REPORT
GEOLOGICAL HAZARDS STUDY
LOTS 22 AND 23
THE LEGENDS AT HAWKINS CREEK
6564 AND 6585 EAST CHAPARRAL ROAD
NEAR EDEN, WEBER COUNTY, UTAH

Submitted To:

Mr. Victor Holtreman
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Submitted By:

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Job No. 2129-01N-16

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Mr. Victor Holtreman
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Attn: Mr. Holtreman

RE: Geological Study
Lots 22 and 23 The Legends at Hawkins Creek
Huntsville Area, Weber County, Utah
(Parts of the SW 1/4 Section 24, Township 6 North, Range 1 East, Salt Lake base and meridian)

1. INTODUCTION

The Legends at Hawkins Creek Subdivision is located in the vicinity of Huntsville Town, Weber County, Utah (41.22369, -111.7929). The subdivision is a gated cluster community located on the east side of Old Snowbasin Road approximately 0.6 miles south from Utah SR-39 intersection as shown on Figure 1, Vicinity Map. The subdivision consists of forty-one residential development lots roughly one to two acres in area, and covers a total area of approximately 165 acres. Approximately 40-percent of the subdivision area is dedicated to common area. The two lots to be investigated as part of this study include Lot 22 and Lot 23. The two property parcels are adjacent and are located on the east side of Chaparral Road, which is a primary access road that loops through the subdivision as shown on Figure 2, Aerial Coverage. Lot 22 is recorded at 6585 East Chaparral Road, and Lot 23 is recorded at 6564 East Chaparral Road.

The present plans for the development of the two lots calls for the construction of a single residential structure to be located on parts of both lots or alternatively on one of the two lots. The proposed location (footprint) for the structure at the time of this reporting is shown on Figure 2. The footprint for the proposed structure is approximately 5,000 square feet. Although design has not been finalized for this project we expect the proposed structure to 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, with maximum column and wall loads projected to be on the order of 10 to 25 kips and 1 to 3 kips per lineal foot, respectively.

1.1 Weber County Natural Hazards Overlay Districts

Because are the lots are located on a sloping hill side area with susceptible expansive soil and rock conditions (Mulvey, 1992), and partially occupy slopes identified as having "Landslide Potential" (Elliott and Harty, 2010), Weber County (Planning Commission) is requesting that geotechnical and geological studies be conducted to evaluate conformance of the proposed development with *Sensitive Lands Overlay District* requirement provisions.

At this time specific guidelines for these studies have not been specified by the County, however Weber County Code Section 104-27-2. - Potential hazards (Weber County Code, 2016), 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 groundwater conditions.*

Referenced Sensitive Lands Overlay District maps addressing Landslide/Tectonic Subsidence zones for Weber County are presently not available for the site, and the present determination by County officials as to potential site geological hazard exposure is bassed upon regional hazrad mapping prepared by the Utah Geological Survey (UGS) and U.S Geological Survey (USGS) agencies (Mulvey, 1992; USGS 2006; Elliott and Harty, 2010),

A preliminary review of site geological mapping prepared by Utah Geological Survey (UGS) geologists (King, et al, 2008), show on Figure 3, Geologic Map has indicated that parts of the Lot 22 and 23 parcels (the Site) is within mapped Quaternary landslide and colluvial deposits (Qms and Qmc), that are within an area largely underlain by Tertiary age Norwood Formation (Tn) rocks (King, et al., 2008).

1.2 Scope of Work and Work Plan

On the basis of the Weber County Sensitive Lands Overlay District requrements and our preliminary review of geological conditions of the site, we (GSH consultants) prepared the following scope of work (work plan) for the evaluation of the Site as applicable to the Weber County Natural Hazards Overlay District Code. In our May 2, 2016 Work Plan we (GHS consultants) provided the following scope of work:

> *1) Work Plan and scope of work development and plan implementation and meetings with Weber County Staff*;*
>
> *2) A search and review of previous relevant documentation of site engineering and geologic studies and including UGS mapping (King, et al, 2008); and reports and studies prepared by others (Earthtec Testing & Engineering, 1999);*
>
> *3) A field reconnaissance study including the geologic logging of a single walk-in trench approximately 250 feet in length and as much as 14 feet in depth, three walk-in test pits to as much as 19 feet in depth, and two geotechnical borings to penetrate as deep as 50 feet...*

4) Development of a geological cross section along slope section line A-A' shown on Figure 4 to be used for geotechnical engineering slope stability analysis;

5) Site specific geological mapping and classification to identify critical geological units and exposure to proposed site improvements;
6) Slope analysis from LiDAR DEM geoprocessing identifying critical areas 25-percent or greater across the site and/or surficial features potentially affecting the proposed site improvements;

7) A laboratory geotechnical soils testing program of samples recovered from the test pits, trenches and borings for typical and critical geological units explored and identified in our subsurface evaluation. Laboratory testing program to include but not be limited to the moisture, density, gradation, Atterberg limits, consolidation, vane shear, and direct shear tests of representative soil samples; And

8) Preparation of summary report presenting results of our analysis and findings 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 property and surrounding area.*
- *Aerial photography showing the site and nearby surficial geologic features.*
- *Logs of trenches, test pits and borings.*
- *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 recommendations for site specific slope stability analysis; alluvial fan processes including debris-flow; surface fault rupture hazards, strong earthquake ground motion, and liquefaction hazards; rockfall and avalanche hazards, flood hazards, and radon*
- *Cross-sections of slopes depicting encountered geological conditions.*
- *Site development recommendations based upon our findings and professional experience.*
- *Following completion of the geologic study, a geotechnical study will be prepared for the subject property based on the findings of the geologic study and concurrent/subsequent geotechnical evaluations.*

*Planning meetings with Weber County Staff were not held for this project.

2. INVESTIGATIONS

2.1 Literature Review

During the Work Plan development, existing previous reports and geological literature sources were reviewed. Specific to the site and immediate surrounding area, reports and mapping by; Earthtec Testing & Engineering, 1999; King, et al., 2008; and Coogan and King, 2016 were reviewed. The Earthtec Testing & Engineering study involved a general geotechnical assessment with no subsurface observations. Summary geological discussions regarding the 160 acre were provided in the Earthtec report; however no geological hazards were delineated or mapped. The King, et al., 2008 document is an Open-file UGS 1:24,000 scale geological mapping project of the Snow Basin and Huntsville, Utah quadrangles, which includes the location of the Lot 22 and 23 site, and the Coogan & King, 2016 mapping is a 1:100,000 scale regional compilation mapping that that includes the Snow Basin and Huntsville quadrangles.

2.2 Field Program

GSH conducted field operations at the site on the dates May 13, 16, and 17, 2016. The field program involved the excavation and geological logging of two exploration trenches and one test pit, and two borings. The excavations and borings were logged to observe and characterize site subsurface/geologic and groundwater conditions for the site and the proposed residence construction location.

The trenches and test pits were excavated using a 20-ton class excavator with a 36-inch bucket. Trench 1 was located to evaluate the conditions beneath the initial proposed residence structure location, and Trench 2 was located to evaluate an alternative locations on the site, and the Test Pit 1 was located to observe conditions within the building lots, but away from the structure locations. The locations of our trenches and test pits are included on Figure 4, Site Evaluation. Trench 1 was 196.0 feet in length and extended to depths of 8.0 to 10.0 feet for walk-in observations, and deepened to 22.0 feet at Station 160 East for deep sampling and observation. Trench 2 was 125.0 feet in length and extended to depths of 10.0 to 12.0 feet for walk-in observations, and deepened to 20.0 feet at Station 110 East for deep sampling and observation. Test Pit 1 was excavated to a depth of 20 feet. The trenches and test pits were logged so as to illustrate the vertical and lateral characteristics and variations of soil and rock conditions underlying the Site.

The borings were completed using a CME 55 truck-mounted drill rig using hollow-stem auger/rotary wash equipment and methods. Soil and rock samples were recovered at 2.5-foot intervals using driven 2.42-inch inside diameter drive Dames & Moore sampler. Boring 1 was advanced to a depth of 31.5 feet and Boring 2 was advanced to a depth of 39.0 feet.

Our field program was conducted under the supervision of Dr. Greg Schlenker, PG of our geotechnical staff. Mr. Amos Allard, Staff Geologist also of our geotechnical staff assisted Dr. Schlenker and supervised drilling operations. In conjunction with field operations, the general surface of the site and surrounding area was reconnoitered to assess geological and slope conditions, and feature location and elevation data were recorded using a hand-held GPS receiver device.

Detailed graphical representations of the subsurface conditions encountered are presented on Figures 5 through 7, Log of Trench 1, Figures 8 and 9, Log of Trench 2, and Figure 10, Log of Test Pit 1. The boring Logs are included on Figures 11 and 12 Boring Log B-1, and Figures 13 and 14 Boring Log B-2.

Bulk and thin wall samples of representative soil layers encountered in the trenches and test pit were obtained and placed in sealable bags and/or were recovered undisturbed using driven sample tubes, and undisturbed ring samples. In the borings soil and rock samples were recovered at 2.5-foot intervals using driven 2.42-inch inside diameter drive Dames & Moore sampler. The borings were also logged in accordance with the Unified Soil Classification System (USCS). The locations of the sample recovery locations are included on our trench, test pit and boring logs. These classifications were supplemented by subsequent inspection and testing in our laboratory. The results of our laboratory analysis and testing of the soils recovered from the trenches, test pit and borings will be included in forthcoming geotechnical reports. Static groundwater was not observed in any of the excavations or borings during the dates of our field program, however vadose water was observed entering the deep section of Trench 1 at Station 160 East at a depth of about 15 feet.

