REPORT
ENGINEERING GEOLOGY STUDY
THE BRIDGES AT WOLF CREEK EAST PHASE 1
PARTS OF SECTIONS 15, 16, AND 22 TOWNSHIP 7 NORTH, RANGE 1 EAST SLBM
EDEN, UTAH

Submitted To:

Lewis Homes
Attention: Mr. Eric Householder
3718 North Wolf Creek Drive
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Submitted By:

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July 25, 2016

Job No. 1661-08N-16

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Mr. Eric Householder
Lewis Homes
3718 North Wolf Creek Drive
Eden, Utah 84310

Re: Engineering Geology Study
The Bridges at Wolf Creek East Phase 1
Parts of Sections 15, 16 and 22 Township 7 North, Range 1 East SLBM
Eden area, Ogden Valley Township, Unincorporated Weber County, Utah
(41.3389 N, 111.8323 W)

1. Introduction

The proposed Bridges at Wolf Creek project (the Project) consists of subdividing and constructing a 357-lot residential subdivision on an approximately 195-acre parcel located northwest of Fairway Drive near Eden, Utah, as shown on Figure 1, Vicinity Map. The present Master Plan concept includes single-family residential lots with utility service and sanitary sewer connections, and associated roadways and pavements. Site development will require a moderate amount of earthwork in the form of site grading. Individual lots will be for single family residences and will be approximately one-quarter acre in size.

A geotechnical engineering study for the Project was completed by GSH Geotechnical Inc., (GSH) on January 21, 2016. The geotechnical study was performed to evaluate the Project site conditions and soils relevant to site development engineering, earthwork and foundation requirements.

During site development review for the Project, Weber County Planning and Engineering staff identified areas of potential geological hazards on the proposed Project area. A meeting was held at the Weber County offices January 29, 2016 to discuss the proposed Project improvements and exposure to potential geological hazards identified during the site development review.

The following individuals were present at the January 29 meeting:

Ronda Kippen (Weber County Planning)
Dana Schuler PE (Weber County Engineering)
Jim Gentry (Weber County Planning)
David Simon PG, (Simon and Associates), Weber County Geological Consultant

Alan Taylor, PE (Taylor Geotechnical) Weber County Geotechnical Engineering Consultant.
Greg Schlenker, PG, (GSH Geotechnical Inc.,) Proponent Geological Consultant.
Andrew Harris, PE, (GSH Geotechnical Inc.,) Proponent Geotechnical Engineering Consultant.
Ryan Christenson, (Gardner Engineering), Proponent Engineering Consultant.
Eric Housholder, (Wolf Creek Bridges Holding Co.) Proponent Project Manager

Because potential geological hazards identified during the development review appeared to impact the proposed Project improvements, and because little is known as to the real potential and severity of the recently identified potential geological hazards, Weber County Staff determined that appropriate studies should be conducted, as stipulated by the requirements of the Weber County Hillside Development Review Procedures and Standards, including Chapter 27, Natural Hazards Overlay District, of the Weber County Zoning Ordinance.

A desktop study including the engineering geology mapping and evaluation for the Project site was conducted by GSH for Lewis Homes on April 22, 2016 (GSH Geotechnical Inc., 2016b). The purpose of the desktop studies was to develop an understanding as to the location, potential and severity of the geological hazards identified on the Project site, and to develop a workable Geologic Hazards scope of work to suffice the Chapter 27, Natural Hazards Overlay District requirements.

On the basis of the findings of the Desktop Studies the following scope of work for this present study was developed for implementation during the Spring of 2016. The desktop studies were conducted for the entirety of the 195-acre area Wolf Creek Master Plan area, however the present Scope of Work and reporting includes only the eastern part (third) of the Project, an area of approximately 85 acres that includes the Parkside Phases 1, 2 and 3, and the Mountainside Phases 1, 3 and 4. The generalized location of these proposed East Phase improvements are shown on Figure 2, Site Plan and Proposed Layout. The Site Plan and Proposed Layout shown on Figure 2 were drawn from a Langvart Design Group drawing titled "Phasing Plan" dated May 31, 2016.

1.1 Scope of Work

The Scope of Work presented for this evaluation includes eastern part of the Project, an area of approximately 85 acres that includes the Parkside Phases 1, 2 and 3, and the Mountainside Phases 1, 3 and 4 (East Phase), as it pertains to the Weber County Chapter 27 Natural Hazards Overlay District Code. Based on the Chapter 27 requirements, GSH has performed the following scope of work for this engineering geology study:

1. ***Literature Review:*** *A preliminary study and review of published and unpublished geologic and geotechnical information pertinent to the site (both regional and site specific);*

2. ***Technical Analysis****: A review and interpretation of available stereoscopic and oblique aerial photographs, DEMs, LiDAR and GIS data;*
3. ***Field Reconnaissance:*** *A field reconnaissance study including the geologic/geotechnical logging and geotechnical sampling of two walk-in exploration trenches approximately 420 feet and 143 feet in length and as much as 10 feet in depth, and the geotechnical logging and sampling of 17 walk-in test pits to a depth of as much as 19 feet, and five geotechnical hollow-stem auger borings to 30 to 50 feet in depth (or auger refusal). The locations of our sub-surface excavations and borings are shown on Figure 3, Site Evaluation and Engineering Geology;*
4. ***Geologic Mapping:*** *Site specific geological mapping and classification to identify critical geological units and exposure to proposed site improvements;*
5. ***Surface Analysis:*** *Surface and 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, and to develop geologic cross sections for our slope stability analysis;*
6. ***Soils Laboratory Program:*** *A laboratory geotechnical soils testing program of samples recovered from the trenches, test pits and borings for typical and critical geological units explored and identified in our subsurface evaluation. The 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 sample; and*
7. ***Summary Report****: Preparation of summary report presenting results of our analysis and findings, and in conjunction with this reporting a concurrent geotechnical slope stability study will be prepared for the subject property based on the findings and analysis of this geologic study.*

2. Site Engineering Geology Analysis

2.1 Literature Review

As part of these preliminary studies existing previous reports and geological literature sources were reviewed. Specific to the site and immediate surrounding area, geotechnical reporting and mapping by our staff GSH Geotechnical Inc. (2016a), and an untitled and undated Site Concept Plan provided by Lewis Homes were reviewed. The 2016 geotechnical study was performed to evaluate the Project site conditions and soils relevant to site development engineering, earthwork and foundation requirements. As part of the 2016 study 33 test pits were excavated and sampled. Geologic mapping and studies pertaining the Project and Ogden Valley area in general, included USGS geological mapping by Sorensen and Crittenden (1979), UGS geological and groundwater reporting by Avery (1994), in-progress UGS mapping by King and McDonald (2014), and recently published mapping by Coogan and King (2016).

2.2 GIS Data Integration and Analysis

Our GIS data integration effort included reviews of previous mapping and literature pertaining to site geology including Sorensen and Crittenden (1979), in-progress UGS mapping by King and McDonald (2014), and recently published mapping by Coogan and King (2016); an analysis of vertical and stereoscopic aerial photography for the site including a 1946 1:20,000 stereoscopic sequence, a 2014 1.0 meter digital NAIP coverage, and a 2012 5.0 inch digital HRO coverage of the site; and a GIS analysis using the QGIS® GIS platform to geoprocess and analyze 2006 2.0 meter LiDAR digital elevation data made available for the site by the Utah Automated Geographic Reference Center (AGRC). The GIS analysis included using the QGIS® platform Geospatial Data Abstraction Library (GDAL, 2013) Contour; the GRASS® (Geographic Resources Analysis Support System, 2013) r.slope and r.shaded.relief modules.

The following GIS layers have been developed or processed for this analysis:

1. <u>Engineering Geology</u>; vector file developed and modified from geological mapping of King and McDonald, 2014, and reviewed from aerial imagery.
2. <u>Cienega Areas</u>; vector file of groundwater effluent zones identified from referenced aerial imagery.
3. <u>Contour Elevations</u> (2 foot); vector file of elevation contours processed from 2006 2.0 meter LiDAR data.
4. <u>Shaded Relief</u>; raster file of surface relief shading processed from 2006 2.0 meter LiDAR data.
5. <u>Slope Gradient</u>; raster file of surface slope gradients processed from 2006 2.0 meter LiDAR data.
6. <u>Geological/Natural Hazards</u>; vector file of data integrated from the above listed layers and reference data classified according the following areal categories;
   a. shallow-seasonal groundwater,
   b. alluvial fan-debris flow hazards,
   c. landslide-mass movement hazards,
   d. alluvial fan-debris flow hazards/landslide-mass movement hazards (combined area),
   e. slope stability hazards,
   f. flood hazards, and
   g. steep slopes.

2.3 Field Program

The field program involved the excavation and geological logging of two exploration trenches and 17 test pits and the advancement of five drilled boreholes on the locations shown on Figure 3. GSH conducted preliminary field operations at the site on the dates of March 16 and 17, 2016 completing Test Pits 1 through 11 (no Test Pit 8 was excavated). The primary phase of our field program was conducted from May 6 through May 19, 2016, during which Trenches 1 and 2, Test Pits 12 to 18, and Borings 1 to 5 were completed. 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 each of the proposed areas of improvement, and borings were placed on slope locations in order to evaluate geologic subsurface conditions relative to slope stability conditions for the East Phase. The locations of our trenches, test pits and borings are included on Figure 3. The trenches were from 420 and 143 feet in length and extended as deep as 10.0 feet, and the test pits consisted of walk-in excavations, 15.0 to 25.0 feet in length and extended as deep as 19.0 feet. The trenches and test pits were logged so as to illustrate the vertical and lateral characteristics and variations of soil and rock conditions comprising the subsurface 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 many of the excavations as indicated on our field logs. In addition to the observations in the trenches and test pits, the general surface of the site and surrounding area was reconnoitered to assess geological and slope conditions. Feature locations and elevation data were recorded using a hand-held GPS receiver device.

Our field program was conducted by Senior Engineering Geologist Dr. Greg Schlenker, PG of our geotechnical staff. Mr. Amos Allard, Staff Geologist also of our geotechnical staff visited the site to assist Dr. Schlenker and to collect soil samples from the trenches test pits for laboratory geotechnical testing. Mr. Allard also supervised drilling operations for the Geotechnical Borings.

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, and the results are included in our geotechnical study. Detailed graphical representations of the subsurface conditions encountered are presented on Figure 4 through Figure 8, Log of Trenches, Figure 9 through Figure 17, Log of Test Pits, and our Boring Logs of the five borings are included in the Appendix A of this report. It should be noted that no Log for Test Pit 8 is presented as this location was eliminated at the time of our preliminary field program. 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 trenches and 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 are included in our accompanying geotechnical report. Groundwater was observed and recorded in several of the excavations or test pits during the dates of our field program. Piezometers were placed in all the test pits and borings except Test Pit 10 and 12.

The logs of the five borings shown at the locations on Figure 3, are include in Appendix A of this report. These borings were made as part of our concurrent geotechnical study and included in this reporting, were supplemental for the development of our Geologic Slope Cross Sections *A-A′* and *B-B′* on Figures 20 and 21. 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. 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. 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 18, LiDAR-Slope Analysis, presents the results of our slope analysis efforts. Shown on Figure 18, is the 25-percent, and greater than 30-percent slope gradients across the site. The shaded relief rendering on Figure 18 also provides a visual basis for landform interpretation, and the contour elevation data shown on Figure 18 is used to develop the cross sections shown on Figures 20 and 21, Geologic Slope Cross Sections *A-A′* and *B-B′*. The critical gradient for slope development considerations according to the Weber County Section 108-14-3, 108-14-7, 108-14-8 , and 108-14-12 includes slopes greater that 25-percent (Weber County Code, 2016). The Geologic Slope Cross Sections shown on Figure 20 and 21 will be used for modeling slope stability analysis in our geotechnical reporting.

