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GEOTECHNICAL STUDY
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RIVERTON, UTAH

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1.0 INTRODUCTION

This report presents the results of a geotechnical study for a proposed residential subdivision to be developed at approximately 1600 West 13200 South in Riverton, Utah. The approximate location of the proposed development is shown on Figure No. 1, *Vicinity Map*, at the end of this report.

The purposes of this investigation were to 1) evaluate the subsurface soil conditions at the site, 2) assess the engineering characteristics of the subsurface soils, and 3) provide geotechnical recommendations for general site grading, and the design and construction of foundations, concrete floor slabs, miscellaneous concrete flatwork, and asphalt pavement sections. The scope of work completed for this study included field reconnaissance, subsurface investigation, field and laboratory soil testing, engineering analysis, and the preparation of this report.

2.0 CONCLUSIONS

The following is a brief summary of our findings and conclusions:

1. Soil conditions encountered at the test pit locations consisted of approximately 6 to 12 inches of topsoil followed by Silt (ML) extending to the maximum depth explored of about 10 feet below the existing surface.

2. Groundwater was not encountered in the test pits, but some of the soils were wet near the bottom of the test pits. Floor slabs should be kept at least 3 feet above any groundwater, if encountered.

3. Consolidation test results indicate that the native soils have low compressibility, and are slightly moisture sensitive (collapsible). If these soils are allowed to become saturated after construction, some additional settlement could occur.

4. Conventional strip and spread footings may be used to support residences. We recommend that foundations be constructed entirely on undisturbed, uniform native soils, or entirely on a minimum 18 inches of properly placed and compacted structural fill placed on undisturbed native soils. A maximum bearing capacity of 1,500 psf may be used for design of the footings. More details regarding foundation design can be found in Section 10.0 of this report.

These findings and conclusions should not be relied upon without reading and consulting this entire report for a more detailed description of the geotechnical evaluation and recommendations contained herein.

3.0 PROPOSED CONSTRUCTION

It is our understanding that the site will be developed with single family residences. We estimate that foundation loads for residences will not exceed 4 kips per linear foot for bearing walls, 40 kips for columns, and 150 pounds per square foot for floor slabs. If structural loads will be greater our office should be notified so that we may review our recommendations and, if necessary, make modifications.

In addition to the construction described above, we anticipate that utilities will be installed to service the proposed residences, that exterior concrete flatwork will be placed in the form of curb, gutter, sidewalks, and driveways, and that a short asphalt paved residential cul-de-sac street will be constructed.

4.0 SURFACE OBSERVATIONS

When we visited the site to excavate the test pits we found it to predominately consist of pasture vegetated with grass and weeds. Existing structures included a home, garage, and barn. The ground surface appeared relatively flat. The site was bounded on the north, east, and west by existing residences, and on the south by 13200 South street.

5.0 SUBSURFACE INVESTIGATION

The subsurface soil conditions at the site were assessed by a member of our geotechnical staff who supervised the excavation of 3 exploratory test pits on October 12, 2007. The test pits were excavated by a rubber tire backhoe to a depth of about 10 feet below the ground surface at the approximate locations shown on Figure No. 2, *Site Plan and Locations of Test Pits*.

The subsurface soils exposed in the test pits were classified by visual examination using the guidelines of the Unified Soil Classification System (USCS). Disturbed bag samples and relatively undisturbed block samples were collected in the test pits. Samples will be retained in our laboratory for 30 days following the date of this report and then discarded unless a written request for additional holding time is received prior to the disposal date.

