REPORT
GEOTECHNICAL STUDY
PROPOSED SINGLE-LOT
KEO HOMESTEAD SUBDIVISION
APPROXIMATELY 5600 EAST HIGHWAY 39
WEBER COUNTY, UTAH

Submitted To:

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Submitted By:

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April 25, 2016

Job No. 1675-02N-15

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Mr. David Orchard
2248 Oneida Street
Salt Lake City, Utah 84109

Mr. Orchard:

Re: Report
Geotechnical Study
Proposed Single-Lot KEO Homestead Subdivision
Approximately 5600 East Highway 39
Weber County, Utah

1. INTRODUCTION

1.1 GENERAL

This report presents the results of our geotechnical study performed at the site of the proposed single-family residence and detached garage to be located at approximately 5600 East Highway 39 near Huntsville in Weber County, Utah. The general location of the site with respect to major topographic features, as of 1998, is presented on Figure 1, Vicinity Map. An aerial view of the site property with surrounding roadways is presented on Figure 2, Site Plan. The locations of the test pits excavated in conjunction with this study are also presented on Figure 2. A geotechnical study[1] was previously completed for the property, dated July 25, 2014. The findings of this study are utilized in the preparation of this report.

1.2 OBJECTIVES AND SCOPE

The objectives and scope of our study were planned in discussions between Mr. David Orchard, property owner, and Mr. Andrew Harris of GSH Geotechnical, Inc. (GSH).

[1] "Report, Geotechnical Study, Proposed Single-Family Residence, Approximately 5600 East Highway 39, Weber County, Utah," GSH Geotechnical, Inc., GSH Job No. 1675-01N-14, July 25, 2014.

In general, the objectives of this study were to:

1. Define and evaluate the subsurface soil and groundwater conditions across the site.

2. Provide appropriate foundation, earthwork, slope stability, and geoseismic information to be utilized in the design and construction of the proposed structure.

In accomplishing these objectives, our scope has included the following:

1. A field program consisting of the excavating, logging, and sampling of 4 exploration test pits and 2 trenches as well as drilling, logging, and sampling of 3 borings.

2. A laboratory testing program.

3. An office program consisting of the correlation of available data, engineering analyses, and the preparation of this summary report.

1.3 AUTHORIZATION

Authorization was provided by returning a signed copy of our Professional Service Agreement No. 16-0224N dated February 8, 2016.

1.4 PROFESSIONAL STATEMENTS

Supporting data upon which our recommendations are based are presented in subsequent sections of this report. Recommendations presented herein are governed by the physical properties of the soils encountered in the exploration test pits/trenches/borings, projected groundwater conditions, and the layout and design data discussed in Section 2, Proposed Construction, of this report. If subsurface conditions other than those described in this report are encountered and/or if design and layout changes are implemented, GSH must be informed so that our recommendations can be reviewed and amended, if necessary.

Our professional services have been performed, our findings developed, and our recommendations prepared in accordance with generally accepted engineering principles and practices in this area at this time.

2. PROPOSED CONSTRUCTION

The proposed project consists of constructing a single-family residence and detached garage on the undeveloped approximately 21.3-acre parcel located about 5600 East Highway 39 near Huntsville in Weber County, Utah. Construction for the home will likely consist of reinforced concrete footings and basement foundation walls supporting 1 to 3 wood-framed levels above grade with some stone, brick, or stucco veneer. The detached garage is anticipated to be a single level wood framed level above grade and constructed slab on grade. Projected maximum column and wall loads are on the order of 10 to 20 kips and 1 to 3 kips per lineal foot, respectively.

Site development will require a moderate amount of earthwork in the form of site grading. We understand that site grading will be minimized on the project to maintain stability of the slopes at the site. We estimate in general that maximum cuts and fills to achieve design grades will be on the order of 2 to 5 feet. Larger fills and cuts may be required at isolated areas and should be engineered accordingly to maintain stability of the slopes at the site.

3. SITE INVESTIGATIONS

3.1 FIELD PROGRAM

In order to define and evaluate the subsurface soil and groundwater conditions at the site, 4 test pits and 2 trenches were excavated to depths of about 10.0 to 15.0 feet below existing grade. The test pits were excavated using a track-mounted excavator provided by the client. Additionally, 3 borings were drilled at the site to depths of about 34.0 to 49.0 feet below existing site grades using an all-terrain geotechnical drill rig equipped with hollow stem augers. The borings were terminated at the associated depths due to auger refusal in the underlying bedrock. The boring, trench, and test pit locations are presented on Figure 2.

The field portion of our study was under the direct control and continual supervision of an experienced member of our geotechnical staff. During the course of the drilling and excavating operations, a continuous log of the subsurface conditions encountered was maintained. In addition, samples of the typical soils encountered were obtained for subsequent laboratory testing and examination. The soils were classified in the field based upon visual and textural examination. These classifications have been supplemented by subsequent inspection and testing in our laboratory. Detailed graphical representation of the subsurface conditions encountered is presented on Figures 3A through 3F, Test Pit Log, and Figures 4A through 4C, Boring Log. Soils were classified in accordance with the nomenclature described on Figure 5, Key to Boring Log (USCS), and Figure 6, Key to Test Pit Log.

A 2.42-inch inside diameter thin-wall drive sampler was utilized in the subsurface sampling within the test pits and trenches at the site.

A 3.25-inch outside diameter, 2.42-inch inside diameter drive sampler (Dames & Moore) and a 2.0-inch outside diameter, 1.38-inch inside diameter drive sampler (SPT) were utilized at select depths. The blow counts recorded on the boring logs were those required to drive the sampler 12 inches with a 140-pound hammer dropping 30 inches.

Following completion of drilling operations, 1.25-inch diameter slotted PVC pipe was installed in Boring B-1, B-2, and B-3 in order to provide a means of monitoring the groundwater fluctuations. The borings were backfilled with auger cuttings.

Following completion of excavating and logging, each test pit was backfilled. Although an effort was made to compact the backfill with the trackhoe, backfill was not placed in uniform lifts and compacted to a specific density. Consequently, settlement of the backfill with time is likely to occur.

3.2 LABORATORY TESTING

3.2.1 General

In order to provide data necessary for our engineering analyses, a laboratory testing program was performed. The program included performing moisture, density, partial gradation, Atterberg limits, direct shear, residual direct shear, and consolidation tests on representative subsurface soil samples. The following paragraphs describe the tests and summarize the test data.

3.2.2 Moisture and Density

To provide index parameters and to correlate other test data, moisture and density tests were performed on selected samples. The results of these tests are presented on the test pits logs, Figures 3A through 3F, and the boring logs, Figures 4A through 4C.

3.2.3 Partial Gradation Test

To aid in classifying the soils, partial gradation tests were performed. Results of the tests are tabulated below:

Test Pit/ Trench/ Boring No.	Depth (feet)	Percent Passing No. 200 Sieve	Soil Classification
TP-2	6.0	32	CH
TP-4	6.0	31	CH
B-1	23.0	37	SC
B-2	15.5	5	SP
B-2	27.5	7	SP-SC
B-3	8.0	11	SP-SC
B-3	18.0	35	SC
B-3	25.5	17	SC
B-3	45.5	14	GM

3.2.4 Atterberg Limits Tests

To aid in classifying the soils, Atterberg limits tests were performed on samples of the fine-grained cohesive soils. Results of the tests are tabulated below:

Test Pit/ Trench/ Boring No.	Depth (feet)	Liquid Limit (percent)	Plastic Limit (percent)	Plasticity Index (percent)	Soil Classification
TP-1	3.0	43	16	27	CL
TP-2	6.0	54	19	35	CH
TP-4	6.0	52	17	35	CH
B-1	8.0	40	18	22	CL
B-2	5.5	31	16	15	CL
B-2	20.5	28	13	15	CL
TR-1	5.0	54	20	34	CH

3.2.5 Laboratory Direct Shear Tests

To determine the shear strength of the soils encountered at the site, laboratory direct shear tests were performed. The results of the tests are tabulated below and on Figures 7, 8, and 9:

Test Pit/ Trench/ Boring No.	Depth (feet)	Soil Type	In-Situ Moisture Content (percent)	Dry Density (pcf)	Internal Friction Angle (degrees)	Apparent Cohesion (psf)
TP-1	2.0	CL	18	109	28	510
TP-4	4.0	CH	11		28	1,060
B-2	20.5	CL	18	97	31	440

3.2.6 Laboratory Residual Direct Shear Test

To determine the residual shear strength of the soils encountered at the site, laboratory residual direct shear tests were performed on samples of the site soils. The results of the tests are tabulated on the following page and on Figures 10, and 11.

Test Pit/ Trench/ Boring No.	Depth (feet)	Soil Type	In-Situ Moisture Content (percent)	Dry Density (pcf)	Internal Friction Angle (degrees)	Apparent Cohesion (psf)
TR-1	5.0	CH	20	84	15	40
B-2	5.5	CL	13	98	20	60

3.2.7 Consolidation Tests

To provide data necessary for our settlement analyses, consolidation tests were performed on a representative sample of the fine-grained soils encountered in the exploration test pits/borings.

The test was performed in accordance with the following procedure:

1. Load sample at in-situ moisture content to specific axial pressure.
2. Measure and record axial deflection.
3. Saturate sample.
4. Measure and record resulting swell/collapse.

The test results are tabulated below:

Test Pit No.	Depth (feet)	Soil Classification	Natural Dry Density (pcf)	Natural Moisture Content (percent)	Axial Load When Saturated (psf)	Collapse/Swell (-/+) (percent)
TP-1	3.0	CL	---	---	200	+3.2
B-3	5.5	CL	117	17	100	+0.7

4. SITE CONDITIONS

4.1 GEOLOGIC SETTING

A geologic hazards reconnaissance study[2] dated April 11, 2016 was prepared for the subject property by GSH and a copy of that report is included in the attached Appendix.

[2] "Summary Report, Geological Study, Proposed Single-lot KEO Homestead Subdivision, Approximately 5600 East Highway 39, Weber County, Utah," GSH Geotechnical, Inc., April 11, 2016.

4.2 SURFACE

The subject property consists of an undeveloped, approximately 21.3-acre parcel at about 5600 East Highway 39 in Weber County, Utah. Vegetation at the site consists primarily of native grasses, dense brush, and scrub oak trees. A generally west-east flowing seasonal drainage exists near the north property line of the subject property. We understand that the driveway for the proposed residence will cross this seasonal drainage and will likely utilize a culvert(s) to create this crossing. The culvert(s) should be appropriately sized by the project civil engineer to accommodate the anticipated design flows. The subject property is situated in the mountain foothills and generally slopes to the northeast at approximate grades of 2.5H:1V (Horizontal:Vertical) to 5H:1V (Horizontal:Vertical), with a change in elevation of about 220 feet across the property. Steeper slopes are present off-site in the mountains above the subject property. The subject property is bordered by undeveloped property to the south and west and by similar residential development on large parcels to the north and east.

4.3 SUBSURFACE SOIL

The soil conditions encountered varied slightly across the site. At the exploration locations, topsoil and disturbed soils were encountered at the surface of the site to about 3 to 12 inches below existing grades. Colluvial material consisting of lean to fat clay with varying amounts of fine to coarse sand, fine and coarse gravel, and cobbles and clayey fine and coarse gravel with fine to coarse sand were encountered beneath the topsoil and disturbed soils within the test pits, trenches, and borings to depths of about 7.0 to 18.0 feet below existing grades. In general, weathered bedrock (Norwood Tuff) was encountered below the surficial colluvial material to the maximum depth explored of about 10.0 to 49.0 feet below existing grade. The weathered bedrock consisted of fine and coarse gravel with varying amounts of silt/clay, fine to coarse sand, and cobbles, silty clay with varying amounts of fine to coarse sand and fine and coarse gravel, and fine to coarse sand with varying amounts of silt/clay and gravel. Borings at the site were terminated at depths ranging from 34.0 to 49.0 feet below existing grade due to auger refusal in the bedrock. Major soil layering encountered ranged from a thickness of roughly 2.0 feet up to about 19.5 feet.

The granular soils encountered were medium dense to very dense, moist, brown to gray in color, and will exhibit moderate strength and low compressibility characteristics under the anticipated loading.

The fine-grained clay/silt soils encountered were medium stiff to hard, moist, dark brown to brown in color, and will exhibit moderate strength and moderate compressibility characteristics under the anticipated loading.

For a more detailed description of the subsurface soils encountered, please refer to Figures 3A through 3F, Test Pit Log, and Figure 4A, Boring Log. The lines designating the interface between soil types on the test pit logs generally represent approximate boundaries. In-situ, the transition between soil types may be gradual.

4.4 GROUNDWATER

Groundwater was not encountered during excavation and drilling operation at the site to the depths penetrated, about 49.0 feet, and is anticipated at significant depths. Groundwater is not anticipated to affect construction. Seasonal and longer-term groundwater fluctuations of 1 to 2 feet should be anticipated. The highest seasonal levels will generally occur during the late spring and summer months. Landscape irrigation on this and surrounding areas may also create additional seasonal groundwater fluctuations. The limitations of landscape irrigation at the site are discussed further in Section 5.9, Site Irrigation, and measures to reduce infiltration of surface water at the site are discussed further in Section 5.8, Subdrains.

5. DISCUSSIONS AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

The most significant geotechnical aspects of the site are the presence of colluvial (mass movement) soil deposits, maintaining stability of the slopes, the expansive potential of the native clays under lighter loading, and the moderate strength characteristics of the fine-grained silts/clays encountered at the site. The results of our analyses indicate that the proposed structure may be supported upon conventional spread and/or continuous wall foundations established upon suitable natural soils or granular structural fill extending to suitable natural soils. Under no circumstance should footings and foundations be established in the mass movement soil deposits observed at the site.

All mass movement soil deposits must be removed to suitable natural soils below foundations. The mass movement soil deposits may remain in pavement areas if they are properly prepared, as discussed in this report.

The on-site soils are not appropriate to be used as structural site grading fill, however, they may be used as general grading fill in landscape areas.

A qualified geotechnical engineer from GSH will need to verify that all mass movement soil deposits, topsoil, and disturbed soils have been completely removed prior to the placement of structural site grading fills, floor slabs, footings, foundations, or rigid pavements.

In the following sections, detailed discussions pertaining to earthwork, foundations, at-grade concrete slabs, slope stability, and the geoseismic setting of the site are provided.

5.2 EARTHWORK

5.2.1 Site Preparation

Initial site preparation will consist of the removal of surface vegetation, topsoil, and other deleterious materials from beneath an area extending out at least 3 feet from the perimeter of the proposed building, pavements, and exterior flatwork areas.

Additional site preparation will consist of the removal of all mass movement soil deposits from an area extending out at least 10 feet from the perimeter of all residential structures. Based on our observations at the test pit/boring/trench locations, the mass movement soil deposits are likely to extend about 7.0 to 18.0 feet in depth below existing site grades; however, variation in the depth of the mass movement deposits is likely.

All non-engineered fills such as backfill from test pits/trenches and mass movement deposit soils must be removed below all structures. In situ, non-engineered fills and mass movement deposit soils may remain below pavements if the owner accepts the risk of movement, if free of debris and deleterious materials, if less than 4 feet in thickness, and if properly prepared. Proper preparation will consist of the scarification of the upper 12 inches below asphalt concrete (flexible pavement) and 24 inches below rigid pavement followed by moisture preparation and re-compaction to the requirements of structural fill. The thicker sequence of prepared soils below rigid pavements would require the temporary removal of 12 inches of fill or mass movement deposit soils, scarifying, moisture conditioning, and recompacting the underlying 12 inches and backfilling with 12 inches of compacted suitable fills.

Even with proper preparation, pavements established overlying non-engineered fills and mass movement soil deposits may encounter some long-term movements unless the non-engineered fills and mass movement deposit soils are completely removed. Installing reinforcement in slabs over fills may help reduce potential displacement cracking.

It must be noted that from a handling and compaction standpoint, onsite soils containing high amounts of fines (silts and clays) are inherently more difficult to rework and are very sensitive to changes in moisture content requiring very close moisture control during placement and compaction. This will be very difficult, if not impossible, during wet and cold periods of the year. Additionally, the onsite soils are likely above optimum moisture content for compacting at present and would require some drying prior to recompacting. As an alternative, the fills may be removed and replaced with imported granular structural fill over unfrozen, proofrolled subgrade.

Subsequent to stripping and prior to the placement of structural site grading fill, pavements, driveway and garage slabs on grade, the prepared subgrade must be proofrolled by passing moderate-weight rubber tire-mounted construction equipment over the surface at least twice. If excessively soft or loose soils are encountered, they must be removed to a maximum depth of 2 feet and replaced with structural fill. Beneath footings, all loose and disturbed soils must be totally removed

Surface vegetation and other deleterious materials should generally be removed from the site. Topsoil, although unsuitable for utilization as structural fill, may be stockpiled for subsequent landscaping purposes.

5.2.2 Excavations

Temporary excavations up to 8 feet deep in fine-grained cohesive soils, above or below the water table, may be constructed with sideslopes no steeper than one-half horizontal to one vertical (0.5H:1V). Excavations deeper than 8 feet are not anticipated at the site.

For granular (cohesionless) soils, construction excavations above the water table, not exceeding 4 feet, should be no steeper than one-half horizontal to one vertical (0.5H:1V). For excavations up to 8 feet, in granular soils and above the water table, the slopes should be no steeper than one horizontal to one vertical (1H:1V). Excavations encountering saturated cohesionless soils will be very difficult and will require very flat sideslopes and/or shoring, bracing and dewatering.

To reduce disturbance of the natural soils during excavation, it is recommended that smooth edge buckets/blades be utilized.

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.

5.2.3 Structural Fill

Structural fill will be required as site grading fill, as backfill over foundations and utilities, and possibly as replacement fill beneath some footings. All structural fill must be free of sod, rubbish, construction debris, frozen soil, and other deleterious materials.

Structural site grading fill is defined as fill placed over fairly large open areas to raise the overall site grade. The maximum particle size within structural site grading fill should generally not exceed 4 inches; although, occasional particles up to 6 to 8 inches may be incorporated provided that they do not result in "honeycombing" or preclude the obtainment of the desired degree of compaction. In confined areas, the maximum particle size should generally be restricted to 2.5 inches.

Only granular soils are recommended in confined areas such as utility trenches, below footings, etc. Generally, we recommend that all imported granular structural fill consist of a well-graded mixture of sands and gravels with no more than 20 percent fines (material passing the No. 200 sieve) and less than 30 percent retained on the 3/4 inch sieve. The plasticity index of import fine-grained soil shall not exceed 18 percent.

To stabilize soft subgrade conditions or where structural fill is required to be placed closer than 1.0 foot above the water table at the time of construction, a mixture of coarse gravels and cobbles and/or 1.5- to 2.0-inch gravel (stabilizing fill) should be utilized. It may also help to utilize a stabilization fabric, such as Mirafi 600X or equivalent, placed on the native ground if 1.5- to 2.0-inch gravel is used as stabilizing fill.

On-site soils are not recommended as structural fill but may be used as non-structural grading fill in landscape areas. Non-structural site grading fill is defined as all fill material not designated as structural fill and may consist of any cohesive or granular soils not containing excessive amounts of degradable material.

5.2.4 Fill Placement and Compaction

All structural fill shall be placed in lifts not exceeding 8 inches in loose thickness. Structural fills shall be compacted in accordance with the percent of the maximum dry density as determined by the ASTM[3] D-1557 (AASHTO[4] T-180) compaction criteria in accordance with the table below:

Location	Total Fill Thickness (feet)	Minimum Percentage of Maximum Dry Density
Beneath an area extending at least 5 feet beyond the perimeter of the structure	0 to 8	95
Site Grading Fills outside area defined above	0 to 5	90
Site Grading Fills outside area defined above	5 to 8	95
Trench Backfill	--	96
Pavement granular base/subbase	--	96

Structural fills greater than 8 feet thick are not anticipated at the site.

Subsequent to stripping and prior to the placement of structural site grading fill, the subgrade shall be prepared as discussed in Section 5.2.1, Site Preparation, of this report. In confined areas, subgrade preparation shall consist of the removal of all loose or disturbed soils.

If utilized for stabilizing fill, coarse gravel and cobble mixtures should be end-dumped, spread to a maximum loose lift thickness of 15 inches, and compacted by dropping a backhoe bucket onto the surface continuously at least twice. As an alternative, the fill may be compacted by passing moderately heavy construction equipment or large self-propelled compaction equipment at least twice. Subsequent fill material placed over the coarse gravels and cobbles shall be adequately compacted so that the “fines” are “worked into” the voids in the underlying coarser gravels and cobbles.

[3] American Society for Testing and Materials
[4] American Association of State Highway and Transportation Officials

5.2.5 Utility Trenches

All utility trench backfill material below structurally loaded facilities (flatwork, floor slabs, roads, etc.) shall be placed at the same density requirements established for structural fill. If the surface of the backfill becomes disturbed during the course of construction, the backfill shall be proofrolled and/or properly compacted prior to the construction of any exterior flatwork over a backfilled trench. Proofrolling may be performed by passing moderately loaded rubber tire-mounted construction equipment uniformly over the surface at least twice. If excessively loose or soft areas are encountered during proofrolling, they must be removed (to a maximum depth of 2 feet below design finish grade) and replaced with structural fill.

Most utility companies and City-County governments are now requiring that Type A-1-a/A-1-b (AASHTO Designation – basically granular soils with limited fines) soils be used as backfill over utilities. These organizations are also requiring that in public roadways the backfill over major utilities be compacted over the full depth of fill to at least 96 percent of the maximum dry density as determined by the AASHTO T-180 (ASTM D-1557) method of compaction. We recommend that as the major utilities continue onto the site that these compaction specifications are followed.

The natural or imported silt/clay soils are not recommended for use as trench backfill, particularly in structurally loaded areas.

5.3 SLOPE STABILTY

5.3.1 Stability Analyses

The properties of the natural weathered bedrock and colluvium (mass movement soil deposits, also clays) observed at the test pit/trench/boring locations were estimated using laboratory direct shear and residual direct shear testing and our experience with similar soils. Accordingly, we estimated the following parameters for use in the stability analyses:

Material	Internal Friction Angle (degrees)	Apparent Cohesion (psf)	Saturated Unit Weight (pcf)
Colluvium	28	100	125
Weathered Bedrock	29	400	140

For the seismic (pseudostatic) analysis, a peak horizontal ground acceleration of 0.27*g* for Site Class C and multiplying by 2/3 per IBC 2012 was obtained for site (grid) locations of 41.2530 degrees latitude (north) and 111.8145 degrees longitude (west). To model sustained accelerations at the site, one-half of this value is typically employed. Accordingly, a value of 0.14 was used as the pseudostatic coefficient for the stability analysis.

We also evaluated the global stability of the slope using the computer program *SLIDE*. This program uses a limit equilibrium (Simplified Bishop) method for calculating factors of safety against sliding on an assumed failure surface and evaluates numerous potential failure surfaces, with the most critical failure surface identified as the one yielding the lowest factor of safety of those evaluated. The configurations we analyzed consisted of the existing slope through the site, which are inclined at approximately 2.5H:1V (Horizontal:Vertical) to 5H:1V (Horizontal:Vertical). Further information related to the slope cross-sections configuration and location can be found in the geological study, attached in the appendix of this report. In addition, a phreatic (groundwater) surface was presumed through the site for static analyses, even though groundwater was not encountered in our explorations. To simulate the load imposed on the slope by the proposed residential construction, a load of 1,500 psf was modeled at the building pad location. Typically, the required minimum factors of safety are 1.5 for static conditions and 1.0 for seismic (pseudostatic) conditions. The results of our analyses indicate that the existing slope configuration with the new residence will meet both these requirements provided our recommendations are followed. The slope stability data are included as Figures 12 through 15, attached.

Slope movements or even failure can occur if the slope soils are undermined or become saturated. Groundwater was not encountered during the course of our field investigation; however saturation of the slope soils can adversely affect the stability of the slope. Measures must be implemented to reduce the potential for saturation of the soils at the site. Surface drainage at the bottom and top of the slope should be directed to prevent ponding at the toe or crest of the slope. Landscape irrigation on this and surrounding areas may also create additional seasonal groundwater fluctuations. The limitations of landscape irrigation at the site are discussed further in Section 5.9, Site Irrigation. The property owner and the owner's representatives should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the slope soils.

Changes to the grading at the site and any retaining walls must be properly engineered to maintain stability of the slopes. <u>GSH must review the final grading plans for the project prior to initiation of any construction</u>.

5.4 SPREAD AND CONTINUOUS WALL FOUNDATIONS

5.4.1 Design Data

The proposed structure may be supported upon conventional spread and continuous wall foundations established upon suitable natural soils and/or structural fill extending to suitable natural soils. Under no circumstance should structures be established on the mass movement soil deposits observed at the site. For design, the following parameters are provided:

Minimum Recommended Depth of Embedment for Frost Protection	- 30 inches
Minimum Recommended Depth of Embedment for Non-frost Conditions	- 15 inches

Recommended Minimum Width for Continuous Wall Footings	- 16 inches
Minimum Recommended Width for Isolated Spread Footings	- 24 inches
Recommended Net Bearing Pressure for Real Load Conditions	- 1,500 pounds per square foot
Bearing Pressure Increase for Seismic Loading	- 50 percent

The term "net bearing pressure" refers to the pressure imposed by the portion of the structure located above lowest adjacent final grade. Therefore, the weight of the footing and backfill to lowest adjacent final grade need not be considered. Real loads are defined as the total of all dead plus frequently applied live loads. Total load includes all dead and live loads, including seismic and wind.

5.4.2 Installation

Under no circumstances shall the footings be established upon mass movement soil deposits, non-engineered fills, loose or disturbed soils, topsoil, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water. If unsuitable soils are encountered, they must be completely removed and replaced with compacted structural fill.

The width of structural replacement fill below footings should be equal to the width of the footing plus one 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.

5.4.3 Settlements

Maximum settlements of foundations designed and installed in accordance with recommendations presented herein and supporting maximum anticipated loads as discussed in Section 2, Proposed Construction, are anticipated to be 1 inch or less.

Approximately 60 percent of the quoted settlement should occur during construction.

5.5 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 0.30 should be utilized for foundation placed on native soils and a coefficient of 0.40 should be utilized for foundations placed on structural fill. Passive resistance provided by properly placed and compacted granular structural fill above the water table may be considered equivalent to a fluid with a density of 300 pounds per cubic foot. Below the water table, this granular soil should be considered equivalent to a fluid with a density of 150 pounds per cubic foot.

A combination of passive earth resistance and friction may be utilized provided that the friction component of the total is divided by 1.5.

5.6 LATERAL PRESSURES

The lateral pressure parameters, as presented within this section, are for backfills which will consist of drained granular soil placed and compacted in accordance with the recommendations presented herein. The lateral pressures imposed upon subgrade facilities will, therefore, be basically dependent upon the relative rigidity and movement of the backfilled structure. For active walls, such as retaining walls which can move outward (away from the backfill), granular backfill may be considered equivalent to a fluid with a density of 35 pounds per cubic foot in computing lateral pressures. For more rigid walls (moderately yielding), generally not exceeding 8 feet in height, granular backfill may be considered equivalent to a fluid with a density of 45 pounds per cubic foot. The above values assume that the surface of the soils slope behind the wall is no steeper than 4 horizontal to 1 vertical and that the granular fill within 3 feet of the wall will be compacted with hand-operated compacting equipment.

For seismic loading, a uniform pressure should be added. The uniform pressures based on different wall heights are provided in the following table:

Wall Height (feet)	**Seismic Loading Active Case (psf)**	**Seismic Loading Moderately Yielding (psf)**
4	25	55
6	40	85
8	55	115

5.7 FLOOR SLABS

Floors slabs at this site should be free-floating and isolated from footings and foundation walls. This can be accomplished through installing a saw cut through the floor slab adjacent to foundation elements or through the installation of an expansion joint material during new construction. Floor slabs may be established upon suitable natural soils and/or upon structural fill extending to suitable natural soils. Under no circumstances should the floor slabs be established overlying existing mass movement soils, loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water. In order to facilitate construction and curing of the concrete, it is recommended that floor slabs be directly underlain by 4 inches of “free-draining” fill, such as “pea” gravel or three-quarters- to one-inch minus clean gap-graded gravel.

Due to the expansive nature of the underlying soils, vertical movement of floor slabs should be anticipated. This movement should be anticipated to be non-uniform. All non-load bearing walls constructed on the floor slabs should utilize slip-joint construction. Slip-joint walls are designed to accommodate vertical movement without translating that movement to the structure above the wall. A detail for typical slip-joint walls can be provided upon request.

5.8 SUBDRAINS

5.8.1 General

Groundwater was not encountered at the site, however we recommend that the perimeter foundation subdrains be installed as indicated below.

5.8.2 Foundation Subdrains

Foundation subdrains should consist of a 4-inch diameter perforated or slotted plastic or PVC pipe enclosed in clean gravel. The invert of a subdrain should be at least 2 feet below the top of the lowest adjacent floor slab. The gravel portion of the drain should extend 2 inches laterally and below the perforated pipe and at least 1 foot above the top of the lowest adjacent floor slab. The gravel zone must be installed immediately adjacent to the perimeter footings and the foundation walls. To reduce the possibility of plugging, the gravel must be wrapped with a geotextile, such as Mirafi 140N or equivalent. Above the subdrain, a minimum 4-inch-wide zone of “free-draining” sand/gravel should be placed adjacent to the foundation walls and extend to within 2 feet of final grade. The upper 2 feet of soils should consist of a compacted clayey cap to reduce surface water infiltration into the drain. As an alternative to the zone of permeable sand/gravel, a prefabricated “drainage board,” such as Miradrain or equivalent, may be placed adjacent to the exterior below-grade walls. Prior to the installation of the footing subdrain, the below-grade walls should be dampproofed. The slope of the subdrain should be at least 0.3 percent. The gravel placed around the drain pipe should be clean 0.75-inch to 1.0-inch minus gap-graded gravel and/or “pea” gravel. The foundation subdrains can be discharged into the area subdrains, storm drains, or other suitable down-gradient location.
We recommend final site grading slope away from the structures at a minimum 2 percent for hard surfaces (pavement) and 5 percent for soil surfaces within the first 10 feet from the structures.

5.9 SITE IRRIGATION

Proper site drainage is important to maintaining slope stability at the site. Saturation of soils at the site may result in slope movement or failure. Therefore, we recommend that no irrigation lines should be placed on the slope. Landscaping at the site should be planned to utilize drought resistant plants that require minimal watering. Plants or lawn may be placed on the slope, with plants watered using direct drip systems targeted only for each plant, and any lawn areas watered using sprinklers placed a minimum of 30 feet from the slope. Overwatering should be strictly avoided. The surface of the site should be graded to prevent the accumulation or ponding of surface water at the site. The property owner and the owner's representatives should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the slope soils.

To reduce the potential for saturation of the site soils, overwatering at the site should be strictly avoided. Watering at the site should be limited to a maximum equivalent rainfall of 0.5 inches per week. Irrigation at the site should be strictly avoided during periods of natural precipitation.