3. SITE CONDITIONS

The site conditions and site engineering 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 and McDonald, 2014; and Coogan and King, 2016), photogeologic analyses of 2012 and 2014 imagery shown on Figure 2, and historical stereoscopic imagery flown in 1946. GIS analyses of elevation and geoprocessed DEM terrain data as discussed in the previous section and shown on Figure 18. Seismic hazards information was developed from United States Geologic Survey (USGS) databases (Peterson, et al., 2008).

3.3 Surface

A surface reconnaissance of the site was conducted on March 16 and 17 and May 6 through May 19 of this year. As shown on Figure 1 and Figure 2, the East Phase consists of an area of approximately 85 acres that is currently vacant and undeveloped. Surface vegetation consists of open areas of grasses, weeds and sage brush, with wooded cover of scrub oak, alder and maple trees occupying slopes on the south side of the site, and cottonwood and willows occupying the riparian zones of the site. The topography of the site consists of a "piedmont" (valley-margin) slope, which is an intermediate slope surface between the mountains and the valley bottom. The elevation of the site is between 5,296 feet on the very southwest of the property and 5,700 feet on the northeast of the property. This piedmont slope is located at the base of 7,000 foot high ridgelines that buttress James Peak which rises to 9,424 feet, approximately 4 miles northeast of the site. The floodplain of the North Fork of the Ogden River forms the lowest elevations in the site vicinity with elevations on the order of 5,060 feet to 5,100 feet along the grade of the river approximately 1/3-mile west of the site. Wolf Creek is a through-flowing perennial stream that drains from the James Peak area on the north, and passes the site near the eastern boundary. Two unnamed, apparently ephemeral, drainages cross the site from northeast to southwest. An array of cienegas occurs along the piedmont slope surface where emergent groundwater appears to intercept the ground surface along the mountain front. A sewer line for the service of Powder Mountain Resort, located approximately 3.5 miles northeast of the site, crosses the northeast corner of the Project and terminates at a lagoon system approximately 4500 feet northwest of the East Phase site. The East Phase site, as shown on Figure 2, is bordered on the south and west by vacant and residential land uses, and on the north and east by steeply sloped unimproved ground. State Road SR-158, locally known as Powder Mountain Road, passes the East Phase site on the east along Wolf Creek.

3.4 Geologic Setting

The site is located in Ogden Valley on the southwestern flank of James Peak. The valley is a northwest trending fault bounded graben structure, with the Wasatch Range comprising the western flank of the valley and the Bear River Range the eastern flank (Avery, 1995). The western boundary of the Wasatch Range (Wasatch Front) is marked by the Wasatch fault, approximately 5.5 miles west of the site, and provides the basis of division between the Middle Rocky Mountain Physiographic Province 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 crests of Lewis Peak (8,031 feet) west of the valley and James Peak on the east. This exposure was the result of movement along locally high-angle faults during late Tertiary and Quaternary age (Bryant, 1988). The older Precambrian rocks that underlie the site are parts of eastward thrusted plates including the Willard thrust sheet, which is believed to have moved onto the vicinity during the Cretaceous Sevier orogeny, approximately 140 million years ago. The older Precambrian rocks have since been exposed by uplift along the valley bounding faults that has been occurring over the past 10 million years.

During the most recent stage of geologic time, the Quaternary Period, including the past one million years, permanent (year-round) ice and glaciers have periodically occupied the higher elevation summits surrounding the site, and waters of Lake Bonneville have risen to within a few feet of the site approximately 15,000 years ago (Currey and Oviatt, 1985).

The site location occupies a piedmont surface that is believed to be largely underlain by eroded Precambrian rocks (Sorensen and Crittenden,1979), Quaternary age valley-fill sediments (Avery, 1994), and mantled on the surface with Quaternary age soils placed by alluvial and mass movement processes and modified by erosion and soil development processes (King and McDonald, 2014; Coogan and King, 2016).

3.5 Site Engineering Geology

The previous existing 1:24,000 scale mapping of the site was prepared by US Geological Survey geologist in 1979 (Sorensen and Crittenden,1979), wherein the 1979 mapping focused on the distribution of bedrock formation contacts and geologic structure of the area. More recent mapping efforts by Utah Geological Survey (UGS) geologist, Coogan and King, (2001, 2016), and King and McDonald (2014) has included mapping that is more inclusive of the surficial Quaternary soils that are more indicative of engineering geology conditions and hazard processes. The King and McDonald (2014) mapping is a 1:24,000 scale U.S. Geological Survey quadrangle based effort that is currently distributed as an "In-Progress Document" subject to review and revision.

Our interpretation of the site engineering geology is presented on Figure 3 Site Evaluation and Engineering Geology. The engineering geologic mapping shown on Figure 4 is largely based on previous mapping prepared by King and McDonald (2014), with amendments to the mapping drawn herein on the basis of the findings of this study. A summary of the mapping units identified on/or in the vicinity of the East Phase are listed below in relative or inferred age sequence (youngest-top to oldest bottom):

Af1 - Alluvial-fan deposits, younger-active (Holocene)
Qaf? - Alluvial-fan deposits, undivided (Holocene and Pleistocene)
Qafy - Younger alluvial-fan deposits (Holocene and uppermost Pleistocene)
Qaf2, Qafp?, Qafb?, Qafo? - Older alluvial-fan deposits (upper and middle (?) Pleistocene)

Qafoe? - Eroded old alluvial-fan deposits (middle and lower Pleistocene)
Qac - Alluvium and colluvium (Holocene and Pleistocene)
Qacg, Qacg? - Gravelly alluvium and colluvium deposits (Holocene and Pleistocene)
Qc - Colluvium (Holocene and Pleistocene)
Qcg - Gravelly colluvial deposits (Holocene and Pleistocene)
Qms - Landslide and slump deposits (Holocene and Pleistocene)
Qmc - Landslide and slump, and colluvial deposits, undivided (Holocene and Pleistocene)
Qmdfp? - Debris- and mud-flow deposits (Holocene and Pleistocene)
Zkc - Kelly Canyon Formation, Siltstone-quartzite
Zmcc - Maple Canyon Formation; **Zmcc1 -** lower conglomerate member; **Zmcc2 -** argillite; **Zmcc3? -** quartzite conglomerate.

The engineering geology mapping included the delineation of **Cienega Areas** on the site. The significance of the cienega areas is that these are areas of groundwater emergence, with affect of shallow groundwater limiting site development, and the affect of groundwater reducing soil strength of the site slopes.

Site slopes and terrain conditions are presented on Figure 18, LiDAR-Slope Analysis. The elevation contours and site slope gradients on Figure 18 were developed from our LiDAR analysis. Surface gradients were found to range from level to over 65-percent as shown on Figure 18. For the site area, the slope gradient averaged 15.6-percent, with areas both above and below the average as shown on Figure 18. As previously mentioned in Section 2.3 of this report, the critical slope gradient for site development considerations according to the Weber County Code is 25-percent or greater. The terrain features illustrated by the relief shading on Figure 18, assisted in the interpretation and/or confirmation of the engineering geology units presented in Figure 3.

3.6 Subsurface Observations Trenches and Test Pits

The soils encountered in the trenches consisted of a complex sequence of clays (CL) silty clays (CL), clayey silts (ML), silts (ML), and sandy silts (ML) , with varying percentages of matrix-supported sub-angular and angular cobble and boulder (oversized) clast. Bedrock was not encountered in any of the trenches or test pits excavated on the East Phase site. Bedrock was however is believed to have been encountered by auger refusal at depth in Boring 1 at 45 feet and Boring 2 at 33 feet. The soils encountered in the trenches and test pits included residual and colluvial deposits, landslide and slope creep deposits, debris flow deposits, and overbank flood deposits.

The soils interpreted to have undergone landslide movement showed soft to medium-stiff consistencies, with rotated over sized clasts, and coloration from oxidation (Fe-iron staining) and reduction (gleization) oxides, and/or mottled coloration from both processes. Higher moisture conditions were generally found in the landslide soil deposits. Landslide and slope creep deposit soils were observed in Trench 1 and 2, Test Pits 1, 2, 3, 4, 5, 6, 7, 9, 15, 16, 17 and 18, and Borings 1 through 5.

The residual and colluvial soil deposits encountered on the site were observed in similar context with the landslide deposits except that these deposits were stiff to very stiff in consistency, and not as strongly colored in response to oxidation and reduction processes. The residual and colluvial deposit soils were observed in Trench 1 and 2, and Test Pits 2, 3, 12, 13, 14 and 15.

The debris flow deposits consisted of sandy clays (CL), and clayey gravels (GC) with clast supported matrices, and significantly higher percentages of sand. Diagnostic pin-hole structures were observed in the sandy clay soils (CL) classified as debris flow deposits. Debris flow deposit soils were observed in Trench 1, Test Pits 10 and 11.

The silty clay (CL) alluvial overbank deposits consisted of massive medium-stiff clay deposits. The Alluvial overbank deposit soils were observed in the west part of Trench 1

Topsoil A horizons observed on the surface of the borings, trenches, and test pits consisted of clayey silts, silts and sandy silts (ML), dark brown in color with herb roots extending 6-inches to a foot below the surface.

3.7 Subsurface Observations Borings

As part of our exploration program five soil borings were drilled on the site at the locations shown on Figure 3. Borings were located in conjunction with proposed site improvements and mapped landslide locations. The borings were drilled between May 4 and May 20 of this year. The borings were completed using a CME 55 drill rig using hollow-stem auger and rotary wash equipment and methods. Soil samples were recovered at 2.5-foot intervals using driven 2.42-inch inside diameter drive Dames & Moore sampler. Recovered samples were returned to our laboratory for testing, and the results of these tests will be included in our concurrent geotechnical report.

The conditions encountered in borings consisted of stiff, very stiff, and hard clays (CL) with traces to some fine and coarse gravels, cobbles, and boulders. Layers of clayey gravels (GC) were encountered between 10 and 17 feet in depth in Boring 4, and 25 and 27 feet in depth in Boring 5. Boring 1 was refused at 45.0 feet, Boring 2 was refused at 33.0 feet, Boring 3 was refused at 41.5 feet, Boring 3 was refused at 36.5 feet, and Boring 5 was refused at 41.5 feet. Each of the borings were completed with slotted PVC to the depths penetrated and backfilled with auger cuttings. Groundwater was encountered about 5.0 to 10.0 feet within the borings at the time of drilling.

3.7 Groundwater

Soil groundwater conditions were recorded in the excavations at the time of our field programs in March and May of 2016. Slotted PVC piezometers were placed in most of the Test Pits and Trench 2, and all of the borings.

Stabilized water levels were measured within the installed piezometers on July 1, 2016 and are summarized on the following page.

Location	Level Below Surface (ft) on 5/4/16 to 5/9/16	Level Below Surface (ft) on 7/1/16	Comments
Test Pit 1	1.0	5.6	Piezometer
Test Pit 2	2.5	7.7	Pizometer
Test Pit 3	0.0	0.0	Piezometer...water at surface
Test Pit 4	4.0	Pipe Damaged	Piezometer
Test Pit 5	Not encountered	Not encountered	Piezometer...dry to 14.0 feet
Test Pit 6	3.0	4.7	Piezometer
Test Pit 7		Not encountered	Piezometer...dry to 12.5 feet
Test Pit 9	3.0	7.6	Piezometer
Test Pit 11	Not encountered	Not encountered	Piezometer...dry to 9.0 feet
Test Pit 13	Not encountered	Not encountered	Piezometer… dry to 11.7 feet
Test Pit 14	10.0	5/9/16	Vadose water entering test pit
Test Pit 15	Not encountered	Not encountered	Piezometer… dry to 9.5 feet
Test Pit 16	Not encountered	7.5	Piezometer
Test Pit 17	Not encountered	Pipe Damaged	Piezometer
Test Pit 18	Not encountered	8.0	Piezometer
Trench 2 STA 05	5.0	Not encountered	Observed in trench
Boring 1	5.0	5.6	Encountered during drilling
Boring 2	5.0	3.2	Encountered during drilling

Boring 3	5.0	5.5	Encountered during drilling
Boring 4	7.5	7.3	Encountered during drilling
Boring 5	5.0	10.5	Encountered during drilling

4. DISCUSSIONS AND RECOMMENDATIONS

4.1. Site Specific Geologic/Natural Hazards

On the basis of our literature reviews, site engineering geology mapping, subsurface exploration and slope and terrain mapping we have prepared a Geologic/Natural Hazards Exposure map for the East Phase site, as shown on Figure 19, Geologic/Natural Hazard Exposure. This map has been classified for the delineation of potential geologic or natural hazards impacting the site, including; a) shallow-seasonal groundwater, b) alluvial fan-debris flow hazards, c) landslide-mass movement hazards, d) alluvial fan-debris flow hazards/landslide-mass movement hazards (combined area), e) slope stability hazards, f) flood hazards, and g) steep slopes.

