Subsurface Exploration Program
Geotechnical Recommendations
City of Grand Junction Contract No. 2790-08-SDH
Proposed Public Safety Facility
Grand Junction, Colorado

Initial Submittal

Prepared for:

City of Grand Junction, Colorado
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Attention: Mr. Jim Shanks

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PURPOSE AND SCOPE OF STUDY

This report presents the results of a subsurface exploration program performed by GROUND Engineering Consultants, Inc., (GROUND) to develop geotechnical recommendations for design and construction of the proposed Public Safety Facility project, to be located on 2½ city blocks of currently occupied property in Grand Junction, Colorado. Our study was conducted in general accordance with the City of Grand Junction Contract No. 2790-08-SDH.

A field exploration program was conducted to obtain information on subsurface conditions. Material samples obtained during the subsurface exploration were tested in the laboratory to provide data on the classification and engineering characteristics of the on-site soils. The results of the field exploration and laboratory testing are presented herein.

This report has been prepared to summarize the data obtained and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Geotechnical design parameters and a discussion of geotechnical engineering considerations related to the construction of the proposed facility are included.

PROPOSED CONSTRUCTION

We understand that the proposed development will consist of redeveloping approximately 2½ city blocks of currently occupied land that is located between Ute Avenue and Pitkin Avenue from 5th Street to approximately ½ a block east of 7th Street.

The proposed development will include removal of the existing public safety buildings in the area, as well as other structures that are currently occupying the parcels, which includes an auto repair shop, vacant houses, and a construction office. After the removal is complete the following structures are proposed for construction:

- A three story, 140,000 square-foot Public Safety Building, which would house the police facility, fire administration, 911 regional communications center, municipal courts and emergency operations center. The building will be located between 5th and 6th Streets.

- A two-story, 60,000 square-foot Public Safety Annex building, between 6th and 7th Street.

- A two-story, 30,000 square-foot Fire Station, east of 7th Street.

- A three-story, 100,000 square-foot Parking Garage, between 6th and 7th Streets.

The buildings will be surrounded by landscaping and flatwork, paved parking areas and driveways. The general site layout is depicted in Figures 1A & 1B, following the text.

Although detailed grading plans were not available for review at the time of this reports preparation, we anticipate that limited material cuts and fills, less than about 5 feet in depth, will be necessary to achieve final site grades. Additional earthworks may be necessary to remove demolished building foundations and related buried utilities, construct below-grade levels, install new utilities, etc.

If the proposed construction differs significantly from that described above, GROUND should be notified to re-evaluate the recommendations contained herein.

SITE CONDITIONS

At the time of our fieldwork multiple buildings, parking areas, drive lanes, and streets, occupied the project site. (See above aerial photo (courtesy of Google) with the proposed development overlay.) The topography was relatively flat to slightly sloping, presumably reflecting the surficial drainage system associated with the existing paved parking areas and streets. The site was bordered by 5th Street to the west, Ute Avenue to the north, Pitkin Avenue to the South, and a strip of cleared land approximately 230' east of 7th Street to the east.

SUBSURFACE EXPLORATION

The subsurface exploration for the project was conducted in October, 2008. A total of twenty (20) test holes were drilled with a truck-mounted, continuous flight, power auger rig to evaluate subsurface conditions, as well as to retrieve samples for laboratory testing and analysis. The test holes were drilled within the approximate areas shown of Figures 1A and 1B to depths of approximately 20 to 50 feet below existing grades. A GROUND engineer directed subsurface exploration, logged the test holes in the field and prepared the samples for transport to our laboratory.

As mentioned in GROUND's October 2, 2008 proposal, an additional five (5) test holes will be drilled once the demolition of the structures is complete. In addition, at the request of City of Grand Junction, no test holes were completed as temporary groundwater observation wells at this time. Installation of monitoring wells could be performed at a later date, upon request by the Client.

Relatively undisturbed samples of the subsurface materials were taken with a 2-inch I.D. "California" -type liner sampler. The sampler was driven into the substrata with blows from a 140-pound hammer falling 30 inches. This procedure is similar to the Standard Penetration Test described by ASTM Method D1586. Penetration resistance values (blows per distance driven, typically 12 inches), when properly evaluated, indicate the relative density or consistency of soils and bedrock. Depths at which the samples were taken and associated penetration resistance values are shown on the test hole logs. Two composite disturbed (bulk) samples of the shallow soils were collected from the auger returns.

The approximate locations of the test holes are shown in Figure 1A and 1B. Logs of the test holes are presented in Figures 2 through 4. Explanatory notes and a legend are provided in Figure 5.

LABORATORY TESTING

Samples retrieved from our test holes were examined and visually classified in the laboratory by the project engineer. Laboratory testing of soil samples obtained from the subject site included standard property tests, such as natural moisture contents, dry unit weights, grain size analyses, and Atterberg limits. Swell-consolidation, water-soluble sulfate content, pH and resistivity tests were performed on selected samples as well. Compaction testing was performed on two composite bulk samples of the soils. Laboratory tests were performed in general accordance with applicable ASTM and AASHTO protocols.

Data from the laboratory-testing program are summarized on Tables 1 and 2. Results of the compaction tests are presented in Figures 6 and 7.

GEOLOGIC SETTING

Published maps, e.g. Scott and others (2002)[1] depict the site as underlain by Upper Pleistocene to Lower Holocene alluvial (stream-laid) and colluvial (slope wash) materials. These deposits consist, in general, of interbedded sands, gravels, silts and clays. The surficial soils are mapped as underlain by strata of the Upper Cretaceous Mancos Shale formation. In the Grand Junction area, the Mancos Shale consists largely of silt to clay shales that commonly are moderately to highly expansive. Thin sandstone beds are interbedded locally with the shales. The bedrock strata dip northeastward at shallow angles (3 to 5 degrees). The Mancos Shale consist upper portion of the Mancos Shale can exhibit voids from gypsum dissolution and be vulnerable to consolidation.

SUBSURFACE CONDITIONS

The subsurface conditions encountered in the test holes generally consisted of a thin layer of pavement, consisting of either asphalt or Portland cement concrete pavement

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[1] Scott, R.B., P.E. Carrara, W.C. Hood, and K.E. Murray, 2002, *Geologic map of the Grand Junction quadrangle, Mesa County, Colorado*, Miscellaneous Field Studies MF-2363, U.S. Geological Survey Denver, Colorado.

that was approximately 2 to 6 inches thick, or approximately 1 foot of gravely, sandy fill. These materials were underlain by variable conditions, generally consisting of interbedded sands, silts, and/or clays that extended to approximately 16 to 20 feet, below existing grades. These soils were underlain by sands, gravels and cobbles that extended to the test hole termination depths of approximately 20 to 50 feet, below existing grade.

Fill material encountered was fine to medium sands with medium to coarse gravels, dry to moist, non- to low plastic, medium dense and reddish brown to grey in color. Please note that the exact extents, limits, and composition of the man-made fill were not determined as part of the scope of work addressed by this study, and should be expected to exist at varying depths and locations across the project site.

Clays encountered were generally lean to sandy with occasional silt, fine to medium grained, moist to very moist, moderately plastic, soft to medium stiff, pale brown to brown in color, and locally calcareous.

Sand and Clays encountered were generally slightly to very clayey, fine to medium grained, with localized gravel lenses, moist, non- to low plastic, medium dense to dense, and pale brown to brown in color.

Sands and Silts encountered were generally slightly silty to sandy, fine to medium grained, moist to very moist, low to moderately plastic, soft to medium stiff, and pale brown to brown in color.

Sands and Gravels encountered generally consisted of fine to medium sands with medium to coarse gravels, and local cobbles. They were moist, non- to low plastic, medium dense to very dense, and reddish brown to brown in color. Although not encountered in our test holes, the possibility of encountering large cobbles and boulders always exists in mountainous terrain. The Contractor should be prepared to handle these materials including boulder removal.

Swell-Consolidation Testing suggested a low potential for volume change in the tested on-site materials. Volume change ranged from -0.3 percent (consolidation) to 0.3 percent (swell) upon wetting under a 1,000 psf surcharge load. Additionally, volume change ranged from -0.1 percent (consolidation) to 0.0 percent upon wetting under a 200 psf surcharge load (see Table 1).

Groundwater was encountered in several test holes at depths of approximately 14 to 18 feet below existing grades, at the time of our subsurface exploration. Groundwater levels should be anticipated to fluctuate, however, in response to annual and longer-term cycles of precipitation, surface drainage, applied irrigation, development and drainage of transient, perched water conditions, and other factors.

SEISMIC CLASSIFICATION

The project area falls within Seismic Performance Category A based on AASHTO guidelines, and is considered to have a low probability for large, damaging earthquakes. We consider the site to fall within the parameters of a Seismic Site Class D site, in accordance with 2003/2006 IBC, based on extrapolation of available data to depth. If a quantitative assessment of the classification is needed, deeper drilling (to at least 100 feet) and down-hole shear wave velocity testing will be required. A proposal for this additional service can be provided upon request. Compared with other regions of Colorado, recorded earthquake frequency in the project area is relatively low.

FOUNDATION SYSTEMS

Concrete Pipe Pile Foundations The following parameters are provided for a concrete filled steel pipe pile foundation system for preliminary design and cost estimation purposes. Geotechnical parameters for other foundation systems can be provided upon request, as well.

We assume that 8 or 10-inch pipe piles may be utilized in the construction of driven pile foundations.

1) The piles should consist of a heavy steel pipe section. The pile tip should be reinforced with a commercial, heavy duty, pile tip.

2) The maximum pile load should not exceed a maximum service stress of 12,000 psi based on the steel pile cross-sectional area.

3) We estimate that piles will be driven to depths up to about 30 feet below the existing grades into the underlying dense to very dense sands and gravels. Final pile depths should be based on building loads, finished floor elevations, and subsurface conditions encountered, however. Due to the variable depth to dense sands and gravels layer (between 16 to 20 feet below the existing grades) encountered during subsurface exploration, the Contractor should be prepared to drive piles at least an additional 5 to 10 feet. We recommend that a program of test pile installation be performed to refine anticipated driving depths/elevations.

4) Additional pile footage also should be included in project planning and bidding to allow for additional piles, locally, where offsets are required due to potential obstructions, such as cobbles and boulders, to pile driving in the native sands and gravels layer. Pre-drilling or pre-blasting of pile locations should be considered where difficult driving conditions are encountered. Although pre-drilled/blasted holes may not remain open in native sands and gravels, pre-drilling could facilitate breaking up the large cobbles and boulders that may impede advancing piles to the necessary depths.

5) Based on the largely low cohesive nature of the native silts and sands above the sands and gravels, we anticipate that post-installation down-drag on the piles will be low. An adhesion coefficient of 0.1 appears appropriate for use in the overburden silts and sands to estimate down-drag. GROUND also recommends, however, re-striking of the piles to evaluate their capacity at least 24 hours after (initial) driving has been completed.

6) Groups of piles required to support concentrated loads will require an appropriate reduction of the estimated bearing capacity based on the effective envelope area of the pile group.

Reduction of axial capacity can be avoided by spacing piles to a distance of at least 3 'diameters' center to center. Pile groups spaced less than 3 diameters center to center should be studied on an individual basis to determine the appropriate axial capacity reduction(s).

To avoid reduction of the capacity of piles to resist the component of lateral loading parallel to the line connecting the pile centers, piles should be spaced at least 6 diameters apart. Groups of piles spaced less than 6 diameters center to center should be studied to determine the appropriate lateral capacity reduction(s).

7) Lateral resistance to horizontal forces can be resisted by battered piles. It is normal to assume a battered pile can resist the same axial load as a vertical pile of the same type and size driven to the same depth. The vertical and horizontal components of the load will depend on the batter inclinations. Batters should not exceed 1:4 (horizontal : vertical).

8) Piles may be designed to resist lateral loads assuming a modulus of horizontal subgrade reaction of 30 pci in the shallow clays, etc. at depths from 5 to 10 feet. Resistance to lateral loads should be neglected in the upper 5 feet of the overburden soils. A modulus of horizontal subgrade reaction of 278 pci may be assumed in native sands with gravels.

9) Uplift on piles should be limited to 25 percent of the indicated vertical load capacities

10) We recommend that the pile-driving hammer should develop a minimum of 20,000 foot-pounds of energy per blow for a 10-inch diameter pile.

    After the actual pile type and proposed hammer have been selected, the Geotechnical Engineer should be retained to perform a Wave Analysis to determine if the driving hammer is sized adequately for the type of pile selected and the soils and bedrock materials into which the piles are driven.

A representative of the Geotechnical Engineer should be retained to observe all pile driving operations.

We recommend that at the start of pile installation the Geotechnical Engineer should be retained to perform pile dynamic testing at each general location at which driven piles will be installed. Testing will be performed in order to a) assess whether piles are being over-stressed relative to the maximum service stress of 12,000 psi recommended above, and b) develop virtual refusal criteria based on the design capacity of the piles. Dynamic pile testing should be performed by means of a Pile Driving Analyzer (PDA) to determine the virtual refusal criteria.

FLOOR SYSTEMS

Concrete Slab-on-Grade Floor As discussed in the *Appendix A, Geotechnical Considerations for Design* section of this report, slab-on-grade construction with over-excavation and processing of the on-site soils in accordance with the recommendations in the *Site Grading* portion of this report will provide a platform that has been used in the western Colorado area with varying degrees of success. Slab movements are directly related to the changes in moisture contents to the underlying soils after construction is completed. Based on the results of the laboratory-testing program, it appears that the materials near the surface at the project site have moisture contents that exceed the optimum moisture contents and will require processing as described below. If the Owner is willing to assume the risk of slab-on-grade construction, the recommendations below are provided to reduce damage, which results from movement of the slab subgrade materials. These measures will not eliminate potential movements but will tend to reduce the magnitude of the movements, make them more uniform, and reduce resultant damage where movement does occur.