5.10 GEOSEISMIC SETTING

5.10.1 General

Utah municipalities adopted the International Building Code (IBC) 2012 and International Residential Code (IRC) for One- to Two-Family Dwellings 2012 on July 1, 2013. The IBC and IRC 2012 codes determine the seismic hazard for a site based upon 2008 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).

The structures must be designed in accordance with the procedure presented in Section 1613, Earthquake Loads, of the IBC 2012 edition.

5.10.2 Site Class

For dynamic structural analysis, the Site Class D - Stiff Soil Profile as defined in Chapter 20 of ASCE 7 (per Section 1613.3.2, Site Class Definitions, of IBC 2012) can be utilized.

5.10.3 Faulting

Based upon our review of available literature, no active faults are known to pass through the site. The nearest active fault is the Wasatch Fault Zone Weber Section, approximately 6.3 miles west of the site.

5.10.4 Ground Motions

The IBC 2012 code is based on 2008 USGS mapping, which provides values of short and long period accelerations for the Site Class B boundary for the Maximum Considered Earthquake (MCE). This Site Class B boundary represents a hypothetical bedrock surface and must be corrected for local soil conditions. The following table summarizes the peak ground and short and long period accelerations for a MCE event and incorporates a soil amplification factor for a Site Class D soil profile in the second column. Based on the site latitude and longitude (41.2530 degrees north and -111.8145 degrees west, respectively), the values for this site are tabulated on the following page.

Spectral Acceleration Value, T	Site Class B Boundary [mapped values] (% g)	Site Coefficient	Site Class D [adjusted for site class effects] (% g)	Design Values (% g)
Peak Ground Acceleration	35.4	F_a = 1.146	40.6	27.1
0.2 Seconds (Short Period Acceleration)	S_S = 88.6	F_a = 1.146	S_{MS} = 101.5	S_{DS} = 67.7
1.0 Second (Long Period Acceleration)	S_1 = 30.1	F_v = 1.798	S_{M1} = 54.1	S_{D1} = 36.1

5.10.5 Liquefaction

Liquefaction is defined as the condition when saturated, loose, finer-grained sand-type soils lose their support capabilities because of excessive pore water pressure which develops during a seismic event.

Liquefaction of near-surface soils at the site is not anticipated during the design seismic event due to the unsaturated nature of the granular soils, and the cohesive (clayey) nature of the other site soils.

5.11 SITE VISITS

As stated previously, prior to placement of foundations, floor slabs, pavements, and site grading fills, a geotechnical engineer from GSH must verify that all mass movement soil deposits, topsoil, and disturbed soils have been removed and suitable subgrade conditions encountered.

GSH

5.12 CLOSURE

If you have any questions or would like to discuss these items further, please feel free to contact us at (801) 393-2012.

Respectfully submitted,

GSH Geotechnical, Inc.

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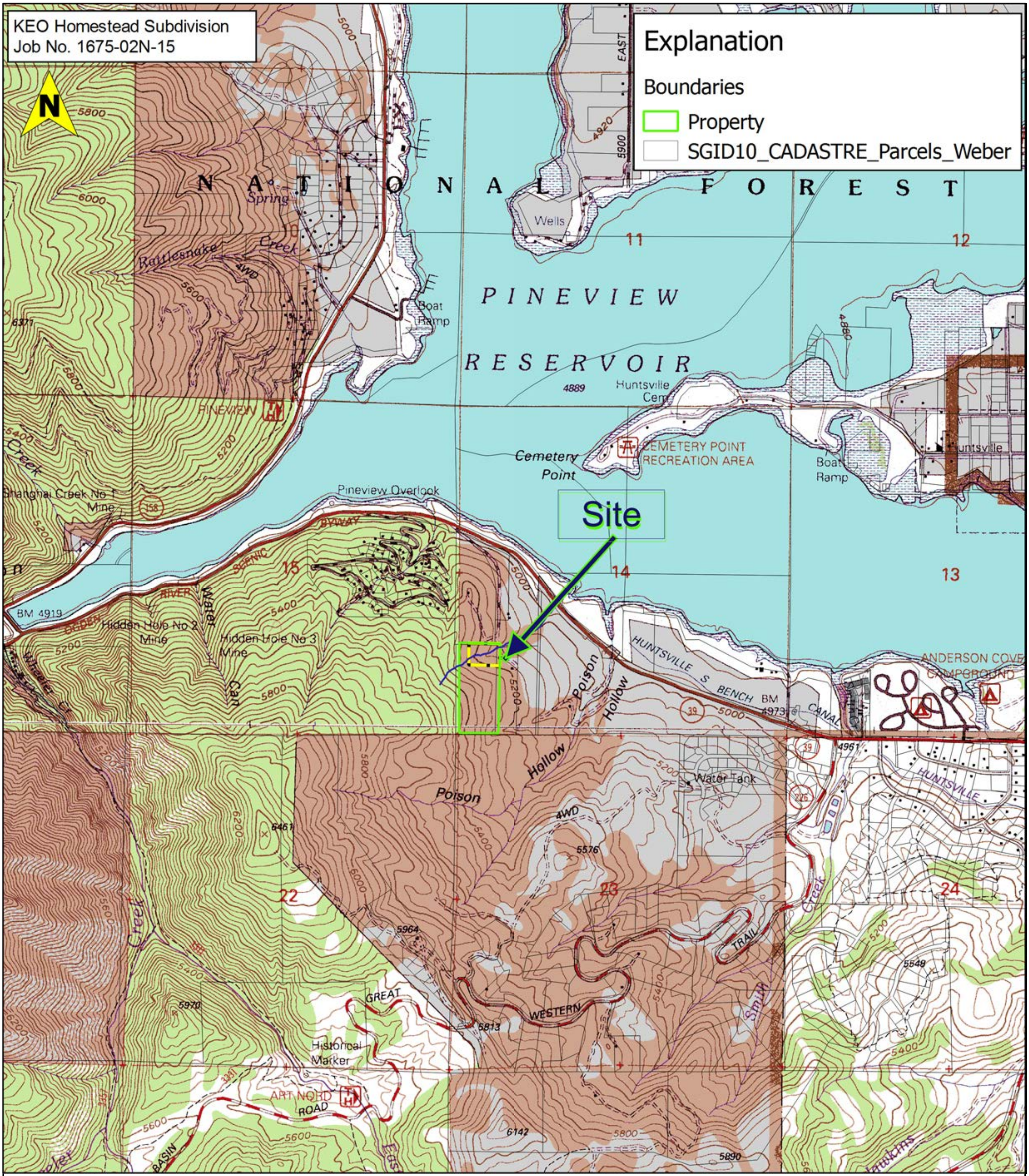
AMH/MSH:mmh

Encl.	Figure	1,	Vicinity Map
	Figure	2,	Site Plan
	Figures	3A	through 3F, Test Pit Logs
	Figures	4A	through 4C, Boring Log
	Figure	5,	Key to Test Pit Log (USCS)
	Figure	6,	Key to Boring Log (USCS)
	Figures	7	through 11, Direct Shear Test
	Figures	12	through 15, Stability Results
	Appendix		

Addressee (email)

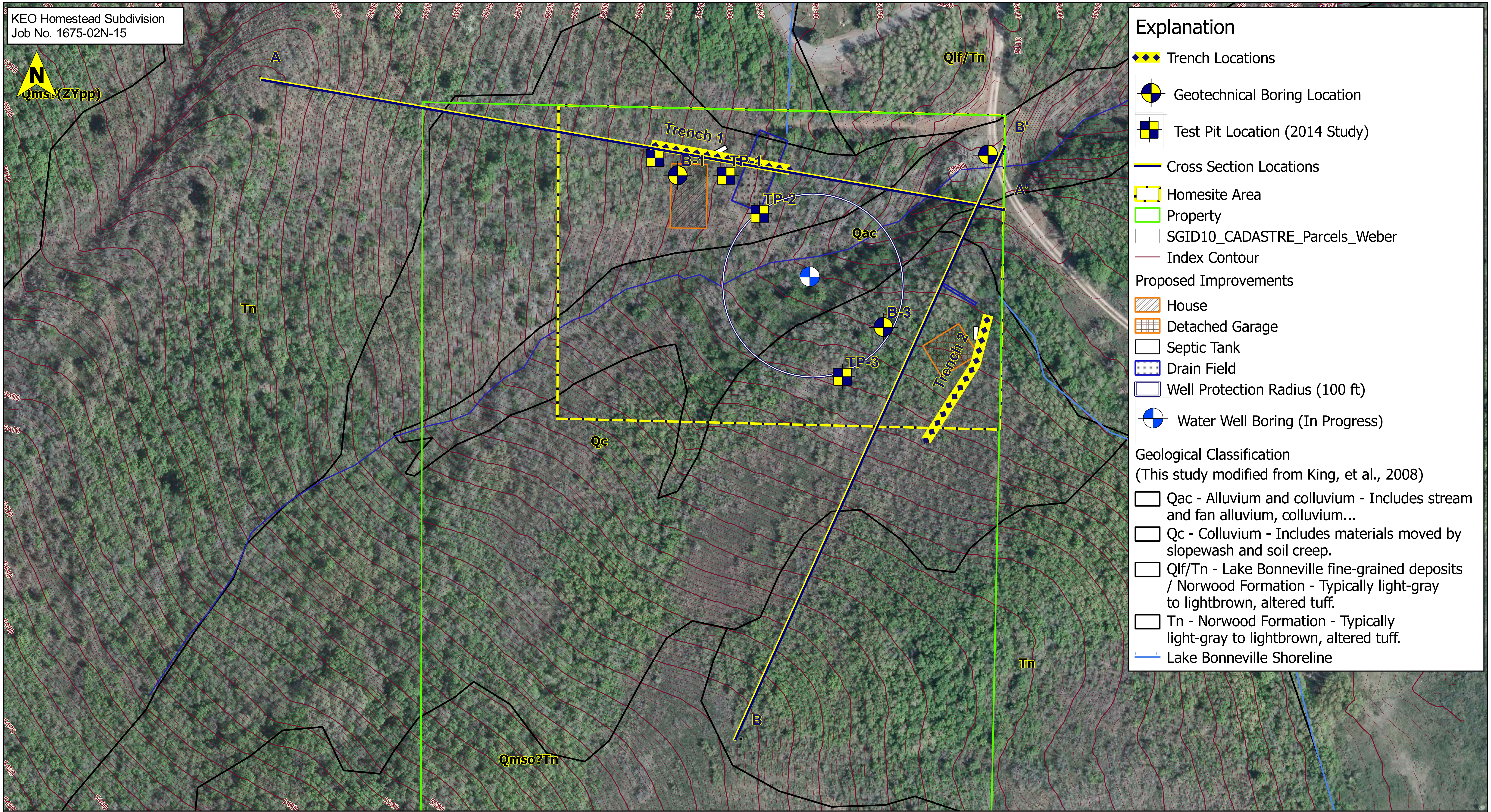


Base:
1998 7.5 Minute USGS Toporgraphic Maps Titled Snowbasin, Utah, and Huntsville, Utah.

0 1000 2000 3000 4000 ft
1:24,000

FIGURE 1
VICINITY MAP

GSH



Base: 2012 5.0 inch Color HRO Orthoimagery, from Utah AGRC; http://gis.utah.gov/
Elevation: 2006 2.0m Geoprocessed LiDARfrom Utah AGRC; http://gis.utah.gov/
Geology: Modified from King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, scale 1:24,000

0 100 200 300 ft

1:1,200

FIGURE 2
SITE PLAN

TEST PIT LOG

TEST PIT: TP-1

CLIENT: David Orchard	PROJECT NUMBER: 1675-01N-14
PROJECT: David Orchard Property (Parcel 20-015-0010)	DATE STARTED: 7/1/14 DATE FINISHED: 7/1/14
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: HRW
DRILLING METHOD/EQUIPMENT: Doosan 75V - Trackhoe	HAMMER: --- WEIGHT: --- DROP: ---
GROUNDWATER DEPTH: Not Encountered (7/1/14)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface								
	CL	SILTY CLAY with some fine gravel; major roots (topsoil) to 3"; brown	0							moist very stiff
								43	27	
			5							
		End of Exploration at 10.0' No groundwater encountered at time of excavation	10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 3A

TEST PIT LOG

Page: 1 of 1

TEST PIT: TP-2

CLIENT: David Orchard	PROJECT NUMBER: 1675-01N-14
PROJECT: David Orchard Property (Parcel 20-015-0010)	DATE STARTED: 7/1/14 — DATE FINISHED: 7/1/14
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: HRW
DRILLING METHOD/EQUIPMENT: Doosan 75V - Trackhoe	HAMMER: --- WEIGHT: --- DROP: ---
GROUNDWATER DEPTH: Not Encountered (7/1/14)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface								
	CL/ CH	SILTY CLAY with some fine to coarse sand; some gravel and occassional cobbles up to 5" in diameter, brown	0							moist stiff
				■	14	115				
				◣						
			5							
		grades with increasing gravel and cobble content		◣	16		32	54	35	very stiff
	SC	CLAYEY FINE TO COARSE SAND with some fine and coarse gravel; cobble size pieces of white volcanic ash; brown		◣						moist dense
		Grades weakly cemented		◣						very dense
		End of Exploration at 10.0' due to practical equipment refusal No groundwater encountered at time of excavation	10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 3B

TEST PIT LOG

GSH

Page: 1 of 1

TEST PIT: TP-3

CLIENT: David Orchard	PROJECT NUMBER: 1675-01N-14
PROJECT: David Orchard Property (Parcel 20-015-0010)	DATE STARTED: 7/1/14 DATE FINISHED: 7/1/14
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: HRW
DRILLING METHOD/EQUIPMENT: Doosan 75V - Trackhoe	HAMMER: --- WEIGHT: --- DROP: ---
GROUNDWATER DEPTH: Not Encountered (7/1/14)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface								
	CL	SILTY CLAY with some fine sand; trace medium to coarse sand; trace gravel; brown	0							moist stiff to very stiff
			2	◣						
			4	◣						
			7	◣						
			9	◣						
		End of Exploration at 10.0' No groundwater encountered at time of excavation	10							

See Subsurface Conditions section in the report for additional information.

FIGURE 3C

TEST PIT LOG

Page: 1 of 1

TEST PIT: TP-4

CLIENT: David Orchard
PROJECT NUMBER: 1675-01N-14
PROJECT: David Orchard Property (Parcel 20-015-0010)
DATE STARTED: 7/1/14 DATE FINISHED: 7/1/14
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah
GSH FIELD REP.: HRW
DRILLING METHOD/EQUIPMENT: Doosan 75V - Trackhoe
HAMMER: --- WEIGHT: --- DROP: ---
GROUNDWATER DEPTH: Not Encountered (7/1/14)
ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface								
	CL/ CH	SILTY CLAY with some fine sand; trace medium to coarse sand; trace gravel; trace organics	0							moist
				▮	17	104				
				◢						
				▮						
			5							
				◢	14		31	52	35	
				◢						
			10	◢						
		End of Exploration at 11.0' No groundwater encountered at time of excavation								
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 3D

TEST PIT LOG

Page: 1 of 1

TEST PIT: TR-1

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 1/28/16 | DATE FINISHED: 1/28/16

LOCATION: Approximately 5600 East Highway 39, Weber County, Utah | GSH FIELD REP.: RAG

EXCAVATING METHOD/EQUIPMENT: JCB 214S - Backhoe

GROUNDWATER DEPTH: Not Encountered (1/28/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0							
	CL	FINE TO COARSE SANDY CLAY with silt; fine gravel; major roots (topsoil); dark brown								moist medium stiff
	CL	SILTY CLAY with some fine to coarse sand; fine and coarse gravel; brown								moist hard
			5							
	CL	FINE TO COARSE SANDY CLAY with fine and coarse gravel; light brown			20			54	34	moist hard
		End of Exploration at 10.0' No groundwater encountered at time of excavation	10							
			15							
			20							
			25							

See Subsurface Conditions section in the report for additional information.

FIGURE 3E

TEST PIT LOG

GSH

Page: 1 of 1

TEST PIT: TR-2

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 1/28/16 | DATE FINISHED: 1/28/16

LOCATION: Approximately 5600 East Highway 39, Weber County, Utah | GSH FIELD REP.: RAG

EXCAVATING METHOD/EQUIPMENT: JCB 214S - Backhoe

GROUNDWATER DEPTH: Not Encountered (1/28/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0							
	CL	SILTY CLAY with fine to coarse sand; fine gravel; major roots (topsoil); dark brown								moist medium stiff
	CL	SILTY CLAY with some fine to coarse sand; trace fine gravel; brown	5							moist hard
	CL	FINE TO COARSE SANDY CLAY with fine and coarse gravel; light brown	10							moist hard
		End of Exploration at 12.0' No groundwater encountered at time of excavation	15 20 25							

See Subsurface Conditions section in the report for additional information.

FIGURE 3F

GSH	BORING LOG Page: 1 of 2	BORING: B-1

CLIENT: David Orchard	PROJECT NUMBER: 1675-02N-15
PROJECT: KEO Homestead Subdivision	DATE STARTED: 2/26/16 DATE FINISHED: 2/26/16
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: RG
DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger	HAMMER: Automatic WEIGHT: 140 lbs DROP: 30"
GROUNDWATER DEPTH: Not Encountered (2/26/16)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CL	SILTY CLAY with some fine sand; some fine and coarse gravel; brown	0								moist loose
					⧗						very stiff
			5								hard
				81	⧗						
				103	⧗	18			40	22	
			10								
				97	⧗						
		grades fine to coarse sandy clay with occasional to some fine and coarse gravel		88	⧗						
			15								
				108	⧗						
	SC	CLAYEY FINE TO COARSE SAND/BEDROCK with occasional fine gravel; brown		107	⧗						moist very dense
			20								
				90	⧗						
		occasional layers of fine sandy clay up to 4" thick		55	⧗	22		37			medium dense
			25								

See Subsurface Conditions section in the report for additional information.

FIGURE 4A

BORING LOG

BORING: B-1

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				58							
				100/4"							very dense
			30								
				100/4"							
				100/2"							
	SC/GC	CLAYEY FINE TO COARSE SAND/CLAYEY FINE GRAVEL/ BEDROCK with fine to coarse sand; brownish-gray	35	50/3"							moist very dense
		End of Exploration at 37.0' No groundwater encountered at time of excavation Installed 1.25" diameter slotted PVC pipe to 36.5'									
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 4A (continued)

BORING LOG

BORING: B-2

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

LOCATION: Approximately 5600 East Highway 39, Weber County, Utah | GSH FIELD REP.: RG

DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger | HAMMER: Automatic | WEIGHT: 140 lbs | DROP: 30"

GROUNDWATER DEPTH: Not Encountered (2/26/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	GC FILL	CLAYEY FINE AND COARSE GRAVEL, FILL with some fine to coarse sand; brown									moist loose medium dense
	CL	SILTY CLAY with some fine sand; occasional fine and coarse gravel; dark brown		23	X						moist stiff
		grades fine to coarse sandy clay; brownish-gray with mottling	5	21	X	16			31	15	
	GC	CLAYEY FINE AND COARSE GRAVEL with fine to coarse sand; gray		58	X						moist medium dense
	CL	FINE TO COARSE SANDY CLAY with some silt; occasional fine and coarse gravel; brown	10	63	X						moist hard
		occasional layers of clayey fine to medium sand up to 4" thick		51	X						
	SP	FINE TO MEDIUM SAND with occasional fine and coarse gravel; brown	15	27	X	3		5			moist medium dense
				42	X						
	CL	SILTY CLAY/BEDROCK with some fine sand; occasional to some fine and coarse gravel; brown with oxidation	20	63	X	13			28	15	moist hard
	SP/SC	CLAYEY FINE TO COARSE SAND/BEDROCK with occasional fine and coarse gravel; brown		72	X						moist dense
			25								

See Subsurface Conditions section in the report for additional information.

BORING: B-2

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				100/5"							very dense
				100/4"		6		7			
			30								
				100/5"							
				100/3"							
		End of Exploration at 34.0' No groundwater encountered at time of drilling Installed 1.25" diameter slotted PVC pipe to 32.5'	35								
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 4B
(continued)

BORING LOG

GSH

BORING: B-3

CLIENT: David Orchard	PROJECT NUMBER: 1675-02N-15
PROJECT: KEO Homestead Subdivision	DATE STARTED: 2/26/16 DATE FINISHED: 2/26/16
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: RG
DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger	HAMMER: Automatic WEIGHT: 140 lbs DROP: 30"
GROUNDWATER DEPTH: Not Encountered (2/26/16)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL	SILTY CLAY with some fine sand; dark brown									moist loose stiff
				23							
	CL	FINE TO COARSE SANDY CLAY occasional fine gravel; brown	5								moist hard
				67		17	126				
	SP/ SC	CLAYEY FINE TO COARSE SAND with some fine and coarse gravel; brown									moist dense
				78		7		11			
	CL	FINE SANDY CLAY/BDROCK with occasional to some fine and coarse gravel; brown	10								moist hard
				105+							
		occasional layers of clayey fine to coarse sand up to 4" thick		110+							
	SC	CLAYEY FINE TO COARSE SAND/BEDROCK with some fine and coarse gravel; brown	15								moist very dense
				100/3"							
				100/5"		10		35			
			20								
				100/5"							
				100/2"							
			25								

See Subsurface Conditions section in the report for additional information.

FIGURE 4C

GSH

BORING LOG

BORING: B-3

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				99		11		17			
				128+							
			30								
				100/5"							
				100/5"							
	GC	CLAYEY FINE AND COARSE GRAVEL/BEDROCK with fine to coarse sand; brown	35								moist very dense
				100/5"							
				100/5.5"							
			40								
				100/5.5"							
	GM	SILTY FINE AND COARSE GRAVEL/BEDROCK with fine to coarse sand; light brown		100/5"							moist very dense
			45								
				100/6"		13		14			
				100/2"							
		End of Exploration at 49.0' due to auger refusal No groundwater encountered at time of drilling Installed 1.25" diameter slotted PVC pipe to 48.0'	50								

See Subsurface Conditions section in the report for additional information.

FIGURE 4C (continued)

CLIENT: David Orchard
PROJECT: KEO Homestead Subdivision
PROJECT NUMBER: 1675-02N-15

KEY TO TEST PIT LOG

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪

COLUMN DESCRIPTIONS

① **Water Level:** Depth to measured groundwater table. See symbol below.

② **USCS:** (Unified Soil Classification System) Description of soils encountered; typical symbols are explained below.

③ **Description:** Description of material encountered; may include color, moisture, grain size, density/consistency,

④ **Depth (ft.):** Depth in feet below the ground surface.

⑤ **Sample Symbol:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

⑥ **Moisture (%):** Water content of soil sample measured in laboratory; expressed as percentage of dryweight of

⑦ **Dry Density (pcf):** The density of a soil measured in laboratory; expressed in pounds per cubic foot.

⑧ **% Passing 200:** Fines content of soils sample passing a No. 200 sieve; expressed as a percentage.

⑨ **Liquid Limit (%):** Water content at which a soil changes from plastic to liquid behavior.

⑩ **Plasticity Index (%):** Range of water content at which a soil exhibits plastic properties.

⑪ **Remarks:** Comments and observations regarding drilling or sampling made by driller or field personnel. May include other field and laboratory test results using the following abbreviations:

CEMENTATION:	MODIFIERS:	MOISTURE CONTENT (FIELD TEST):
Weakly: Crumbles or breaks with handling or slight finger pressure.	**Trace** <5%	**Dry:** Absence of moisture, dusty, dry to the touch.
Moderately: Crumbles or breaks with considerable finger pressure.	**Some** 5-12%	**Moist:** Damp but no visible water.
Strongly: Will not crumble or break with finger pressure.	**With** > 12%	**Saturated:** Visible water, usually soil below water table.

Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on the logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

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** More than 50% of coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (little or no 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 (appreciable amount of fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More than 50% of coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (little or no fines)	SW	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (appreciable amount of 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 Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands 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 o f 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, Humus, Swamp Soils with High Organic Contents

Note: Dual Symbols are used to indicate borderline soil classifications.

STRATIFICATION:

DESCRIPTION	THICKNESS
Seam	up to 1/8"
Layer	1/8" to 12"

Occasional: One or less per 6" of thickness

Numerous; More than one per 6" of thickness

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Bulk/Bag Sample
- Standard Penetration Split Spoon Sampler
- Rock Core
- No Recovery
- 3.25" OD, 2.42" ID D&M Sampler
- 3.0" OD, 2.42" ID D&M Sampler
- California Sampler
- Thin Wall

WATER SYMBOL

Water Level

FIGURE 5

GSH

CLIENT: David Orchard PROJECT: KEO Homestead Subdivision PROJECT NUMBER: 1675-02N-15	**KEY TO BORING LOG**

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫

COLUMN DESCRIPTIONS

① **Water Level:** Depth to measured groundwater table. See symbol below.

② **USCS:** (Unified Soil Classification System) Description of soils encountered; typical symbols are explained below.

③ **Description:** Description of material encountered; may include color, moisture, grain size, density/consistency,

④ **Depth (ft.):** Depth in feet below the ground surface.

⑤ **Blow Count:** Number of blows to advance sampler 12" beyond first 6", using a 140-lb hammer with 30" drop.

⑥ **Sample Symbol:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

⑦ **Moisture (%):** Water content of soil sample measured in laboratory; expressed as percentage of dryweight of

⑧ **Dry Density (pcf):** The density of a soil measured in laboratory; expressed in pounds per cubic foot.

⑨ **% Passing 200:** Fines content of soils sample passing a No. 200 sieve; expressed as a percentage.

⑩ **Liquid Limit (%):** Water content at which a soil changes from plastic to liquid behavior.

⑪ **Plasticity Index (%):** Range of water content at which a soil exhibits plastic properties.

⑫ **Remarks:** Comments and observations regarding drilling or sampling made by driller or field personnel. May include other field and laboratory test results using the following abbreviations:

CEMENTATION:	MODIFIERS:	MOISTURE CONTENT (FIELD TEST):
Weakly: Crumbles or breaks with handling or slight finger pressure.	**Trace** <5%	**Dry:** Absence of moisture, dusty, dry to the touch.
Moderately: Crumbles or breaks with considerable finger pressure.	**Some** 5-12%	**Moist:** Damp but no visible water.
Strongly: Will not crumble or break with finger pressure.	**With** > 12%	**Saturated:** Visible water, usually soil below water table.

Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on the logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.

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** More than 50% of coarse fraction retained on No. 4 sieve.	**CLEAN GRAVELS** (little or no 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 (appreciable amount of fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More than 50% of coarse fraction passing through No. 4 sieve.	**CLEAN SANDS** (little or no fines)	SW	Well-Graded Sands, Gravelly Sands, Little or No Fines
			SP	Poorly-Graded Sands, Gravelly Sands, Little or No Fines
		SANDS WITH FINES (appreciable amount of 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 Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands 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 o f 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, Humus, Swamp Soils with High Organic Contents

Note: Dual Symbols are used to indicate borderline soil classifications.

