REPORT
GEOLOGICAL STUDY
LOTS 46, 47, AND 48, THE SUMMIT AT SKI LAKE
PHASE 12
WEBER COUNTY, UTAH
(PARTS OF SECTION 24, TOWNSHIP 6 NORTH, RANGE 1 EAST, SALT LAKE BASE AND MERIDIAN)

Submitted To:

Valley Enterprise Investment Company
5393 East 3850 North
Eden, Utah 84310

Submitted By:

GSH Geotechnical, Inc.
473 West 4800 South
Salt Lake City, Utah 84123

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Job No. 2077-02N-16

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Mr. Ray Bowden
Valley Enterprise Investment Company
5393 East 3850 North
Eden, Utah 84310

Mr. Bowden:

RE: Report
Geological Study
Lots 46, 47, and 48, The Summit at Ski Lake Phase 12
Weber County, Utah
(Parts of Section 24, Township 6 North, Range 1 East, Salt Lake base and meridian)

1. INTRODUCTION

In response to your request, GSH Geotechnical, Inc (GSH) has prepared this Geological Study for proposed residential construction for Lots 46, 47, and 48 at The Summit at Ski Lake Phase 12. The Summit at Ski Lake Phase 12 Subdivision (Parcel) is located in the vicinity of Huntsville Town, Weber County, Utah (41.2430, -111.7831). The general Ski Lake Development area is located on the south side of Utah SR-39 between MP-16.6 and -17.4, and entirely within Section 24, Township 6 North, Range 1 East, Salt Lake base and meridian, as shown on Figure 1, Vicinity Map. As recorded, the Summit at Ski Lake Phase 12 consists of 6 residential development lots roughly 1-acre or greater in area with common space, comprising a total area of approximately 9.15 acres, of which Lots 46, 47, and 48 comprise 3.93 acres as shown on Figure 2, Aerial Coverage. Previous phases of the Summit at Ski Lake Development are established to the north, west, and generally downslope of the Phase 12 parcel. The Summit Peak Circle roadway accesses the 3 development lots as shown on Figure 2. The general central elevation of the site is approximately 5186 feet, with elevation rising approximately 152 feet from the northeast side of the site to the southwest side of the site.

1.1 Weber County Natural Hazards Overlay Districts

Because the site is located on a sloping hill side area with slopes in the vicinity of the site identified as having "Landslide Potential" (Elliott and Harty, 2010), and "Expansive Soils" (Mulvey, 1992), Weber County (Planning Commission) is requesting that geotechnical and geological studies be conducted to evaluate conformance of the proposed site development with

GSH Geotechnical, Inc.
473 West 4800 South
Salt Lake City, Utah 84123
Tel: 801.685.9190 Fax: 801.685.2990
www.gshgeo.com

the provisions included in the Weber County Code, Chapter 27, Natural Hazards Overlay District (Weber County, 2016). These hazards include, but are not limited to*: Surface-Fault Rupture, Landslide, Tectonic Subsidence, Rock Fall, Debris Flows, Liquefaction Areas, Flood, or other Hazardous Areas.*

To evaluate the proposed site development in compliance with the Weber County Natural Hazards Overlay District requirements, GSH developed a Work Plan to address the Natural Hazards Overlay District provisions. Our proposed work plan actions for the geological and geotechnical studies were as follows:

1) *Work Plan and scope of work development and plan implementation;*
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;*
3) *A field reconnaissance study including the geologic logging of a walk-in trenches approximately 75 to 150 feet in length and as much as 12 feet in depth, two short walk-in test pits to a depth of up to 18 feet, and two geotechnical borings to penetrate as deep as 30 to 50 feet, at locations shown on Figure 2, Work Plan;*
4) *Development of a geological cross section 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 30 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.*
   - *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; surface fault rupture; alluvial fan processes including debris-flow; surface fault rupture hazards, strong earthquake ground motion, and liquefaction hazards; rockfall and avalanche hazards, flood hazards, and*
   - *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.

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 KPS and Associates, Inc., 2001; King, et al., 2008; Applied GeoTech, 2013; and GSH Geotechnical Inc., 2015; Coogan and King, 2016; and GSH Geotechnical Inc., 2016a and 2016b were reviewed. The KPS and Associates study involved a geotechnical evaluation and test pit excavations for a water tank constructed on the south side of the Parcel. The King, et al , 2008 document is an Open-file UGS geological mapping project of the Snow Basin and Huntsville, Utah quadrangles, which includes the location of the Phase 12 Parcel. The 2013 Applied GeoTech study was a geotechnical evaluation conducted for surrounding Phases 12 and 13 of the Ski Lake Development that included 4 test pit explorations. The 2015 GSH Geotechnical, Inc. study was a geological investigation conducted for the extension of the Via Cortina roadway on the southwest side of the site, where the geological logging of approximately 700 feet of vertical cut exposure made for the roadway extension, and 4 "walk-in" test pits. The 2016a GSH Study included the geological and geotechnical study of the Lot 43 of The Summit at Ski Lake Phase 11, on the west side of Phase 12, that included 2 exploration trenches and 4 test pit excavations. The 2016b GSH Study included the geological and geotechnical study of the Phase 13, of the Ski Lake Development, also to the west of the Phase 12 Site, that included 5 exploration trenches, 4 test pit excavations, and 2 geotechnical borings. The Coogan and King (2016) mapping is a reduced scale, 1:100,000 scale, UGS published mapping document that includes the Snow Basin and Huntsville, Utah quadrangles. Site-specific geological mapping overlays developed from this review are included on Figure 3, Site Evaluation.

2.2 Field Program

GSH conducted field operations at the site on the dates May 11 and 12, and May 26 and 27, 2016. The field program involved the excavation and geological logging of 3 exploration trenches and 2 test pits, and the advancement of 2 geotechnical borings on site locations shown on Figure 3. The excavations and borings were logged to observe and characterize site subsurface/geologic and groundwater conditions for the site and the proposed residential development improvements. Trenches and test pits were located to evaluate the conditions for the site building areas and borings were placed on slope locations in order to evaluate geologic subsurface conditions relative to slope stability conditions for the 3 lots. The locations of our trenches, test pits, and borings are included on Figure 3. Trenches were from 72 to 312 feet in length and extended to depths of 4.0 to 12.0 feet, and the test pits consisted of walk-in

excavations, roughly 30.0 feet in length, and were extended to depths of 13.5 and 14.0 feet, whereupon trackhoe refusal was encountered. 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 proposed building areas across the site. The trenches and test pits were excavated using a 20-ton class excavator with a 36-inch bucket and was refused at depth in most of the excavations, as indicated in our field logs.

The borings were completed using a CME 55 truck-mounted drill rig using solid flight auger methods. 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 (Key to Boring Log) (USCS).

In addition to the observations in the trenches, test pits, and borings, the general surface of the site and surrounding area was reconnoitered to assess geological and slope conditions. Feature location and elevation data were recorded using a hand-held GPS receiver device.

Our field program was conducted by Dr. Greg Schlenker, PG of our geotechnical staff. Mr. Jed McFarland, Staff Engineer, also of our geotechnical staff, supervised the geotechnical drilling for the site.

The soils and geology in the trenches, test pits, and borings were classified in the field based upon visual and textural examination, and interpretation of geologic site formation processes. These classifications have been supplemented by subsequent inspection and testing in our laboratory. Detailed graphical representations of the subsurface conditions encountered are presented on Figure 4 through Figure 9, Log of Trenches, and Figure 10, Log of Test Pit 46 and Test Pit 48. The soil and rock units observed in the trenches and test pits were classified in accordance with the Unified Soil Classification System (USCS), and were further classified on the basis of geological site formation processes.

Bulk and thin wall samples of representative soil layers encountered in the test pits were obtained and placed in sealable bags and/or were recovered undisturbed using driven sample tubes. The locations of the sample recovery locations are included on our trench and test pit logs. The results of our laboratory analysis and testing of the soils recovered from the test pits will be included in our accompanying geotechnical report.

The logs of the 2 borings shown on Figure 3 that were made for our concurrent geotechnical study and included in this reporting, are included on Figure 11 and Figure 12 of this report. The borings were completed using a CME 55 truck-mounted drill rig using solid flight augers. 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).