If slab-on-grade construction is used in accordance with the following criteria, as well as other applicable recommendations contained in this report, we estimate that potential slab movements may be on the order of 1 inch. The actual magnitude of movement is difficult to estimate and may be more or less.

1) In order to reduce post-construction slab movements, GROUND recommends construction of a prism of properly moisture-density conditioned fill soils at least 4 to 6 feet, or more, in thickness beneath each building floor slab. The final vertical depth fill prisms should be based on the actual conditions encountered under each building, after the demolition is complete.

   The removal and replacement should extend at least 5 feet beyond the building perimeter. The floor slab should be cast on approved materials placed as properly moisture-conditioned and compacted fill.

Recommendations for fill specifications, fill placement, and fill compaction, are provided in the *Project Earthworks* section of this report.

2) A Geotechnical Engineer should be retained to observe the prepared surfaces on which the floor slabs will be cast prior to placement of reinforcement. Loose, soft or otherwise unsuitable materials should be excavated and replaced with properly compacted fill, and placed in accordance with the recommendations in the *Project Earthworks* section of this report.

3) Floor slabs should be separated from all bearing walls and columns with slip joints, which allow unrestrained vertical movement.

   Joints should be observed periodically, particularly during the first several years after construction. Slab movement can cause previously free-slipping joints to bind. Measures should be taken to assure that slab isolation is maintained in order to reduce the likelihood of damage to walls and other interior improvements.

4) Interior partitions resting on floor slabs should ideally be provided with slip joints so that if the slabs move, the movement cannot be transmitted to the upper structure. This detail is also important for wallboards and doorframes.

5) Concrete slabs-on-grade should be placed on properly prepared subgrade. They should also be constructed and cured according to applicable standards and be provided with properly designed and constructed control joints. The design and construction of such joints should account for cracking as a result of shrinkage, tension, and loading; curling; as well as proposed slab use. Joint layout based on the slab design may require more frequent, additional, or deeper joints, and should also be based on the ultimate use and configuration of the slabs. Areas where slabs consist of interior corners or curves (at column blockouts or around corners) or where slabs have high length to width ratios, high degree of slopes, thickness transitions, high traffic loads, or other unique features should be carefully considered. The improper placement or construction of control joints will increase the potential for slab cracking. ACI, AASHTO, and other industry groups provide many guidelines for proper design and construction of concrete slabs-on-grade and the associated jointing.

6) Floor slabs should be adequately reinforced. Recommendations based on structural considerations for slab thickness, jointing, and steel reinforcement in floor slabs should be developed by the Structural Engineer.

7) GROUND recommends that the Client/Project Team review the American Concrete Institute's (ACI) Sections 301/302/360 for additional guidance and recommendations regarding slab on grade design and construction.

8) All plumbing lines should be carefully tested before operation. Where plumbing lines enter through the floor, a positive bond break should be provided. Flexible connections allowing 2 or more inches of vertical movement should be provided for slab-bearing mechanical equipment.

9) Moisture can be introduced into a slab subgrade during construction and additional moisture will be released from the slab concrete as it cures. GROUND recommends placement of a properly compacted layer of free-draining gravel, 4 or more inches in thickness, beneath the slabs. This layer will help distribute floor slab loadings, ease construction, reduce capillary moisture rise and aid in drainage. The free-draining gravel should contain less than 5 percent material passing the No. 200 Sieve, more than 50 percent retained on the No. 4 Sieve, and a maximum particle size of 2 inches.

The capillary break and the drainage space provided by the gravel layer also may reduce the potential for excessive water vapor fluxes from the slab after construction as mix water is released from the concrete. A vapor barrier beneath a building floor slab can be beneficial with regard to reducing exterior moisture moving into the building, but can retard downward drainage of construction moisture. Uneven moisture release can result in slab curling. Elevated vapor fluxes can be detrimental to the adhesion and performance of many floor coverings and may exceed various flooring manufacturers' usage criteria.

Therefore, in light of the several, potentially conflicting effects of the use vapor-barriers, the Owner and the Architect and/or Flooring Contractor should weigh the performance of the slab and appropriate flooring products in light of the intended building use, etc., during the floor system design process and the selection of flooring materials. Use of a plastic vapor-barrier membrane may be appropriate for some buildings and not for others.

LATERAL LOADS

We understand that while the proposed plans may not specifically call for below-grade levels in the buildings. There may be underground walkways or other retaining-type structures. Therefore, the lateral load parameters below are suggested for preliminary design purposes where on-site materials are used as backfill. Unit dry weights and moisture contents for site earth materials are provided in Table 1.

"At-rest" Condition:	63 pcf.
"Active" Condition:	43 pcf.
"Passive" Condition:	332 pcf.

The additional loading of an upward sloping backfill, hydrostatic loads if sufficient drainage is not provided, as well as loads from traffic, stockpiled materials, etc., should be included in retaining wall design.

Geotechnical recommendations for retaining structures can be provided upon request. Additional subsurface exploration may be necessary along wall alignments, etc., to develop design parameters.

WATER-SOLUBLE SULFATES

The concentrations of water-soluble sulfates measured in selected samples retrieved from the test holes ranged up to 0.9 percent by weight (see Table 2). Such concentrations of water-soluble sulfates represent a severe environment for sulfate attack on concrete exposed to these materials. Degrees of attack are based on the scale of 'negligible,' 'moderate,' 'severe' and 'very severe' as described in the "Design and Control of Concrete Mixtures," published by the Portland Cement Association (PCA).

Based on these data and PCA and Colorado Department of Transportation (CDOT) guidelines, GROUND recommends use of sulfate-resistant cement in all concrete exposed to site soil and bedrock, conforming to one of the following requirements:

1) Type V, as specified by ASTM C150.

2) Type II with a maximum C3A content of 5 percent and a maximum content of (C4AF +2[C3A]) of 25 percent.

3) Type II or Type I/II, and 15 to 20 percent of the cement shall be replaced with an approved Type F fly ash.

4) A blended cement conforming to Type HS, as specified by ASTM C1157.

Other cement types or blends may be acceptable, however, if type-specific test data demonstrate equal or superior sulfate-resistance to Type V cement. Test data should be provided to the Geotechnical Engineer for review, and the cement approved, prior to use.

All concrete exposed to site soil and bedrock should have a maximum water/cement ratio of 0.45 by weight. All concrete exposed to site soil and bedrock should have a minimum compressive strength of 4,500 psi. Concrete mixes should be relatively rich and should be air entrained.

The Contractor should be aware that certain concrete mix components affecting sulfate resistance including, but not limited to, the cement, entrained air, and fly ash, can affect workability, set time, and other characteristics during placement, finishing and curing. The Contractor should develop mix(es) for use in project concrete which are suitable with regard to these construction factors, as well as sulfate resistance. A reduced, but still significant, sulfate resistance may be acceptable to the Owner, in exchange for desired construction characteristics.

SOIL CORROSIVITY

The degree of risk for corrosion of metals in soils commonly is considered to be in two categories: corrosion in undisturbed soils and corrosion in disturbed soils. The potential for corrosion in undisturbed soil is generally low, regardless of soil types and conditions, because it is limited by the amount of oxygen that is available to create an electrolytic cell. In disturbed soils, the potential for corrosion typically is higher, but is strongly affected by soil conditions for a variety of reasons but primarily soil chemistry.

A corrosivity analysis was performed to provide a general assessment of the potential for corrosion of ferrous metals installed in contact with earth materials at the site, based on the conditions existing at the time of GROUND's evaluation. Soil chemistry and physical property data including pH, oxidation-reduction (redox) potential, sulfides, and moisture content were obtained. Test results are summarized on Table 2.

Soil Resistivity In order to assess the "worst case" for mitigation planning, samples of materials retrieved from the test holes were tested for resistivity in the laboratory, after being saturated with water, rather than in the field. Resistivity also varies inversely with temperature. Therefore, the laboratory measurements were made at a controlled temperature.

Measurements of electrical resistivity indicated values from approximately 49 ohm-centimeters in a sample of soil, to more than 11,529 ohm-centimeters. The following table presents the relationship between soil resistivity and a qualitative Corrosivity rating[2]:

Corrosivity Ratings Based on Soil Resistivity

Soil Resistivity (ohm-cm)	Corrosivity Rating
>20,000	Essentially non-corrosive
10,000 – 20,000	Mildly corrosive
5,000 – 10,000	Moderately corrosive
3,000 – 5,000	Corrosive
1,000 – 3,000	Highly corrosive
<1,000	Extremely corrosive

pH Where pH is less than 4.0, soil serves as an electrolyte; the pH range of about 6.5 to 7.5 indicates soil conditions that are optimum for sulfate reduction. In the pH range above 8.5, soils are generally high in dissolved salts, yielding a low soil resistivity[3]. Testing indicated pH values of approximately 6.5 through 7.9.

The American Water Works Association (AWWA) has developed a point system scale used to predict corrosivity. The scale is intended for protection of ductile iron pipe but is valuable for project steel selection. When the scale equals 10 points or higher, protective measures for ductile iron pipe are recommended. The AWWA scale is

[2] ASM International, 2003, *Corrosion: Fundamentals, Testing and Protection*, ASM Handbook, Volume 13A.
[3,3] American Water Works Association ANSI/AWWA C105/A21.5-05 Standard

presented below. The soil characteristics refer to the conditions at and above pipe installation depth.

Table A.1 Soil-test Evaluation [4]

Soil Characteristic / Value	Points
Resistivity	
<1,500 ohm-cm	10
1,500 to 1,800 ohm-cm	8
1,800 to 2,100 ohm-cm	5
2,100 to 2,500 ohm-cm	2
2,500 to 3,000 ohm-cm	1
>3,000 ohm-cm	0
pH	
0 to 2.0	5
2.0 to 4.0	3
4.0 to 6.5	0
6.5 to 7.5	0*
7.5 to 8.5	0
>8.5	3
Redox Potential	
< 0 (negative values)	5
0 to +50 mV	4
+50 to +100 mV	3½
> +100 mV	0
Sulfide Content	
Positive	3½
Trace	2
Negative	0
Moisture	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

If sulfides are present and low or negative redox-potential results (< 50 mV) are obtained, add three points for this range.

We anticipate that drainage at the site after construction will be good. Nevertheless, based on the values obtained for the soil parameters, the overburden soils appear(s) to comprise a highly corrosive environment for metals.

Corrosive conditions can be addressed by use of materials not vulnerable to corrosion, heavier gauge materials with longer design lives, polyethylene encasement, or cathodic protection systems. If additional information or recommendations are needed regarding soil corrosivity, GROUND recommends contacting the American Water Works Association or a Corrosion Engineer. It should be noted, however, that changes to the site conditions during construction, such as the import of other soils, or the intended or unintended introduction of off-site water, may alter corrosion potentials significantly.

SURFACE DRAINAGE

The following drainage precautions should be observed during construction and maintained at all times after the facility has been completed. If the drainage measures below are not implemented and maintained effectively, the movement estimates provided in this report could be exceeded.

1) Wetting or drying of the foundation excavations and under-slab area should be avoided during and after construction, as well as throughout the use of the facilities. Permitting increases/variations in moisture to the supporting soils may result in a decrease in bearing capacity and increase in settlement, heave, and/or differential movement.

2) Positive surface drainage measures should be provided and maintained to reduce water infiltration into foundation soils. The ground surface surrounding the exterior of the buildings should be sloped to drain away from the foundations in all directions. We recommend a minimum slope of 12 inches in the first 10 feet in landscaped areas and 3 inches in the first 10 feet in areas where hardscaping covers the ground adjacent to the addition. (It may be necessary to incorporate ramps or other measures into project design to implement this recommendation while complying with access requirements.) In no case should water be allowed to pond near or adjacent to foundation elements. Ponding may lead to increased infiltration and post-construction building movements.

3) In sloping terrain, it is common to have slopes descending toward buildings. Such slopes can be created during grading even on comparatively flat sites. In such cases, even where the recommendation above regarding slopes adjacent to the building is followed, water will flow to and beneath the building with

resultant additional post-construction movements. Where the final site configuration includes graded or retained slopes descending toward the building, and the toe-of-slope (-wall) is less than 3 times the total slope (wall) height from the building, then an interceptor drain should be installed between the building and the slope. Ideally, the interceptor drain should be installed either about 10 feet from the building or along the axis of a swale between the building and the toe-of-slope (-wall). The actual layout, outlets, etc., of an interceptor should be designed by the Civil Engineer. GROUND can provide more specific geotechnical recommendations for an interceptor drain system upon request.

In addition, where irrigation is applied on or above graded slopes, drainage structures commonly are needed near the toe-of-slope to prevent on-going or recurrent wet conditions there.

4) Drainage measures also should be included in project design to direct water away from sidewalks and other hardscaping as well as utility trench alignments which are likely to be adversely affected by moisture-volume changes in the underlying soils or flow of infiltrating water. Routine maintenance of site drainage should be undertaken throughout the design life of the project.

5) In GROUND's experience, it is common during construction that in areas of partially completed paving or hardscaping, bare soil behind curbs and gutters, and utility trenches, water is allowed to pond after rain or snow-melt events. Wetting of the subgrade can result in loss of subgrade support and increased settlements or heave. By the time final grading has been completed, significant volumes of water can already have entered the subgrade, leading to subsequent distress and failures. The Contractor should maintain effective site drainage throughout construction so that water is directed into appropriate drainage structures.