STRATIFICATION:

DESCRIPTION	THICKNESS
Seam	up to 1/8"
Layer	1/8" to 12"

Occasional: One or less per 6" of thickness

Numerous; More than one per 6" of thickness

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Bulk/Bag Sample
- Standard Penetration Split Spoon Sampler
- Rock Core
- No Recovery
- 3.25" OD, 2.42" ID D&M Sampler
- 3.0" OD, 2.42" ID D&M Sampler
- California Sampler
- Thin Wall

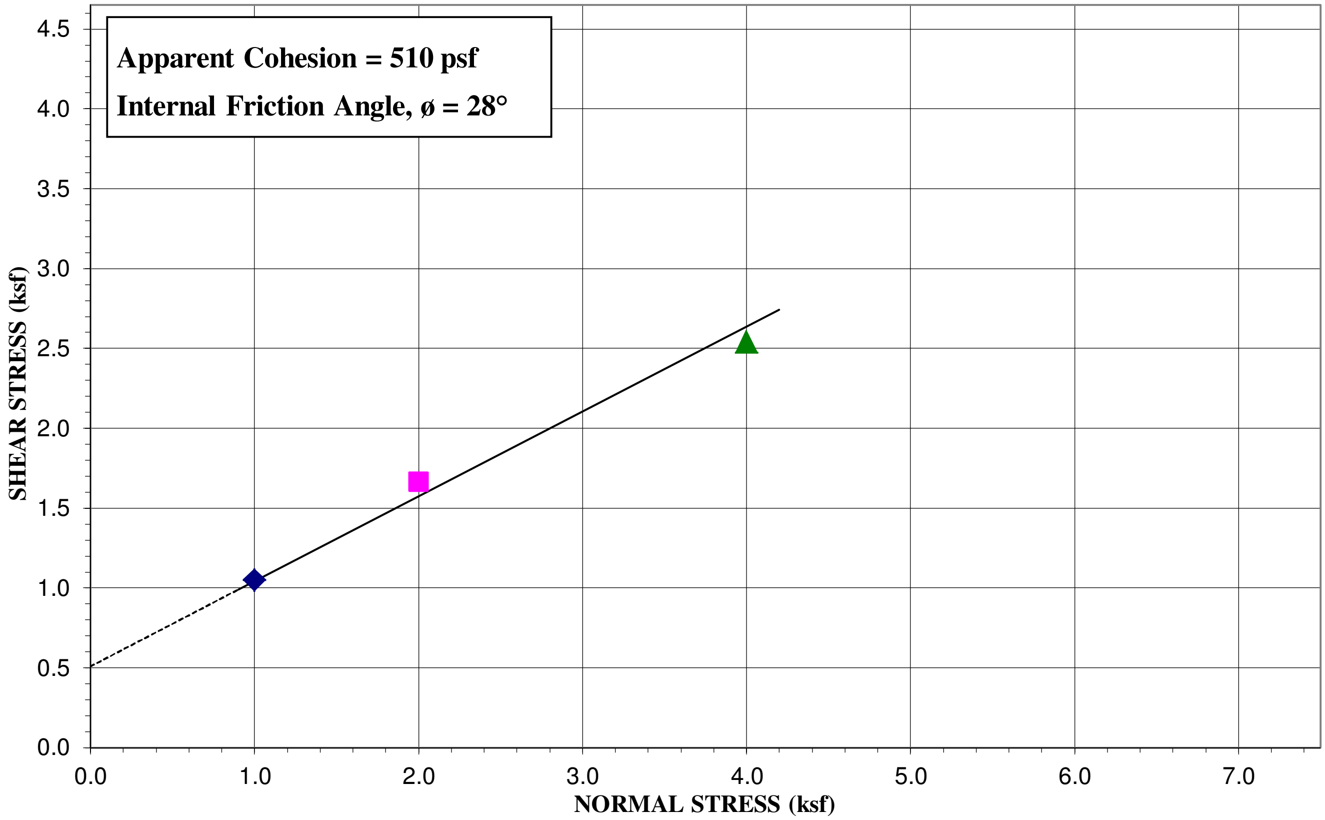
WATER SYMBOL

Water Level

FIGURE 6

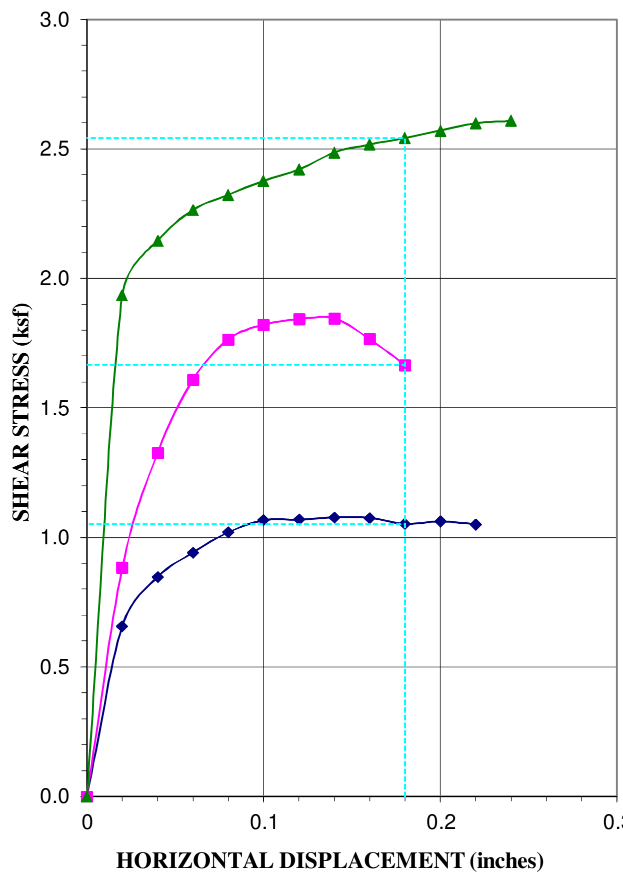
GSH

DIRECT SHEAR TEST



Source: TP-1		Depth: 2 feet	
Type of Test:	Consolidated Drained		
Sample Type	Undisturbed (Liner)		
Strain Rate	0.002 in/min		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Initial Height, in.	1	1	1
Diameter, in.	2.42	2.42	2.42
Dry Density Before, pcf	109.4	108.3	109.3
Dry Density After, pcf	110.3	109.1	107.7
Moisture % Before	18.7	17.7	16.7
Moisture % After	24.4	23.6	21.6
Saturation % Before	82.9	76.4	73.8
Saturation % After	110.4	104.0	92.1
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	1.05	1.67	2.54
Sample Properties			
Cohesion, psf	510		
Friction Angle, ϕ	28		
Liquid Limit, %	---		
Plasticity Index, %	---		
Percent Gravel	---		
Percent Sand	---		
Percent Passing #200 sieve	---		
Classification	Lean Clay (CL)		

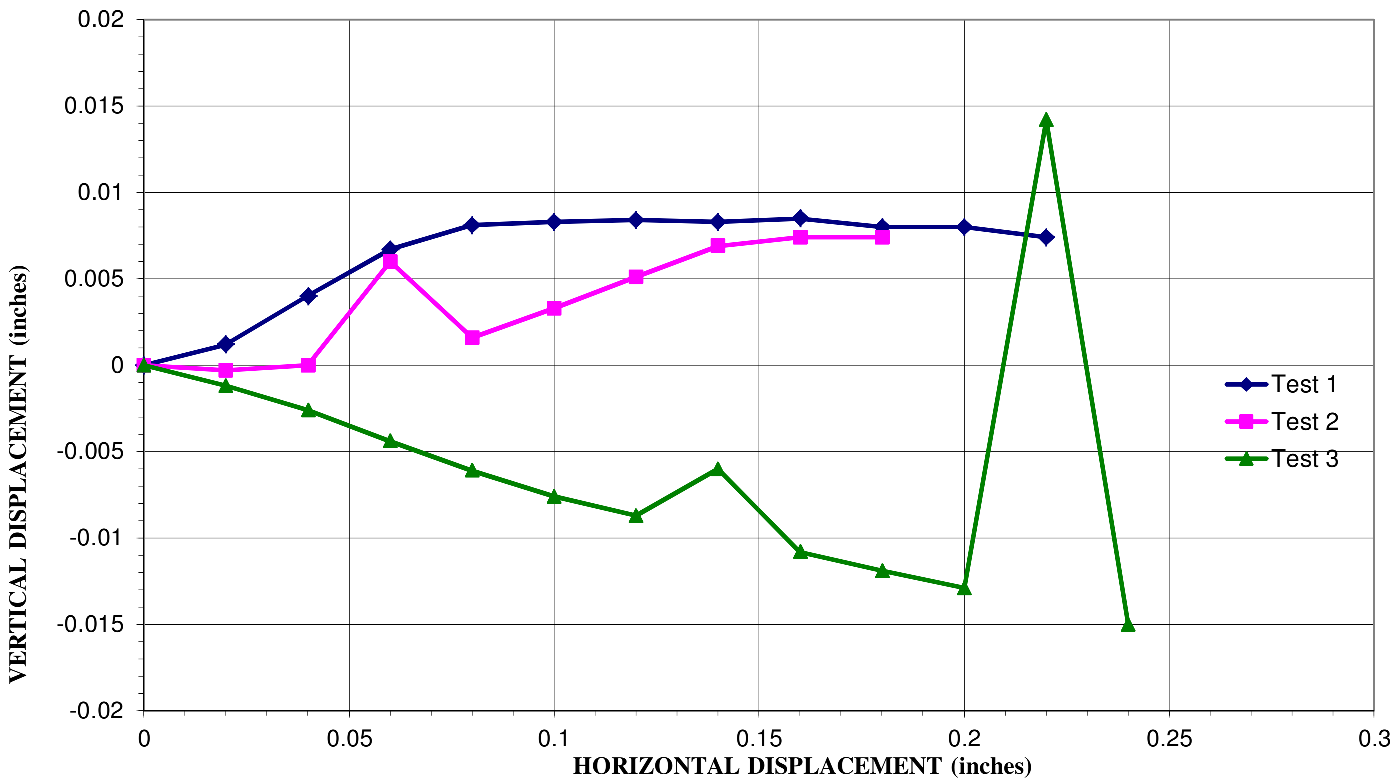
Testing Laboratory: AMEC, SLC, Utah

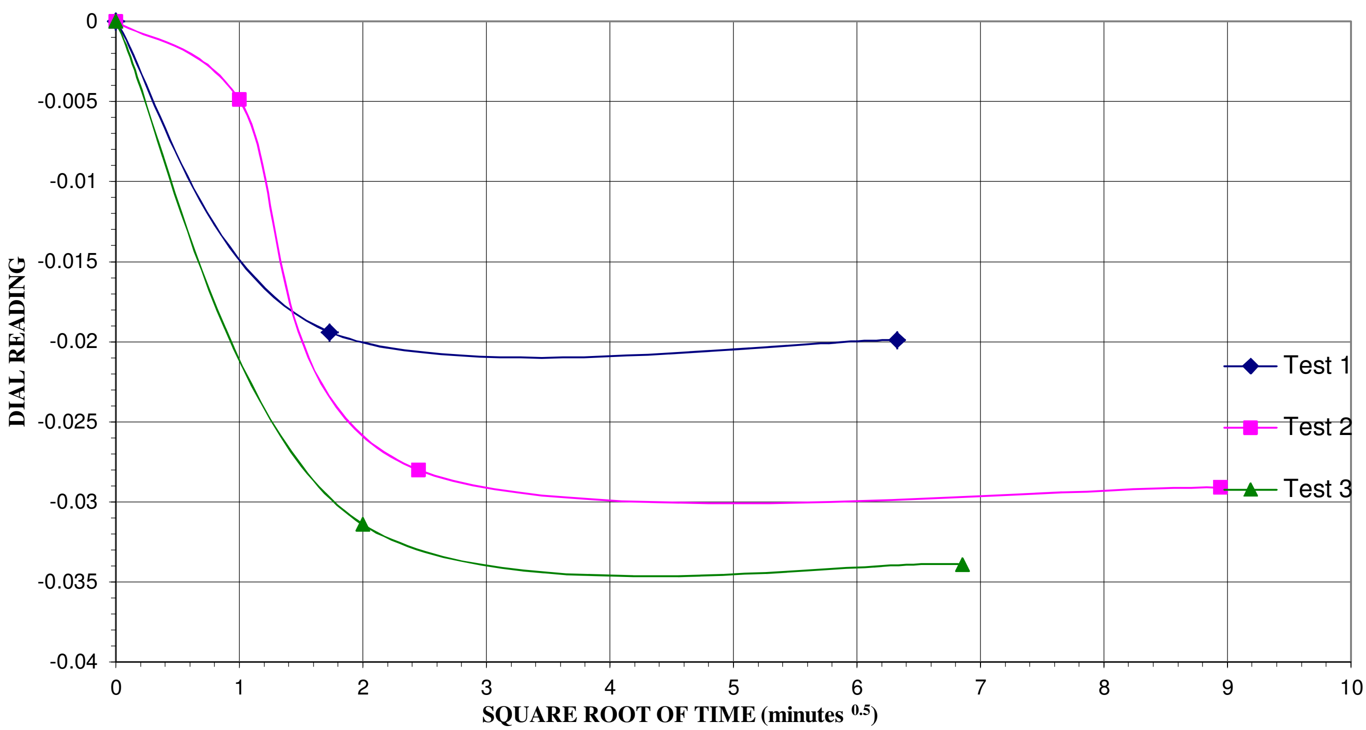


PROJECT: David Orchard Property, Weber County

PROJECT NO.: 1675-01N-14	GSH	**FIGURE NO.:** 7A

DIRECT SHEAR TEST





Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
t_{90} (from sq-root time)	#N/A	#N/A	#N/A
$t_f = 50\ t_{90} / 4.28$	#N/A	#N/A	#N/A
max. $d_r = 0.5 / t_f$	#N/A	#N/A	#N/A
selected d_r (in./min)	0.0020	0.0020	0.0020

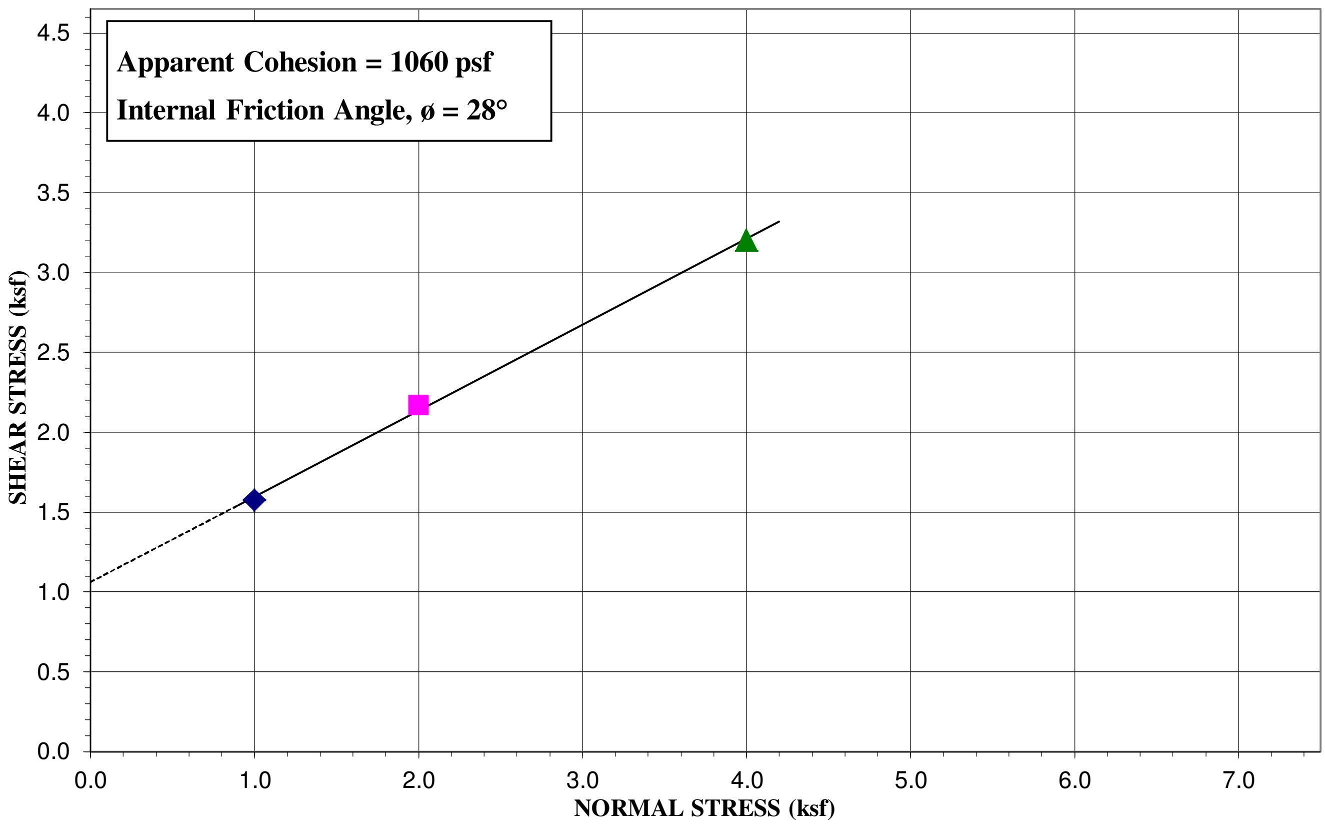
PROJECT: David Orchard Property, Weber County

PROJECT NO.: 1675-01N-14

GSH

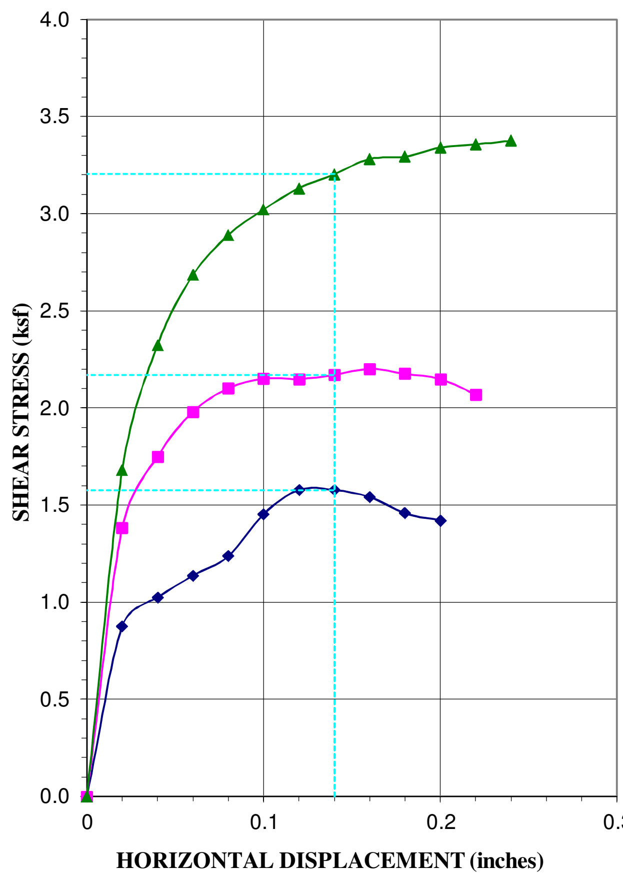
FIGURE NO.: 7B

DIRECT SHEAR TEST



Source: TP-4	Depth: 4 feet		
Type of Test:	Consolidated Drained		
Sample Type	Undisturbed (Liner)		
Strain Rate	0.002 in/min		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Initial Height, in.	1	1	1
Diameter, in.	2.42	2.42	2.42
Dry Density Before, pcf	109.6	108.9	111.7
Dry Density After, pcf	109.6	108.8	109.2
Moisture % Before	15.6	11.3	7.2
Moisture % After	20.8	17.6	12.4
Saturation % Before	69.7	49.7	33.7
Saturation % After	92.6	76.7	54.6
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	1.58	2.17	3.20
Sample Properties			
Cohesion, psf	1060		
Friction Angle, ϕ	28		
Liquid Limit, %	---		
Plasticity Index, %	---		
Percent Gravel	---		
Percent Sand	---		
Percent Passing #200 sieve	---		
Classification	Lean Clay (CL)		

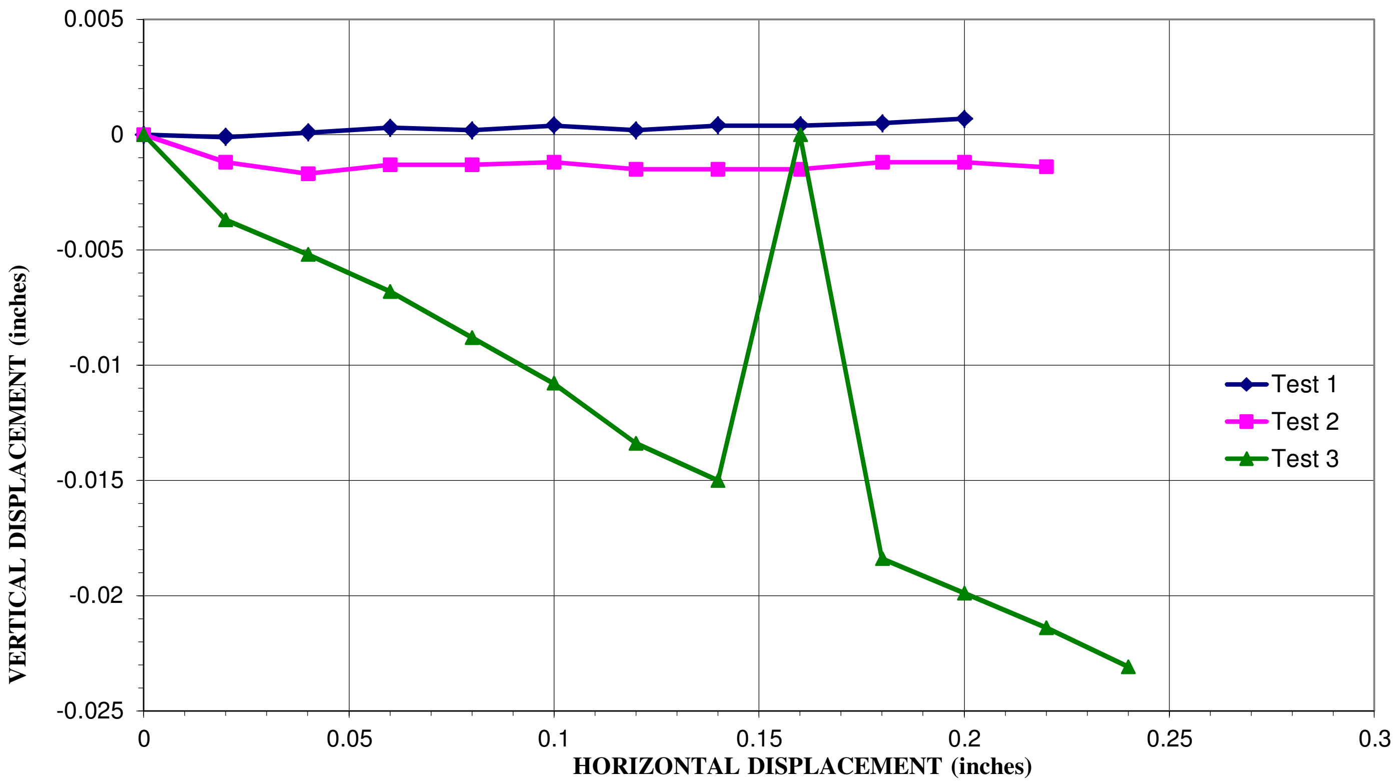
Testing Laboratory: AMEC, SLC, Utah

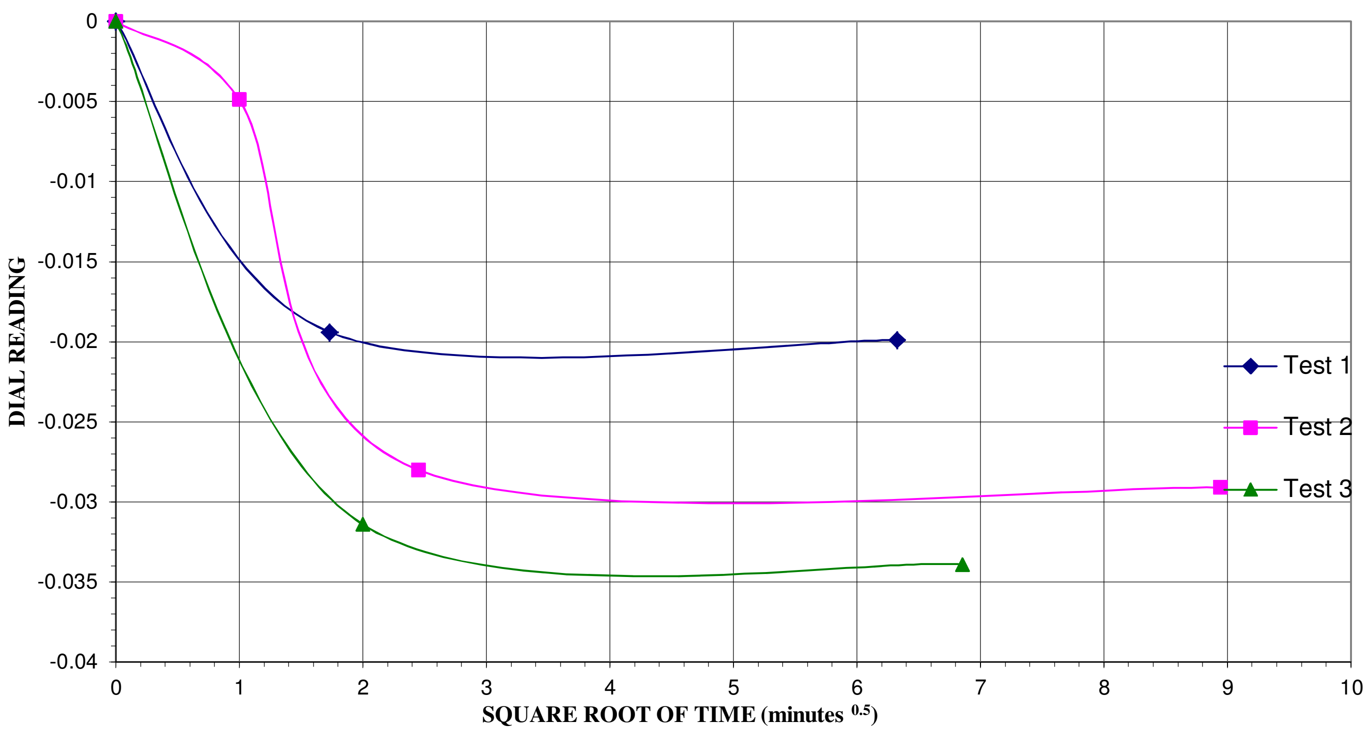


PROJECT: David Orchard Property, Weber County

PROJECT NO.: 1675-01N-14 | GSH | **FIGURE NO.:** 8A

DIRECT SHEAR TEST





Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
t_{90} (from sq-root time)	#N/A	#N/A	#N/A
$t_f = 50\ t_{90} / 4.28$	#N/A	#N/A	#N/A
max. $d_r = 0.5 / t_f$	#N/A	#N/A	#N/A
selected d_r (in./min)	0.0020	0.0020	0.0020

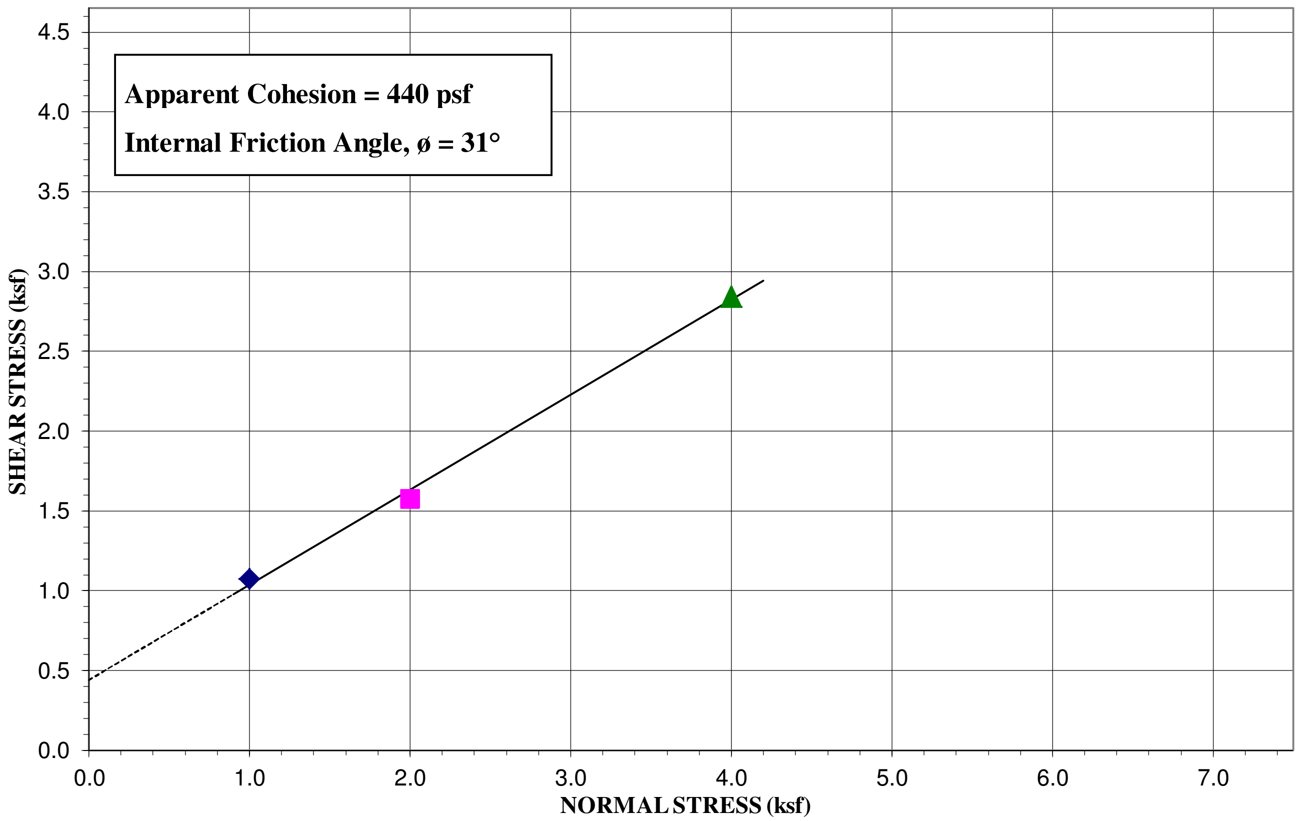
PROJECT: David Orchard Property, Weber County

PROJECT NO.: 1675-01N-14

GSH

FIGURE NO.: 8B

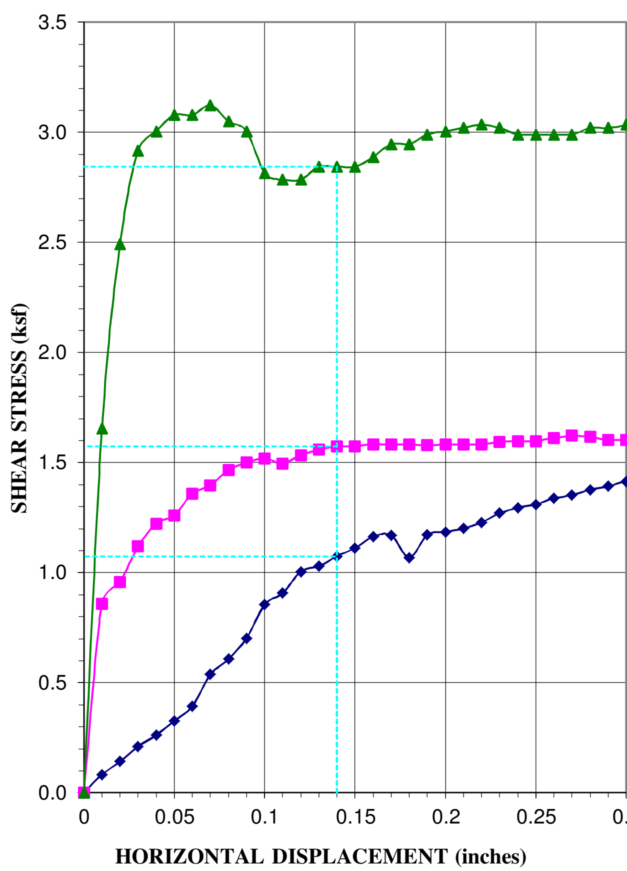
DIRECT SHEAR TEST



Source:	B-2	**Depth:**	20.5 ft
Type of Test:	Consolidated - Undrained		
Test No. (Symbol)	**1 (◆)**	**2 (■)**	**3 (▲)**
Sample Type	Undisturbed (Rings)		
Initial Height, in.	1.10	1.10	1.05
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	98.1	97.0	96.3
Dry Density After, pcf	98.8	97.1	96.3
Moisture % Before	17.1	22.1	16.1
Moisture % After	25.3	26.4	26.8
Saturation % Before	61.3	77.2	55.3
Saturation % After	92.3	92.4	92.1
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	1.08	1.57	2.84
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	440
Friction Angle, ϕ	31
Liquid Limit, %	28
Plasticity Index, %	15
Percent Gravel	---
Percent Sand	---
Percent Passing No. 200 sieve	---
Classification	Silty Clay with sand (CL)

