ENGINEERING •GEOTECHNICAL •ENVIRONMENTAL (ESA I & II) • MATERIALS TESTING •SPECIAL INSPECTIONS • ORGANIC CHEMISTRY • PAVEMENT DESIGN •GEOLOGY

GEOTECHNICAL ENGINEERING STUDY

Lot 27 Seven Springs

10471 South Wasatch Boulevard
Sandy, Utah
CMT PROJECT NO. 13300

FOR:
Mr. Bryce Zundel
10471 South Wasatch Boulevard
Sandy, Utah 84092

August 16, 2019

CMT ENGINEERING LABORATORIES

August 16, 2019

Mr. Bryce Zundel
10471 South Wasatch Boulevard
Sandy, Utah 84092

Subject: Geotechnical Engineering Study
Lot 27 Seven Springs
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Sandy, Utah
CMT Project No. 13300

Mr. Zundel:

Submitted herewith is the report of our geotechnical engineering study for the subject site. This report contains the results of our findings and an engineering interpretation of the results with respect to the available project characteristics. It also contains recommendations to aid in the design and construction of the earth related phases of this project.

On August 2, 2019, a CMT Engineering Laboratories (CMT) engineer was on-site and supervised the excavation of 1 test pit extending to a depth of about 4 feet below the existing ground surface. Soil samples were obtained during the field operations and subsequently transported to our laboratory for further testing and observation.

Conventional spread and/or continuous footings may be utilized to support the proposed residence, provided the recommendations in this report are followed. A detailed discussion of design and construction criteria is presented in this report.

We appreciate the opportunity to work with you at this stage of the project. CMT offers a full range of Geotechnical Engineering, Geological, Material Testing, Special Inspection services, and Phase I and II Environmental Site Assessments. With 9 offices throughout Utah, Idaho and Arizona, our staff is capable of efficiently serving your project needs. If we can be of further assistance or if you have any questions regarding this project, please do not hesitate to contact us at (801) 492-4132.

Sincerely,
CMT Engineering Laboratories

William G. Turner, P.E., M.ASCE
Senior Geotechnical Engineer

Reviewed by:

Steven L. Smith, P.E., M. ASCE
Senior Geotechnical Engineer

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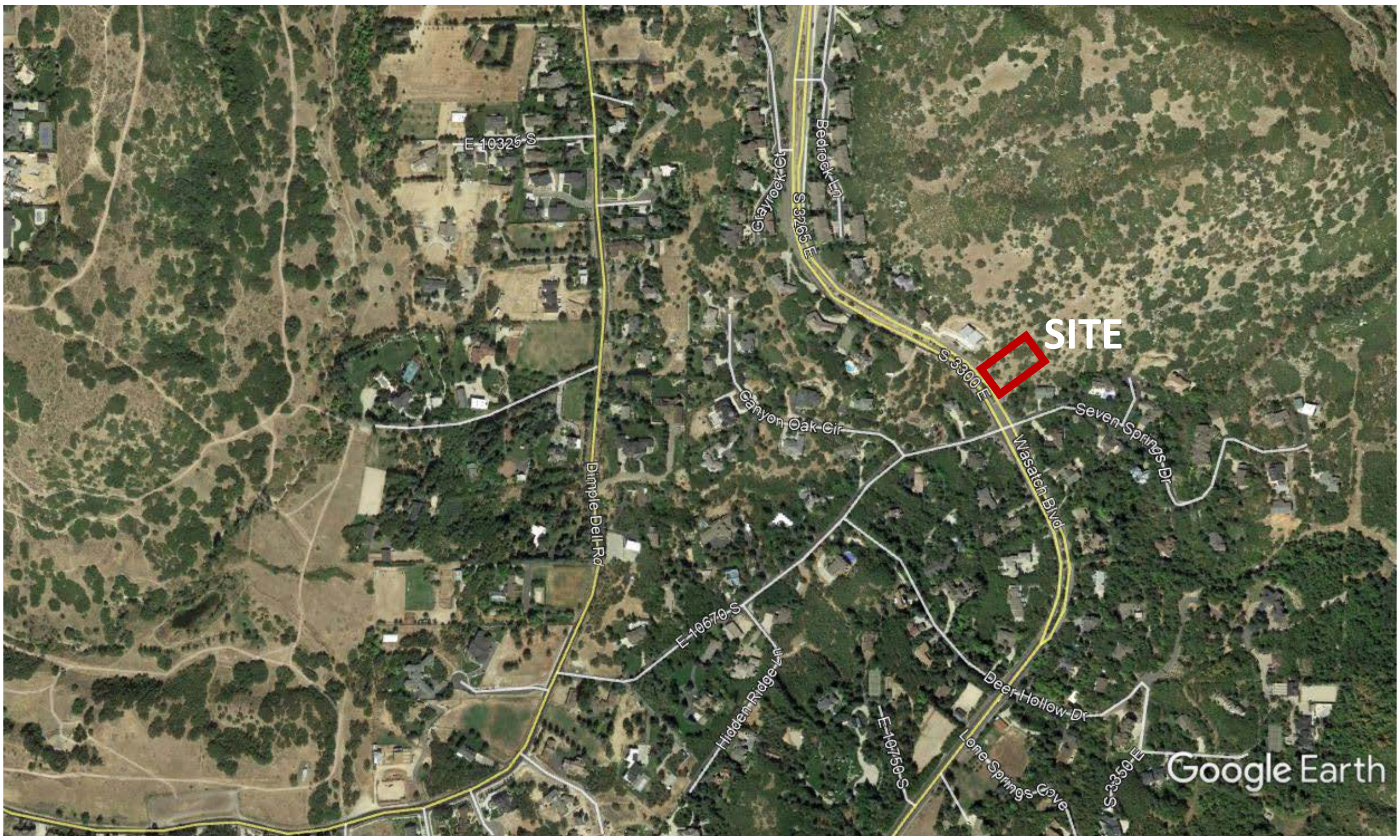
1.0 INTRODUCTION

1.1 General

CMT Engineering Laboratories (CMT) was retained to conduct a geotechnical subsurface study for the proposed residence to be constructed on the subject lot. The parcel is situated on the northeast side of Wasatch Boulevard at about 10471 South in Sandy, Utah, as shown in the **Vicinity Map** below.



VICINITY MAP

1.2 Objectives, Scope and Authorization

The objectives and scope of our study were planned in discussions between Mr. Mark Miller of Xpectations Excavating, and Mr. Bill Turner of CMT Engineering Laboratories (CMT). In general, the objectives of this study were to define and evaluate the subsurface soil and groundwater conditions at the site, and provide appropriate foundation, earthwork, pavement and seismic recommendations to be utilized in the design and construction of the proposed development.

In accomplishing these objectives, our scope of work has included performing field exploration, which consisted of the excavating/logging/sampling of 1 test pit to refusal, performing laboratory testing on representative samples, and conducting an office program, which consisted of correlating available data, performing engineering analyses, and preparing this summary report. This scope of work was authorized by returning a signed copy of our proposal dated August 15, 2019 and executed on August 16, 2019.

1.3 Description of Proposed Construction

We understand that the proposed structure will be a single family residence which we project will have two levels of wood frame construction above grade and a single level of reinforced concrete below grade (basement). We project that maximum loads for the residence will be on the order of 4,000 pounds per lineal foot for walls and 50,000 pounds for columns. Floor slab loads are anticipated to be relatively light, with an average uniform loading not exceeding 100 pounds per square foot. If the loading conditions are different than we have projected, please notify us so that any appropriate modifications to our conclusions and recommendations contained herein can be made.

Site development will require some earthwork in the form of cutting and filling. A site grading plan was not available at the time of this report, but we project that maximum cuts and fills may be on the order of 10 feet. If deeper cuts or fills are planned, CMT should be notified to provide additional recommendations, if needed.

1.4 Executive Summary

Proposed structures can be supported upon conventional spread and continuous wall foundations. The most significant geotechnical aspects regarding site development include the following:

1. Topsoil and some vegetation blankets the site, which will require removal beneath the residence footprint and exterior flatwork;
2. Rockery walls will meet stability requirements if constructed as recommended herein; and
3. Foundations and floor slabs may be placed on suitable, undisturbed natural soils or on properly placed and compacted structural fill extending to suitable, undisturbed natural soils.

CMT must assess that topsoil, undocumented fills, debris, disturbed or unsuitable soils have been removed and that suitable soils have been encountered prior to placing site grading fills, footings, slabs, and pavements.

In the following sections, detailed discussions pertaining to the site and subsurface descriptions, geologic/seismic setting, earthwork, foundations, lateral resistance, lateral pressure, floor slabs, and pavements are provided.