6.0 LABORATORY TESTING

Selected soil samples were tested in the laboratory to assess pertinent engineering properties and to aid in classification. Laboratory testing consisted of natural moisture content tests, a natural dry density test and one-dimensional consolidation test, Atterberg limits determinations, and mechanical gradation analyses. The table below presents the results of the laboratory testing. Test results are also given on the enclosed test pit logs at the respective sample depths, and on Figure No. 7, *Consolidation-Swell Test.*

Table No. 1: Laboratory Test Results

TEST PIT NO.	DEPTH (ft.)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (pcf)	ATTERBERG LIMITS		GRAIN SIZE DISTRIBUTION (%)			SOIL TYPE
				LIQUID LIMIT	PLASTICITY INDEX	GRAVEL #4	SAND	SILT/ CLAY #200	
TP-1	1	11	---	N.P.*	N.P.	---	---	---	ML
TP-1	2	9	92	25	2	0	31	69	ML
TP-1	7½	16	---	N.P.	N.P.	0	31	69	ML
TP-2	6	20	---	N.P.	N.P.	0	27	73	ML
TP-2	9½	22	---	N.P.	N.P.	0	26	74	ML
TP-3	9½	35	---	N.P.	N.P.	0	22	78	ML

*Non-plastic

As part of the consolidation test procedure, water was added to saturate the sample when the sample was loaded to an equivalent pressure of 1,000 psf to assess moisture sensitivity. The

sample from Test Pit 1 showed a minor amount (less than ½ %) of moisture sensitivity in the form of collapse (settlement). Recommendations for reducing the potential for foundation soils to become saturated are given in Section 13.0.

7.0 SUBSURFACE CONDITIONS

7.1 Soil Types

At the locations of the test pits the surface of the site was covered with topsoil which we observed to extend about 6 to 12 inches in depth. Below the topsoil we encountered Silt (ML) with varying amounts of sand extending to the maximum depth explored of 10 feet below the ground surface. Laboratory testing indicated that the subsurface silt soils are slightly moisture sensitive.

Graphical representations and detailed descriptions of the soils encountered are shown on Figure Nos. 3 through 5, *Test Pit Log* at the end of this report. The stratification lines shown on the logs represent the approximate boundary between soil units; the actual transition may be gradual. Due to potential natural variations inherent in soil deposits, care should be taken in interpolating between and extrapolating beyond exploration points. A key to the symbols and terms on the logs is presented on Figure No. 6, *Legend.*

7.2 Groundwater Conditions

Groundwater was not encountered in the test pits, but the soil near the base of Test Pit 3 appeared to be wet and iron oxide stains (indicators of past water levels) were observed. Groundwater depths will fluctuate in response to the season, precipitation, irrigation, and other on and off site influences. Precisely quantifying these fluctuations would require long term monitoring which is beyond the scope of this investigation.

8.0 SITE GRADING

8.1 General Site Grading

Unsuitable soils and vegetation should be removed from below areas which will ultimately support structural loads. These areas include those below foundations, floor slabs, exterior concrete flatwork, and pavements. Unsuitable soils consist of topsoil, organic soils, undocumented fill, soft, loose, or disturbed native soils, and any other inapt materials. The topsoil on the surface extended about 6 to 12 inches in depth. The topsoil, along with any soil containing roots ¼ inch in diameter or larger, even if found to extend deeper, and any other unsuitable soils if encountered, should be completely removed from the areas described above.

Placing more than 3 feet of grading fill above the existing surface could result in settlement of the underlaying native soils. Earthtec should be notified if development plans included placing more than 3 feet of grading fill so that we may assess potential settlement and make additional recommendations if needed.

8.2 Excavations

For excavations less than five feet in depth into the native soils or structural fill, slopes should not be made steeper than 0.5:1.0 (horizontal:vertical). Excavations extending up to ten feet in depth should not be made steeper than 1:1. If unstable conditions or groundwater seepage are encountered flatter slopes or shoring or bracing may be required.

8.3 Fill Material

Native soils are not suitable for use as structural fill, but may be stockpiled for use as fill in landscape areas.

Regular structural fill, if needed, should consist of imported material meeting the following requirements:

Maximum particle size:	4 inches
Percent retained on the 3/4 inch sieve (coarse gravel):	30 maximum
Percent passing the No. 200 sieve (fines):	15 maximum
Liquid Limit of fines:	35 maximum
Plasticity Index of fines:	15 maximum

In some situations, particles larger than 4 inches and/or more than 30 percent coarse gravel may be acceptable, however, compaction and compaction testing may be more difficult. As a result more strict quality control measures than normally used may be required. Such measures may include using thinner lifts, and increased or full time observation of fill placement.