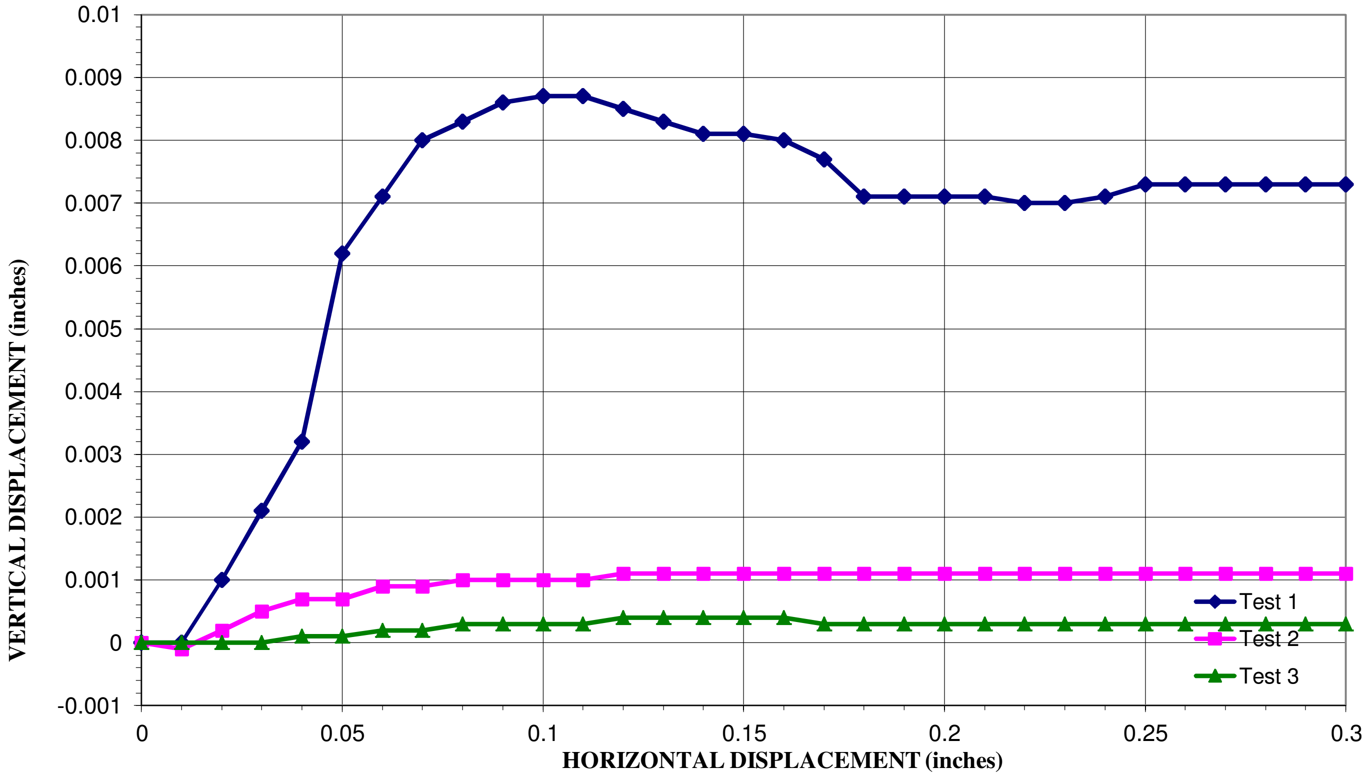
Testing Laboratory: GSH

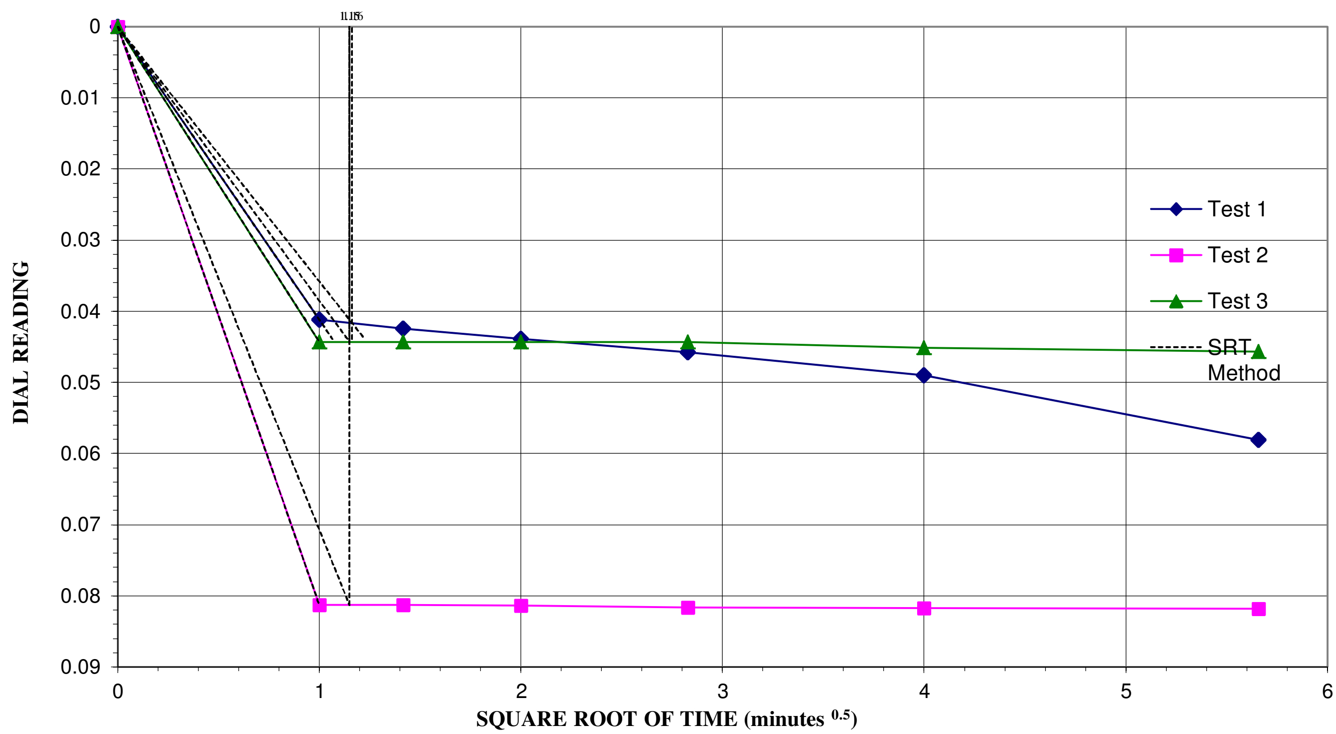


PROJECT: KEO Homestead Subdivision

PROJECT NO.: 1675-02N-15 | GSH | **FIGURE NO.:** 9A

DIRECT SHEAR TEST



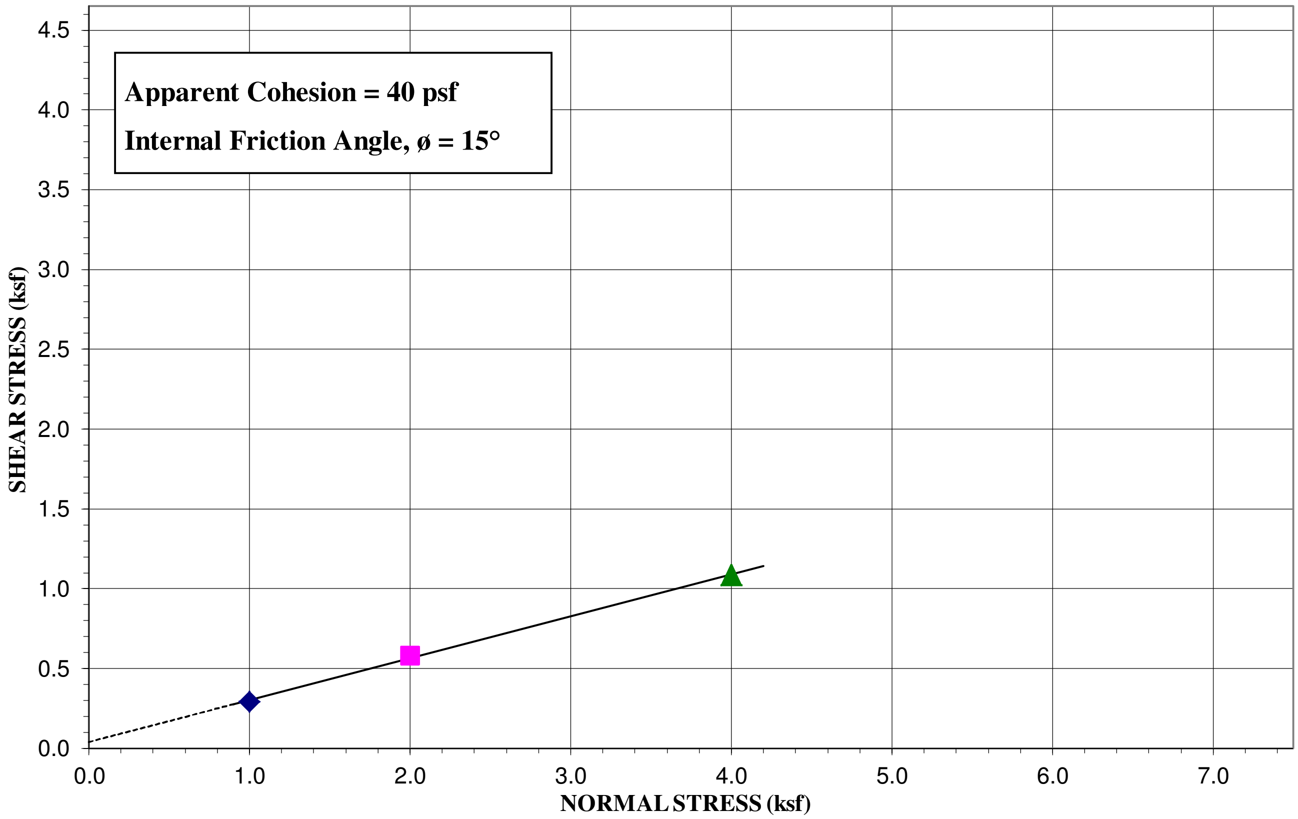


Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
t_{90} (from sq-root time)	1.35	1.32	1.32
$t_f = 50\ t_{90} / 4.28$	15.8	15.4	15.4
max. $d_r = 0.5 / t_f$	0.0317	0.0324	0.0324
selected d_r (in./min)	0.0050	0.0050	0.0050

PROJECT: KEO Homestead Subdivision

PROJECT NO 1675-02N-15	GSH	**FIGURE NO.:** 9B

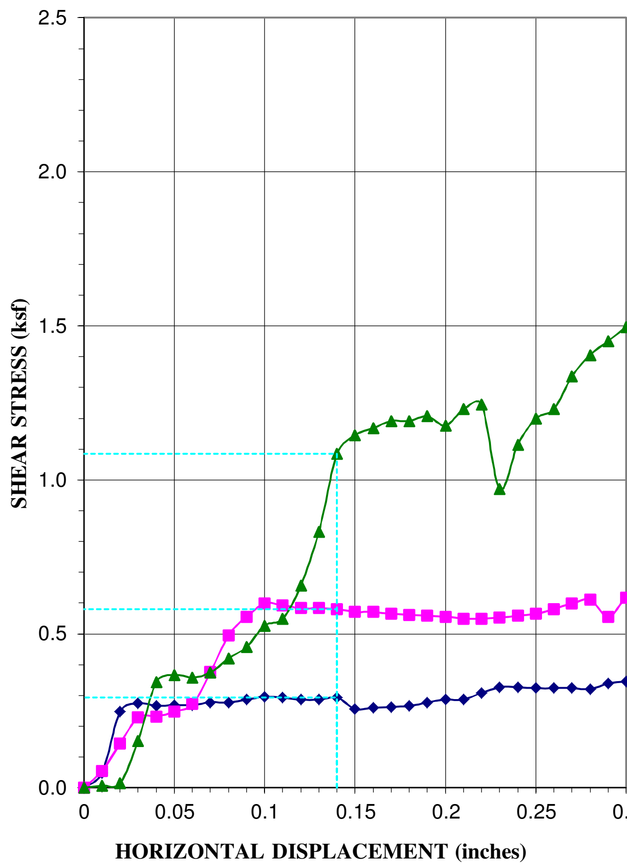
DIRECT SHEAR TEST



Source:	TR-1	Depth:	200 ft
Type of Test:	Consolidated - Undrained (Residual)		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Remolded		
Initial Height, in.	1.15	1.15	1.05
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	78.7	82.0	88.6
Dry Density After, pcf	78.3	81.9	88.6
Moisture % Before	23.7	19.1	18.9
Moisture % After	42.3	38.1	33.8
Saturation % Before	54.4	47.4	54.5
Saturation % After	96.4	94.1	97.4
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.29	0.58	1.08
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	40
Friction Angle, ϕ	15
Liquid Limit, %	54
Plasticity Index, %	34
Percent Gravel	---
Percent Sand	---
Percent Passing No. 200 sieve	---
Classification	Clay (CH)

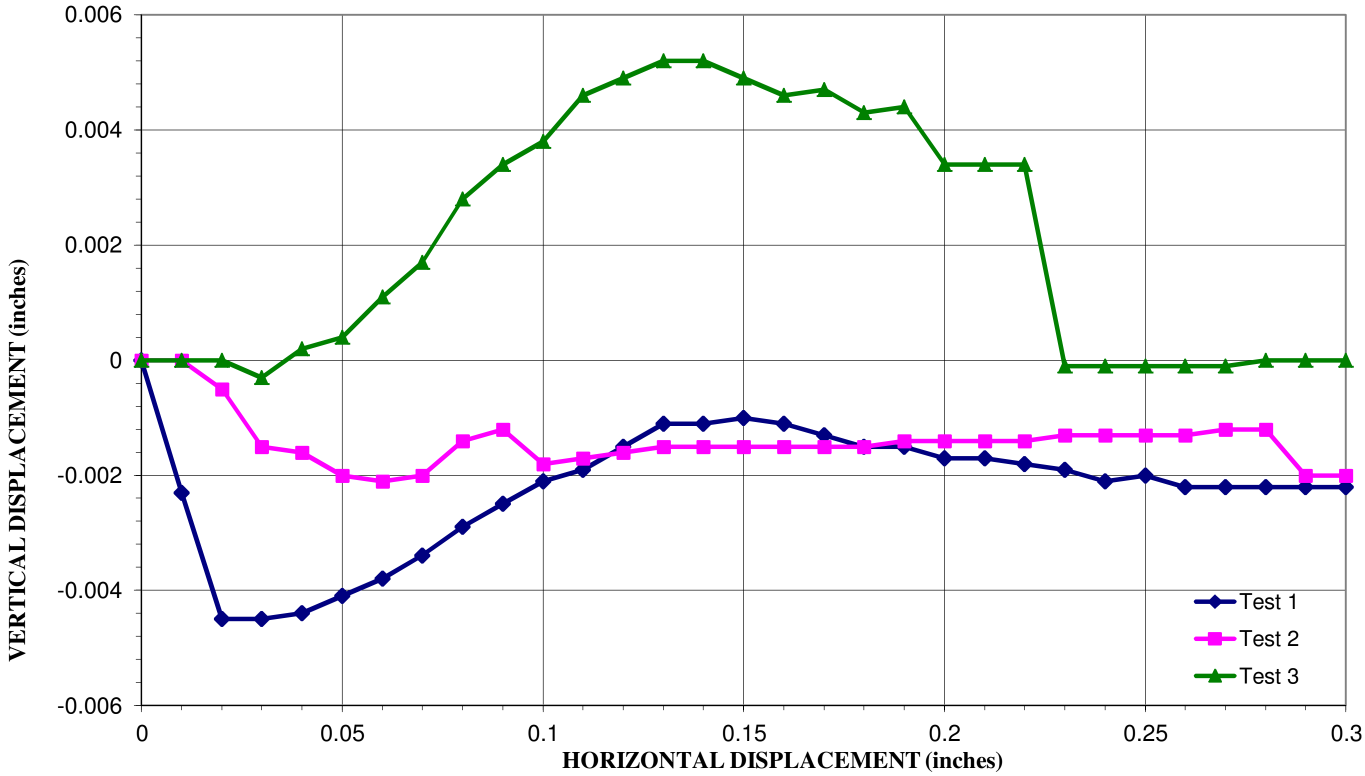
Testing Laboratory: GSH

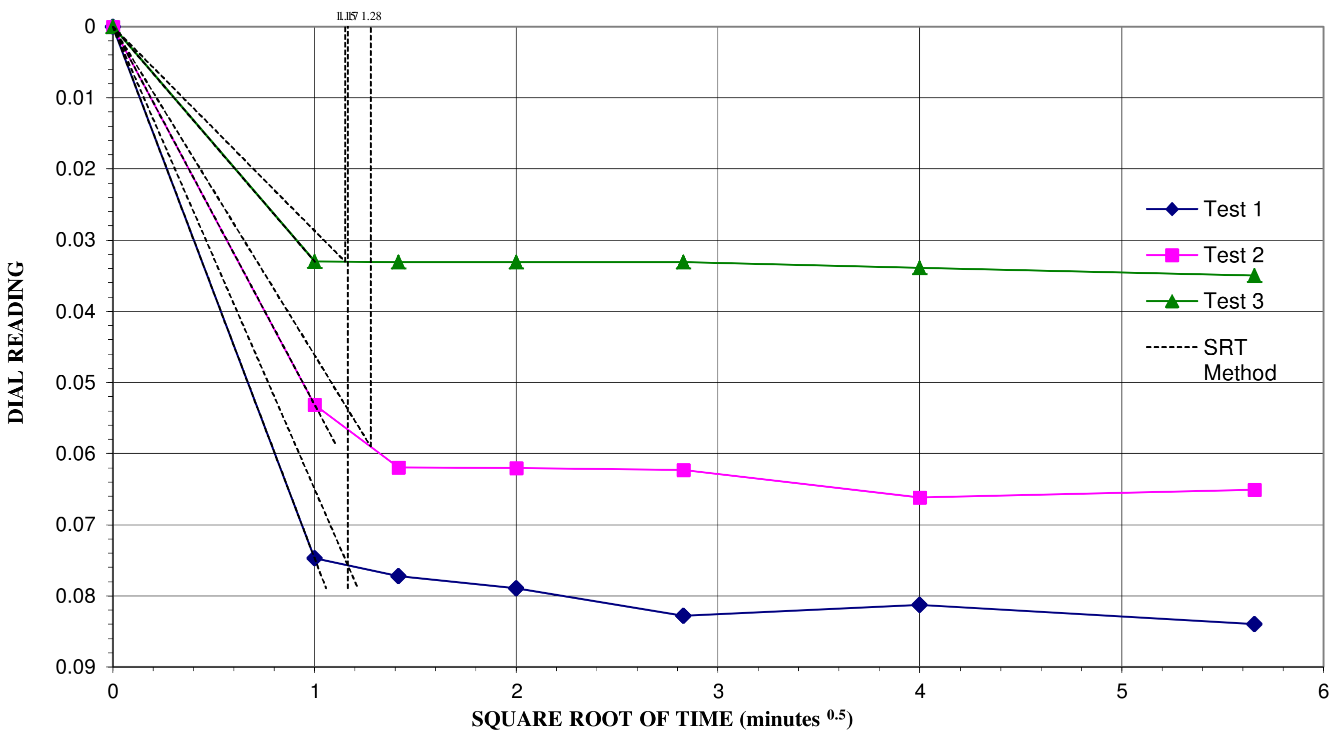


PROJECT: KEO Homestead Subdivision

PROJECT NO.: 1675-02N-15	GSH	**FIGURE NO.:** 10A

DIRECT SHEAR TEST





Test No. (Symbol)	1◆( )	2■( )	3 (▲)
t_{90} (from sq-root time)	1.36	1.63	1.33
$t_f = 50\ t_{90} / 4.28$	15.9	19.0	15.5
max. $d_r = 0.5 / t_f$	0.0315	0.0263	0.0322
selected d_r (in./min)	0.0050	0.0050	0.0050

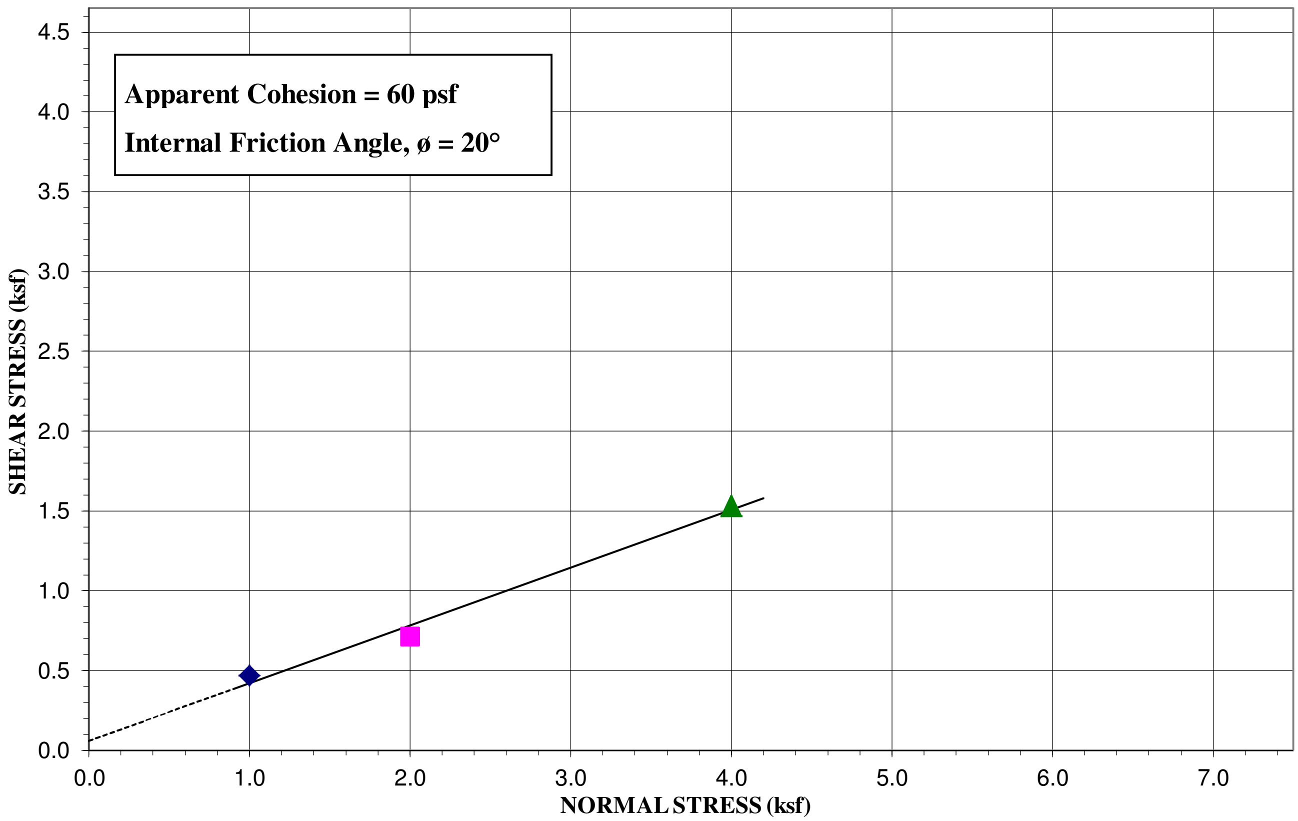
PROJECT: KEO Homestead Subdivision

ROJECT NO 1675-02N-15

GSH

FIGURE NO.: 10B

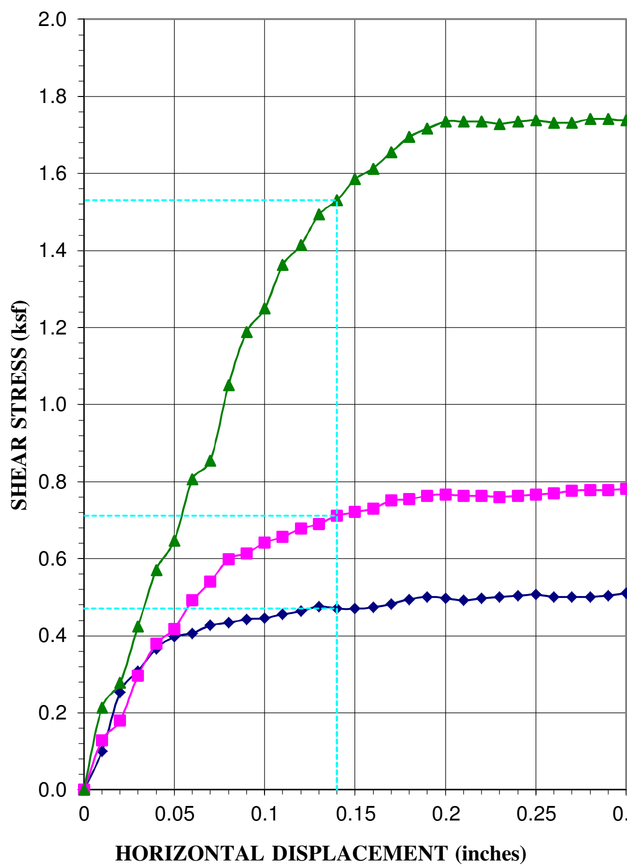
DIRECT SHEAR TEST



Source: B-2	**Depth:** 5.5 ft		
Type of Test:	Consolidated - Undrained (Residual)		
Test No. (Symbol)	1 (◆)	2 (■)	3 (▲)
Sample Type	Remolded		
Initial Height, in.	1.05	1.10	1.10
Diameter, in.	2.45	2.45	2.45
Dry Density Before, pcf	96.8	95.7	101.3
Dry Density After, pcf	96.8	95.7	101.4
Moisture % Before	12.2	15.1	15.5
Moisture % After	25.7	29.1	24.9
Saturation % Before	42.4	51.2	59.9
Saturation % After	89.3	98.7	96.5
Normal Load, ksf	1.0	2.0	4.0
Shear Stress, ksf	0.47	0.71	1.53
Strain Rate	0.005 in/min		

Sample Properties	
Cohesion, psf	60
Friction Angle, ϕ	20
Liquid Limit, %	31
Plasticity Index, %	15
Percent Gravel	---
Percent Sand	---
Percent Passing No. 200 sieve	---
Classification	Silty Clay with sand (CL)

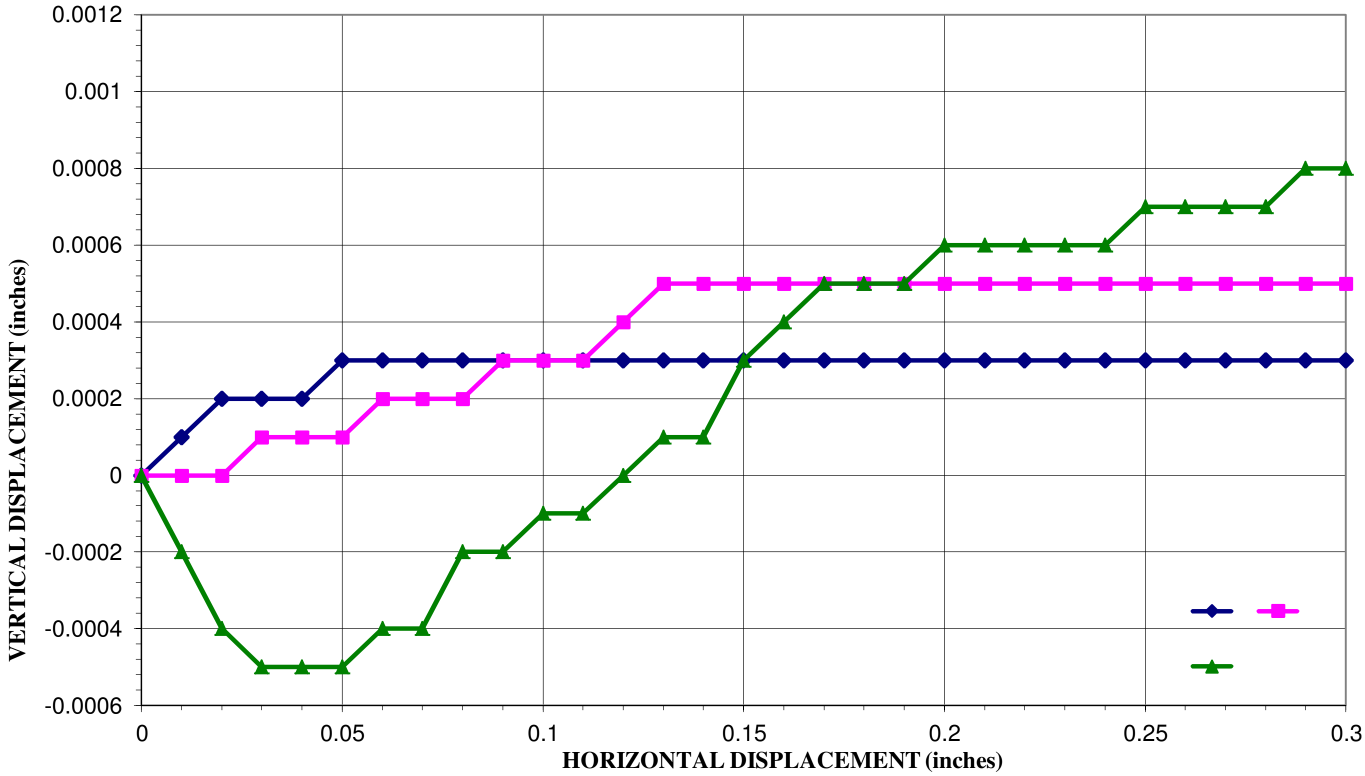
Testing Laboratory: GSH

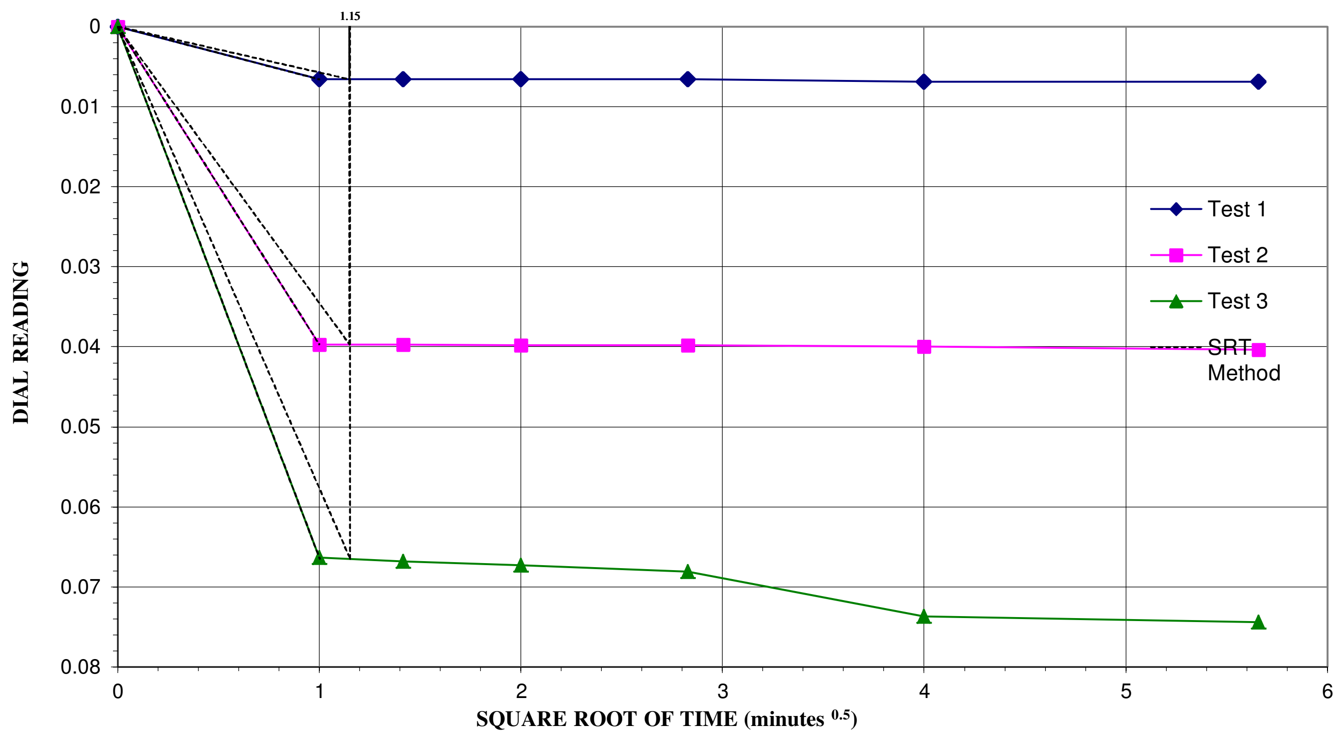


PROJECT: KEO Homestead Subdivision

PROJECT NO.: 1675-02N-15	GSH	**FIGURE NO.:** 11A

DIRECT SHEAR TEST





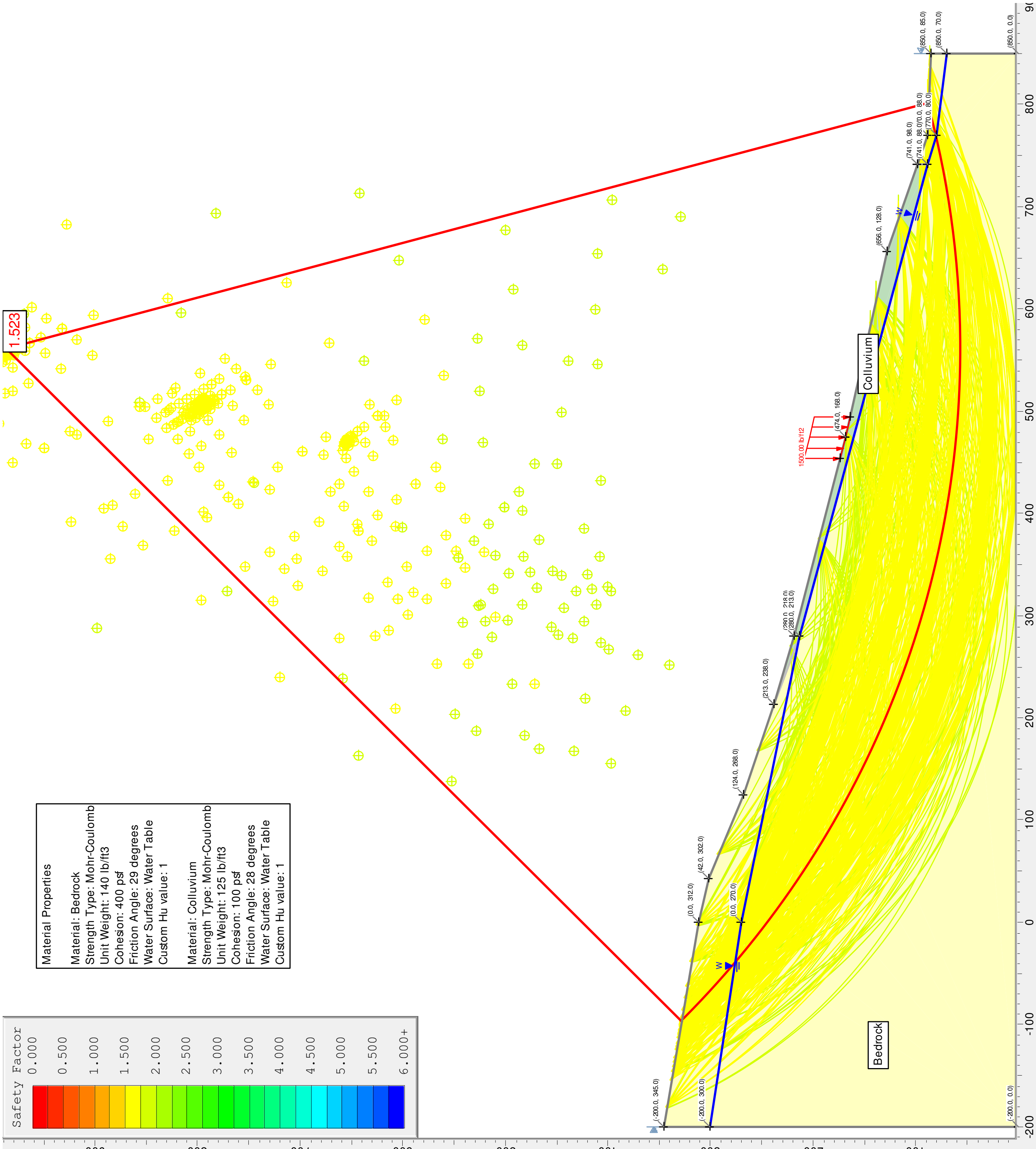
Test No. (Symbol)	1◆( )	2■( )	3 (▲)
t_{90} (from sq-root time)	1.32	1.32	1.33
$t_f = 50\ t_{90} / 4.28$	15.4	15.4	15.5
max. $d_r = 0.5 / t_f$	0.0324	0.0324	0.0322
selected d_r (in./min)	0.0050	0.0050	0.0050