2.0 FIELD EXPLORATION

In order to define and evaluate the subsurface soil and groundwater conditions at the site, 1 test pit was excavated with a backhoe at the site to a depth of approximately 4 feet below the existing ground surface. The location of the test pit is shown on **Figure 1, Site Plan**, included in the Appendix. The field exploration was performed under the supervision of an experienced member of our geotechnical staff.

Representative soil samples were collected by obtaining disturbed "grab" samples from within the test pit. The samples were placed in sealed plastic bags prior to transport to the laboratory.

The subsurface soils encountered in the test pit were logged and described in general accordance with ASTM[1] D-2488. Soil samples were collected as described above, and were classified in the field based upon visual and textural examination. These field classifications were supplemented by subsequent examination and testing of select samples in our laboratory. Graphical representations of the subsurface conditions encountered are presented on the Test Pit Log, **Figure 2**, included in the Appendix. A Key to Symbols defining the terms and symbols used on the log, is provided as **Figure 3** in the Appendix.

3.0 LABORATORY TESTING

Selected samples of the subsurface soils were subjected to various laboratory tests to assess pertinent engineering properties, as follows:

1. Moisture Content, ASTM D-2216, Percent moisture representative of field conditions
2. Atterberg Limits, ASTM D-4318, Plasticity and workability
3. Gradation Analysis, ASTM D-1140/C-117, Grain Size Analysis

Laboratory test results are presented on the test pit log (**Figure 2**) and in the following Lab Summary table:

LAB SUMMARY TABLE

TEST PIT	DEPTH (feet)	SOIL CLASS	SAMPLE TYPE	MOISTURE CONTENT(%)	DRY DENSITY (pcf)	GRADATION			ATTERBERG LIMITS			COLLAPSE (-)/ EXPANSION(+)
						GRAV.	SAND	FINES	LL	PL	PI	
TP-1	2	GC-GM	Bag	2				22	24	17	7	

4.0 GEOLOGIC & SEISMIC CONDITIONS

4.1 Geologic Setting

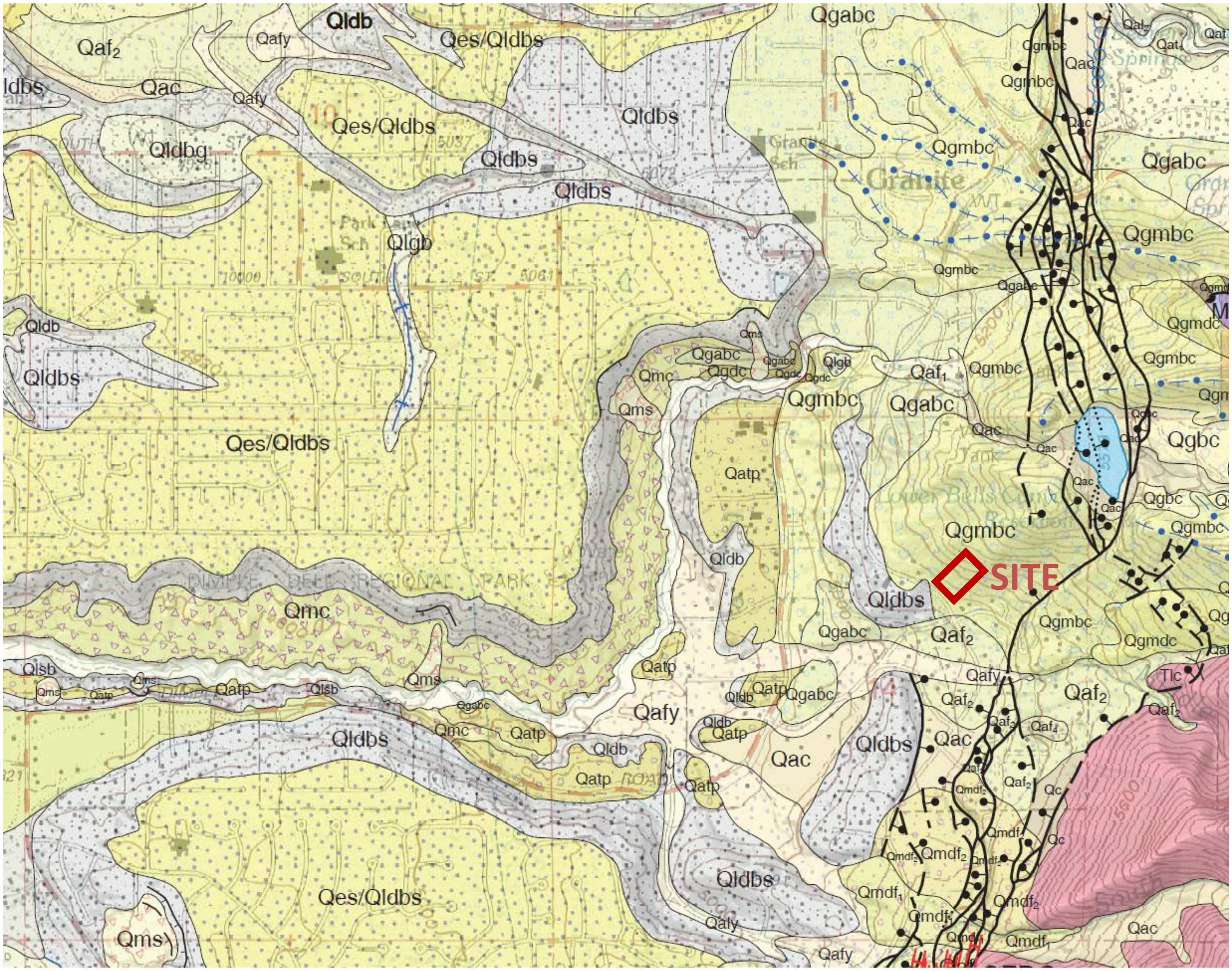
The subject site is located in the southeast-central portion of the Salt Lake Valley in north-central Utah at an elevation of approximately 5,120 to 5,190 feet above sea level. The Salt Lake Valley is a deep, sediment-filled basin that is part of the Basin and Range Physiographic Province and was formed by extensional tectonic processes during the Tertiary and Quaternary geologic time periods. The valley is bordered by the Wasatch Mountain Range on the east and the Oquirrh Mountains on the west. The Salt Lake Valley is located within the Intermountain Seismic Belt, a zone of ongoing tectonism and seismic activity extending from southwestern Montana to southwestern Utah. The active Wasatch Fault Zone is part of the Intermountain Seismic Belt and extends from southeastern Idaho to central Utah along the western base of the Wasatch Mountain Range.

[1]American Society for Testing and Materials

Much of northwestern Utah, including the Salt Lake Valley, was also previously covered by the Pleistocene age Lake Bonneville. The Great Salt Lake, located to the northwest of the valley, is a remnant of this ancient fresh water lake. Lake Bonneville reached a high-stand elevation of approximately 5,092 feet above sea level at between 18,500 and 17,400 years ago. Approximately 17,400 years ago, the lake breached its basin in southeastern Idaho and dropped relatively fast, by almost 300 feet, as water drained into the Snake River. Following this catastrophic release, the lake level continued to drop slowly over time, primarily driven by drier climatic conditions, until reaching the current level of the Great Salt Lake. Shoreline terraces formed at the high-stand elevation of the lake and several subsequent lower lake levels are visible in places on the mountain slopes surrounding the valley. Much of the sediment within the Salt Lake Valley was deposited as lacustrine sediments during both the transgressive (rise) and regressive (fall) phases of Lake Bonneville.

The geology of the USGS Draper, Utah 7.5 Minute Quadrangle, that includes the location of the subject site, has been mapped by McKean and Solomn[2]. The surficial geology at the location of the subject site and adjacent properties is mapped as “Glacial moraines of Bells Canyon age” (Map Unit Qgmbc) dated to be upper Pleistocene. Unit Qgmbc is described in the mapping as “Unsorted boulder, cobble, and pebble gravel with a matrix of sand and silt; clasts subangular to subround; non-stratified; mapped at the mouths of Little Cottonwood and Bells Canyons where distinct U-shaped end, lateral, and regressional moraines are visible, and at higher elevations in the Wasatch Range in cirques and canyons; at the mouth of Bells Canyon, end moraine is partially overlapped by a wedge of transgressive Lake Bonneville lacustrine gravel and sand (Qlgb) (Madsen and Currey, 1979); may locally include mass-movement and colluvial deposits too small to show separately at map scale; estimated maximum thickness less than 240 feet (70 m).” No fill has been mapped at the location of the site on the geologic map. Refer to the **Geologic Map**., shown below.