Utility trench fill below structures, concrete flatwork, and asphalt should consist of structural fill as defined above. In other areas, utility trenches can be backfilled with native soils, however, the native clay and silt soils may be difficult to compact due to problems controlling the moisture content. All backfill soil should meet the following requirements:

Maximum particle size:	4 inches
Liquid Limit of fines:	35 maximum
Plasticity Index of fines:	15 maximum

8.4 Fill Placement and Compaction

The thickness of each lift should be appropriate for the compaction equipment that is used. We recommend a maximum lift thickness of 4 inches for hand operated equipment, 6 inches for most "trench compactors", and 8 inches for larger rollers, unless it can be demonstrated by in-place density tests that the required compaction can be obtained throughout a thicker lift. The full thickness of each lift of structural fill placed should be compacted to at least the following percentages of the maximum dry density, as determined by ASTM D-1557:

In landscape areas not supporting structural loads:	90%
Less than 5 feet of fill below foundations, flatwork and pavements:	95%
Five or more feet of fill below foundations, flatwork and pavements:	98%

Generally, placing and compacting fill at a moisture content within 2% of the optimum moisture content, as determined by ASTM D-1557, will facilitate compaction. Typically, the further the moisture content is from the optimum the more difficult it will be to achieve the required compaction.

We recommend that fill be tested frequently during placement. Early testing is recommended to demonstrate that placement and compaction methods are achieving the required compaction. It is the contractors responsibility to ensure that fill materials and compaction efforts are consistent so that tested areas are representative of the entire fill.

8.5 Stabilization

During construction and grading, near surface soils may be moist and susceptible to rutting and pumping. The likelihood of rutting and/or pumping, and the depth of disturbance, is proportional to the moisture content in the soil, the load applied to the ground surface, and the frequency of the load. Consequently, rutting and pumping can be minimized by avoiding concentrated traffic, minimizing the load applied to the ground surface by using lighter equipment and/or partial loads, by working in dry times of the year, or by providing a working surface for equipment.

The soil in any obvious soft spots should be removed and replaced with granular material. If rutting or pumping occurs traffic should be stopped in the area of concern. The soil in rutted areas should be removed and replaced with granular material. In areas where pumping occurs the soil should either be allowed to sit until pore pressures dissipate (several hours to several days) and the soil firms up, or be removed and replaced with granular material. Typically, we recommend removal to a minimum depth of 18 inches. Removal and replacement to a greater depth, or the use of fabric as discussed below, may be required.

For granular material, we recommend using angular well-graded gravel, such as pit run, or crushed rock with a maximum particle size of four inches. We suggest that the initial lift be approximately 12 inches thick and be compacted with a static roller-type compactor. A finer granular material such as sand, gravelly sand, sandy gravel or road base may also be used. The more angular and coarse the material, the thinner the lift that will be required. We recommend that the fines content (percent passing the no. 200 sieve) be less than 15%, the liquid limit be less than 35, and the plasticity index be less than 15.

Using a geosynthetic fabric, such as Mirafi 500X or equivalent, may also reduce the amount of material required and avoid mixing of the granular material and the subgrade. If a fabric is used, following removal of disturbed soils and water, the fabric should be placed over the bottom and up the sides of the excavation a minimum of 18 inches. The fabric should be placed in accordance with the manufacturer's recommendations, including proper overlaps. The granular material should then be placed over the fabric in compacted lifts. Again, we suggest that the initial lift be approximately 12 inches thick and be compacted with a static roller-type compactor.

9.0 SEISMIC CONSIDERATIONS

9.1 Faulting

Based on published data no active faults are known to traverse the site and no surficial evidence of faulting was observed during our field investigation. The nearest mapped fault trace is the Wasatch Fault[1] located approximately 5 to 6 miles east of the site.

[1]Hecker, S., 1993, Quaternary Faults and Folds, Utah, Utah Geologic Survey, Bulletin 127.