4.1.1 Shallow-Seasonal Groundwater, Hazards or conditions include the mapped Cienega Areas as shown on Figure 3, where groundwater emerges to the surface. These areas were identified through the aerial photography analysis and site reconnaissance. The affect of shallow groundwater presents limitations for site development, and will also affect the soil strength and mass of site slopes, and can negatively affect slope stability.

4.1.2 Alluvial Fan-Debris Flow Hazards, Hazards or conditions include debris flows and clear-water flooding that are systemic processes that occur on active alluvial fan surfaces. Debris-flow hazards involve the rapid downslope movement of hyper-concentrated sediments in response to intense rainfall and/or snowmelt events. The debris-flow sediments typically originate in steep drainage basins, and move downslope as a concentrated and confined flow. After the flow passes through the originating canyon mouth, beyond the steep and confining limits of the drainage basin onto an open valley floor, the flow will slow and come to a rest, forming an alluvial fan deposit (Giraud, 2005). Over time successive debris-flow and/or alluvial fan events will construct significantly large alluvial fan systems at the mouths of the contributing canyons or drainage basins.

Clear-water flood, without debris, can also occur on alluvial fan surfaces in response to meteorological/snowmelt events.

Alluvial Fan-Debris Flow Hazard areas shown on Figure 19 include engineering geology units mapped as **Af1, Qaf?,** and **Qafy** on Figure 3. Older alluvial fan deposits mapped as **Qaf2, Qafp?, Qafb?, Qafo?,** and **Qafoe?** on Figure 3, are believed to have been formed by alluvial fan debris-flow processes, but are believed to not presently be subject to those process activities.

4.1.3 Landslide-Mass Movement Hazards, are the downslope movement of a mass of soil, surficial deposits or bedrock, that includes a continuum of processes between landslides, earth-flows, debris flows and debris avalanches, and rock falls. Landslide hazards are identified where terrain features such as; head scarps (main scarps), minor scarps, transverse cracks and ridges, hummocky surfaces and toe development are observed (Varnes, 1978).

The Landslide-Mass Movement Hazard areas shown on Figure 19 include engineering geology units mapped as **Qms** on Figure 3. The locations of the landslide deposits on the East Phase area appear to correlate to areas downslope of Maple Canyon Formation argillite beds mapped as **Zmcc2** on Figure 3.

For the East Phase site the areas of landsliding include two areas, an eastern slide area near the eastern boundary of the site where Snowflake drive accesses the site, and a northwestern slide area clustered along the axis of the unnamed northeast to southwest drainage that emerges from the Cienega on the northeast corner of the site. Both of these landslide areas display complex combined earth-flow/soil creep morphology (Varnes, 1978), that has occurred on relatively low gradient slopes. These landslide deposits appear to be relatively shallow (extending about 30 to 45 feet below existing site grades) in context to the areal distribution of the deposits.

4.1.4 Alluvial Fan-Debris Flow Hazards/Landslide-Mass Movement Hazards (combined area) shown on Figure 19, include areas on Figure 3 where both these hazard conditions are present.

4.1.5 Slope Stability Hazards Although evidence of active landslide movement is not apparent, areas on the site covered with soils that are inherently weak and/or expansive, or consisting of older landslide deposits, may become unstable upon implementation of site grading and/or improvements. The areas classified on Figure 19 as Slope Stability Hazards, and include areas mapped on Figure 3 as **Qmc** and **Qmso**.

4.1.6 Flood Hazards shown on Figure 19 include areas on or near the East Phase where alluvial stream deposition along Wolf Creek has occurred in response to overbank stream flows. These include areas mapped as **Qac** on Figure 3.

The FEMA 100-year flood hazard zone as delimited by recent FEMA studies conducted in the Ogden Valley and Wolf Creek area fall within the **Qac** unit shown on Figure 3 (FEMA 2015). On the basis of the FEMA determination *...mandatory flood insurance purchase requirements and floodplain management standards apply...* for improvements made in the 100-year flood hazard zone, however the entirety of the East Phase site is **Qac** area shown on Figure 19.

4.1.7 Steep Slopes Steep slope conditions present difficulty in maintaining and controlling slope stability and runoff when improvements such as grading are made in these areas. By rule Weber County limits site development improvements on slopes 25-

percent grade or steeper. Rules or limits that apply to improvements are included Weber County code Sections 108-14-3, 108-14-7, 108-14-8 , and 108-14-12 (Weber County Code, 2016). The areas shown on Figure 19 as Steep Slopes, include slopes identified through our LiDAR analysis and shown on Figure18.

4.1.8 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 0.17*g*, and for a two-percent probability of exceedance in 50 years is as high as 0.37*g* for the site. Ground accelerations greater than these are possible but will have a lower probability of occurrence.

4.1.9 Active Earthqauke Faults: Based upon our review of available literature, no active faults are known to pass through or immediately adjacent to the site. The nearest active (Holocene) fault is the Weber Segment of the Wasatch fault, located 5.5 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). An older Quaternary aged fault, the Ogden Valley northeastern margin fault ends approximately 0.7 miles east of the site (Black et al., 2004). This older fault is not expected to move during the design life of the project.

4.1.10 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.

No area-wide liquefaction potential studies have been conducted for the Ogden Valley area, thus this potential hazard has not been mapped in the East Phase vicinity. Because liquefaction commonly occurs in saturated non-cohesive soils such as alluvium, areas of the East Phase vicinity mapped as **Qac** should be considered susceptible to liquefaction processes.

4.1.11 Rockfall and Avalanche Hazards: Rockfall and avalanche hazards were not identified on the East Phase during this desk top study. The East Phase boundary appears to be located an adequate distance from the steep slope areas northeast of the site where such hazards may originate.

4.1.12 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 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 is mapped as "Moderate" for parts of the East Phase site 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.

5. Hazard Exposure and Mitigation

Hazards exposure for the East Phase of the Bridges at Wolf Creek is shown on Figure 19, and includes Shallow-Seasonal Groundwater areas **(Cienega)**, Landslide-Mass Movement Hazard areas **(Qms)**, and Alluvial Fan - Debris Flow Hazard areas **(Qafy).**

The two landslide areas described herein are complex combined earth-flow/soil creep features that have occurred on relatively low gradient slopes, and appear to be relatively shallow in thickness. Apparent from the mapping on Figure 19, is the areal relationship between Shallow-Seasonal Groundwater areas Landslide-Mass Movement Hazard areas. The location of the Shallow-Seasonal Groundwater areas over Landslide-Mass Movement Hazard areas indicates a systemic relationship between these two phenomena. As previously mentioned, the Landslide-Mass Movement Hazard areas appear to correlate to areas downslope of Maple Canyon Formation argillite beds mapped as **Zmcc2** on Figure 3. The emergence of the ground water on the surface on the same areas suggest the argillite beds may also controlling factor for the location of the groundwater emergence. The occurrence of the Shallow-Seasonal Groundwater on the Landslide-Mass Movement Hazard areas is believed to have a negative effect on the soil strength and stability of these soils, thus the removal of the water in these areas is believed to be a possible strategic measure for attaining stability in these areas.

The Weber County Natural Hazards Overlay Sec. 104-27-2 - Potential hazards section, provides the following guidance for landslide hazard reduction:

> *Many methods have been developed for reducing landslide hazards. Proper planning and avoidance is the least expensive measure, if landslide-prone areas*

> *are identified early in the planning and development process. Care in site grading with proper compaction of fills and engineering of cut slopes is a necessary follow-up to good land use planning. Where avoidance is not feasible, various engineering techniques are available to stabilize slopes, including de-watering (draining), retaining structures, piles, bridging, weighting or buttressing slopes with compacted earth fills and drainage diversion. Since every landslide and unstable slope has differing characteristics, any development proposed within a designated landslide hazard area...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.*

These guidelines should be considered a basis for landslide hazards reductions where proposed improvements are exposed to landslide hazards as shown on Figure 19.

Debris Flow Hazard areas **(Qafy)** are shown on Figure 19 to occur on the very southeast side of the East Phase site. These Younger Alluvial Fan Deposits (Holocene and Pleistocene) **(Qafy)**, occur adjacent to the active floodplain deposits along the Wolf Creek channel. The Debris Flow Hazard area defined by the **Qafy** deposits is potentially exposed to both debris flows and clear-water flooding should Wolf Creek avulse during a future flood event. It is our understanding that no flood control or significant diversion structures on Wolf Creek exist upstream from the East Phase site, thus these hazards exist under the present conditions.

The area exposed to the debris flow hazards includes four residential development lots on the very southeast side of the East Phase, however the source of the hazard (Wolf Creek) is located off site, and is thus not feasible for hazard modification remediation. Therefore modifying what is at risk may be the only feasible approach to protect the improvements proposed for this area. Risk modification may include disclosure that exposed properties are subject to the potential debris-flow/flood hazards, and prescribed site specific grading and structural measures taken to reduce the potential impact of the hazards to the proposed improvements, which may include building setbacks, deflection berms, minimum finished floor elevations, limits to basement locations, and/or limits to door/window openings in basements.

6. CONCLUSIONS

The East Phase site is located on a piedmont surface that is essentially the transition zone between the mountains and the valley bottom, where exposure to potential geologic and natural hazards may exist. Based upon our geological studies herein, we believe that the proposed Bridges at Wolf Creek East Phase site is suitable for development. This conclusion assumes that remedial measures will made for improvements that may be exposed to the hazard areas identified on Figure 19 and discussed in Section 4.1 of this report.

Remedial hazard risk reduction measures will need to be implemented where improvements will be exposed or potentially exposed to the hazard processes. These areas are shown on Figure 19, however more detailed and specific studies in-grading circumstances may find conditions different than presented on Figure 19. Hazard reduction measures may include site engineering measures to contain, deflect, drain or stabilize these processes, and/or include site development planning to avoid exposure to the hazards.

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,	Site Vicinity Map
	Figure	2,	Site Plan and Proposed Layout
	Figure	3,	Site Evaluation and Engineering Geology
	Figure	4,	Trench 1 STA 00 to 140 West
	Figure	5	Trench 1 STA 140 to 280 West
	Figure	6	Trench 1 STA 280 to 420 West
	Figure	7	Trench 2 STA 00 to 70 West
	Figure	8	Trench 2 STA 70 to 143 West
	Figure	9	Log of Test Pit 1 and Test Pit 2
	Figure	10	Log of Test Pit 3 and Test Pit 4
	Figure	11	Log of Test Pit 5 and Test Pit 6
	Figure	12	Log of Test Pit 7 and Test Pit 9
	Figure	13	Log of Test Pit 10 and Test Pit 11
	Figure	14	Log of Test Pit 12 and Test Pit 13
	Figure	15	Log of Test Pit 14 and Test Pit 15
	Figure	16	Log of Test Pit 16 and Test Pit 17
	Figure	17	Log of Test Pit 18
	Figure	18	LiDAR-Slope Analysis
	Figure	19	Geologic/Natural Hazard Exposure
	Figure	20	Geologic Cross Section *A-A′*
	Figure	21	Geologic Cross Section *B-B′*
	Appendix A		Boring Logs
			Key to Boring Logs

REFERENCES

Arabasz, W.J., Pechmann, J.C., and Brown, E.D., 1992, Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, in Gori, P.L., and Hays, W.W., eds., Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1500-D, 36 p.