6) The ground surface near foundation elements should be able to convey water away readily. Ground coverings that direct water downward rather than away from the addition should not be used to cover the ground surface near the foundations or other improvements sensitive to post-construction soil movements. Cobbles or other materials that tend to act as baffles and restrict surface flow should not be used.

Correspondingly, near other project improvements such as hardscaping, where the ground surface does not convey water away readily additional post-construction movements and distress should be anticipated.

7) Roof downspouts and drains should discharge well beyond the perimeters of the structure foundations, or be provided with positive conveyance off-site for collected waters.

8) Landscaping which requires watering should ideally be located 10 or more feet from the building perimeter. Irrigation sprinkler heads should be deployed so that applied water is not introduced into foundation soils. Landscape irrigation should be limited to the minimum quantities necessary to sustain healthy plant growth.

   Use of drip irrigation systems can be beneficial for reducing over-spray beyond planters. Drip irrigation also can be beneficial for reducing the amounts of water introduced to building foundation soils, but only if the total volumes of applied water are controlled with regard to limiting that introduction. Controlling rates of moisture increase beneath the foundations and floors should take higher priority than minimizing landscape plant losses.

   Where plantings are desired within 10 feet of the building, GROUND recommends that the plants be placed in water-tight planters, constructed either in-ground or above-grade, to reduce moisture infiltration in the surrounding subgrade soils. Planters should be provided with positive conveyance well away from the foundation soils or off-site for collected waters.

9) We do not recommend the use of plastic membranes to cover the ground surface near the building without careful consideration of other components of project drainage. Plastic membranes can be beneficial to directing surface waters away from the building and toward drainage structures. However, they effectively preclude evaporation or transpiration of shallow soil moisture. Therefore, soil moisture tends to increase beneath a continuous membrane. Where plastic membranes are used, additional shallow, subsurface drains should be installed. Perforated "weed barrier" membranes, which allow ready evaporation from the underlying soils may be used.

10) Detention ponds commonly are incorporated into drainage design. When a detention ponds fills, the rate of release of the water is controlled and water is retained in the pond for a period of time. Where in-ground storm sewers direct surface water to the pond, the granular pipe bedding also can direct shallow groundwater or infiltrating surface water toward the pond. Thus, detention ponds can become locations of enhanced and concentrated infiltration into the subsurface, leading to wetting of foundation soils in the vicinity with consequent heave or settlement. Therefore, unless the pond is clearly down-gradient from the proposed building and other structures that would be adversely affected by wetting of the subgrade soils, including off-site improvements, GROUND recommends that the detention pond should be provided with an effective, low permeability liner. In addition, cut-off walls and/or drainage provisions should be provided for the bedding materials surrounding storm sewer lines flowing to the pond.

SUBSURFACE MOISTURE INFILTRATION AND DRAINAGE

Common practice for the combination of soil and foundation system proposed for this project includes the installation of perimeter underdrains. As a component of project civil design, properly functioning, subsurface drain systems (underdrains) can provide an added level of protection by draining saturated conditions near building foundations should they arise, and limiting the volume of wetted soil.

As previously mentioned in this report, project design should incorporate measures to prevent water from wetting the project soils. Surface drainage gradients, pavements, flatwork, piping, drainage structures, etc., should be maintained during and after construction to prevent infiltration. Pipes, below-grade drainage structures, etc., should be maintained during and after construction to prevent infiltration.

It is the responsibility of the design team, Ownership, as well as the construction and maintenance Contractor(s) within their respective disciplines, and in accordance with their familiarity with the site conditions, to evaluate the possible sources of water that could affect the project area and provide design and/or construction measures that address the conditions, so that moisture is directed away from the foundations and supporting materials prior to being allowed to infiltrate the subsurface, both during and after construction. Wetting or drying of the foundation excavations and underslab areas should be avoided during and after construction as well as throughout the life of the structure. Permitting increases/variations in moisture to the supporting soils may result in a decrease in bearing capacity and an increase in total and/or differential movements.

GROUND recommends that a perimeter underdrain system should be incorporated in the design and construction of this project for any below grade or partial below grade levels. Depending on final site grades and building design, underdrains may also be necessary for at-grade levels. The perimeter underdrain systems should consist of perforated PVC collection pipe at least 4 inches in diameter, non-perforated PVC discharge pipe at least 4 inches in diameter, free-draining gravel, and filter fabric. The free-draining gravel should contain less than 5 percent passing the No. 200 Sieve and more than 50 percent retained on the No. 4 Sieve, and have a maximum particle size of 2 inches. Each collection pipe should be surrounded on the sides and top only with 6 or more inches of free-draining gravel. The gravel surrounding the collection pipe should be wrapped with filter fabric to reduce the migration of fines into the drain system. Lateral drains may be necessary depending on final design and elevations, especially for below grade (basement) level floor slabs, elevator shafts, etc.

The high point(s) of the drainpipe should be placed at least 12 inches below the bottom of the slabs. The drainpipe for should be graded at a minimum slope of 1 percent to one or more sumps from which water can be removed by pumping, or to an outlet for gravity discharge.

No grading plans were available for our review at the time of preparation of this report. Therefore, the project Civil Engineer, based on final site grades and finished floor elevations, should design the actual layout, outlets, and locations for the underdrain system. A typical cross-section detail of an underdrain, as recommended above, can be provided upon request.

RADON

Radon is a naturally occurring, colorless, odorless, radioactive gas that can cause lung cancer, according to the U.S. Environmental Protection Agency (EPA). The occurrence of radon is difficult to predict, and structures with all types of foundations can be affected by radon build up. Where radon is allowed to concentrate in an enclosed structure represents a potential hazard. It is not a hazard that can be mitigated by geotechnical measures, however.

Testing for the possible presence of radon gas prior to project development does not yield useful results regarding the potential accumulation of radon in completed structures. Radon accumulations most typically are found in basements, crawl spaces or other enclosed portions of buildings built in areas underlain at relatively shallow depths by granitic crystalline rock. The likelihood of encountering radon in concentrations exceeding applicable health standards on the subject site, underlain by relatively deep soils and sedimentary bedrock, is significantly lower, but cannot be excluded. Additional information regarding radon and radon-resistant building design can be obtained from the EPA (e.g., www.epa.gov/radon) as well as from many local building and/or health departments.

GROUND recommends that radon testing be performed in the buildings after construction is completed. However, we understand that incorporating sufficient ventilation and other measures into a structure to address radon accumulation during construction is significantly less costly than installing them after construction has been completed. We recommend that the Architect consider radon mitigative measures for the proposed structure and incorporate appropriate systems into the design.

PROJECT EARTHWORKS

General Considerations We anticipate cuts and fills of limited nominal depth to construct the building pads and hardscape areas, etc. Deeper excavations and backfills will be needed to install utilities and perform remedial earthworks where selected. Site grading should be planned carefully to provide positive surface drainage away from the buildings, and all pavements, utility alignments, and flatwork. Surface diversion features should be provided around paved areas to prevent surface runoff from flowing across the paved surfaces. Site grading should be performed as early as possible in the construction sequence to allow settlement of fills and surcharged ground to be realized to the greatest extent prior to building construction.

Prior to earthwork construction, existing structures, vegetation and other deleterious materials should be removed and disposed of off-site. Relic underground utilities should be abandoned in accordance with applicable regulations, removed as necessary, and capped at the margins of the property.

All remnant structural components resulting from site demolition should be removed in their entirety. It may be possible to recycle portions of these materials for use as fill material. GROUND should be contacted to provide additional recommendations, should use of on-site recycled materials are desired.

The limited volumes of topsoils present in the portions of the site should not be incorporated into ordinary fills. Instead, topsoils should be stockpiled during initial grading operations for placement in areas to be landscaped or for other approved uses.

Areas of previously placed fill soils may be present across the site. These fills should be tested, and as necessary, excavated and replaced with properly moisture - conditioned and compacted fill.

Use of On-Site Materials as Fill Site soils, including both native and existing fill materials, free of organic debris, large cobbles and other deleterious materials are suitable, in general, for placement as fill. Cobbles, boulders and rock fragments larger than 6 inches in maximum dimension will require special handling and/or placement to be incorporated into project fills. In general, such materials should be placed as deeply as possible in the proposed fills. The Geotechnical Engineer should be consulted regarding appropriate recommendations for usage of such materials on a case-by-case basis when such materials have been identified during earthworks. Standard recommendations that likely will be generally applicable can be found in Section 203 of the CDOT Standard Specifications for Road and Bridge Construction (2005).

Imported Fill Materials If it is necessary to import material to the site as fill, the imported soils should contain no boulders, cobbles or rock fragments coarser than 6 inches in maximum dimension, be free of claystone, organic material, and other deleterious materials. Imported material should have less than 60 percent passing the No. 200 Sieve and should have a plasticity index of less than 15.

Fill Platform Preparation Prior to filling, the top 8 to 12 inches of in-place materials on which fill soils will be placed should be scarified, moisture conditioned and properly compacted to provide a uniform base for fill placement. Soils that classify as GP, GW, GM, GC, SP, SW, SM, or SC in accordance with the USCS classification system (granular materials) should be compacted to 95 or more percent of the maximum modified Proctor dry density at moisture contents within 2 percent of optimum moisture content as determined by ASTM D1557, the "modified Proctor." Soils that classify as ML, MH, CL or CH should be compacted to 95 percent of the maximum standard Proctor density at moisture contents from 1 percent below to 3 percent above the optimum moisture content as determined by ASTM D698, the "standard Proctor."

If surfaces to receive fill expose loose, wet, soft or otherwise deleterious material, additional material should be excavated, or other measures taken, to establish a firm platform for filling. The surfaces to receive fill must be effectively stable prior to placement of fill.

Because of the elevated moisture contents encountered at the site at shallow depths, the Contractor should anticipate an unstable subgrade that may require stabilization prior to fill placement. The actual methods to achieve a stable platform for filling and compaction should be determined by the Contractor based on the conditions encountered during grading operations. Suitable methods may include deeper excavation and placement of materials at lower moisture contents as fill, use of a stabilization geo-textile and/or use of a coarse aggregate as a stabilization fill.

Fill Placement Fill materials should be thoroughly mixed to achieve a uniform moisture content, placed in uniform lifts not exceeding 8 inches in loose thickness, and compacted in accordance with the recommendations above. No fill materials should be placed, worked, rolled while they are frozen, thawing, or during poor/inclement weather conditions.

Care should be taken with regard to achieving and maintaining proper moisture contents during placement and compaction. We anticipate that some on-site soils may exhibit significant pumping, rutting, and deflection at moisture contents near optimum and above. In addition to local plastic soils, some excavated soils likely will classify as non-plastic to slightly plastic silty sands or silts. In our experience, achieving and maintaining compaction in such soils can be very difficult, particularly if water contents are not monitored closely. The Contractor should be prepared to handle soils of this type, including the use of chemical stabilization, if necessary.

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.

To achieve adequate compaction near the outer faces of fill slopes, it may be beneficial to over-build the slopes and trim them back.

Use of Squeegee Relatively uniformly graded fine gravel or coarse sand, i.e., "squeegee," or similar materials commonly are proposed for backfilling foundation excavations, portions of utility trenches and other areas where employing compaction equipment is difficult. In general, GROUND does not recommend this procedure for the following reasons:

> Although commonly considered "self compacting," uniformly graded granular materials require densification after placement, typically by vibration. The equipment to densify these materials is not available on many job-sites.
>
> Even when properly densified, uniformly graded granular materials are permeable and allow water to reach and collect in the lower portions of the excavations backfilled with those materials. This leads to wetting of the underlying soils and resultant potential loss of bearing support as well as increased local heave or settlement.

GROUND recommends that wherever possible, excavations be backfilled with approved, on-site soils placed as properly compacted fill. Where this is not feasible, use of "Controlled Low Strength Material" (CLSM), i.e., a lean, sand-cement slurry ("flowable fill") or a similar material for backfilling should be considered.

Where "squeegee" or similar materials are proposed for use by the Contractor, the design team should be notified by means of a Request for Information (RFI), so that the proposed use can be considered on a case-by-case basis.

Quality Assurance A Geotechnical Engineer should be retained to observe project excavations prior to placement of fill. The Geotechnical Engineer also should be retained to observe earthwork operations and test the soils. The Geotechnical Engineer should provide a written declaration stating that the project site, including the building pad area, was filled with acceptable materials and was placed in general accordance with the requirements outlined in this report or otherwise specified for the project.

It should be noted that in the later stages of projects such as construction of the proposed facility, multiple sub-contractors commonly are installing or adjusting/replacing components of the project simultaneously. These can include utility laterals, electrical boxes, sidewalk access ramps, lighting fixtures and other components. In order to facilitate proper observation and testing of the associated earthworks, GROUND recommends that the Contractor verify that his sub-contractors mobilize the necessary equipment and personnel to moisture-condition and compact disturbed or excavated soils effectively. The Contractor also should coordinate with his sub-contractors to ensure that these local earthwork operations are observed with sufficient frequency, and the soils tested, by the Geotechnical Engineer.

Settlements Settlements will occur in filled ground, typically on the order of 1 to 2 percent of the fill depth. For a 3-foot fill, this corresponds to settlement on the order of ½ inch, without imposition of foundation loads. If fill placement is performed properly and is tightly controlled, in GROUND's experience the majority of that settlement will take place during earthwork construction. The remaining potential settlements likely will take several months or longer, to be realized.

Cut and Filled Slopes Permanent site slopes supported by on-site soils up to 8 feet in height may be constructed no steeper than 3:1 (horizontal : vertical). Minor raveling or surficial sloughing should be anticipated on slopes cut at this angle until vegetation is well re-established. Surface drainage should be designed to direct water away from slope faces.