[2] McKean, A.P. and Solomon, B.J., 2018, Interim Geologic Map of the Draper Quadrangle, Salt Lake County, Utah; Utah Geological Survey Open-File Report 683DM, Scale 1:24,000.



GEOLOGIC MAP

4.2 Faulting

No surface fault traces are shown on the referenced geologic map crossing or projecting toward the subject site. The nearest mapped active fault trace is the Salt Lake segment of the Wasatch fault located about 700 feet southeast of the site.

The Wasatch Fault is considered a "normal" fault because movement along the fault is typically vertical. The east side of the fault, or the mountain block, typically moves upward relative to the valley block on the west side of the fault. The fault generally dips to the west below the valleys. In an earthquake, the point where the fault initially ruptures is called the 'focus" and generally occurs about 10 miles below the surface. The point on the surface directly above the focus, the epicenter, typically out in the valley, is usually where the strongest ground shaking occurs. The Wasatch Fault is one of the longest and most active normal faults in the world.

4.3 Seismicity

4.3.1 Site Class

Utah has adopted the International Building Code (IBC) 2018, which determines the seismic hazard for a site based upon 2014 mapping of bedrock accelerations prepared by the United States Geologic Survey (USGS) and the soil site class. The USGS values are presented on maps incorporated into the IBC code and are also available based on latitude and longitude coordinates (grid points). For site class definitions, IBC 2018 Section 1613.2.2 refers to Chapter 20, Site Classification Procedure for Seismic Design, of ASCE[3] 7-16. Given the subsurface soils encountered at the site, it is our opinion the site best fits Site Class D – Stiff Soil Profile, which we recommend for seismic structural design.

4.3.2 Seismic Design Category

The 2014 USGS mapping utilized by the IBC provides values of peak ground, short period and long period accelerations for the Site Class B/C boundary and the Maximum Considered Earthquake (MCE). This Site Class B boundary represents average bedrock values for the Western United States and must be corrected for local soil conditions. The Seismic Design Categories in the International Residential Code (IRC 2018 Table R301.2.2.1.1) are based upon the Site Class as addressed in the previous section. For Site Class D at site grid coordinates of 40.5610 degrees north latitude and -111.8007 degrees west longitude, $\mathbf{S_{DS}}$ is 0.925 and the **Seismic Design Category** is D_2.

4.3.3 Liquefaction

The site is located within an area designated by the Utah Geologic Survey[4] as having "Very Low" liquefaction potential. Liquefaction is defined as the condition when saturated, loose, sandy soils lose their support capabilities because of excessive pore water pressure which develops during a seismic event. Clayey soils, even if saturated, will generally not liquefy during a major seismic event.

A special liquefaction study was not warranted nor performed for this site. We encountered unsaturated, dense gravel soils within the depths we explored. In our opinion, the soils we encountered support the mapped very low liquefaction potential designation.

4.4 Other Geologic Hazards

No landslide deposits or features, including lateral spread deposits, are mapped on or adjacent to the site. The site is not located within a currently known or mapped potential debris flow or stream flooding hazard area. Given the proximity of the site to the adjacent mountainsides, rock fall hazards might exist for this lot.

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[3]American Society of Civil Engineers

[4] Utah Geological Survey, "Liquefaction-Potential Map for a Part of Salt Lake County, Utah," Utah Geological Survey Public Information Series 25, August 1994. https://ugspub.nr.utah.gov/publications/public_information/pi-25.pdf

5.0 SITE CONDITIONS

5.1 Surface Conditions

At the time the test pit was excavated the site consisted of vacant land vegetated with weeds and scattered scrub oak. The site grade sloped downward to the southwest with an overall gradient of about 70 feet. Based upon aerial photos readily available online dating back to 1993, it appears the site has remained unchanged since that time. The site is bordered on the northeast by similar vacant land, on the southeast and northwest by existing residences, and on the southwest by Wasatch Boulevard (see **Vicinity Map** in **Section 1.1** above).

5.2 Subsurface Soils

At the location of the test pit we encountered approximately 6 inches of topsoil at the surface. Natural soils were observed beneath the topsoil, consisting of Silty Clayey GRAVEL with sand, cobbles, and some boulders (GC-GM), extending to the full depth penetrated, 4 feet. The natural gravel soils were dry to slightly moist, grayish brown in color, and estimated to be dense to very dense.

For a more descriptive interpretation of subsurface conditions, please refer to the test pit log, **Figure 2**, which graphically represent the subsurface conditions encountered. The lines designating the interface between soil types on the log generally represent approximate boundaries - in situ, the transition between soil types may be gradual.

5.3 Groundwater

Groundwater was not encountered at the time of our field explorations within the maximum depth explored of about 4 feet below the existing ground surface. Groundwater is not anticipated to affect proposed construction.

Groundwater levels can fluctuate as much as 1.5 to 2 feet seasonally. Numerous other factors such as heavy precipitation, irrigation of neighboring land, and other unforeseen factors, may also influence ground water elevations at the site. The detailed evaluation of these and other factors, which may be responsible for ground water fluctuations, is beyond the scope of this study.

5.4 Site Subsurface Variations

Based on the results of the subsurface explorations and our experience, variations in the continuity and nature of subsurface conditions should be anticipated. Due to the heterogeneous characteristics of natural soils, care should be taken in interpolating or extrapolating subsurface conditions between or beyond the exploratory location.

6.0 SITE PREPARATION AND GRADING

6.1 General

All deleterious materials should be stripped from the site prior to commencement of construction activities. This includes loose and disturbed soils, topsoil, vegetation, etc. Based upon the conditions observed in the test pit there is topsoil on the surface of the site which we estimated to be about 6 inches in thickness. Locally, existing root balls likely extend deeper and should be removed from beneath the residential footprint.

The site should be examined by a CMT geotechnical engineer to assess that suitable natural soils have been exposed and any deleterious materials, loose and/or disturbed soils have been removed, prior to placing site grading fills, footings, slabs, and pavements.

6.2 Temporary Excavations

Excavations deeper than 8 feet are not anticipated at the site. Groundwater was not encountered within the depths explored, and is not anticipated to affect excavations.

The natural soils encountered at this site predominantly consisted of gravel. For gravelly (cohesionless) soils, temporary construction excavations not exceeding 4 feet in depth should be no steeper than one-half horizontal to one vertical (0.5H:1V). For excavations up to 8 feet and above groundwater, side slopes should be no steeper than one horizontal to one vertical (1H:1V). Excavations encountering saturated cohesionless soils will be very difficult to maintain, and will require very flat side slopes and/or shoring, bracing and dewatering.

All excavations must be inspected periodically by qualified personnel. If any signs of instability or excessive sloughing are noted, immediate remedial action must be initiated. All excavations should be made following OSHA safety guidelines.

6.3 Fill Material

Following are our recommendations for the various fill types we anticipate will be used at this site:

FILL MATERIAL TYPE	DESCRIPTION | RECOMMENDED SPECIFICATION
Structural Fill	Placed below structures, flatwork and pavement. Well-graded sand/gravel mixture, with maximum particle size of 4 inches, a minimum 70% passing 3/4-inch sieve, a maximum 20% passing the No. 200 sieve, and a maximum Plasticity Index of 10.
Site Grading Fill	Placed over larger areas to raise the site grade. Sandy to gravelly soil, with a maximum particle size of 6 inches, a minimum 70% passing 3/4-inch sieve, and a maximum 50% passing No. 200 sieve.

FILL MATERIAL TYPE	DESCRIPTION | RECOMMENDED SPECIFICATION
Non-Structural Fill	Placed below non-structural areas, such as landscaping. On-site soils or imported soils, with a maximum particle size of 8 inches, including silt/clay soils not containing excessive amounts of degradable/organic material (see discussion below).
Stabilization Fill	Placed to stabilize soft areas prior to placing structural fill and/or site grading fill. Coarse angular gravels and cobbles 1 inch to 8 inches in size. May also use 1.5-inch to 2.0-inch gravel placed on stabilization fabric, such as Mirafi RS280i, or equivalent (see **Section 6.6**).

On-site gravel soils might be suitable for use as structural fill, if processed (larger cobbles and boulders are removed) to meet the requirements given above, and may also be used in site grading fill and non-structural fill situations.

All fill material should be approved by a CMT geotechnical engineer prior to placement.

