PRELIMINARY GEOTECHNICAL INVESTIGATION
FIVE PARCELS NEAR
WEST 71ST AVENUE AND HOOKER STREET
NORTHWEST CORRIDOR CATALYTIC PROJECT
ADAMS COUNTY HOUSING AUTHORITY
PROPERTIES AT WESTMINSTER STATION
WESTMINSTER, COLORADO

Prepared For:

TORTI GALLAS AND PARTNERS, INC.
523 West 6th Street, Suite 212
Las Angeles, California 90014

Attention: Martin Leitner
Neal Payton

Project No. DN47,420-115

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SCOPE

This report presents the results of our Preliminary Geotechnical Investigation for five parcels owned by the Adams County Housing Authority located northwest, northeast and southeast of West 71st Avenue and Hooker Street in Westminster, Colorado (Fig. 1). The purpose of our investigation was to evaluate the subsurface conditions to assist in operation and redevelopment of the properties in the future. This letter includes descriptions of subsurface conditions and groundwater levels found in our exploratory borings and discussions of site development and building and pavement construction as influenced by geotechnical considerations. Evaluation of the property for the possible presence of potentially hazardous materials (Environmental Site Assessment) was not included in the scope.

This report was prepared from site reconnaissance and data developed during field exploration, field and laboratory testing, engineering analysis of field and laboratory data, previous investigations and experience with similar conditions and projects. The preliminary recommendations presented in the report are intended for evaluation and planning purposes only. Additional investigation will be necessary to provide geotechnical design recommendations for specific buildings, pavements and other improvements. A summary of our conclusions is presented below with more complete descriptions included in the report.

SUMMARY

1. The site is judged suitable for redevelopment. The primary geotechnical concerns are expansive soils and bedrock and the presence of existing structures and fill. No geotechnical constraints were identified which, in our opinion, preclude redevelopment.

2. Strata found in our borings consisted of nil to about 5 feet of clay fill and/or 3 to 26.5 feet of natural clay, sand and gravel underlain by claystone and sandstone bedrock. About 3 to 6 inches of asphalt
and 3 to 6 inches of base course were penetrated at the ground surface in five borings drilled in pavement areas. Testing indicated the soils and bedrock are predominantly non-expansive or low swelling. Planning and design of the proposed construction should consider the impacts of expansive soils and bedrock.

3. Groundwater was encountered during drilling in 7 borings at depths of about 13 to 34 feet. When the holes were checked after drilling, water levels were measured at depths of about 13 to 24.5 feet or relative elevations 83.5 to 94 feet. We do not expect groundwater will affect construction unless relatively deep basements or drilled pier foundations are used for buildings. Basements are suitable if planned to be at least 3 feet, and preferably 5 feet, above groundwater levels. Groundwater may be encountered during utility installation and temporary construction dewatering may be necessary. Water levels may fluctuate seasonally and rise in response to precipitation and landscape irrigation.

4. Our investigation indicates expansive soil and bedrock and existing fill are present at depths likely to influence the performance of shallow foundations and slab-on-grade floors. Expansive materials can cause heave upon wetting. We estimate potential heave up to about 2 inches. The site is judged to have low to moderate risk of damage due to expansive soil and bedrock. Settlement is also possible for improvements constructed over poorly compacted fill.

5. We believe sub-excavation can be used to reduce potential future movements, provide more uniform support conditions and likely allow use of shallow foundations and slab-on-grade floors. Based on preliminary data, we believe it would be beneficial to sub-excavate to a depth of 7 feet below grade for most of the site. Deeper sub-excavation to a depth of 12 feet below grade or 5 to 10 feet below basement foundations can be used where claystone is shallow. If potential heave is not mitigated, most structures will likely require use of drilled pier foundations and some may need structurally supported basement floors. Perimeter drains should be used around below-grade spaces.

6. Calculated potential heave at the anticipated below-grade levels was up to about 1 inch. Risk of poor lower-level slab-on-grade floor performance varies from low to moderate. The risk rating should be lower after sub-excavation, and should allow use of slab-on-grade floors on most or all parcels.
7. Pavement subgrade soils are likely to be derived of clay, which is considered poor subgrade material. Based on the City of Westminster standards and specifications, we anticipate parking lots and access drives will require 5 to 6 inches of full-depth asphalt or concrete or an equivalent composite section. Sub-excavation can be considered below pavements to enhance performance. A site-specific design-level subgrade investigation should be done prior to development.

8. Control of surface and subsurface drainage will be critical to the performance of foundations, slabs-on-grade and pavements. Overall surface drainage should be designed to provide rapid run-off of surface water away from structures and off pavements and flatwork. Water should not be allowed to pond near the crests of slopes, near structures or on pavements and flatwork.

SITE CONDITIONS AND PROPOSED CONSTRUCTION

The site consists of five parcels or ten lots totaling about 6.5 acres located northwest, northeast and southeast of West 71st Avenue and Hooker Street in Westminster, Colorado (Fig. 1 and Photo 1). The properties are owned by the Adams County Housing Authority and are currently occupied by multifamily residential developments. The site is planned for transportation-oriented development as part of Westminster Station. The surrounding areas have residential, commercial and mixed-use developments. The ground surface is generally flat, with a gentle slope toward Little Dry Creek which is about ¼-mile southwest.
Each parcel except the far east is developed with existing two or three-story apartment buildings (which were constructed between 1961 and 1974) and associated pavements and utilities. The east parcel has a one-story single-family residence on the far north lot and the remaining lots are vacant. Structures were demolished from the vacant parcels. We do not know if any of the previous or existing structures contain basements or below-grade areas. Ground cover in the developed areas consists of buildings, asphalt pavement, concrete flatwork, and landscaping (irrigated grass, bushes and trees). The southern portion of the far east parcel is undeveloped and the ground is sparsely covered with grasses, weeds, bushes, building materials and debris.

