agreement with the recommendations contained in this report. Qualified subcontractors utilizing appropriate techniques and construction materials should perform construction of the proposed improvements.

### 9.11. Plan Review

The recommendations presented in this report are based on preliminary design information for the proposed project, as provided by Huitt-Zollars, Inc. personnel, and on the findings of our geotechnical evaluation. When finished, project plans and specifications should be reviewed by the geotechnical consultant prior to submitting the plans and specifications for bid. Additional field exploration and laboratory testing may be needed upon review of the project design plans.

### 9.12. Pre-Construction Meeting

We recommend that a pre-construction meeting be held. The owner or the owner's representative, the architect, the contractor, and the geotechnical consultant should be in attendance to discuss the plans and the project.

## 10. LIMITATIONS

The field evaluation, laboratory testing, and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request. Please also note that our evaluation was limited to assessment of the geotechnical aspects of the project, and did not include evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

This report is intended for design purposes only. It does not provide sufficient data to prepare an accurate bid by contractors. It is suggested that the bidders and their geotechnical consultant perform an independent evaluation of the subsurface conditions in the project areas. The independent evaluations may include, but not be limited to, review of other geotechnical reports prepared for the adjacent areas, site reconnaissance, and additional exploration and laboratory testing.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site could change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

## 11. SELECTED REFERENCES

American Association of State Highway and Transportation Officials (AASHTO), 1993, AASHTO Guide for Design of Pavement Structures.

American Association of State Highway and Transportation Officials (AASHTO), 2011, Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 31st Edition, and Provisional Standards.

American Concrete Institute (ACI), 2008, Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary.

American Society for Testing and Materials (ASTM), 2010 Annual Book of ASTM Standards.

Colorado Department of Transportation (CDOT), 2011, Standard Specifications for Road and Bridge Construction.

Colorado Department of Transportation (CDOT), 2013, Pavement Design Manual.

Gable, Geologic Map of Proterozoic Rocks of the Central Front Range, Colorado, 2000.

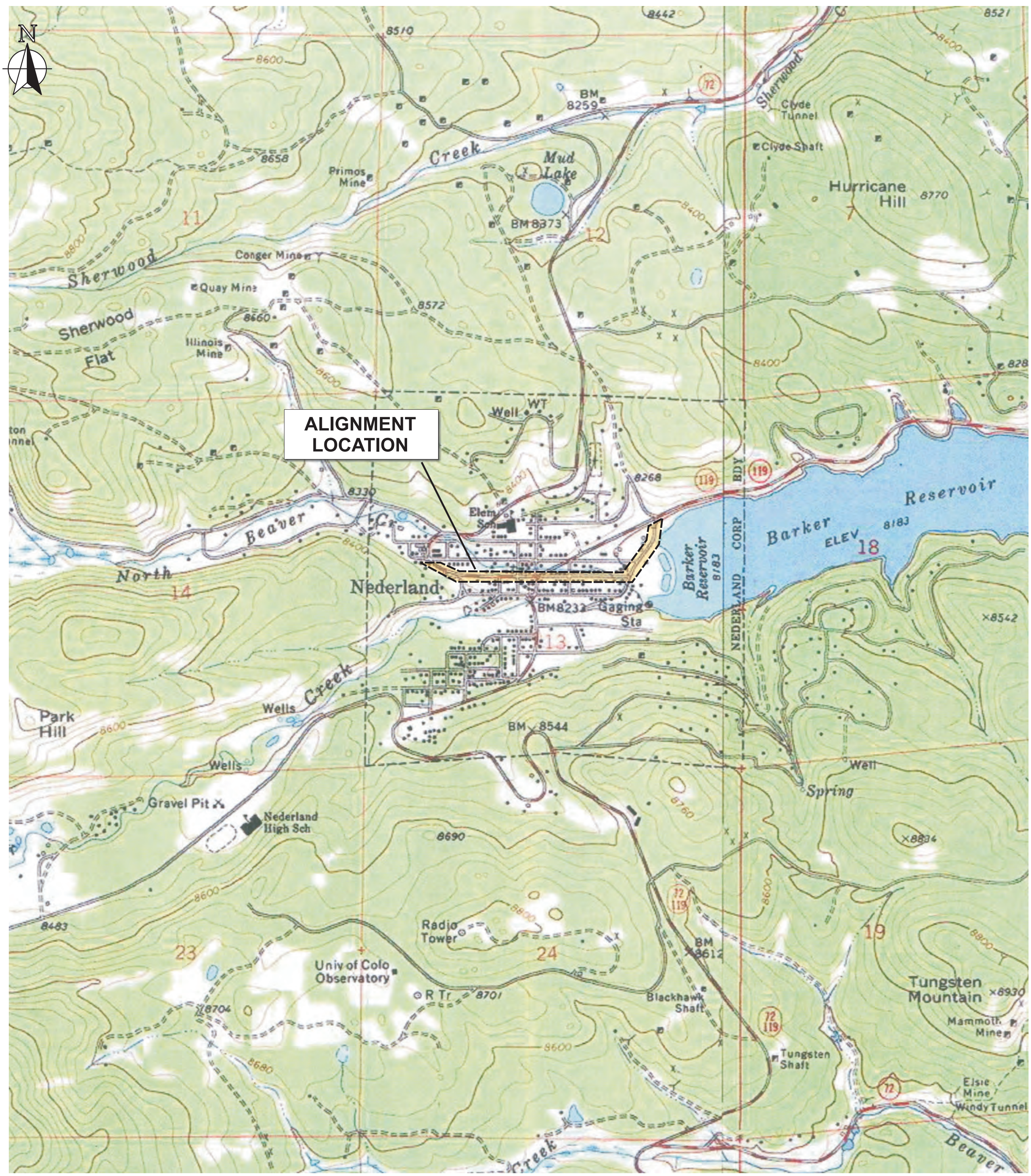
International Building Code, 2012, International Code Council.

Ninyo & Moore, In-house Proprietary Information.

Occupational Safety and Health Administration (OSHA), 2005, OSHA Standards for the Construction Industry, 29 CFR Part 1926: dated June.

**Aerial Photograph References**

| Source | Dates |
|---|---|
| Google Earth | September 1999, March 2006, August 2006 |




Source: US Geological Survey 7.5-minute topographic map, Nederland, Colorado, rev. 1972.

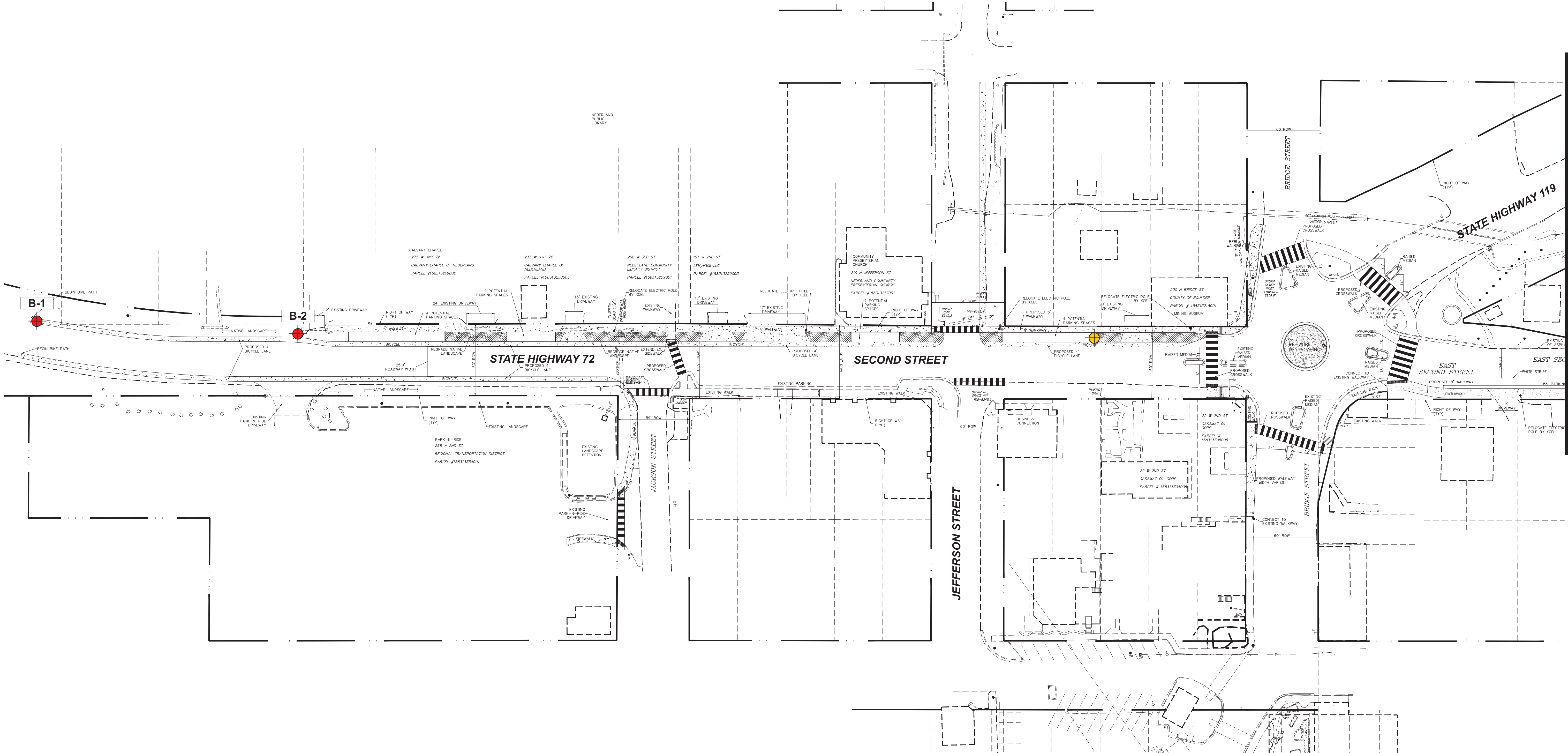
0 1900

Approximate Scale:
1 inch = 1900 feet

Note: Dimensions, directions, and locations are approximate.