2.3 LiDAR - Slope Analysis

To asses slope conditions, interpret terrain, and develop site specific geologic cross section for the site, a LiDAR - Slope Analysis was performed for the site. Elevation data consisting of 2.0 meter LiDAR digital elevation data (DEM), for the site was obtained from Utah Automated Geographic Reference Center (AGRC). These data were geo-processed using the QGIS® GIS platform, and using the r.slope, r.shaded.relief and r.contour.level GRASS® (Geographic Resources Analysis Support System) modules, slope percentages, relief renderings and elevation contours for the site area were processed.

Figure 15, LiDAR-Slope Analysis, presents the results of our slope analysis efforts. Shown on Figure 15 is the 25-percent and greater slope gradients across the site. The critical limiting gradient for slope development considerations according to the Weber County Section 108-14-3. (Weber County Code, 2016), includes slopes greater that 25-percent. The shaded relief rendering on Figure 15 also provides a visual basis for landform interpretation mapping, and the contour elevation data shown on Figure 15 was used to develop the Geologic Slope Cross Sections shown on Figure 16 and Figure 17 that will be used for slope stability analysis to be included our geotechnical reporting.

3. SITE CONDITIONS

The site conditions and site geology were interpreted through an integrated compilation of data including a review of literature and mapping from previous studies conducted in the area (Sorensen and Crittenden, 1979; Bryant, 1988; Coogan and King, 2001; and King et al., 2008) including a review previous evaluations discussed previously in the Literature Review Section of this report, photogeologic analyses of 2014 and 2012 imagery shown on Figure 2 and Figure 4, and historical stereoscopic imagery flown in 1946. GIS analyses of elevation and geoprocessed DEM terrain data as discussed in the previous section (LiDAR-Slope Analysis) and shown on Figure 15, field reconnaissance of the general site area, and the interpretation of the trenches, test pit and borings made on the site as part of our field program. Seismic hazards information was developed from United States Geologic Survey (USGS) databases (Peterson, et al., 2008).

3.1 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 7.0 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 claystone, siltstone and sandstone occurrences of the formation are primarily a result of lacustrine (lake processes) redeposition of the volcanic ash. The site location is largely underlain by Norwood Formation lacustrine rock units which beds appear to slope gently down to the northeast across the site (King et. al, 2008). A previous investigation for the Via Cortina roadway extension approximately 2,000 feet to the north of the site, revealed bedded exposures of lucustrine rock sequences generally consisting of moderate to thick bed units, (one to two feet in thickness) typically fining upward (sandstone-siltstone-claystone), colored light shades of buff, tan red and green and gray, and ranged from *weak* to *strong* in field test competency (GSH Geotechnical Inc., 2015). The existing surface of the site and vicinity 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).

3.2 Surface Conditions

As shown on Figure 2 and Figure 4, the site consists of an area of approximately 3.9 acres in size that is currently vacant and undeveloped. Surface vegetation consists of open areas of grasses, weeds and sage brush with clustered wooded areas of scrub oak, alder and maple trees. The topography of the site consist of a primarily north facing swale with slopes on the property generally facing downward toward the northeast, north and northwest toward Ogden Valley.

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 and Figure 4 is bordered on the south, west and north by vacant undeveloped residential lots, and on the east and by open-space land uses.

3.3 Subsurface Conditions

The natural rock and soils sequence observed in the trenches, test pits and borings, and illustrated on Figures 5 through 14, generally consisted, from bottom to top of:

1. **Residual Weathered Norwood Formation** consisting of reddish brown claystone (CS); very stiff to hard slightly moist to moist, gray, gray-brown to reddish-brown silty clays (CL), and stiff, slightly moist, dark olive gravelly clays (CL), with beds of dense, slighlty moist, gray, brown and reddish-gray fine to coarse sand (SP). The observed thickness of the residual weathered Norwood Formation deposits extended from the top of the gravelly clay deposits observed from 14.0 feet below the surface at Station 165 East in Trench 1 to the 39.0 foot depth penetrated by Boring 2.

2. **Alluvial Deposits** consisting of slightly moist to moist, reddish brown, clayey silt (ML), and reddish brown and light-olive silty clays (CL). These deposits are believed to have accumulated on the site by means of local sheet flow and colluvial slope wash processes. The observed thickness of the Alluvial Deposits extended from clay deposits observed from a foot or two from the site surface to 14.0 feet below the surface at Station 165 East in Trench 1. Based upon observed stratigraphic relations the deposition of Alluvial deposits appear to both precede and proceed the movement of the Slide Mass deposits.

3. **Slide Mass** landslide deposits. The Slide Mass deposits was observed in Trench 1 (Station 00 to 172 East) and Trench 2 (Station 00 to 45 East), and was likely present in Test Pit 1. These deposits displayed tilted, rotated and disturbed bedding, and a variety of textural classifications including stiff, slightly moist, reddish-brown silty clays (CL), and stiff, slightly moist, dark olive gravelly clays (CL) containing angular fine and coarse gravel and tabular siltstone cobbles and boulders (ST). Beds of slightly moist, dense, light olive fine silty sand (SM) were interbedded with the Slide Mass clay deposits. The Slide Mass deposits also displayed zones of Fe-oxide accumulation and thin wavy beds of clay. The observed thickness of the Slide Mass deposits extended from the uppermost gravelly clay deposits observed from a foot or two from the site surface to 14.0 feet below the surface at Station 160 in Trench. We believe the Slide Mass deposits extend deeper than the 14.0 feet depth observed in Trench 1.

4. **Surficial Pedogenic Soils** including A-B soil vertisol sequences that extended in depth as much as 1.5 to 11 feet in the trenches. These consisted of surficial clayey silt (ML), moist, medium stiff, dark brown, major herb roots to 6' inches, and becoming with depth stiff, brown silty clay (CL), slightly moist, with deep vertical (vertisol) cracking in the two trenches. These soils are believed to be locally derived from weathered rock, slide mass and colluvial sources.

   Deep cumlic clayey silt (ML) soil sequences characterized by abundant organic eluviates 5.0 feet in thickness were observed on the east side of Trench 2, and thick clayey silt (ML) top soil fills 6.5 feet in thickness were observed on the surface of Test Pit 1.

Landslide movement was observed in Trench 1, Trench 2, and possibly in Test Pit 1. The landslide movement observed in the two trenches appears to be downslope in a northward direction, with the lateral right flank boundary observed at Station 170 East in Trench 1, and Station 45 East in Trench 2 believed to be the lateral flanks of a larger landslide feature mapped as **Qms** on Figure 3 that extends both upslope and downslope of the Lot 22 and 23 location.

Static groundwater was not observed in any of the trenches, test pit or borings during our field program, however a vadose zone of water was encountered at a depth of 15 feet in Trench 1.

3.4 Site Engineering Geology

Our interpretation of the site engineering geology is presented on Figure 4 and Figure 15 of this report. The engineering geology shown on the two figures is largely based on previous mapping prepared by King, et al. (2008) which is presented on Figure 3, with amendments to the mapping drawn on the basis of the findings of this and previous studies. A summary of the mapping units identified on the site vicinity are listed below in relative age sequence (youngest-top to oldest bottom):

Qh - Human deposits, deposits and exposures resulting primarily from previous site grading activities.

Qac - Alluvium and colluvium, as found by this study, mapped as **Qmc** - landslide and slump, and colluvial deposits by King, et al., 2008.

Qms - Landslide and slump deposits, resulting fro past landslide movement

Tn; Norwood Formation, rock and residual soils.

4. DISCUSSIONS AND RECOMMENDATIONS

4.1 Summary of Findings

4.1.1 Subsurface Observations: The geology exposed by trenches and test pits were generally found to consists of surficial, upper 1.0 to 1.5 feet of pedogenic soil A horizons, B horizon vertisol sequences that extended in depth (thickness) as much as 11.0 feet, and consisting of stiff silty clays derived from weathered rock and colluvial sources. At depth weathered rock and soil sequences consisting of alluvial deposits, landslide slide mass deposits, and weathered Norwood Formation soils and rock were observed.

4.1.2 Expansive soils. Vertical cracking associated with vertisol development was observed to extend from 1.0 to 6.0 feet below the surface in the two 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.

4.1.3 Sloping Surfaces. The surface of site slopes developed from our LiDAR analysis range from level to over 55-percent as shown on Figure 5, LiDAR-Slope Analysis. For the two lot Site the slope gradient averaged 23.0-percent, for the general vicinity of the 165 acre subdivision area the slope gradient averaged 29.4-percent. As previously discussed in the LiDAR-Slope Analysis section of this report, the critical gradient for slope development considerations according to the Weber County Code is 25-percent.

4.1.4 Site Engineering Geology And Mapping. The engineering geology mapping of the site presented on Figure 4 and Figure 15 reveals three issues that pertain to site development planning. These issues include: (1) **Landslide and slump deposits Qms -** the presence of Landslide and slump deposits deposits on the west side of the site; (2) **Norwood Formation (Tn)** - the presence of Norwood Formation **Tn** projected underlie the site; and (3) **Non-Engineered Fills,** mapped as **Qh -** human deposits associated with the placement of thick fill soils on the north side of the site, and observed in Test Pit 1. These issues are addressed in order importance below:

> **1. Landslide and slump deposits:** Presence of mass-movement landslide and slump deposits mapped as **Qms** is based upon developed field observations including; deformation of soils observed in Trench 1 and Trench 2, location of the topographic features evident on the LiDAR imagery on Figure 15 indicating the planform area of movement observed in the trenches and test pits, and the mapping by King et al. (2008).
>
> The area of movement mapped as Qms on Figures 4 and 15 consists of a relatively thick, greater than 14.0-feet in thickness, block of soil and rock that appears to have moved or "creeped" downslope in response to inherent weak and expansive soil characteristics, and the moderately steep slope conditions in this area. Based upon our observations of evident topographic surface expression of this feature, and observed stratigraphic sequences in the trenches, we believe that this movement should be considered active.
>
> **2. Norwood Formation (Tn):** The Norwood Formation has a notoriety of poor stability performance and geotechnically challenging soils throughout Northern Utah (Mulvey, 1992). Furthermore, we have observed an apparent genetic relationship with the occurrence of the Norwood Formation (and Norwood "Tuff") and surficial vertisol soils (discussed previously in section 4.1.2), which are subject seasonal shrink-swell processes (Graham and Southard, 1982). Based upon our past experience with areas underlain by Norwood Formation rock and soil, we believe that appropriate geological/geotechnical studies should be conducted before structural improvements are made in those areas.
>
> **3. Non-Engineered Fills,** mapped as **Qh -** human deposits apparently have been placed on the north boundary of the of as part of subdivision site development and grading. Although the area mapped as **Qh** comprises only a small part of the Lot 22 and 23 property, all the non-engineered fills will need to be removed and suitable subgrade conditions prepared for any structural improvements that occur in the areas mapped as **Qh.**

4.1.5 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.