EXCAVATION CONSIDERATIONS

Test holes for subsurface exploration were advanced to the depths indicated on the test hole logs by means of truck-mounted, flight auger equipment. We anticipate no unusual excavation difficulties, in general, for the proposed construction in these materials with conventional, heavy-duty excavating equipment in good working condition. However, cobbles and boulders may be encountered in the alluvial deposits in the project setting, with resultant excavation difficulties. The Contractor should anticipate such material and be prepared to install deep foundations, excavate, handle, and process them.

Groundwater was encountered during subsurface exploration at depths as shallow as 14 feet. Based on the likely depths of earthworking and construction, groundwater is not anticipated to be a significant factor for shallow earthworks during construction of this project, although the Contractors should anticipate elevated moisture contents in the subsurface soils in various areas of the project excavations. Groundwater will be encountered in deep utility installations and deep foundation construction, however.

If seepage or groundwater is encountered in shallow project excavations, the Geotechnical Engineer should evaluate the conditions and provided additional recommendations, as appropriate.

We recommend that temporary, un-shored excavation slopes up to 10 feet in height be cut no steeper than 2 :1 (horizontal : vertical) in the sandy site soils in the absence of seepage. Significant sloughing on the slope faces should be anticipated at this angle due to the cohesionless nature of some of the project soils. Local conditions encountered during construction, such as groundwater seepage, or soft, wet materials, etc., will require flatter slopes. Stockpiling of materials should not be permitted closer to the tops of temporary slopes than 5 feet or a distance equal to the depth of the excavation, which ever is greater.

Should site constraints prohibit the use of the recommended slope angles, then temporary shoring should be used. A registered engineer should design actual shoring system(s) for the Contractor.

Good surface drainage should be provided around temporary excavation slopes to direct surface runoff away from the slope faces. A properly designed drainage swale should be provided at the top of the excavations. In no case should water be allowed to pond at the site. Slopes should also be protected against erosion. Erosion along the slopes will result in sloughing and could lead to a slope failure.

Excavations in which personnel will be working must comply with all OSHA Standards and Regulations. Project excavations and shoring should be observed regularly by the Geotechnical Engineer throughout construction operations. The Contractor's "responsible person" should evaluate the soil exposed in the excavations as part of the Contractor's safety procedures. GROUND has provided the information above solely as a service to *City of Grand Junction*, and is not assuming responsibility for construction site safety or the Contractor's activities.

UTILITY INSTALLATION

Recommendations regarding utility trench excavation are provided in the *Excavation Considerations* section of this report. On-site soils excavated from trenches are suitable, in general, for use as trench backfill. Backfill soils should be free of vegetation, debris, trash and other deleterious materials. Cobbles and non-expansive rock fragments coarser than 6 inches in maximum dimension should not be incorporated into trench backfills.

Pipe bedding materials, placement and compaction should meet the specifications of the pipe manufacturer and applicable municipal standards. Some of the excavated, on-site sands and gravels may be suitable, with processing, for use where relatively free-draining bedding materials are called for. Materials proposed for use as pipe bedding should be tested for suitability prior to use. Imported materials should be tested and approved by the Geotechnical Engineer prior to transport to the site. Bedding should be brought up uniformly on both sides of the pipe to reduce differential loadings.

Trench backfill materials above the pipe-bedding zone should be conditioned to a uniform moisture content, placed in uniform lifts not exceeding 6 inches in loose thickness, and properly compacted. Recommendations for fill placement and compaction are presented in the Project Earthworks section of this report.

The Contractor should take adequate measures to achieve adequate compaction in the utility trench backfills, particularly in the lower portions of the excavations. Some settlement of trench backfill materials should be anticipated, even where materials are placed and compacted correctly. The Contractor also should take particular care to achieve and maintain adequate compaction of the backfill soils around manholes, valve risers and other vertical pipeline elements where greater settlements commonly are observed. Use of "controlled low strength material" (CLSM), i.e., a lean, sand-cement slurry, "flowable fill," or similar material should be considered in lieu of compacted soil backfill for areas with low tolerances for surface settlements. Placement of flowable fill in the lower portions of the excavations and around risers, etc., likely will yield a superior backfill, although at an increased cost.

We assume that surface drainage will direct water away from trench alignments. Nevertheless, GROUND recommends that non-woven filter fabric (e.g., Mirafi® 140N, or the equivalent) should be placed around the granular bedding materials to reduce migration of fines into the bedding which can result in severe, local settlements. Where this protection is not provided, severe settlements can result as much as several months or years after construction is completed, even where backfill soils have be compacted properly.

Development of site grading plans should consider the subsurface transfer of water in utility trenches and the pipe bedding. Sandy pipe bedding materials can function as efficient conduits for re-distribution of natural and applied waters in the subsurface. Cut-off walls in utility trenches or other water-stopping measures should be implemented to reduce the rates and volumes of water transmitted along utility alignments and toward buildings, pavements and other structures where excessive wetting of the underlying soils will be damaging. Incorporation of water cut-offs and/or outlet mechanisms for saturated bedding materials into development plans could be beneficial to the project. These measures also will reduce the risk of loss of fine-grained backfill soils into the bedding material with resultant surface settlement.

PAVEMENT SECTIONS

A pavement section is a layered system designed to distribute concentrated traffic loads to the subgrade. Performance of the pavement structure is directly related to the physical properties of the subgrade soils and traffic loadings. Because the project pavements will be privately maintained, the recommended pavement sections 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 local construction practice.

Subgrade Materials Based on the results of our field and laboratory studies, subgrade materials in the proposed pavement areas consisted predominantly of low to moderately plastic clays. These materials were classified typically as A-4 and A-6 soils in accordance with the AASHTO classification system with a group index values from about 0 to 25.

Resilient Modulus (M_R) testing (AASHTO T-307) was performed on a representative composite sample of the subgrade materials encountered at the site. Typically, the R-value, unconfined compressive strength, California Bearing Ratio (CBR), or other index properties of subgrade materials have been obtained and the resilient modulus obtained only by correlation. However, due to the variability in the correlations, subjecting representative samples of the subgrade to the actual resilient modulus testing is the most accurate way to determine soil support characteristics for development of pavement sections.

A dynamic load test, the resilient modulus measures the elastic rebound stiffness of flexible pavement materials, base courses and subgrades under repeated loading. The loading cycles were applied under various confining and deviatoric stresses. The material was compacted to 95 percent of maximum dry density at optimum moisture content, and at 2 percent and 4 percent above the optimum, based on AASHTO T-99 (the "standard Proctor") for cohesive soils, or AASHTO T-180 (the "modified Proctor") for granular soils.

The resilient modulus at 2 percentage points above the optimum moisture content is typically used for fine-grained soils. Therefore, for the clayey subgrade materials, a resilient 3,980 psi obtained at 2 percent above optimum moisture content was used to develop the pavement sections.

It is important to note that significant decreases in soil support as quantified by the resilient modulus have been observed as the moisture content increases above the optimum. Therefore, pavements that are not properly drained may experience a loss of the soil support and subsequent reduction in pavement life.

Anticipated Traffic Specific traffic loadings were provided by the draft City of Grand Junction Public Safety – Justice Building and Fire Station #1 Traffic Impact Study submitted by Jacobs dated October 2008. Based on the information provided in that report regarding current traffic loads and projected traffic loads, a design EDLA of 10 was calculated for parking areas and 30 was calculated for project roadways. The EDLA values of 10 and 30 were converted to equivalent 18-kip single-axle load (ESAL) values of 109,768 and 328,412 respectively, for 30-year design lives. An EDLA of 30, corresponding to an ESAL value of 460,048, was calculated for primary heavy vehicle routes including bus routes, fire truck lanes, trash collection areas, loading/unloading zones, and other areas subject to heavier traffic including large trucks where rigid pavements are to be placed. If design traffic loadings differ significantly from these assumed values, GROUND should be notified to re-evaluate the pavement recommendations below.

Pavement Sections The soil resilient modulus and the anticipated ESAL values were used to determine the required structural number for the project pavements. The required structural number was then used to develop recommended pavement sections. Pavement sections were based on the DARWin™ computer program that solves the 1993 AASHTO pavement design equation. Pavement section parameters and calculations are summarized in *Appendix B*. A Reliability Level of 85 percent was utilized for development of the pavement sections. Structural coefficients of 0.44 and 0.12 were used for hot bituminous asphalt and high quality aggregate base course, respectively. The minimum pavement sections recommended by GROUND are tabulated below.

Recommended Minimum Pavement Sections

Location	***Full Depth Asphalt*** *(inches Asphalt)*	***Composite Section**** *(inches Asphalt / inches Aggregate Base)*
Project Roadways / Drivelanes	7.5	5.5 / 8.0
Parking Areas	6.5	4.5 / 8.0
Heavy Vehicle Traffic & High Turning Stresses	6 inches of Portland cement concrete over 6 inches of aggregate base	

We recommend that primary truck routes serving the facility such as the fire station aprons, shipping / receiving routes, material storage and distribution areas, loading/unloading docks, and trash collection zones, as well as other pavement areas subjected to high turning stresses or heavy truck traffic be provided with rigid pavements consisting of 6 or more inches of Portland cement concrete placed over a minimum of 6-inches of properly compacted aggregate base.

Asphalt pavement should consist of a bituminous plant mix composed of a mixture of aggregate and bituminous material. Asphalt mixture(s) should meet the requirements of a job-mix formula established by a qualified engineer.

Concrete pavements should consist of a plant mix composed of a mixture of aggregate, Portland cement and appropriate admixtures meeting the requirements of a job-mix formula established by a qualified engineer. Concrete should have a minimum modulus of rupture of third point loading of 650 psi. Normally, concrete with a 28-day compressive strength of 4,500 psi should develop this modulus of rupture value. The concrete should be air-entrained with approximately 6 percent air and should have minimum cement content of 6.5 sacks per cubic yard. Maximum allowable slump should be 4 inches.

The concrete pavement should contain sawed or formed joints. In areas of repeated turning stresses we recommend that the concrete pavement joints be fully tied and doweled. We suggest that civil design consider joint layout in accordance with CDOT's M standards. Standard plans for placement of ties and dowels, etc., (CDOT M Standards) for concrete pavements can be found at the CDOT website: http://www.dot.state.co.us/DesignSupport/.

Where composite flexible sections are placed or if aggregate base course is placed beneath a concrete pavement, the aggregate base material should meet the criteria of CDOT Class 6 aggregate base course. Base course should be placed in uniform lifts not exceeding 8 inches in loose thickness and compacted to at least 95 percent of the maximum dry density a uniform moisture contents within 3 percent of the optimum as determined by ASTM D1557 / AASHTO T-180, the "modified Proctor."

Subgrade Preparation Shortly before placement of pavement, including aggregate base, the exposed subgrade soils should be scarified to a depth of 12 inches, mixed to achieve a uniform moisture content and then re-compacted. Subgrade preparation should extend the full width of the pavement from back-of-curb to back-of-curb.

Shortly before placement of pavement, including aggregate base, the exposed subgrade soils should be scarified to a depth of 12 inches, mixed to achieve a uniform moisture content and then re-compacted. Subgrade preparation should extend the full width of the pavement from back-of-curb to back-of-curb.

Due to the variable density of the potential subgrade soils, some post-construction movements of the pavements should be anticipated. A greater depth of excavation and replacement may result in improved pavement performance over its design life. Recommendations in this regard can be provided upon request.

The Contractor should be prepared either to dry the subgrade materials or moisten them, as needed, prior to compaction. Many site soils likely will "pump" or deflect during compaction if moisture levels are not carefully controlled.

Where adequate drainage cannot be achieved or maintained, a greater depth of excavation and replacement is recommended, in addition to the edge drains recommended below.

Even on a prepared subgrade, pavement performance commonly is poor on materials such as the moderately plastic A-6 soils comprising much of the pavement subgrade soils. Some post-construction movements should be anticipated. Where water is allowed to enter the pavement subgrade, movements will occur. Greater depths of fill beneath the pavements, such as 2 or 3 feet, will result in improved pavement performance over its design life but not eliminate the potential for movements. Recommendations in this regard can be provided upon request. This is also true for curbs and gutters, sidewalks, and other hardscaping.

Proof Rolling Immediately prior to paving, the subgrade should be proof rolled with a heavily loaded, pneumatic tired vehicle. Areas that show excessive deflection during proof rolling should be excavated and replaced and stabilized. Areas allowed to pond prior to paving will require significant re-working prior to proof-rolling. Passing proof-rolling is an additional requirement for pavement subgrade soils; it may be possible for soils to be compacted within the limits indicated in the Project Earthworks section of this report and fail proof rolling, particularly in the upper range of recommended moisture contents.

Additional Observations The collection and diversion of surface drainage away from paved areas is extremely important to satisfactory performance of the pavement. The subsurface and surface drainage systems should be carefully designed to ensure removal of the water from paved areas and subgrade soils. 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. The long-term performance of the pavement also can be improved greatly by proper backfilling and compaction behind curb, gutter, and sidewalk. Unless the interceptor drain and edge drains (where included) are installed properly and maintained, and site drainage in general is well maintained, there is an increased risk of poor pavement performance at this site due to the expansive subgrade materials and the local introduction of off-site irrigation water.