Avery, C., 1994, Ground-weter hydrology of Ogden Valley and sudrrounding area , eastern Weber County, Utah, and simulation of ground-water flor in the valley-fill aquifer system; Utah Department of Natural Resources, Technical Publication no. 99, 84 p.

Black, B.D., DuRoss, C.B., Hylland, M.D., McDonald, G.N., and Hecker, S., compilers, 2004, Fault number 2351e, Wasatch fault zone, Weber section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 04/21/2016.

Black, B.D., and Hecker, S., compilers, 1999, Fault number 2379, Ogden Valley northeastern margin fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.gov/hazards/qfaults, accessed 04/21/2016.

Bryant, B.B., 1988, Geology of the Farmington Canyon Complex, Wasatch Mountains, Utah: USGS Professional Paper 1476, 54 p., 1 scale 1:50,000

Coogan, J.C., and King, J.K., 2016, Interim geologic map of the Ogden 30' x 60' quadrangle, Box Elder, Cache, Davis, Morgan, Rich, and Summit Counties, Utah, and Uinta County, Wyoming: Utah Geological Survey Open File Report 653DM, for use at 1:62,500 scale, 3 plates, 147 p.

Coogan, J.C., and King, J.K., 2001, Geologic map of the Ogden 30’ x 60’ quadrangle: Utah Geological Survey Open-File Report 380, scale 1:100,000.

Currey, D.R., and Oviatt, C.G., 1985, Durations, average rates, and probable causes of Lake Bonneville expansion, still-stands, and contractions during the last deep-lake cycle, 32,000 to 10,000 years ago, in Kay, P.A., and Diaz, H.F., (eds.), Problems of and prospects for predicting Great Salt Lake levels - Processing of a NOAA Conference, March 26-28, 1985: Salt Lake City, Utah

EPA 2016, Radon-Resistant Construction Basics and Techniques: Environmental Protection Agency website, https://www.epa.gov/radon/radon-resistant-construction-basics-and-techniques accessed 07/20/2016

FEMA 2015, Flood Insurance Rate Map, Weber County, Utah, Panel 49057C0018F and 49057C0019F, Scale 1 inch equals 1000 feet.

GDAL-SOFTWARE-SUITE, 2013, Geospatial data abstraction library. http://www.gdal.org

Giraud, R.E., 2005, Guidelines for the geologic evaluation of debris-flow hazards on alluvial fans in Utah: Utah Geological Survey Miscellaneous Publication 05-6, 16 p.

GRASS-PROJECT, 2013. Geographic resource analysis support system. http://grass.osgeo.org.

GSH Geothchnical Inc., 2016a, Report Geotechnical Study, The Bridges at Wolf Creek, Northwest of Fairway Drive, near Eden, Weber County, Utah: Unpublished consultants report, 17p.

GSH Geothchnical Inc., 2016b, Report Desk Top Studies-Preliminary Engineering Geology Study, The Bridges at Wolf Creek, Parts of Sections 15, 16 and 22 Township 7 North, Range 1 East SLBM, near Eden, Weber County, Utah: Unpublished consultants report, 13p.

King, J.K., and McDonald, G.N., 2014, Progress report geologic map of the Huntsville quadrangle, Weber and Cache Counties, Utah: Utah Geological Survey files, scale 1:24,000.

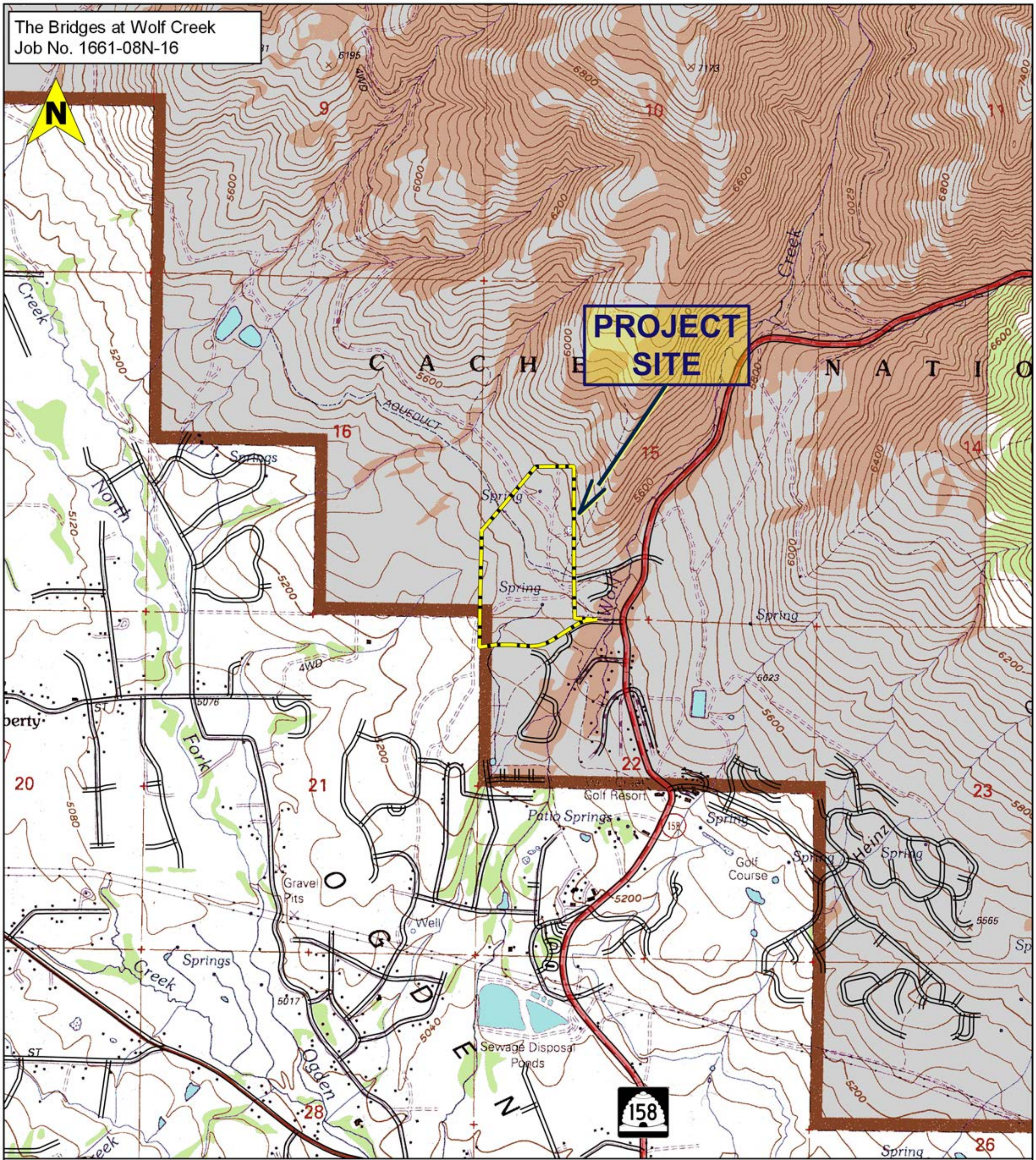
Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, S.C., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N., Field, E.H., Wills, C.J., and Rukstales, K.S., 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps: USGS Open-File Report 2008-1128, 128p.

Solomon, B.J., 1996, Radon-Hazard potential in Ogden Valley, Utah, Utah Geological Survey, Public Information Series 36, 2p., scale 1:100,000.

Sorensen, M.L., and Crittenden, M.D., Jr., 1979, Geologic map of the Huntsville quadrangle, Weber and Cache Counties, Utah: U.S. Geological Survey Geologic Quadrangle Series
Map GQ-1503, scale 1:24,000.

Varnes, D.J., 1978, Slope movement types and processes, in Schuster, R.L., and Krizek, R.J., eds., Landslides—Analysis and control: National Research Council, Washington, D.C., Transportation Research Board, Special Report 176, p. 11–33

Weber County Code (2016), retrieved from: https://www.municode.com/library/ut/weber_county/codes/code_of_ordinances?nodeId=14935



Base: 1998 7.5 Minute USGS Topographic Map
Titled Huntsville, Utah.

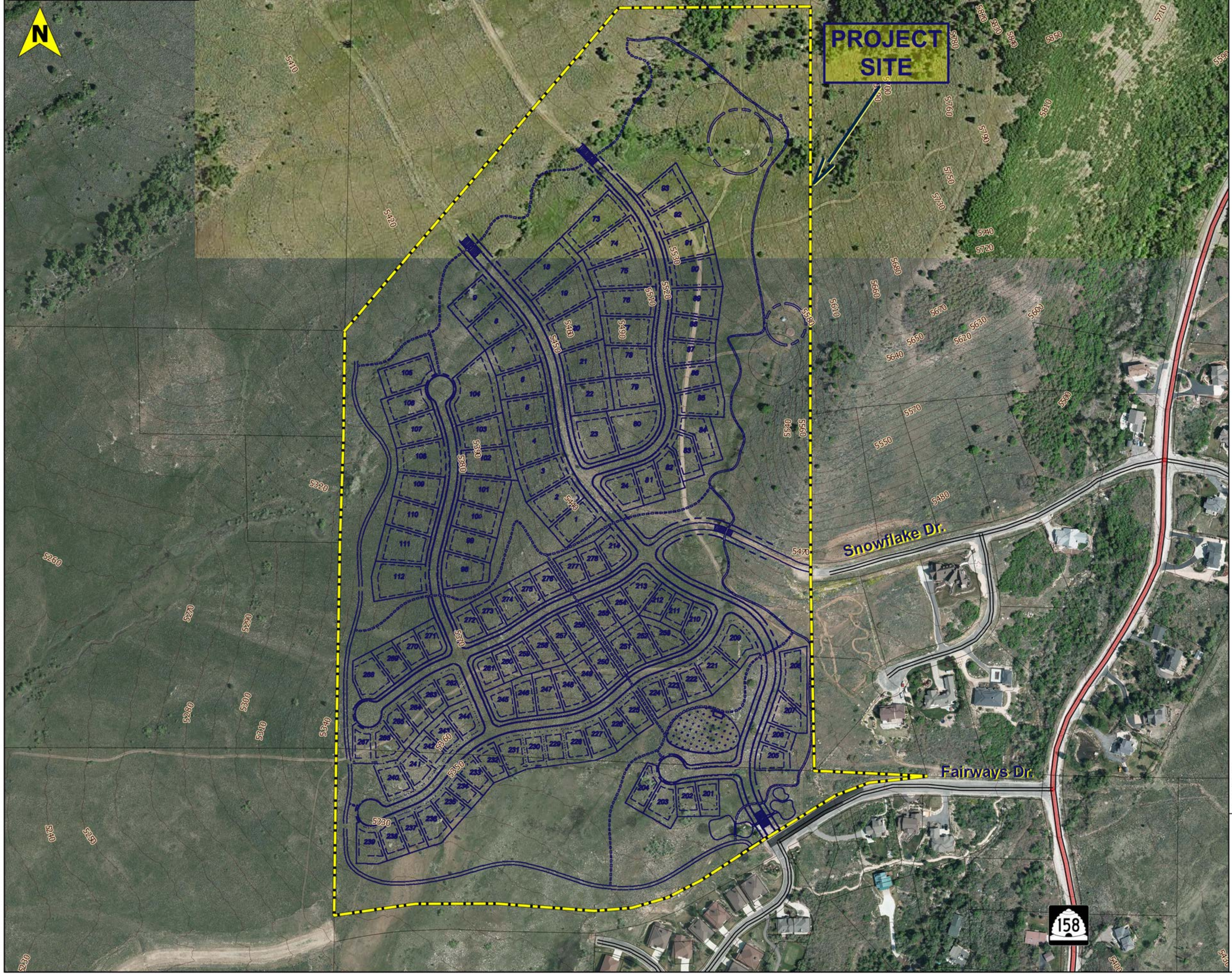
0 2000 4000 ft

1:24,000

FIGURE 1
VICINITY MAP

GSH

The Bridges at Wolf Creek
Job No. 1661-08N-16



Explanation

Phase Boundary

Layout
Park Side 1,2 & 3
Mountainside 1,3, & 4

Index Contour (10ft)