9.2 Liquefaction Potential

The site is located within an area which has been mapped by the Utah Geological Survey[2] as having very low liquefaction potential. As a part of this investigation, the potential for liquefaction to occur in the soils we observed was assessed. Liquefaction is a phenomenon where a soil loses intergranular strength due to an increase in soil pore water pressures during a dynamic event such as an earthquake. The potential for liquefaction is based on several factors, including 1) the grain size distribution of the soil, 2) the plasticity of the fine fraction of the soil (material passing the No. 200 sieve), 3) relative density of the soil, 4) earthquake strength (magnitude) and duration, and 5) overburden pressures. In addition, the soils must be saturated for liquefaction to occur.

Loose, saturated sands are most susceptible to liquefaction. However, soft, sensitive silt soils also have the potential to experience failure and movement during a seismic event. Sensitive silt soils typically have moisture contents higher than the liquid limit. The subsurface silt soils were not saturated and estimated to be of stiff to very stiff consistency, therefore we concur with the very low liquefaction potential designation.

9.3 IRC Seismic Design Category

The Seismic Design Categories in the International Residential Code (IRC) are based upon the short period design accelerations determined using the seismic provisions of the International Building Code (IBC) and the soil properties in the upper 100 feet of the soil profile. These properties are determined from SPT blow counts and undrained shear strength measurements. The IBC code also states that "Where site specific data are not available to a depth of 100 feet, appropriate soil properties may be estimated by the registered design professional preparing the soils report...." We recommend using Site Class D.

[2]Liquefaction Potential Map, Utah Geological Survey, Public Information Series 28. 1994.

The site is located at approximately 40.51 degrees north latitude and about -111.94 degrees west longitude. For Site Class D, Fa is 1.00 and $S_{DS} = 0.83$. The Seismic Design Category is D_1.

10.0 FOUNDATIONS

10.1 General

The foundation recommendations presented in this report are based on the soil conditions encountered in the test pits, the results of laboratory testing of the native soils, the site grading recommendations presented in this report, and the foundation loading conditions presented in Section 3.0, *Proposed Construction*, of this report. If loading conditions are significantly different, we should be notified in order to re-evaluate our design parameters and estimates, and to provide additional recommendations if necessary.

Foundations should not be installed on disturbed soils, undocumented fill, debris, frozen soil, combination soils, or in ponded water. We recommend that foundations be placed entirely on undisturbed, uniform native soils, or entirely on a minimum 18 inches of properly placed and compacted structural fill placed on native soils. If loose soil remains in the completed excavation, it should be rolled with a smooth drum roller without vibration to provide a firm surface for footing construction or structural fill placement. For design of conventional strip and spread footings, the following parameters are recommended:

Minimum embedment for frost protection:	30 inches
Minimum strip footing width:	20 inches
Minimum spot footing width:	30 inches
Maximum allowable net bearing pressure:	1,500 psf
Bearing pressure increase for transient loading:	33 percent

Structural fill used below foundations should extend laterally a minimum of 6 inches for every 12 vertical inches of structural fill placed. For example, if 18 inches of structural fill are required to bring the excavation to footing grade, the structural fill should extend laterally a minimum of 9 inches beyond both edges of the footings.

10.2 Estimated Settlement

If the proposed foundations are properly designed and constructed using the parameters provided above, total estimated settlement is less than one inch for non-seismic conditions. Differential settlement is anticipated to be one-half of the total settlement over a 25-foot length of foundation. Additional settlement could occur during an earthquake due to ground shaking, if more than 3 feet of grading fill is placed above the existing ground surface, or if foundation soils are allowed to become wetted.

11.0 SUBSURFACE DRAINAGE

According to Section R405 of the 2003 International Residential Code, "Drains shall be provided around all concrete or masonry foundations that retain earth and enclose habitable or usable spaces located below grade." An exception is allowed when the foundation is installed on well drained ground consisting of Group 1 soils. These soils include those defined by the Unified Soil Classification System as GW, GP, SW, SP, GM, and SM. The native soils encountered in the test pits are not Group 1 soils. We recommend that foundation drains be installed if floor slabs will be placed at depths greater than 5 feet below the existing ground surface.

