Soil and Foundation Investigation

Proposed Elevator Building Addition, University Theatre Building, University of Colorado Boulder, Colorado

Prepared For

University of Colorado at Boulder
Department of Facilities Management
Office of Design and Construction
Research Laboratory No. 2
Attn: Mr. Keith Gardner
Project Manager
1540 30th Street, Room 352
Boulder, Colorado 80309-0453

March 20, 2009
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Proposed Elevator Building Addition,
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University of Colorado
Boulder, Colorado

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**Figure 1** Location of Exploratory Boring  
**Figure 2** Log of Exploratory Boring  
**Figure 3** Legend and Notes For Exploratory Boring  
**Figure 4** Swell-Compression Test Results  
**Figure 5** Gradation Test Results  
**Table 1** Summary of Laboratory Test Results
1.0 PURPOSE AND SCOPE

This report contains the results of a soil and foundation investigation conducted for a proposed elevator building addition to the existing University Theatre Building on the University of Colorado-Boulder Campus in Boulder, Colorado. A field subsurface investigation was conducted to obtain information on soil, bedrock, and ground water conditions. Soil and bedrock samples collected were visually classified by our project engineer, and selected samples were laboratory tested to evaluate strength, compressibility and swell characteristics, classification, and other engineering properties.

The results of the field and laboratory investigations were analyzed to develop recommendations for foundation types, depths, and allowable pressures for the proposed building addition. The investigation was conducted in general accordance with the proposal submitted to the University of Colorado at Boulder by Geocal dated February 13, 2009.

This report has been prepared to summarize the data obtained and to present our conclusions and recommendations based on the proposed construction and subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction of the proposed structure are included. Environmental considerations related to hazardous materials are beyond the scope of this study.
2.0 PROPOSED CONSTRUCTION

Based on information from the University of Colorado-Boulder, it is understood that the proposed construction will consist of an elevator addition to the existing University Theatre Building (Building 218). The addition will be approximately 240 square feet in plan area and will be located near the northeast corner of the existing building. The addition will be 2 stories high and will have a basement level approximately 6 feet to 7 feet below the existing ground surface. The addition will be of steel frame construction with an exterior brick facing. A concrete slab-on-grade is proposed for the basement floor.

It is understood that the existing University Theatre building is approximately 100 years old and is supported by a tapered foundation wall-on-grade. The base of the foundation wall is approximately 20 inches wide. The existing building has a basement approximately 6 to 7 feet below grade. No signs of significant foundation movement were observed based on a cursory observation by our on-site field engineer.

3.0 SITE CONDITIONS

The project area is located on the Main Campus of the University and is situated on an originally natural terraced piedmont surface that has been well modified by grading and construction related to building development, landscaping, and surface drainage modifications. It lies in an uplands locale positioned slightly above the historic floodplains of Boulder Creek and Skunk Creek whose channels are located about one-fourth mile to the north and a mile south respectively. At the specific proposed elevator addition location, the existing ground surface consisted of landscaped grass, concrete sidewalk, and occasional trees. The ground surface is relatively level directly adjacent to the existing theatre building.
and then begins to slope downward at approximately 20 feet to the east and north. Additional landscaped grass, trees and concrete sidewalks were present further away from the theatre building.

Published geologic mapping assigns natural (pre-construction) surficial soil in the project area to terrace deposits of the Verdos Alluvium that are typified as clayey sand and gravel with cobbles and small boulders locally common; larger stones are reported to be partly decomposed. Bedrock is mapped as having been exposed within about one-fourth mile north and east of the site as mostly well-laminated layers assigned to the upper silty shale or claystone member of the Pierre Shale. The units are commonly limey with very hard concretionary zones and are rated by the Colorado Geological Survey as generally having high to very high potential for swelling. Bedrock structural attitudes in the area, mapped prior to the exposures having been covered by construction or landscaping, show generally north-south strikes and low dips to the east.