SGID10_CADASTRE_Parcels_Weber

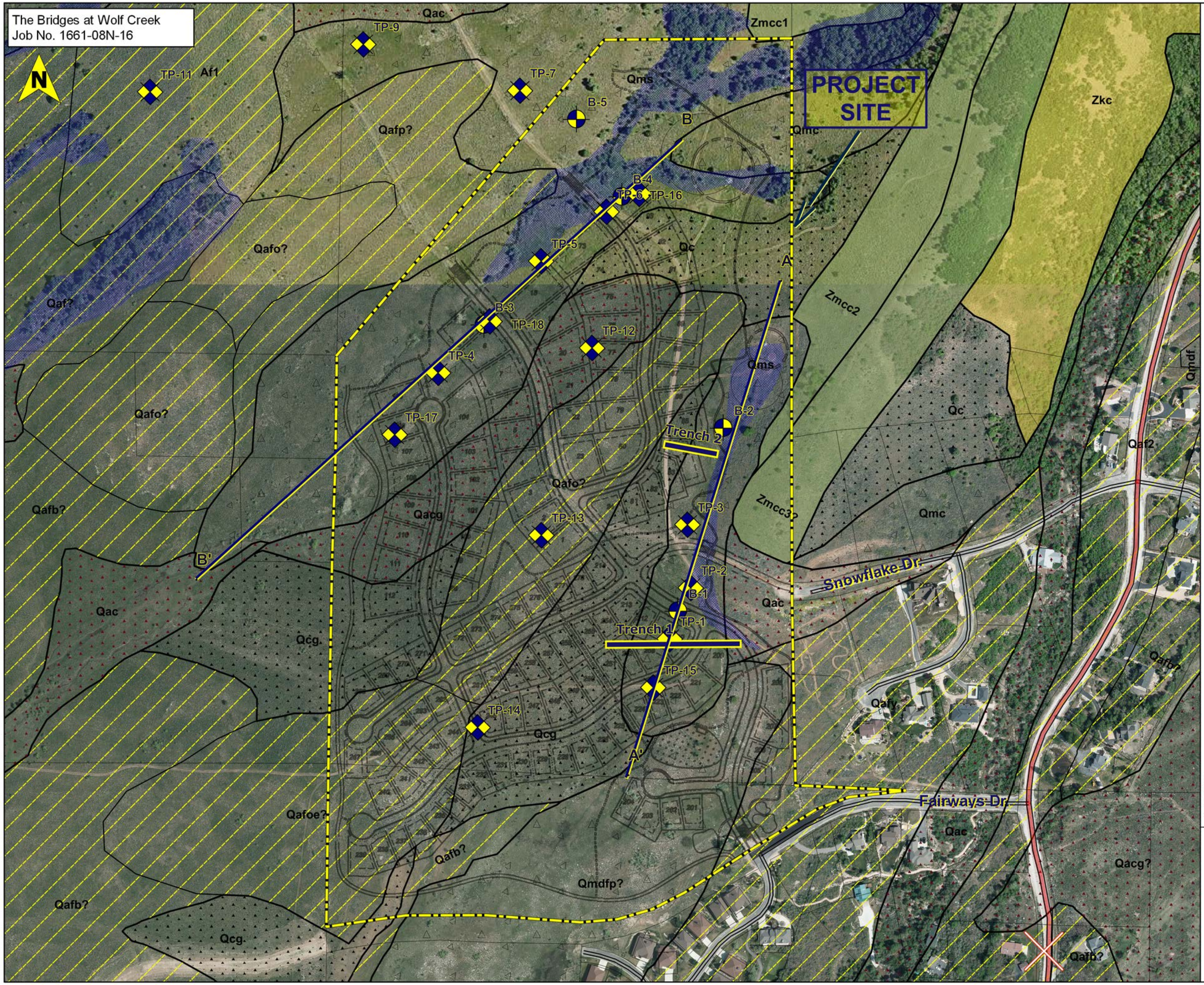
0 300 600 900 ft

1:3,600

Base:
2012 5.0 inch Color HRO Orthoimagery, and 2014 1.0 m NAIP Orthimagery, from Utah AGRC; http://gis.utah.gov/

FIGURE 2
SITE PLAN AND PROPOSED LAYOUT

GSH



Explanation

- Phase Boundary
- Test Pit Locations
- Boring Locations
- Trench Locations
- Slope Cross Section Locations
- Cienega Areas

Engineering Geology
(modified from Coogan and King 2016; King and McDonald, 2014; and Sorensen and Crittenden, 1979)

- Af1 - Alluvial-fan deposits, younger-active (Holocene)
- Qaf? - Alluvial-fan deposits, undivided (Holocene and Pleistocene)
- Qafy - Younger alluvial-fan deposits (Holocene and uppermost Pleistocene)
- Qaf2, Qafp?, Qafb?, Qafo? - Older alluvial-fan deposits (upper and middle(?) Pleistocene)
- Qafoe? - Eroded old alluvial-fan deposits (middle and lower Pleistocene)
- Qac - Alluvium and colluvium (Holocene and Pleistocene)
- Qacg, Qacg? - Gravelly alluvium and colluvium deposits (Holocene and Pleistocene)
- Qc - Colluvium (Holocene and Pleistocene)
- Qcg - Gravelly colluvial deposits (Holocene and Pleistocene)
- Qms - Landslide and slump deposits (Holocene and Pleistocene)
- Qmc - Landslide and slump, and colluvial deposits, undivided (Holocene and Pleistocene)
- Qmdfp? - Debris- and mud-flow deposits (Holocene and Pleistocene)
- Zkc - Kelly Canyon Formation, siltstone-quartzite
- Zmcc - Maple Canyon Formation; Zmcc1 - lower conglomerate member; Zmcc2 - argillite; Zmcc3? - quartzite-conglomerate

0 300 600 900 ft

1:3,600

Base:
2012 5.0 inch Color HRO Orthoimagery, and 2014 1.0 m NAIP Orthimagery, from Utah AGRC; http://gis.utah.gov/