PROJECT: KEO Homestead Subdivision

PROJECT NO 1675-02N-15	GSH	**FIGURE NO.:** 11B

STABILITY RESULTS

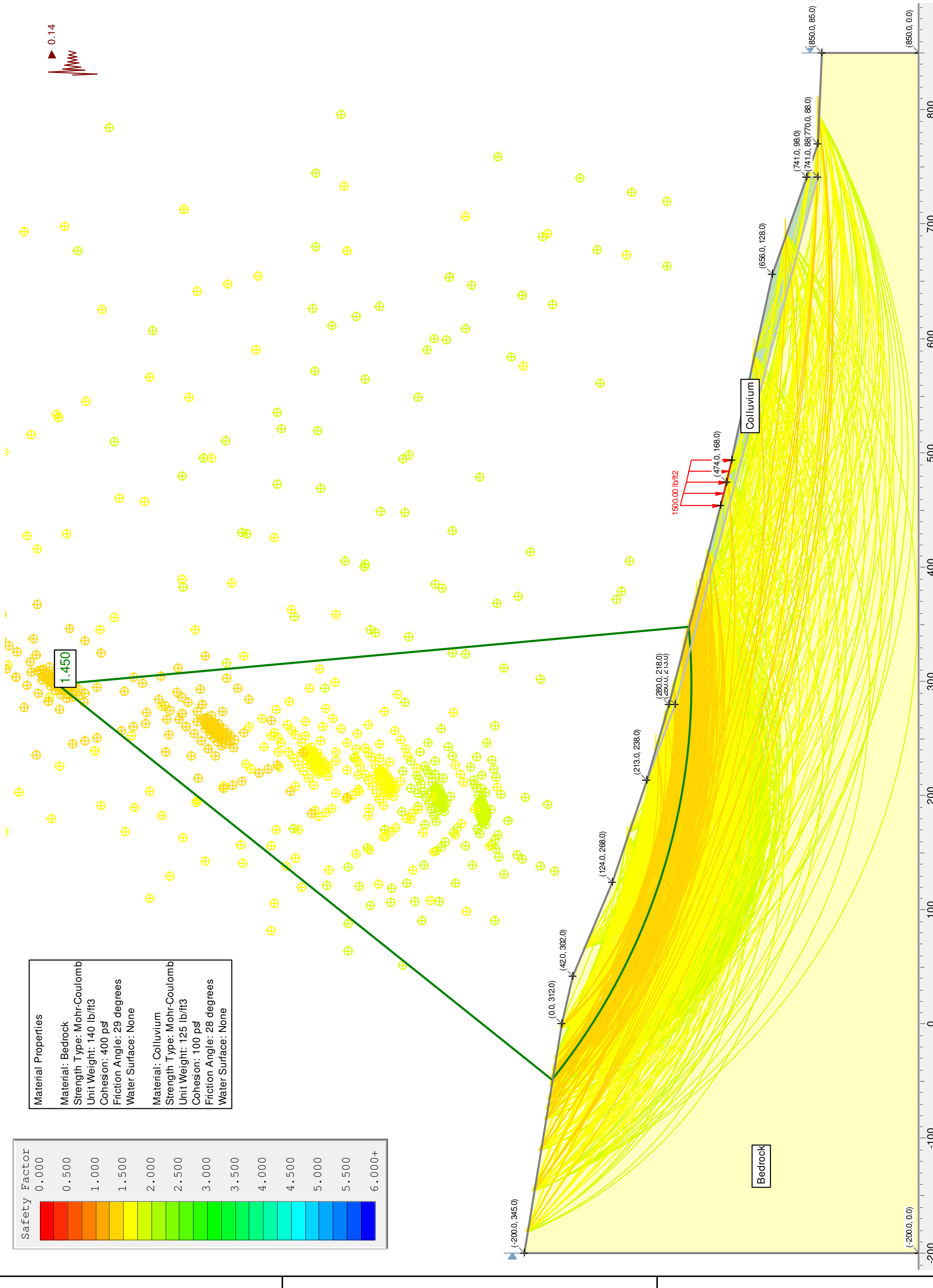
KEO HOMESTEAD SUBDIVISION, HUNTSVILLE (SECTION A-A')



PROJECT NO.: 1675-02N-16	GSH	FIGURE NO.: 12

STABILITY RESULTS

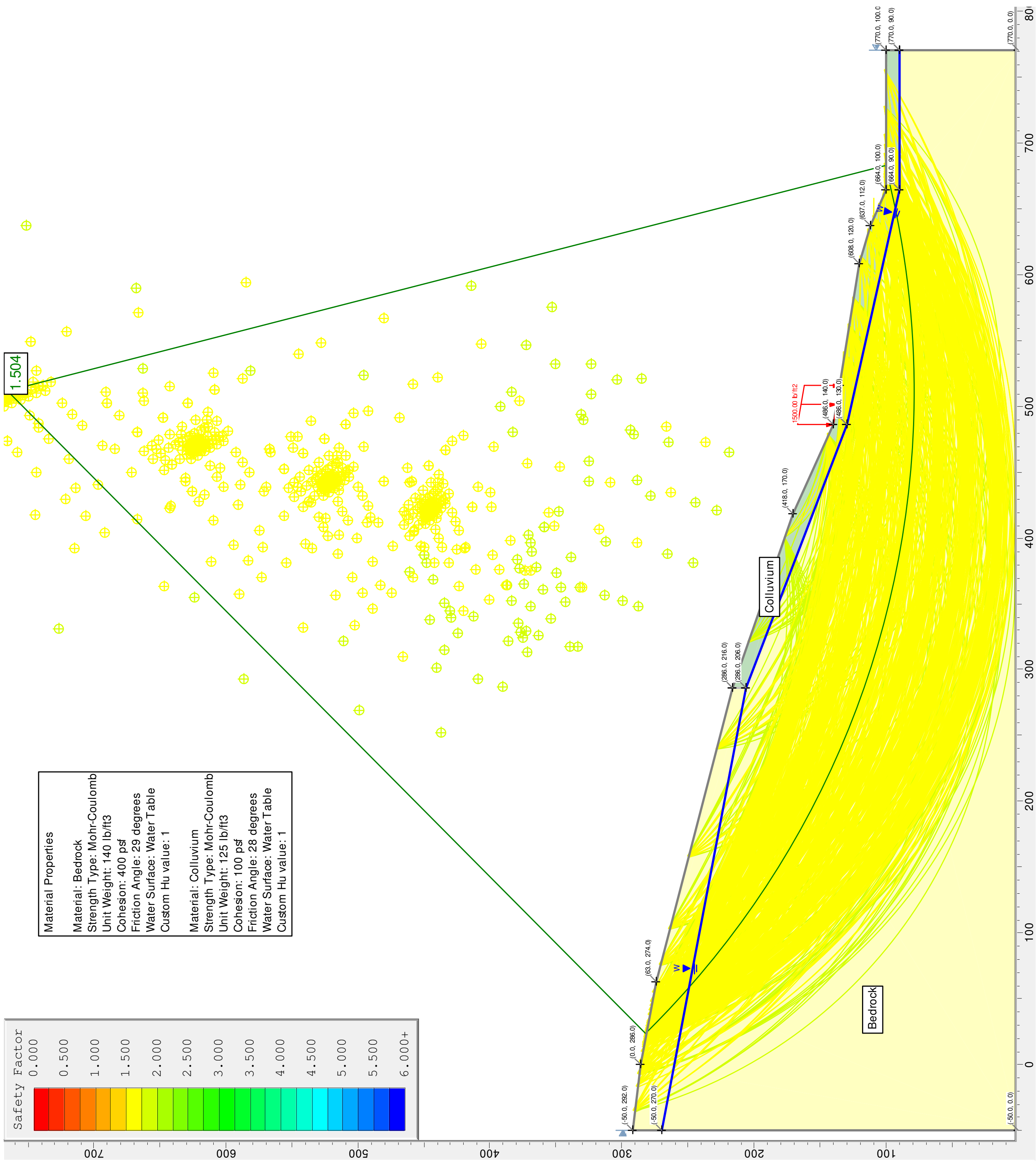
KEO HOMESTEAD SUBDIVISION, HUNTSVILLE (SECTION A-A')



PROJECT NO.: 1675-02N-16	GSH	**FIGURE NO.:** 13

STABILITY RESULTS

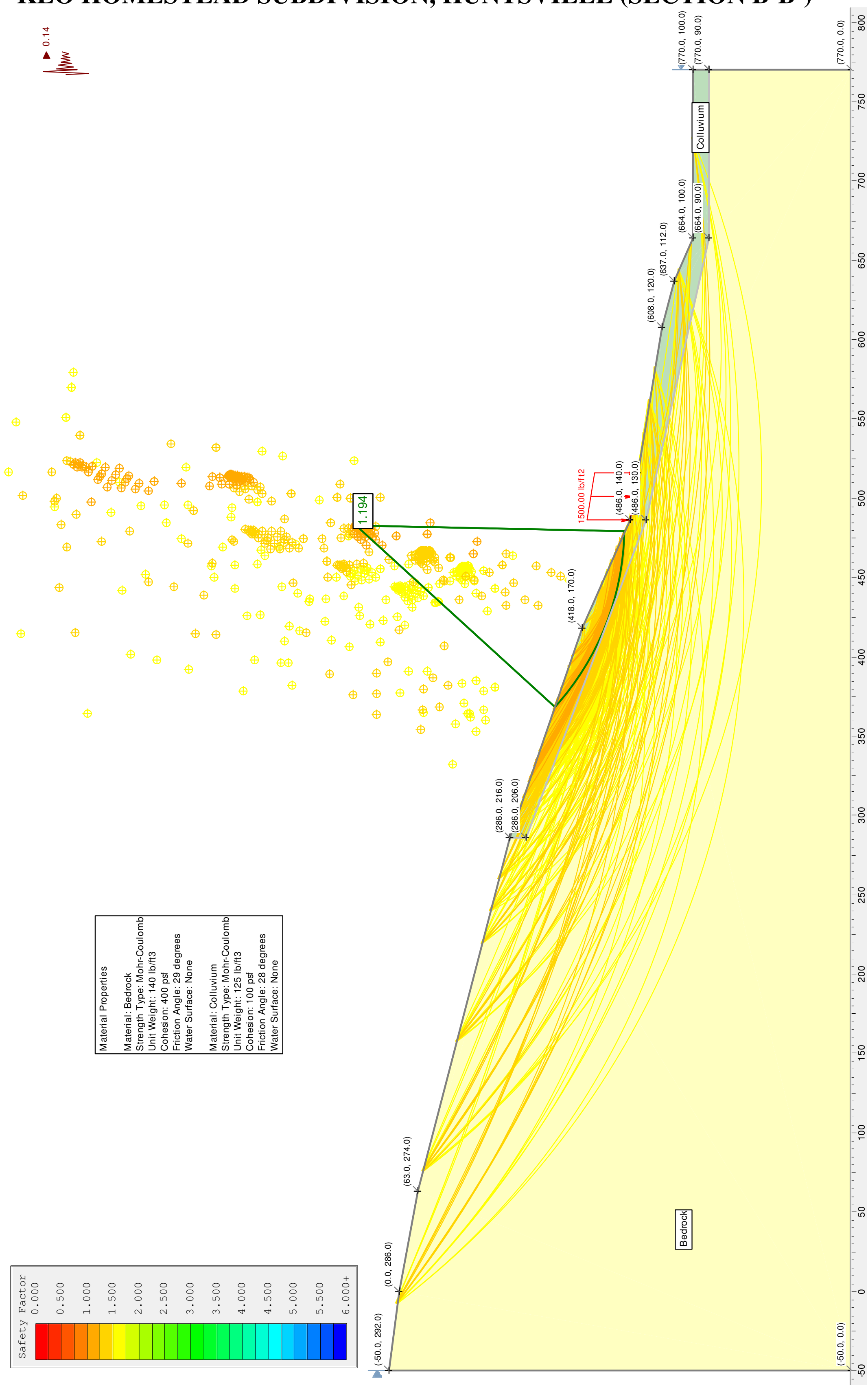
KEO HOMESTEAD SUBDIVISION, HUNTSVILLE (SECTION B-B')



PROJECT NO.: 1675-02N-16	GSH	FIGURE NO.: 14

STABILITY RESULTS

KEO HOMESTEAD SUBDIVISION, HUNTSVILLE (SECTION B-B')



PROJECT NO.: 1675-02N-16

GSH

FIGURE NO.: 15

APPENDIX

SUMMARY REPORT
GEOLOGICAL STUDY
PROPOSED SINGLE-LOT KEO HOMESTEAD SUBDIVISION
APPROXIMATELY 5600 EAST HIGHWAY 39
WEBER COUNTY, UTAH

Submitted To:

Mr. David Orchard
2248 Oneida Street
Salt Lake City, Utah

Submitted By:

GSH Geotechnical, Inc.
1596 West 2650 South
Ogden, Utah 84401

April 11, 2016

Job No. 1675-02N-15

April 11, 2016
Job No. 1675-02N-15

Mr. David Orchard
2248 Oneida Street
Salt Lake City, Utah 84109

Mr. Orchard:

Re: Geological Study Summary Report
Proposed Single-Lot KEO Homestead Subdivision
Approximately 5600 East Highway 39
(Part of Section 14, Township 6 North, Range 1 East, Salt Lake base and meridian)
Weber County, Utah

1. Introduction

In response to your request, GSH Geotechnical, Inc (GSH) has prepared this Geological Study for the proposed single-lot KEO Homestead Subdivision referenced above. The proposed subdivision is located in the vicinity of Huntsville Town, Weber County, Utah (41.2429, -111.7884). The general location of the subdivision is on the south side of Utah SR-39 with access at approximately 5600 East (MP-15.2), and entirely within Section 14, T6N-R1E SLBM, as shown on Figure 1.

The area of the proposed subdivision consists of approximately 21.3 acres of lands zoned by Weber County as FV-3, "Forest Valley Zone." A smaller area of approximately four acres within northeastern part of the subdivision property has been surveyed for single-family residential use, and is shown on Figure 2 as "Aerial Coverage." Figure 3 presents our geological mapping of the site on both LiDAR and Aerial Coverage. A more detailed drawing of proposed improvements for the Homesite Area is provided on Figure 4 "Homesite Aerial Geological Mapping," showing the proposed improvements, which are to include; a residence and a detached garage, with both structures to be served by independent septic/drain field systems, a water well with a 100-foot protection radius is shown to be located between the residence and the garage, and a paved turn-around area for vehicle access on the northeast side of the site. Figure 5, "Homesite LiDAR Geological Mapping" presents the layout of the proposed site improvements with respect geological and slope gradient conditions.

A previous Geotechnical Study for this subdivision was conducted by our office for this property in 2014 (GSH Geothchnical Inc., 2014). Details from this report indicate:

> *Construction for the home will likely consist of reinforced concrete footings and basement foundation walls supporting 1 to 3 wood-framed levels above grade with some stone, brick, or stucco veneer. The detached garage is anticipated to be a single level*

> *wood framed level above grade and constructed slab on grade. Projected maximum column and wall loads are on the order of 10 to 20 kips and 1 to 3 kips per lineal foot, respectively. Site development will require a moderate amount of earthwork in the form of site grading. We understand that site grading will be minimized on the project to maintain stability of the slopes at the site. We estimate in general that maximum cuts and fills to achieve design grades will be on the order of 2 to 5 feet. Larger fills and cuts may be required at isolated areas and should be engineered accordingly to maintain stability of the slopes at the site.*

As shown on Figure 3 and Figure 5 the general area of the proposed KEO Homestead Subdivision and the Homesite area includes slopes on the order of 20-pecent to greater than 50-percent.

2. Weber County Natural Hazards Overlay Districts

Because the proposed KEO Homestead Subdivision is located on a sloping hill side area with susceptible expansive soil and rock conditions, Weber County (Planning Commission) has requested that geological studies be conducted to evaluate conformance with development plans.

At this time specific guidelines for these studies have not been specified by the County, however Weber County Chapter 38 Natural Hazards Overlay Districts, Section 38-2B (Weber County Code, 2015), pertaining to Landslide/Tectonic Subsidence provides the following requirements:

> *...any development proposed within a designated landslide hazard area, as delineated on the Sensitive Lands Overlay District maps, shall require the submittal, review and approval by the Planning Commission, of specific site studies, including grading plans, cut/fill, and plans produced by a qualified engineering geologist and a Utah licensed Geotechnical Engineer. The site specific study shall address slope stability (including natural or proposed cut slopes), evaluate slope-failure potential, effects of development and recommendations for mitigative measures. Slope stability analysis shall include potential for movement under static, development-induced and earthquake-induced conditions as well as likely ground water conditions.*

Sensitive Lands Overlay District maps addressing Landslide/Tectonic Subsidence zones for Weber County are not available for the site. A review of site geological mapping prepared by Utah Geological Survey (UGS) geologists (King, et al, 2008) has indicated that the proposed KEO Homestead Subdivision is upon or within mapped Quaternary landslide deposits (Qms and Qmc) or sensitive Tertiary age Norwood Formation (Tn) rocks (King, et al., 2008).

To address the concerns and expectations of the Weber County Planning and Engineering Staff a scoping meeting was held on December 8, 2015 between the KEO Subdivision applicant proponents and Weber County Staff. Based upon our experience with Weber County the purpose of the scoping meeting was to accomplish the following:

> *Scoping Meeting: The developer or consultant should schedule a scoping meeting with the Weber County to evaluate the engineering geologist's/geotechnical engineer's*

investigative approach. At this meeting, the consultant should present a work plan that includes locations of anticipated geologic hazards and locations of proposed exploratory excavations, such as trenches, borings, CPT soundings, etc., which meet the minimum standard of practice. The investigation approach should allow for flexibility due to unexpected site conditions. Field findings may require modifications to the work plan

3. Scoping Meeting, December 8, 2015

The following individuals were present for the December 8 scoping meeting with Weber County Planning and Engineering Staff:

Chad Meyerhoffer (Weber County Engineering)
Dana Schuler PE (Weber County Engineering)
Ben Hatfield (Weber County Engineering)
David Simon PG, (Simon and Associates), Weber County Geological Consultant (teleconference)
Alan Taylor PE (Taylor Geotechnical) Weber County Geotechnical Engineering Consultant.
Greg Schlenker, PG, GSH Geoterchnical Inc., Applicant Geological Consultant.
Andrew Harris, PE, GSH Geotecnical Inc., Applicant Geotechnical Engineering Consultant
Andy Hubbard, PE PLS Great Basin Engineering, Applicant Engineering Consultant.

During the December 8 scoping meeting GSH consultants presented the following scope of work (work plan) for the evaluation of the KEO Subdivision site relevant to the Weber County Natural Hazards Overlay District Code:

For the present circumstances, but pending the consent of the scoping meeting, GSH proposes to conduct an engineering geology evaluation of the KEO Homestead Subdivision. A preliminary layout of our, test pit locations and slope geologic cross-sections to be evaluated for this study is show on Figure 2 Proposed Work Plan. Our proposed work plan effort is to include; 1) a search and review of previous relevant documentation of site engineering and geologic studies and including UGS mapping (King, et al, 2008), and previous reports and studies, 2) a field reconnaissance study including the geologic logging of four walk-in test pits on the Homesite Area, and to include field review by the Weber County Geologist, 4) site specific geological mapping and classification to identify critical geological units and exposure of proposed improvements, 5) slope analysis from DEM-LiDAR geoprocessing identifying critical areas of 25-percent or greater across the site, and 6) preparation of summary report presenting results of our analysis including:

- *A vicinity map showing the location of the property relative to site vicinity and topographic features.*

- *A geologic map showing the site specific surficial geology of the KEO Homestead Subdivision and surrounding area.*

- *Aerial photography showing the site and nearby surficial geologic features, site reconnaissance and test pit features, and site development features.*

- *An assessment of potential geologic hazards in the vicinity of the site and the exposure of the site and proposed site improvements to hazards named in the ordinance including but not limited to: landsliding and slope stability; alluvial fan processes including debris-flow; surface fault rupture hazards, strong earthquake ground motion, and liquefaction hazards; rockfall and avalanche hazards, flood hazards, and*

- *Site development recommendations based upon our findings and professional experience.*

Because parts of the KEO Subdivision are mapped by the UGS geologists (King, et al, 2008) as upon or within mapped Quaternary landslide deposits (Qms and Qmc) or sensitive Tertiary age Norwood Formation (Tn) rocks (King, et al., 2008), Weber County Geological Consultant, Mr. David Simon requested that a more detailed geological mapping of the site using currently available LiDAR data/imagery be performed before selecting test pit and/or boring locations for final work plan implementation. The County, following Mr. Simon's recommendation, has requested GHS to prepare geological mapping of the KEO Subdivision vicinity to better ascertain the geological conditions of the site prior to the acceptance test pit and/or boring locations for the subdivision work plan and evaluation.

In response to the discussions above, GSH prepared a preliminary reconnaissance level geological study of the site which was submitted January 6, 2016. The results of the January 6, 2016 reconnaissance level report are largely reiterated within this present report, however our present findings are supported by subsurface analysis including two exploration trenches and three auger borings. The locations of the trenches and borings are shown on Figure 6 "Homesite Field Program." In addition to the trenches and borings, two geological cross sections were calculated and drawn across the site where the proposed improvements and the trenches and borings were located. The cross section locations are also shown on Figure 6. The geological cross section data is to be used in our geotechnical slope stability analysis, to be presented in our concurrent geotechnical report.

The logs of the trenches and borings for this summary report are included on attached Figures 7 through 10, Logs of Trenches, and Figures 11 through 13, Boring Logs. The cross section drawings are presented on Figures 14 and 15, Cross Section A-A' and B-B'.

4. Surficial Geological Analysis

4.1 Detailed Geological Mapping and LiDAR Analysis

The previous existing mapping of the site by the UGS geologists (King, et al, 2008), is a 1:24,000 scale U.S. Geological Survey quadrangle based effort that is currently published as an "Interim - Open-File Report." The Utah Geological Survey discloses that *"... open-file release makes information available to the public that may not conform to UGS standards; the report may be* *incomplete and possible inconsistencies, errors, and omissions have not been resolved. Therefore it may be premature for an individual or group to take action based on its contents."* The UGS mapping effort shows the KEO Subdivision Homesite Area to be largely covered by units classified as **Qms** and **Qmc,** landslide and slump, and colluvial deposits undivided.

Our initial approach for the mapping was to assume the Quaternary landslide deposits (Qms and Qmc) as mapped by the UGS in the vicinity of the KEO Subdivision was correct, and that landslide terrain features such as; head scarps (main scarps), minor scarps, transverse cracks and ridges, hummocky surfaces and toe development could be identified in the site vicinity to clarify the areal limits, geometry and mode of movement (Varnes, 1978) of the landsliding mapped in the vicinity of the site (King, et al, 2008).

Our geological mapping effort included reviews of previous mapping and literature pertaining to site geology including Sorensen and Crittenden (1979), Bryant (1988) Coogan and King (2001) and King, et al. (2008); an analysis of vertical and stereoscopic aerial photography for the site including a 1946 1:20,000 stereoscopic sequence, a 2014 1.0 meter digital NAIP coverage, and a 2012 5.0 inch digital HRO coverage of the site; and a GIS analysis using the QGIS® GIS platform to geoprocess and analyze 2006 2.0 meter LiDAR digital elevation data made available for the site by the Utah Automated Geographic Reference Center (AGRC).

The GIS analysis included using the QGIS® platform Geospatial Data Abstraction Library (GDAL, 2013) Contour, Roughness, Ruggedness Index utilities; the GRASS® (Geographic Resources Analysis Support System, 2013) r.slope and r.shaded.relief modules; and the LiDAR First Return Intensity models; where features related to landslide morphology in the site vicinity were explored for detection and mapping.

4.2 Surface

As shown on Figure 1 and 2, the site consists of an area of 21.3 acres that is currently vacant and undeveloped. Surface vegetation consists of open areas of grasses, weeds and sage brush on rigelines, with a predominant wooded cover of scrub oak, alder and maple trees. The topography of the site consists of foothill slopes with the property occupying generally north facing slopes facing downward toward the north toward Ogden Valley. A small unnamed intermittent drainage passes from southwest to northeast across the Homesite area.

Topographically the site is located on base foothills on the northeast side of Mount Ogden, and overlooks Ogden Valley and the South Fork of the Ogden River floodplain, which is inundated by Pineview Reservoir waters, to the north of the site. The site, as shown on Figure 2, is bordered on the south, and west by vacant undeveloped lands, and on the north and west and by similar residential estate property land uses.

4.3 Geologic Setting

The site is located on the eastern flank of Mount Ogden which western flank comprises the Wasatch Front. The Wasatch Front is marked by the Wasatch fault, which is 5.8 miles west of the site, and provides the basis of division between the Middle Rocky Mountain Physiographic on the east and the Basin and Range Physiographic Province on the west. The Basin and Range Physiographic Province is characterized by approximately north-south trending valleys and mountain ranges that have been formed by extensional tectonics and displacement along normal faults, and extends from the Wasatch Range on the east to the Sierra Nevada Range on the west (Hunt, 1967).

The Middle Rocky Mountain province covers parts of Utah, Colorado, Wyoming, Idaho, and Montana. The geology of the province is an assemblage of sedimentary, igneous, and metamorphic rocks that have been folded, faulted, and uplifted. Mountain building (tectonic) activity commenced about 30 million years ago (Cretaceous time) and continues to the present. The province is characterized by mountainous terrain with deep canyons and broad intervening basins, with temperate semi-arid to mesic climatic conditions (Hunt, 1967).

The surficial geology of the site vicinity is the result of the uplift and exposure of older pre-Cambrian rocks which forms the crest of Mount Ogden east of the site. This exposure was the result of movement along high-angle faults during late Tertiary and Quaternary age (Bryant, 1988).

Bounding the east foothill flank of Mount Ogden are mid Teritary units of the Norwood Formation that ramp along the base of the mountains south and west of the Ogden Valley floor. The Norwood Formation is described as "light-gray to light brown, altered tuff (claystone), tuffaceous siltstone, sandstone, and conglomerate" derived from volcanic ash deposition (King, et al., 2008), and has been measured to be as much as 7000 feet thick in the vicinity of the site. . The site location is believed to be largely underlain by Norwood Formation tuff rock units which beds appear to slope gently down to the northeast across the site (King et. al, 2008). The existing surface of the site appears to have been modified by Quaternary age erosion, and localized late-Quaternary stream, lacustrine (Currey and Oviatt, 1985), residual soil weathering and development, and mass movement processes (King, et al., 2008).