4.1.6 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 7.0 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).

4.1.7 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 in the vicinity of the site appears to be susceptible to liquefaction processes.

4.1.8 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 Qafy by King, et al. (2008), are located on a small fan surface (<4.0 acres in area) approximately 500 feet north of the site, and do not appear to represent a potential impact the site.

4.1.9 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 for this area at this time (FEMA, 2016). Local sheet flow, slope wash, and seasonally perched soil water typical of sloping areas should be anticipated for the site, and site improvements.

4.1.10 Rockfall and Avalanche Hazards: The site is over two miles from steep slope areas where such hazards may originate.

4.1.10 Radon Exposure: Radon is a naturally occurring radioactive gas that has no smell, taste, or color, 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 mapping has been prepared for most of Ogden Valley by the Utah Geological Survey (Solomon, 1996), however that mapping does not extend far enough to the south to include the Lot 22 and 23 site. The radon-hazard potential is mapped as "Moderate" for the area directly north of the site (250 feet) included in studies by the UGS (Solomon, 1996). For new structures radon-resistant construction techniques as provided by the EPA (EPA 2016) should be considered.

4.2 Conclusions

Based upon our geological studies herein, we believe that the Lot 22/23 Legends at Hawkins Creek is suitable for development, provided that soils identified in our borings, trenches and test pits as subject to past landslide movement (Qms) as discussed in Section 3.3 of this report, are avoided or mitigated. Due to the extensive nature of the past landslide movement soils on the western portion of the site, the proposed structure must be sited within the alluvial/colluvial soils observed over the eastern portion of the site. This will require vacating the existing drainage easement at the site and relocation of the associated drainage channel. Under no circumstance should structures be placed in the landslide deposits or slopes associated with landslide deposits be steepened as part of the development process. <u>We also recommend that structures be setback at least 20 feet from the landslide deposits (Qms) shown on Figure 4 and Figure 15.</u>

The site has been shown to be underlain by Norwood Formation deposits, and expansive vertisol soils were observed in all of the excavations made for this study. Areas where these soils are present or uncovered should be evaluated prior to the placement of structural loads. Additional evaluation of the expansive potential of the soils must be conducted as part of the geotechnical study for the site.

A pinhole texture was observed in the deeper natural soils within Trench 2 excavated at the site. Further evaluation of the collapse potential for the soils containing a pinhole structure must be conducted as part of the site geotechnical study.

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.

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,

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Encl.	Figure	1,	Vicinity Map
	Figure	2,	Aerial Coverage
	Figures	3,	Geologic Map
	Figure	4,	Site Evaluation
	Figure	5,	Log of Trench 1 - Station 00 to 70
	Figure	6,	Log of Trench 1 - Station 70 to 140
	Figure	7,	Log of Trench 1 - Station 140 to 196
	Figure	8,	Log of Trench 2 - Station 00 to 70
	Figure	9,	Log of Trench 2 - Station 70 to 125
	Figure	10,	Log of Test Pit 1
	Figure	11,	Boring Log B-1 - 0 to 25 Feet
	Figure	12	Boring Log B-1. - 25 to 31.5 Feet
	Figure	13,	Boring Log B-2 - 0 to 25 Feet
	Figure	14	Boring Log B-2 - 25 to 39 Feet
	Figure	15,	LiDAR-Slope Analysis
	Figure	16,	Geologic Cross Section *A-A′*
	Figure	17,	Geologic Cross Section *B-B′*

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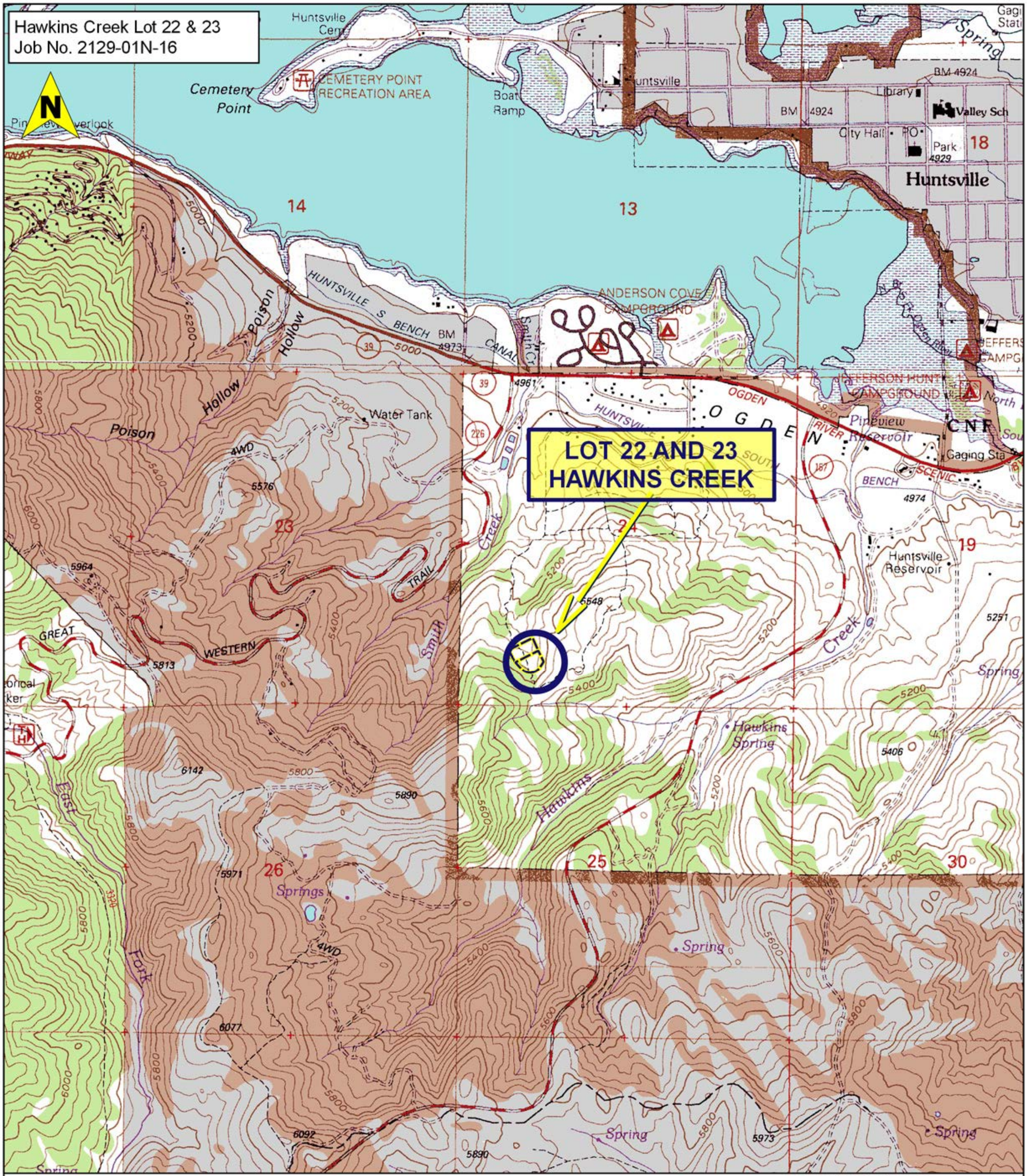
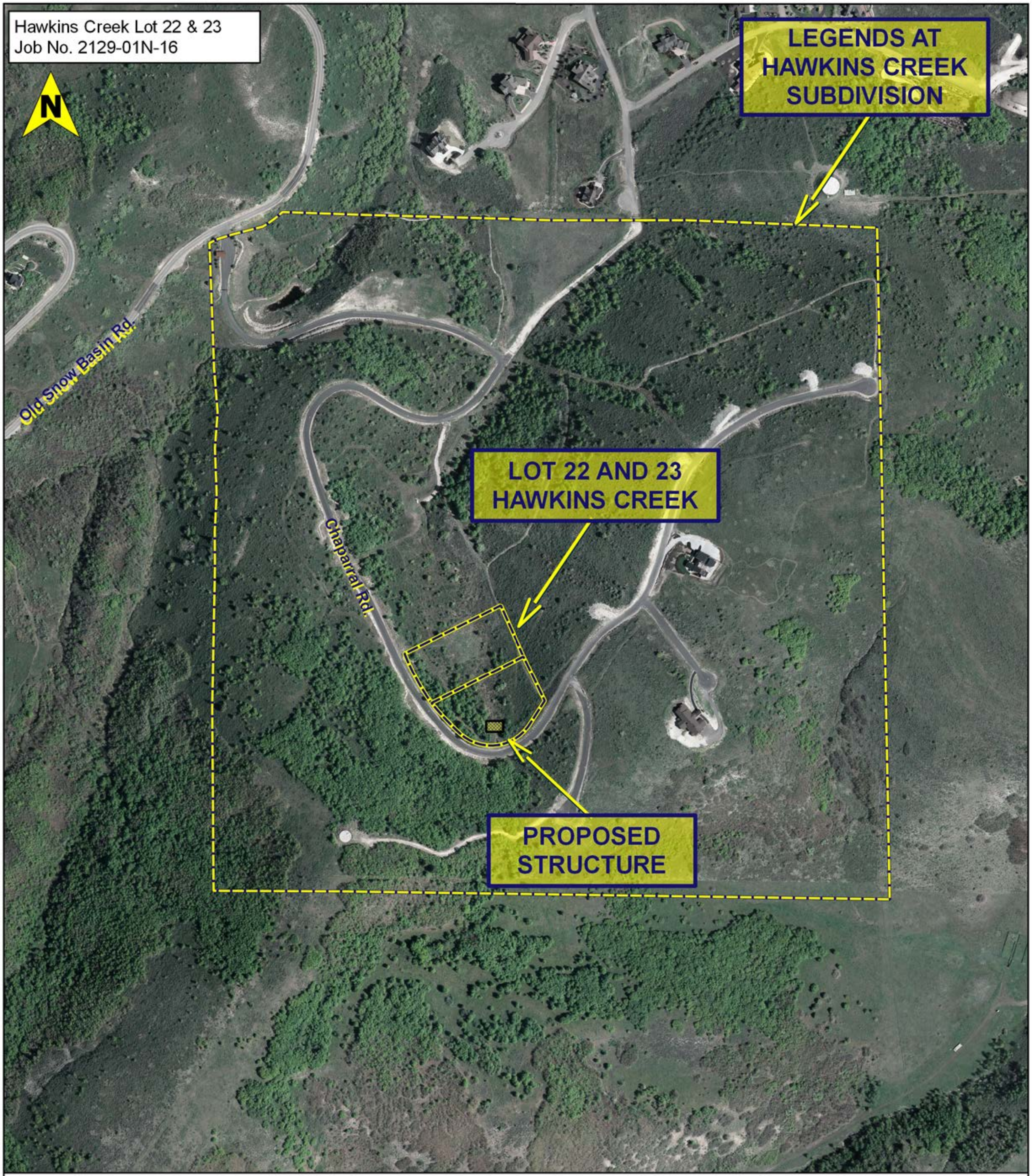