FIGURE 3
SITE EVALUATION AND ENGINEERING GEOLOGY

GSH

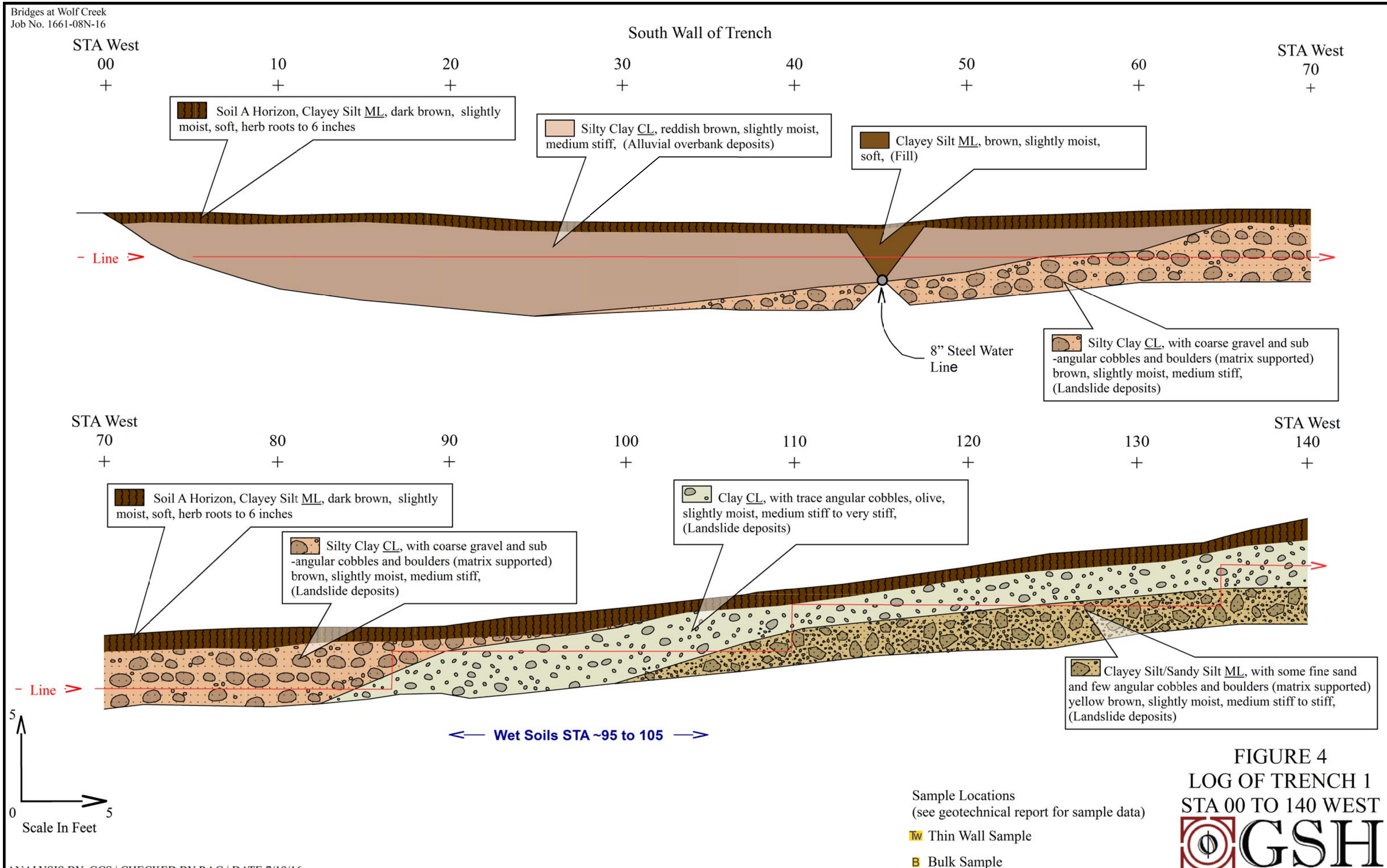


FIGURE 4
LOG OF TRENCH 1
STA 00 TO 140 WEST

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

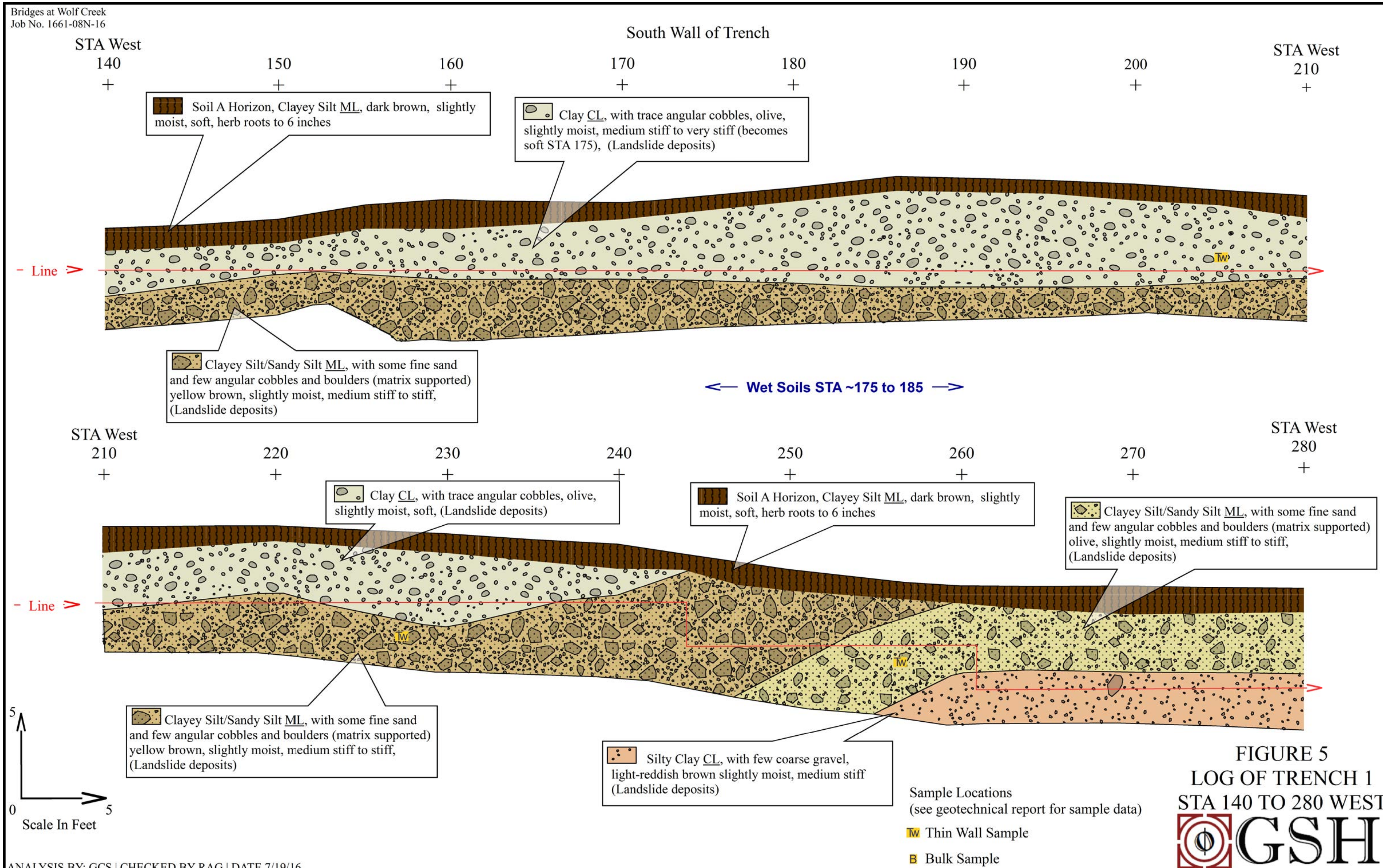


FIGURE 5
LOG OF TRENCH 1
STA 140 TO 280 WEST

Bridges at Wolf Creek
Job No. 1661-08N-16

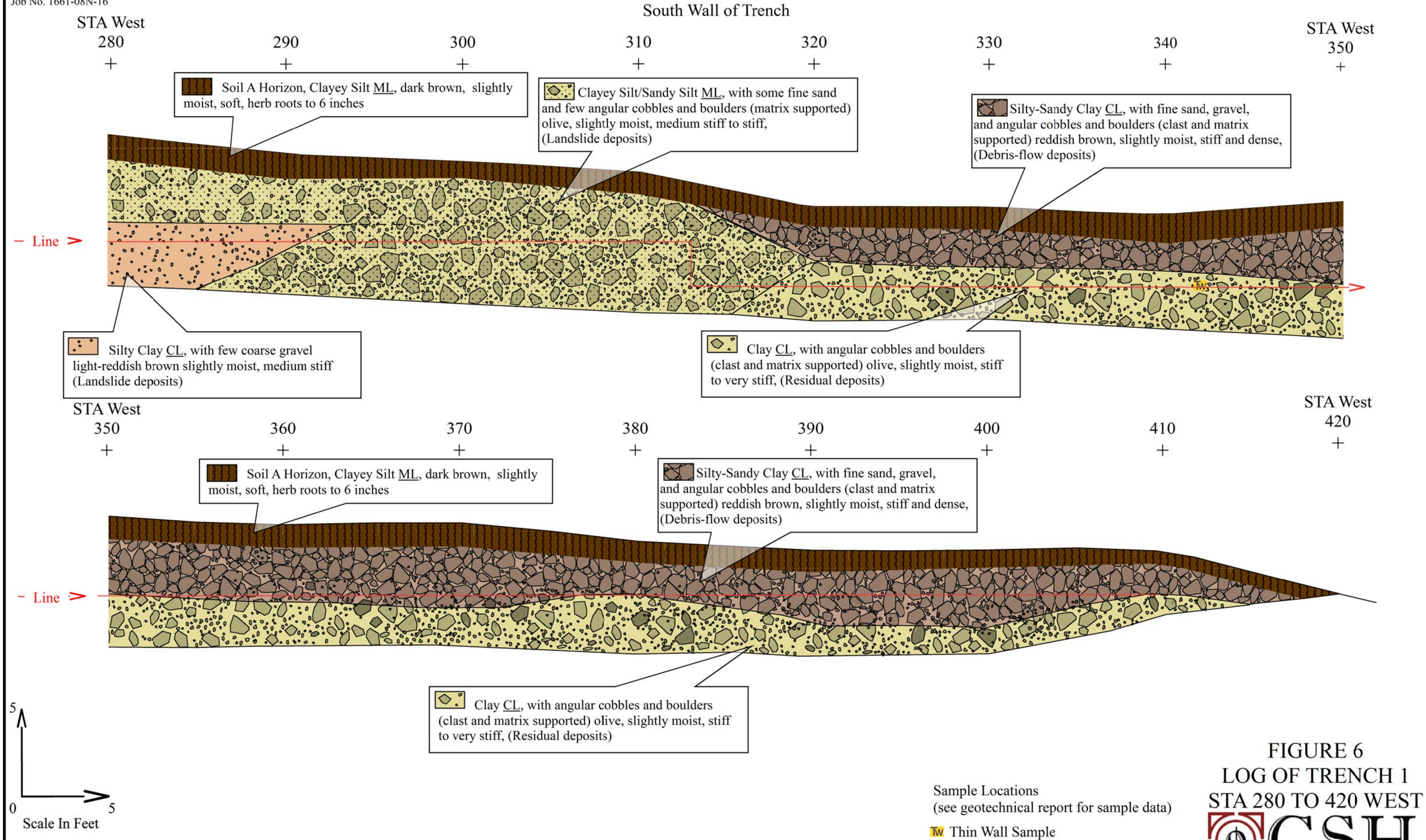
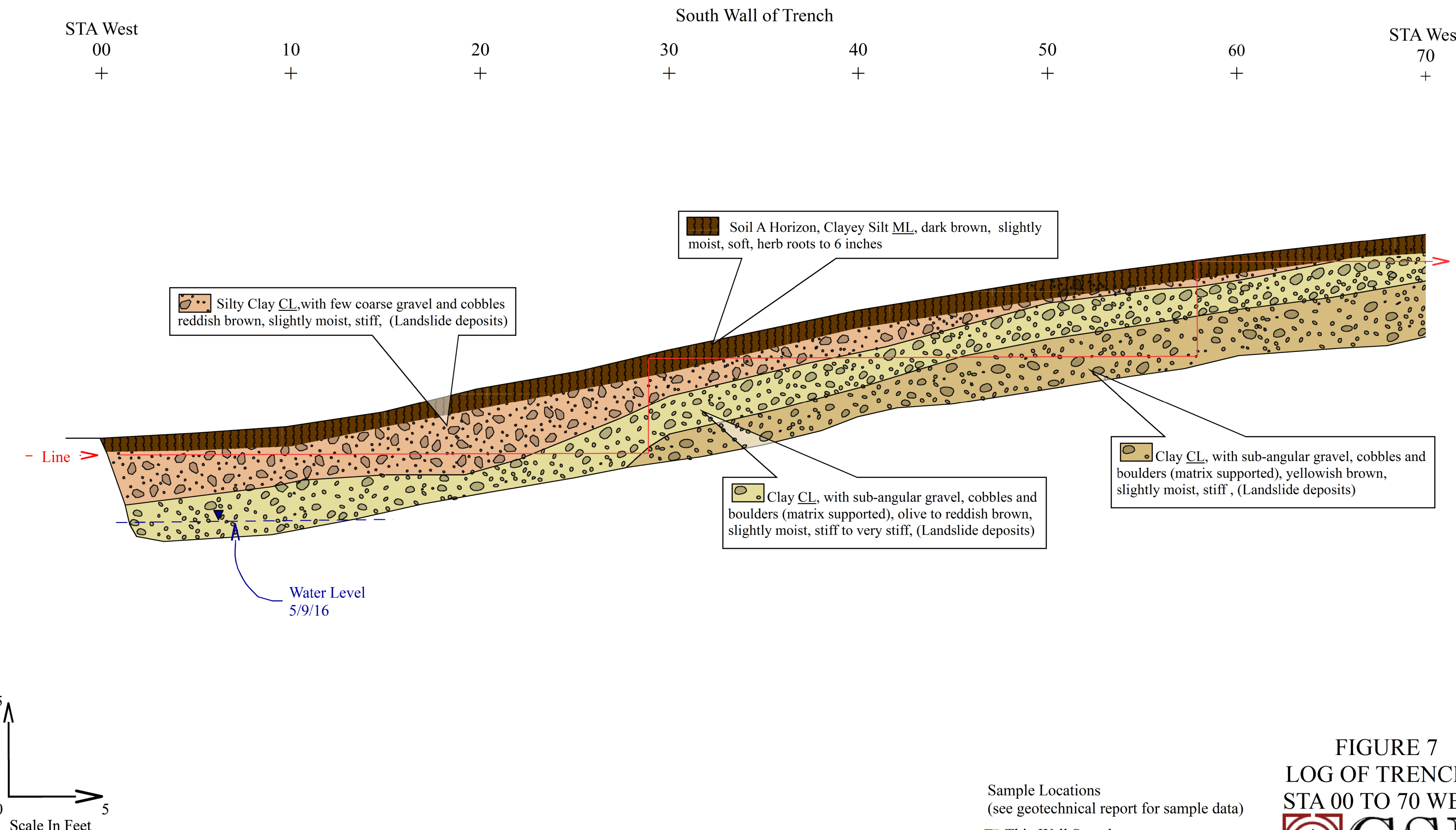