4.0 SUBSURFACE INVESTIGATION

The subsurface investigation was conducted on February 27, 2009 by drilling an exploratory boring at the approximate location shown on Figure 1. A truck-mounted Longyear BK-51 drill rig equipped with 4-inch diameter solid-stem augers was used to advance the boring. A representative of Geocal, Inc. logged the boring.

Subsurface soil samples were obtained using a nominal 2-inch inside diameter California spoon sampler with brass liners. The sampler was driven into the various strata with blows from a 140-pound hammer falling 30 inches, similar to ASTM D1586 test standard. Penetration resistance values when properly evaluated provide an indication of the relative density or consistency of the soils or bedrock. Depths at which samples were taken, penetration resistance values, and a legend and notes are shown on Figures 2 and 3. Due to
safety concerns, the boring was backfilled immediately after completion of the drilling activities.

5.0 SUBSURFACE CONDITIONS

The boring encountered a thin layer of landscaped grass underlain by artificial fill consisting primarily of loose to dense clayey, sandy gravel which extended to a depth of approximately 7 feet below the existing ground surface. The artificial fill was underlain by natural dense clayey, sandy gravel which contained occasional rock fragments and extended to a depth of approximately 17 feet. Slightly sandy to very sandy claystone bedrock was encountered at approximately 17 feet and continued to the maximum depth explored, approximately 35 feet.

Ground water was observed in the boring at the time of drilling at a depth of approximately 30-1/2 feet. This observation represents only current groundwater conditions, and may not be indicative of other times, or at other locations. Groundwater levels can be expected to fluctuate with varying seasonal and weather conditions.

6.0 LABORATORY TESTING

As presented on Figures 4 and 5, and Table 1, laboratory tests conducted on soil and bedrock samples consisted of swell-compression, gradation analyses, Atterberg Limits, natural moisture content, natural dry density, unconfined compressive strength, and water-soluble sulfate content. Results of the gradation analyses and Atterberg Limits testing were used to classify the soils.
Water-soluble sulfate test results are used to evaluate the potential degree of sulfate attack on concrete exposed to the onsite materials. Laboratory test results on selected samples of the on-site soils indicated water-soluble sulfate concentrations below standard laboratory detection limits. The test results represent a negligible degree of sulfate attack to concrete as defined by the Portland Cement Association. Based on the test results, Type I Portland cement may be used for concrete which will be in contact with the on-site soils. However, the test results are limited in nature and Type II Portland cement should be considered if there is no significant increase in cost.

7.0 FOUNDATION RECOMMENDATIONS

Based on the soil conditions encountered in the exploratory boring and the proposed construction, a spread footing foundation system may be considered for support of the new elevator addition. Swell-compression test results from a sample of the natural clayey, sandy gravel indicate that the clay fraction of this soil stratum has low expansive potential. Due to this low expansive potential, it is recommended that the spread footings be designed with a minimum dead load requirement. The footings should not be placed on the old artificial fill present in this area, nor be placed within 4 feet of the claystone bedrock which was encountered at a depth of approximately 17 feet in the exploratory boring. It is also recommended that the new and existing foundation bearing elevations match as closely as possible.

The following design and construction details should be observed for spread footings:

1. Footings should be placed on undisturbed natural clayey, sandy gravel below any existing fill, or placed on controlled structural fill. The controlled structural fill should be placed after complete removal of all old artificial fill, debris, and any other deleterious materials. New structural fill to support footings should be impermeable, non-expansive and compacted in uniform 8 inch thick lifts to at least 100% of the
maximum standard Proctor density (ASTM D698) at a moisture content between 1 percent below and 2 percent above optimum moisture content.