6.4 Fill Placement and Compaction

The various types of compaction equipment available have their limitations as to the maximum lift thickness that can be compacted. For example, hand operated equipment is limited to lifts of about 4 inches and most "trench compactors" have a maximum, consistent compaction depth of about 6 inches. Large rollers, depending on soil and moisture conditions, can achieve compaction at 8 to 12 inches. The full thickness of each lift should be compacted to at least the following percentages of the maximum dry density as determined by ASTM D-1557 (or AASHTO[5] T-180) in accordance with the following recommendations:

LOCATION	TOTAL FILL THICKNESS (FEET)	MINIMUM PERCENTAGE OF MAXIMUM DRY DENSITY
Beneath an area extending at least 4 feet beyond the perimeter of structures, and below flatwork and pavement (applies to structural fill and site grading fill) extending at least 2 feet beyond the perimeter	0 to 5 5 to 10	95 98
Site grading fill outside area defined above	0 to 5 5 to 10	92 95
Utility trenches within structural areas	--	96
Roadbase and subbase	-	96
Non-structural fill	0 to 5 5 to 10	90 92

Structural fills greater than 10 feet thick are not anticipated at the site. For best compaction results, we recommend that the moisture content for structural fill/backfill be within 2% of optimum. Field density tests should be performed on each lift as necessary to verify that proper compaction is being achieved.

[5] American Association of State Highway and Transportation Officials

6.5 Utility Trenches

For the bedding zone around the utility, we recommend utilizing sand bedding fill material that meets current APWA[6] requirements.

All utility trench backfill material below structurally loaded facilities (foundations, floor slabs, flatwork, parking lots/drive areas, etc.) should be placed at the same density requirements established for structural fill in the previous section.

Most utility companies and local governments are requiring Type A-1a or A-1b (AASHTO Designation) soils (sand/gravel soils with limited fines) be used as backfill over utilities within public rights of way, and the backfill be compacted over the full depth above the bedding zone to at least 96% of the maximum dry density as determined by AASHTO T-180 (ASTM D-1557).

Where the utility does not underlie structurally loaded facilities and public rights of way, on-site fill and natural soils may be utilized as trench backfill above the bedding layer, provided they are properly moisture conditioned and compacted to the minimum requirements stated above in **Section 6.4**.

6.6 Stabilization

To stabilize soft subgrade conditions (if encountered), a mixture of coarse, clean, angular gravels and cobbles and/or 1.5- to 2.0-inch clean gravel should be utilized, as indicated above in **Section 6.3**. Often the amount of gravelly material can be reduced with the use of a geotextile fabric such as Mirafi RS280i or equivalent. Its use will also help avoid mixing of the subgrade soils with the gravelly material. After excavating the soft/disturbed soils, the fabric should be spread across the bottom of the excavation and up the sides a minimum of 18 inches. Otherwise, it should be placed in accordance with the manufacturer's recommendation, including proper overlaps. The gravel material can then be placed over the fabric in compacted lifts as described above.

7.0 SLOPE STABILITY/ROCKERY WALLS

7.1 Input Parameters

The properties of the gravelly soils encountered at the site were estimated using published correlations[7], and our experience with similar soils. Accordingly, we estimated the following parameters for use in the stability analyses:

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[6] American Public Works Association
[7] U.S. Bureau of Reclamation, 1987, "Design Standards No. 13, Embankment Dams," Denver, Colorado.

SOIL LAYER	INTERNAL FRICTION ANGLE (degrees)	APPARENT COHESION (psf)	UNIT WEIGHT (pcf)
Silty Clayey Gravel with sand	35	50	135
Boulders	0 (global) 45 (local)	9,000 (global) 0 (local)	150

For the seismic (pseudostatic) analysis, a peak horizontal ground acceleration of 0.695*g* after adjusting for Site Class D was obtained for the site. To obtain the pseudostatic coefficient for the seismic analysis, we utilized the method outlined in Bray and Travasarou[8] for an overall slope height of roughly 100 feet and a potential deformation of 6 inches. Accordingly, a value of 0.19g was used as the pseudostatic coefficient for the stability analysis.

7.2 Stability Analyses

Using the input parameters presented above, the local (boulder-to-boulder) stability of the proposed rockery wall was evaluated considering sliding, overturning and bearing capacity to achieve respective minimum factors of safety of 1.5, 2.0 and 2.5 for static conditions and 1.1, 1.5 and 1.5 for seismic conditions. The results of this analysis (see attached **Figure 4**) indicate that a maximum wall tier (exposed) height of 6 feet can be achieved for boulders with depths into the hillside of 3 feet for the bottom row grading to 2 feet for the upper row.

We also evaluated the global stability of the proposed rockery wall using the computer program *SLIDE* (version 7.0). The configuration analyzed consisted of a two-tiered rockery wall, with each tier 6 feet tall (exposed height), the tiers separated by a distance of 6 feet (face to face) and the upper tier retaining ground sloping at about 3H:1V (Horizontal:Vertical). The typical required minimum factors of safety are 1.5 for static conditions and 1.1 for seismic (pseudostatic) conditions. The results of our analyses indicate that the proposed rockery wall will meet both these requirements, provided our recommendations are followed. The slope stability results are shown on **Figures 5 and 6**.

7.3 Rockery Wall Recommendations

Based on the results of our analyses, the proposed rockery walls at this site will be stable if constructed as follows (also see **Figure 7**, attached):

- The rockery wall may be constructed in two levels or tiers, with both tiers up to a maximum exposed height of 6 feet (total wall height of 12 feet) and the tiers separated by a distance of 6 feet (face to face).

[8] Bray, J.D., & Travasarou, T., "Pseudostatic Coefficient for Use in Simplified Seismic Slope Stability Evaluation," Journal of Geotechnical & Geoenvironmental Engineering, ASCE, September 2009, p 1336-1340.

- The bottom row of boulders in each tier should be embedded a minimum 12 inches below the ground surface.

- The rockery wall facing should slope at 1H:2V (Horizontal:Vertical) or flatter.

- The rockery wall should be composed of boulders with nominal depths into the hillside of 36 inches for the lowest row of rocks, grading in depth to 24 inches for the top row.

- Boulders used in the rockery wall should be durable (i.e. not limestone, soft sandstone, or other rocks which have weakened planes that could cause rocks to split) and placed in a staggered manner (not creating a vertical column) that will not significantly weaken their internal integrity. There should be maximum rock-to-rock contact when placing the rock boulders and no rocks should bear on a downward-sloping face of any supporting rocks. Larger gaps may be filled with smaller rocks or sealed with a cement grout.

- Drainage behind the rockery wall is recommended, as shown on **Figure 4**. The drain should consist of a perforated 4-inch minimum diameter pipe wrapped in fabric and placed at the bottom and behind the lowest row of boulders in each tier. The pipe should daylight at one end of the wall and discharge to an appropriate drainage device or area. Clean gravel ¾- to 2-inch in size, with less than 10% passing the No. 4 sieve and less than 5% passing the No. 200 sieve, should be placed around the drain pipes. A fabric, such as Mirafi 140N or equivalent, should be placed between the clean gravel and the adjacent soils.

- Surface drainage at the bottom and top of the walls should also be directed away from the walls as much as possible.

- CMT should observe construction of the rockery walls at the following critical times: (1) when the lowest row of boulders has been placed along with the drain pipe and bottom gravel; (2) when the rockery wall is about halfway constructed; and (3) upon completion of the rockery wall construction.

It should be noted that rockery walls are constructed of natural materials and are therefore subject to natural weathering processes and environmental attacks that may, in time, compromise the stability of the rockery wall. Boulders used during construction are subject to natural weathering by seasonal changes, wind, frost action, chemical reaction, water, etc. Additionally, the stability of rockery walls can be affected by other on-site and off-site influences such as saturation of retained soils, saturation of supporting soils, root action of vegetation and trees adjacent to the wall, and animal activities including burrowing and nesting. Rockery walls and the associated slopes must be frequently and closely monitored for signs of excessive weathering, drainage characteristics, signs of movement in the boulder, obstruction of drain outlets, etc. If any signs of erosion or movement are noticed, CMT must be contacted immediately to provide appropriate recommendations.

8.0 FOUNDATION RECOMMENDATIONS

The following recommendations have been developed on the basis of the previously described project characteristics, including the maximum loads discussed in **Section 1.3**, the subsurface conditions observed in the field and the laboratory test data, and standard geotechnical engineering practice.

8.1 Foundation Recommendations

Based on our geotechnical engineering analyses, the proposed residence may be supported upon conventional spread and/or continuous wall foundations placed on suitable, undisturbed natural soils and/or on structural fill extending to suitable natural soils. Footings may be designed using a net bearing pressure of 2,500 psf. The term “net bearing pressure” refers to the pressure imposed by the portion of the structure located above lowest adjacent final grade, thus the weight of the footing and backfill to lowest adjacent final grade need not be considered. The allowable bearing pressure may be increased by 1/3 for temporary loads such as wind and seismic forces.