Development plans are not available. At this time, we understand the site is being master planned for retail, commercial and medium to high density housing. Existing structures, pavements, flatwork and utilities will be demolished to allow the new construction. Because the surrounding land is developed, we do not anticipate significant cut and fill grading will be necessary to redevelop the site.
INVESTIGATION

We investigated subsurface conditions on August 6 and 7, 2014 by drilling and sampling 10 exploratory borings at the approximate locations shown on Fig. 1. The borings were drilled to depths of 25 to 40 feet below the existing ground surface using 4-inch diameter, continuous-flight solid-stem auger and a truck-mounted CME-55 drill rig. Samples were obtained at 5-foot intervals using a 2.5-inch diameter (O.D.) modified California barrel sampler driven by blows of an automatic 140-pound hammer falling 30 inches. Our field representative was present to observe drilling operations, log the strata encountered, obtain samples for laboratory tests and survey the boring elevations relative to the temporary benchmark shown on Fig. 1 (existing sanitary sewer manhole rim, assumed elevation 100.0 feet). If survey datum is provided, we can revise our boring elevations to reflect that datum. Upon completion of drilling, the drilling areas were cleaned and hand-slotted PVC pipe was installed in the holes to allow delayed groundwater measurements. In paved areas, the ground surface was restored using asphalt cold-patch. Summary logs of the exploratory borings including results of field penetration resistance tests and a portion of laboratory test results are presented in Appendix A.

Samples were returned to our laboratory where they were examined and testing was assigned. Laboratory tests included moisture content, dry density, percent silt and clay-sized particles (passing No. 200 sieve), Atterberg limits, unconfined compressive strength, swell-consolidation and water-soluble sulfate concentration. Laboratory test results are presented in Appendix B and summarized on Table B-I.
SUBSURFACE CONDITIONS

Strata encountered in our exploratory borings consisted of nil to about 5 feet of sandy clay fill and/or 3 to 26.5 feet of natural clay, sand and gravel underlain by claystone and sandstone bedrock to the maximum explored depth of 40 feet. About 3 to 6 inches of asphalt over 3 to 6 inches of base course were penetrated at the ground surface in five borings drilled in pavement areas (TH-2, TH-4, TH-5, TH-6 and TH-10). Some pertinent engineering characteristics of the soil and bedrock are described in the following paragraphs.

Fill

We found about 3 and 5 feet of sandy clay fill at the ground surface in two borings, TH-5 and TH-10, respectively. The fill was darker brown than the natural soils, but was of similar composition as the natural sandy clay. The fill is likely associated with construction of the existing improvements. The fill was stiff based on the result of a field penetration resistance test. A sandy clay fill sample swelled 0.6 percent when wetted under an applied pressure of 500 psf.

Natural Clay, Sand and Gravel

Natural soils generally consisted of 3 to 23 feet of sandy to very sandy, silty clay and/or silty to very clayey sand over nil to 9.5 feet of slightly silty to clayey sand and gravel. The sand and gravel caved below groundwater at a depth of about 15 feet in one boring, TH-10. The clay was medium stiff to very stiff and the sand and gravel was loose to dense. One sandy clay sample compressed 0.1 percent and eight swelled 0.3 to 3.1 percent when wetted. We estimated load-back swell pressures of about 1,400 to 7,000 psf on 4 samples. Three clay samples had unconfined compressive strengths of about 3,400 to 7,100 psf. Two clay samples contained 55 and 69 percent fines and showed
moderate to high plasticity with liquid limits of 36 and 52 and plasticity indices of 15 and 32. Eight sand samples had 11 to 49 percent silt and clay-sized particles.

**Bedrock**

Bedrock consisted of claystone and interbedded claystone/sandstone and was found in all borings except TH-5 at depths of about 3 to 26.5 feet or elevations 80.5 to 105 feet. The bedrock was medium hard to very hard. Four bedrock samples swelled 0.6 to 1.1 percent when wetted and we estimate load-back swell pressures of approximately 5,000 to 8,100 psf on 3 samples. Four samples exhibited unconfined compressive strengths of about 9,400 to 13,800 psf. Two claystone samples had 83 and 95 percent fines and showed moderate to very high plasticity with liquid limits of 44 and 75 and plasticity indices of 23 and 45. Three interbedded bedrock samples contained 23 to 43 percent silt and clay-sized particles.

**Groundwater**

Groundwater was encountered during drilling in 7 borings at depths of about 13 to 34 feet below grade. When the holes were checked after drilling on September 10, 2014, water levels were measured in all 8 borings at depths of about 12.7 to 24.5 feet or relative elevations 83.5 to 93.8 feet. We do not expect groundwater will affect construction unless relatively deep basements or drilled pier foundations are used for buildings. Basements are suitable if planned to be at least 3 feet, and preferably 5 feet, above groundwater levels. Groundwater may be encountered during utility installation and temporary construction dewatering may be necessary. Water levels may fluctuate seasonally and rise in response to precipitation and landscape irrigation.
Seismicity

The soils and bedrock are not expected to respond unusually to seismic activity. According to the 2009 International Building Code (IBC, Standard Penetration Resistance method of Section 1613.5.2) and based upon the results of our investigation, we judge the site classifies as Seismic Site Class C. The subsurface conditions indicate nil susceptibility to liquefaction. Only minor damage to relatively new, properly designed and constructed structures would be expected with a major seismic event. Wind loads typically govern dynamic structural design in this area.