2. Spread footing foundations should be designed for a maximum allowable soil bearing capacity of 3,000 pounds per square foot (psf). In addition, the footings should be designed for a minimum dead load pressure of 800 psf. Total settlement is estimated at approximately 1 inch for uniform loading and similar sized footings. Differential settlement will be a function of variable loading and footing widths, wall and backfill heights, as well as different soil bearing conditions. To help reduce the effects of local soil anomalies, continuous spread footings should be designed for an unsupported length of at least 12 feet, and have a minimum width of 16 inches.

3. The footings should have a minimum 3 feet of soil cover above bearing elevation for frost protection.

4. The project structural engineer has indicated that an east-west trending retaining wall approximately 10 feet long will be located to the south of the proposed elevator addition. The wall will retain approximately 3 feet to 4 feet of fill. The bottom of the wall will be approximately 3 feet below grade for frost protection. Based on Geocal’s exploratory boring, it is likely that old artificial fill to a depth of approximately 7 feet will be present in this area. We have no information indicating that the artificial fill has been properly placed and compacted for support of footings. A footing foundation system bearing on the artificial fill will have a risk of potential differential foundation movement. Provided that the owner and the other design professionals are willing to accept this risk, the footings may be designed using the same parameters as presented in Item 2 above. If the risk is unacceptable, then the footings and wall should extended down to natural undisturbed soils, or the old artificial fill should be subexcavated and replaced with properly compacted structural fill as described in Item 1 above.

5. A coefficient of sliding friction of 0.35 may be assumed for the clayey, sandy gravel interface for spread footings.

6. We recommend that the addition be structurally isolated from the existing building. Structural isolation will help ensure that structural loadings from the new addition do not initiate movement in the existing building.

7. Areas of loose or soft material or existing old artificial fill encountered within the foundation excavation should be removed and replaced with new non-expansive relatively impermeable structural fill material compacted in uniform lifts to at least 100% of the maximum standard Proctor density. New structural fill should extend laterally beyond the bearing surface for at least 3 feet and down at a 1:1 horizontal to vertical slope. Care should be taken to avoid undermining the existing foundation.

8. Natural granular soils encountered in footing areas should be compacted with a heavy vibratory plate compactor prior to concrete placement.
9. A representative of Geocal, Inc. should observe footing excavations prior to concrete placement.

8.0 SLABS-ON-GRADE

Non-expansive or low expansive soils or structural fill are anticipated to support the basement floor slab. Some differential movement of a slab-on-grade floor system is possible if the subgrade soils increase in moisture content. Such movements are typically considered within general tolerance for normal slab-on-grade construction. To reduce potential slab movements, the following floor slab design and construction recommendations should be observed:

1. Positive separations and/or isolation joints should be provided between slabs and all foundations, columns or utility lines to allow independent movement.

2. Interior non-bearing partitions resting on floor slabs should be provided with slip joints at the bottom or top so that, if the slabs move, the movement will not be transmitted to the upper structure. This detail is also important for drywall, stairways and door frames. Slip joints which will allow at least 2 inches of vertical movement are recommended.

3. Floor slab control joints should be used to reduce damage from shrinkage cracking. Control joint spacing is a function of slab thickness, aggregate size, slump and curing conditions. The requirements for concrete slab thickness, joint spacing and reinforcement should be established by the designer based on experience, recognized design guidelines and the intended slab use. Placement and curing conditions will have a significant impact on the final concrete slab integrity.

4. Prior to placement of the slabs, the slab subgrade soils should be scarified to a minimum 6 inch depth and recompacted to at least 95% of the maximum standard Proctor density (ASTM D698) at a moisture content between 1 percent below and 2 percent above optimum moisture content. Interior trench backfill placed beneath slabs should also be compacted as recommended above.

5. If moisture sensitive floor coverings are used on interior slabs, consideration should be given to the use of barriers to reduce potential vapor rise through the slab.

6. Floor slabs should not be constructed on frozen subgrade.
7. For structural design of concrete slabs-on-grade, a modulus of subgrade reaction of 150 pounds per cubic inch (pci) may be used for floors supported on existing or engineered fill consisting of on-site soils.