2.3 LiDAR - Slope Analysis

To asses slope conditions, interpret terrain, and develop site-specific geologic cross sections 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 13, LiDAR Analysis, presents the results of our slope analysis efforts. Shown on Figure 13 is the 25 percent and greater than 30 percent slope gradients across the site. The shaded relief rendering on Figure 13 provides a visual basis for landform interpretation, and the contour elevation data shown on Figure 13 is used to develop the cross sections shown on Figure 14, Geologic Slope Cross Section *A-A'*. The critical gradient for slope development considerations according to the Weber County Section 108-14-3 (Weber County Code, 2015), includes slopes greater that 25 percent. The Geologic Slope Cross Section shown on Figure 14 will be used for modeling slope stability analysis in 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; Currey and Oviatt, 1985; Bryant, 1988; Coogan and King, 2001; King et al., 2008; and Coogan and King, 2016) including a review of previous evaluations discussed previously in the Literature Review Section of this report, photogeologic analyses of 2012 and 2016 imagery shown on Figure 2 and Figure 3, 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 13, field reconnaissance of the general site area, and the interpretation of the trenches, test pits, and borings excavated and drilled 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 7,000 feet thick in the vicinity of the site. The claystone, siltstone, and sandstone occurrences of the formation in the Ski Lake area are primarily a result of lacustrine (lake processes) re-deposition 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). Our previous 2015 observations of the logged roadway geology cut on Via Cortina revealed bedded exposures of lucustrine rock sequences generally consisting of moderate to thick bed units, (1 to 2 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 3, the 3 lot area consists of an area of approximately 3.93 acres in size that is currently vacant and undeveloped. At the time of our 2016 field program, grading and pavements for the Via Cortina and Summit Peak Circle roadways were in place. Surface vegetation on the site consists of open areas of grasses, weeds, and sage brush with clustered wooded areas of scrub oak, alder, box elder, and maple tree cover. The topography of the site consists of a northeast-facing hillslope with slopes on the property generally facing downward toward the north and northeast 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 3, is bordered on the south and east by vacant undeveloped lands and on the north and west and by residential estate property land uses.

3.3 Subsurface Conditions

The natural rock and soils observed in the trenches and test pits and illustrated on our logs, Figures 4 to Figure 9, Logs of Trenches, and Figure 10, Logs of Test Pits, generally consisted, from bottom to top of:

Weathered bedrock sequences consisting of: 1) weathered Siltstone (ST-ML) red-yellow in color, slightly moist, slightly to moderately weathered, tabular where bedded, with very stiff to weak consistency; and 2) clayey Silt soil (ML), buff and light reddish-brown in color, and stiff to very stiff in consistency.

Surficial pedogenic soil sequences, consisting soil A horizons of clayey Silt (ML), moist, medium stiff, dark brown, with major herb roots approximately 8.0 inches in thickness that were observed on the surfaces of the trench and test pit exposures. Below the surface, thick soil B horizon, vertisol sequences extending as much as 6.0 feet in depth were observed. The vertisol soils consisted of silty clays (CL), dark brown, stiff, slightly moist, with vertical cracks extending the thickness of the vertisol units.

The soils in the 2 borings consisted of stiff silty clay (CL) fill soils in the upper 10.0 to13.0 feet. Below the fills, the native soils and rock consisting of silty Clays (CL), clayey Silts (ML) and silty- clayey- Sands (SM), very stiff to hard in consistency, were encountered to the 51.5 foot depth penetrated in the 2 borings.

Groundwater was not observed in any of the trenches, test pits, or borings during our field program.

3.4 Site Engineering Geology

Our interpretation of the site Engineering Geology is presented on Figure 3 of this report. The mapped geology shown 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 and previous studies (GSH Geotechnical, Inc., 2015; 2016a; and 2016b). A summary of the mapping units identified on the site vicinity are listed below in relative age sequence (youngest-top to oldest bottom):

The **Qmc** deposits are landslide and slump, and colluvial deposits, undivided Holocene and Pleistocene in age (0 to 30,000 ybp -years before present), consisting of poorly sorted to unsorted clay- to boulder-sized material. These mapped units include smaller landslide slopes and slopes comprised of slopewash and soil-creep deposits.

The **Qms**, **Qmsy** and **Qms?(Tn)** deposits include landslide and colluvial deposits associated with failed or moving slopes, Holocene and Pleistocene in age (0 to 30,000 ybp), consisting of poorly sorted to unsorted clay- to boulder-sized material. These units include slides, slumps, and locally flows and floods. Areas mapped as **Qms?Tn** include apparent thin landslide and colluvial deposits associated with failed or moving slopes, Holocene and Pleistocene in age (0 to 30,000 ybp), over Norwood Formation (**Tn**) rocks formed 20 to 30

million years ago. The **Qmsy** deposits are believed to be Holocene in age, having moved since the regression of Lake Bonneville 14,000 ybp (Currey and Oviatt, 1985).

The **Qmc, Qms, Qmsy** and **Qms?Tn** classified areas should be considered exposed to landslide and/or slope-creep hazards. On Figure 3, **Qmc** deposits are shown to occupy much of the three lot area, however no evidence of failure movement was no observed in the trenches, and we believe that any movement occurring in the **Qmc** mapped areas is a function of slope creep processes in the upper 6.0 feet of the soils in these areas. Areas classified as **Qms?Tn** are shown on Figure 3 to occur on the very east margin of the site and were not exposed by our excavations or borings.

The **Qlf/Tn** mapped areas consist of thin Lake Bonneville deposits 15,000 to 19,000 ybp in age, over Norwood Formation (**Tn**) rocks formed 20 to 30 million years ago. The Lake Bonneville deposits **(Qlf),** undivided (upper Pleistocene) consist of silt, clay, and sand.

The Norwood Formation, **Tn,** is a lower Oligocene and upper Eocene (20 to 30 million years ago) ash deposit that originated from regional volcanic activity. The Norwood Formation typically consists of light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate.

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 consist of surficial, upper 1.0 feet of pedogenic soil A horizons, and B horizon vertisol sequences that extended in depth (thickness) as much as 6.0 feet. At depth residual weathered soil and weathered rock sequences consisting of hard clays, siltstones, and sandstones were observed extending to the depths penetrated by our excavations and borings.

4.1.2 Expansive soils. Vertical cracking associated with vertisol development was observed to extend from 3.0 to 6.0 feet (and possibly deeper) below the surface in the trenches and test pits 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 100 percent as shown on Figure 11, LiDAR Analysis. For the 3 lots, the slope gradient averaged 22.2 percent. For the general vicinity of the Summit at Ski Lake Phase 12 area, the slope gradient averaged 24.4 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. Areas on and in the vicinity of the site exceeding 25 percent are shown on Figure 13.

4.1.4 Site Engineering Geology and Mapping. The engineering geology mapping of the site vicinity presented on Figure 3 reveals 2 issues pertinent to site development planning. These issues include: (1) **Landslide and slump deposits** (**Qmc, Qms**, **Qmsy** and **Qms?(Tn)**) - the presence and proximity of landslide and slump deposits on or near the three lots; (2) **Norwood Formation (Tn)** - the presence of Norwood Formation **Tn** deposits underlying much of the area comprising the 3 lots and site vicinity. These issues are addressed in order importance below:

1. **Landslide and slump deposits:** Presence of mass-movement landslide and slump deposits, **Qmc, Qms, Qmsy** and **Qms?(Tn)** is based upon mapping prepared by King et al. (2008) and our own previous investigations (GSH Geotechnical Inc., 2015; 2016a; and 2016b). The occurrence and mapping of the **Qmc** deposits on the three lots appears to coincide with thick colluvial soils and/or vertisol-soil expansion, whereas slump movement was not observed in the trenches and test pits excavated on the site. Although no landslide and slump deposits classified as **Qms** and **Qmsy** are shown to occur on the property, the close proximity of these deposits to the site should be disclosed. It is our opinion that if the proposed construction should avoid the very eastern margin of lots 46 and 47 where **Qms?(Tn)** deposits are mapped within a few feet of the site boundary. The mapped location of the **Qms?(Tn)** deposits appear to be within the prescribed 30 foot setback for the recorded lot boundaries in this area.

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, 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. Vertisol soil layers inherent to expansive soils were observed in the trenches and test pits excavated for this study to as much as 6.0 feet below the surface.

4.1.5 Geoseismic Setting: Strong ground motion originating from the Wasatch fault or other near-by seismic sources is capable of impacting the site. The Wasatch fault zone is considered active and capable of generating earthquakes as large as magnitude 7.3 (Arabasz et al., 1992). Utah municipalities have adopted the International Building Code (IBC) 2015. The IBC 2015 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 0.16g, and for a two-percent probability of exceedance in 50 years is as high as 0.33g for the site.

The a 10 percent probability of exceedance in 50 years event has a return period of 475 years, and the 0.16*g* acceleration for this event corresponds "strong" perceived shaking with "light" potential damage based on instrument intensity correlations (Wald et al., 1999).

The 2 percent probability of exceedance in 50 years event has a return period of 2475 years, and the 0.33*g* acceleration for this event corresponds "very strong" perceived shaking with "moderate" potential damage based on instrument intensity correlations (Wald et al., 1999).