| Ninyo & Moore | ALIGNMENT LOCATION | | FIGURE |
|---|---|---|---|
| PROJECT NO: 500651001 | DATE: 4/13 | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS NEDERLAND, COLORADO | 1 |

file no: 0651vmap0413




**LEGEND**

B-2 Boring Location

Grab Sample Location

N

0 80

Approximate Scale:
1 inch = 80 feet

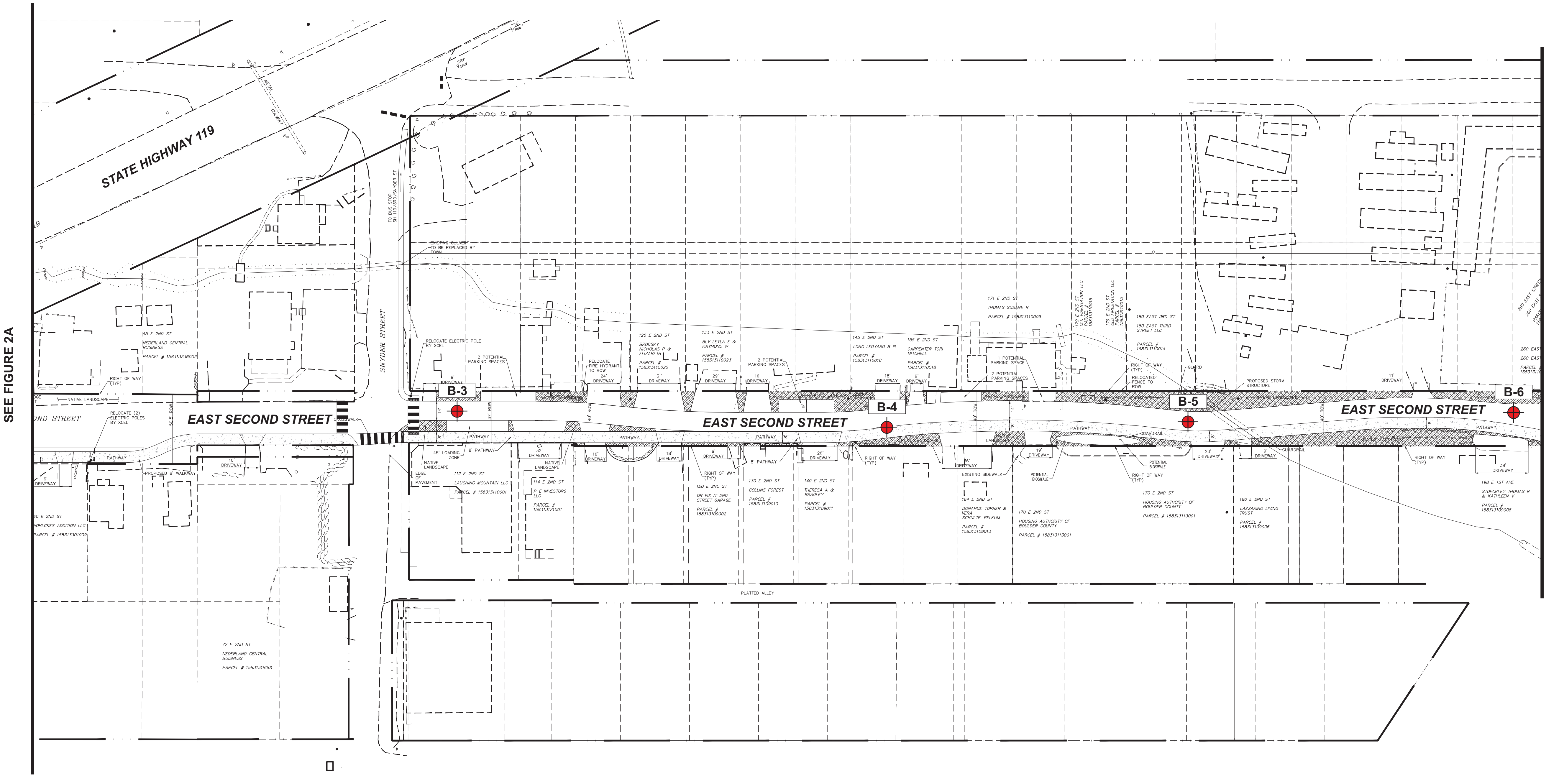
Source: Huitt-Zollars, 02/08/13.
Note: Dimensions, directions, and locations are approximate.

file no: 0651blm0413a

**Ninyo & Moore**

BORING LOCATIONS

| PROJECT NO: | DATE: | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS NEDERLAND, COLORADO | FIGURE 2A |
|---|---|---|---|
| 5000651001 | 4/13 | | |




## LEGEND

B-6 Boring Location

N

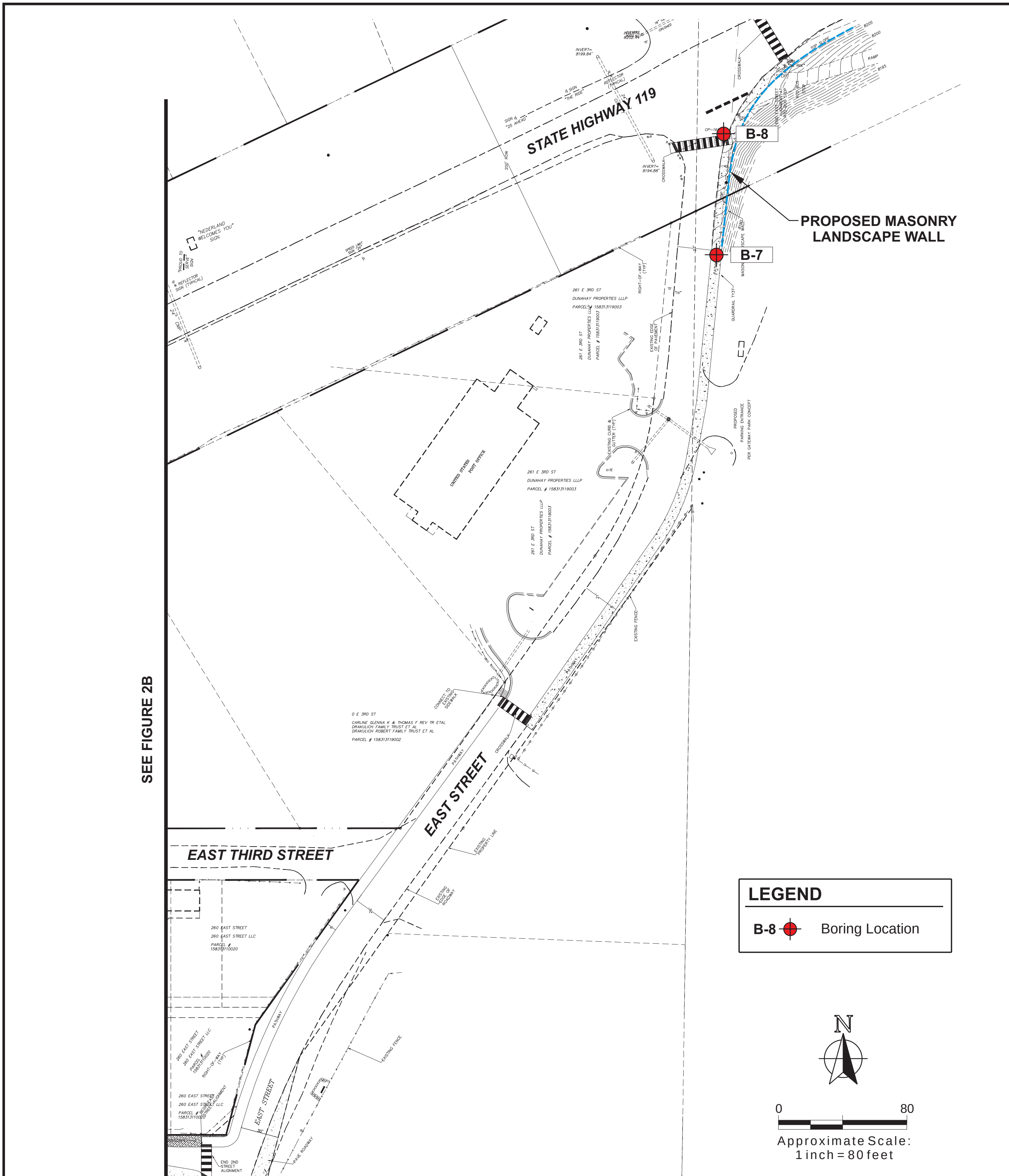
0 80

Approximate Scale: 1 inch = 80 feet

Source: Huitt-Zollars, 02/08/13.
Note: Dimensions, directions, and locations are approximate.