Landscape irrigation in planters adjacent to pavements and in "island" planters within paved areas should be carefully controlled or differential heave and/or rutting of the nearby pavements will result. Drip irrigation systems are recommended for such planters to reduce over-spray and water infiltration beyond the planters. Enclosing the soil in the planters with plastic liners and providing them with positive drainage also will reduce differential moisture increases in the surrounding subgrade soils. In our experience, infiltration from planters adjacent to pavements is a principal source of moisture increase beneath those pavements. This wetting of the subgrade soils from infiltrating irrigation commonly leads to loss of subgrade support for the pavement with resultant accelerating distress, loss of pavement life and increased maintenance costs. This is particularly the case in the later stages of project construction after landscaping has been emplaced but heavy construction traffic has not ended. Heavy vehicle traffic over wetted subgrade commonly results in rutting and pushing of flexible pavements, and cracking of rigid pavements. Where the subgrade soils are expansive, wetting also typically results in increased pavement heave. In relatively flat areas where design drainage gradients necessarily are small, subgrade settlement or heave can obstruct proper drainage and yield increased infiltration, exaggerated distress, etc.

Also, GROUND's experience indicates that longitudinal cracking is common in asphalt-pavements generally parallel to the interface between the asphalt and concrete structures such as curbs, gutters or drain pans. This of this type is likely to occur even where the subgrade has been prepared properly and the asphalt has been compacted properly.

The anticipated traffic loading does not include excess loading conditions imposed by heavy construction vehicles. Consequently, heavily loaded concrete, lumber, and building material trucks can have a detrimental effect on the pavement. GROUND recommends that an effective program of regular maintenance be developed and implemented to seal cracks, repair distressed areas, and perform thin overlays throughout the life of the pavement. In areas where the maintenance traffic is turning, concrete pavement is recommended.

EXTERIOR FLATWORK

Proper design, drainage, construction and maintenance of the areas between individual buildings and hardscape areas are critical to the satisfactory performance of the project. Sidewalks, entranceway slabs and roofs, fountains, raised planters and other highly visible improvements commonly are installed within these zones, and distress in or near these improvements is common. Commonly, proper soil preparation in these areas receives little attention during overlot construction because they fall between the building and pavement areas, which typically are built with heavy equipment. Multiple sub-contractors, with light or hand equipment, often perform subsequent landscaping and hardscape installation. This results in necessary over-excavation and soil processing and compaction not being performed. Consequently, subgrade soil conditions commonly deviate significantly from recommended ranges. Therefore, GROUND recommends that the Contractor take particular care with regard to proper subgrade preparation in the immediate building exteriors.

As recommended in the *Project Earthworks* and *Surface Drainage* sections of this report, positive surface drainage away from all pavements and flatwork should be included in project design. Proper drainage also should be maintained after completion of the project, and re-established as necessary.

Exterior flatwork and other hardscaping placed on the clayey/silty soils encountered on-site likely will experience post-construction movements due to the both the expansive and collapsible nature of those soils. Both vertical and lateral soil movements can be anticipated as the site soils are wetted and dried. Distress to rigid hardscaping likely will result and should be anticipated.

The most positive means to reduce distress to these elements is to support them on deep foundations in the same manner as the buildings. Other mitigative measures could include casting flatwork over a 12-inch or thicker void form and pinning the flatwork to the building grade beams, or development of an accelerated maintenance and replacement schedule, anticipating post-construction movements and distress.

Where deep foundations are not utilized to support exterior improvements, the following measures will help to reduce damages to these improvements.

1) Shortly before installation, the subgrade soils beneath project sidewalks, paved entryways and patios, masonry planters and short, decorative walls, and other flatwork should be excavated and/or scarified to a depth of 12 or more inches. The excavated soil should be replaced as properly moisture-conditioned and compacted fill as outlined in the Project Earthworks section of this report, in order to reduce the magnitude of potential movements. Greater depths of moisture-density conditioning of the subgrade soils beyond the above minimum, as indicated for the pavements, will improve hardscape performance.

2) Prior to placement of flatwork, a proof roll should be performed to identify areas that exhibit instability and deflection. The deleterious soils in these areas should be removed and replaced with properly compacted fill. The Contractor should take care to achieve and maintain compaction behind curbs to reduce differential sidewalk settlements. As in the case of pavements, passing a proof roll is an additional requirement to placing and compacting the subgrade fill soils within the recommended ranges of moisture content and relative compaction presented in the *Project Earthworks* section of this report.

3) Flatwork should be provided with control joints extending to an effective depth and spaced no more than 10 feet apart, both ways. Narrow flatwork, such as sidewalks, likely will require more closely spaced joints.

4) In no case should exterior flatwork extend to under any portion of the building where there is less than 2 inches of clearance between the flatwork and any element of the building. Exterior flatwork in contact with brick, rock facades, or any other element of the building can cause damage to the structure if the flatwork experiences movements.

Frost and Ice Considerations Nearly all soils other than relatively coarse, clean, granular materials are susceptible to loss of density if allowed to become saturated and exposed to freezing temperatures and repeated freeze – thaw cycling. The formation of ice in the underlying soils can result in heaving of pavements, flatwork and other hardscaping ("frost heave") in sustained cold weather up to 2 inches or more. This heaving can develop relatively rapidly. Much of this movement typically is recovered when the soils thaw, but due to loss of soil density, some degree of displacement commonly will remain. This can result even where the subgrade soils were prepared properly.

Where hardscape movements are a design concern, e.g., at doorways, replacement of the subgrade soils with 3 or more feet of clean, coarse sand or gravel should be considered or supporting the element on foundations similar to the building and spanning over a void. Detailed recommendations in this regard can be provided upon request. It should be noted that where such open graded granular soils are placed, water can infiltrate and accumulate in the subsurface relatively easily, which can lead to increased settlement or heave from factors unrelated to ice formation. The relative risks from these soil conditions should be taken into consideration where frost heave is a concern. GROUND will be available to discuss these concerns upon request.

Where soils supporting foundations or on which foundation will be placed are exposed to these conditions during construction – commonly due to water ponding in foundation excavations – bearing capacity typically is reduced and/or settlements increased due to the loss of density in the supporting soils. After periods of freezing conditions, the Contractor should re-work areas affected by the formation of ice to re-establish adequate bearing support.

The site soils include low plasticity silts as well as some clays and fine sands that due to their capillarity appear vulnerable to frost heave where an underlying source of water is present. Groundwater was not encountered to the depths explored, however. Therefore, if surface drainage is effective, the likelihood of movement of pavements, flatwork and other hardscaping is relatively low. However, if other source(s) of water develop and are not drained effectively, frost heave may develop.

Concrete Scaling Surface scaling of sidewalks and other exterior concrete can result from poor workmanship during construction, such as 'over-finishing' the surface. It also can result from exposure to relatively severe weather conditions with repeated freeze-thaw cycles. In GROUND's experience, if reducing the potential for freeze-thaw scaling is a design consideration, the following measures are beneficial: a) maintaining a maximum water/cement ratio of 0.45 by weight for exterior concrete, b) including Type F fly ash in the mix for exterior concrete as 20 percent of the cementitious material, and c) use of exterior concrete that exhibits a minimum compressive strength of 4,500 psi. Inclusion of 'fibermesh' in the concrete mix also may be beneficial for reducing surficial scaling. (These concrete mix design criteria should be coordinated with other project requirements including the criteria for sulfate resistance presented in the *Water-Soluble Sulfates* section of this report.) In addition, the use of de-icing salts on exterior concrete flatwork during the first winter after construction will increase the likelihood of the development of scaling. Placement of flatwork concrete during cold weather so that it is exposed to freeze-thaw cycling before it is fully cured also increases its vulnerability to scaling. Concrete placing during cold weather conditions should be blanketed or tented to allow full curing. Depending on the weather conditions, this may result in 3 to 4 weeks of curing, and possibly more.

CLOSURE

Geotechnical Review The poor performance of many pavements, foundations and subsurface structures has been directly attributed to inadequate geotechnical review and earthwork quality control. Therefore, project plans and specifications should be reviewed by the Geotechnical Engineer to evaluate whether they comply with the intent of the recommendations in this report. This review should be reported in writing.

Project earthwork construction operations should be observed by the Geotechnical Engineer. All excavations should be observed by the Geotechnical Engineer prior to placement of fill or backfill soils, installation of shoring, or foundation construction. Placement of fill/backfill soils should be observed by the Geotechnical Engineer, and the soils tested.

The geotechnical recommendations presented in this report are highly contingent upon observation and testing of project earthworks by representatives of GROUND. If another geotechnical consultant is selected to provide construction observation and quality control, then that consultant must assume all responsibility for the geotechnical aspects of the project by concurring in writing with the recommendations in this report, or by providing alternative recommendations.

Limitations This report has been prepared for the *City of Grand Junction*, as it pertains to design of the subject project as described herein. It may not contain sufficient information for other parties or other purposes. In addition, GROUND has assumed that project construction will commence by Winter, 2010. Changes in project plans or schedule should be brought to the attention of the Geotechnical Engineer, in order that the geotechnical recommendations may be re-evaluated and, as necessary, modified.

The geotechnical conclusions and recommendations in this report relied upon subsurface exploration at a limited number of exploration points, as shown in Figures 1A and 1B. Subsurface conditions were interpolated between and extrapolated beyond these locations. Findings were dependent on the limited amount of direct evidence obtained at the time of this geotechnical evaluation. Our recommendations were developed for site conditions as described above. Actual conditions exposed during construction may be anticipated to differ, somewhat, from those encountered during site exploration. Moreover, additional test holes must be drilled after site demolition is complete to provide additional information.

If during construction, surface, soil, bedrock, or groundwater conditions appear to be at variance with those described herein, the Geotechnical Engineer should be advised at once, so that re-evaluation of the recommendations may be made in a timely manner.

The recommendations presented in this report are based on the current state-of-the-art for improvements placed on expansive or collapsible earth materials. The Owner should be aware that there is a risk in construction on these types of soils. Performance of the proposed structures and pavement will depend on implementation of the recommendations in this report and on proper maintenance after construction is completed. Because water is the principal cause of volume change in expansive soils and rock, it is necessary that the changes in moisture content be kept to a minimum. Any indications of distress to project installations should be brought to the attention of a Geotechnical Engineer in a timely manner.

This report was prepared in accordance with generally accepted soil and foundation engineering practice in the Grand Junction, Colorado, area, at the date of preparation. GROUND makes no other warranties, either express or implied, as to the professional data, opinions or recommendations contained herein.

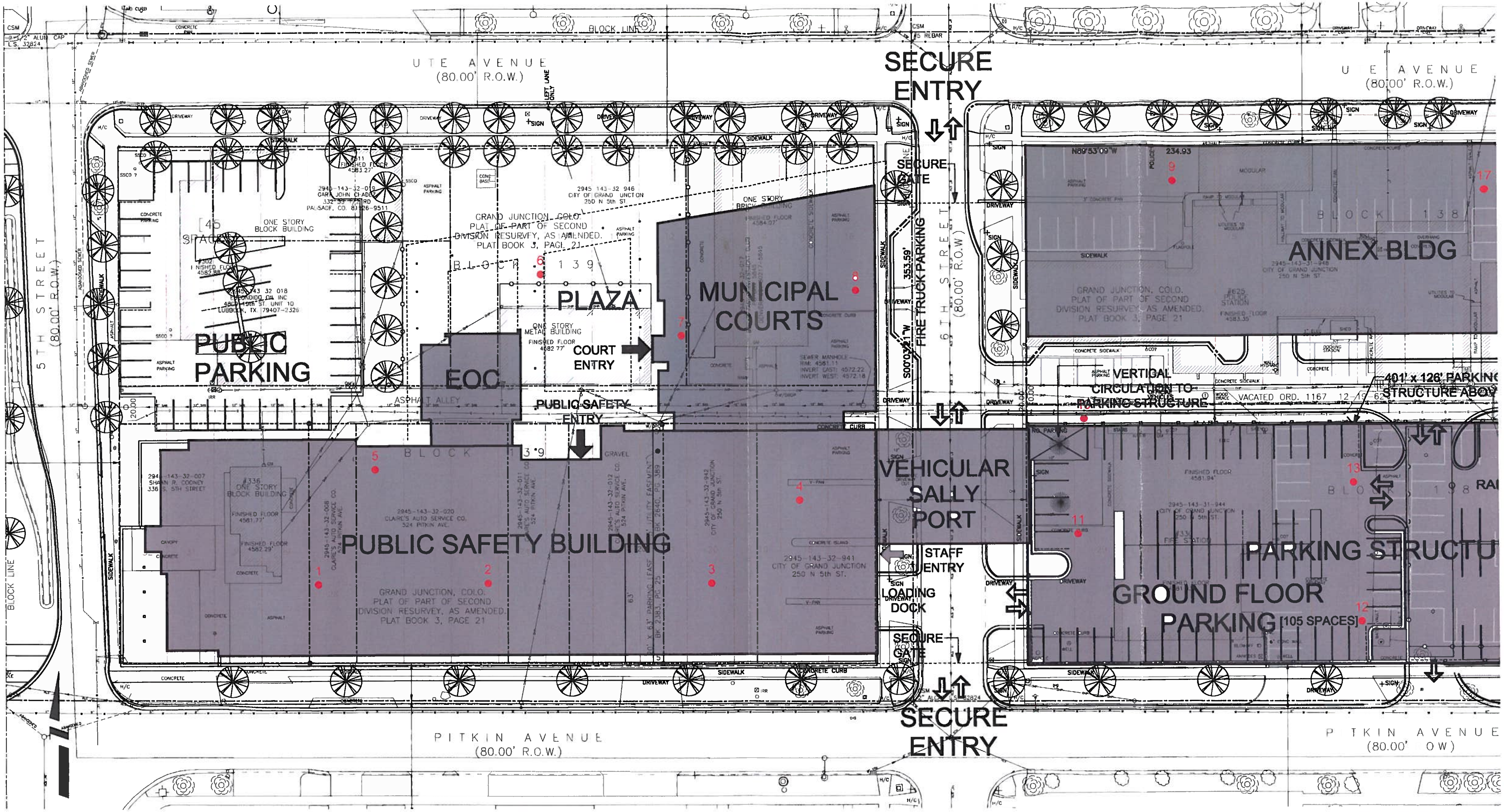
Sincerely,

GROUND Engineering Consultants, Inc.