Future ground accelerations greater than these are possible but will have a lower probability of occurrence.

4.1.6 Active Earthquake Faults: The nearest active (Holocene) earthquake fault to the site is the Weber segment of the Wasatch fault zone (UT2351E) which is located 7.0 miles west of the site, thus fault rupture hazards are not considered present on the site (Black et al., 2004). The Ogden Valley southwestern margin faults (UT2375) are located much closer to the site, approximately 1.0 mile to the southwest, however the most recent movement along this fault is estimated to be pre-Holocene (>15,000 ybp), and presently is not considered an active risk (Black, et al., 1999).

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, and no areas in the vicinity of the site appear to have characteristics 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 2,000 feet southwest 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 at this time (FEMA, 2015).

4.1.10 Rockfall and Avalanche Hazards: The site is over 2 miles from steep slope areas where such hazards may originate.

4.1.11 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. Radon-hazard potential mapping has been prepared for most of Ogden Valley by the Utah Geological Survey, and the radon-hazard potential for the 3-lot location appears to be mapped as "Moderate" by the UGS study (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 Lots 46, 47, and 48 Summit at Ski Lake Phase 12 are suitable for development, provided that **Qms?(Tn)** soils identified near the eastern margin of the site are avoided.

The site has been shown to be underlain by Colluvial (**Qms)** and Norwood Formation (**Tn**) deposits, and expansive vertisol soils were observed in trenches and test pits made for this study. Areas where these vertisol soils are present should be evaluated by a geotechnical engineer prior to the placement of structural loads.

Although not addressed by the Weber County ordinances, we recommend that radon exposure be evaluated to determine if radon reduction measures are necessary for the new construction. It is our understanding that new construction in Ogden Valley area often includes radon remedial measures as part of final design.

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) 6385-9190.

Respectfully submitted,

GSH Geotechnical, Inc.

LICENSED PROFESSIONAL GEOLOGIST
11/10/16
GREGORY C. SCHLENKER
5224720-2250
STATE OF UTAH

Reviewed by:

Gregory C. Schlenker PhD, P.G.
State of Utah No. 5224720
Senior Geologist

Andrew M. Harris, P.E.
State of Utah No. 7420456
Senior Geotechnical Engineer

GCS/AMH:jlh

Encl. Figure 1, Vicinity Map
Figure 2, Aerial Coverage
Figures 3, Site Evaluation
Figure 4, Log of Trench 46, STA 00 to 70 East
Figure 5, Log of Trench 46, STA 70 to 136 East
Figure 6, Log of Trench 47-48, STA 00 to 140 East
Figure 7, Log of Trench 47-48, STA 140 to 210 East
Figure 8, Log of Trench 47-48, STA 210 to 312 East
Figure 9, Log of Trench 48, STA 00 to 72 East
Figure 10, Log of Test Pits 46 and 48
Figure 11, Log of Boring 1
Figure 12, Log of Boring 2
Figure 13, LiDAR Analysis
Figure 14, Geologic Slope Cross Section *A-A'*

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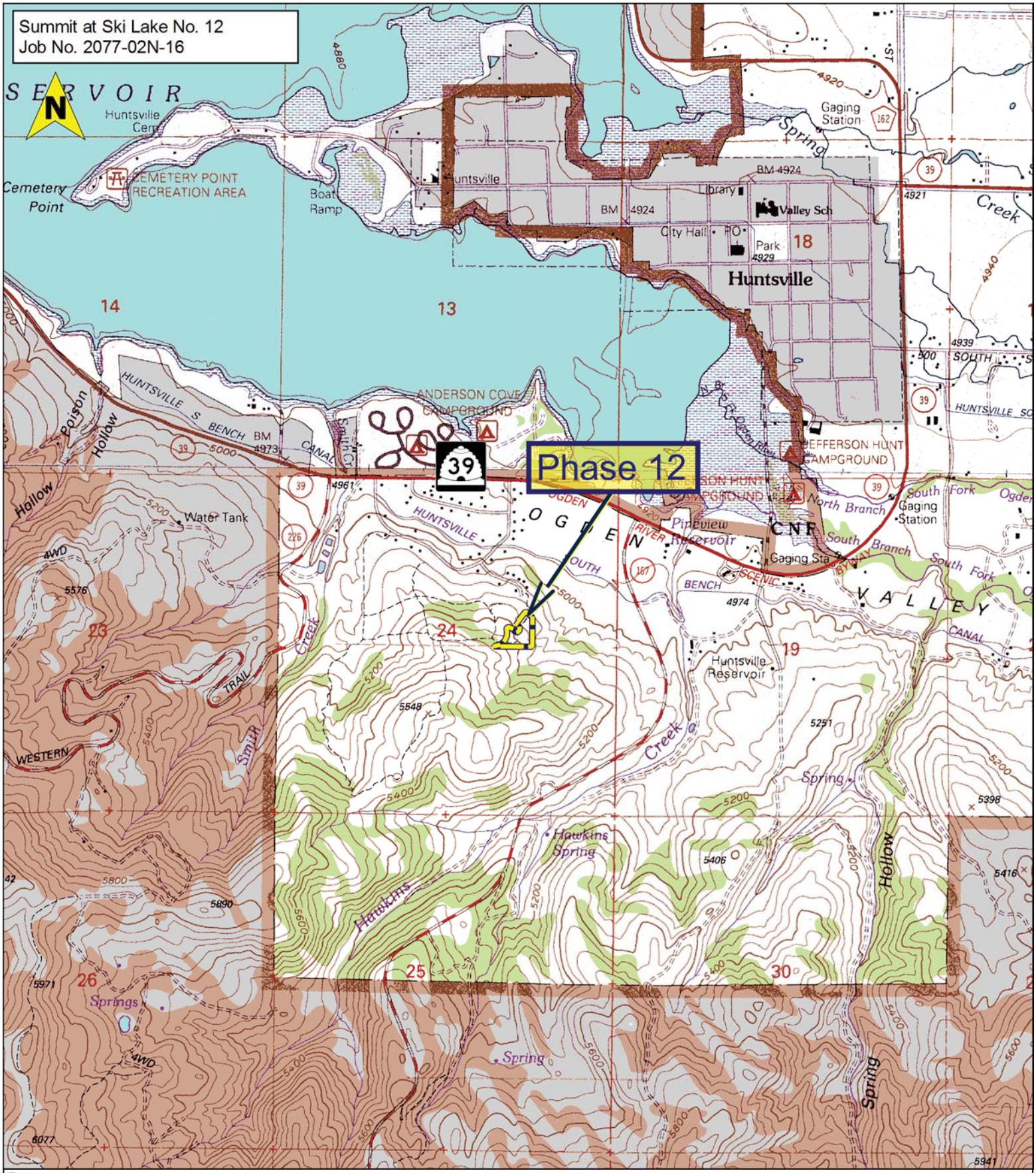