Base:
1998 7.5 Minute USGS Toporgraphic Maps Titled
Snowbasin, Utah, and Huntsville, Utah.

0 2000 4000 ft
1:24,000

FIGURE 1
VICINITY MAP

GSH

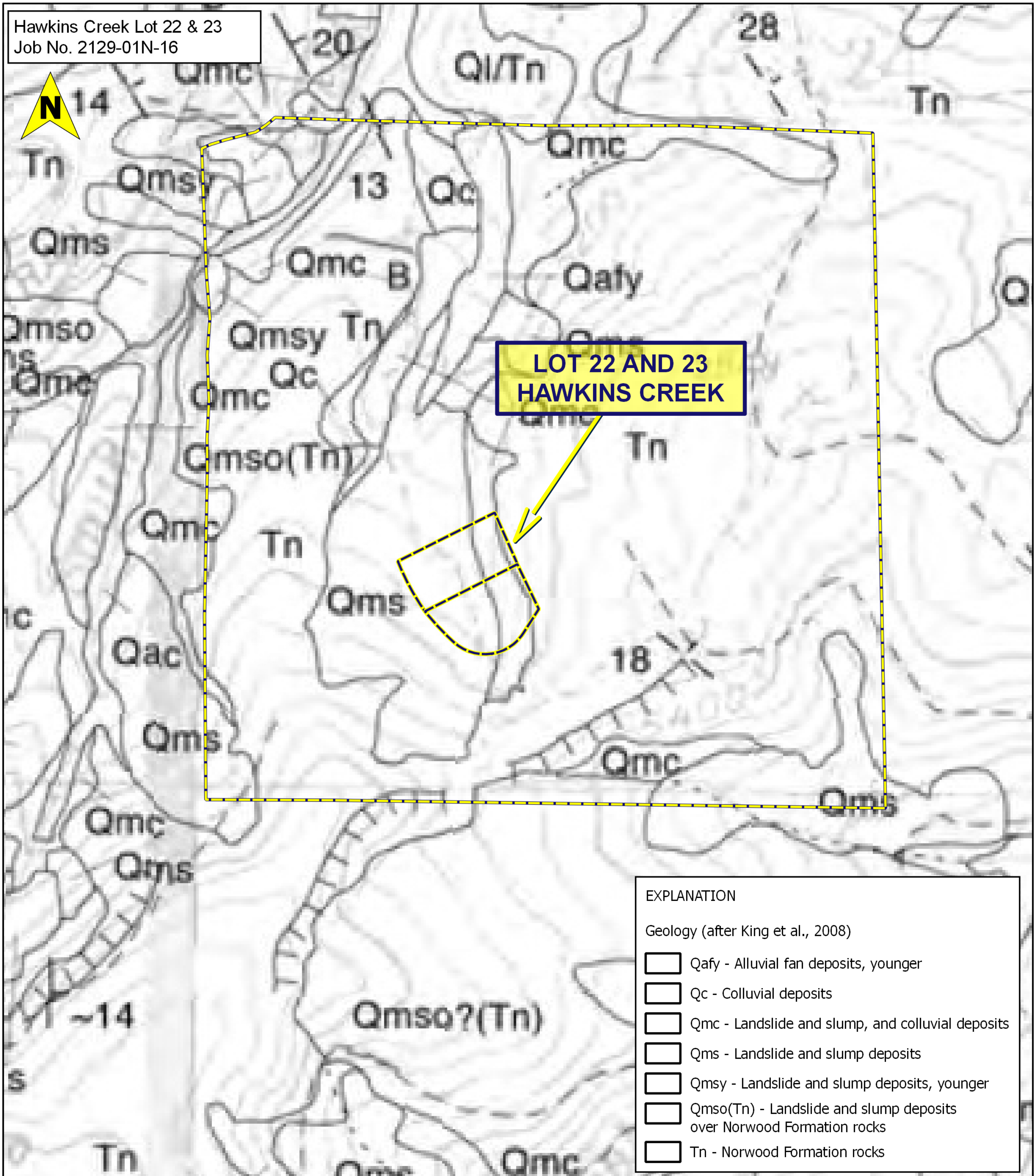


Base:
2012 0.5ft Color Orthoimagery
from Utah AGRC, http://gis.utah.gov/

0 500 1000 ft
1:6,000

FIGURE 2
AERIAL COVERAGE

GSH



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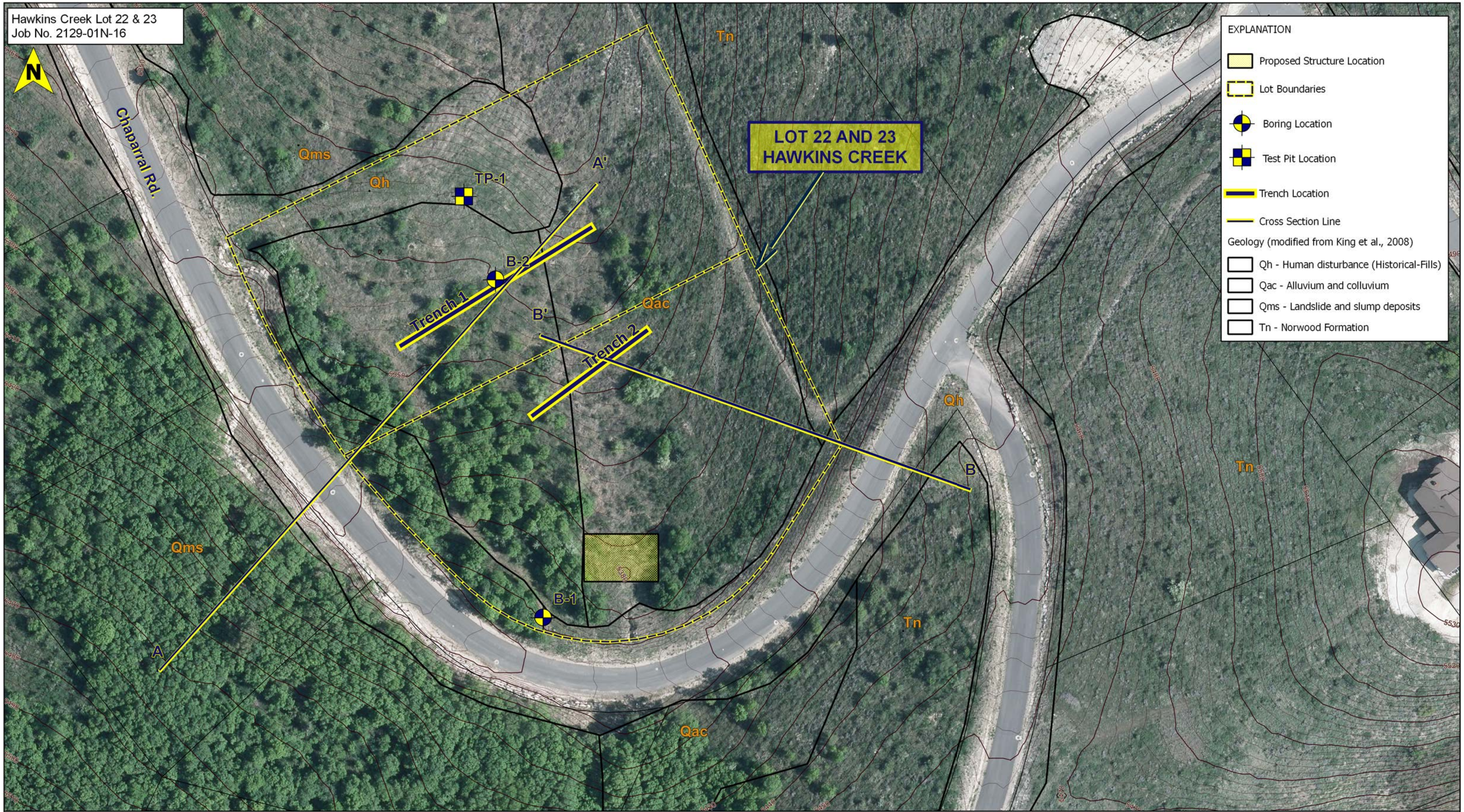
0 500 1000 ft