file no: 0651blm0413b

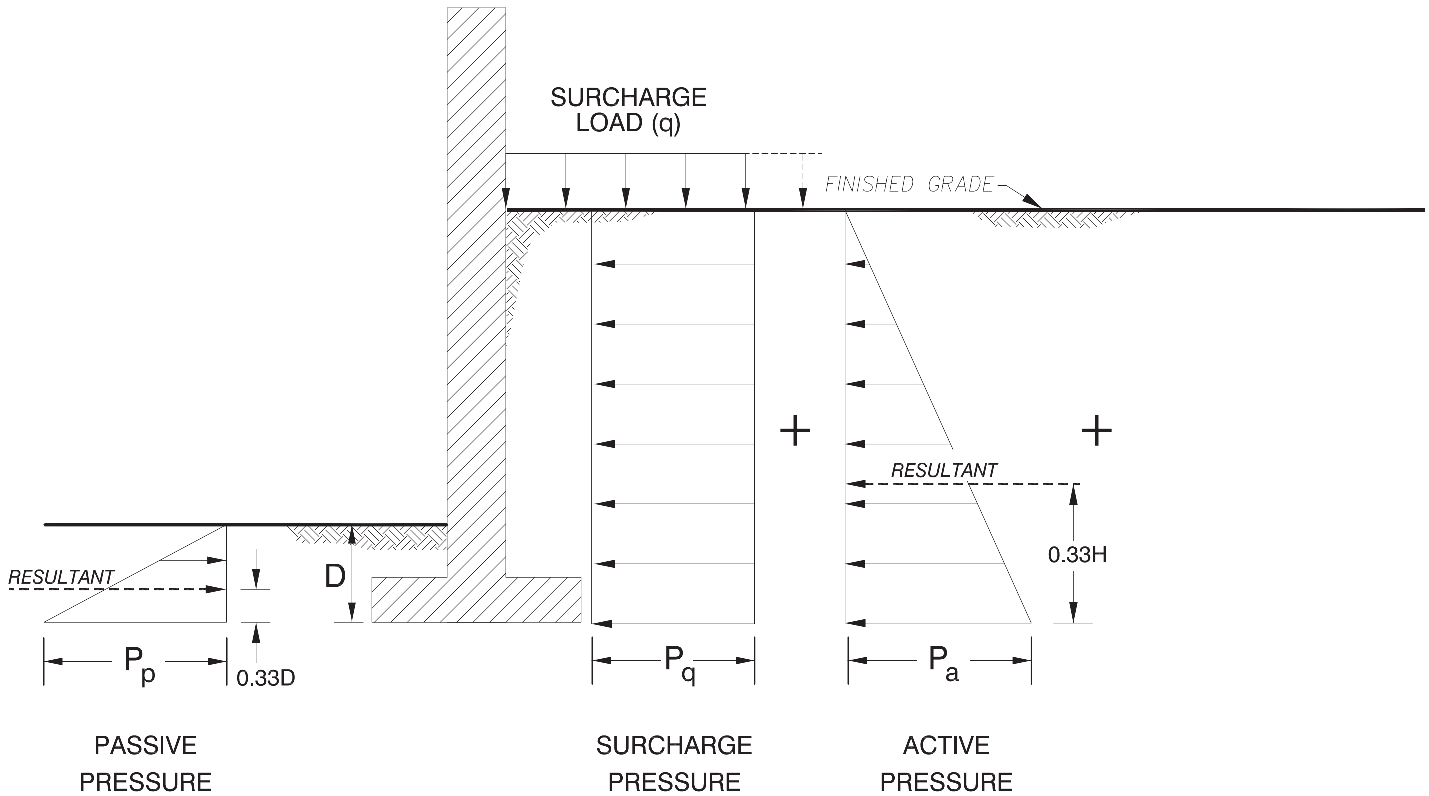
| Ninyo & Moore | BORING LOCATIONS | FIGURE |
|---|---|---|
| PROJECT NO: 5000651001 / DATE: 4/13 | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS NEDERLAND, COLORADO | 2B |




Source: Huitt-Zollars, 02/08/13.
Note: Dimensions, directions, and locations are approximate.

| Ninyo & Moore | BORING LOCATIONS | | FIGURE |
|---|---|---|---|
| PROJECT NO: 500651001 | DATE: 4/13 | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS NEDERLAND, COLORADO | 2C |

file no: 0651blm0413c




NOTES:

1. ASSUMES NO HYDROSTATIC PRESSURE BUILD-UP BEHIND THE RETAINING WALL
2. ASSUMES LEVEL, GRANULAR BACKFILL MATERIALS
3. DRAINS AS RECOMMENDED IN THE RETAINING WALL DRAINAGE DETAIL SHOULD BE INSTALLED BEHIND THE RETAINING WALL
4. H AND D ARE IN FEET
5. SETBACK SHOULD BE IN ACCORDANCE WITH SECTION 1808.7 OF THE 2009 IBC

RECOMMENDED GEOTECHNICAL DESIGN PARAMETERS

| Lateral Earth Pressure | Equivalent Fluid Pressure |
|---|---|
| $P_p$ | 300 **D** psf |
| $P_q$ | 0.35 **q** psf |
| $P_a$ | 44 **H** psf |