ESTIMATED POTENTIAL SETTLEMENT AND HEAVE

We estimate 1 to 2 inches of potential ground heave based on 15 to 20-foot depth of wetting below existing grade, considered typical for this type of project. Shallow foundations and slabs constructed on poorly compacted fill may experience settlement. It is not certain these movements will occur. Overall, we found relatively favorable conditions that lead us to judge that most of the site is low or moderate risk of damage caused by expansive soil and bedrock. Potential movements can be reduced and more uniform support conditions can be provided with shallow-depth sub-excavation of about 7 to 12 feet below existing grades. We judge the majority of the site can use sub-excavation to a depth of 7 feet, and the far east parcel can be sub-excavated 12 feet or 5 to 10 feet below basement foundations due to shallow claystone, as discussed later in this report.

SITE DEVELOPMENT CONSIDERATIONS

The site is judged suitable for redevelopment. The primary geotechnical concerns are expansive soils and bedrock and the presence of existing structures and fill. These concerns can be mitigated with proper investigation, plan-
ning, engineering, design, and construction. No geotechnical constraints were identified which, in our opinion, preclude redevelopment.

Existing Fill and Demolition

Existing fill, if poorly compacted, is considered unsuitable to support improvements and should be substantially removed and replaced as moisture conditioned, compacted fill as discussed below. Clean portions of the fill can be reused. The fill may require screening and unsuitable material will require proper disposal. An environmental specialist should be consulted about screening tests on this material and debris. The existing structures may contain asbestos. We can assist with a pre-demolition asbestos investigation and other environmental services upon request. Environmental considerations can significantly affect construction costs and impacts should be evaluated early in the development process. Utilities, structures and debris below the new improvements should be removed and replaced with moisture conditioned, compacted fill.

Excavation

We believe the soils and bedrock encountered in our exploratory borings can be excavated with conventional, heavy-duty excavation equipment. We recommend the owner and contractor become familiar with applicable local, state and federal safety regulations, including the current OSHA Excavation and Trench Safety Standards. Based on our investigation and OSHA Standards governing excavations published in 29 CFR, Part 1926, we anticipate the bedrock, clay and sand will classify as Type A, B and C soils, respectively. Maximum slope inclinations of ¾:1, 1:1 and 1½:1 (horizontal:vertical) are required for Type A, B and C soils, respectively. Flatter slopes will be required below groundwater or where seepage is present. The contractor’s “competent person” should review excavation conditions and refer to
OSHA Standards when worker exposure is anticipated. Stockpiles of soil and equipment should not be placed within a horizontal distance equal to one-half the excavation depth, from the edge of the excavation. A Professional Engineer should design excavations greater than 20 feet deep.

Fill and Backfill

The on-site soils are generally suitable for reuse as new fill, provided they are substantially free of debris, vegetation/organics and other deleterious materials. Soil and bedrock particles larger than 3 inches in diameter should not be used for fill unless broken down. If imported fill is necessary, it should ideally have maximum particle size of 2 inches, less than 45 percent passing a No. 200 sieve, a liquid limit less than 30 and a plasticity index less than 15. Potential fill materials should be submitted to our office for approval prior to importing to the site.

Prior to fill placement, debris, vegetation/organics and other deleterious materials should be substantially removed from areas to receive fill. Deep removal may be necessary where tree roots are present. The surface to be filled should be scarified to a depth of at least 8 inches, moisture conditioned, and compacted to the criteria below. Subsequent fill should be placed in thin (8 inches or less) loose lifts, moisture conditioned to between optimum and 3 percent above optimum moisture content for clay or within 2 percent of optimum moisture content for sand, and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698). Guideline grading specifications are presented in Appendix C.

Water and sewer lines are usually constructed below pavements and flatwork. Compaction of trench backfill can have a significant effect on the life and serviceability of floor slabs, pavements, and exterior flatwork. We recom-
mend utility trench backfill be placed and compacted as outlined above. Our experience indicates use of self-propelled compactors results in more reliable performance compared to fill compacted by a sheepsfoot wheel attachment on a backhoe or trackhoe. The upper portion of the trench should be widened to allow the use of a self-propelled compactor. Special attention should be paid to backfill placed adjacent to manholes and valves as we have seen instances where settlement in excess of 2 percent has occurred. Any improvements placed over backfill should be designed to accommodate movement. The placement and compaction of fill and backfill and utility trench backfill should be observed and tested by a representative of our firm during construction.

Soft/loose, wet soils should be removed or stabilized. Removal is preferred to reduce settlement and seepage. If thick soft soils are present, a combination of removal and stabilization may be used. The stabilization may be achieved by placing 12 inches or more recycled concrete or rock with or without a geotextile fabric (Mirafi 500X or equal), or placing 2 to 3 feet of fill to “bridge” over the soft soil before proper compaction of the fill can be achieved. If groundwater is encountered during utility construction, temporary dewatering may be required. Dewatering can likely be accomplished by sloping excavations to temporary sumps and removing the water by pumping. The sumps should bottom several feet below the bottom of the excavations so that water is drawn down through the soils rather than up through the bottom of the excavation.