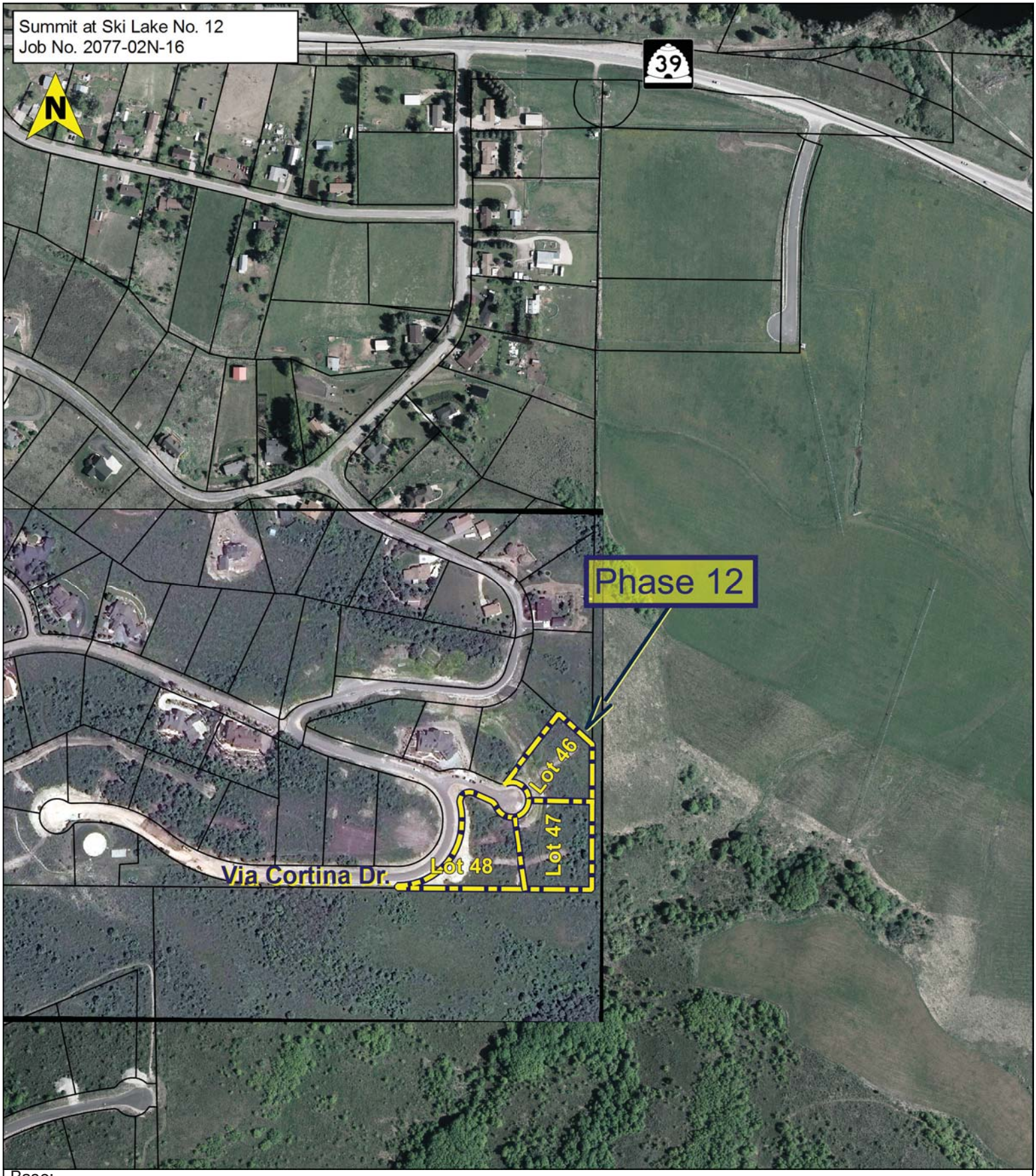
Base:
1998 7.5 Minute USGS Toporgraphic Maps
TitledSnowbasin, Utah, and Huntsville, Utah.
from Utah AGRC; http://gis.utah.gov/

0 2000 4000 ft

1:24,000

FIGURE 1
VICINITY MAP

GSH



Base:
2016 1.5-foot TerraServer Image Overlay,
2012 6-inch Color HRO Orthoimagery,
from Utah AGRC; http://gis.utah.gov/

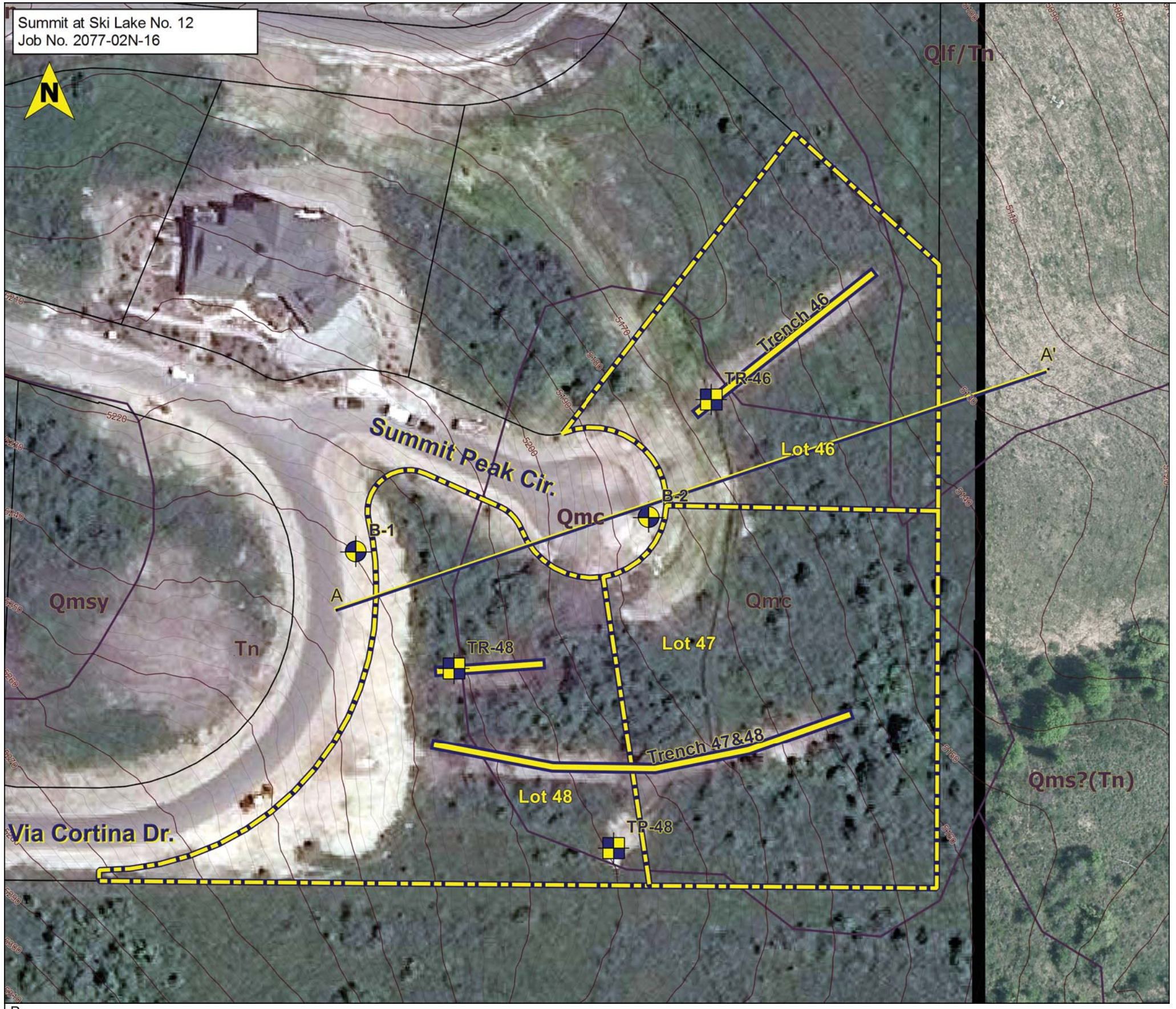
0 400 800 ft

1:4,800

FIGURE 2
AERIAL COVERAGE

GSH

Summit at Ski Lake No. 12
Job No. 2077-02N-16



Explanation

- Lot Boundaries
- Test Pit Location
- Boring Location
- Trench Location
- Geologic Cross Section Line A-A'

Geology after King, 2008

- Qmc - Landslide and slump, and colluvial deposits undivided
- Qmsy - Landslide and slump deposits (younger)
- Qms - Landslide and slump deposits
- Qms?(Tn) - Landslide and slump deposits over Norwood Formation
- Qlf/Tn - Lake Bonneville fine-grained deposits over Norwood Formation
- Tn - Norwood Formation

Base:
2016 1.5-foot TerraServer Image Overlay
2012 6-inch Color HRO Orthoimagery,
Elevation: 2006 2.0m Geoprocessed LiDAR
from Utah AGRC; http://gis.utah.gov/

0 80 160 240 ft

1:960

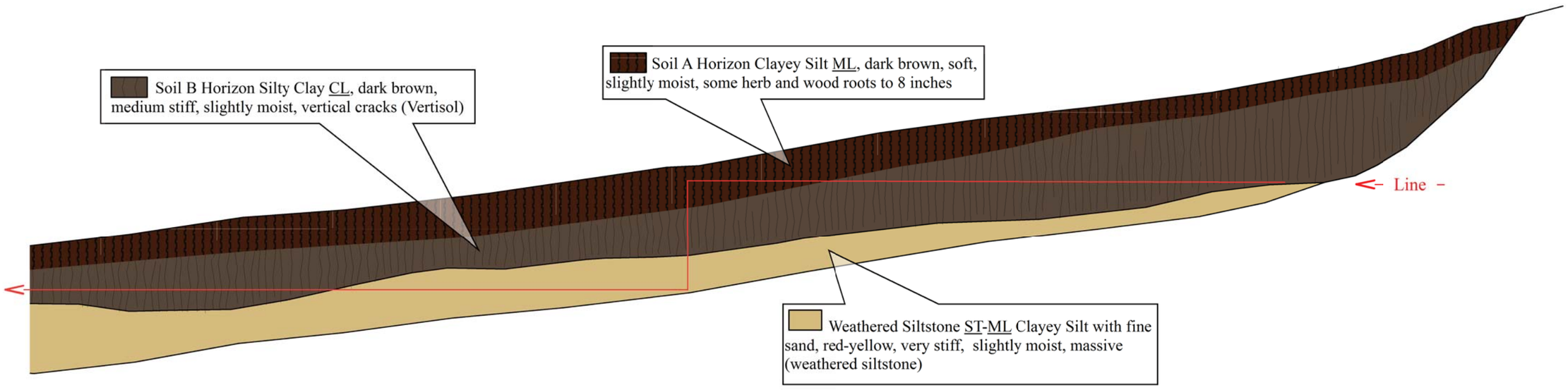
FIGURE 3
SITE EVAULATION

GSH

Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 70 | 60 | 50 | 40 | 30 | 20 | 10 | STA East 00