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# LATERAL EARTH PRESSURES FOR YIELDING RETAINING WALLS

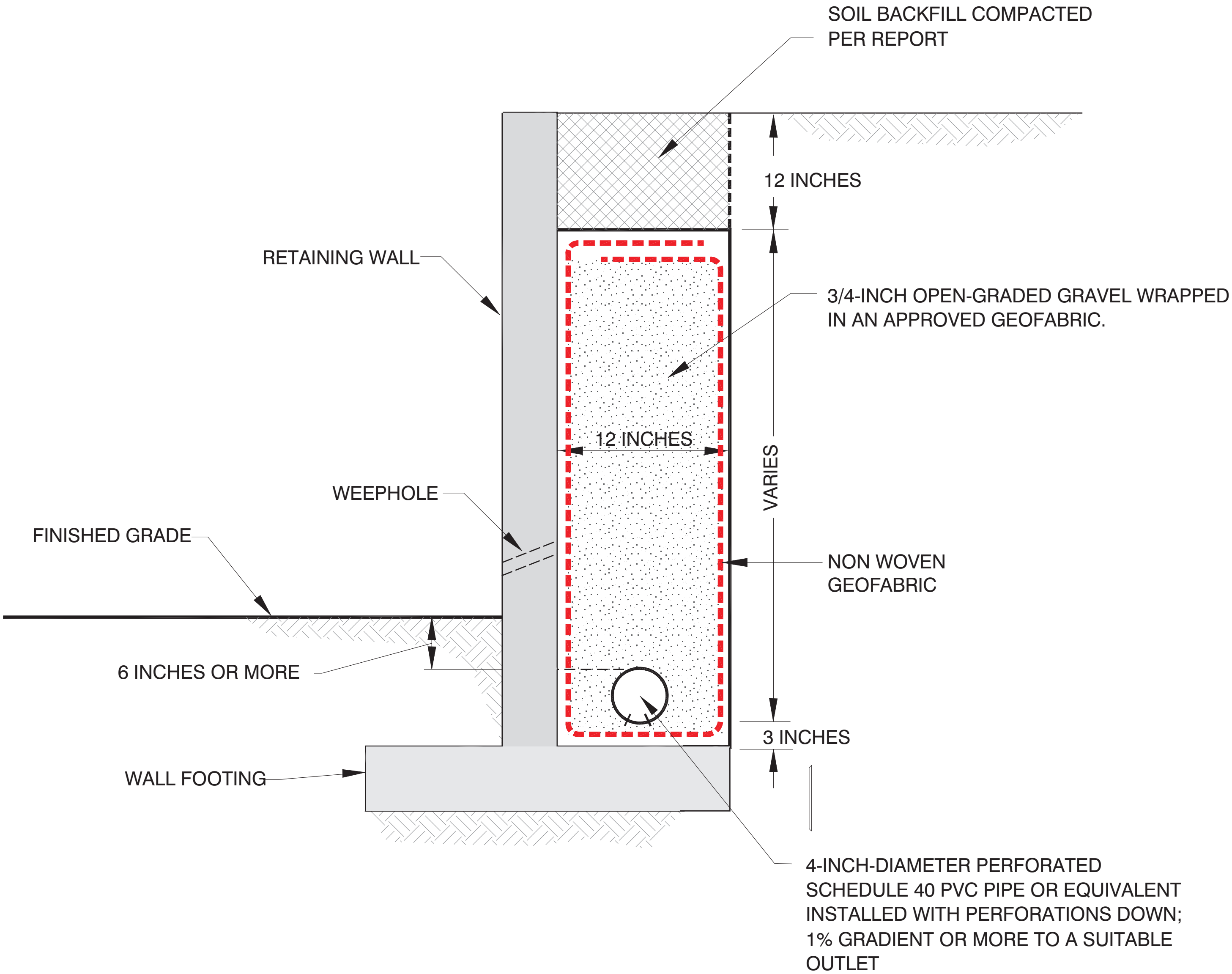
FIGURE 3

PROJECT NO: 500651001

DATE: 4/13

PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS
NEDERLAND, COLORADO

file no: 0651lep0413




**NOTE:**

IN LIEU OF THE WRAPPED OPEN-GRADED GRAVEL, A GEOCOMPOSITE DRAINAGE MAT ATTACHED TO THE WALL AND DISCHARGING INTO THE DRAIN PIPE OR WEEP HOLES MAY BE CONSIDERED.

NOT TO SCALE

| Ninyo & Moore | | RETAINING WALL<br>DRAINAGE GUIDELINES | FIGURE<br>**4** |
|---|---|---|---|
| PROJECT NO:<br>500651001 | DATE:<br>4/13 | PEDESTRIAN ENHANCEMENT AND<br>STORM WATER IMPROVEMENTS<br>NEDERLAND, COLORADO | |

file no: 0651dtl0413

# APPENDIX A

# BORING LOGS

**Field Procedure for the Collection of Disturbed Samples**

Disturbed soil samples were obtained in the field using the following methods.

**Bulk Samples**

Bulk samples of representative earth materials were obtained from the exploratory borings. The samples were bagged and transported to the laboratory for testing.

**The Standard Penetration Test (SPT) Sampler**

Disturbed drive samples of earth materials were obtained by means of a Standard Penetration Test sampler. The sampler is composed of a split barrel with an external diameter of 2 inches and an unlined internal diameter of 1-3/8 inches. The sampler was driven into the ground 12 to 18 inches with a 140-pound hammer free-falling from a height of 30 inches in general accordance with ASTM D 1586. The blow counts were recorded for every 6 inches of penetration; the blow counts reported on the logs are those for the last 12 inches of penetration. Soil samples were observed and removed from the sampler, bagged, sealed and transported to the laboratory for testing.

**Field Procedure for the Collection of Ring-lined Samples**

Ring-lined soil samples were obtained in the field using the following methods.

**The Modified California Split-Barrel Drive Sampler**

The sampler, with an external diameter of 3.0 inches, was lined with thin brass rings with inside diameters of approximately 2.4 inches. The sample barrel was driven into the ground with the weight of a hammer in general accordance with ASTM D 3550. The driving weight was permitted to fall freely. The approximate length of the fall, the weight of the hammer or bar, and the number of blows per foot of driving are presented on the boring logs as an index to the relative resistance of the materials sampled. The samples were removed from the sample barrel in the brass rings, sealed, and transported to the laboratory for testing.

**The California Drive Sampler**

The sampler, with an external diameter of 2.4 inches, was lined with four 4-inch long, thin brass rings with inside diameters of approximately 1.9 inches. The sample barrel was driven into the ground with the weight of a hammer in general accordance with ASTM D 3550. The driving weight was permitted to fall freely. The approximate length of the fall, the weight of the hammer, and the number of blows per foot of driving are presented on the boring logs as an index to the relative resistance of the materials sampled. The samples were removed from the sample barrel in the brass liners, sealed, and transported to the laboratory for testing.

# BORING LOG EXPLANATION SHEET

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | Bulk sample. |
| | | | | | | | | Modified split-barrel drive sampler. |
| | | | | | | | | No recovery with modified split-barrel drive sampler. |
| | | | | | | | | Sample retained by others. |
| | | | | | | | | Standard Penetration Test (SPT). |
| 5 | | | | | | | | No recovery with a SPT. |
| | | | XX/XX | | | | | Shelby tube sample. Distance pushed in inches/length of sample recovered in inches. |
| | | | | | | | | No recovery with Shelby tube sampler. |
| | | | | | | | | Continuous Push Sample. |
| | | | | | | | | Seepage. |
| 10 | | | | | | | | Groundwater encountered during drilling. |
| | | | | | | | | Groundwater measured after drilling. |
| | | | | | | | SM | ALLUVIUM: Solid line denotes unit change. |
| | | | | | | | | Dashed line denotes material change. |
| 15 | | | | | | | | Attitudes: Strike/Dip<br>b: Bedding<br>c: Contact<br>j: Joint<br>f: Fracture<br>F: Fault<br>cs: Clay Seam<br>s: Shear<br>bss: Basal Slide Surface<br>sf: Shear Fracture<br>sz: Shear Zone<br>sbs: Sheared Bedding Surface |
| 20 | | | | | | | | The total depth line is a solid line that is drawn at the bottom of the boring. |

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**BORING LOG**

EXPLANATION OF BORING LOG SYMBOLS

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| | Rev. 01/03 | |

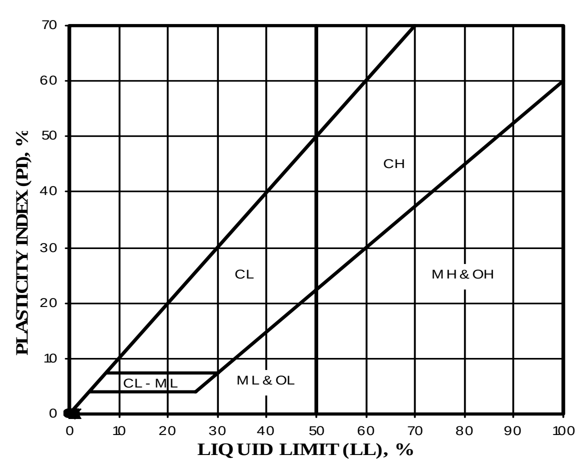
# U.S.C.S. METHOD OF SOIL CLASSIFICATION

| MAJOR DIVISIONS | | SYMBOL | TYPICAL NAMES |
|---|---|---|---|
| COARSE-GRAINED SOILS (More than 1/2 of soil >No. 200 sieve size) | GRAVELS (More than 1/2 of coarse fraction > No. 4 sieve size) | GW | Well graded gravels or gravel-sand mixtures, little or no fines |
| | | GP | Poorly graded gravels or gravel-sand mixtures, little or no fines |
| | | GM | Silty gravels, gravel-sand-silt mixtures |
| | | GC | Clayey gravels, gravel-sand-clay mixtures |
| | SANDS (More than 1/2 of coarse fraction <No. 4 sieve size) | SW | Well graded sands or gravelly sands, little or no fines |
| | | SP | Poorly graded sands or gravelly sands, little or no fines |
| | | SM | Silty sands, sand-silt mixtures |
| | | SC | Clayey sands, sand-clay mixtures |
| FINE-GRAINED SOILS (More than 1/2 of soil <No. 200 sieve size) | SILTS & CLAYS Liquid Limit <50 | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with |
| | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean |
| | | OL | Organic silts and organic silty clays of low plasticity |
| | SILTS & CLAYS Liquid Limit >50 | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| | | CH | Inorganic clays of high plasticity, fat clays |
| | | OH | Organic clays of medium to high plasticity, organic silty clays, organic silts |
| HIGHLY ORGANIC SOILS | | Pt | Peat and other highly organic soils |

## GRAIN SIZE CHART

| CLASSIFICATION | RANGE OF GRAIN SIZE | |
|---|---|---|
| | U.S. Standard Sieve Size | Grain Size in Millimeters |
| **BOULDERS** | Above 12" | Above 305 |
| **COBBLES** | 12" to 3" | 305 to 76.2 |
| **GRAVEL**<br>**Coarse**<br>**Fine** | 3" to No. 4<br>3" to 3/4"<br>3/4" to No. 4 | 76.2 to 4.76<br>76.2 to 19.1<br>19.1 to 4.76 |
| **SAND**<br>**Coarse**<br>**Medium**<br>**Fine** | No. 4 to No. 200<br>No. 4 to No. 10<br>No. 10 to No. 40<br>No. 40 to No. 200 | 4.76 to 0.075<br>4.76 to 2.00<br>2.00 to 0.420<br>0.420 to 0.075 |
| **SILT & CLAY** | Below No. 200 | Below 0.075 |

## PLASTICITY CHART

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**U.S.C.S. METHOD OF SOIL CLASSIFICATION**

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. |
|---|---|---|---|---|---|---|---|
| 0 | | | | | | | SM |
| 5 | | | | | | | |
| 10 | | | | | | | |
| 15 | | | | | | | |
| 20 | | | | | | | |

DATE DRILLED 4/04/13 BORING NO. B-1

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DLH LOGGED BY DLH REVIEWED BY NAA

**DESCRIPTION/INTERPRETATION**

RECYCLED ASPHALT: Approximately 2 inches thick.