Sub-Excavation

Deep foundations, such as drilled piers or helical piles bottomed in bedrock, and structurally supported floors are normally recommended for sites with significant potential heave or settlement. Sub-excavation is a ground improvement method used to reduce the potential swell or compression and mitigate impacts of compressible soils and swelling soils and bedrock. At this time, we
believe it would be beneficial to sub-excavate the site to a depth of 7 feet below the existing ground surface. In the eastern portion of the site where shallow claystone is present, deeper sub-excavation to a depth of 12 feet below grade or 5 to 10 feet below foundations can be performed to mitigate swell from claystone. Guideline sub-excavation specifications are presented in Appendix D.

Sub-excavation has been used in this area with satisfactory performance for the large majority of the sites where this ground modification method has been completed. We have seen isolated instances where settlement of sub-excavation fill has led to damage to houses supported on footings. In most cases, the settlement was caused by wetting associated with poor surface drainage or seepage, and/or poorly compacted fill placed at the horizontal limits of excavation. Wetting of the fill may cause softening and settlement. Use of deep foundations would be prudent if risk of footing movement is not tolerable.

There can be cases where the sub-excavation limits and depth are not adequate to encompass an entire building footprint including ancillary structures. As a result, the building has to be founded on deep foundations. Proper planning of the sub-excavation limits and depth based on the largest model plan and as-built surveying of the limits and depth during the sub-excavation are important to reduce this risk.

The excavation slopes should meet OSHA, state, and local safety standards. The bottom of the sub-excavated area should extend laterally at least 5 feet outside the largest possible foundation footprints to ensure foundations are constructed over moisture-conditioned fill. A conceptual sub-excavation profile is shown on Fig. 2.
The excavation contractor should be chosen carefully to verify they have experience with fill placement at above-optimum moisture and have the necessary mixing and compaction equipment. The contractor should provide a construction disc to break down fill materials and anticipate use of push-pull scraper operations and dozer assistance. The operation will be relatively slow. In order for the procedure to be performed properly, close contractor control of fill placement to specifications is required. Sub-excavation fill should be moisture-conditioned between optimum moisture content and 3 percent above optimum with an average test moisture content each day of at least 1 percent above optimum. Fill should be compacted to at least 95 percent of standard Proctor maximum dry density.

Special precautions should be taken for compaction of fill at corners, access ramps, and along the perimeters of the sub-excavation as large compaction equipment cannot easily reach these areas. Our representative should observe placement procedures and test compaction of the fill on a nearly full-time basis. The swell of the moisture-conditioned fill should be tested during and after the fill placement.

If the fill dries excessively prior to construction, it may be necessary to rework the upper drier materials just prior to constructing foundations. We judge the fill should retain adequate moisture for about two years and can check moisture conditions in each excavation as construction progresses, if requested.

Sub-excavation and replacement with low swell fill will likely allow use of shallow footing or post-tensioned slab-on-grade foundation systems for lightly to moderately loaded structures and enhance performance of slab-on-grade floors. Sub-excavation will also enhance performance of concrete flatwork (driveways and sidewalks) and pavements, potentially reducing maintenance costs. We recommend a surveyor document the actual limits of the treatment, and create
"as-built" plans. These plans should be provided to the civil/surveyor so that they can verify that each building is over the treated area. The "treated area" stops at the toe of the deep sub-excavation slope. It would be prudent to show the horizontal limits and bottom elevation of treatment on plans.

Pavements

Existing fill will need to be completely removed below pavements for the best performance. If left in place, geogrid can be considered to help bridge anomalies in the fill. Pavement subgrade soils are likely to be derived of clay, which is considered relatively poor subgrade material. Based on the City of Westminster standards and specifications, we anticipate parking lots and access drives will require 5 to 6 inches of full-depth asphalt or portland cement concrete. An equivalent composite section can be used consisting of 4 inches of asphalt over 8 inches of base course. For public roadways, the City may require shallow-depth sub-excavation to depths of 1 to 3 feet to mitigate potential heave caused by swelling subgrade. A design-level subgrade investigation should be done prior to paving.

BUILDING CONSTRUCTION CONSIDERATIONS

The following discussions are preliminary and are not intended for design or construction. Design-level investigation(s) should be performed once plans are more developed and proposed building locations and floor elevations are known.

Foundations

Site soils generally include expansive soils and bedrock at depths likely to affect foundation performance. Deep foundations are typically used where swelling soil and bedrock are encountered, or foundation loads are moderate to high.
Use of drilled piers will be challenging in parts of the site due to groundwater, caving sand and gravel, and deep bedrock in some areas. Helical piles bottomed in the natural sand and gravel are a suitable deep-foundation alternative.

We believe sub-excavation could allow use of footing or post-tensioned slab-on-grade foundations for lightly to moderately loaded structures, as discussed previously. Large buildings may impose moderate or heavy foundation loads which may require comparatively high allowable footing design pressures and/or larger footings. Mat foundations are gaining interest in this area for mid-rise structures with column loads of about 200 to 600 kips. Bearing capacity for moderately to heavily loaded foundations may be limited by clay layers which can consolidate over a period of months or years upon additional loading as pore water pressure slowly dissipates.

Slab-On-Grade Construction

The choice of floor support methods should depend on the tolerance for movement. The use of slab-on-grade floors should be limited to areas where potential movements are judged to be low to moderate. We judge slab performance risk will be low with minor sub-excavation. The performance of garage floors, driveways, sidewalks, and other surface flatwork installed outside sub-excavated areas may be erratic at this site. Shallower sub-excavation of 3 to 6 feet can be considered in these areas.

The following precautions will be required to reduce the potential for damage due to movement of slabs-on-grade placed at this site:

1. Isolation of the slab from foundation walls, columns or other slab penetrations;
2. Voiding of interior partition walls to allow for slab movement without transferring movement to the structures;
3. Use of flexible water and gas connections to allow for slab movement. A flexible duct above furnaces will also be required; and

4. Proper surface grading and foundation drain installation to reduce water availability to sub-slab and foundation soils.