5
0 5
Scale In Feet

Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

B Bulk Sample

FIGURE 4
LOG OF TRENCH 46
STA 00 TO 70 EAST

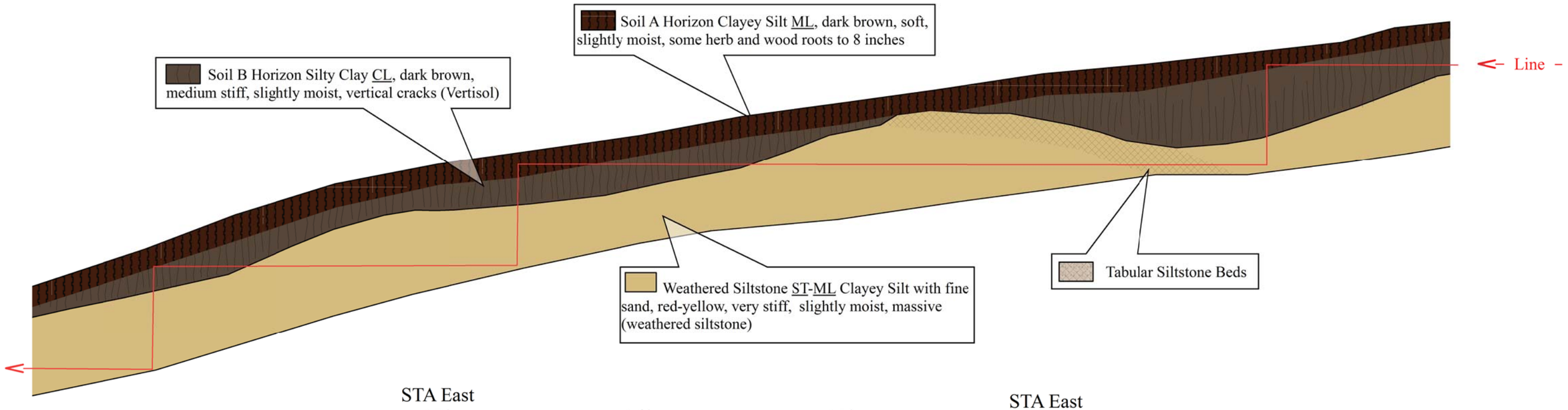
GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

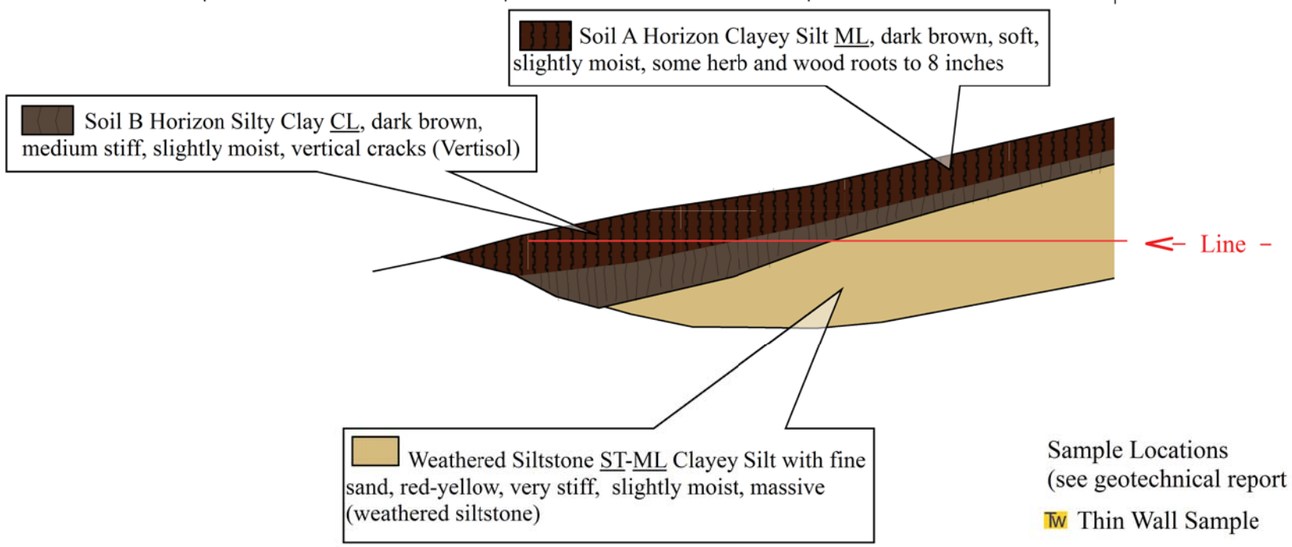
Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 140 + | 130 + | 120 + | 110 + | 100 + | 90 + | 80 + | STA East 70 +



STA East 170 + | 160 + | 150 + | STA East 140 +



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 10/24/16

FIGURE 5
LOG OF TRENCH 46
STA 70 TO 136 EAST

GSH

Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 70 + | 60 + | 50 + | 40 + | 30 + | 20 + | 10 + | STA East 00 +

Soil B Horizon Silty Clay CL, dark brown, medium stiff, slightly moist, vertical cracks (Vertisol)

Soil A Horizon Clayey Silt ML, dark brown, soft, slightly moist, some herb and wood roots to 8 inches

Line –

Weathered Siltstone ST-ML Clayey Silt with fine sand, red-yellow, very stiff, slightly moist, massive (weathered siltstone)

Clayey Silt ML, light reddish brown, stiff , slightly moist, massive (weathered siltstone)

Clayey Silt ML, mottled light reddish brown-olive, stiff , slightly moist, massive (weathered siltstone)

Tabular Siltstone Blocks

$CaCO_3$ Accumulations

STA East 140 + | 130 + | 120 + | 110 + | 100 + | 90 + | 80 + | STA East 70 +

Soil A Horizon Clayey Silt ML, dark brown, soft, slightly moist, some herb and wood roots to 8 inches

Soil B Horizon Silty Clay CL, dark brown, medium stiff, slightly moist

Line –

$CaCO_3$ Accumulations

Clayey Silt ML, mottled light reddish brown-olive, stiff , slightly moist, massive (weathered siltstone)

Weathered Siltstone ST-ML Clayey Silt with fine sand, red-yellow, very stiff, slightly moist, massive (weathered siltstone)

5

0 5

Scale In Feet

Sample Locations
(see geotechnical report for sample data)

Tw Thin Wall Sample

B Bulk Sample

FIGURE 6
LOG OF TRENCH 47-48
STA 00 TO 140 EAST

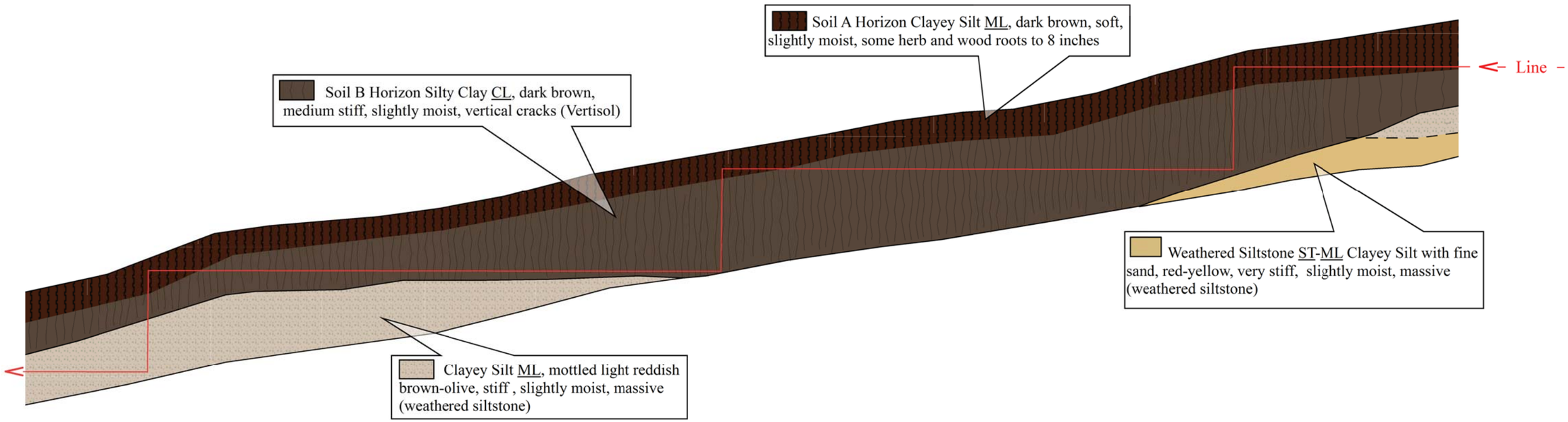
GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 210 | 200 | 190 | 180 | 170 | 160 | 150 | STA East 140