9.0 RETAINING STRUCTURES

Foundation walls and retaining structures which are laterally supported and can be expected to undergo only a slight amount of deflection should be designed for the "at-rest" earth pressure condition. Cantilevered or gravity retaining structures which rotate and/or deflect sufficiently to mobilize the internal soil strength of the wall backfill may be designed for the "active" earth pressure condition. The following ultimate earth pressure coefficients are recommended for imported structural fill material, and for the on-site clayey, sandy gravel materials. Claystone bedrock present at the site will produce excessive earth pressures on walls and is not recommended for use as structural fill or backfill.

<table>
<thead>
<tr>
<th>Material or location</th>
<th>Active (K_a)</th>
<th>At-Rest (K_o)</th>
<th>Passive (K_p)</th>
<th>γT – Unit Weight (pcf)</th>
<th>Friction angle (φ), degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported Structural Backfill</td>
<td>0.28</td>
<td>0.44</td>
<td>3.53</td>
<td>135</td>
<td>34</td>
</tr>
<tr>
<td>On-site clayey, sandy gravel</td>
<td>0.31</td>
<td>0.47</td>
<td>3.25</td>
<td>135</td>
<td>32</td>
</tr>
</tbody>
</table>

The above values are for properly compacted backfill. These values are not valid for submerged conditions.

Lateral wall movements or rotation equal to 0.5% of the wall height are typically required to develop the full active case for granular backfill, whereas lateral movement equal to at least 1% of the wall height is required to establish full passive resistance. Suitable factors of safety should be applied to the above ultimate values to limit strain needed to reach ultimate strength, particularly in the case of passive resistance.
Imported structural fill material should meet the following requirements or be approved by the project engineer prior to importation to the site:

<table>
<thead>
<tr>
<th>Sieve Size or Number</th>
<th>Percent Finer by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 Sieve</td>
<td>30-100</td>
</tr>
<tr>
<td>No. 50 Sieve</td>
<td>10-60</td>
</tr>
<tr>
<td>No. 200 Sieve</td>
<td>5-20</td>
</tr>
<tr>
<td>• Liquid Limit</td>
<td>35 (max)</td>
</tr>
<tr>
<td>• Plasticity Index</td>
<td>6 (max)</td>
</tr>
</tbody>
</table>

A sufficient number of tests such as direct shear should be performed during construction to confirm that backfill material meets the friction angle requirements. Natural borrow sources often have wider grading variability than plant mixes and will require that more frequent tests be done.

Equivalent fluid unit weights should be taken as follows:

Above ground water: \( \gamma_{eq} = \gamma_T \times K_{s,o,p} \)
Below ground water: \( \gamma_{eq} = (\gamma_T - 62.4) \times K_{s,o,p} \)
where \( \gamma_T = \) soil total unit weight
\( K_{s,o,p} = \) appropriate earth pressure coefficient

The above parameters are for a horizontal backfill and no surcharge loading. Retaining structures should be designed for appropriate surcharge pressures such as from traffic, upsloped backfill, water buildup behind the wall, or other external loadings that will increase the lateral pressure on the wall. A perimeter drain should be provided to help reduce hydrostatic pressure buildup, unless the wall is designed to accommodate the additional pressure.

Wall backfill should be compacted in uniform 8 inch thick lifts to at least 95% of the maximum standard Proctor density (ASTM D698) at a moisture content between 1 percent below and 2 percent above optimum moisture content. Care should be taken not to over-
compact the backfill or use large equipment immediately adjacent to the walls because this could result in excessive lateral loadings.

10.0 DRAINAGE PRECAUTIONS

10.1 SURFACE DRAINAGE

1. Positive drainage should be provided during construction and maintained throughout the life of the proposed elevator addition. Infiltration of water into utility or foundation excavations should be prevented during construction. Planters and other surface features which could retain water in areas adjacent to the building should be sealed or eliminated.