If basements are used, structurally supported basement floors are recommended for areas of high or very high risk, or where claystone is present below floor levels. A structurally supported basement floor should also be used where a buyer cannot tolerate potential movement. Structurally supported floor systems should be anticipated in all finished living areas. Design and construction issues associated with structural floors include ventilation and lateral loads. Where structurally supported floors are installed over a crawl space, the required air space depends on the materials used to construct the floor and the potential expansion of the underlying soils. Building codes require a clear space of 18 inches between exposed earth and untreated wood floor components.

Below-Grade Areas

Surface water can penetrate relatively permeable loose backfill soils located adjacent to buildings and collect at the bottom of relatively impermeable basement excavations causing wet or moist conditions after construction. Basement foundation walls should be designed to resist lateral earth pressures. Foundation drains should be constructed around the lowest excavation levels of basement areas. Foundation drains will be necessary around all below-grade areas, with a piped connection to sump(s) where water can be removed by pumping, or appropriate storm sewer outfall.

Relatively shallow groundwater conditions may require the use of underslab gravel layers and deeper than normal drains. These types of systems are recommended where groundwater will be within 3 to 5 feet of the basement.
excavation. We recommend basement level construction be limited to a minimum of 3 feet, and preferably 5 feet, above groundwater levels.

Concrete

Concrete in contact with soil can be subject to sulfate attack. We measured water-soluble sulfate concentrations of 0.05 percent in three samples from this site. For this level of sulfate concentration, ACI 332-08 Code Requirements for Residential Concrete indicates there are no special requirements for sulfate resistance. Superficial damage may occur to the exposed surfaces of highly permeable concrete, even though sulfate levels are relatively low. To control this risk and to resist freeze-thaw deterioration, the water-to-cementitious materials ratio should not exceed 0.50 for concrete in contact with soils that are likely to stay moist due to surface drainage or high water tables. Concrete in the frost zone should have a total air content of 6 percent ± 1.5 percent. We advocate all foundation walls and grade beams in contact with the subsoils be damp-proofed.

Surface Drainage

The performance of foundations, floors, pavements and other improvements is affected by moisture changes within the soil and bedrock. This is largely influenced by surface drainage. When developing an overall drainage scheme, consideration should be given to drainage around each structure. The ground surface around the buildings should be sloped to provide positive drainage away from the foundation. We recommend a slope of at least 5 percent for the first 10 feet surrounding each building, where practical. If the distance between buildings is less than 20 feet, the slope in this area should be at least 5 percent to the swale between buildings. Roof downspouts and other water collection systems should discharge well beyond the limits of all backfill around structures.
Proper control of surface runoff is also important to control the erosion of surface soils. Sheet flow should not be directed over unprotected slopes. Water should not be allowed to pond at the crest of slopes. Permanent slopes should be prepared to reduce erosion.

Attention should be paid to compaction of the soils behind curb and gutter adjacent to streets and in utility trenches during the construction and development. If surface drainage between preliminary development and construction phases is neglected, performance of the roadways, flatwork and foundations may be poor.

**RECOMMENDED FUTURE INVESTIGATIONS**

Once specific plans are available for redevelopment, we should review them and determine where additional subsurface investigations are merited. We should assist with providing specific foundation design criteria for each improvement and recommendations for items such as demolition, grading, fill and backfill, and pavements. We can also assist you with environmental assessment, including asbestos investigations. We recommend the following investigations and services:

1. Construction testing and observation during site development, subexcavation, and pavement construction;
2. Subgrade investigation and pavement design after grading;
3. Design-level geotechnical investigations after grading; and
4. Construction observations during foundation construction.
LIMITATIONS

Our borings were widely spaced across the site to provide a general indication of subsurface conditions for preliminary assessment and planning of site development and building construction. The borings are representative of conditions encountered only at the exact boring locations. Variations not indicated by our borings are likely.

Proposed development plans and construction details were not available at this time this report was written. We should review plans once they are developed to determine whether our report and recommendations need to be revised.

We believe this investigation was conducted in a manner consistent with that level of care and skill ordinarily used by geotechnical engineers practicing in this area at this time. No warranty, express or implied, is made. If we can be of further service in discussing the contents of this letter or analysis of the influence of subsurface conditions on the project, please call.

Benny I. Lujan, P.E.
Project Engineer

Reviewed by:
Marc E. Cleveland, P.E.
Vice President

BIL: MEC/bil/nt
(3 copies)

Via e-mail: mleitner@tortigallas.com
npayton@tortigallas.com
APPENDIX A
SUMMARY LOGS OF EXPLORATORY BORINGS
BEDROCK, CLAYSTONE, SANDY AT TIMES, SILTY, MEDIUM HARD TO VERY HARD, MOIST, OLIVE, BROWN, GRAY, RUST, BLUISH-GRAY, WHITE.

CLAY, SANDY TO VERY SANDY, SILTY, GRAVELLY AT DEPTH, MEDIUM STIFF TO VERY STIFF, SLIGHTLY MOIST TO VERY MOIST, BROWN, TAN, OLIVE, GRAY, WHITE, RUST (CL).

SAND, SILTY TO VERY CLAYEY, GRAVELLY AT DEPTH, LOOSE TO DENSE, SLIGHTLY MOIST TO VERY MOIST, BROWN, LIGHT BROWN, OLIVE, TAN, GRAY (SM, SC).