COLORADO REGISTERED
MICHAEL K. WARINER
39422
PROFESSIONAL ENGINEER
11/4/08

Michael K. Wariner, P.E.

Reviewed by James B. Kowalsky, P.E.



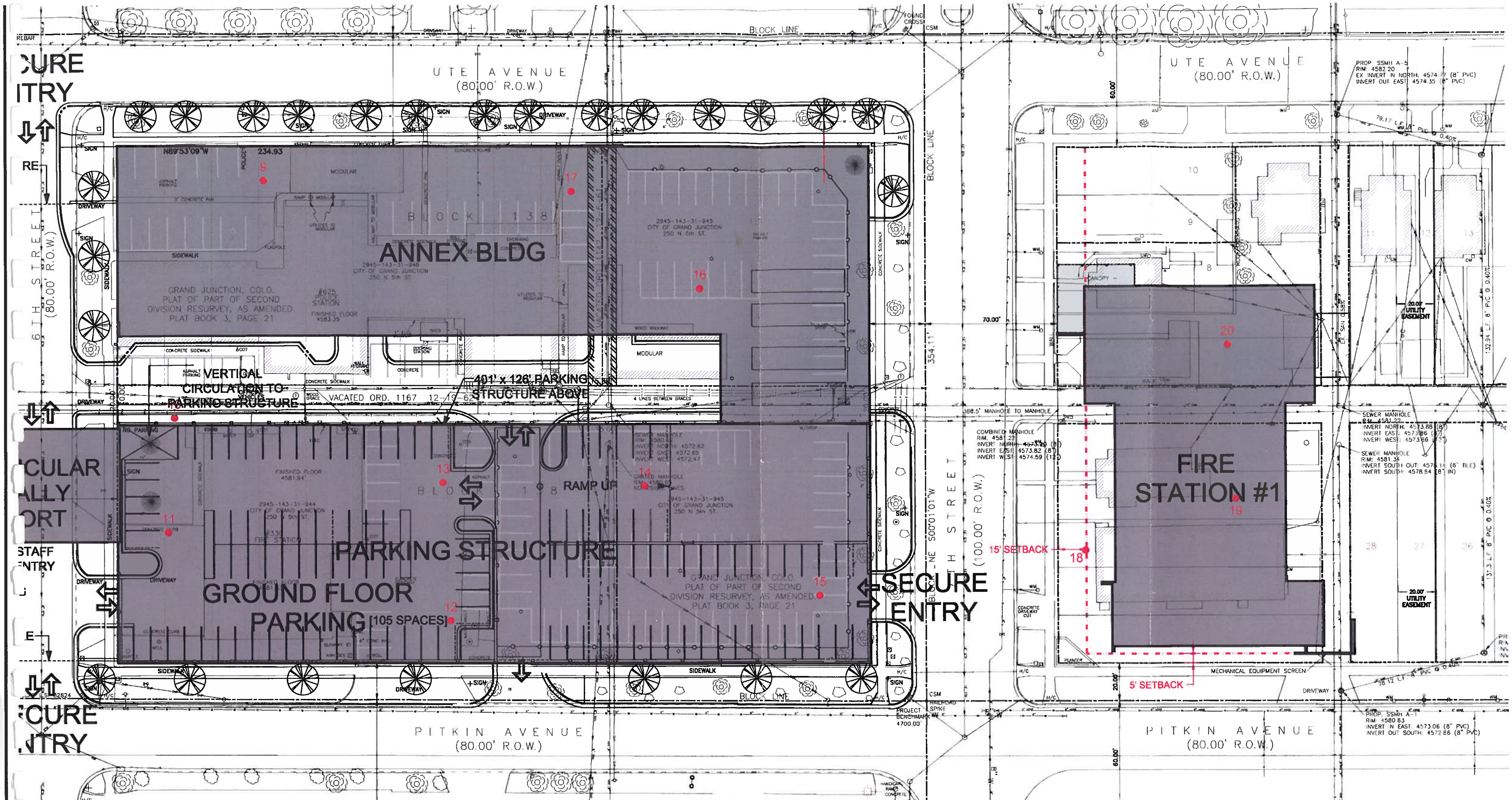
1 ● Indicates test hole number and approximate location.

(Not to Scale)

GROUND ENGINEERING CONSULTANTS

LOCATION OF TEST HOLES

JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 1A	APPROVED BY: JK
CADFILE NAME: 6037SITE.DWG	



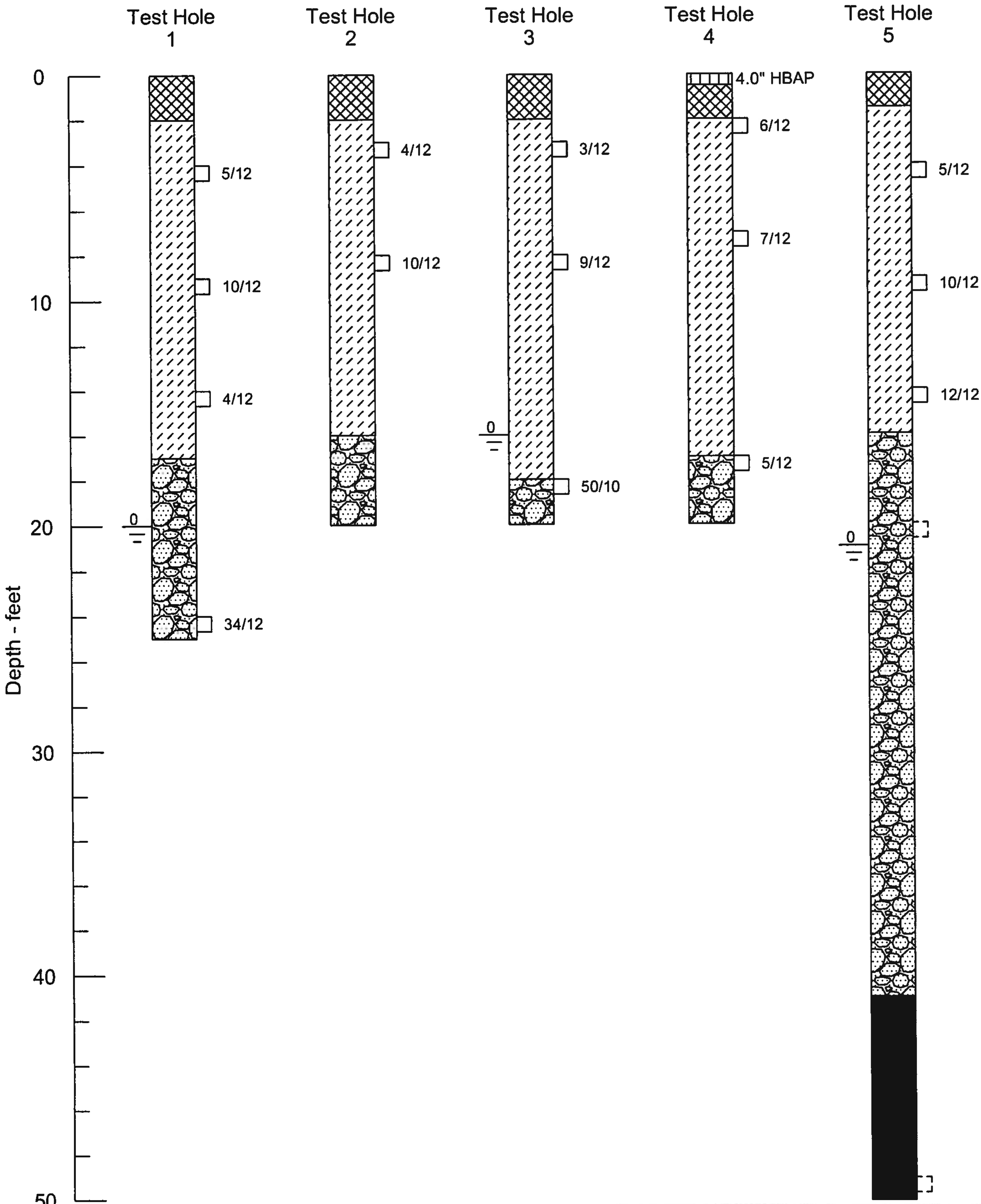
1
● Indicates test hole number and approximate location.

(Not to Scale)

GROUND
ENGINEERING CONSULTANTS

LOCATION OF TEST HOLES

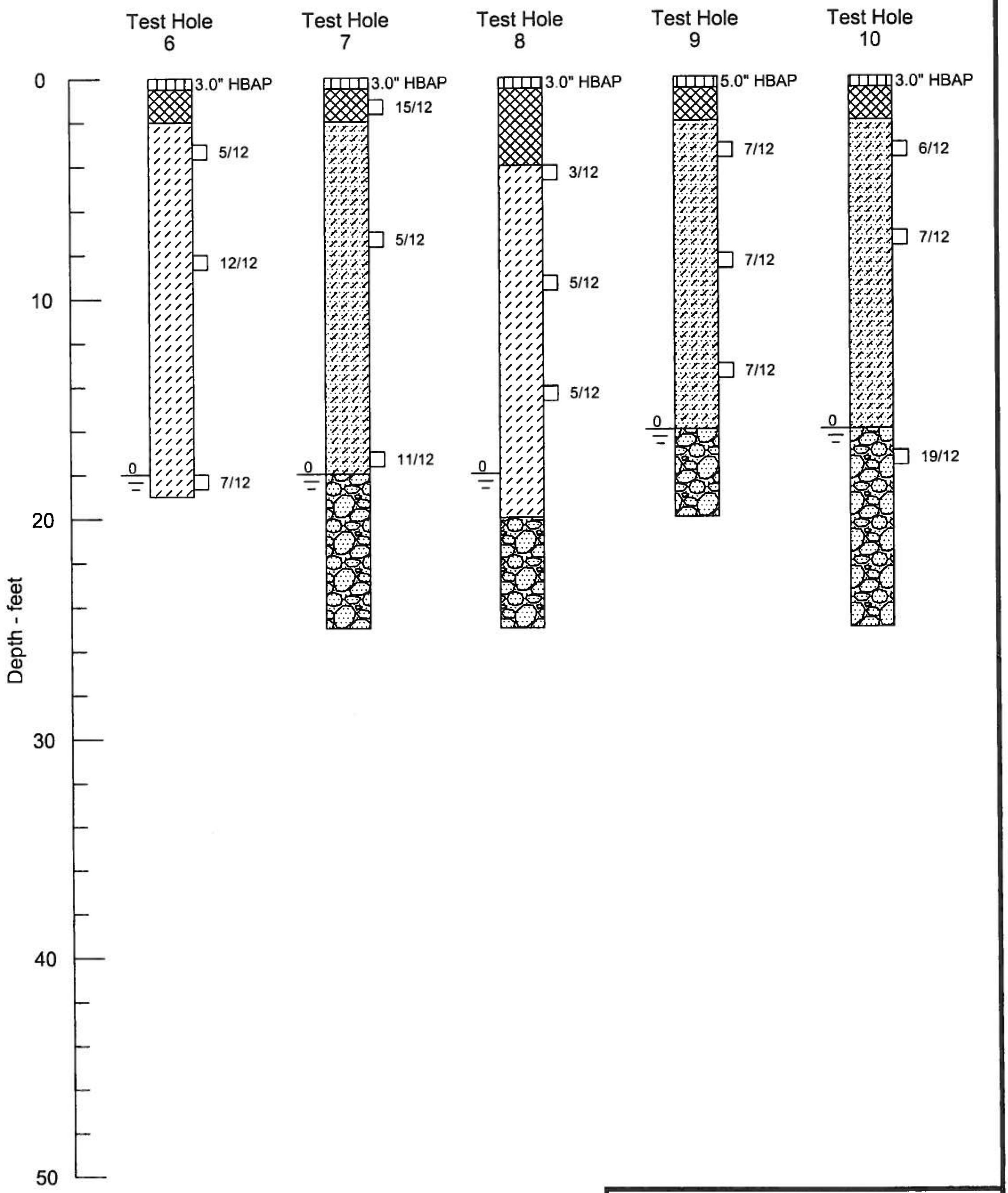
JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 1B	APPROVED BY: JK
CADFILE NAME: 6037SITE.DWG	