1:6,000

FIGURE 3
GEOLOGIC MAP

GSH



Base:
2012 0.5ft Color Orthoimagery
from Utah AGRC, http://gis.utah.gov/
Elevation:
2006 2.0m Geoprocessed LiDAR
from Utah AGRC, http://gis.utah.gov/

0 80 160 240 320 ft
1:960

FIGURE 4
SITE EVALUATION
GSH

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

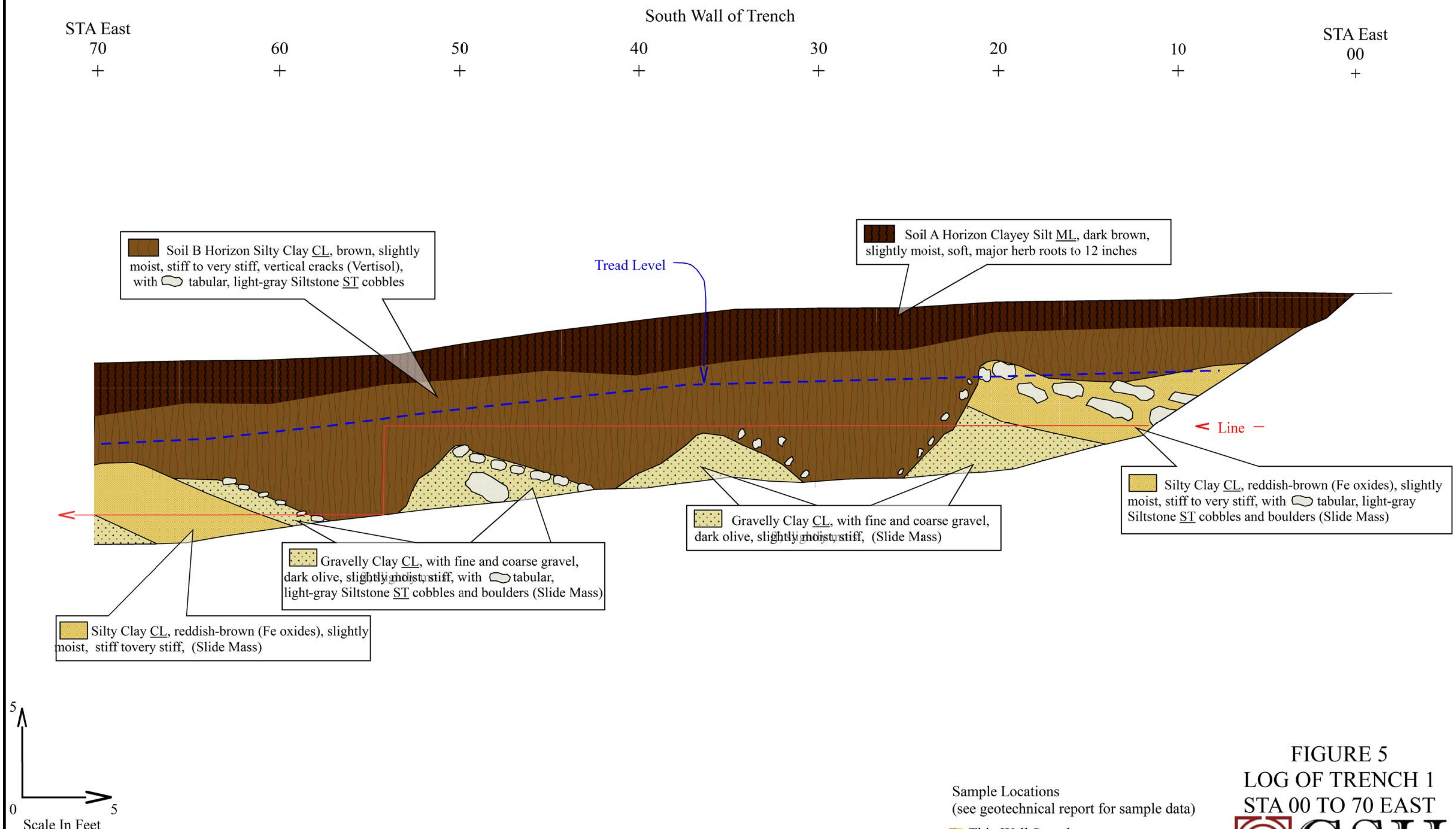
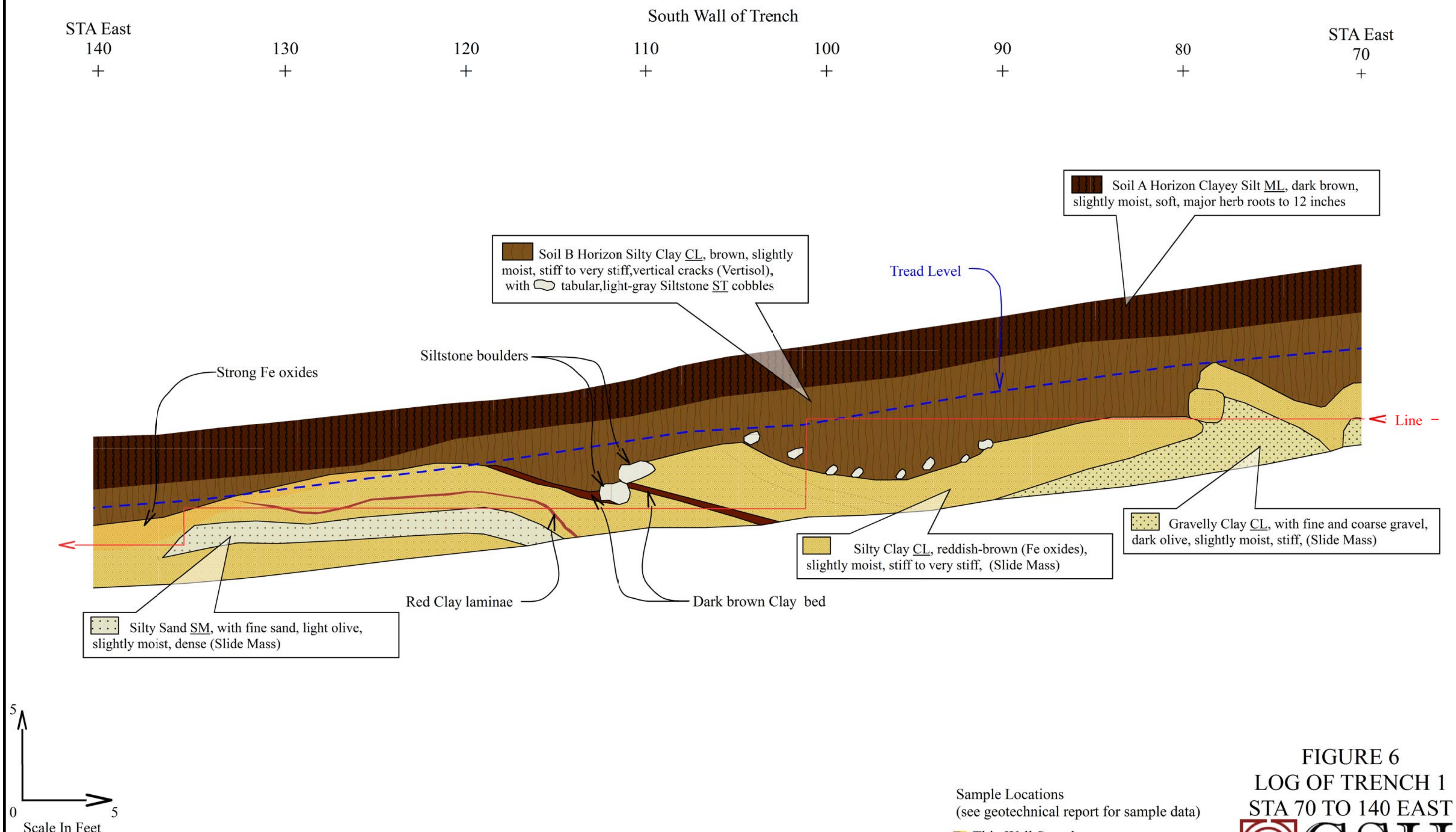


FIGURE 5
LOG OF TRENCH 1
STA 00 TO 70 EAST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 8/8/16

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16



Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

B Bulk Sample

FIGURE 6
LOG OF TRENCH 1
STA 70 TO 140 EAST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 8/8/16