FIGURE 6
LOG OF TRENCH 1
STA 280 TO 420 WEST

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-07N-16



Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

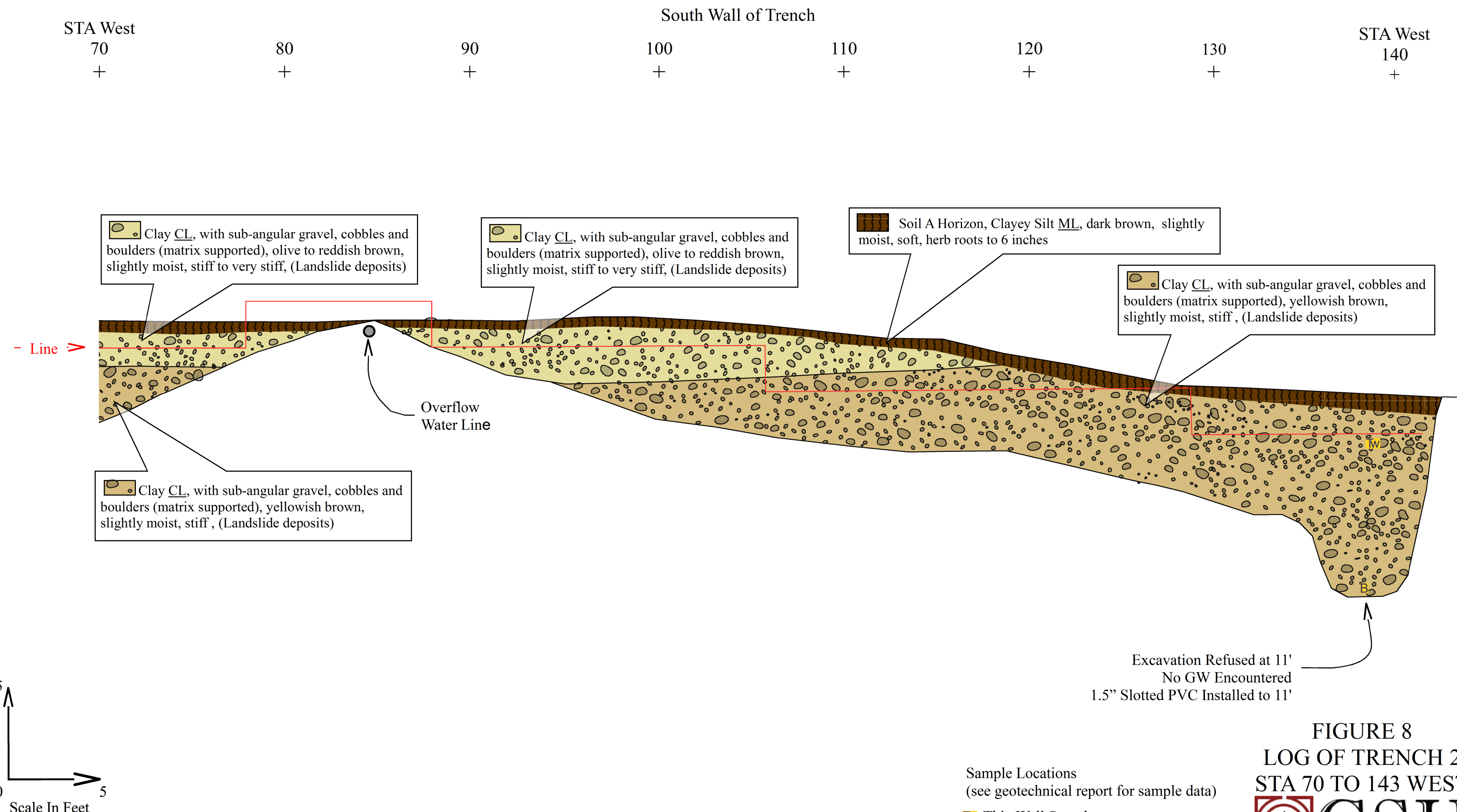
B Bulk Sample

FIGURE 7
LOG OF TRENCH 2
STA 00 TO 70 WEST

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-07N-16



Scale In Feet

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

FIGURE 8
LOG OF TRENCH 2
STA 70 TO 143 WEST

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-08N-16

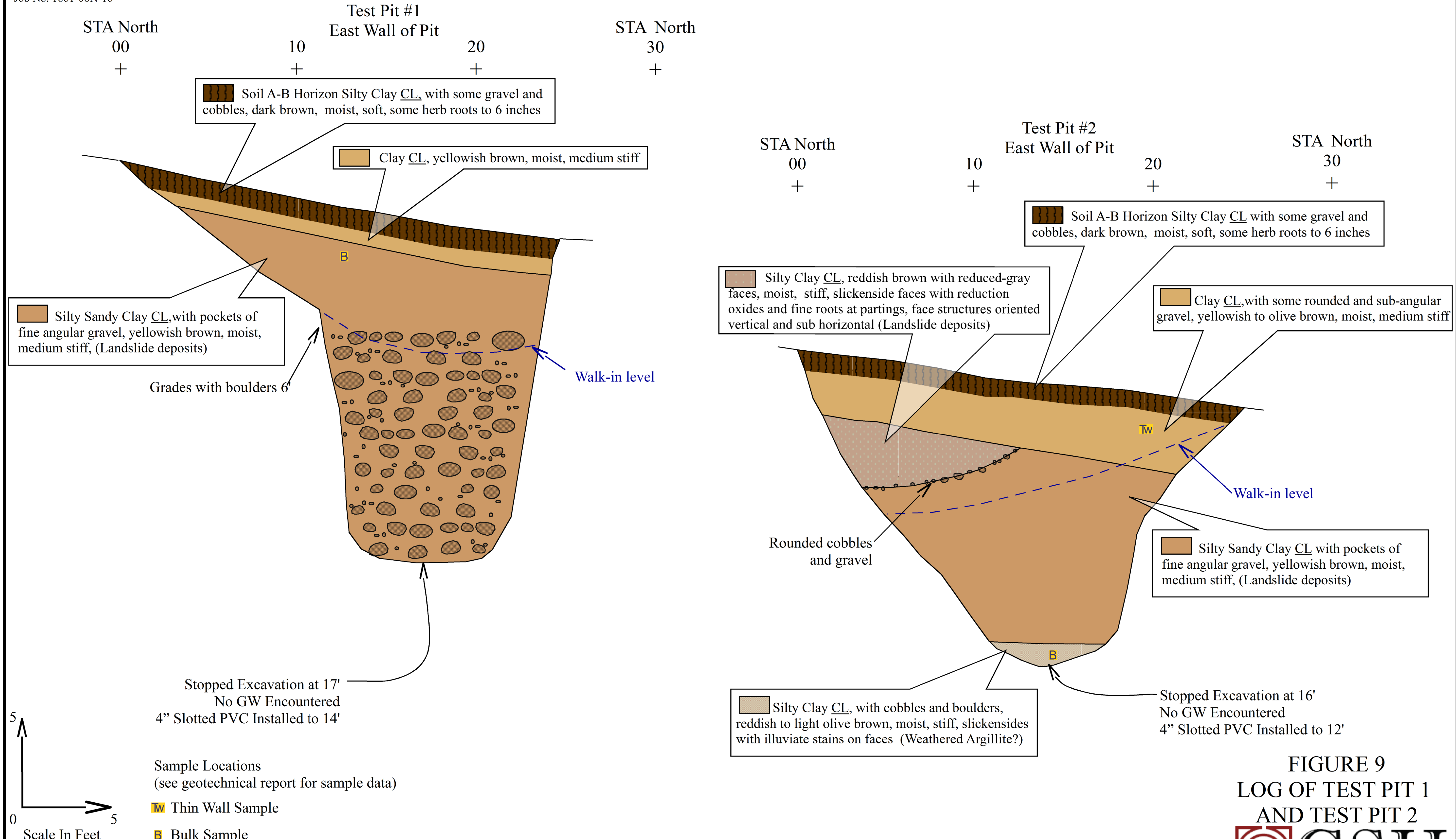
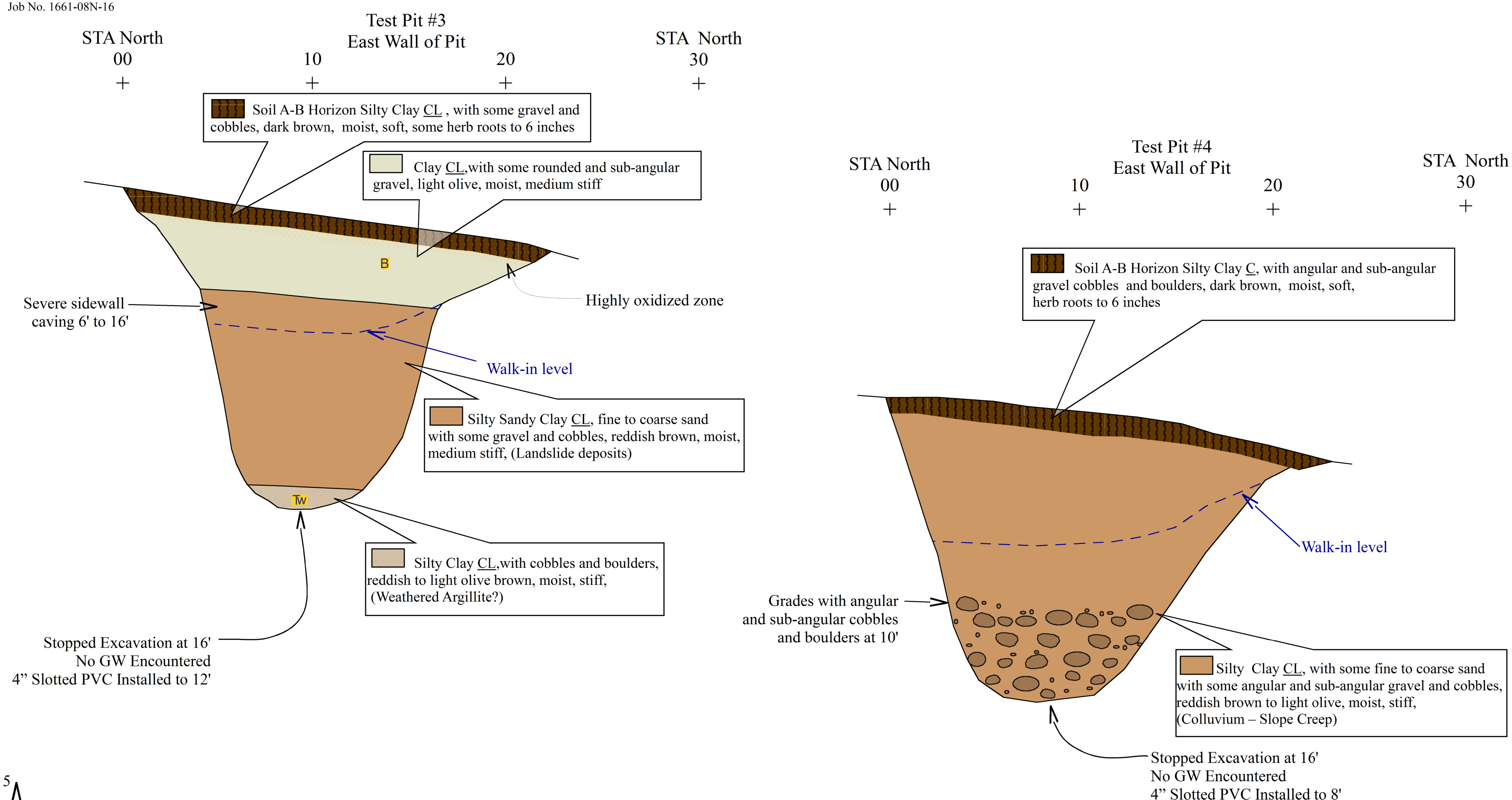