4.4 Site Engineering Geology

Our interpretation of the site engineering geology is presented on Figure 3 Aerial and LiDAR Geologic Mapping. The engineering geologic mapping shown on Figure 3 is largely based on previous mapping prepared by King, et al., (2008), with amendments to the mapping drawn on the basis of the findings of this study including our LiDAR analysis incorporated in our January 6, 2016 report. A summary of the mapping units identified on the KEO Subdivision Property are listed below in relative age sequence (youngest-top to oldest bottom):

Qac; Alluvium and colluvium - Includes stream and fan alluvium...
Qc; Colluvium - Includes materials moved by slopewash and soil creep.
Qms; Landslide and slump, and colluvial deposits undivided.
Qmc; Landslide and slump, and colluvial deposits, undivided
Qlf/Tn; Lake Bonneville fine-grained deposits over Norwood Formation - Typically light-gray to light brown, altered tuff.

Qmso/Tn; Landslide and slump, and colluvial deposits, over Norwood Formation.
Qmso?Tn; Landslide and slump, and colluvial deposits, likely over Norwood Formation.
Tn; Norwood Formation.

In addition to the areal distribution of the geological deposits shown on Figure 3, a wave-cut shoreline attributed to the "Bonneville" highstand of ancient Lake Bonneville that was cut approximately 15,000 years ago (Currey and Oviatt, 1985), is shown to cross on the northwest corner of the property along the uppermost margins of the deposits mapped as **Qlf/Tn**.

Areas shown on the Homesite Area on Figure 3 mapped as **Qc** Colluvium and **Tn** Norwood Formation, were previously mapped by King et al. (2008) as consisting of **Qms and Qmc** Landslide and slump and colluvial deposits undivided. Our revision of the mapping in this area reflects the results of our LiDAR analysis included in our January 6, 2016 reconnaissance report, where landslide terrain features such as head scarps (main scarps), minor scarps, transverse cracks and ridges, hummocky surfaces and toe development were not detected. However, terrain features such as these were observed on mapped **Qms** regions on the southwest and south margins of the property.

4.5 Subsurface Evaluation:

Previous Subsurface Observations. Previous subsurface observations were made during our initial Geotechnical Evaluation conducted in 2014 (GSH Geotechnical Inc., 2014), where four vertical test pits were excavated on the Homesite area. The discussions pertaining to the site soils observed during our 2014 study are paraphrased below:

> *At the test pit locations, topsoil and disturbed soils were encountered at the surface of the site to about 3 to 12 inches below existing grades. Natural soils consisting of lean to fat clay with varying amounts of sand, gravel, and cobbles were encountered beneath the topsoil and disturbed soils within test pits TP-1, TP-2 and TP-3 to depths of about 8.0 to 10.0 feet (full depth penetrated in TP-1 and TP-3) below existing grades. Clayey fine to coarse sand with fine and coarse gravel and cobbles comprised of volcanic ash was observed below the clay soils in TP-2 and extended to the maximum depth explored of 10.0 feet below existing grades. Excavating in TP-2 was terminated at about 10.0 feet due to practical equipment refusal in the weakly cemented clayey sands with gravel and cobbles.*

A verbal driller's report was provided by Mr. Bob Sutton (Well Driller) regarding well drilling progress on the site for the Water Well Location shown on Figure 4 and 5. In December, 2015 Mr. Sutton indicated that:

> *Well drilling activities at the site are being completed with a cable-tool (wire-line) drill rig. Drilling for the well became difficult at about 5 feet below the ground surface. At this depth they encountered a "shale" bedrock that generated a clayey gravel cutting. At about 32 to 40 feet, the bedrock material generated more gravelly cuttings with less clay content. Below 40 feet to the current depth of 280 feet, the bedrock material was*

> *relatively consistent and consisted of "shale." Minor groundwater was encountered at about 275 feet; however the flow rate was estimated at less than 2 gallons per minute. The well is anticipated to extend about 100 feet further (TD at about 380 to 400 feet). Mr. Sutton indicated that the drilling rates through this material were very slow by comparison to the rates achieved on wells in the Mountain Green area and other parts of the Ogden Valley. Drilling was limited to about 3 to 9 feet per day in the bedrock on this well, where wells in the Mountain Green area and other parts of the Ogden Valley average about 20 feet per day in bedrock.*

Current Subsurface Observations. Two exploration trenches were excavated and logged at the house and garage locations on the site on January 21 and 22, 2016 at the locations (Trench 1 and Trench 2) shown on Figure 6. A January 26, 2016 field review of the trenching was conducted, and Weber County geological and geotechnical engineering consultants Mr. David Simon and Mr. Alan Taylor observed exposures in the two trenches. Their conclusions from the January 26, 2016 field review, found that the trenches were not adequately deep, and the trench walls were insufficiently cleaned for their evaluation. A copy of their review letter of the January 26, 2016 field review is included in Appendix A of this report. On February 1 and 2, 2016, the trenches were deepened and, lengthened and cleaned in their original locations, and a field review was again held on February, 3, 2016. During the February 3, 2016 field review discussions between GSH and the Weber County reviewers, Mr. David Simon and Mr. Alan Taylor, were conducted. No review letter summarizing the February 3, 2016 observations of the Weber County reviewers has been received by GSH prior to this reporting.

The three borings made for our geotechnical study and included in this reporting, were drilled on February, 25, 26 and 29, 2016.

4.5.1 Subsurface Observations Trench 1 and Trench 2

Trench 1 and Trench 2 were both 162 feet in length, and extended from 5.0 to 12.0 feet in depth, at the locations shown on Figure 6. Excavation of the trenches was completed on February 1 and 2, 2016 using a 20-ton class track-mounted excavator, and the depths penetrated by the excavator were at or nearing refusal resistance. The trenches were logged in the field, and report logs of the trenches are presented on Figure 7, Figure 8, Figure 9 and Figure 10, "Logs of Trenches."

The natural rock and soils observed in the trenches and illustrated on Figure 7, Figure 8, Figure 9 and Figure 10, generally consisted, from bottom to top of:

1. Weathered Norwood Formation tuff (TU-CL), weathering to sandy clay with zones of coarse sand and fine gravel, silt, slightly moist, very stiff to dense, yellowish to olive to reddish brown, massive matrix with mostly angular gravel and cobble clasts.

2. Colluvial accumulations, consisting of silty clay (<u>CL</u>) with trace of fine to coarse sand, slightly moist, very stiff, reddish brown, massive matrix with rounded coarse gravel and cobble clasts.

3. Soil B Horizon consisting of silty clay (CL) with fine sand, brown, slightly moist, medium stiff to stiff, with pedogenic vertical cracks or vertisol development

4. Surficial pedogenic Soil A Horizon consisting of silty clay (CL) with some fine to coarse sand, dark brown, moist, medium stiff, with woody and herbaceous roots

The rock and soil sequences observed in the trenches are interpreted to consist of tuffaceous parent-rock material of the Norwood Formation, overlain by colluvial accumulations derived from weathering of the Norwood Formation parent material. The weathered Norwood Formation observed in the trenches consisted of a volcanic tuff that is believed to have been deposited across northern Utah during the Tertiary Period roughly 40 million years ago (King, et al., 2008).

As observed in the trenches, the colluvial accumulations are believed to have moved into place through slope wash and slope creep processes. The colluvial accumulations are likely derived from the underlying weathered tuff parent material. The colluvial accumulations observed in the trenches are likely to have been deposited during the Holocene Epoch, or within the past 10,000 years, and are probably susceptible to movement (slope wash and slope creep) under the present conditions.

The Soil B horizon vertisol sequences that extended in depth from 1.5 to 6.0 feet below the surface are a pedogenic-soil forming response to the inherent expansive clays that are weathered from tuff and the colluvial accumulations. Seasonal wetting and drying of these soils combined with expansive clays results in the development of deep vertical cracking in the vertisol soil sequences (Graham and Southard, 1982). The repetitive expansion and contraction of these soils results in a periodic loss of strength to the soil, and can impose stresses on structural loads and foundations (Mulvey, 1992).

Angular, sub-angular and rounded cobble clasts of apparent volcanic origin were observed in the weathered tuff and colluvial accumulation matrixes. There appeared to be a higher propensity, for the angular and sub-angular clasts to occur in the weathered tuff matrix.

No evidence or indications of deep-seated landslide movement was observed in the two trenches.

The locations of disturbed and undisturbed soil samples collected in the trenches to be used for our geotechnical analysis are shown on the trench logs. Copies of our field trench logs drawn during our field program are included in Appendix B of this report.

4.5.1 Subsurface Observations Boring 1, 2, and 3

As part of our exploration program study three soil borings were drilled on the site at the locations shown on Figure 6. Borings were located in conjunction with proposed site improvements. The borings were drilled on February 25, 26, and 29 of 2016. The borings were completed using a Mobile B-53 drill rig using hollow-stem auger equipment and methods. Soil samples were recovered at 2.5-foot intervals using driven 2.42-inch inside diameter drive Dames

& Moore sampler. Recovered samples were returned to our laboratory for testing, and the results of these tests will be included in our concurrent geotechnical report.

The conditions encountered in borings consisted of soft / loose to stiff clays (CL) and medium dense clayey gravels (GC) within the upper 5.0 to 9.0 feet of the borings, becoming hard clays (CL) to medium dense, dense to very dense clayey sands (SC), poorly graded sands (SP) and clayey gravels (GC) at depth to auger refusal. Boring 1 was refused at 36.5 feet, Boring 2was refused at 32.5 feet and Boring 3 was refused at 47.5 feet. Each of the borings were completed with slotted PVC to the depths penetrated.

4.6 Geological Slope Cross Sections:

Two geological slope cross sections were developed from areal surface measurements, and from our observed subsurface observations. The cross sections are included on Figure 14, Geologic Slope Cross Section A-A' and Figure 15, Geologic Slope Cross Section B-B. The locations of these cross sections are shown on Figure 6.

5. DISCUSSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

5.1.1 Expansive soils. Vertical cracking associated with vertisol development was observed to extend from 1.5 to 6.0 feet below the surface in the trenches excavated for this study. The vertical cracking demonstrated by these soils is a result of naturally high expansive clay content within these soils (Graham and Southard, 1982). The presence or absence of the vertisol soils should be evaluated where structural loads are to be placed during future development.

5.1.2 Sloping Surfaces. The surface of site slopes developed from our LiDAR analysis range from level to over 55-percent as shown on Figure 5, Homesite LiDAR Geology and Slope. For the Homesite Area, the slope areas averaged 30.3-percent, and for overall the Property area the slopes averaged 33.0-percent. As previously discussed in the Slope Analysis section of this report, the critical gradient for slope development considerations according to the Weber County Code is 25-percent.

5.1.3 Site Engineering Geology And Mapping. The engineering geology mapping of the site presented on Figure 3 reveals two issues pertinent to site development planning for the Homesite Area. These issues include: (1) **Colluvium deposits (Qc)** - the presence of materials moved by slopewash and soil creep; (2) **Norwood Formation (Tn)** - the presence of Norwood Formation tuff **Tn** underlying much of the area of the property including the Homesite Area. These issues are addressed in order importance below:

1. **Colluvium deposits (Qc):** Presence of **Qc** Colluvium deposits on the site is based upon reconnaissance and field observations and the analysis of aerial imagery and the LiDAR Analysis included in Appendix A. The engineering geology significance of the

Colluvium deposits **(Qc)** is the propensity of deposits of this genera to experience slope creep. Slope creep is described by Varnes (1978) as:

...the imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure. There are generally three types of creep: (1) seasonal, where movement is within the depth of soil affected by seasonal changes in soil moisture and soil temperature; (2) continuous, where shear stress continuously exceeds the strength of the material; and (3) progressive, where slopes are reaching the point of failure as other types of mass movements. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges.

Vertisol-colluvium sequences were observed as deep as 9.5 feet in the trenches excavated on the site. These soils should considered and treated as potential slope creep hazards to the site improvements.

2. Norwood Formation (Tn): The Norwood Formation has a notoriety of poor stability performance and geotechnically challenging soils throughout Northern Utah (Mulvey, 1995). Based upon our past experience with areas underlain by Norwood Formation rock and soil, we believe that appropriate geotechnical studies should be conducted before structural improvements are made in those areas.

5.1.4 Geoseismic Setting: Utah municipalities have adopted the International Building Code (IBC) 2012. The IBC 2012 code determines the seismic hazard for a site based upon 2008 mapping of bedrock accelerations prepared by the United States Geologic Survey (USGS) and the soil site class (Peterson, et al., 2008). The USGS values are presented on maps incorporated into the IBC code and are also available based on latitude and longitude coordinates (grid points).

Based on probabilistic estimates (Peterson, et al., 2008) queried for the site, the expected peak horizontal ground acceleration on rock from a large earthquake with a ten-percent probability of exceedance in 50 years is as high as 0.16*g*, and for a two-percent probability of exceedance in 50 years is as high as 0.33*g* for the site. Ground accelerations greater than these are possible but will have a lower probability of occurrence.

5.1.5 Active Earthquake Faults: Based upon our review of available literature, no active faults are known to pass through or immediately adjacent to the site. The nearest active (Holocene) fault is the Weber Segment of the Wasatch fault, located 5.8 miles west of the site (Black et al., 2004). . The Wasatch Fault Zone is considered capable of generating earthquakes as large as magnitude 7.3 (Arabasz, et al., 1992).

5.1.6 Liquefaction Potential Hazards: In conjunction with the ground shaking potential of large magnitude seismic events as discussed previously, certain soil units may also possess a potential for liquefaction during a large magnitude event. Liquefaction is a phenomenon whereby loose, saturated, granular soil units lose a significant portion of their shear strength due to excess pore water pressure buildup resulting from dynamic loading, such as that caused by an earthquake. Among other effects, liquefaction can result in densification of such deposits causing settlements of overlying layers after an earthquake as excess pore water pressures are dissipated. Horizontally continuous liquefied layers may also have a potential to spread laterally where sufficient slope or free-face conditions exist. The primary factors affecting liquefaction potential of a soil deposit are: (1) magnitude and duration of seismic ground motions; (2) soil type and consistency; and (3) occurrence and depth to groundwater.

Liquefaction commonly occurs in saturated non-cohesive soils such as alluvium, thus no areas of the site appears to be susceptible to liquefaction processes.

5.1.7 Alluvial Fan Deposits: Alluvial fan deposits indicative of processes including flash flooding and debris flow hazard do not occur on the site: The nearest active alluvial fan deposits to the site, mapped as Qaf by king, et al., (2008), are located on a small fan surface approximately 1,000 feet northeast of the site, and do not appear to represent a potential impact the site.

5.1.8 Flooding Hazards: No significant water ways pass in the vicinity of the site and flood insurance rate mapping by Federal Emergency Management Agency for the site vicinity has not been prepared at this time.

5.1.9 Rockfall and Avalanche Hazards: The site is located roughly a mile from steep slope areas where such hazards may originate.

5.1.10 Radon Exposure: Radon is a naturally occurring radioactive gas that has no smell, taste, orcolor, and comes from the natural decay of uranium that is found in nearly all rock and soil. Radon and has been found occur in the Ogden Valley area, and can be a hazard in buildings because the gas collects in enclosed spaces. Indoor testing following construction to detect and determine radon hazard exposure should be conducted to determine if radon reduction measures are necessary for new construction. The radon-hazard potential for site location is mapped as "Moderate" by the UGS (Solomon, 1996).

6. CONCLUSIONS

Based upon our geological studies herein, we believe that the proposed KEO Subdivision is suitable for development as discussed in Section 1 of this report. The Homesite Area is generally covered with an approximately 10-foot thick mantle of Colluvial deposits (Qc) that is potentially susceptible to slope creep processes, but does not appear to be exposed to deep-seated landslide movement.

The site appears to be underlain by Norwood Formation deposits and colluvial and expansive vertisol soils were observed in the excavations made for this study. Areas where these soils are present should be evaluated prior to the placement of structural loads. Further study of the expansive potential of the near surface soils will be included as part of our concurrent geotechnical study.

Due to the "moderate" radon potential for the site, radon testing of the home following construction is recommended.

Test pits and trenches were excavated in the vicinity of the proposed home or garage structure areas. The backfill soils for these explorations is likely unsuitable for bearing structures. The trench/test pit backfill soils within the structure locations must be removed and replaced with compacted structural fill meeting the requirements of the lot specific geotechnical study. Due to the potential for unsuitable soils at the site, observation of the home excavation during construction is required.

CLOSURE

If you have any questions or would like to discuss the results of this study further, please feel free to contact us at (801) 393 2012..

Respectfully submitted,

GSH Geotechnical, Inc.

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Encl. Figure 1, Vicinity Map
Figure 2, Aerial Coverage
Figure 3, Aerial and LiDAR Geologic Mapping
Figure 4, Homesite Aerial Geologic Mapping
Figure 5, Homesite LiDAR Geology and Slope
Figure 6, Homesite Field Program
Figure 7, Log of Trench 1 STA 00 to 70 West
Figure 8, Log of Trench 1 STA 70 to 162 West
Figure 9, Log of Trench 2 STA 00 to 70 West
Figure 10, Log of Trench 2 STA 70 to 162 West
Figure 11, through 13 Boring Log
Figure 14, Geologic Slope Cross Section A-A'
Figure 15, Geologic Slope Cross Section B-B'

Appendix A Simon and Associates January 26, 2016 Field Review Letter.
Appendix B Field Trench Logs

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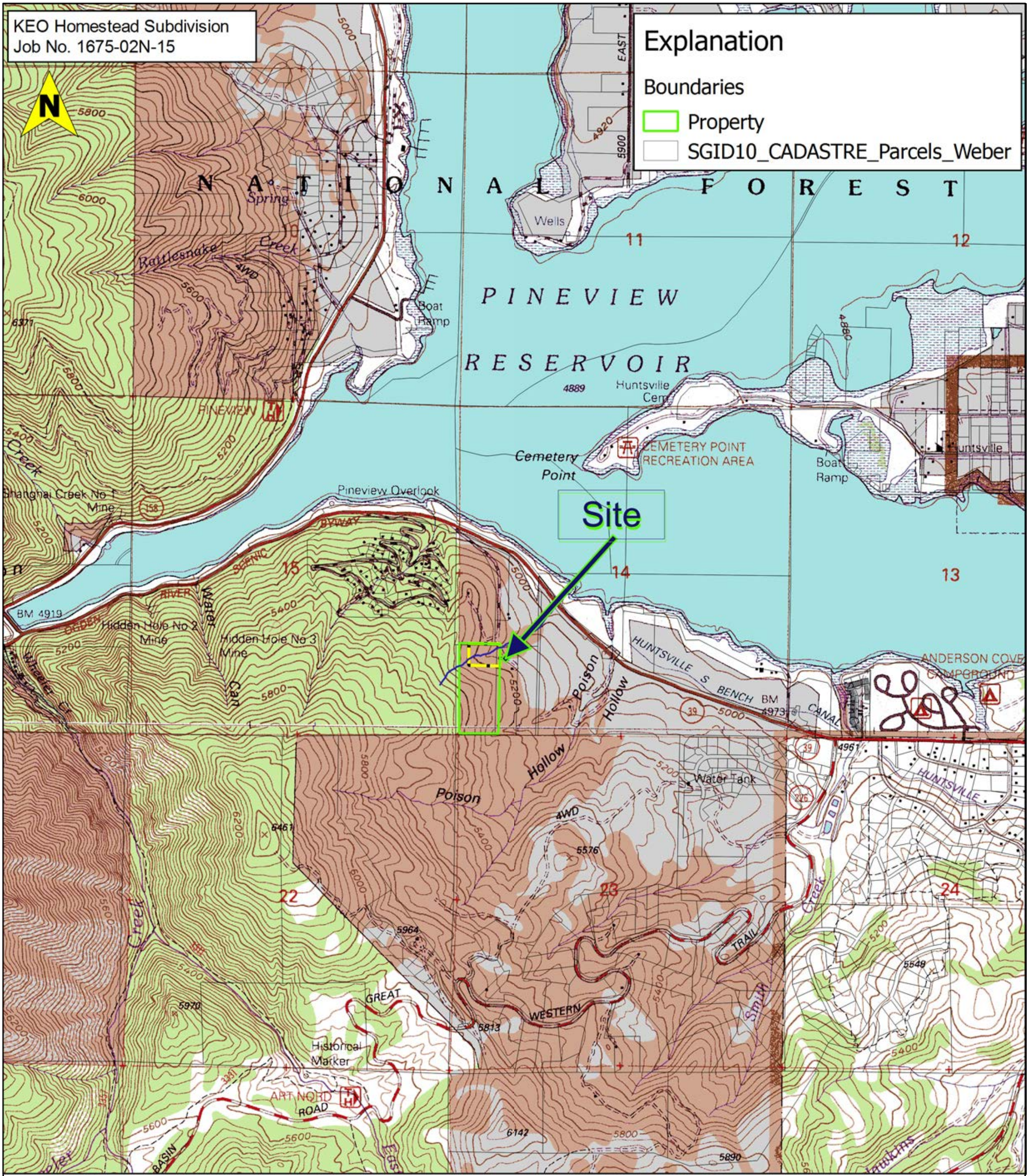


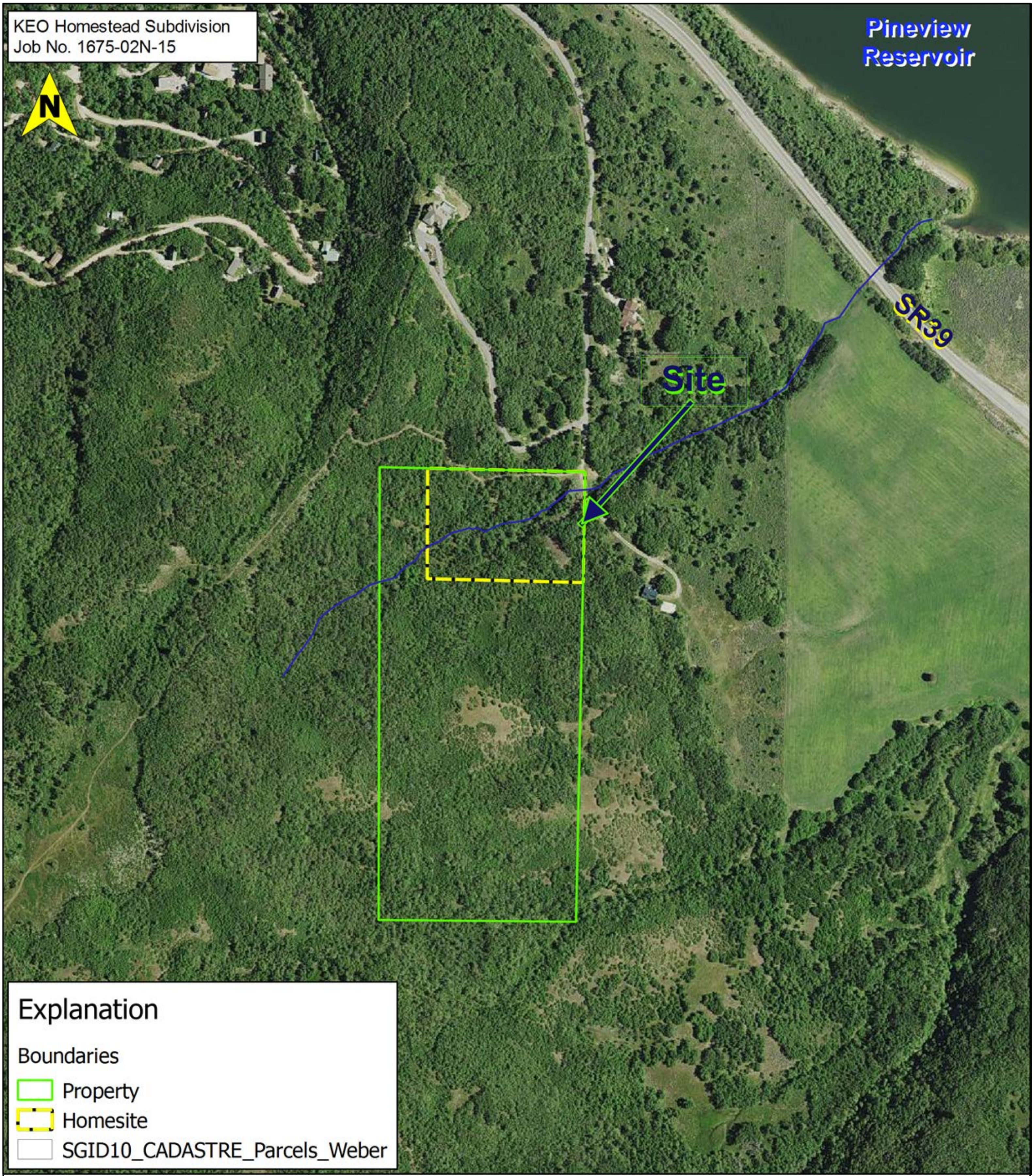
Base:
1998 7.5 Minute USGS Toporgraphic Maps Titled
Snowbasin, Utah, and Huntsville, Utah.

0 1000 2000 3000 4000 ft

1:24,000

FIGURE 1
VICINITY MAP

GSH



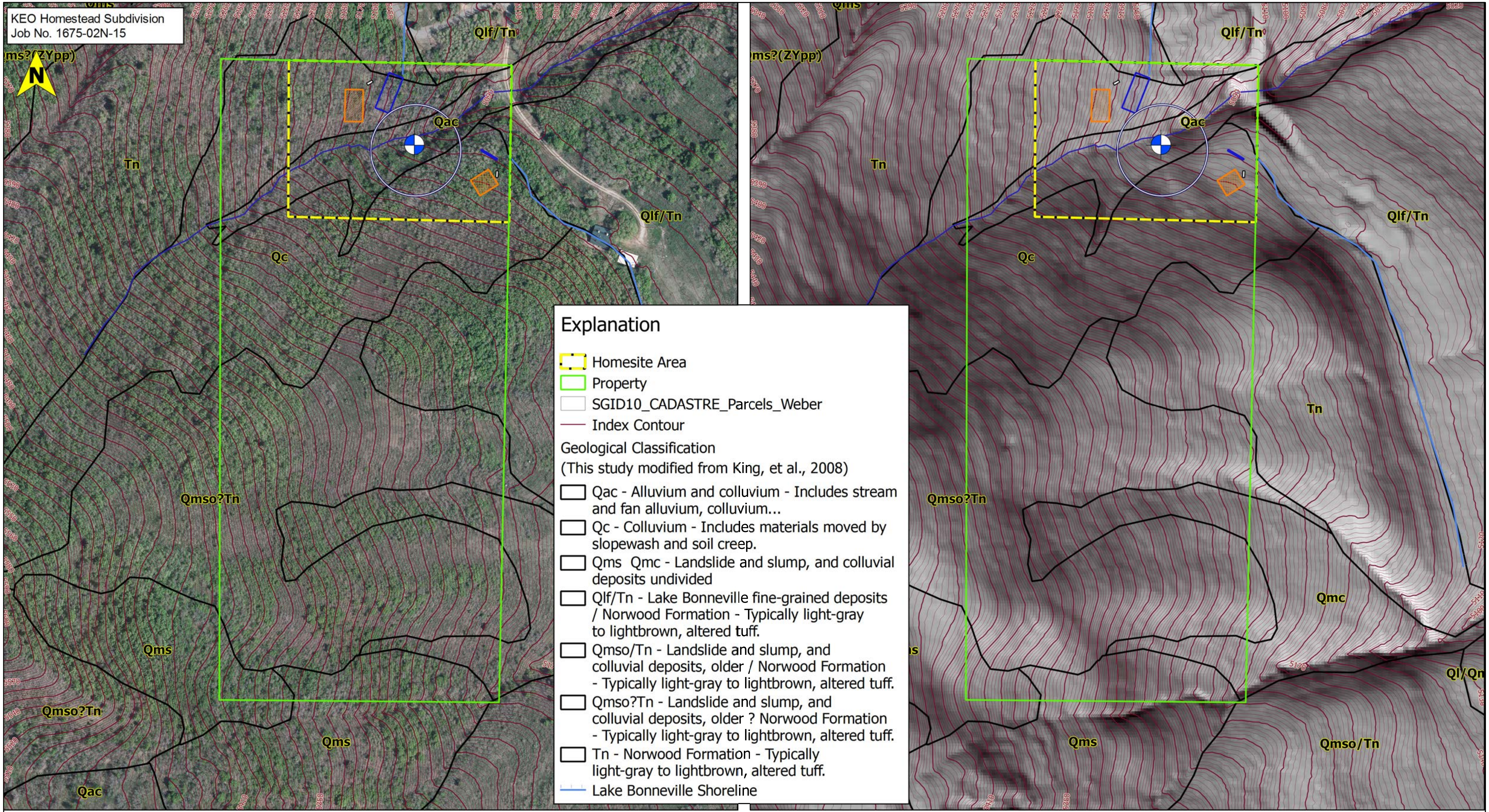
Base:
2014 1.0m Color NAIP Orthoimagery,
from Utah AGRC. http://gis.utah.gov/