BEDROCK, INTERBEDDED CLAYSTONE/SANDSTONE, SILTY, HARD TO VERY HARD, MOIST TO VERY MOIST, OLIVE, BROWN, GRAY, RUST, BLUISH-GRAY, WHITE.

FILL, CLAY, SANDY, STIFF, MOIST, DARK BROWN, BROWN, TAN.

WATER LEVEL MEASURED AT TIME OF DRILLING.

ROAD BASE (3-6 INCHES THICK).

ASPHALT PAVEMENT (3-6 INCHES THICK).

ILL. CLAY, SANDY, STIFF, MOIST, DARK BROWN, BROWN, TAN.

CLAY, SANDY TO VERY SANDY, SILTY, GRAVELLY AT DEPTH, MEDIUM STIFF TO VERY STIFF, SLIGHTLY MOIST TO VERY MOIST, BROWN, TAN, OLIVE, GRAY, WHITE, RUST (CL).

SAND, SILTY TO VERY CLAYEY, GRAVELLY AT DEPTH, LOOSE TO DENSE, SLIGHTLY MOIST TO VERY MOIST, BROWN, LIGHT BROWN, OLIVE, TAN, GRAY (SM, SC).

BEDROCK, CLAYSTONE, SANDY AT TIMES, MEDIUM HARD TO VERY HARD, MOIST, OLIVE, BROWN, GRAY, RUST, BLUISH-GRAY, WHITE.

BEDROCK, INTERBEDDED CLAYSTONE/SANDSTONE, SILTY, HARD TO VERY HARD, MOIST TO VERY MOIST, OLIVE, BROWN, GRAY, RUST, BLUISH-GRAY.

Drive sample. The symbol 43/12 indicates 43 blows of an automatic 140-pound hammer falling 30 inches were required to drive a 2.5-inch O.D. sampler 12 inches.

Water level measured at time of drilling.

Water level measured after drilling on September 10, 2014.

Indicates depth where hole caved.

Notes:

1. The borings were drilled on August 6 and 7, 2014 using 4-inch diameter, continuous-flight solid stem auger and a truck-mounted CME 55 drill rig.

2. Boring Elevations are approximate and were determined by our representative by surveying referencing the temporary benchmark shown on Fig. 1.

3. WC - indicates moisture content (%).
   DD - indicates dry density (pcf).
   SW - indicates swell when wetted under approximate overburden pressure (%).
   COM - indicates compression when wetted under approximate overburden pressure (%).
   LL - indicates liquid limit.
   PI - indicates plasticity index.
   -200 - indicates Passing No. 200 SIEVE (%).
   UC - indicates unconfined compressive strength (psf).
   SS - indicates water-soluble Sulfate content (%).

4. These logs are subject to the explanations, limitations and conclusions contained in this report.
APPENDIX B
LABORATORY TEST RESULTS
Swell Consolidation Test Results

FIG. B-1

Sample of CLAY, SANDY (CL) From TH-1 AT 4 FEET
DRY UNIT WEIGHT = 119 PCF
MOISTURE CONTENT = 7.9%

Sample of CLAY, SANDY (CL) From TH-2 AT 9 FEET
DRY UNIT WEIGHT = 108 PCF
MOISTURE CONTENT = 17.5%
Swell Consolidation Test Results

FIG. B-2

Sample of CLAY, SANDY (CL) From TH-3 AT 4 FEET
Dry Unit Weight = 110 PCF
Moisture Content = 16.7%

Sample of CLAY, SANDY (CL) From TH-3 AT 14 FEET
Dry Unit Weight = 95 PCF
Moisture Content = 26.5%
Sample of CLAY, SANDY (CL)  
From TH-4 AT 14 FEET  
DRY UNIT WEIGHT = 104 PCF  
MOISTURE CONTENT = 17.4 %

Sample of CLAY, SANDY (CL)  
From TH-5 AT 4 FEET  
DRY UNIT WEIGHT = 105 PCF  
MOISTURE CONTENT = 18.7 %

Swell Consolidation Test Results

FIG. B-3
Sample of CLAY, SANDY (CL) from TH-6 AT 4 FEET:
- Dry Unit Weight = 112 PCF
- Moisture Content = 16.6%

Sample of CLAY, SANDY (CL) from TH-7 AT 4 FEET:
- Dry Unit Weight = 106 PCF
- Moisture Content = 6.5%

Swell Consolidation Test Results

FIG. B-4
Swell Consolidation Test Results

FIG. B-5

Sample of CLAY, SANDY (CL)
From TH-7 AT 9 FEET
DRY UNIT WEIGHT = 98 PCF
MOISTURE CONTENT = 20.7 %

Sample of CLAYSTONE
From TH-7 AT 14 FEET
DRY UNIT WEIGHT = 103 PCF
MOISTURE CONTENT = 21.8 %
Sample of CLAYSTONE