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

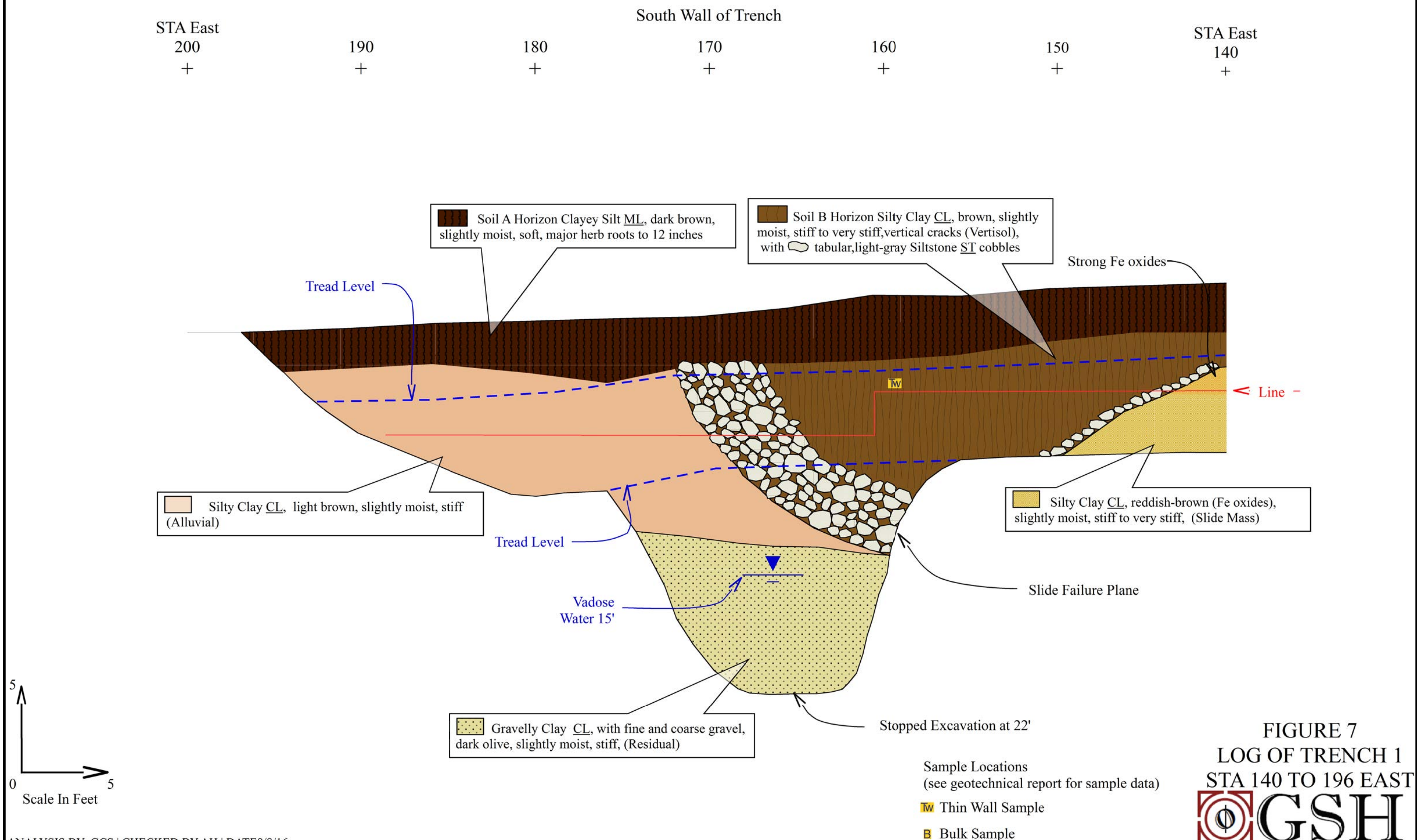


FIGURE 7
LOG OF TRENCH 1
STA 140 TO 196 EAST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE8/8/16

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

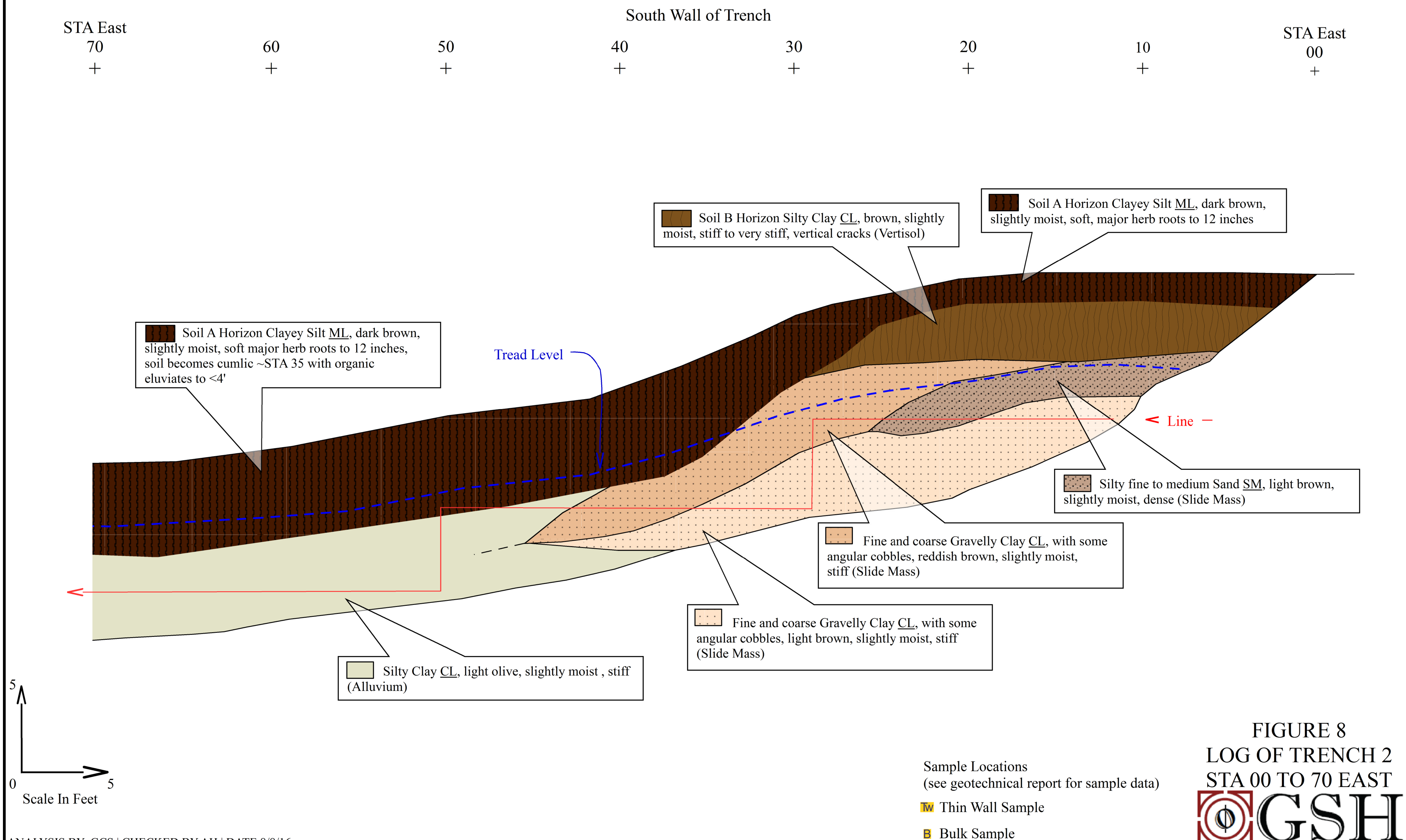


FIGURE 8
LOG OF TRENCH 2
STA 00 TO 70 EAST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 8/8/16