We also recommend the following:

1. Exterior footings subject to frost should be placed at least 30 inches below final grade.
2. Interior footings not subject to frost should be placed at least 16 inches below grade.
3. Continuous footing widths should be maintained at a minimum of 18 inches.
4. Spot footings should be a minimum of 24 inches wide.

8.2 Installation

Under no circumstances shall foundations be placed on undocumented fill, topsoil with organics, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

Deep, large roots may be encountered where trees and larger bushes are located or were previously located at the site; such large roots should be removed. If unsuitable soils are encountered, they must be completely removed and replaced with properly compacted structural fill. Excavation bottoms should be examined by a qualified geotechnical engineer to confirm that suitable bearing materials soils have been exposed.

All structural fill should meet the requirements for such, and should be placed and compacted in accordance with **Section 6** above. The width of structural replacement fill below footings should be equal to the width of the footing plus 1 foot for each foot of fill thickness. For instance, if the footing width is 2 feet and the structural fill depth beneath the footing is 2 feet, the fill replacement width should be 4 feet, centered beneath the footing.

The minimum thickness of structural fill below footings should be equivalent to one-third the thickness of structural fill below any other portion of the foundations. For example, if the maximum depth of structural fill is 6 feet, all footings for the new structure should be underlain by a minimum 2 feet of structural fill.

8.3 Estimated Settlement

Foundations designed and constructed in accordance with our recommendations could experience some settlement, but we anticipate that total settlements of footings founded as recommended above will not exceed 1 inch, with differential settlements on the order of 0.5 inches over a distance of 25 feet. We expect approximately 50% of the total settlement to initially take place during construction.

8.4 Lateral Resistance

Lateral loads imposed upon foundations due to wind or seismic forces may be resisted by the development of passive earth pressures and friction between the base of the footings and the supporting soils. In determining frictional resistance, a coefficient of 0.45 for natural gravel soils and structural fill, may be utilized for design. Passive resistance provided by properly placed and compacted structural fill above the water table may be considered equivalent to a fluid with a density of 350 pcf. A combination of passive earth resistance and friction may be utilized if the friction component of the total is divided by 1.5.

9.0 LATERAL EARTH PRESSURES

We project that basement walls up to 8 feet tall will be constructed at this site. The lateral earth pressure values given below anticipate that native gravelly soils will be used as backfill material, placed and compacted in accordance with the recommendations presented herein. If other soil types will be used as backfill, we should be notified so that appropriate modifications to these values can be provided, as needed.

The lateral pressures imposed upon subgrade facilities will depend upon the relative rigidity and movement of the backfilled structure. For rigid basement walls that are not more than 10 inches thick, sand/gravel backfill may be designed using an at-rest equivalent fluid pressure of 55 pcf (psf/ft). This value assumes that the soil surface behind the wall is horizontal and that the backfill within 3 feet of the wall will be compacted with hand-operated compacting equipment.

For seismic loading of rigid basement walls up to 8 feet tall, we recommend using a uniform (rectangular) at-rest lateral pressure of 125 psf for design.

10.0 FLOOR SLABS

Floor slabs may be established upon suitable, undisturbed, natural soils and/or on structural fill extending to suitable natural soils (same as for foundations). Under no circumstances shall floor slabs be established directly on any topsoil, non-engineered fills, loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

In order to facilitate curing of the concrete, we recommend that floor slabs be directly underlain by at least 4 inches of “free-draining” fill, such as “pea” gravel or 3/4-inch to 1-inch minus, clean, gap-graded gravel. To help control normal shrinkage and stress cracking, the floor slabs should have the following features:

1. Adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints;
2. Frequent crack control joints; and
3. Non-rigid attachment of the slabs to foundation walls and bearing slabs.

11.0 DRAINAGE RECOMMENDATIONS

11.1 Surface Drainage

It is important to the long-term performance of foundations and floor slabs that water not be allowed to collect near the foundation walls and infiltrate into the underlying soils. We recommend the following:

1. All areas around the structure should be sloped to provide drainage away from the foundations. We recommend a minimum slope of 4 inches in the first 10 feet away from the structure. This slope should be maintained throughout the lifetime of the structure.

2. All roof drainage should be collected in rain gutters with downspouts designed to discharge at least 10 feet from the foundation walls or well beyond the backfill limits, whichever is greater.

3. Adequate compaction of the foundation backfill should be provided. We suggest a minimum of 90% of the maximum laboratory density as determined by ASTM D-1557. Water consolidation methods should not be used under any circumstances.

4. Landscape sprinklers should be aimed away from the foundation walls. The sprinkling systems should be designed with proper drainage and be well-maintained. Over watering should be avoided.

5. Other precautions that may become evident during construction.

11.2 Foundation Subdrains

Groundwater was not encountered at this site. The soils also consist of gravel (GM) that is considered a Group 1 soil per IRC 2018, thus perimeter foundation subdrains are not needed.

12.0 QUALITY CONTROL

We recommend that CMT be retained to as part of a comprehensive quality control testing and observation program. With CMT on-site we can help facilitate implementation of our recommendations and address, in a timely manner, any subsurface conditions encountered which vary from those described in this report. Without such a program CMT cannot be responsible for application of our recommendations to subsurface conditions which may vary from those described herein. This program may include, but not necessarily be limited to, the following:

12.1 Field Observations

Observations should be completed during all phases of construction such as site preparation, foundation excavation, structural fill placement and concrete placement.

12.2 Fill Compaction

Compaction testing by CMT is required for all structural supporting fill materials. Maximum Dry Density (Modified Proctor, ASTM D-1557) tests should be requested by the contractor immediately after delivery of any fill materials. The maximum density information should then be used for field density tests on each lift as necessary to ensure that the required compaction is being achieved.

12.3 Excavations

All excavation procedures and processes should be observed by a geotechnical engineer from CMT or their representative. In addition, for the recommendations in this report to be valid, all backfill and structural fill placed in trenches and all pavements should be density tested by CMT. We recommend that freshly mixed concrete be tested by CMT in accordance with ASTM designations.

12.4 Vibration Monitoring

Construction activities, particularly site grading and fill placement, can induce vibrations in existing structures adjacent to the site. Such vibrations can cause damage to adjacent buildings, depending on the building composition and underlying soils. It can be prudent to monitor vibrations from construction activities to maintain records that vibrations did not exceed a pre-defined threshold known to potentially cause damage. CMT can provide this monitoring if desired.