FILL:
Light brown to brown, moist, silty SAND.

Total Depth = 2 feet.
Groundwater not encountered during drilling.
Backfilled on 4/04/13 promptly after completion of drilling.

Note:
Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.

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**BORING LOG**

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-1 |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | ASPHALT: Approximately 4 inches thick. |
| | | | | | | | SM | Brown to dark brown, moist, silty SAND with gravel. |
| | | | | | | | | Total Depth = 2 feet.<br>Groundwater not encountered during drilling.<br>Backfilled on 4/04/13 promptly after completion of drilling.<br><br>Note:<br>Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 5 | | | | | | | | |
| 10 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

DATE DRILLED 4/04/13 BORING NO. B-2

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DLH LOGGED BY DLH REVIEWED BY NAA

Ninyo & Moore

## BORING LOG

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-2 |

| | | |
|---|---|---|
| DATE DRILLED 4/04/13 | BORING NO. B-3 | |
| GROUND ELEVATION -- | SHEET 1 OF 1 | |
| METHOD OF DRILLING CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling) | | |
| DRIVE WEIGHT 140 lbs. (Automatic) | DROP 30" | |
| SAMPLED BY DLH | LOGGED BY DLH | REVIEWED BY NAA |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | GM | ALLUVIUM:<br>Brown, damp, medium dense, silty gravel with SAND. |
| | | | 28 | 6.5 | 122.1 | | | |
| 5 | | | | | | | | Total Depth = 5 feet.<br>Groundwater not encountered during drilling.<br>Backfilled on 4/04/13 promptly after completion of drilling.<br><br>Note:<br>Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 10 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

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## BORING LOG

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-3 |

| | |
|---|---|
| DATE DRILLED | 4/04/13 |
| BORING NO. | B-4 |
| GROUND ELEVATION | -- |
| SHEET | 1 OF 1 |
| METHOD OF DRILLING | CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling) |
| DRIVE WEIGHT | 140 lbs. (Automatic) |
| DROP | 30" |
| SAMPLED BY | DLH |
| LOGGED BY | DLH |
| REVIEWED BY | NAA |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | SM | ALLUVIUM: Light brown to reddish brown, damp to moist, silty SAND with gravel. |
| | | | 17 | 6.1 | 129.7 | | | |
| 5 | | | | | | | | Total Depth = 5 feet. Groundwater not encountered during drilling. Backfilled on 4/04/13 promptly after completion of drilling. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 10 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

Ninyo & Moore

**BORING LOG**

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-4 |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | 32 | 3.5 | 144.7 | | GM | ALLUVIUM: Reddish brown, damp to moist, dense, silty GRAVEL with sand. |
| | | | | | | | SM | Dark grayish brown to brownish gray, moist to saturated, loose, silty SAND. |
| 5 | | | 9 | 13.9 | 112.2 | | | Groundwater was encountered at approximately 5 feet during drilling. |
| | | | | | | | | Total Depth = 5.5 feet.<br>Groundwater was measured at a depth of approximately 5 feet in borehole.<br>Backfilled on 4/04/13 promptly after completion of drilling.<br><br>Note:<br>Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 10 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

DATE DRILLED 4/04/13 BORING NO. B-5

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DLH LOGGED BY DLH REVIEWED BY NAA

Ninyo & Moore

## BORING LOG

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-5 |

| | |
|---|---|
| DATE DRILLED | 4/04/13 |
| BORING NO. | B-6 |
| GROUND ELEVATION | -- |
| SHEET | 1 OF 1 |
| METHOD OF DRILLING | CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling) |
| DRIVE WEIGHT | 140 lbs. (Automatic) |
| DROP | 30" |
| SAMPLED BY | DLH |
| LOGGED BY | DLH |
| REVIEWED BY | NAA |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | X | | | | | | SM | ALLUVIUM: Light brown to brown, damp, silty SAND. |
| | X | X | 21 | | | | GM | Dark brown, damp, medium dense, silty GRAVEL with sand. |
| 5 | | | | | | | | Total Depth = 4.5 feet.<br>Groundwater not encountered during drilling.<br>Backfilled on 4/04/13 promptly after completion of drilling.<br><br>Note:<br>Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 10 | | | | | | | | |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

Ninyo & Moore

**BORING LOG**

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-6 |

| | |
|---|---|
| DATE DRILLED | 4/04/13 |
| BORING NO. | B-7 |
| GROUND ELEVATION | -- |
| SHEET | 1 OF 1 |
| METHOD OF DRILLING | CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling) |
| DRIVE WEIGHT | 140 lbs. (Automatic) |
| DROP | 30" |
| SAMPLED BY | DLH |
| LOGGED BY | DLH |
| REVIEWED BY | NAA |

| DEPTH (feet) | SAMPLES Bulk | SAMPLES Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | ASPHALT: Approximately 4 inches thick. |
| | | | | | | | | RECYCLED ASPHALT BASE COURSE: Approximately 7 inches thick. |
| | | | | | | | GM | FILL: Reddish brown, moist, dense, silty GRAVEL with sand; cobbles. |
| | | | 31 | 4.9 | 116.3 | | | |
| 5 | | | | | | | | |
| | | | 20 | | | | | |
| | | | | | | | SM | ALLUVIUM: Brown to reddish brown, damp to moist, medium dense, silty fine to coarse SAND with gravel. |
| 10 | | | | | | | | |
| | | | 17 | 7.1 | 112.2 | | | |
| | | | | | | | | Total Depth = 13 feet. Groundwater not encountered during drilling. Backfilled on 4/04/13 promptly after completion of drilling. |
| 15 | | | | | | | | Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 20 | | | | | | | | |

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## BORING LOG

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-7 |

DATE DRILLED 4/04/13 BORING NO. B-8

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME-45, 4" Diameter Solid-Stem Auger (Precision Sampling)

DRIVE WEIGHT 140 lbs. (Automatic) DROP 30"

SAMPLED BY DLH LOGGED BY DLH REVIEWED BY NAA

| DEPTH (feet) | SAMPLES: Bulk | SAMPLES: Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S. | DESCRIPTION/INTERPRETATION |
|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | | | ASPHALT: Approximately 5 inches thick. |
| | | | | | | | | RECYCLED ASPHALT BASE COURSE: Approximately 4.5 inches thick. |
| | | | | | | | SM | FILL: Brown, damp, medium dense, silty fine to coarse SAND with gravel. |
| | | | 20 | | | | | |
| 5 | | | | | | | | |
| | | | 7 | | | | | |
| | | | 18 | | | | SM | ALLUVIUM: Light brown to brown, moist, medium dense, silty fine to coarse SAND with gravel and cobbles. |
| 10 | | | | | | | | |
| | | | 16 | 15.7 | 113.7 | | | |
| | | | | | | | | Total Depth = 14 feet. Groundwater not encountered during drilling. Backfilled on 4/04/13 promptly after completion of drilling. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report. |
| 15 | | | | | | | | |
| 20 | | | | | | | | |

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## BORING LOG

PEDESTRIAN ENHANCEMENT AND STROM WATER IMPROVEMENTS
NEDERLAND, COLORADO

| PROJECT NO. | DATE | FIGURE |
|---|---|---|
| 500651001 | 4/13 | A-8 |

# APPENDIX B

## LABORATORY TESTING

**Classification**

Soils were visually and texturally classified in accordance with the Unified Soil Classifications System (USCS) in general accordance with ASTM D 2488. Soil classifications are indicated on the logs of the exploratory excavations in Appendix A.

**In-Place Moisture and Density Tests**

The moisture content and dry density of ring-lined samples obtained from the exploratory borings were evaluated in general accordance with ASTM D 2837. These test results are presented on the logs of the exploratory borings in Appendix A.