From TH-7 AT 19 FEET

DRIY UNIT WEIGHT = 99 PCF

MOISTURE CONTENT = 23.4 %

EXPANSION UNDER CONSTANT
PRESSURE DUE TO WETTING

Swell Consolidation Test Results

FIG. B-6
Sample of CLAYSTONE

DRIY UNIT WEIGHT = 103 PCF

From TH-7 AT 24 FEET

MOISTURE CONTENT = 20.2 %

EXPANSION UNDER CONSTANT PRESSURE DUE TO WETTING

Swell Consolidation Test Results

FIG. B-7
Sample of CLAYSTONE
From TH-8 AT 14 FEET
DRY UNIT WEIGHT = 89 PCF
MOISTURE CONTENT = 27.5 %

Sample of FILL, CLAY, SANDY
From TH-10 AT 4 FEET
DRY UNIT WEIGHT = 105 PCF
MOISTURE CONTENT = 15.3 %

Swell Consolidation Test Results
FIG. B-8
## TABLE B-1

SUMMARY OF LABORATORY TEST RESULTS

<table>
<thead>
<tr>
<th>BORING</th>
<th>DEPTH (ft)</th>
<th>MOISTURE CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>SWELL (%</th>
<th>COMPRESSION (%)</th>
<th>APPLIED PRESSURE (psf)</th>
<th>SWELL PRESSURE (psf)</th>
<th>LIQUID LIMIT</th>
<th>PLASTICITY INDEX</th>
<th>ATMOSPHERIC COMPRRESSIVE STRENGTH (psf)</th>
<th>SULFATE CONTENT (%)</th>
<th>PASSING NO. 200 SIEVE (%)</th>
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APPENDIX C

GUIDELINE SITE GRADING SPECIFICATIONS

Adams County Housing Authority Westminster Station Housing
Westminster, Colorado
GUIDELINE SITE GRADING SPECIFICATIONS
Adams County Housing Authority Westminster Station Housing
Westminster, Colorado

1. DESCRIPTION

This item shall consist of the excavation, transportation, placement and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve preliminary street and overlot grade elevations. These specifications shall also apply to compaction of excess cut materials that may be placed outside of the development boundaries.

2. GENERAL

The Soils Representative shall be the Owner's Representative. The Soils Representative shall approve fill materials, method of placement, moisture contents and percent compaction, and shall give written approval of the completed fill.

3. CLEARING JOB SITE

The Contractor shall substantially remove all debris, vegetation, organics and other deleterious materials before excavation or fill placement. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill or where the material will support structures of any kind.

4. AREA TO BE FILLED

Debris, vegetation, organics and other deleterious materials shall be substantially removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified until the surface is free from ruts, hummocks or other uneven features, which would prevent uniform compaction.

After the foundation for the fill has been cleared and scarified, it shall be disced or bladed until it is free from large clods, brought to the proper moisture content (optimum to 3 percent above optimum moisture content for clays and within 2 percent of optimum moisture content for sands) and compacted to at least 95 percent of maximum dry density as determined in accordance with ASTM D 698.

5. FILL MATERIALS

Fill soils shall be substantially free from debris, vegetation, organics and other deleterious materials, and shall not contain rocks or lumps having a diameter greater than six (6) inches. Claystone bedrock should be broken down to three (3) inches or smaller in size. Fill materials shall be obtained from cut areas shown on the plans or staked in the field by the Engineer.
On-site materials classifying as CL, CH, SC, SM, SW, SP, GP, GC and GM are acceptable.

6. MOISTURE CONTENT

Fill material classifying as CH, CL and SC shall be moisture conditioned to between 0 and 3 percent above optimum moisture content. Granular soils classifying as SM, SW, SP, GP, GC and GM shall be moisture conditioned to within 2 percent of optimum moisture content as determined from Proctor compaction tests. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas.

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Representative, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor may be required to rake or disc the fill soils to provide uniform moisture content through the soils.

The application of water to embankment materials shall be made with any type of watering equipment approved by the Soils Representative, which will give the desired results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling and all work on that section of the fill shall be delayed until the material has been allowed to dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

7. COMPACTION OF FILL AREAS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density. Fill shall be compacted to at least 95 percent of the maximum density as determined in accordance with ASTM D 698. At the option of the Soils Representative, soils classifying as SW, GP, GC, or GM may be compacted to 95 percent of maximum density as determined in accordance with ASTM D 1557 or 70 percent relative density for cohesionless sand soils. Fill materials shall be placed such that the thickness of loose materials does not exceed 10 inches and the compacted lift thickness does not exceed 6 inches.

Compaction as specified above, shall be obtained by the use of sheepsfoot rollers, multiple-wheel pneumatic-tired rollers, or other equipment for soils classifying as CL, CH, or SC. Granular fill shall be compacted using vibratory equipment or other approved equipment. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to ensure that the required density is obtained.
8. **COMPACTION OF SLOPES**

Fill slopes shall be compacted by means of sheepsfoot rollers or other suitable equipment. Compaction operations shall be continued until slopes are stable, but not too dense for planting, and there is not appreciable amount of loose soils on the slopes. Compaction of slopes may be done progressively in increments of three to five feet (3’ to 5’) in height or after the fill is brought to its total height. Permanent fill slopes shall not exceed 3:1 (horizontal to vertical).

9. **PLACEMENT OF FILL ON NATURAL SLOPES**

Where natural slopes are steeper than 20 percent in grade and the placement of fill is required, benches shall be cut at the rate of one bench for each 5 feet in height (minimum of two benches). Benches shall be at least 10 feet in width. Larger bench widths may be required by the Engineer. Fill shall be placed on completed benches as outlined within this specification.

10. **DENSITY TESTS**

Field density tests shall be made by the Soils Representative at locations and depths of his choosing. Where sheepsfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate that the density or moisture content of any layer of fill or portion thereof is not within specification, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

11. **SEASONAL LIMITS**

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Representative indicates that the moisture content and density of previously placed materials are as specified.

12. **NOTICE REGARDING START OF GRADING**

The Contractor shall submit notification to the Soils Representative and Owner advising them of the start of grading operations at least three (3) days in advance of the starting date. Notification shall also be submitted at least 3 days in advance of any resumption dates when grading operations have been stopped for any reason other than adverse weather conditions.