GROUND ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

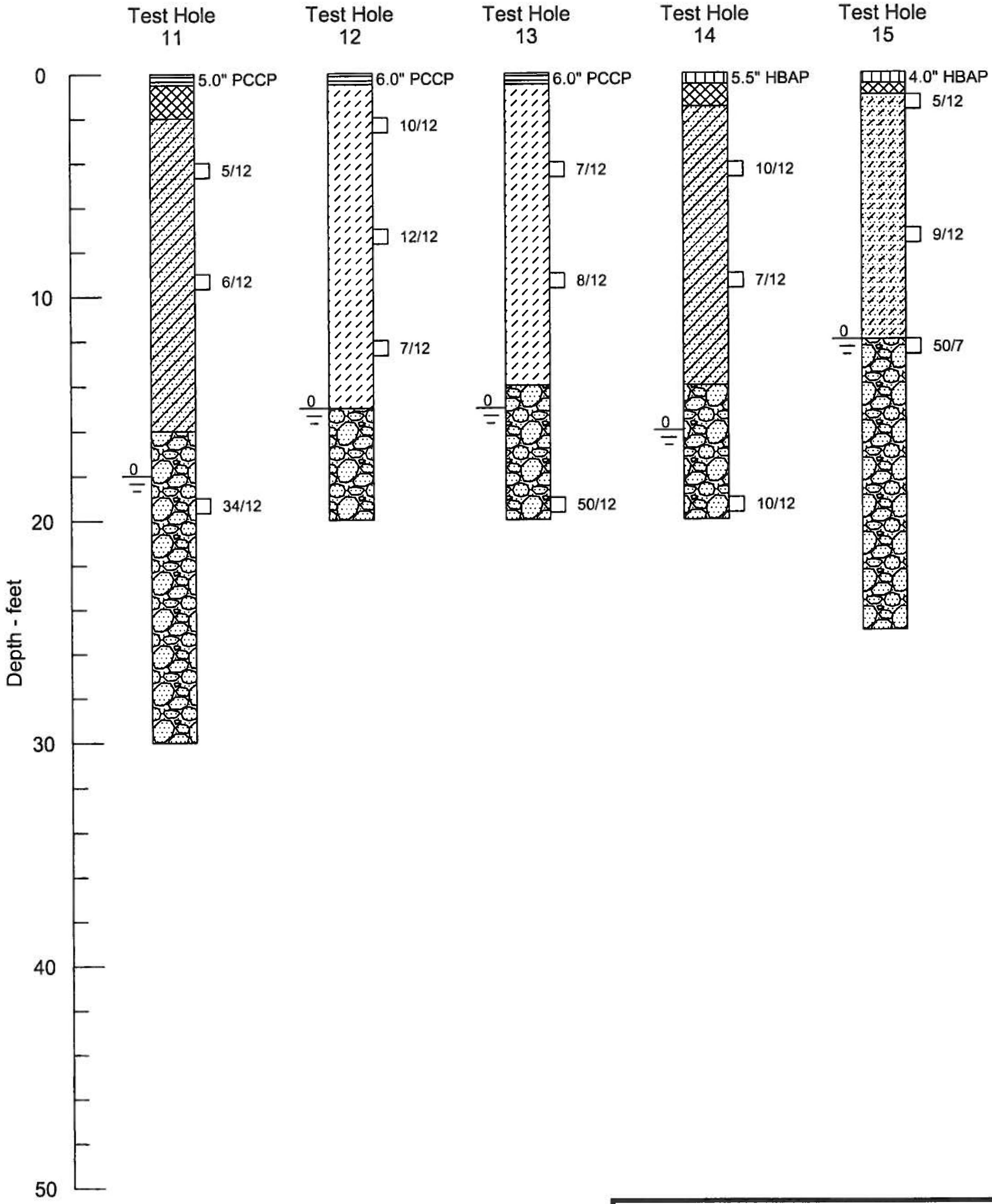
JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 2	APPROVED BY: JK
CADFILE NAME: 6037LOG01.DWG	



GROUND ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

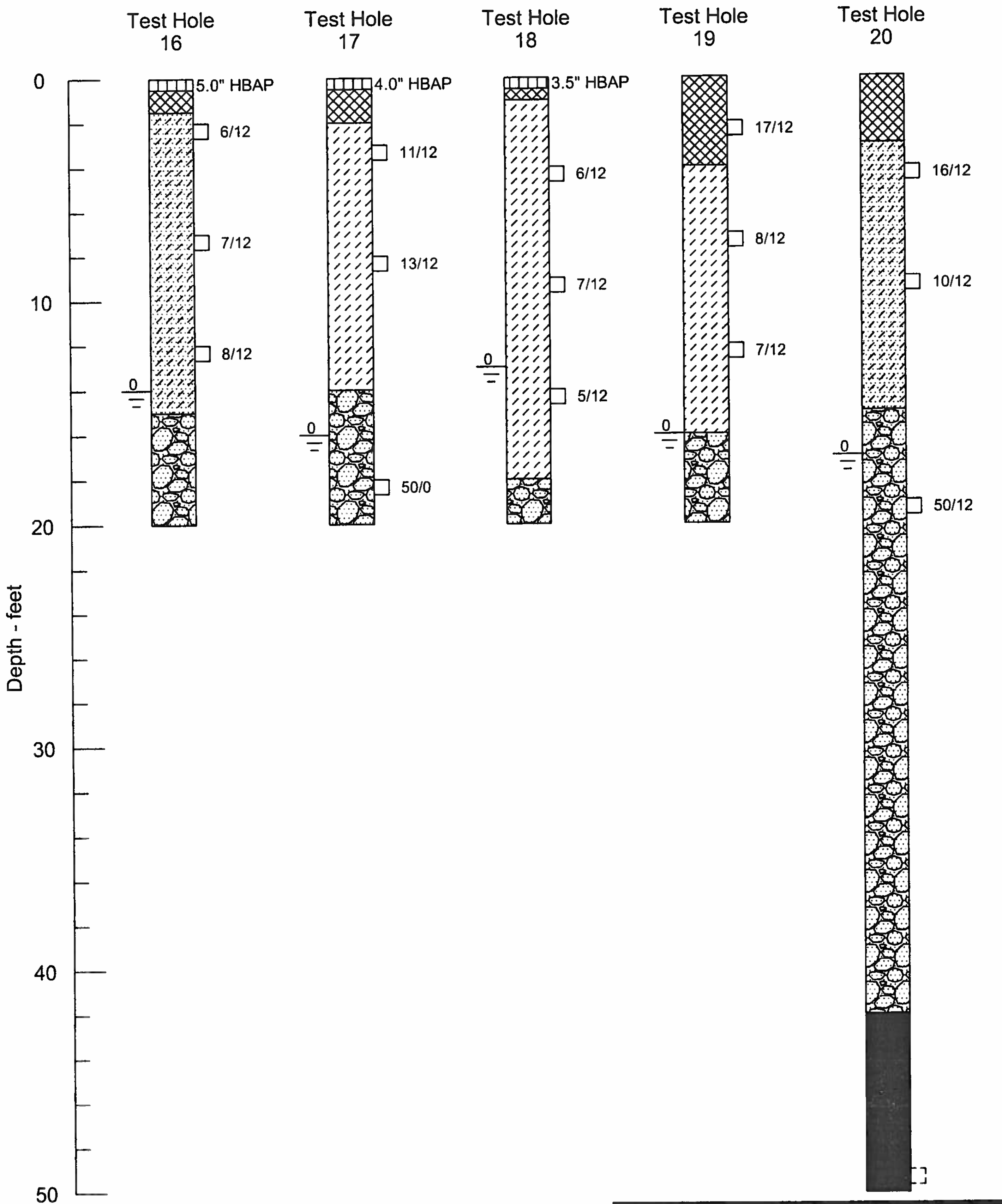
JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 3	APPROVED BY: JK
CADFILE NAME: 6037LOG04.DWG	



GROUND
ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 4	APPROVED BY: JK
CADFILE NAME: 6037LOG03.DWG	



GROUND ENGINEERING CONSULTANTS

LOGS OF TEST HOLES

JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 5	APPROVED BY: JK
CADFILE NAME: 6037LOG04.DWG	

LEGEND:

Hot Bituminous Asphalt Pavement (HBAP)

Portland Cement Concrete Pavement (PCCP)

Fill: Fine to medium sands with medium to coarse gravels commonly; dry to moist, non to low plastic, medium dense, and reddish brown to grey in color.

Clay: Lean to sandy with occasional silt; fine to medium grained, moist to very moist, moderately plastic, soft to medium stiff, pale brown to brown in color, and locally calcareous.

Sand and Clay: Slightly to very clayey; fine to medium grained with localized gravel lenses, moist, non to low plastic, medium dense to dense, and pale brown to brown in color.

Sand and Silt: Slightly silty to sandy; fine to medium grained, moist to very moist, low to moderately plastic, soft to medium stiff, and pale brown to brown in color.

Sand and Gravel: Fine to medium sands with medium to coarse gravels commonly and local cobbles and possibly boulders; moist, non to low plastic, medium dense to very dense, and reddish brown to brown in color.

Drive sample, 2-inch I.D. California liner sample

Small disturbed sample

23/12 Drive sample blow count, indicates 23 blows of a 140-pound hammer falling 30 inches were required to drive the sampler 12 inches.

0 Depth to water level and number of days after drilling that measurement was taken.

NOTES:

1) Test holes were drilled on 10/15/08 with 4-inch diameter continuous flight power augers.

2) Locations of the test holes were measured approximately by pacing from features shown on the site plan provided.

3) Elevations of the test holes were not measured and the logs of the test holes are drawn to depth.

4) The test hole locations and elevations should be considered accurate only to the degree implied by the method used.

5) The lines between materials shown on the test hole logs represent the approximate boundaries between material types and the transitions may be gradual.

6) Groundwater level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level may occur with time.

The material descriptions on this legend are for general classification purposes only. See the full text of this report for descriptions of the site materials and related recommendations.

GROUND
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LEGEND AND NOTES

JOB NO. 08-6037	DRAWN BY: HS
FIGURE: 6	APPROVED BY: JK
CADFILE NAME: 6037LEG.DWG	

COMPACTION TEST REPORT

Curve No.: 2590

Project No.: 08-6037 **Date:** 10/27/08
Project: GJ Safety

Location: Auger Cuttings from top 5 feet of Test Holes
Elev./Depth: 0-5'Below Grade **Sample No.** 2590
Remarks:

MATERIAL DESCRIPTION

Description: Light Brown Clayey Sand

Classifications - **USCS:** SC **AASHTO:** A-4(1)
Nat. Moist. = **Sp.G. =**
Liquid Limit = 24 **Plasticity Index =** 8
% > No.4 = 13.7 % **% < No.200 =** 45.4 %

ROCK CORRECTED TEST RESULTS	UNCORRECTED
Maximum dry density = 120 pcf	116 pcf
Optimum moisture = 12 %	13 %

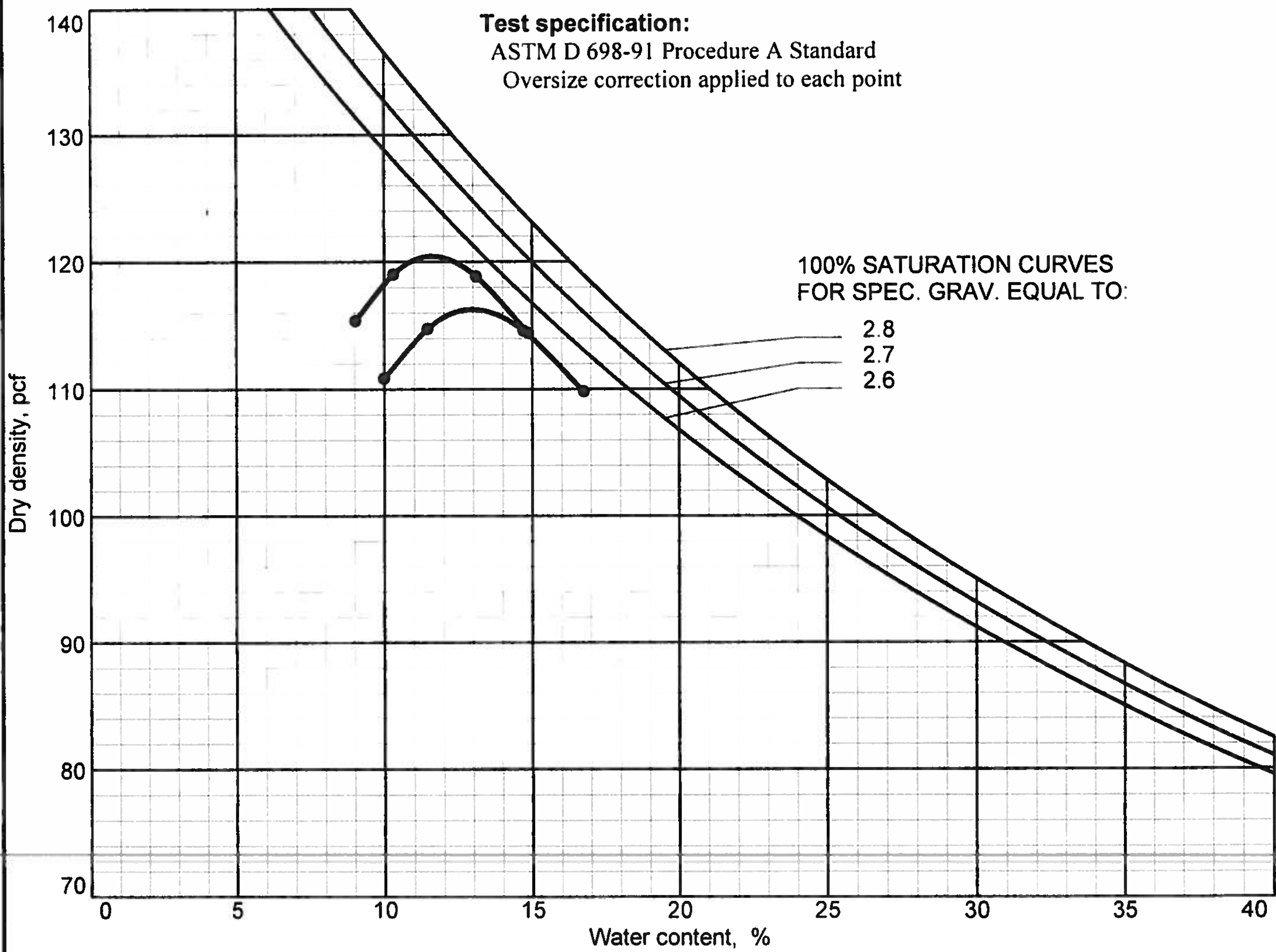

Figure 6

GROUND ENGINEERING CONSULTANTS, INC.