12.0 FLOOR SLABS

If groundwater is encountered in foundation excavations, floor slabs should be kept at least 3 feet above the groundwater.

To facilitate construction, act as a capillary break, and aid in distributing floor loads we recommend that all at-grade slabs and exterior flatwork be underlain by four inches of free-draining granular material such as "pea" gravel or three-quarters to one-inch minus clean gravel placed on native soils or structural fill.

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 and bearing walls.

Special precautions should be taken during placement and curing of all concrete slabs and flatwork. Excessive slump (high water-cement ratios) of the concrete and/or improper finishing and curing procedures used during hot or cold weather conditions may lead to excessive shrinkage, cracking, spalling, or curling of slabs. We recommend all concrete placement and curing operations be performed in accordance with American Concrete Institute (ACI) codes and practices.

13.0 MOISTURE CONTROL AND SURFACE DRAINAGE

The native silt soils were found to be slightly moisture sensitive during laboratory testing. Allowing these soils to become wetted after construction could lead to additional settlement. To reduce the potential for surface runoff water from landscaping and roof drains to collect near foundation walls and saturate foundation soils, we recommend the following precautions be taken:

1. Adequate compaction of foundation backfill should be provided i.e. a minimum of 90% of ASTM D-1557. **Water consolidation methods should not be used.**
2. The ground surface should be graded to drain away from the residences in all directions. We recommend a minimum fall of 8 inches in the first 10 feet.
3. Roof runoff should be collected in rain gutters with down spouts designed to discharge well outside of the backfill limits and at least 10 feet from structures.

4. Sprinkler heads, lines and valves should be kept at least 5 feet from foundation walls. Sprinkler nozzles should be aimed away from foundation walls. Sprinkler systems should be designed with proper drainage and well maintained. Over-watering should be avoided.

5. Other precautions which may become evident during design and construction should be taken.

14.0 PAVEMENT DESIGN

We understand that residential streets will be constructed as part of the development. The native soils encountered in the test pits were composed of silt. To aid in the design of the pavement section, test results indicate the on site silt soils have a California Bearing Ratio (CBR) of 13. For our design, we used a CBR value of 8, which appears to be conservative for these soils. We anticipate the traffic volume will be approximately 100 vehicles per day or less and consist primarily of cars and pickup trucks, a daily school bus, a weekly garbage truck, and some occasional delivery trucks. Based upon these assumptions, the laboratory test results, and the procedures outlined in the *AASHTO Guide for Design of Pavement Structures (1993)*, we recommend the minimum asphalt pavement section presented in the table below.

Table No. 2: Pavement Section Design

ASPHALT THICKNESS (in)	COMPACTED ROADBASE THICKNESS (in)	COMPACTED SUBBASE THICKNESS (in)
3.0	6.0	0.0*

*Stabilization may be required in some areas.

The pavement section recommended is not intended to support frequent construction traffic, or more than an occasional semi truck. All base material and asphalt should conform to local requirements regarding thickness, gradation, oil content, and any other requirements pertaining to the project. We recommend that all roadbase and subbase be properly processed, moisture conditioned, and compacted to a minimum of 95% of the maximum dry density as determined

by ASTM-D 1557. All asphalt should be compacted to a minimum of 95% of the laboratory Marshal mix design density.

15.0 GENERAL CONDITIONS

The exploratory data presented in this report was collected to provide geotechnical design recommendations for this project. The test pits may not be representative of subsurface conditions outside the study area or between points explored and thus have a limited value in depicting subsurface conditions for contractor bidding. Variations from the conditions portrayed on the test pit logs may occur and be sufficient to require modifications in the design. If during construction, conditions are different than presented in this report, please advise us so that the appropriate modifications can be made.

The geotechnical study as presented in this report was conducted within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession in the area. No other warranty or representation, either expressed or implied, is intended in our proposals, contracts or reports.

We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please call.

Respectfully;

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