0 200 400 600 800 ft

1:4,800

FIGURE 2
AERIAL COVERAGE

GSH

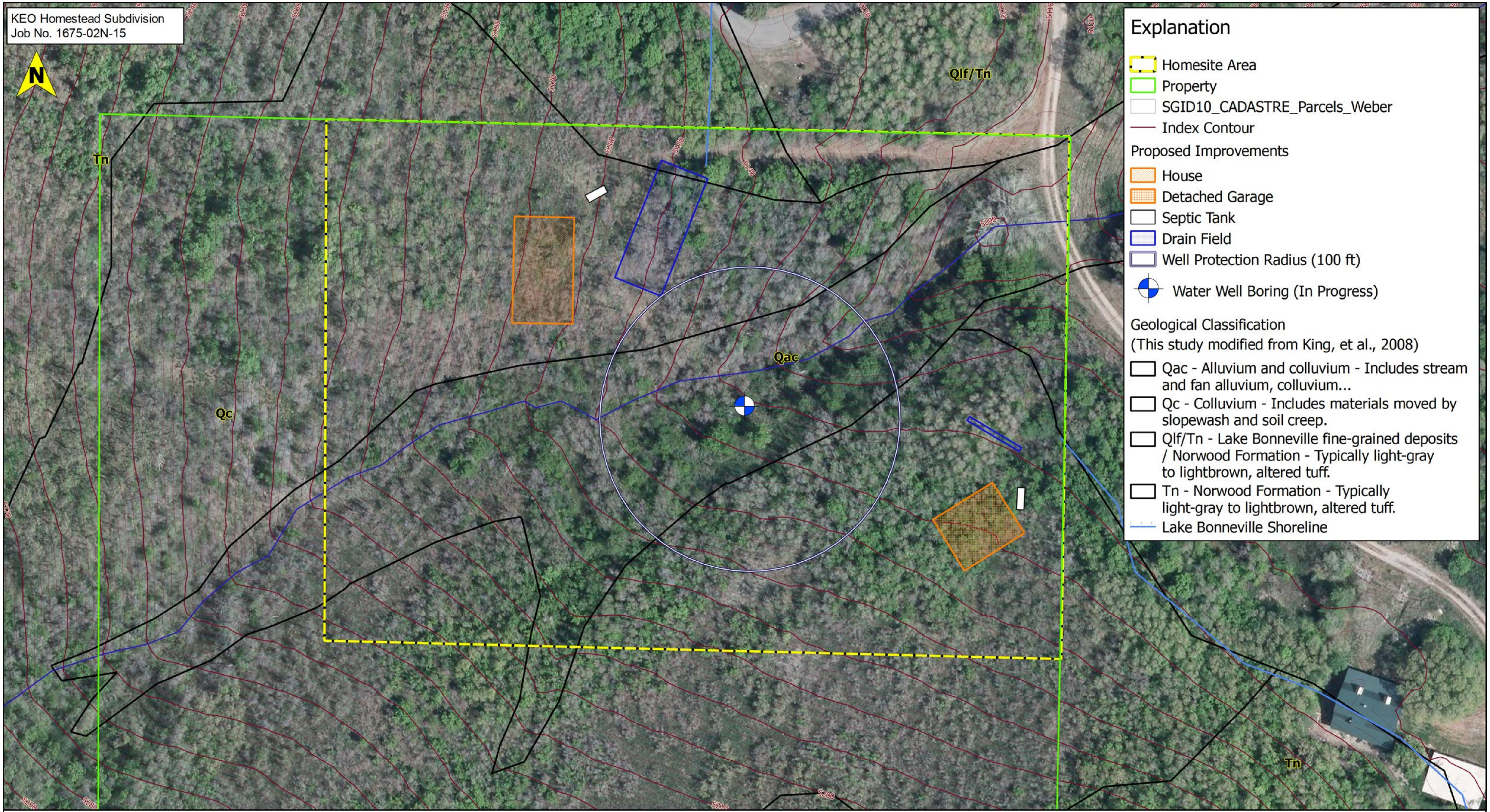


Base: 2012 5.0 inch Color HRO Orthoimagery, from Utah AGRC; http://gis.utah.gov/
Elevation: 2006 2.0m Geoprocessed LiDARfrom Utah AGRC; http://gis.utah.gov/
Geology: Modified from King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, scale 1:24,000

0 100 200 300 400 500 600 ft

1:2,400

FIGURE 3
AERIAL AND LiDAR GEOLOGIC MAPPING



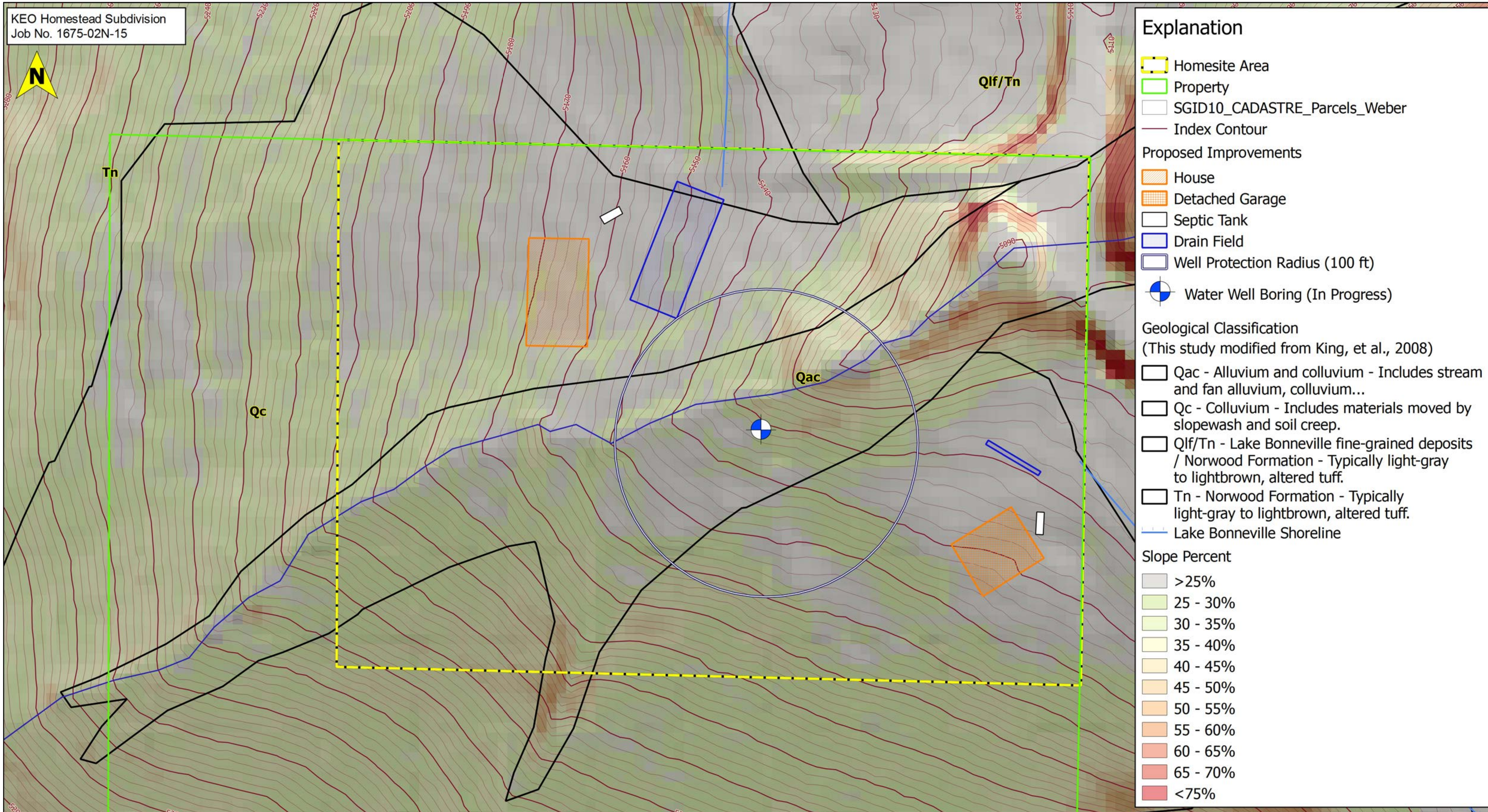
Base: 2012 5.0 inch Color HRO Orthoimagery,
from Utah AGRC; http://gis.utah.gov/
Elevation: 2006 2.0m Geoprocessed LiDARfrom Utah AGRC;
http://gis.utah.gov/
Geology: Modified from King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, scale 1:24,000

0 60 120 180 ft

1:720

FIGURE 4
HOMESITE AERIAL GEOLOGIC MAPPING

GSH



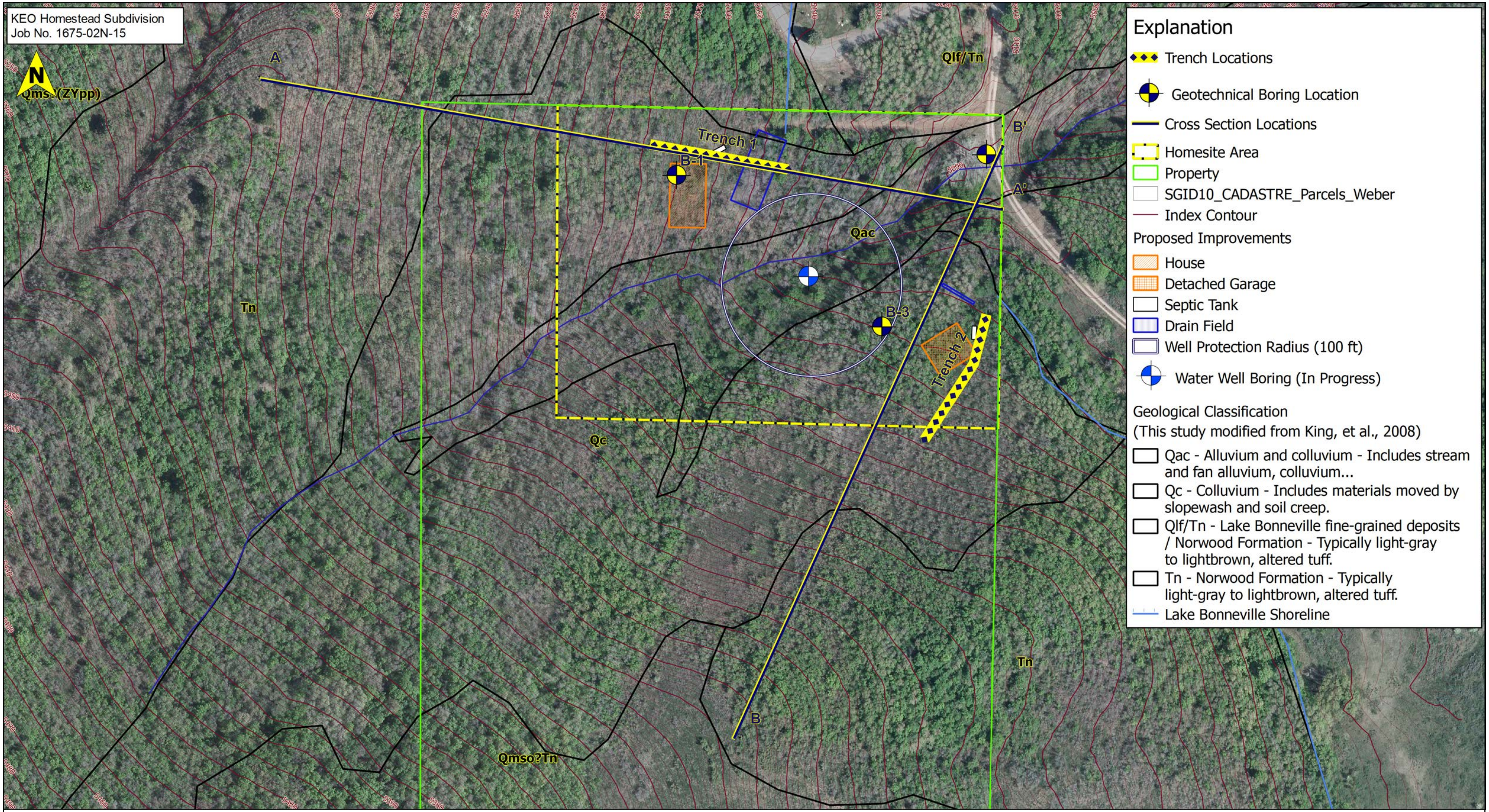
Base & Elevation: 2006 2.0m Geoprocessed LiDAR from Utah AGRC; http://gis.utah.gov/
Geology: Modified from King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, scale 1:24,000

0 60 120 180 ft

1:720

FIGURE 5
HOMESITE LiDAR GEOLOGY AND SLOPE

GSH



Base: 2012 5.0 inch Color HRO Orthoimagery, from Utah AGRC; http://gis.utah.gov/
Elevation: 2006 2.0m Geoprocessed LiDARfrom Utah AGRC; http://gis.utah.gov/
Geology: Modified from King, J.K., Yonkee, W.A., and Coogan, J.C., 2008, Interim geologic map of the Snow Basin and part of the Huntsville quadrangle, Davis, Morgan, and Weber Counties, Utah: Utah Geological Survey Open-File Report 536, scale 1:24,000

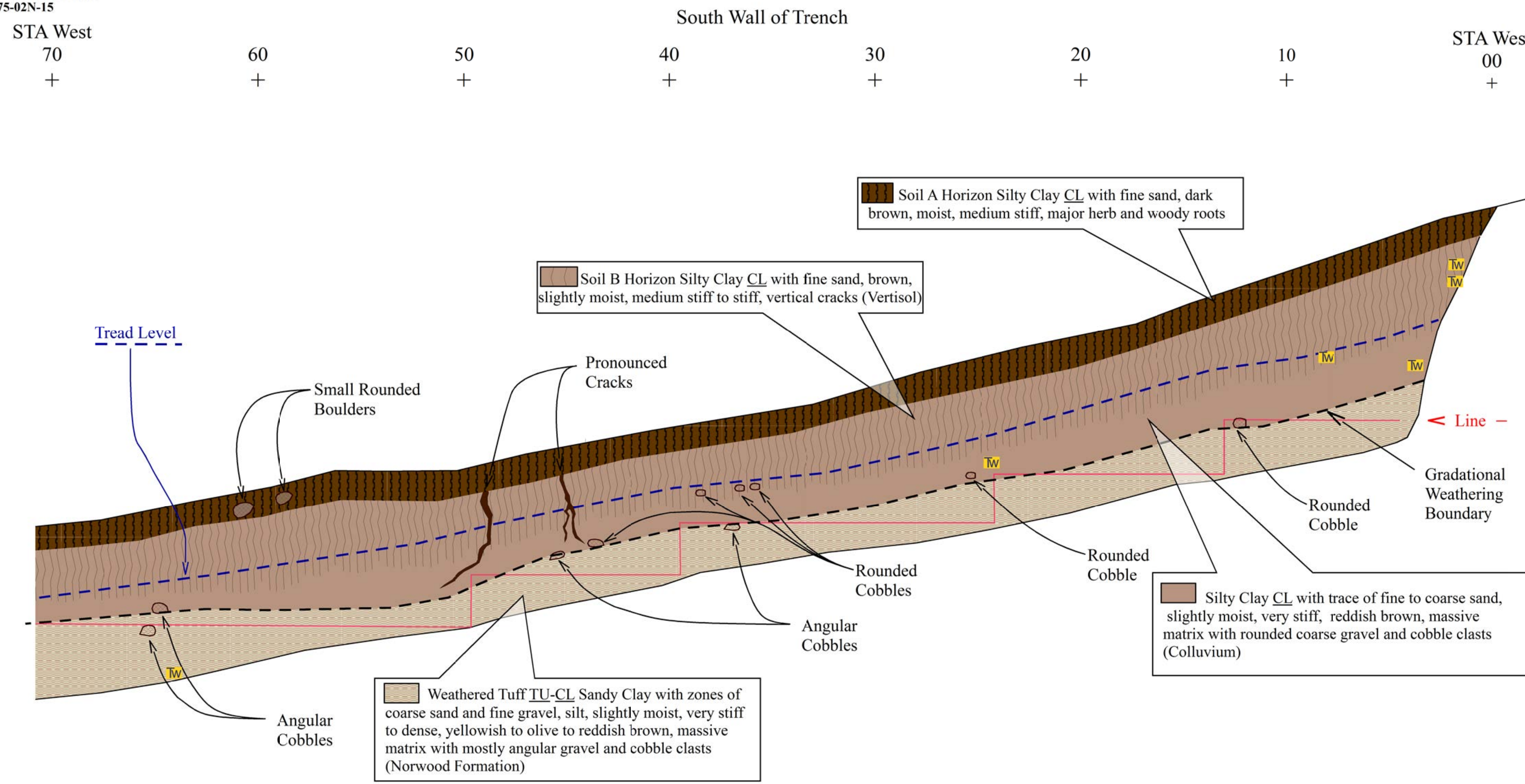
0 60 120 180 ft

1:1,200

FIGURE 6
HOMESITE
FIELD PROGRAM

GSH

KEO Homestead Subdivision
Job No. 1675-02N-15



5
0 5
Scale In Feet

Sample Locations
(see geotechnical report for sample data)
Tw Thin Wall Sample
B Bulk Sample

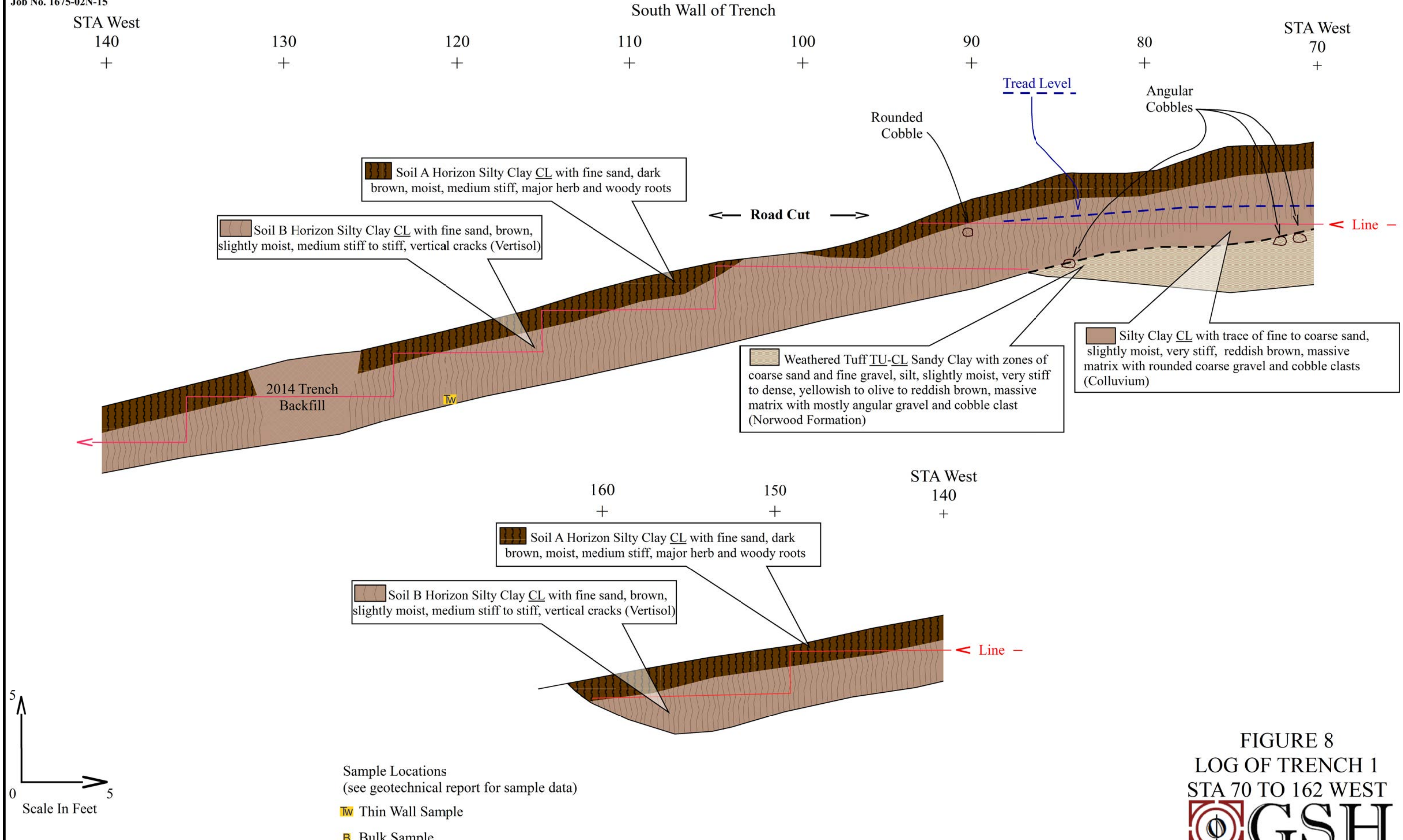
Sample Locations
(see geotechnical report for sample data)
Thin Wall Sample
B Bulk Sample

FIGURE 7
LOG OF TRENCH 1
STA 00 TO 70 WEST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 4/4/16

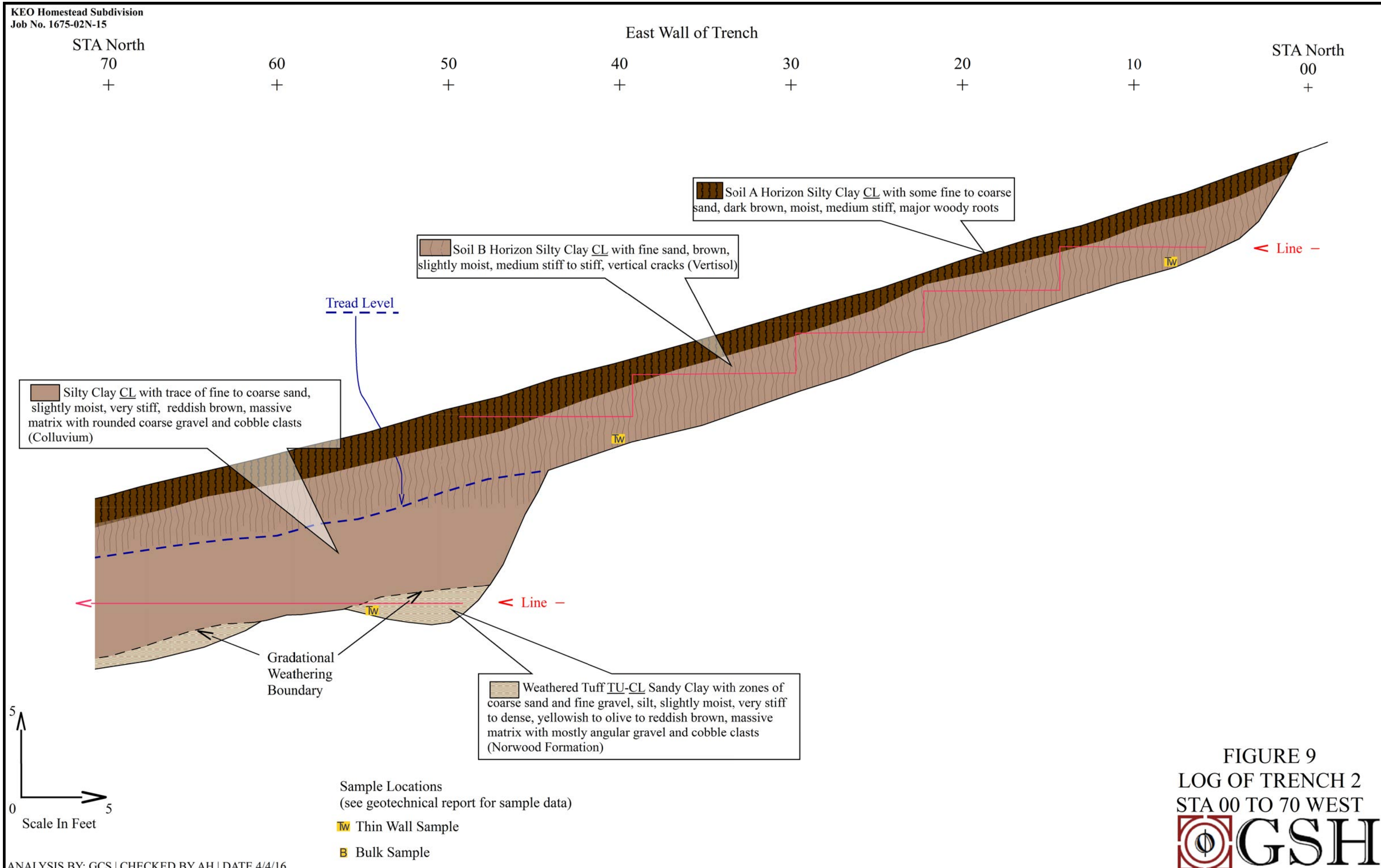
KEO Homestead Subdivision
Job No. 1675-02N-15



ANALYSIS BY: GCS | CHECKED BY AH | DATE 4/4/16

FIGURE 8
LOG OF TRENCH 1
STA 70 TO 162 WEST

GSH



KEO Homestead Subdivision
Job No. 1675-02N-15
East Wall of Trench
STA North 70
60
50
40
30
20
10
STA North 00
Soil A Horizon Silty Clay CL with some fine to coarse sand, dark brown, moist, medium stiff, major woody roots
Soil B Horizon Silty Clay CL with fine sand, brown, slightly moist, medium stiff to stiff, vertical cracks (Vertisol)
Tread Level
Silty Clay CL with trace of fine to coarse sand, slightly moist, very stiff, reddish brown, massive matrix with rounded coarse gravel and cobble clasts (Colluvium)
< Line –
< Line –
Tw
Gradational Weathering Boundary
Weathered Tuff TU-CL Sandy Clay with zones of coarse sand and fine gravel, silt, slightly moist, very stiff to dense, yellowish to olive to reddish brown, massive matrix with mostly angular gravel and cobble clasts (Norwood Formation)
5
0
5
Scale In Feet
Sample Locations
(see geotechnical report for sample data)
Tw Thin Wall Sample
B Bulk Sample
ANALYSIS BY: GCS | CHECKED BY AH | DATE 4/4/16
FIGURE 9
LOG OF TRENCH 2
STA 00 TO 70 WEST
GSH

KEO Homestead Subdivision
Job No. 1675-02N-15

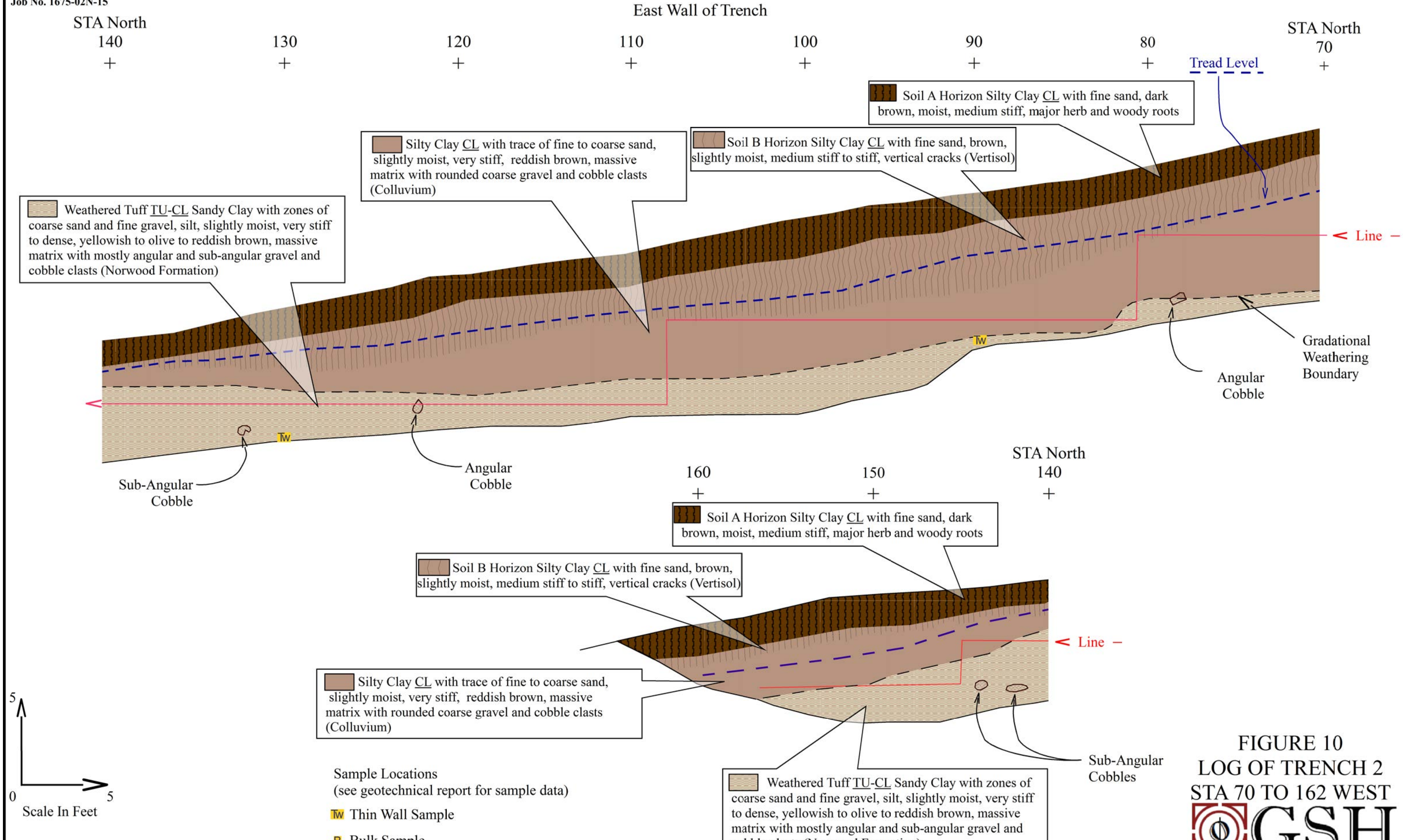


FIGURE 10
LOG OF TRENCH 2
STA 70 TO 162 WEST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 4/4/16

BORING LOG

BORING: B-1

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

LOCATION: Approximately 5600 East Highway 39, Weber County, Utah | GSH FIELD REP.: RG

DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger | HAMMER: Automatic | WEIGHT: 140 lbs | DROP: 30"

GROUNDWATER DEPTH: Not Encountered (2/26/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL	SILTY CLAY with some fine sand; some fine and coarse gravel; brown									moist loose
					X						very stiff
			5	81	X						hard
				103	X	18			40	22	
			10	97	X						
		grades fine to coarse sandy clay with occasional to some fine and coarse gravel		88	X						
			15	108	X						
	SC	CLAYEY FINE TO COARSE SAND with occasional fine gravel; brown		107	X						moist very dense
			20	90	X						
		occasional layers of fine sandy clay up to 4" thick		55	X	22		37			medium dense
			25								

See Subsurface Conditions section in the report for additional information.

BORING LOG

BORING: B-1

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				58							
				100/4"							very dense
			30								
				100/4"							
				100/2"							
	SC	CLAYEY FINE TO COARSE SAND/CLAYEY FINE GRAVEL with fine to coarse sand; brownish-gray	35	50/3"							moist very dense
		End of Exploration at 37.0' No groundwater encountered at time of excavation Installed 1.25" diameter slotted PVC pipe to 36.5'	40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 11
(continued)

BORING LOG

BORING: B-2

CLIENT: David Orchard	PROJECT NUMBER: 1675-02N-15
PROJECT: KEO Homestead Subdivision	DATE STARTED: 2/26/16 DATE FINISHED: 2/26/16
LOCATION: Approximately 5600 East Highway 39, Weber County, Utah	GSH FIELD REP.: RG
DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger	HAMMER: Automatic WEIGHT: 140 lbs DROP: 30"
GROUNDWATER DEPTH: Not Encountered (2/26/16)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	GC FILL	CLAYEY FINE AND COARSE GRAVEL, FILL with some fine to coarse sand; brown									moist loose medium dense
	CL	SILTY CLAY with some fine sand; occasional fine and coarse gravel; dark brown		23							moist stiff
		grades fine to coarse sandy clay; brownish-gray with mottling	5	21		16			31	15	
	GC	CLAYEY FINE AND COARSE GRAVEL with fine to coarse sand; gray		58							moist medium dense
	CL	FINE TO COARSE SANDY CLAY with some silt; occasional fine and coarse gravel; brown	10	63							moist hard
		occasional layers of clayey fine to medium sand up to 4" thick		51							
	SP	FINE TO MEDIUM SAND with occasional fine and coarse gravel; brown	15	27		3		5			moist medium dense
				42							
	CL	SILTY CLAY with some fine sand; occasional to some fine and coarse gravel; brown with oxidation	20	63		13			28	15	moist hard
	SC	CLAYEY FINE TO COARSE SAND with occasional fine and coarse gravel; brown		72							moist dense
			25								

See Subsurface Conditions section in the report for additional information.