13.0 LIMITATIONS

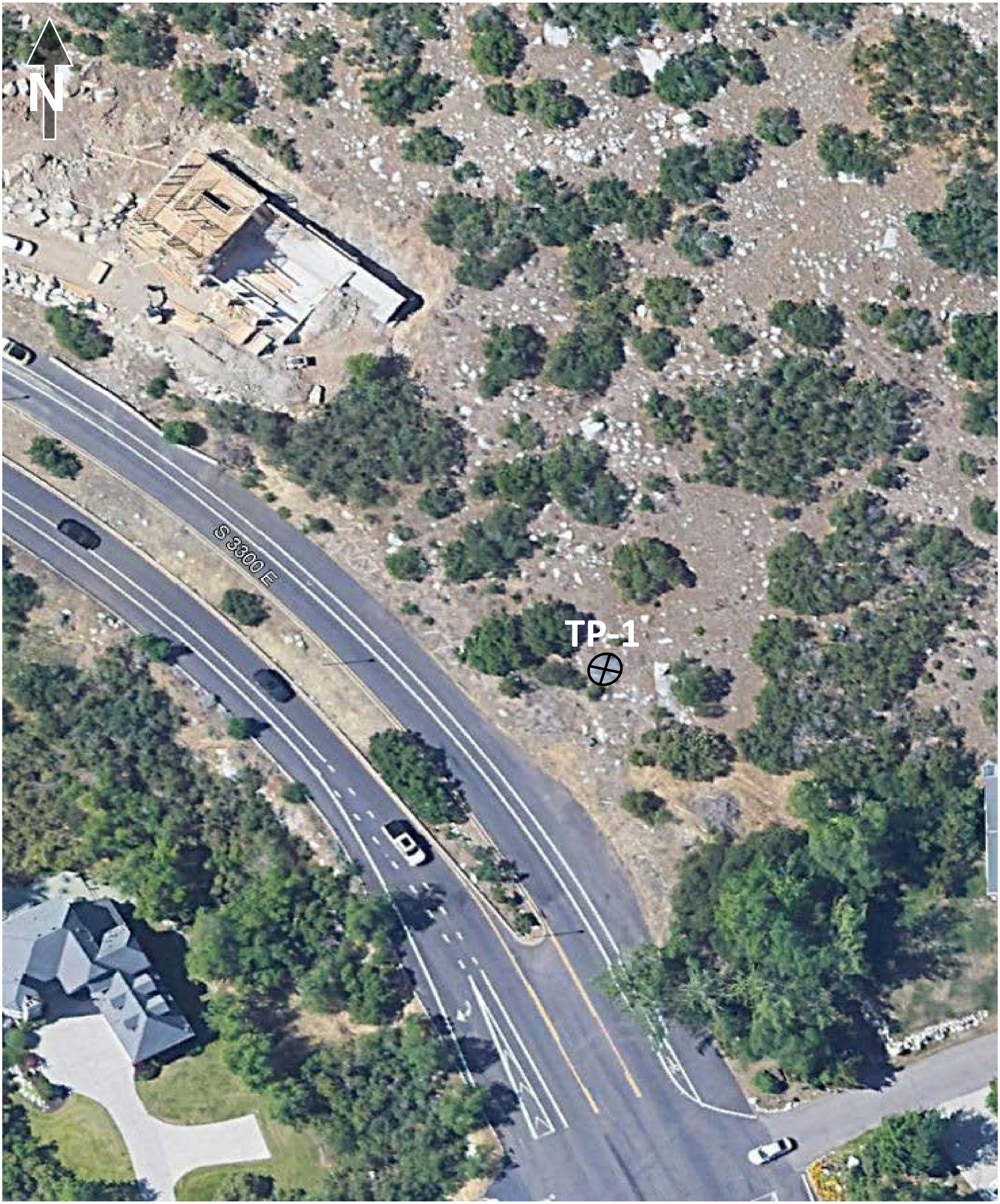
The recommendations provided herein were developed by evaluating the information obtained from the subsurface explorations and soils encountered therein. The exploration log reflects the subsurface conditions only at the specific location at the particular time designated on the log. Soil and ground water conditions may differ from conditions encountered at the actual exploration locations. The nature and extent of any variation in the explorations may not become evident until during the course of construction. If variations do appear, it may become necessary to re-evaluate the recommendations of this report after we have observed the variation.

Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

We appreciate the opportunity to be of service to you on this project. If we can be of further assistance or if you have any questions regarding this project, please do not hesitate to contact us at (801) 492-4132. To schedule materials testing, please call (801) 381-5141.

APPENDIX

SUPPORTING
DOCUMENTATION



Lot 27 Seven Springs

10471 South Wasatch Boulevard, Sandy, Utah

CMT ENGINEERING LABORATORIES

Site Map

Date: 2-Aug-19
Job # 13300

Figure:
1

Lot 27 Seven Springs

Test Pit Log

TP-1

10471 South Wasatch Boulevard, Sandy, Utah

Equipment: Mini-Ex Trackhoe
Surface Elev. (approx):

Total Depth: 4'
Water Depth: (see Remarks)

Date: 8/2/19
Job #: (enter job #)

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation			Atterberg		
							Gravel %	Sand %	Fines %	LL	PL	PI
0		TOPSOIL	◢									
1		Grayish Brown Silty Clayey GRAVEL with sand (GC-GM), some cobbles and boulders — dry to slightly moist, dense										
2			◢	1	2				22	24	17	7
3		very dense										
4		END AT 4'										
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

Remarks: Groundwater not encountered during excavation.

Figure: 2

CMT ENGINEERING LABORATORIES

Excavated By: Mark Miller
Logged By: Bill Turner

Lot 27 Seven Springs

10471 South Wasatch Boulevard, Sandy, Utah

Key to Symbols

Date: 8/2/19

Job #: (enter job #)

Depth (ft)	GRAPHIC LOG	Soil Description	Sample Type	Sample #	Moisture (%)	Dry Density(pcf)	Gradation			Atterberg		
							Gravel %	Sand %	Fines %	LL	PL	PI

COLUMN DESCRIPTIONS

Depth (ft.): Depth (feet) below the ground surface (including groundwater depth - see water symbol below).

Graphic Log: Graphic depicting type of soil encountered (see below).

Soil Description: Description of soils encountered, including Unified Soil Classification Symbol (see below).

Sample Type: Type of soil sample collected at depth interval shown; sampler symbols are explained below-right.

Sample #: Consecutive numbering of soil samples collected during field exploration.

Moisture (%): Water content of soil sample measured in laboratory (percentage of dry weight of sample).

Dry Density (pcf): The dry density of a soil measured in laboratory (pounds per cubic foot).

Gradation: Percentages of Gravel, Sand and Fines (Silt/Clay), obtained from lab test results of soil passing the No. 4 and No. 200 sieves.

Atterberg: Individual descriptions of Atterberg Tests are as follows:

LL = Liquid Limit (%): Water content at which a soil changes from plastic to liquid behavior.

PL = Plastic Limit (%): Water content at which a soil changes from liquid to plastic behavior.

PI = Plasticity Index (%): Range of water content at which a soil exhibits plastic properties (= Liquid Limit - Plastic Limit).

STRATIFICATION	
Description	**Thickness**
Seam	Up to ½ inch
Lense	Up to 12 inches
Layer	Greater than 12 in.
Occasional	1 or less per foot
Frequent	More than 1 per foot

MODIFIERS
Trace
<5%
Some
5-12%
With
> 12%

MOISTURE CONTENT
Dry: Absence of moisture, dusty, dry to the touch.
Moist: Damp / moist to the touch, but no visible water.
Saturated: Visible water, usually soil below groundwater.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS SYMBOLS		TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS More than 50% of material is larger than No. 200 sieve size.	**GRAVELS** The coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (< 5% fines)	GW		Well-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
			GP		Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or No Fines
		GRAVELS WITH FINES (≥ 12% fines)	GM		Silty Gravels, Gravel-Sand-Silt Mixtures
			GC		Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS The coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (< 5% fines)	SW		Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP		Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (≥ 12% fines)	SM		Silty Sands, Sand-Silt Mixtures
			SC		Clayey Sands, Sand-Clay Mixtures
FINE-GRAINED SOILS More than 50% of material is smaller than No. 200 sieve size.	**SILTS AND CLAYS** Liquid Limit less than 50%		ML		Inorganic Silts and Sandy Silts with No Plasticity or Clayey Silts with Slight Plasticity
			CL		Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
			OL		Organic Silts and Organic Silty Clays of Low Plasticity
	SILTS AND CLAYS Liquid Limit greater than 50%		MH		Inorganic Silts, Micacious or Diatomacious Fine Sand or Silty Soils
			CH		Inorganic Clays of High Plasticity, Fat Clays
			OH		Organic Silts and Organic Clays of Medium to High Plasticity
HIGHLY ORGANIC SOILS			PT		Peat, Soils with High Organic Contents

SAMPLER SYMBOLS

- Block Sample
- Bulk/Bag Sample
- Modified California Sampler
- 3.5" OD, 2.42" ID D&M Sampler
- Rock Core
- Standard Penetration Split Spoon Sampler
- Thin Wall (Shelby Tube)

WATER SYMBOL

- Encountered Water Level
- Measured Water Level

(see Remarks on Logs)

Note: Dual Symbols are used to indicate borderline soil classifications (i.e. GP-GM, SC-SM, etc.).

1. The results of laboratory tests on the samples collected are shown on the logs at the respective sample depths.
2. The subsurface conditions represented on the logs are for the locations specified. Caution should be exercised if interpolating between or extrapolating beyond the exploration locations.
3. The information presented on each log is subject to the limitations, conclusions, and recommendations presented in this report.