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

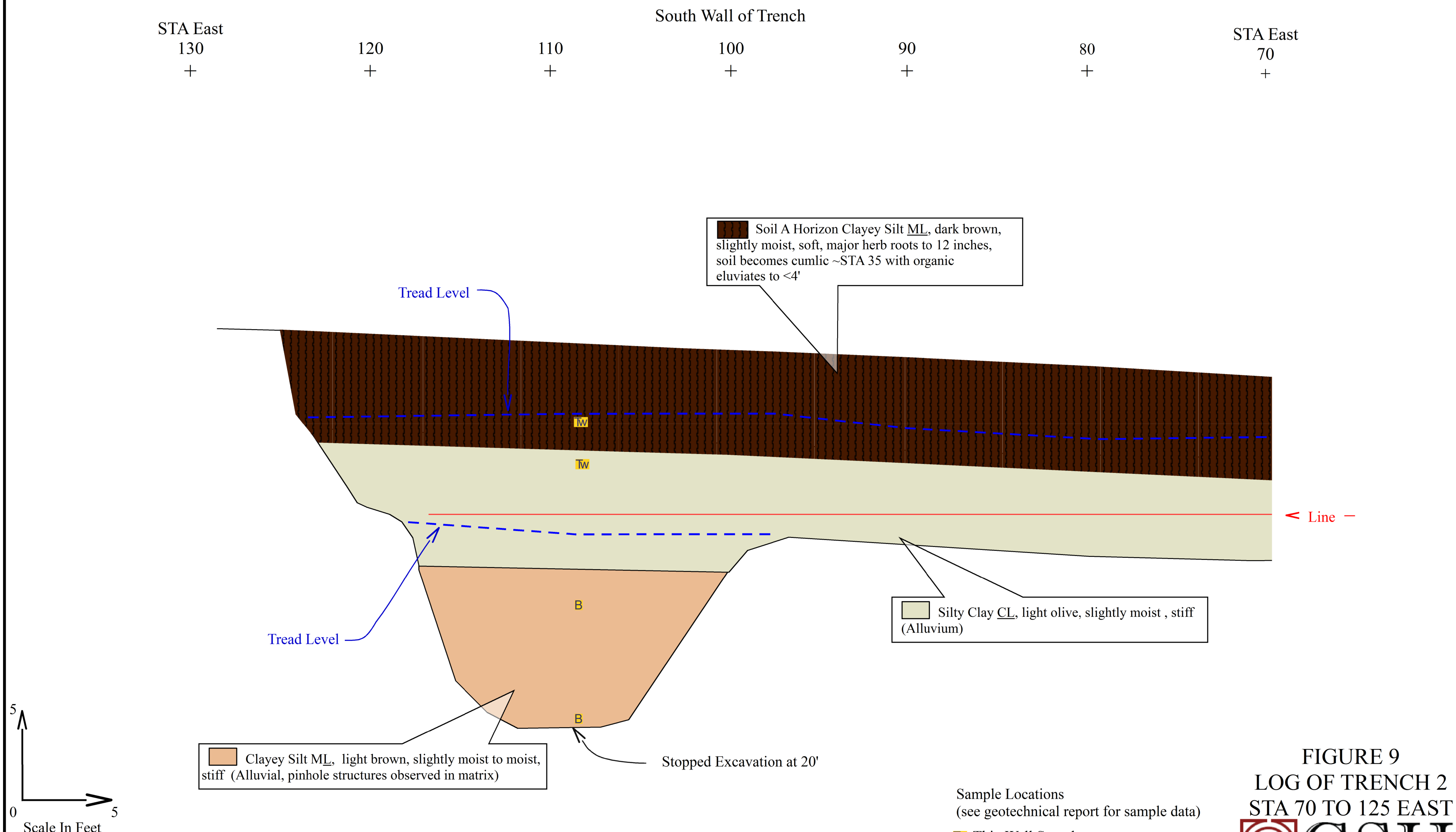


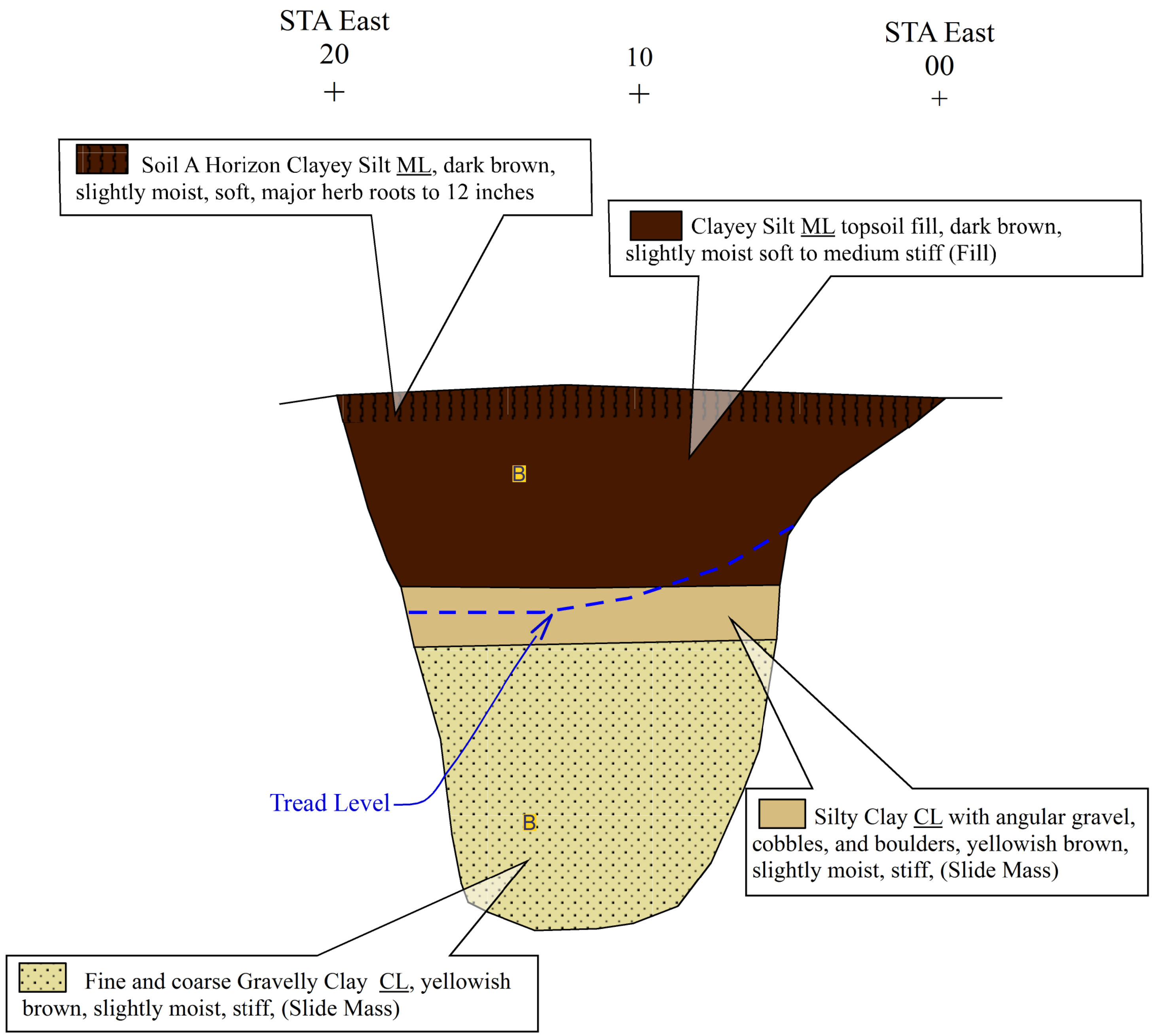
FIGURE 9
LOG OF TRENCH 2
STA 70 TO 125 EAST

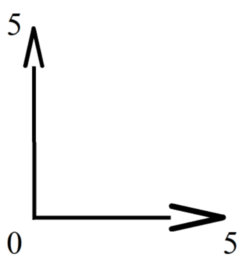
GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 8/8/16

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

South Wall of Test Pit





Scale In Feet

Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

B Bulk Sample

FIGURE 10
LOG OF TEST PIT 1

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE8/8/16

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

CLIENT: Victor Holtreman — PROJECT NUMBER: 2129-01N-16

PROJECT: Lots 22 and 23 The Legends at Hawkins Creek — DATE STARTED: 5/17/16 — DATE FINISHED: 5/17/16

LOCATION: 6564 and 6585 East Chaparral Road, Near Eden, Weber County, Utah — GSH FIELD REP.: JM/AA

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

GROUNDWATER DEPTH: Not Encountered (5/17/16), 20.2' (7/12/16) — ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
		GRADING FOR DRILL PAD	0								
			5								
	CL	SILTY CLAY with trace fine to coarse sand; siltstone fragments; brownish-gray	10	33							moist very stiff
				82		21	109				
			15	50+							
		grades claystone; reddish-brown									hard
				50+							
			20	80+							
	SP	FINE TO COARSE SAND with trace silt; gray		76		29	92		NP	NP	moist dense
	CH/ MH	SILTY CLAY/CLAYEY SILT with trace fine sand; claystone; reddish-brown	25								moist hard

See Subsurface Conditions section in the report for additional information.

FIGURE 11

GSH

BORING LOG

BORING: B-1

CLIENT: Victor Holtreman | PROJECT NUMBER: 2129-01N-16

PROJECT: Lots 22 and 23 The Legends at Hawkins Creek | DATE STARTED: 5/17/16 | DATE FINISHED: 5/17/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25	86+		29	86		54	20	
				50+							
	SP	FINE TO COARSE SAND with trace silt; sandstone; reddish-gray	30	76							moist dense
		End of Exploration at 31.5' No groundwater encountered at time of drilling Installed 1.25" diameter slotted PVC pipe to 30.0'	35								
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

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

CLIENT: Victor Holtreman — PROJECT NUMBER: 2129-01N-16

PROJECT: Lots 22 and 23 The Legends at Hawkins Creek — DATE STARTED: 5/17/16 — DATE FINISHED: 5/17/16

LOCATION: 6564 and 6585 East Chaparral Road, Near Eden, Weber County, Utah — GSH FIELD REP.: JM/AA

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

GROUNDWATER DEPTH: Not Encountered (5/17/16), 21.7' (7/12/16) — ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CH/ MH	SILTY CLAY/CLAYEY SILT with some fine to coarse sand; some organics; dark brown	0								moist stiff
				12							
			5	32							
		siltstone fragments; light brown		86+							
			10	50+							
				46		35	83				
			15	31				56	66	13	
		reddish-brown		32							
	SP/ SM	FINE TO COARSE SAND with some silt; some clay; brown	20	54							dry dense
	SP	FINE TO COARSE SAND with trace silt; sandstone; grayish-white		53							dry dense
	MH/	CLAYEY SILT	25								

See Subsurface Conditions section in the report for additional information.