**Atterberg Limits**

Tests were performed on selected representative fine-grained soil samples to evaluate the liquid limit, plastic limit, and plasticity index in general accordance with ASTM D 4318. These test results were utilized to evaluate the soil classification in accordance with the Unified Soil Classification System. The test results and classifications are shown on Figure B-1.

**No. 200 Sieve Analysis**

An evaluation of the percentage of particles finer than the No. 200 sieve in selected soil samples was performed in general accordance with ASTM D 1140. The results of the tests are presented on Figure B-2.

**Gradation Analysis**

Gradation analysis tests were performed on selected representative soil samples in general accordance with ASTM D 422. The test results were utilized in evaluating the soil classifications in accordance with the AASHTO Classification system. The grain-size distribution curves are shown on Figures B-3 and B-4.

**Maximum Dry Density and Optimum Moisture Content Test**

The maximum dry density and optimum moisture content of a selected representative soil sample was evaluated in general accordance with AASHTO T99 Method A. The results of this test are summarized on Figure B-5.

**R-Value**

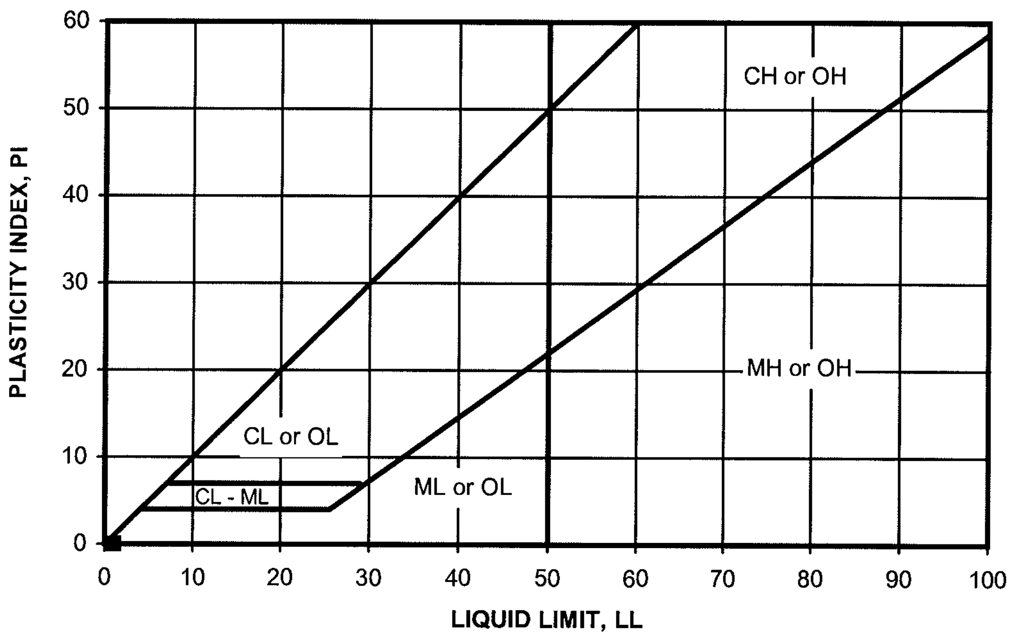
The resistance value, or R-value, for selected representative site soils were evaluated in general accordance with AASHTO T190. Samples were prepared and evaluated for exudation pressure. The resulting R-values are the index value of the soils at an exudation pressure of 300 psi. The results of the R-value tests are presented on Figure B-6.

**Soil Corrosivity Tests**

The sulfate content of a selected sample was evaluated in general accordance with CDOT Test Method CP-L 2103. The chloride content of a selected sample was evaluated in general accordance with CDOT Test Method CP-L 2104. The test results are presented on Figure B-7.

| SYMBOL | LOCATION | DEPTH (FT) | LIQUID LIMIT, LL | PLASTIC LIMIT, PL | PLASTICITY INDEX, PI | USCS CLASSIFICATION (Fraction Finer Than No. 40 Sieve) | USCS (Entire Sample) |
|---|---|---|---|---|---|---|---|
| ● | B-5 | 4-5 | | | NP | SM | SM |
| ■ | B-7 | 7-8 | | | NP | SM | SM |
| ◆ | B-8 | 3-4.5 | | | NP | SM | SM |
| ○ | | | | | | | |
| □ | | | | | | | |
| Δ | | | | | | | |
| X | | | | | | | |
| + | | | | | | | |

NP - INDICATES NON-PLASTIC




PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4318

| Ninyo & Moore | | ATTERBERG LIMITS TEST RESULTS | FIGURE |
|---|---|---|---|
| PROJECT NO. | DATE | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS | |
| 500651001 | 4/13 | NEDERLAND, COLORADO | B-1 |

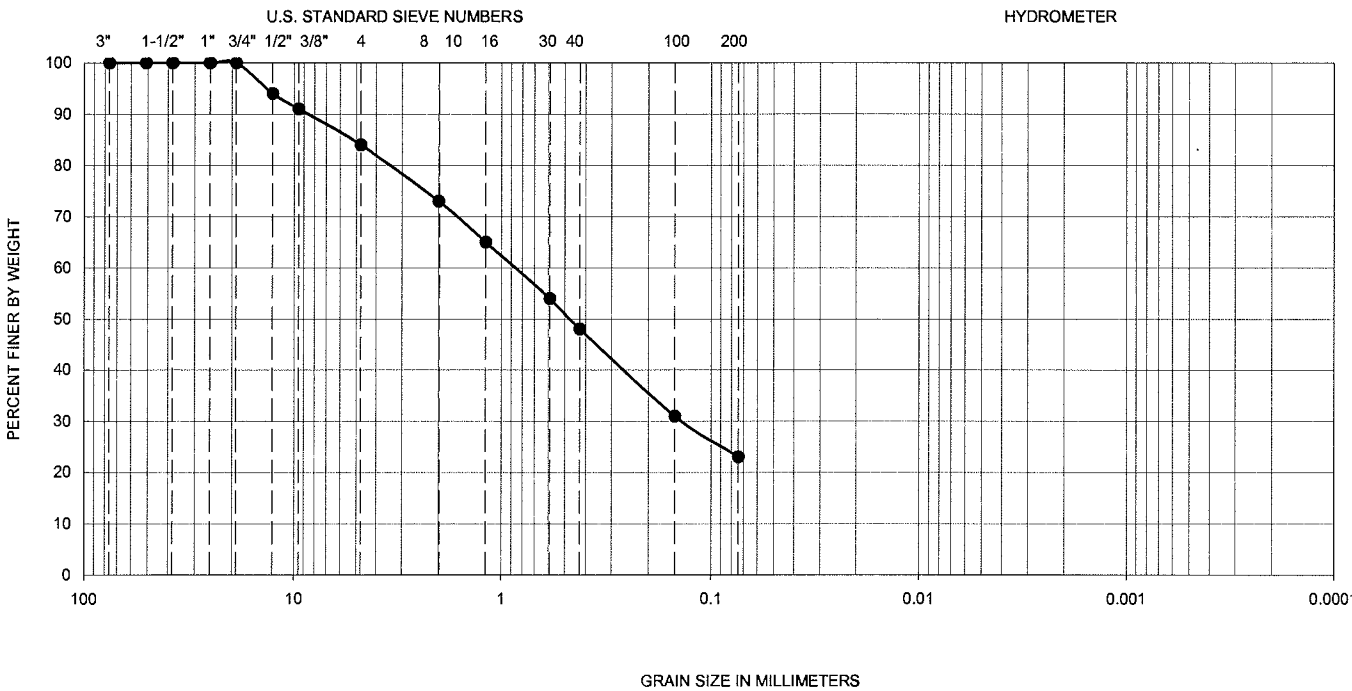
| SAMPLE LOCATION | SAMPLE DEPTH (FT) | DESCRIPTION | PERCENT PASSING NO. 4 | PERCENT PASSING NO. 200 | EQUIVALENT USCS |
|---|---|---|---|---|---|
| B-7 | 7'-8' | Reddish brown, Silty Sand with Gravel | 84 | 23 | SM |
| B-8 | 8'-8.5' | Brown, Silty Sand with Gravel | 79 | 18 | SM |

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 1140

| Ninyo & Moore | | NO. 200 SIEVE ANALYSIS | FIGURE |
|---|---|---|---|
| PROJECT NO. | DATE | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS | B-2 |
| 500651001 | 4/13 | NEDERLAND, COLORADO | |

FIG B-2 200-WASH

| GRAVEL | | SAND | | | FINES | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |




| Symbol | Sample Location | Depth (ft) | Liquid Limit | Plastic Limit | Plasticity Index | $D_{10}$ | $D_{30}$ | $D_{60}$ | $C_u$ | $C_c$ | Passing No. 200 (%) | U.S.C.S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | B-5 | 4 | -- | -- | NP | -- | -- | -- | -- | -- | 23 | SM |