CMT ENGINEERING LABORATORIES

Figure:

3

Local Stability Evaluation

Backfill slope angle:	18.4	degrees (β)	Foundation soil γ :	135	pcf
Batter angle (from vertical):	26.6	degrees (α)	Foundation soil ϕ :	35	degrees
Soil/wall interface friction:	0	degrees (δ)	Found. soil cohesion:	50	psf
Surcharge pressure:	0	psf	Retained soil γ :	135	pcf
	static	**seismic**	Retained soil ϕ :	35	degrees
FS against sliding (Static & Seismic):	1.5	1.1	Retained soil cohesion:	50	psf
FS against overturning (Static & Seismic):	2.0	1.5	Rock boulder γ :	150	psf
FS for bearing (Static & Seismic):	2.5	1.5	Rock boulder ϕ :	45	degrees
Horizontal seismic coeff., k_h:	0.2	(typically ½ of PGA)	Embedment depth:	0	feet
Vertical seismic coeff., k_v:	0	(typically 0)	Average rockery wall γ :	150	pcf
Rock to Rock interface factor:	0.67	(typically 2/3)	Min. top rock size:	24	inches
Bearing Capacity	14308	psf (Meyerhoff)	Min.bottom rock size:	36	inches

STATIC

Wall Ht, H (ft)	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**
Back of wall, y (°)	0.0	0.0	9.5	14.0	16.7	18.4	19.7	20.6
Wall Wt, W (lbs/ft)	375	750	1125	1500	1875	2250	2625	3000
Wall $x_{centroid}$ (ft)	1.50	1.73	1.97	2.20	2.43	2.67	2.76	2.87
Wall $y_{centroid}$ (ft)	0.467	0.933	1.400	1.867	2.333	2.800	3.300	3.787
Coulomb K_a	0.3349	0.3349	0.2583	0.2247	0.2058	0.1938	0.1854	0.1793
F_a (lbs/ft)	0	33	80	143	224	321	436	567
$F_{sliding}$ (lbs/ft)	0	33	78	139	215	305	410	530
$F_{resisting}$ (lbs/ft)	263	525	779	1026	1268	1504	1735	1961
$FS_{base\ sliding}$	**> 100**	**16.1**	**9.9**	**7.4**	**5.9**	**4.9**	**4.2**	**3.7**
$FS_{interface\ shear}$	**> 100**	**15.4**	**9.6**	**7.2**	**5.9**	**4.9**	**4.3**	**3.8**
$M_{overturn}$ (ft-lbs/ft)	0	22	78	186	358	610	957	1415
$M_{resisting}$ (ft-lbs/ft)	563	1300	2171	3184	4337	5627	6693	7821
$FS_{overturn}$	**> 100**	**59.9**	**27.7**	**17.2**	**12.1**	**9.2**	**7.0**	**5.5**
Eccentricity, e (ft)	0.00	-0.20	-0.38	-0.55	-0.70	-0.84	-0.82	-0.80
Bearing Pressure	125	352	654	1024	1450	1921	2186	2424
$FS_{bearing}$	**114.4**	**40.6**	**21.9**	**14.0**	**9.9**	**7.4**	**6.5**	**5.9**

SEISMIC

Mononobe-Okabe K_{ae} =	0.5687	0.5687	0.4745	0.4340	0.4114	0.3969	0.3868	0.3794
F_{ae} (lbs/ft)	1	78	185	337	534	775	1062	1393
$F_{sliding}$ (lbs/ft)	76	228	407	627	886	1186	1525	1904
$F_{resisting}$ (lbs/ft)	263	525	766	993	1205	1404	1588	1758
$FS_{base\ sliding}$	**3.5**	**2.3**	**1.9**	**1.6**	**1.4**	**1.2**	**1.0**	**0.9**
$FS_{interface\ shear}$	**3.3**	**2.2**	**1.9**	**1.6**	**1.4**	**1.3**	**1.2**	**1.1**
$M_{overturn}$ (ft-lbs/ft)	35	216	581	1196	2123	3421	5166	7400
$M_{resisting}$ (ft-lbs/ft)	563	1300	2114	3015	3990	5024	5746	6428
$FS_{overturn}$	**15.9**	**6.0**	**3.6**	**2.5**	**1.9**	**1.5**	**1.1**	**0.9**
Eccentricity (ft)	0.09	0.06	0.10	0.22	0.42	0.70	1.24	1.89
Bearing Pressure	149	278	437	678	1051	1604	2638	3996
$FS_{bearing}$	**96.3**	**51.5**	**32.7**	**21.1**	**13.6**	**8.9**	**5.4**	**3.6**

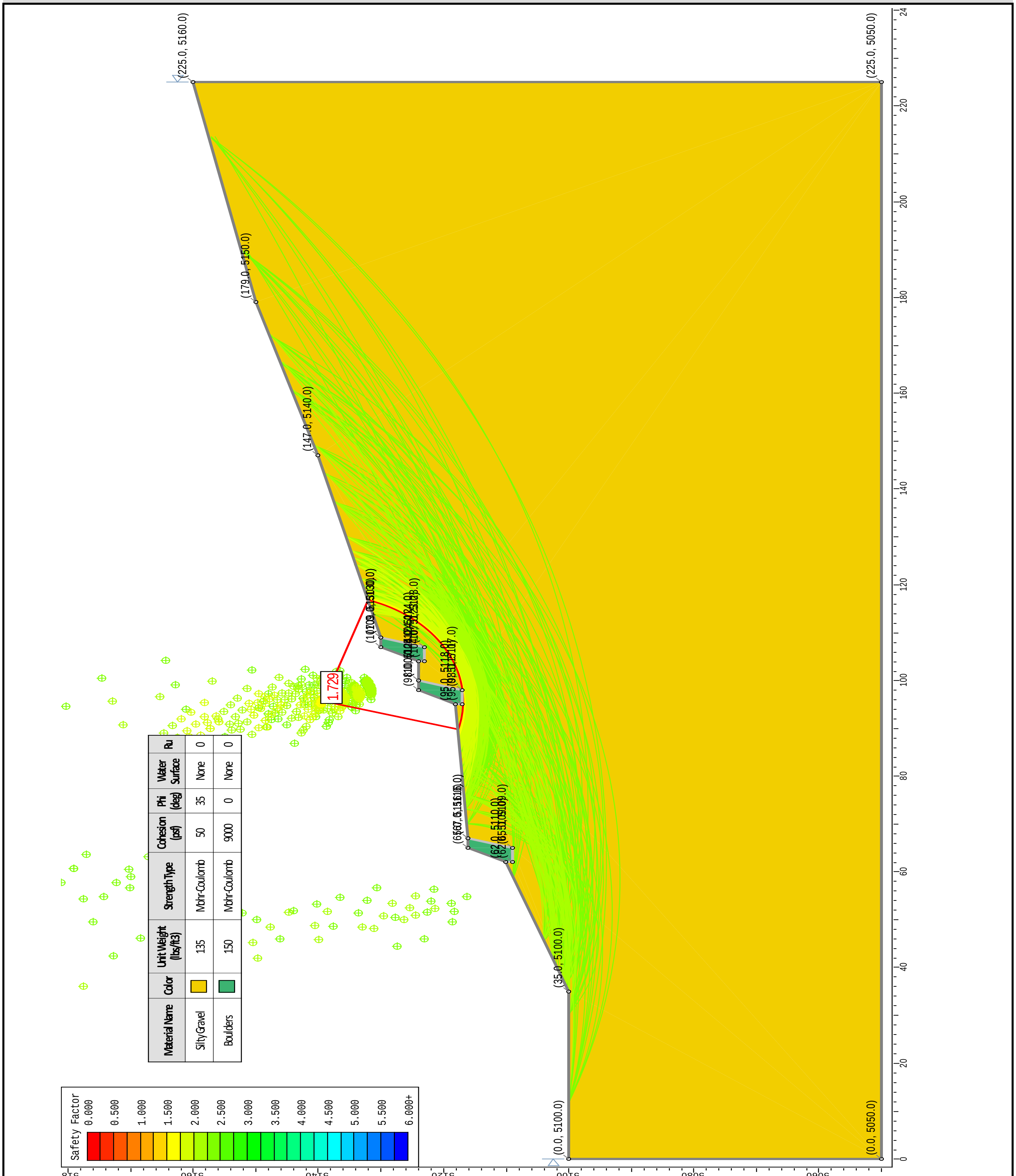
Max. Recommended Wall Height: 6 feet for 24-inch (top row) to 36-inch (bottom row) size boulders

Notes:

1. Equations from "Recommended Rockery Design & Construction Guidelines" Publication FHWA-CLF/TD-06-006, Nov. 2006.
2. Cohesion included in active pressure force by subtracting (2 * c * $\sqrt{K_a}$), but force is not allowed to be less than 0.
3. Other equations: W=[p*(average rock radius) ² *H]* g_{rock} ; $FS_{interface\ shear}$=(Rock to Rock interface factor)*[W*tan(f $_{rock}$)/$P_{sliding}$]

Lot 27 Seven Springs	CMT ENGINEERING LABORATORIES		Figure 4
10471 South Wasatch Boulevard, Sandy, Utah	**Evaluation**	**Date** 16-Aug-19 / **Job No.** 13300	