FIGURE 12

BORING LOG

BORING: B-2

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				100/5"							very dense
				100/4"		6		7			
			30								
				100/5"							
				100/3"							
		End of Exploration at 34.0' No groundwater encountered at time of drilling Installed 1.25" diameter slotted PVC pipe to 32.5'	35								
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 12
(continued)

BORING: B-3

CLIENT: David Orchard — PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision — DATE STARTED: 2/26/16 — DATE FINISHED: 2/26/16

LOCATION: Approximately 5600 East Highway 39, Weber County, Utah — GSH FIELD REP.: RG

DRILLING METHOD/EQUIPMENT: 3-3/4" ID Hollow-Stem Auger — HAMMER: Automatic — WEIGHT: 140 lbs — DROP: 30"

GROUNDWATER DEPTH: Not Encountered (2/26/16) — ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface	0								
	CL	SILTY CLAY with some fine sand; dark brown									moist loose stiff
				23	X						
	CL	FINE TO COARSE SANDY CLAY occasional fine gravel; brown	5								moist hard
				67	X	17	126				
	CL/GC	CLAYEY FINE TO COARSE SAND with some fine and coarse gravel; brown									moist dense
				78	X	7		11			
	CL/GC	FINE SANDY CLAY with occasional to some fine and coarse gravel; brown	10								moist hard
				105+	X						
		occasional layers of clayey fine to coarse sand up to 4" thick		110+	X						
	SC	CLAYEY FINE TO COARSE SAND with some fine and coarse gravel; brown	15								moist very dense
				100/3"	X						
				100/5"	X	10		35			
			20								
				100/5"	X						
				100/2"	X						
			25								

See Subsurface Conditions section in the report for additional information.

BORING LOG

BORING: B-3

CLIENT: David Orchard | PROJECT NUMBER: 1675-02N-15

PROJECT: KEO Homestead Subdivision | DATE STARTED: 2/26/16 | DATE FINISHED: 2/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25								
				99		11		17			
				128+							
			30								
				100/5"							
				100/5"							
	GC	CLAYEY FINE AND COARSE GRAVEL with fine to coarse sand; brown	35								moist very dense
				100/5"							
				100/5.5"							
			40								
				100/5.5"							
	GM	SILTY FINE AND COARSE GRAVEL with fine to coarse sand; light brown		100/5"							moist very dense
			45								
				100/6"		13		14			
				100/2"							
		End of Exploration at 49.0' due to auger refusal No groundwater encountered at time of drilling Installed 1.25" diameter slotted PVC pipe to 48.0'	50								

See Subsurface Conditions section in the report for additional information.

FIGURE 13
(continued)

KEO Homestead Subdivision
Job No. 1675-02N-15

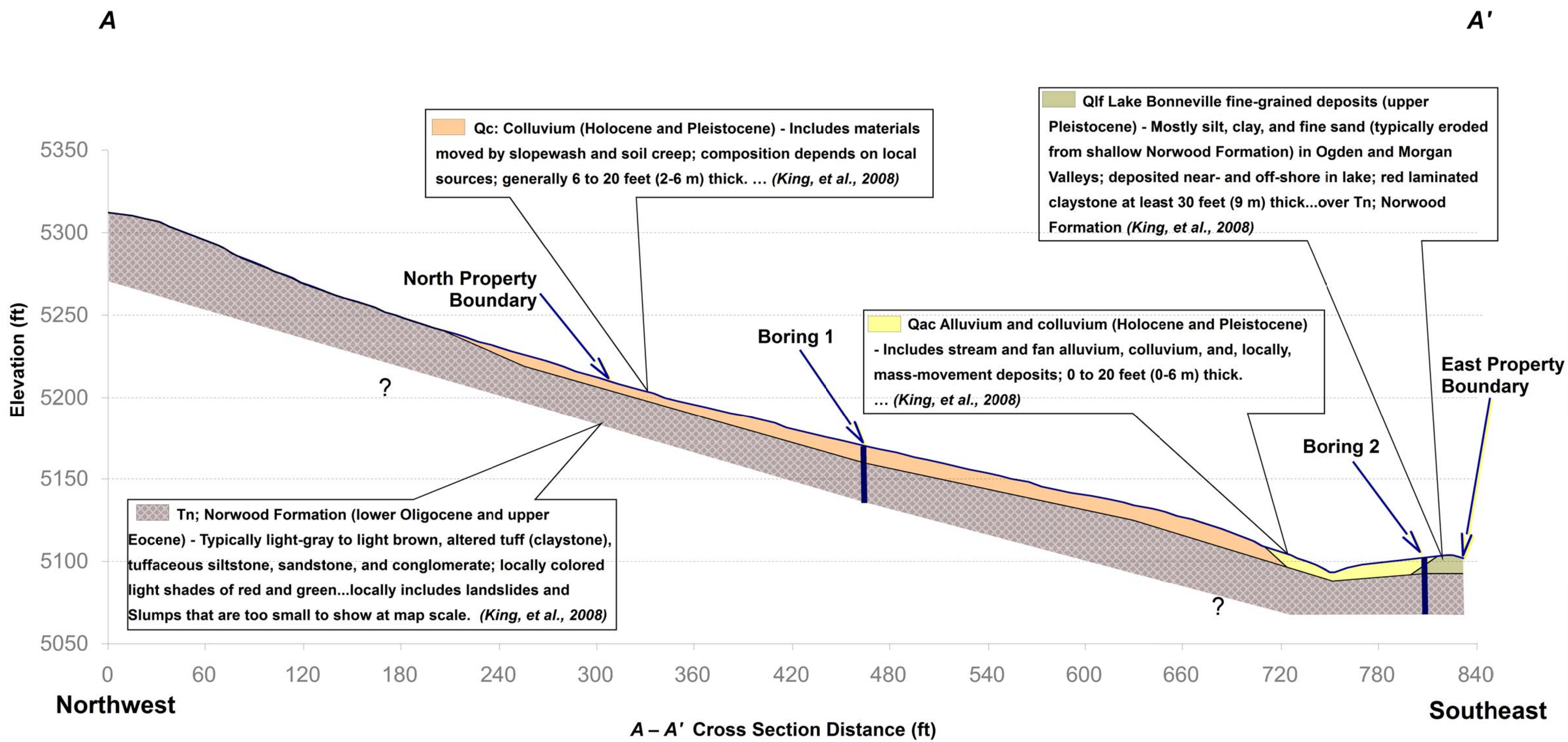


FIGURE 14
GEOLOGIC SLOPE
CROSS SECTION A-A'

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 03/21/16

* From Section Shown On Figure 6

KEO Homestead Subdivision
Job No. 1675-02N-15

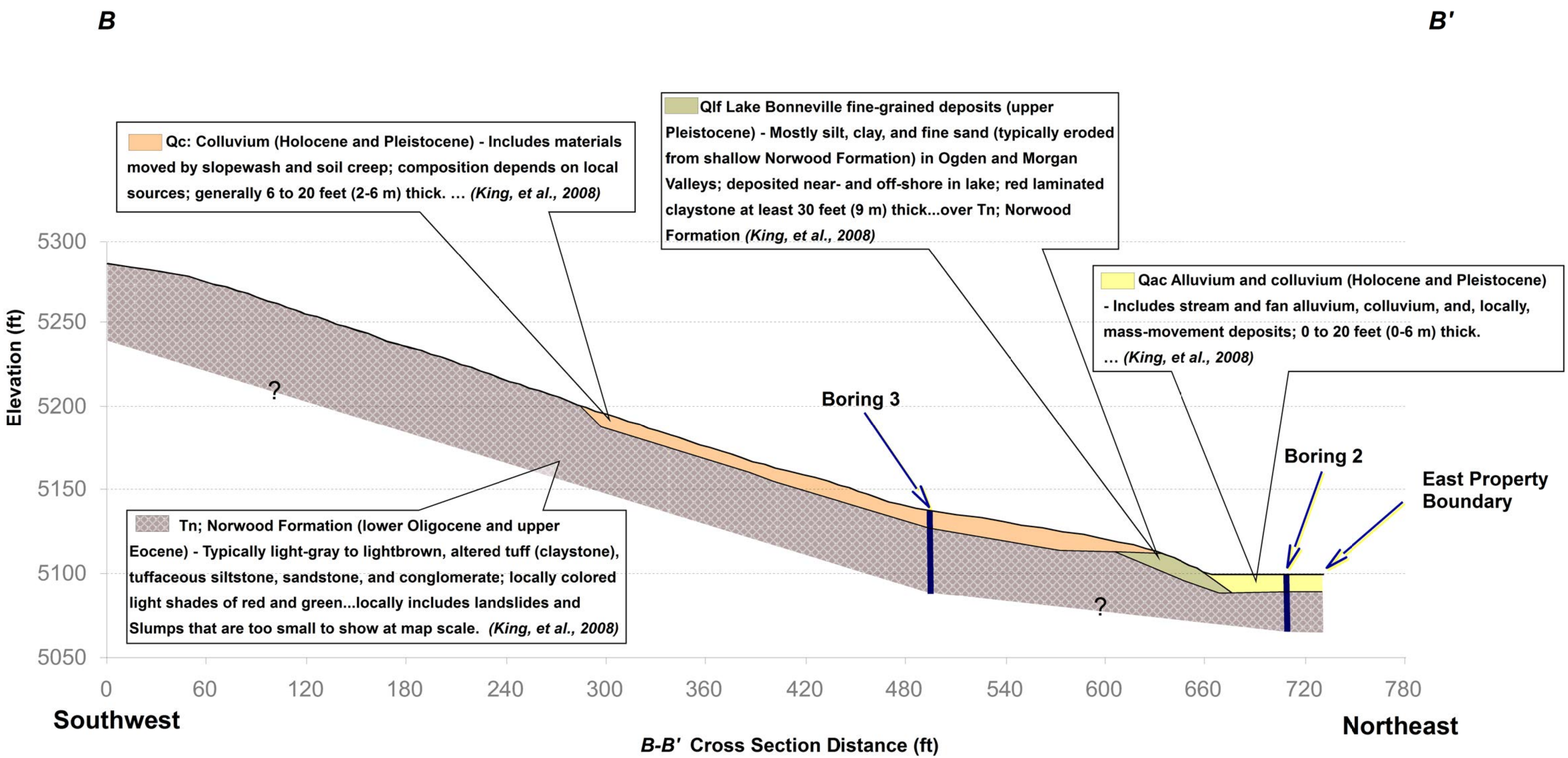


FIGURE 15
GEOLOGIC SLOPE
CROSS SECTION B-B'

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 03/21/16

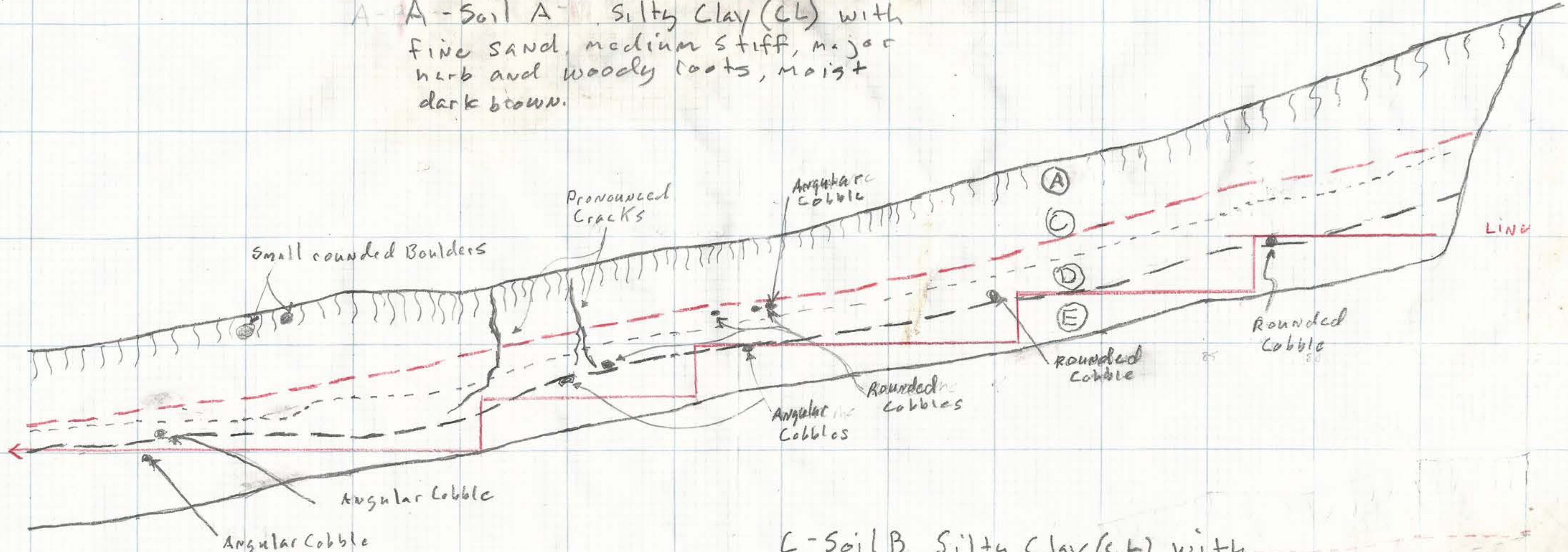
* From Section Shown On Figure 6

APPENDIX

Trench 1
[illegible]
GCS BAG 2/1/16

South Wall of Trench

A - Soil A, Silty Clay (CL) with fine sand, medium stiff, major herb and woody roots, moist dark brown.



C - Soil B, Silty Clay (CL) with fine sand, medium stiff to stiff vertical cracks (vertisol) slightly moist, brown

D - Silty Clay (CL) with trace of fine to to coarse sand, v-stiff, sl-moist, reddish brown, massive matrix with angular and rounded coarse gravel & cobble clast (Colluvium)

E - Silty Sandy Clay (CL) with zones SL-moist coarse sand and fine gravel, yellowish to olive to reddish brown, v-stiff to dense, massive matrix with mostly angular gravel and cobbles clast (Residual - Weathered Tuff)

Trench 1
0' - 70' W
2/01/16

GCS Geoscience

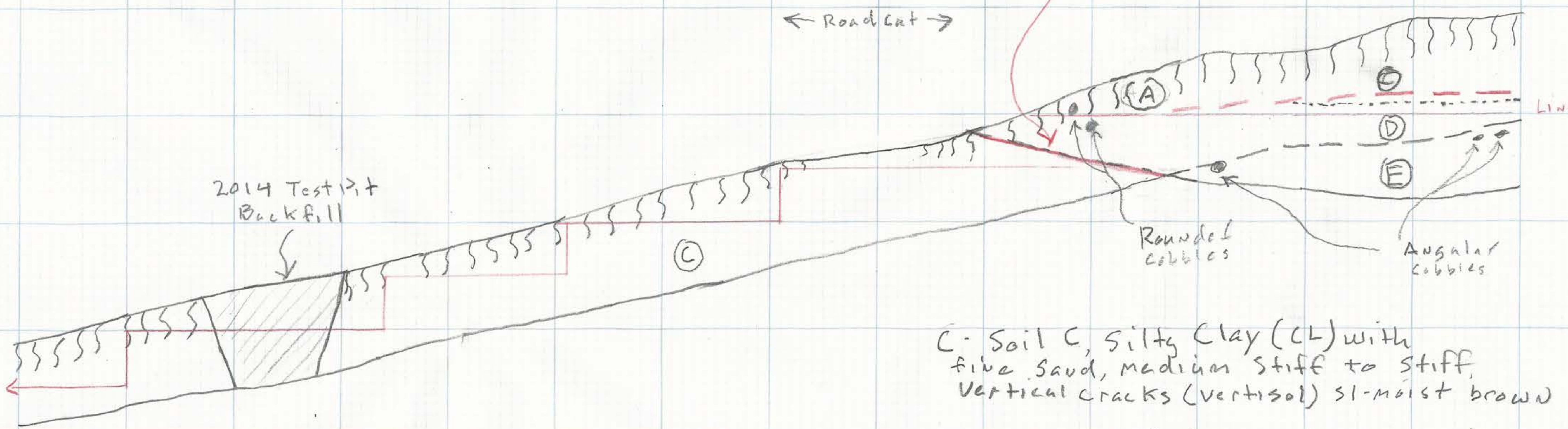
Project
By
Date

South Wall of Trench

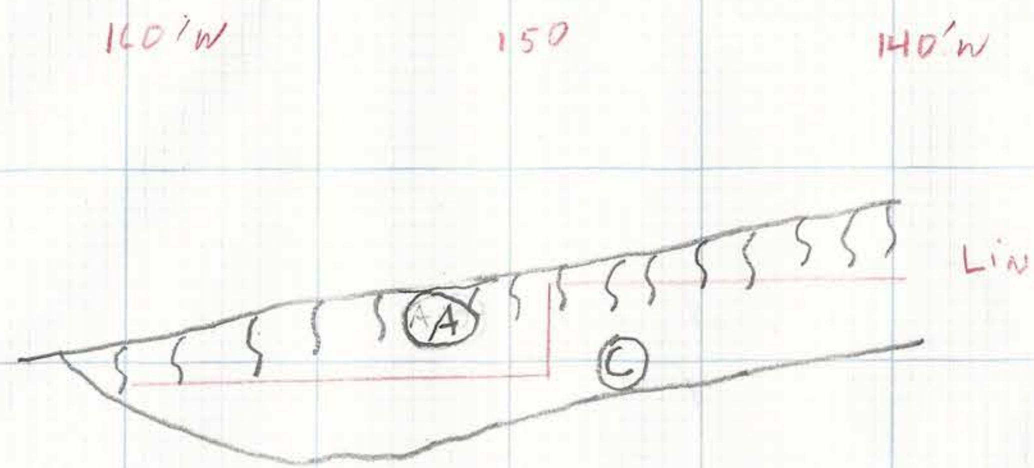
140'W 130 120 110 100 90 80 70'W

96'-162' Logged 1/25/16 | 0-96' Logged 2/01/16

A - Soil A, Silty Clay (CL) with fine sand, medium stiff, major herb and woody roots, moist, dark brown



C - Soil C, Silty Clay (CL) with fine sand, medium stiff to stiff, vertical cracks (vertisol) sl-moist brown



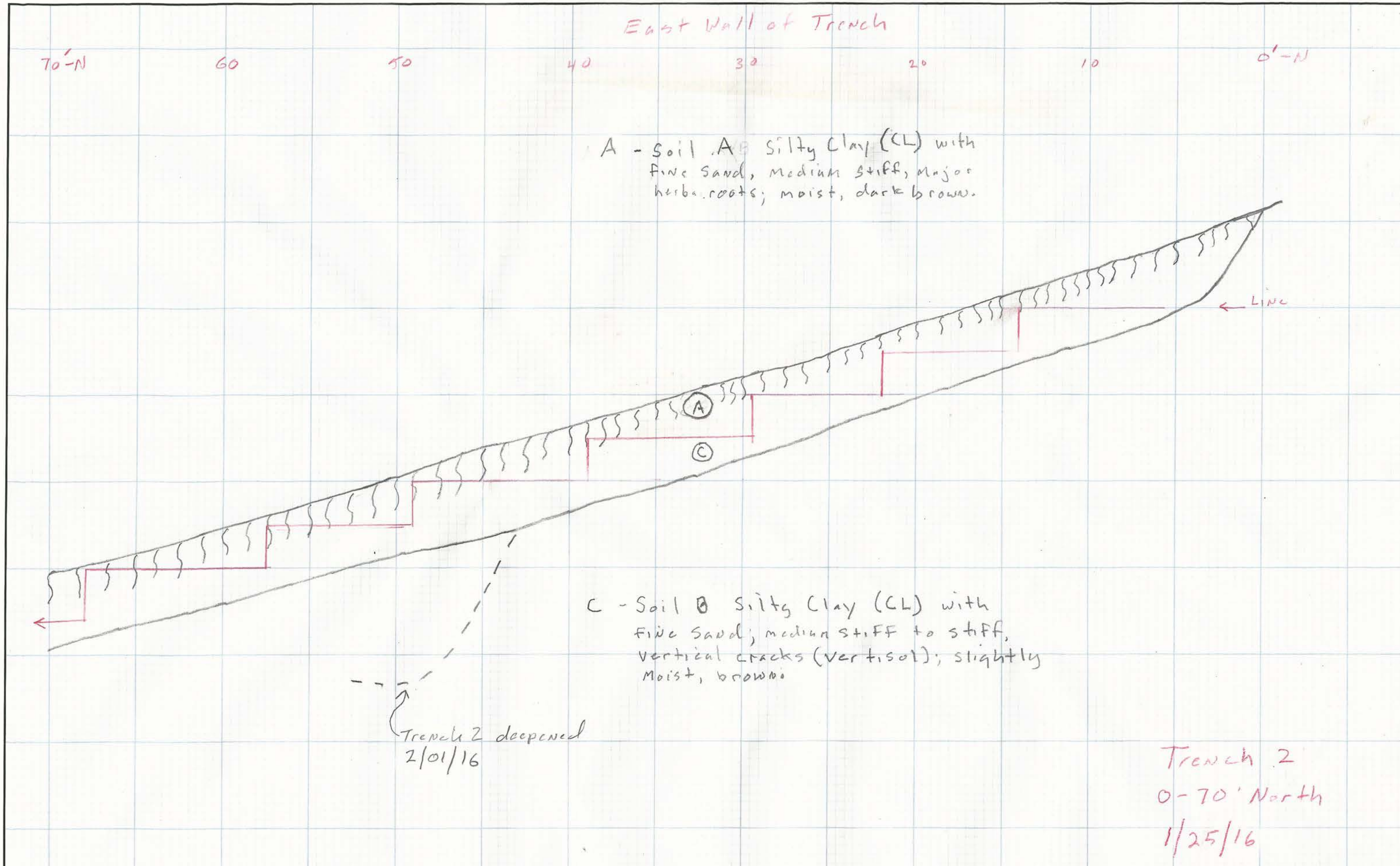
D - Silty Clay (CL) with trace of fine to coarse sand, v-stiff, sl-moist, reddish brown, massive matrix with angular and rounded coarse gravel & cobble clast (colluvium)

E - Silty Sandy Clay (CL) with zones of coarse sand & fine gravel, yellowish to olive to reddish brown, v-stiff to dense, massive with mostly angular gravel and cobble clast. (Residual - Weathered Tuff)

Trench 1
70-162' W
1/25/16 &
2/01/16

GCS Geoscience

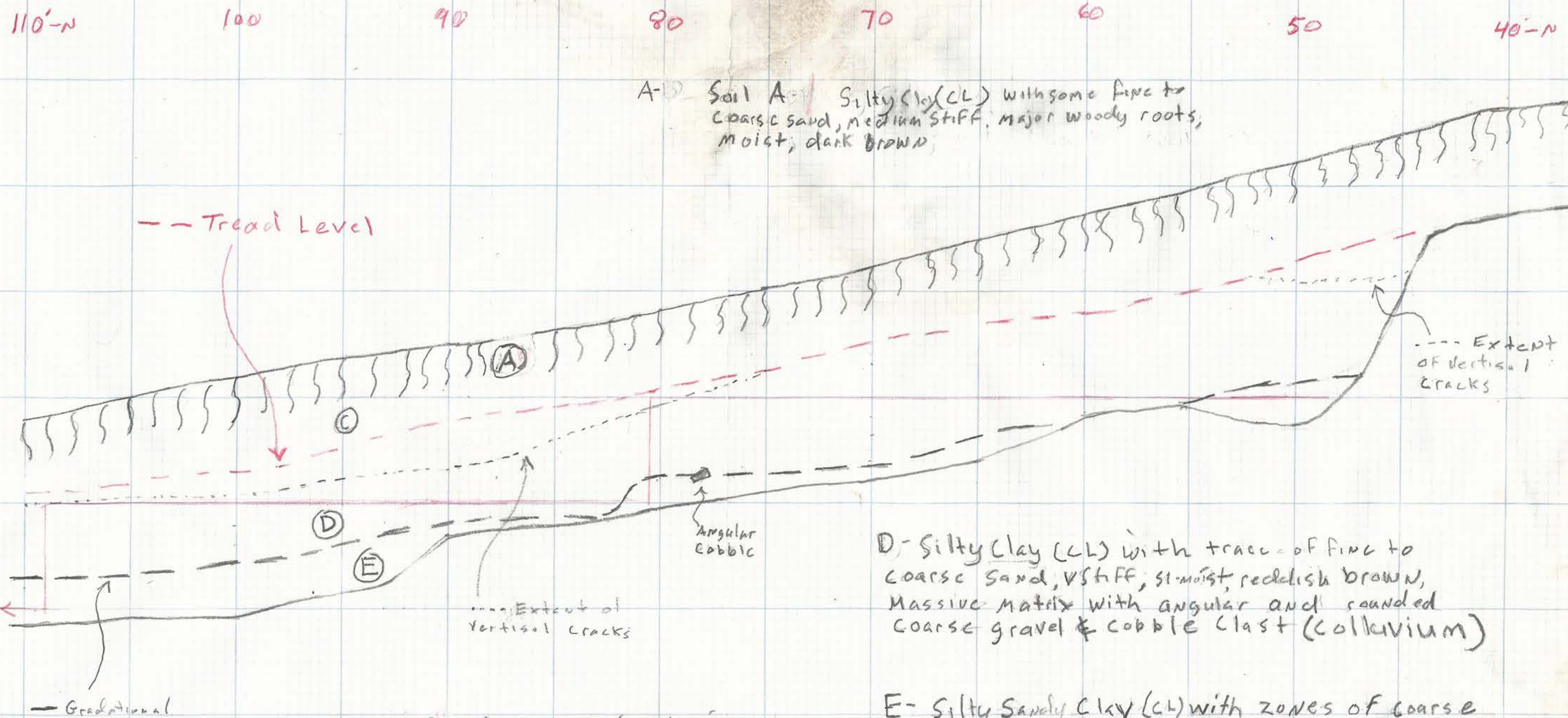
Project Kep HomeStead
By GCS & BAG
Date 2/01/16 - 1/25/16



GCS Geoscience

Project Keo Homestead
By GCS & BAG
Date 1/25/16

East Wall of Trench



A- Soil A- Silty Clay (CL) with some fine to coarse sand, medium stiff, major woody roots, moist, dark brown

C - Soil B Silty Clay (CL) with fine sand, medium stiff to stiff vertical cracks (vertisol), slightly moist, brown

D - Silty Clay (CL) with trace of fine to coarse sand, V stiff, sl-moist, reddish brown, Massive matrix with angular and rounded coarse gravel & cobble clast (colluvium)

E - Silty Sandy Clay (CL) with zones of coarse sand and fine gravel, yellowish to olive to reddish brown v-stiff to dense, Massive Matrix with mostly angular gravel and cobble clast (Residual - Weathered Tuff)

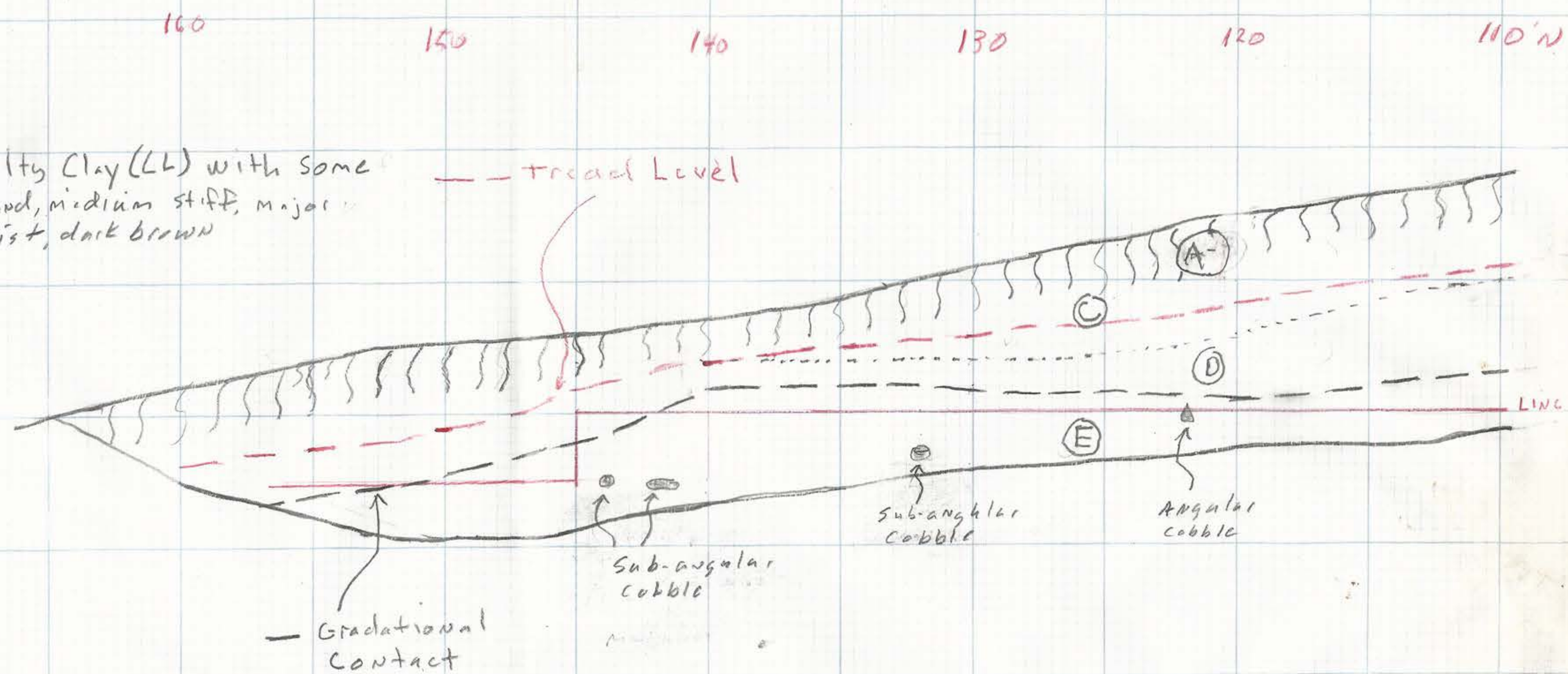
Trench 2
40-110' North
2/01/16

GCS Geoscience

Project Keo Homestead
By GCS & BAG
Date 2/01/16

East Wall of Trench

A A Soil A-, Silty Clay (CL) with some fine to coarse sand, medium stiff, major woody roots, moist, dark brown



C- Soil B, Silty Clay (CL) with fine sand, medium stiff to stiff, vertical cracks (vertisol) slightly moist, brown

D- Silty Clay, (CL) with trace of fine to coarse sand, v-stiff, sl-moist, reddish-brown massive matrix with angular and rounded coarse gravel & cobble clast (colluvium)

E- Silty Sandy Clay (CL) with zones of coarse sand and fine gravel, yellowish to olive to reddish brown; v-stiff to dense, massive matrix with mostly angular gravel & cobble clast. weathered Tuff)

Trench 2
110-170'N
2/01/16

GCS Geoscience

Project Keo Homestead
By GCS & BAG
Date 2/01/16