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

Ninyo & Moore

| PROJECT NO. | DATE |
|---|---|
| 500651001 | 4/13 |

# GRADATION TEST RESULTS

PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS

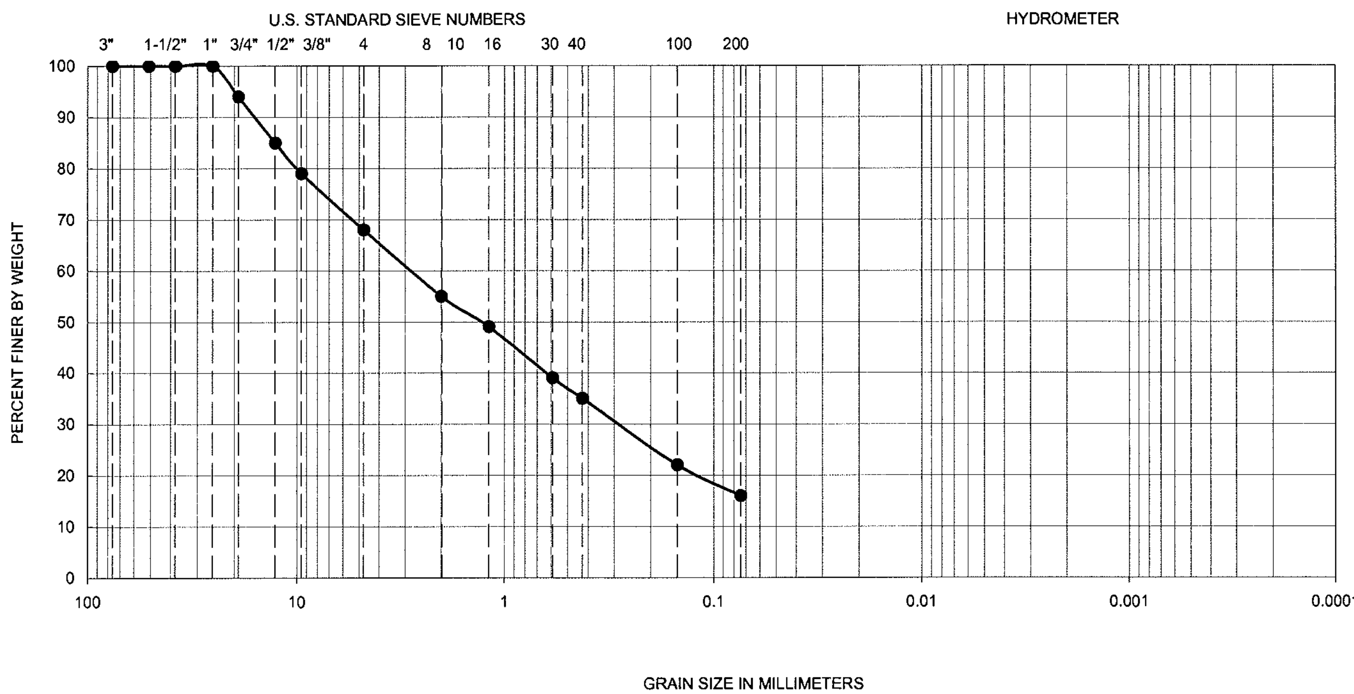
NEDERLAND, COLORADO

FIGURE

**B-3**

FIG B-3 SIEVE B-5 @4

| GRAVEL | | SAND | | | FINES | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

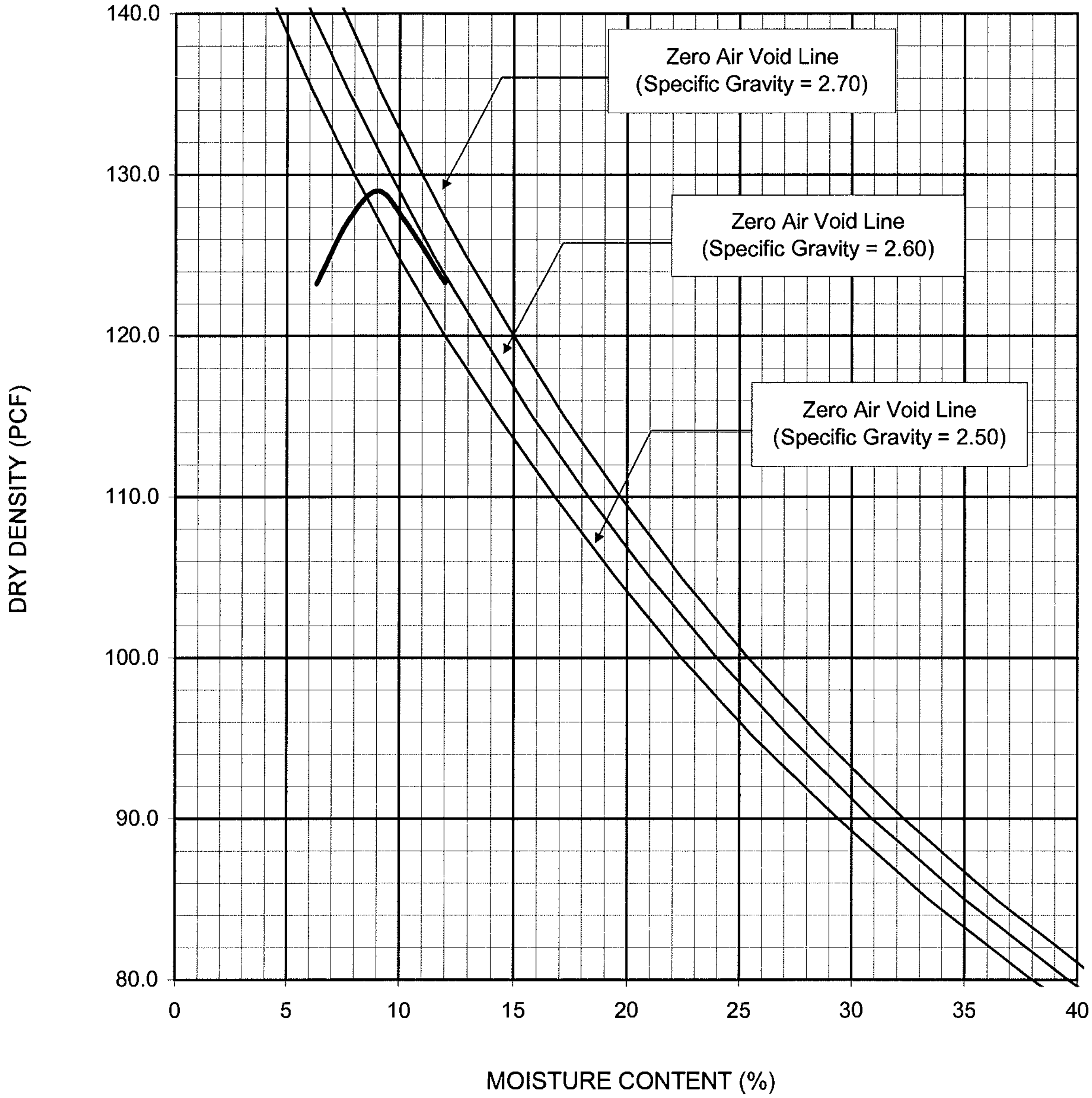



| Symbol | Sample Location | Depth (ft) | Liquid Limit | Plastic Limit | Plasticity Index | $D_{10}$ | $D_{30}$ | $D_{60}$ | $C_u$ | $C_c$ | Passing No. 200 (%) | U.S.C.S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | B-8 | 9 | -- | -- | NP | -- | -- | -- | -- | -- | 16 | SM |

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 422

| Ninyo & Moore | | GRADATION TEST RESULTS | FIGURE |
|---|---|---|---|
| PROJECT NO. | DATE | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS | B-4 |
| 500651001 | 4/13 | NEDERLAND, COLORADO | |

FIG B-4 SIEVE B-8 @9




| Sample Location | Depth (ft) | Soil Description | Maximum Dry Density (pcf) | Optimum Moisture Content (%) |
|---|---|---|---|---|
| B-3 to B-6 | 0 - 5 | Light brown, silty sand | 129.0 | 9.0 |
| Dry Density and Moisture Content Values Corrected for Oversize (ASTM D 4718-87) | | | N/A | N/A |