2. In areas where sidewalks or paving do not immediately adjoin the structure, we recommend that protective slopes be provided with a minimum grade of approximately 5 percent for at least 10 feet from perimeter foundation walls. Backfill against footings, exterior walls and in utility and sprinkler line trenches should be well compacted and free of all construction debris to reduce the possibility of moisture infiltration.

3. Downspouts, roof drains or scuppers should discharge into splash blocks or extensions when the ground surface beneath such features is not protected by exterior slabs or sidewalks.

4. Sprinkler systems should not be installed within 5 feet of foundation walls. Landscaped irrigation adjacent to the foundation system should be minimized or eliminated.

10.2 SUBSURFACE DRAINAGE

The existing groundwater table at the site, unless a source of water not presently contributing becomes available, is not expected to rise to a level which will detrimentally affect the construction or utilization of the proposed addition. However, a locally high groundwater condition can develop immediately adjacent to the addition even if surface drainage precautions are taken. If the owner is concerned about possible groundwater seepage into below grade areas, then it is recommended that a subsurface perimeter drainage system be installed. A properly designed and constructed perimeter drainage system should prevent an accumulation of water adjacent to the foundation walls from building up sufficient pressure to cause seepage into below
grade interior areas. The drainage system should consist of minimum 4 inch diameter perforated plastic pipe bedded on a minimum of 2 inches of 1-1/2 inch washed gravel and then backfilled with at least 12 inches of washed gravel above the top of the pipe. The gravel should be surrounded by a geotextile filter fabric. The invert of the pipe should be at or below the bottom of the adjacent floor slab. The drainage pipes should be channeled to a sump pit from which water can be removed. The sump pit should be equipped with a pump as needed.

11.0 LIMITATIONS

This report has been prepared in accordance with generally accepted geotechnical engineering practices used in this area, and has been prepared for design purposes. The conclusions and recommendations are based upon the data obtained from the boring at the approximate location shown on Figure 1 and the proposed construction. The nature and extent of the variations from the boring location may not become evident until excavation is performed. If during construction, soil, bedrock, fill, or ground water conditions appear to be different from those described, this office should be advised so that re-evaluation of our recommendations may be made. Onsite observation of foundation bearing materials and testing of fill placement by a representative of this office is recommended.

It is recommended that the Geotechnical Engineer be retained to provide a general review of final design plans and specifications in order to confirm that grading and foundation recommendations have been interpreted and implemented. In the event that any changes of the proposed project are planned, the conclusions and recommendations contained in this report should be reviewed and the report modified or supplemented as necessary.

Our professional services were performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in this or similar localities. No warranty, express or implied, is made. We have prepared the report as an
aid in design of the proposed project. This report is not a bidding document. Any contractor reviewing this report must draw his or her own conclusions regarding site conditions and specific construction techniques to be used on this project.

This report is for the exclusive purpose of providing geotechnical engineering and/or testing information and recommendations. The scope of services for this project does not include, either specifically or by implication, any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.
FIGURE 1
C.U. BOULDER, ADDITION TO UNIVERSITY THEATER
LOCATION OF EXPLORATORY BORING
LEGEND

- FILL-Gravel, clayey, sandy, slightly silty, loose to dense, slightly moist, brown, greenish brown and reddish brown, fine to coarse sand and gravel.
- GRAVEL, clayey, sandy, dense, slightly moist, reddish brown, yellowish brown, fine to coarse sand and gravel, occasional rock fragments.
- CLAYSTONE BEDROCK, slightly sandy to very sandy, hard to very hard, slightly moist to wet, brown, greenish brown and gray.

Drive sample blow count, indicates that 7 blows from a 140-pound hammer falling 30 inches were required to drive the California sampler 12 inches.
Indicates drive sample, 2-inch I.D. California liner sample.
Indicates depth at which caved material accumulated.
Indicates depth to water level and number of days after drilling measurement was made.