13. **REPORTING OF FIELD DENSITY TESTS**

Density tests made by the Soils Representative, as specified under "Density Tests" above, shall be submitted progressively to the Owner. Dry density, moisture content, and percentage compaction shall be reported for each test taken.
14. DECLARATION REGARDING COMPLETED FILL

The Soils Engineer shall provide a written declaration stating that the site was filled with acceptable materials, and was placed in general accordance with the specifications.
APPENDIX D
GUIDELINE SUB-EXCAVATION SPECIFICATIONS

Adams County Housing Authority Westminster Station Housing
Westminster, Colorado

Note: This guideline is intended for use with sub-excavation. If sub-excavation is not selected, the guidelines in Appendix C should be followed.
GUIDELINE SUB-EXCAVATION SPECIFICATIONS

Adams County Housing Authority Westminster Station Housing
Westminster, Colorado

1. DESCRIPTION

This item shall consist of the excavation, transportation, placement and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve preliminary street and overlot grade elevations. These specifications shall also apply to compaction of excess cut materials that may be placed outside of the development boundaries.

2. GENERAL

The Soils Representative shall be the Owner's Representative. The Soils Representative shall approve fill materials, method of placement, moisture contents and percent compaction, and shall give written approval of the completed fill.

3. CLEARING JOB SITE

The Contractor shall substantially remove all debris, vegetation, organics and other deleterious materials before excavation or fill placement. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill or where the material will support structures of any kind.

4. AREA TO BE FILLED

Debris, vegetation, organics and other deleterious materials shall be substantially removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified until the surface is free from ruts, hummocks or other uneven features, which would prevent uniform compaction.

After the foundation for the fill has been cleared and scarified, it shall be disced or bladed until it is free from large clods, brought to the proper moisture content (between optimum moisture content and 3 percent above optimum for clay and within 2 percent of optimum moisture content for sand) and compacted to at least 95 percent of maximum dry density as determined in accordance with ASTM D 698.

5. FILL MATERIALS

Fill soils shall be substantially free from debris, vegetation, organics and other deleterious materials, and shall not contain rocks or lumps having a diameter greater than six (6) inches. Clay and claystone should be broken down to three (3) inches or smaller in size. Fill materials shall be obtained from cut areas shown on the plans or staked in the field by the Engineer.
On-site materials classifying as CL, CH, SC, SM, SW, SP, GP, GC and GM are acceptable. Concrete, asphalt, and other deleterious materials or debris shall not be used as fill.

6. MOISTURE CONTENT

Fill materials shall be moisture-conditioned to within limits of optimum moisture content specified in “Moisture Content and Density Criteria”. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas or imported to the site.

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor will be required to rake or disc the fill to provide uniform moisture content throughout the fill.

The application of water to embankment materials shall be made with any type of watering equipment that will give the desire results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling and all work on that section of the fill shall be delayed until the material has been allowed to dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

7. COMPACTION OF FILL MATERIALS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density given in “Moisture Content and Density Criteria”. Fill materials shall be placed such that the thickness of loose material does not exceed 8 inches and the compacted lift thickness does not exceed 6 inches.

Compaction, as specified above, shall be obtained by the use of suitable equipment. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to ensure that the required density is obtained.

8. MOISTURE CONTENT AND DENSITY CRITERIA

Fill material shall be substantially compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99) at 0 to 3 percent above optimum moisture content. Additional criteria for acceptance are presented in DENSITY TESTS.
9. **DENSITY TESTS**

Field density tests shall be made by the Soils Engineer at locations and depths of his choosing. Where sheepfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate the density or moisture content of any layer of fill or portion thereof not within specifications, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

Allowable ranges of moisture content and density given in **MOISTURE CONTENT AND DENSITY CRITERIA** are based on design considerations. The moisture shall be controlled by the Contractor so that moisture content of the compacted earth fill, as determined by tests performed by the Soils Engineer, shall be within the limits given. The Soils Engineer will inform the Contractor when the placement moisture is less than or exceeds the limits specified and the Contractor shall immediately make adjustments in procedures as necessary to maintain placement moisture content within the specified limits, to satisfy the following requirements.

A. **Moisture**

1. The average moisture content of material tested each day shall not be less than 1 percent over optimum moisture content.

2. Material represented by samples tested having moisture lower than optimum will be rejected. Such rejected materials shall be reworked until moisture equal to or greater than optimum is achieved.

B. **Density**

1. The average dry density of material tested each day shall not be less than 95 percent of standard Proctor maximum dry density (ASTM D 698).

2. No more than 10 percent of the material represented by the samples tested shall be at dry densities less than 95 percent of standard Proctor maximum dry density (ASTM D 698).

3. Material represented by samples tested having dry density less than 94 percent of standard Proctor maximum dry density (ASTM D 698) will be rejected. Such rejected materials shall be reworked until a dry density equal to or greater than 95 percent of standard Proctor maximum dry density (ASTM D 698) is obtained.
10. OBSERVATION AND TESTING OF FILL

Observation by the Soils Engineer shall be sufficient during the placement of fill and compaction operations so that they can declare the fill was placed in general conformance with specifications. All observations necessary to test the placement of fill and observe compaction operations will be at the expense of the Owner.

11. SEASONAL LIMITS

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Engineer indicates the moisture content and density of previously placed materials are as specified.

12. REPORTING OF FIELD DENSITY TESTS

Density tests made by the Soils Engineer, as specified under “Density Tests” above, shall be submitted progressively to the Owner. Dry density, moisture content and percentage compaction shall be reported for each test taken.