*NOTE: BG - below grade

PERFORMED IN GENERAL ACCORDANCE WITH ☐ AASHTO T180 ☑ AASTHO T99 METHOD ☑ A ☐ B ☐ C ☐ D

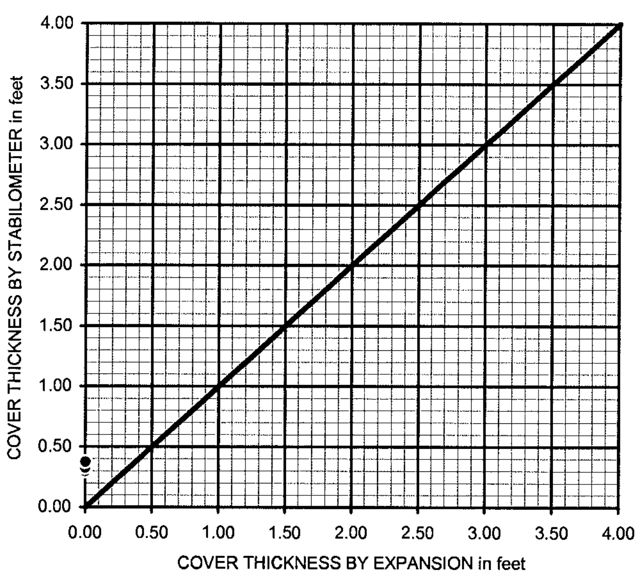
| | | | |
|---|---|---|---|
| Ninyo & Moore | | **PROCTOR DENSITY TEST RESULTS** | FIGURE |
| PROJECT NO. | DATE SAMPLED | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS | **B-5** |
| 500651001 | 4/4/2013 | NEDERLAND, COLORADO | |

# Ninyo & Moore — R-VALUE TEST RESULTS

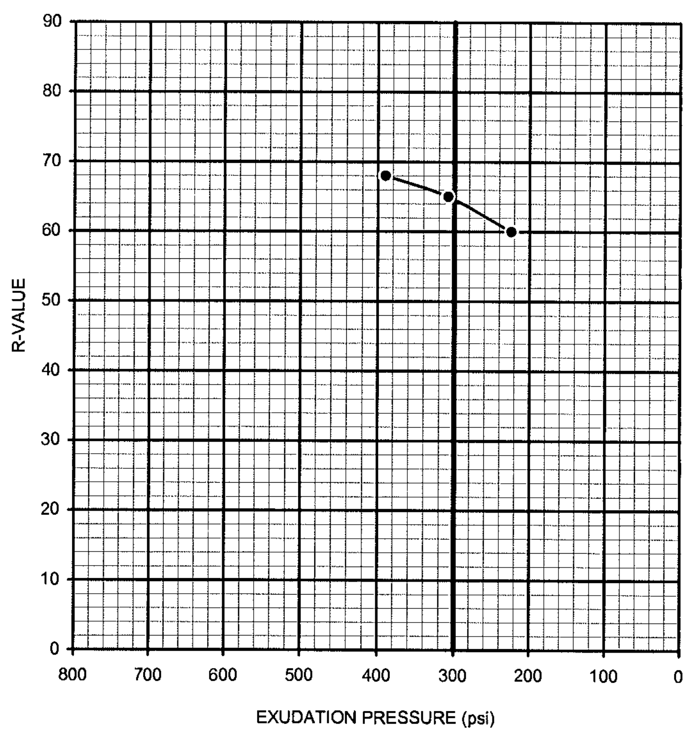
| | | | |
|---|---|---|---|
| PROJECT NAME: | PEDESTRIAN ENHANCEMENT AND STORM | PROJECT NUMBER: | 500651001 |
| SAMPLE DESCRIPTION: | Silty Sand with Gravel | DATE SAMPLED: | 4/4/2013 |
| SAMPLE LOCATION: | B3-B6 @ 0.0-5.0 | TECHNICIAN: | MM |
| | | SAMPLE NUMBER: | |

| **TEST SPECIMEN** | a | b | c |
|---|---|---|---|
| MOISTURE AT COMPACTION % | 7.6 | 8.1 | 8.6 |
| HEIGHT OF SAMPLE, Inches | 2.40 | 2.40 | 2.41 |
| DRY DENSITY, pcf | 130.6 | 130.2 | 129.2 |
| COMPACTOR AIR PRESSURE, psi | 350 | 350 | 350 |
| EXUDATION PRESSURE, psi | 390 | 308 | 224 |
| EXPANSION, Inches x 10exp-4 | 0 | 0 | 0 |
| STABILITY Ph 2,000 lbs (160 psi) | 28 | 32 | 37 |
| TURNS DISPLACEMENT | 4.97 | 5.03 | 5.07 |
| R-VALUE UNCORRECTED | 70 | 67 | 62 |
| R-VALUE CORRECTED | 68 | 65 | 60 |
| R-VALUE BY EXUDATION | | **65** | |
| **DESIGN CALCULATION DATA** | a | b | c |
| GRAVEL EQUIVALENT NEEDED ft. | 0.51 | 0.56 | 0.64 |
| TRAFFIC INDEX | | 5.0 | |
| STABILOMETER THICKNESS, ft. | 0.30 | 0.33 | 0.37 |
| EXPANSION PRESSURE THICKNESS, ft. | 0.00 | 0.00 | 0.00 |

EXPANSION PRESSURE CHART




EXUDATION PRESSURE CHART




| | |
|---|---|
| R-VALUE BY EXPANSION: | N/A |
| R-VALUE BY EXUDATION: | 65 |
| EQUILIBRIUM R-VALUE: | 65 |

**FIGURE B-6**

| SAMPLE LOCATION | SAMPLE DEPTH (FT) | pH [1] | RESISTIVITY [2] (Ohm-cm) | SULFATE CONTENT [3] (ppm) | SULFATE CONTENT [3] (%) | CHLORIDE CONTENT [4] (ppm) |
|---|---|---|---|---|---|---|
| B-1 | 0-2 | | | 200 | 0.020 | 62.9 |
| B-2 | 0-2 | | | 100 | 0.010 | 29.7 |
| Grab Sample | 0-1 | | | 100 | 0.010 | 26.7 |

[1] PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4972

[2] PERFORMED IN GENERAL ACCORDANCE WITH AASHTO T288

[3] PERFORMED IN GENERAL ACCORDANCE WITH CDOT TEST METHOD CP-L 2103

[4] PERFORMED IN GENERAL ACCORDANCE WITH CDOT TEST METHOD CP-L 2104

| Ninyo & Moore | CORROSIVITY TEST RESULTS | FIGURE |
|---|---|---|
| PROJECT NO. 500651001 / DATE 4/13 | PEDESTRIAN ENHANCEMENT AND STORM WATER IMPROVEMENTS<br>NEDERLAND, COLORADO | B-7 |

# APPENDIX C

# PAVEMENT DESIGN CALCULATIONS

# AASHTO FLEXIBLE PAVEMENT CALCULATIONS

Ninyo & Moore

**Project Name:** Pedestrian Enhancement and Storm Water Improvements
**Project Number:** 500651001
**Date:** 4/18/2013
**Calculations by:** JMJ
**Case:** 20 - Year Design Life - Composite Section

## Structural Number Calculation

**Equations:** $\log(W_{18}) = Z_R S_o + 9.36\log(SN+1) - 0.20 + \log\{[(P_o - P_t)/(4.3-1.5)]/[0.40+(1094/(SN+1)^{5.19}]\} + 2.32\log(M_R) - 8.07$

$M_R = 145(10)^{[(0.0147R)+1.23]}$

| | | | | |
|---|---|---|---|---|
| Design ESAL, $W_{18}$ | = | **36,000** | | Equivalent TI = 6.1 |
| Reliability, R | = | **80** | | |
| Std. Normal Deviation, $Z_R$ | = | -0.841 | | |
| Standard Deviation, $S_o$ | = | **0.44** | | |
| Initial Serviceability, $P_o$ | = | **4.2** | | |
| Terminal Serviceability, $P_t$ | = | **2.0** | | |
| Subgrade R-Value | = | **50** | | |
| Resilient Modulus, $M_R$ | = | 13,400 | psi | |
| Structural Number, SN | = | **1.44** | | |
| target | = | 1.001 | | |

**Structural Number (Design), $SN_D$ =** 1.44

## Pavement Section Calculations

**Equations:** $SN_P = (a_a)(D_a) + (a_b)(D_b) + (a_s)(D_s)$

$SN_P \geq SN_D$

| | | | |
|---|---|---|---|
| Asphalt Layer Coefficient, $a_a$ | = | **0.4** | |
| Base Layer Coefficient, $a_b$ | = | **0.12** | |
| Subbase Layer Coefficient, $a_s$ | = | | |
| Asphalt Concrete Thickness, $D_a$ | = | 3 | in. |
| Base Thickness, $D_b$ | = | 4 | in. |
| Subbase Thickness, $D_s$ | = | | in. |
| Structural Fill Thickness, $D_{sf}$ | = | | in. |
| Structural Number (Provided), $SN_P$ | = | 1.68 | **OKAY** |
| Structural Number (Design), $SN_D$ | = | 1.44 | |

**Asphalt Concrete Thickness, $D_a$ =** 3 in.
**Base Thickness, $D_b$ =** 4 in.
**Subbase Thickness, $D_s$ =** in.
**Structural Fill Thickness, $D_{sf}$ =** in.