5
0 5
Scale In Feet

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

FIGURE 7
LOG OF TRENCH 47-48
STA 140 TO 280 EAST

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 280 + | 270 + | 260 + | 250 + | 240 + | 230 + | 220 + | STA East 210 +

Clayey Silt ML, mottled light reddish brown-olive, stiff , slightly moist, massive (weathered siltstone)

Soil A Horizon Clayey Silt ML, dark brown, soft, slightly moist, some herb and wood roots to 8 inches

Soil B Horizon Silty Clay CL, dark brown, medium stiff, slightly moist, vertical cracks (Vertisol)

Line

Sandstone SS fine to medium sand, light reddish-brown, slightly moist, weak, massive

Clayey Silt ML, buff, very stiff, slightly moist, massive

Silt Stone Cobbles and Boulders

STA East 320 + | 310 + | 300 + | 290 + | STA East 280 +

Soil A Horizon Clayey Silt ML, dark brown, soft, slightly moist, some herb and wood roots to 8 inches

Soil B Horizon Silty Clay CL, dark brown, medium stiff, slightly moist, vertical cracks (Vertisol)

Line

Clayey Silt ML, buff, very stiff, slightly moist, massive

5
0 5
Scale In Feet

Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

B Bulk Sample

FIGURE 8
LOG OF TRENCH 47-48
STA 210 TO 312 EAST

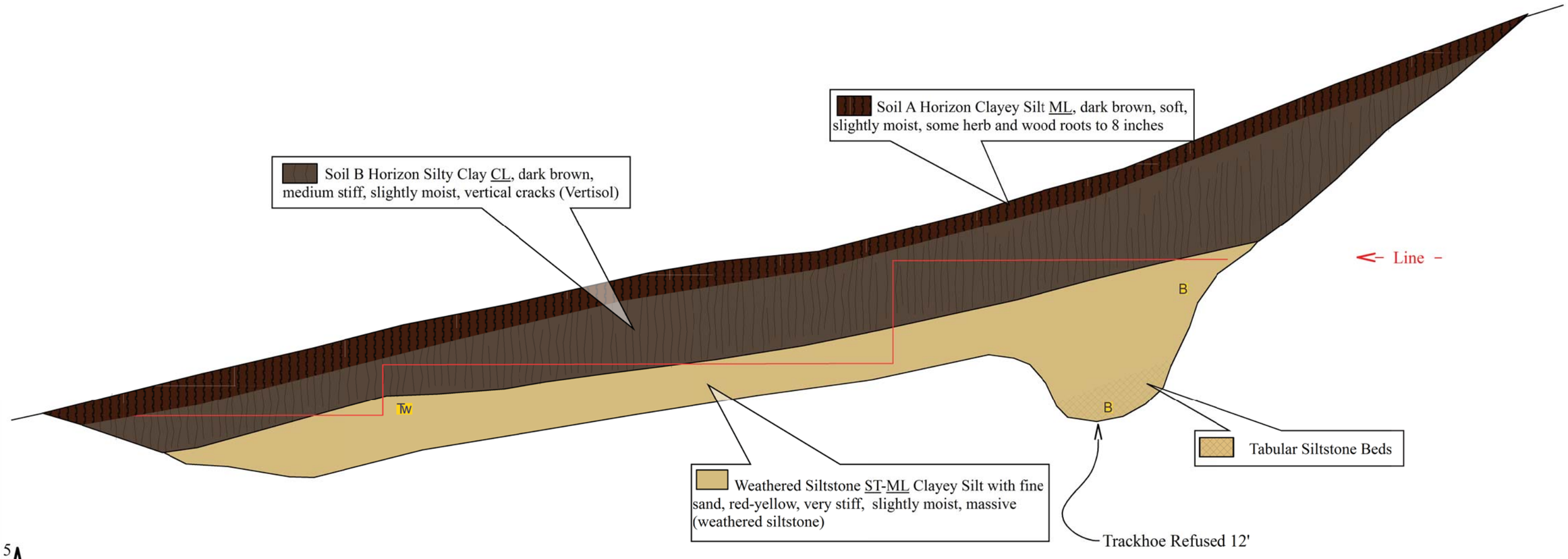
GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

Summit at Ski Lake No. 12
Job No. 2077-02N-16

South Wall of Trench

STA East 70 | 60 | 50 | 40 | 30 | 20 | 10 | STA East 00



5
0 5
Scale In Feet

Sample Locations
(see geotechnical report for sample data)