NOTES
1. Boring was drilled on February 27, 2009 with a Longyear BK-51 equipped with 4-inch diameter solid stem augers.
2. Location of boring shown on Figure 1 is approximate.
3. Elevation of boring was based on an assumed 100' elevation of the existing sidewalk located approximately 10' east.
4. The lines between strata represent approximate boundaries between material types. Transitions between materials may actually be gradual.
5. Water level reading shown on the log was made at the time and under conditions indicated. Fluctuation in the water level may occur with time.
### SWELL-COMPRESSION TEST

![Graph showing SWELL-COMPRESSION TEST results.](image)

**Expansion under constant pressure due to wetting**

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Boring 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Depth</td>
<td>10 feet</td>
</tr>
<tr>
<td>Sample Description</td>
<td>Clayey gravel with sand</td>
</tr>
<tr>
<td>USCS Classification</td>
<td>GC</td>
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<tr>
<td>AASHTO Classification</td>
<td>A-2-6(0)</td>
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<tr>
<td>Dry Density</td>
<td>127 pcf</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>3.9 %</td>
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<tr>
<td>Volume Change</td>
<td>2.0 %</td>
</tr>
<tr>
<td>Swell Pressure</td>
<td>2,400 psf</td>
</tr>
</tbody>
</table>
Gradation Test Results

Material Description

- clayey gravel with sand
- claystone bedrock

<table>
<thead>
<tr>
<th>LL</th>
<th>PL</th>
<th>D_15</th>
<th>D_60</th>
<th>D_30</th>
<th>D_10</th>
<th>Cc</th>
<th>Cu</th>
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<tbody>
<tr>
<td>27</td>
<td>16</td>
<td>25.0621</td>
<td>7.1585</td>
<td>1.5228</td>
<td>0.1913</td>
<td></td>
<td></td>
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<tr>
<td>31</td>
<td>18</td>
<td>25.7641</td>
<td>21.0464</td>
<td>19.2567</td>
<td>1.4595</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>24</td>
<td>0.5692</td>
<td>0.1478</td>
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GEOCAL, INC.

Project No. G09.1224.000
Client: CU Boulder
Project: University Theater Elevator Addition

Location: Boring 1
- Depth: 5 feet
- Sample Number: 4551-1

Location: Boring 1
- Depth: 10 & 15 feet
- Sample Number: 4551-2

Location: Boring 1
- Depth: 20 feet
- Sample Number: 4551-3

Remarks:
<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Natural Moisture Content (%)</th>
<th>Natural Dry Density (pcf)</th>
<th>Gradation</th>
<th>Percent Passing No. 200 Sieve</th>
<th>Atterberg Limits Liquid Limit (%)</th>
<th>Plasticity Index (%)</th>
<th>Water Soluble Sulfates (%)</th>
<th>Swell Pressure w/0.5ksf Surcharge (%)</th>
<th>Unconfined Compressive Strength (psf)</th>
<th>Unified Soil Class.</th>
<th>Soil or Bedrock Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 5</td>
<td>6.8</td>
<td>12</td>
<td>42</td>
<td>38</td>
<td>27</td>
<td>11</td>
<td>Not detected</td>
<td>2,400</td>
<td>2.0</td>
<td>GC</td>
<td>Clayey gravel with sand</td>
</tr>
<tr>
<td>1 10 &amp; 15</td>
<td>3.9</td>
<td>127</td>
<td>64</td>
<td>20</td>
<td>31</td>
<td>13</td>
<td>Not detected</td>
<td>2,400</td>
<td>2.0</td>
<td>GC</td>
<td>Clayey gravel with sand</td>
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<tr>
<td>1 20</td>
<td>16.2</td>
<td>114</td>
<td>0</td>
<td>48</td>
<td>45</td>
<td>21</td>
<td></td>
<td>10,140</td>
<td></td>
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<td>Claystone bedrock</td>
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</table>