COMPACTION TEST REPORT

Curve No.: 2591

Project No.: 08-6037

Date: 10/21/08

Project: GJ Safety

Location: Auger Cuttings from more than 5 feet below grade in test holes

Elev./Depth: 5'+ Below Grade

Sample No. 2591

Remarks:

MATERIAL DESCRIPTION

Description: Light Brown Lean Clay

Classifications - **USCS:** CL **AASHTO:** A-6(12)

Nat. Moist. =

Sp.G. =

Liquid Limit = 32

Plasticity Index = 15

% > No.4 = 0.0 %

% < No.200 = 87.3 %

TEST RESULTS
Maximum dry density = 110 pcf
Optimum moisture = 16 %

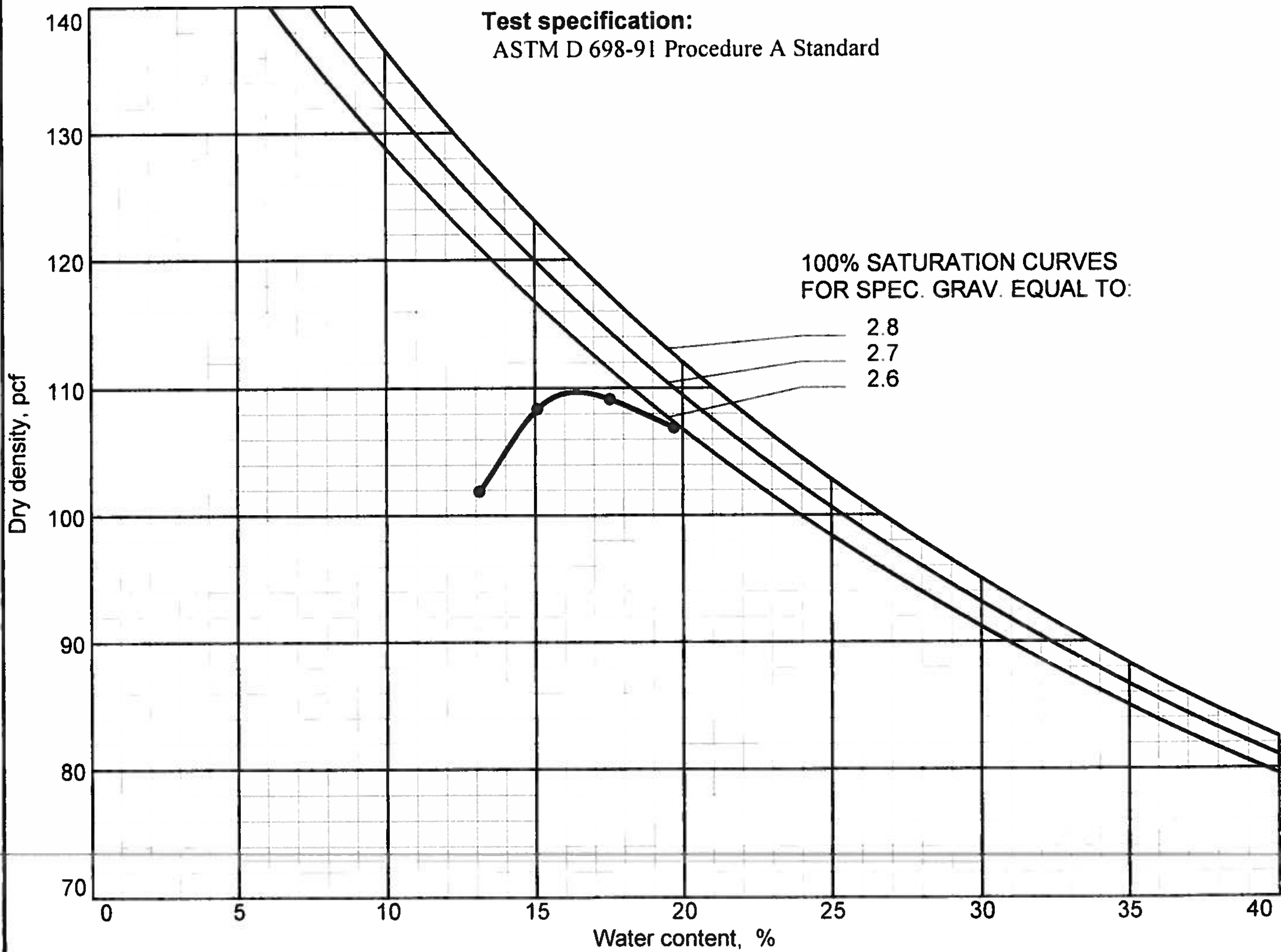

Figure 7

GROUND
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TABLE 1

SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation		Percent Passing No. 200 Sieve	Atterberg Limits		Percent Swell (1000 psf Surcharge)	Percent Swell (200 psf Surcharge)	USCS Classification	AASHTO Classification (GI)	Soil or Bedrock Type
Test Hole No.	Depth (feet)			Gravel (%)	Sand (%)		Liquid Limit (%)	Plasticity Index (%)					
TH 1	4	26.5	94.3	-	-	99	39	25	-	-	CL	A-6 (25)	Lean Clay
TH 1	9	22.4	102.2	-	-	98	38	18	-	-	CL	A-6 (19)	Lean Clay
TH 2	3	28.9	90.0	-	-	99	40	18	-0.3	-	CL	A-6 (20)	Lean Clay
TH 3	8	25.9	96.9	0	2	98	45	23	-	-	CL	A-7-6 (25)	Lean Clay
TH 4	2	22.9	100.3	0	4	96	41	21	-	-	CL	A-7-6 (21)	Lean Clay
TH 5	9	25.8	94.7	-	-	97	48	25	0.3	-	CL	A-7-6 (27)	Lean Clay
TH 5	20	4.2	SD	-	-	42	NV	NP	-	-	SM	A-4 (0)	Silty Sand
TH 5	50	19.4	SD	0	20	77	31	8	-	-	ML	A-4 (5)	Silty Clay w/Sand
TH 6	5	24.1	94.3	-	-	94	25	8	-	-	CL	A-4 (6)	Lean Clay
TH 7	1	8.1	SD	38	33	26	25	9	-	-	GC	A-2-4 (0)	Silty Clayey Gravel w/Sand
TH 8	9	29.8	88.7	-	-	94	29	11	-	-	CL	A-6 (9)	Lean Clay
TH 9	13	18.7	SD	-	-	70	24	7	-	-	CL-ML	A-4 (3)	Sandy Silty Clay
TH 10	2	22.9	96.8	-	-	94	28	11	-	-	CL	A-6 (9)	Lean Clay
TH 10	17	10.9	123.5	-	-	9	NV	NP	-	-	SP-SM	A-3 (1)	Sand w/Silt
TH 11	9	15.6	85.6	0	37	63	NV	NP	-	-	SM	A-4 (0)	Sand w/Silt
TH 12	7	26.8	85.0	-	-	96	30	11	-	-	CL	A-6 (10)	Lean Clay
TH 13	4	20.5	102.8	-	-	95	30	13	-	-	CL	A-6 (11)	Lean Clay
TH 14	9	15.3	90.9	-	-	63	22	3	-	-	ML	A-4 (0)	Sandy Silt
TH 15	1	24.0	89.6	-	-	88	35	16	-	-0.1	CL	A-6 (14)	Lean Clay w/Sand
TH 16	12	18.0	106.3	-	-	59	28	6	-	-	CL-ML	A-4 (2)	Sandy Silty Clay
TH 18	4	22.7	98.7	-	-	99	38	17	-	-	CL	A-6 (18)	Lean Clay
TH 19	2	11.1	102.6	-	-	96	35	15	-	-	CL	A-6 (15)	Lean Clay
TH 20	9	22.5	95.4	0	4	95	32	13	-	0.0	CL	A-6 (12)	Lean Clay
TH 20	49	18.1	SD	0	31	67	32	14	-	-	CL	A-6 (7)	Sandy Lean Clay

Job # 08-6037

GROUND
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TABLE 2

SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Water Soluble Sulfates	pH Reading	Redox Potential	Sulfides Content	Resistivity			USCS Classification	AASHTO Classification	Soil or Bedrock Type
Test Hole No.	Depth *(feet)*	*(%)*		*(mV)*		Resitivity *(ohm-CM)*	Soil Class	Corrosive Resistance		*(GI)*	
TH 1	9	0.9	7.84	-48	Positive	49	4	BAD	CL	A-6 (19)	Lean Clay
TH 8	9	0.63	7.88	-50	Positive	78	4	BAD	CL	A-6 (9)	Lean Clay
TH 14	9	0.07	7.75	-40	Positive	11,529	1	EXCELLENT	ML	A-4 (0)	Sandy Silt
TH 19	2	0.8	6.55	-22	Positive	2,114	3	FAIR	CL	A-6 (15)	Lean Clay

Job # 08-6037

Appendix A

Geotechnical Considerations for Design

GEOTECHNICAL CONSIDERATIONS FOR DESIGN

The data obtained for this study, and our experience on other projects in the vicinity, our estimates indicate likely post-construction movements, generally settlements, of approximately 1 to 3 inches where building elements are supported directly on the native soils that become wetted following construction. Movements of this magnitude can cause severe cosmetic and/or structural distress to the proposed buildings. These same general potentials for post-construction movement and damage also apply to project pavements, hardscaping, piping, and all other improvements in contact with the site soils where subject to surcharge loads and post-construction wetting.

Supporting the proposed buildings on a deep foundation system, and providing it with a similarly supported structural floor is the most effective way to minimize post-construction movements. However, based on our conversations with the Project Team and experience in other projects in the vicinity, we understand that structural floors are generally not utilized, and performance of slab-on-grade floors has been acceptable. Therefore, geotechnical recommendations for deep foundations and slab-on-grade floors constructed on a man-made fill prism are provided in the *Foundation Systems* and Floor Systems sections of this report, respectively. If recommendations for structural floors are requested, GROUND should be contacted.

Deep foundations systems such as drilled piers, steel 'screw' piles, rammed aggregate piers (vibro piers) could be utilized on this site. Drilled pier foundation construction, although possible, will be complicated due to the presence of caving granular soils, relatively shallow groundwater levels, and cobbles and boulders near the penetration zone. Drilled pier foundations systems will likely require casing and use of slurry in order to achieve penetration depths, and therefore will be time and labor intensive to construct. Recommendations for drilled pier foundations are not provided in this report. Other deep foundation systems such as steel 'screw' piles and rammed aggregate piers (vibro piers) also appear feasible on this project site. These systems are typically designed by Specialty Contractor's who also provide recommendations for such specialized systems. Driven pile foundations or concrete pipe pile foundations are deep foundations types that do not require drilling and casing appear suitable and practical for use on this project site. Recommendations for concrete pipe pile foundation systems are provided in this report. This deep foundation system has been used with success for similar-sized structures in this area.

Based on the subsurface conditions encountered, the assumptions outlined herein, including effective maintenance of site drainage, we estimate post-construction movements of concrete pipe pile foundations to be approximately ¾ inch or less, with similar differential movements over a span of about 50 feet.

The geotechnical recommendations for the slab-on-grade concrete floors for this project are provided in the *Floor Systems* section of this report. These recommendations were developed accordingly to reduce damage resulting from movement of the slab subgrade soils. Slab-on-grade floors together with excavation of a portion of the underlying soils, and replacement as approved backfill have been used in the Colorado Rocky Mountain Region with varying degrees of success. If the criteria recommended in this report are implemented effectively in design and construction, and site drainage is maintained, likely post-construction movements of the soils supporting the floor slabs will be approximately 1-inch, with similar differential movements over a span of about 50 feet.

GROUND is available to meet, however, to discuss the risks and remedial approaches presented in this report, as well as other possible design approaches, upon request.

Appendix B

Pavement Section Calculations

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Flexible Structural Design Module

Composite Flexible Section
Parking Areas
Public Safety Facility
Grand Junction, Colorado

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	109,768
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,980 psi
Stage Construction	1
Calculated Design Structural Number	2.81 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	New Asphalt	0.44	1	4.5	1	1.98
2	Class 6 ABC	0.12	1	8	1	0.96
Total	-	-	-	12.50	-	2.94

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Flexible Structural Design Module

Composite Flexible Section
Project Roadways
Public Safety Facility
Grand Junction, Colorado

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	328,412
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,980 psi
Stage Construction	1
Calculated Design Structural Number	3.30 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	New Asphalt	0.44	1	5.5	1	2.42
2	Class 6 ABC	0.12	1	8	1	0.96
Total	-	-	-	13.50	-	3.38

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Flexible Structural Design Module

Full Depth Flexible Section
Project Roadways
Public Safety Facility
Grand Junction, Colorado

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	328,412
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,980 psi
Stage Construction	1
Calculated Design Structural Number	3.30 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	New Asphalt	0.44	1	7.5	1	3.30
Total	-	-	-	7.50	-	3.30

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Flexible Structural Design Module

Full Depth Flexible Section
Parking Areas
Public Safety Facility
Grand Junction, Colorado

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	109,768
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,980 psi
Stage Construction	1
Calculated Design Structural Number	2.81 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	New Asphalt	0.44	1	6.5	1	2.86
Total	-	-	-	6.50	-	2.86

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Network Administrator

Rigid Structural Design Module

Rigid Pavement Section
Public Safety Facility
Grand Junction, Colorado

Rigid Structural Design

Pavement Type	JPCP
18-kip ESALs Over Initial Performance Period	460,048
Initial Serviceability	4.5
Terminal Serviceability	2
28-day Mean PCC Modulus of Rupture	650 psi
28-day Mean Elastic Modulus of Slab	3,400,000 psi
Mean Effective k-value	142 psi/in
Reliability Level	85 %
Overall Standard Deviation	0.34
Load Transfer Coefficient, J	3.6
Overall Drainage Coefficient, Cd	1
Calculated Design Thickness	5.90 in