Tw Thin Wall Sample

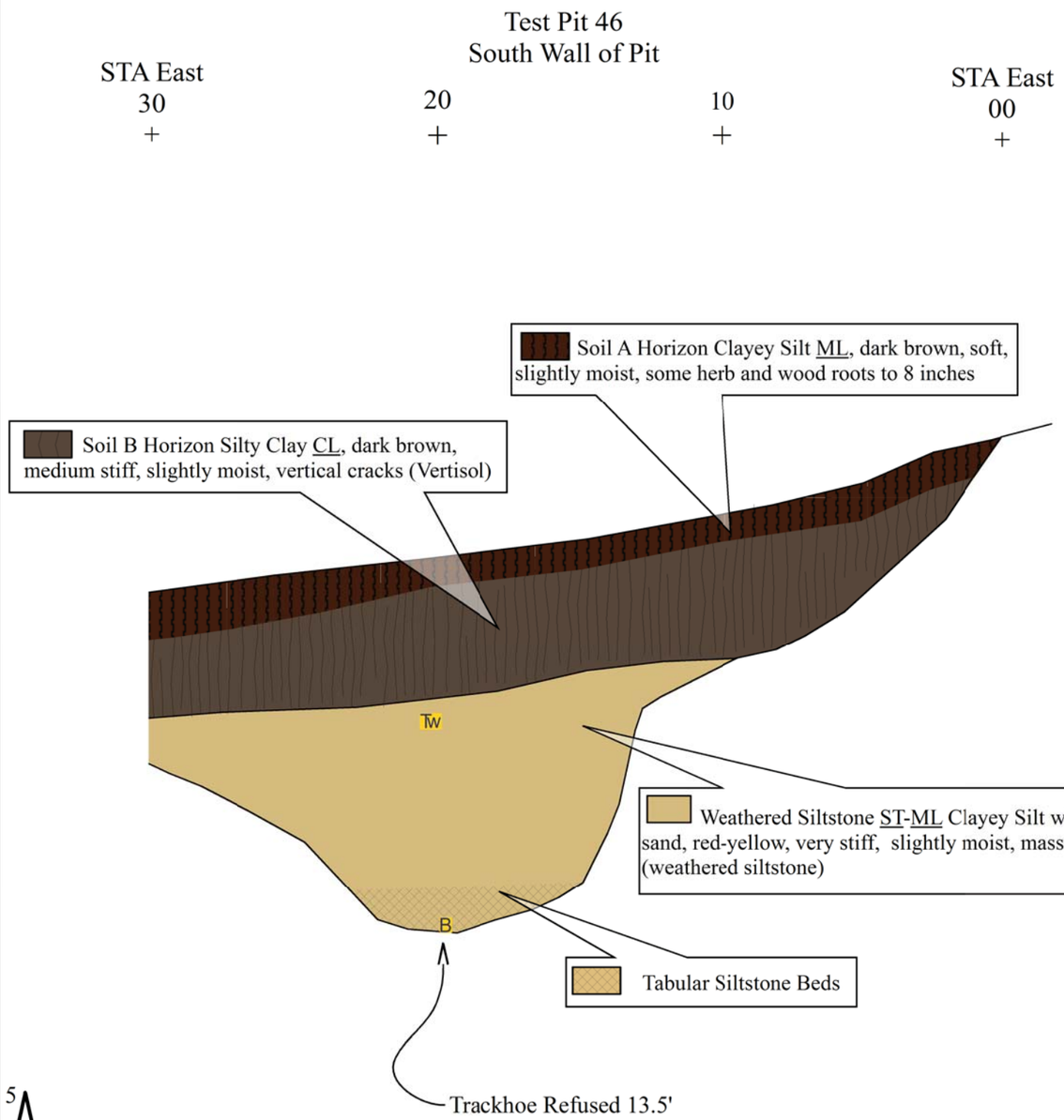
B Bulk Sample

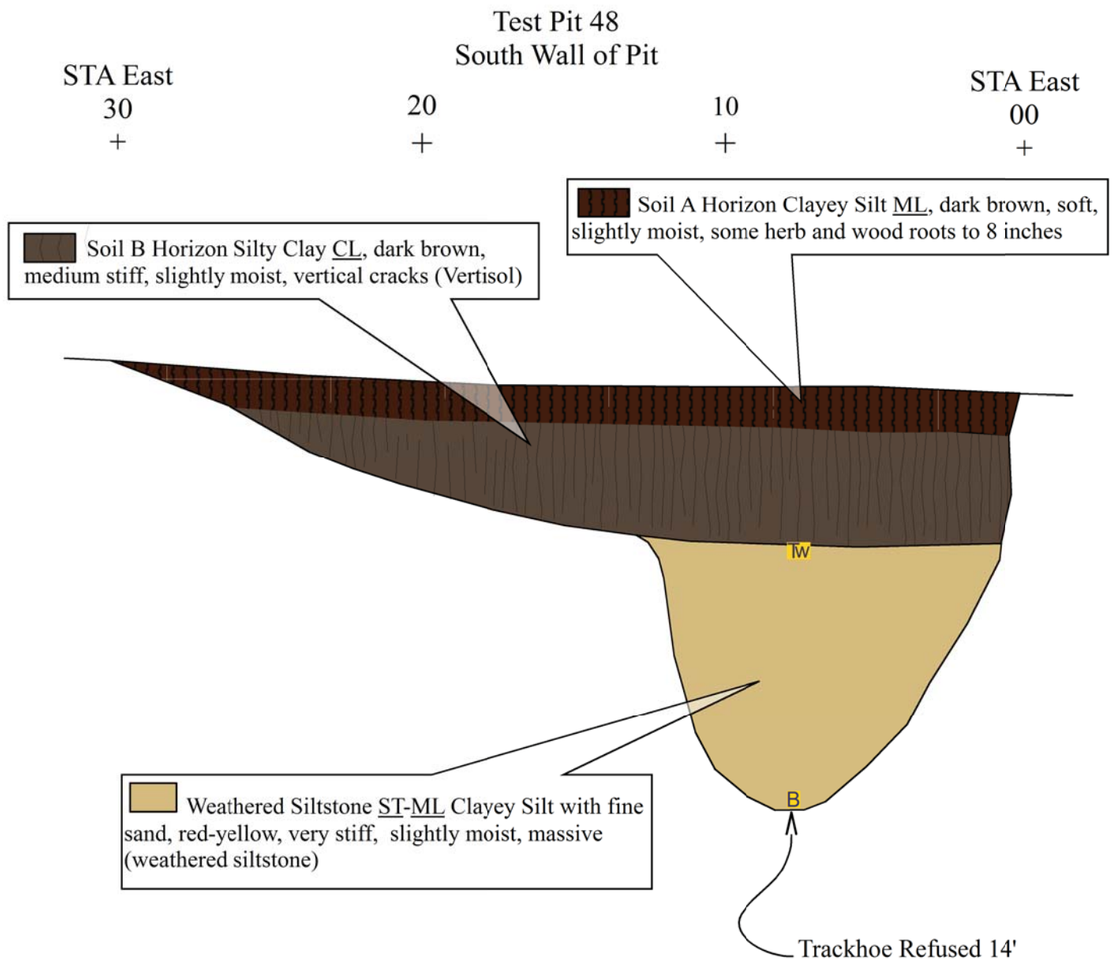
FIGURE 9
LOG OF TRENCH 48
STA 00 TO 72 EAST

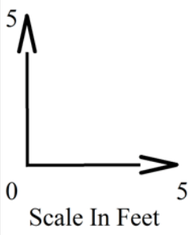
GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

Summit at Ski Lake No. 12
Job No. 2077-02N-16







Sample Locations
(see geotechnical report for sample data)

Tw Thin Wall Sample

B Bulk Sample

FIGURE 10
LOG OF TEST PIT 46
AND TEST PIT 48

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/24/16

BORING LOG

Page: 1 of 2

BORING: B-1

CLIENT: Valley Enterprise Investment Company | PROJECT NUMBER: 2077-02N-16

PROJECT: Lots 46, 47, and 48 Summit at Ski Lake No.12 | DATE STARTED: 5/26/16 | DATE FINISHED: 5/26/16

LOCATION: 6839, 6861, and 6858 Summit Peak Circle, near Huntsville, Weber County, Utah | GSH FIELD REP.: JM

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

GROUNDWATER DEPTH: Not Encountered (5/26/16) | 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 FILL	SILTY CLAY, FILL with some fine to coarse sand; some fine and coarse gravel; dark brown									moist
				8							medium stiff
			5	3							soft
				8							medium stiff
			10	20							very stiff
	CL/ SC	SILTY CLAY/CLAYEY SAND with trace fine to coarse sand; gray		80		27		55	43	17	moist hard
	ML/ CL	WEATHERED SILTSTONE/CLAYSTONE with some fine to coarse sand; gray	15	60+							moist hard
				50+		19		70	50	20	
			20	50+							
				50+							
	SM	SILTY FINE TO COARSE SAND/WEATHERED SANDSTONE	25								

See Subsurface Conditions section in the report for additional information.

FIGURE 11

BORING LOG

Page: 2 of 2

BORING: B-1

CLIENT: Valley Enterprise Investment Company | PROJECT NUMBER: 2077-02N-16

PROJECT: Lots 46, 47, and 48 Summit at Ski Lake No.12 | DATE STARTED: 5/26/16 | DATE FINISHED: 5/26/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
	SM	SILTY FINE TO COARSE SAND/WEATHERED SANDSTONE reddish-brown	25	50+							moist dense
				50+							
		grayish-red	30	50+							
	ML/CL	WEATHERED SILTSTONE/CLAYSTONE with some fine to coarse sand; gray to dark gray		50+							moist hard
			35	62					50	23	
				66							
			40	50+							
				50+							
			45	50+					43	13	
				50+							
			50	50+							
		End of Exploration at 51.5'; No groundwater at time of drilling.									

See Subsurface Conditions section in the report for additional information.

FIGURE 11
(continued)

BORING LOG

Page: 1 of 2

BORING: B-2

CLIENT: Valley Enterprise Investment Company | PROJECT NUMBER: 2077-02N-16

PROJECT: Lots 46, 47, and 48 Summit at Ski Lake No.12 | DATE STARTED: 5/27/16 | DATE FINISHED: 5/27/16

LOCATION: 6839, 6861, and 6858 Summit Peak Circle, near Huntsville, Weber County, Utah | GSH FIELD REP.: JM

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

GROUNDWATER DEPTH: Not Encountered (5/27/16) | 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 FILL	SILTY CLAY, FILL with trace fine to coarse sand; trace fine and coarse gravel; dark brown		10							moist stiff
			5	7							medium stiff
				7							
	CL	SILTY CLAY with trace fine to coarse sand; brown to black	10	21							moist very stiff
				37		25	97				
			15	46							
				75							hard
			20	47					54	27	
				53							
	CL/	SILTY CLAY/CLAYEY SILT	25								

See Subsurface Conditions section in the report for additional information.

FIGURE 12

GSH

BORING LOG

Page: 2 of 2

BORING: B-2

CLIENT: Valley Enterprise Investment Company | PROJECT NUMBER: 2077-02N-16

PROJECT: Lots 46, 47, and 48 Summit at Ski Lake No.12 | DATE STARTED: 5/27/16 | DATE FINISHED: 5/27/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
	CL/ML	SILTY CLAY/CLAYEY SILT with trace fine sand; brown	25	30							moist very stiff
		grades with trace fine and coarse gravel; light brown		13							stiff
		grades with layers of fine to coarse sand up to 1" thick	30	24					78	41	very stiff
	ML/CL	WEATHERED SILTSTONE/CLAYSTONE with some fine sand; gray		50+							moist hard
			35	50+		18					
				50+							
		grades with some oxidation	40	50+							
				50+		21		72			
		grades with layers of fine to coarse silty sand up to 6" thick	45	50+							
	SM	FINE TO COARSE SILTY SAND/WEATHERED SILTSTONE brown		50+							moist very dense
			50	50+							
		End of Exploration at 51.5'; No groundwater at time of drilling.									