BORING LOG

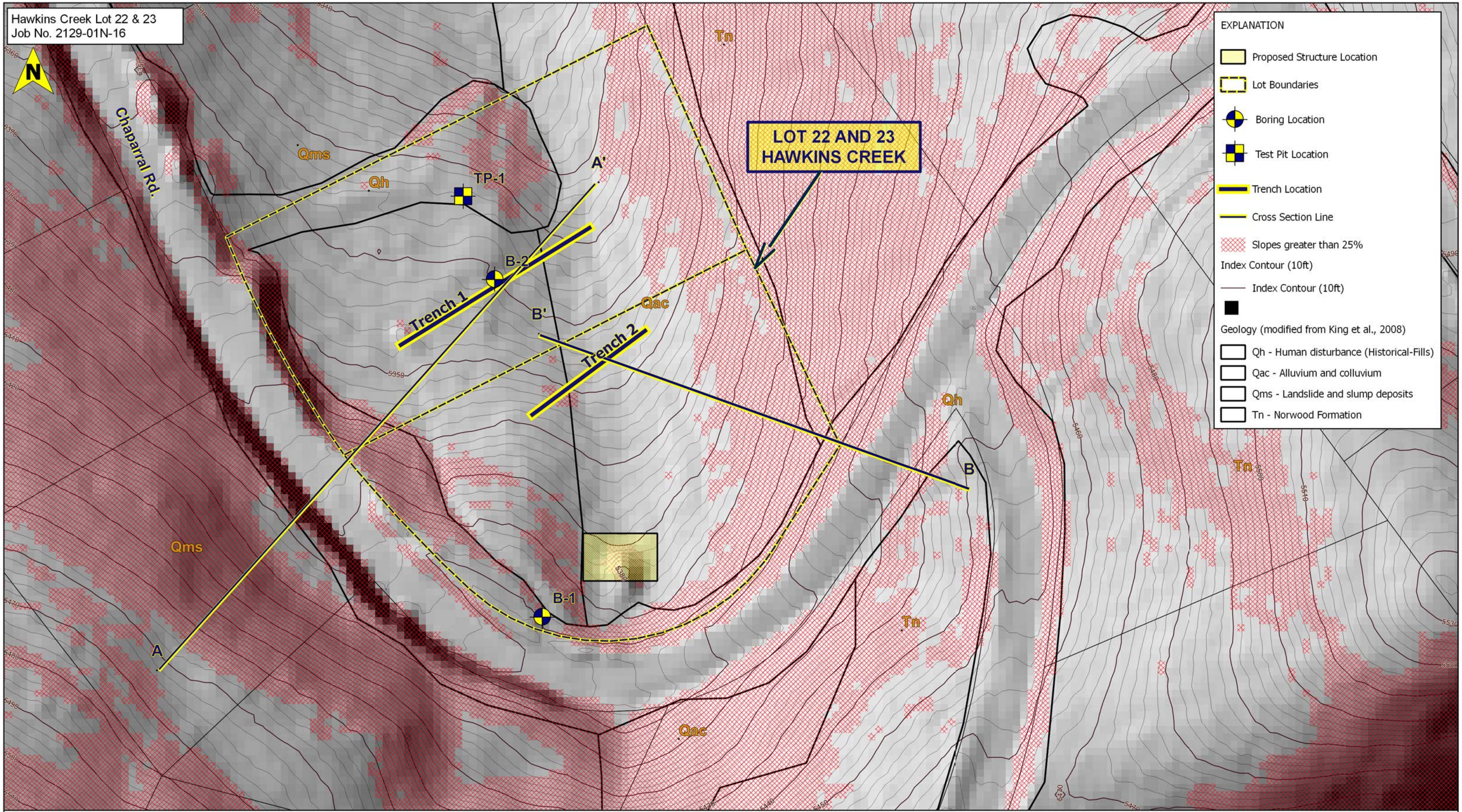
BORING: B-2

CLIENT: Victor Holtreman | PROJECT NUMBER: 2129-01N-16

PROJECT: Lots 22 and 23 The Legends at Hawkins Creek | DATE STARTED: 5/17/16 | DATE FINISHED: 5/17/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
	MH/ ML	CLAYEY SILT with some fine to coarse sand; siltstone fragments; gray	25	38	X						moist very stiff
				30	X	21	105		46	14	
			30	22	X	22	91	57	66	31	
				50+	X	24	93	64	71	35	hard
			35	50+	X						
				50+	X						
		End of Exploration at 39.0' No groundwater encountered at time of drilling Installed 1.25" diameter slotted pipe to 37.5'	40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.



Terrain-Elevation:
2006 2.0m Geoprocessed LiDAR
from Utah AGRC, http://gis.utah.gov/

0 80 160 240 320 ft

1:960

FIGURE 15
LiDAR-SLOPE ANALYSIS

GSH

Hawkins Creek Lot 22 & 23
Job No. 2129-01N-16

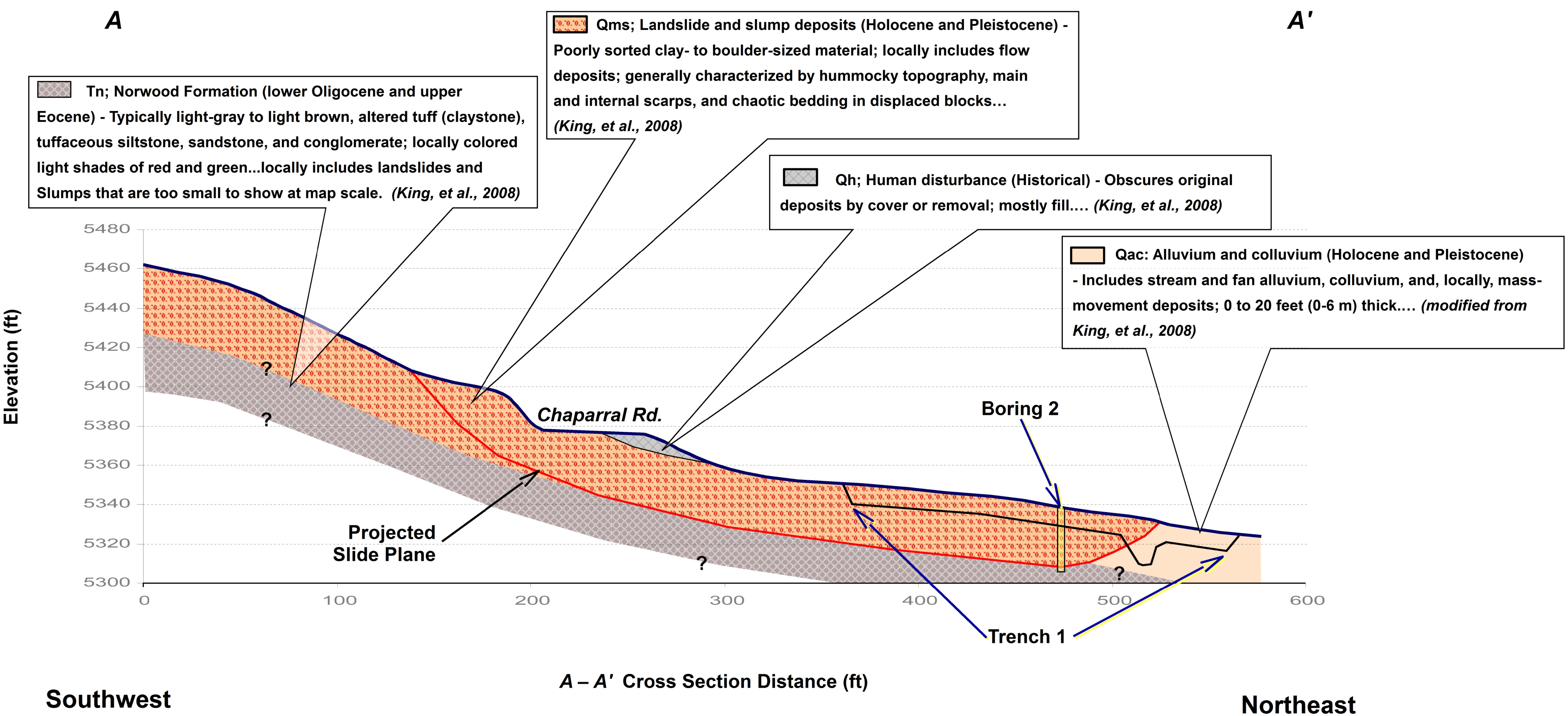


FIGURE 16
SLOPE CROSS
SECTION *A-A'*

GSH

* From Section Shown on Figure 4 and 15

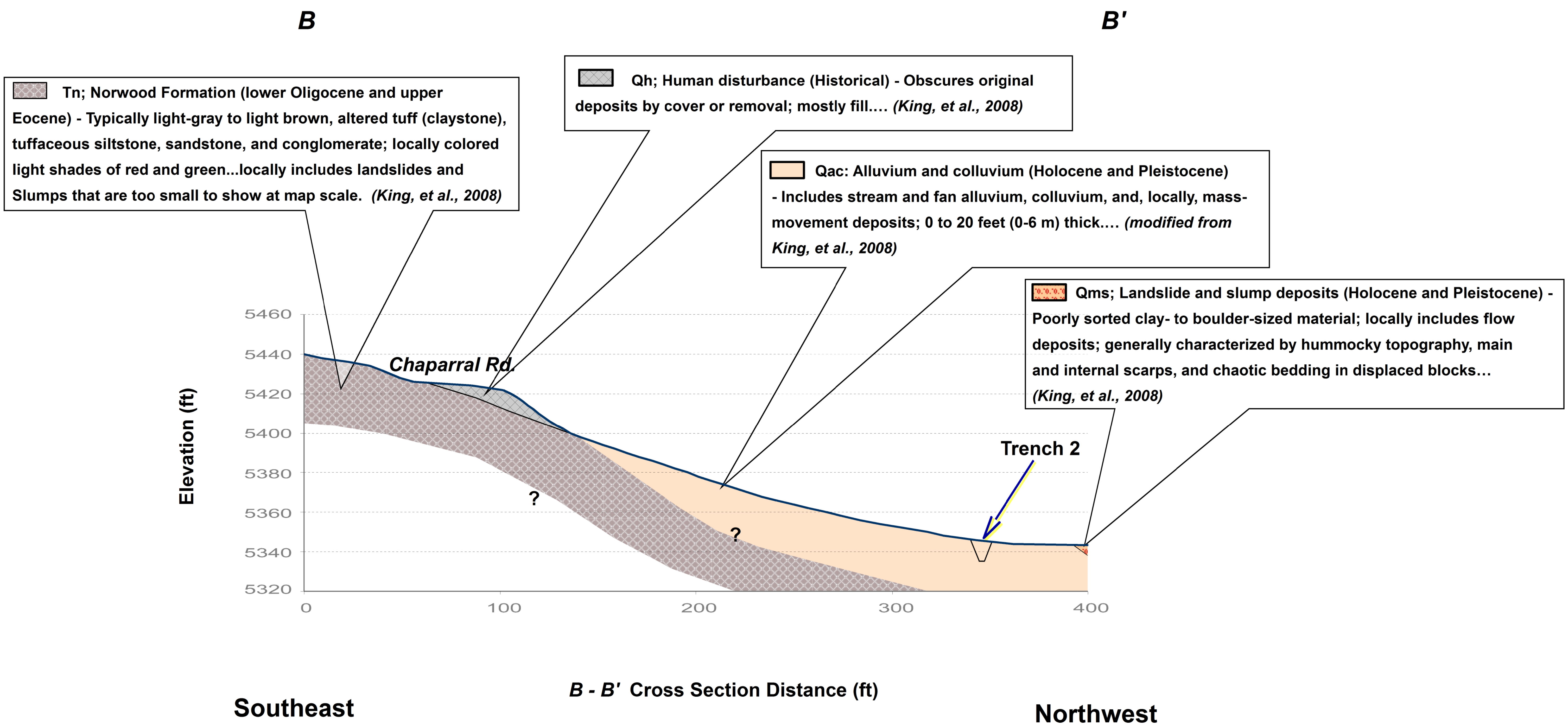


FIGURE 17
SLOPE CROSS
SECTION *B-B'*

GSH

* From Section Shown on Figure 4 and 15