Stability Results - Static



Lot 27 Seven Springs

10471 South Wasatch Boulevard, Sandy, Utah

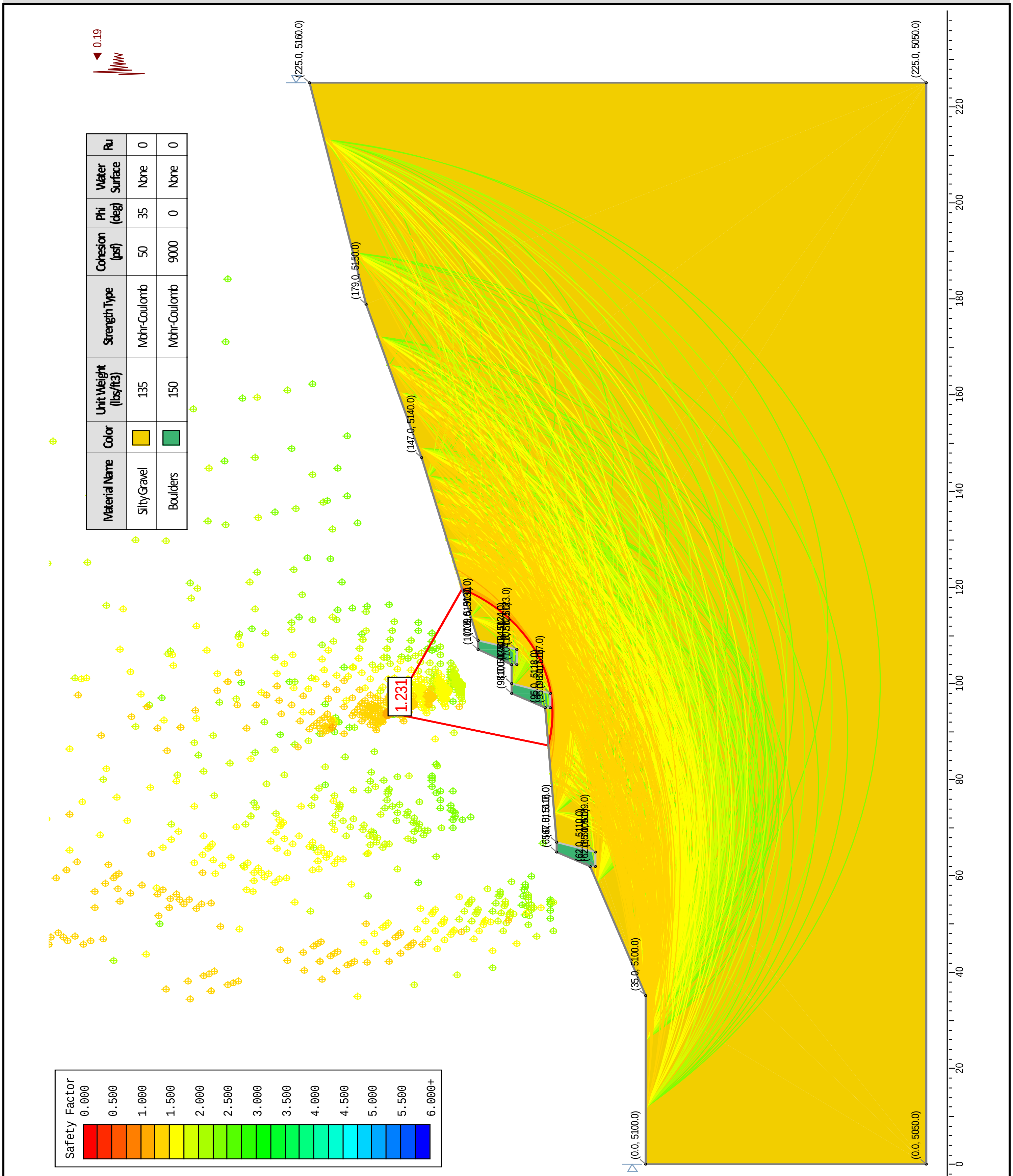
CMT ENGINEERING LABORATORIES

Results

Date	16-Aug-19
Job No.	13300

Figure 5

Stability Results - Seismic



Lot 27 Seven Springs	CMT ENGINEERING LABORATORIES		Figure 6
10471 South Wasatch Boulevard, Sandy, Utah	Results	Date: 16-Aug-19 Job No.: 13300	

Rockery Wall Details

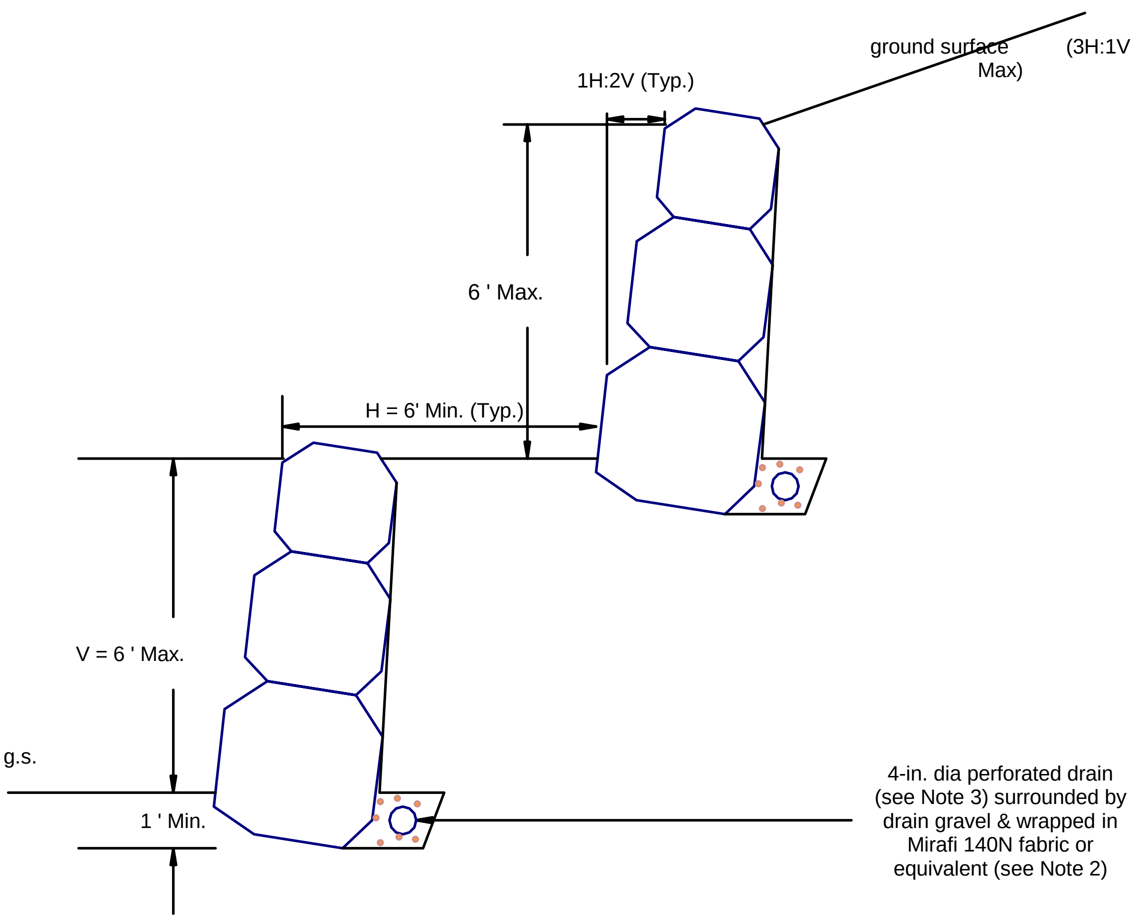
NOTES:

1. Backfill soils should be placed in loose lifts not exceeding a thickness of 12 inches, moisture conditioned to within 2% of optimum, and compacted to a minimum 95% of the maximum dry density as determined by ASTM D-1557.

2. Free-draining backfill shall consist of clean 3/4-inch to 2-inch size gravel having less than 10% passing the No. 4 sieve and less than 5% passing No. 200 sieve, or may use Miradrain (or equivalent) instead of gravel & fabric above the drain pipe.

3. Perforated drain shall be wrapped with fabric, sloped at a minimum 1%, and discharged to an appropriate drainage device.

4. Boulder depths into the hillside shall be a minimum 36 inches for the bottom row grading to a minimum 24 for the upper row for each tier.



NOT TO SCALE

Lot 27 Seven Springs	CMT ENGINEERING LABORATORIES		Figure 7
10471 South Wasatch Boulevard, Sandy, Utah	**Wall Details**	Date: 16-Aug-19 Job No.: 13300	