See Subsurface Conditions section in the report for additional information.

FIGURE 12
(continued)

CLIENT: Valley Enterprise Investment Company
PROJECT: Lots 46, 47, and 48 Summit at Ski Lake No.12
PROJECT NUMBER: 2077-02N-16

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:

Weakly: Crumbles or breaks with handling or slight finger pressure.

Moderately: Crumbles or breaks with considerable finger pressure.

Strongly: Will not crumble or break with finger pressure.

MODIFIERS:

Trace <5%

Some 5-12%

With > 12%

MOISTURE CONTENT (FIELD TEST):

Dry: Absence of moisture, dusty, dry to the touch.

Moist: Damp but no visible water.

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	

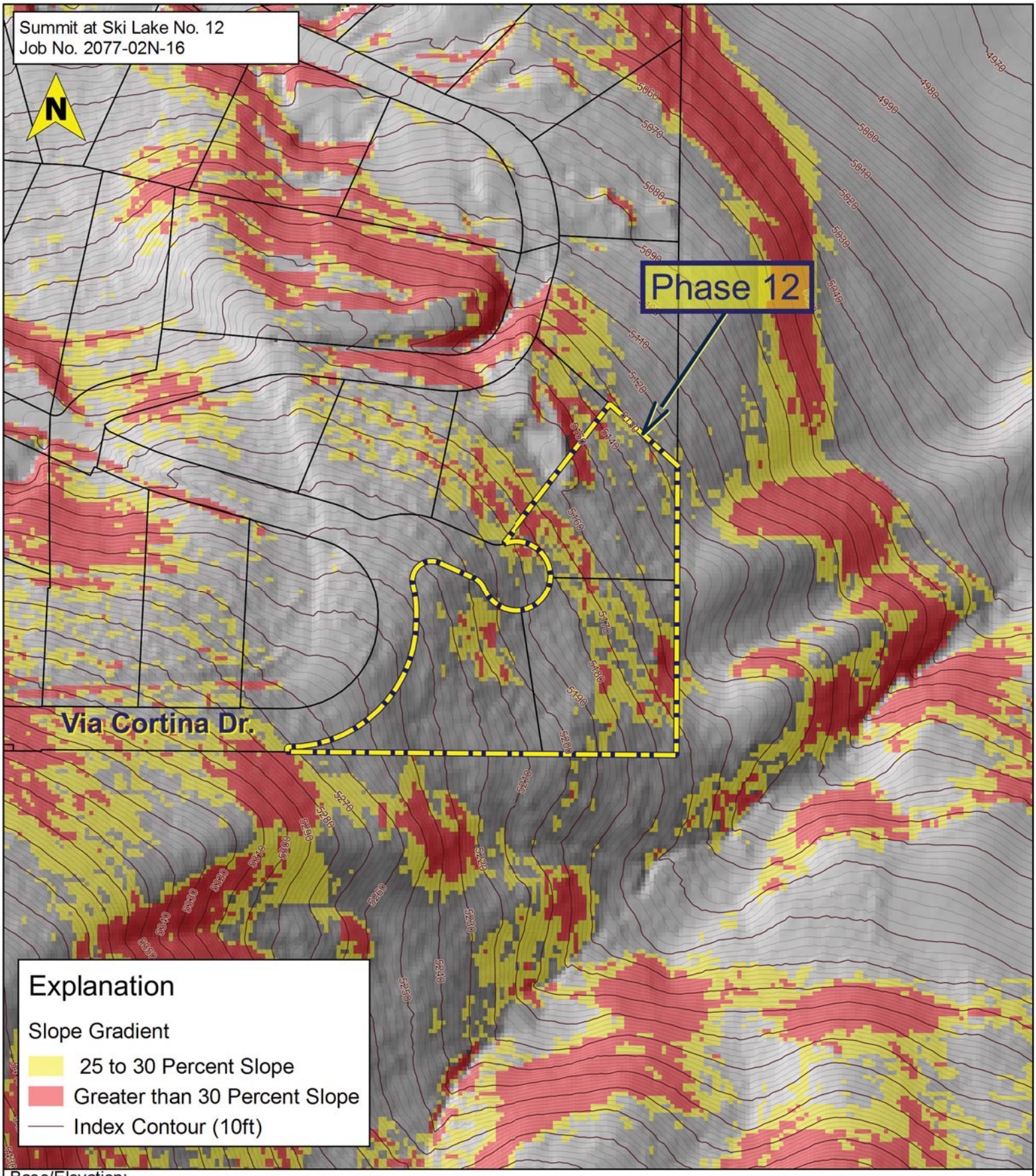
TYPICAL SAMPLER GRAPHIC SYMBOLS

- 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

GSH



Base/Elevation:
2006 2.0m Geoprocessed LiDAR
from Utah AGRC; http://gis.utah.gov/

0 200 400 ft

1:2,400

FIGURE 13
LiDAR ANALYSIS

GSH

Summit at Ski Lake No. 12
Job No. 2077-02N-16

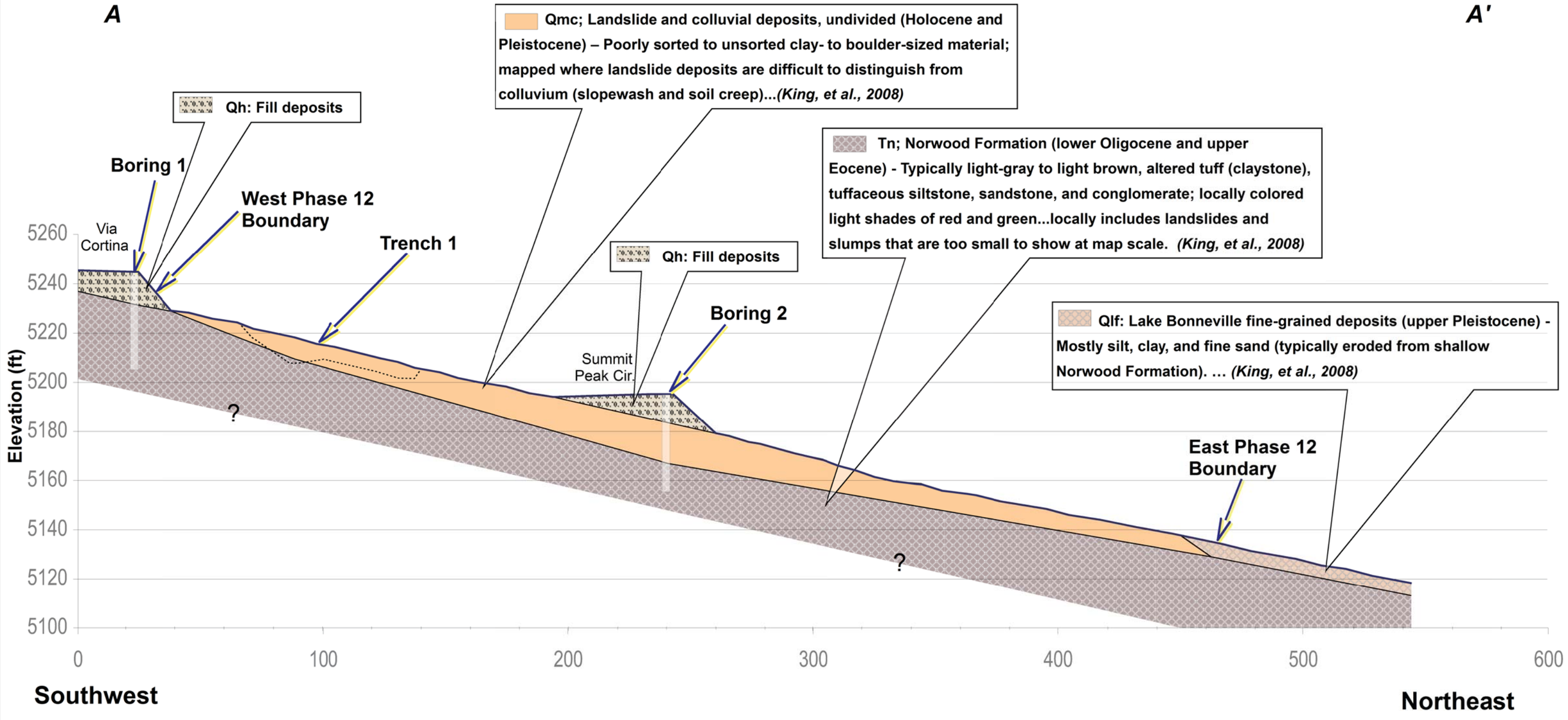


FIGURE 14
GEOLOGIC SLOPE
CROSS SECTION *A-A'*

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 10/21/16

* From Section Shown On Figure 3