FIGURE 9
LOG OF TEST PIT 1
AND TEST PIT 2

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-08N-16



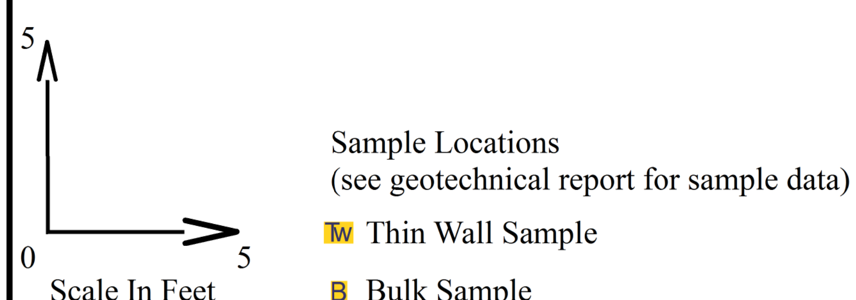


FIGURE 10
LOG OF TEST PIT 3
AND TEST PIT 4

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

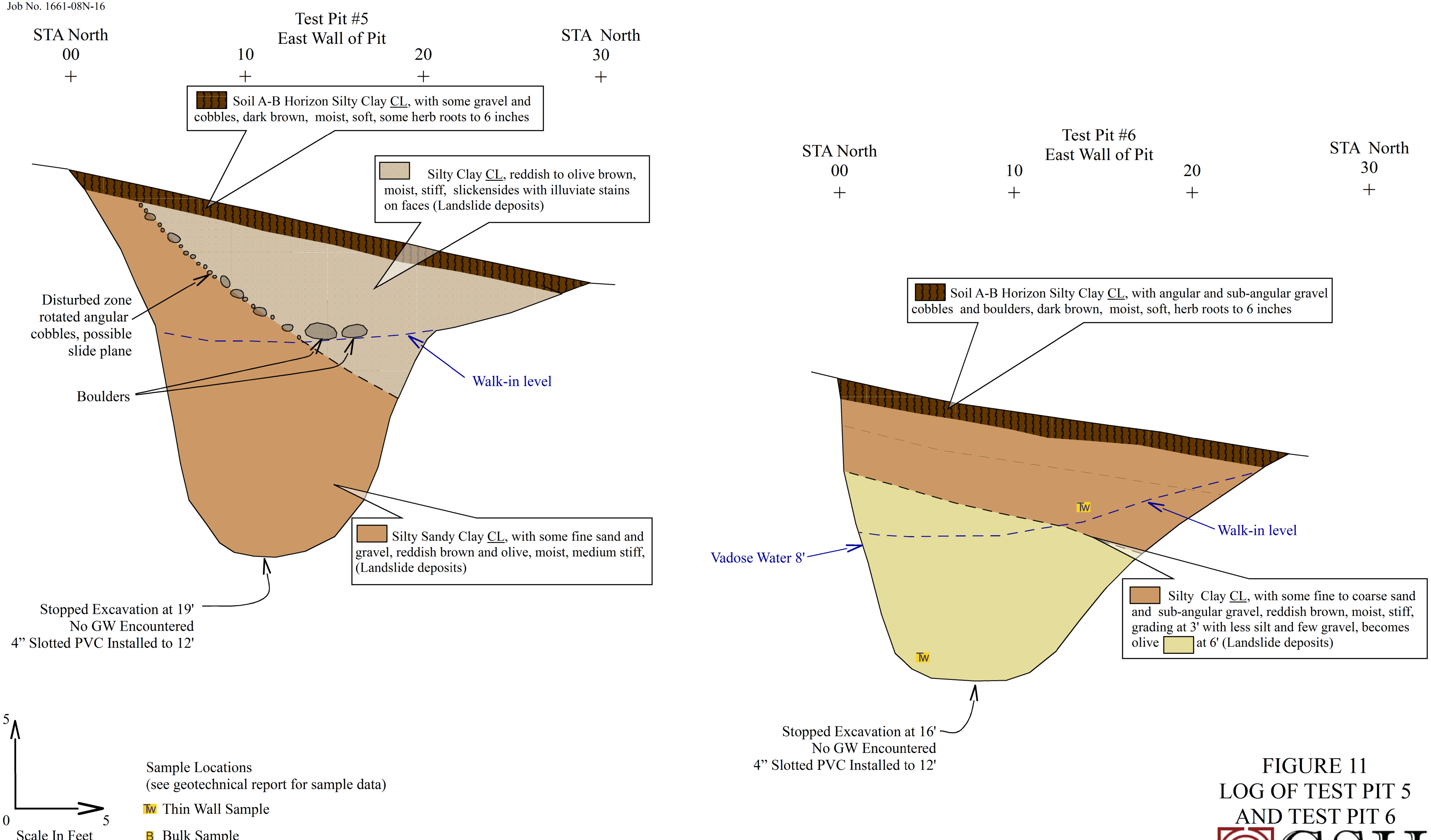


FIGURE 11
LOG OF TEST PIT 5
AND TEST PIT 6

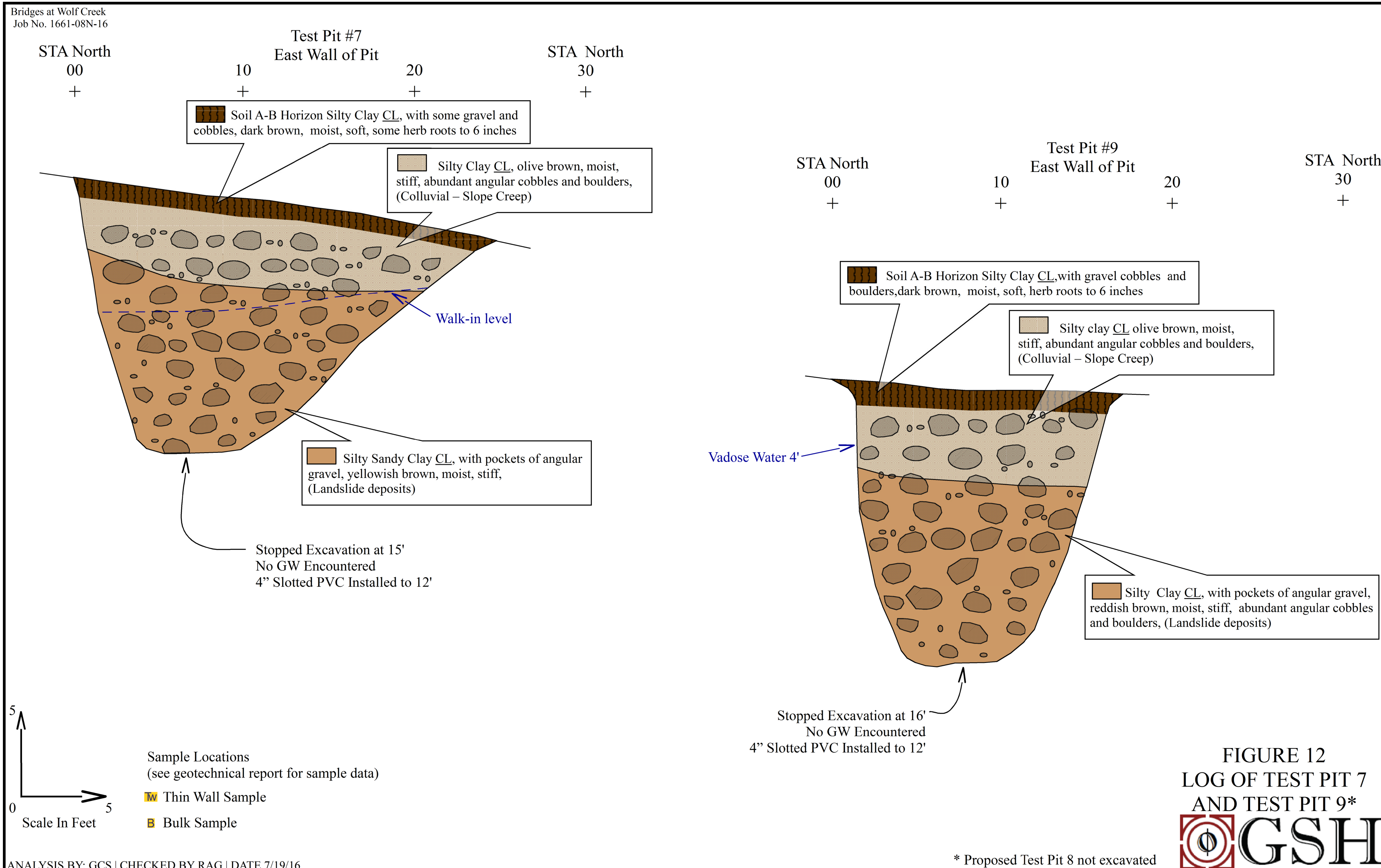


FIGURE 12
LOG OF TEST PIT 7
AND TEST PIT 9*

Bridges at Wolf Creek
Job No. 1661-08N-16

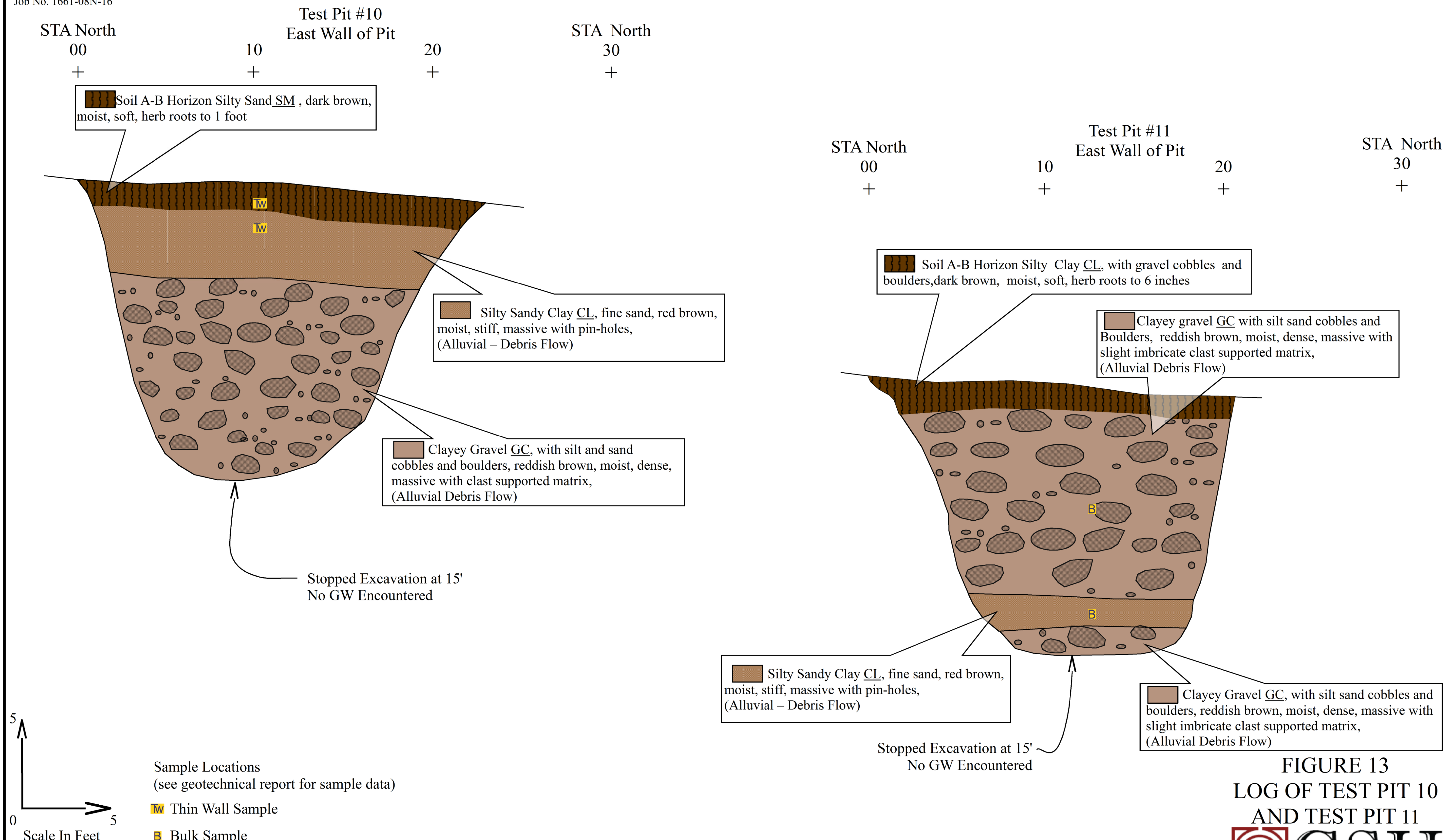


FIGURE 13
LOG OF TEST PIT 10
AND TEST PIT 11

GSH

ANALYSIS BY: GCS | CHECKED BY RAG| DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-08N-16

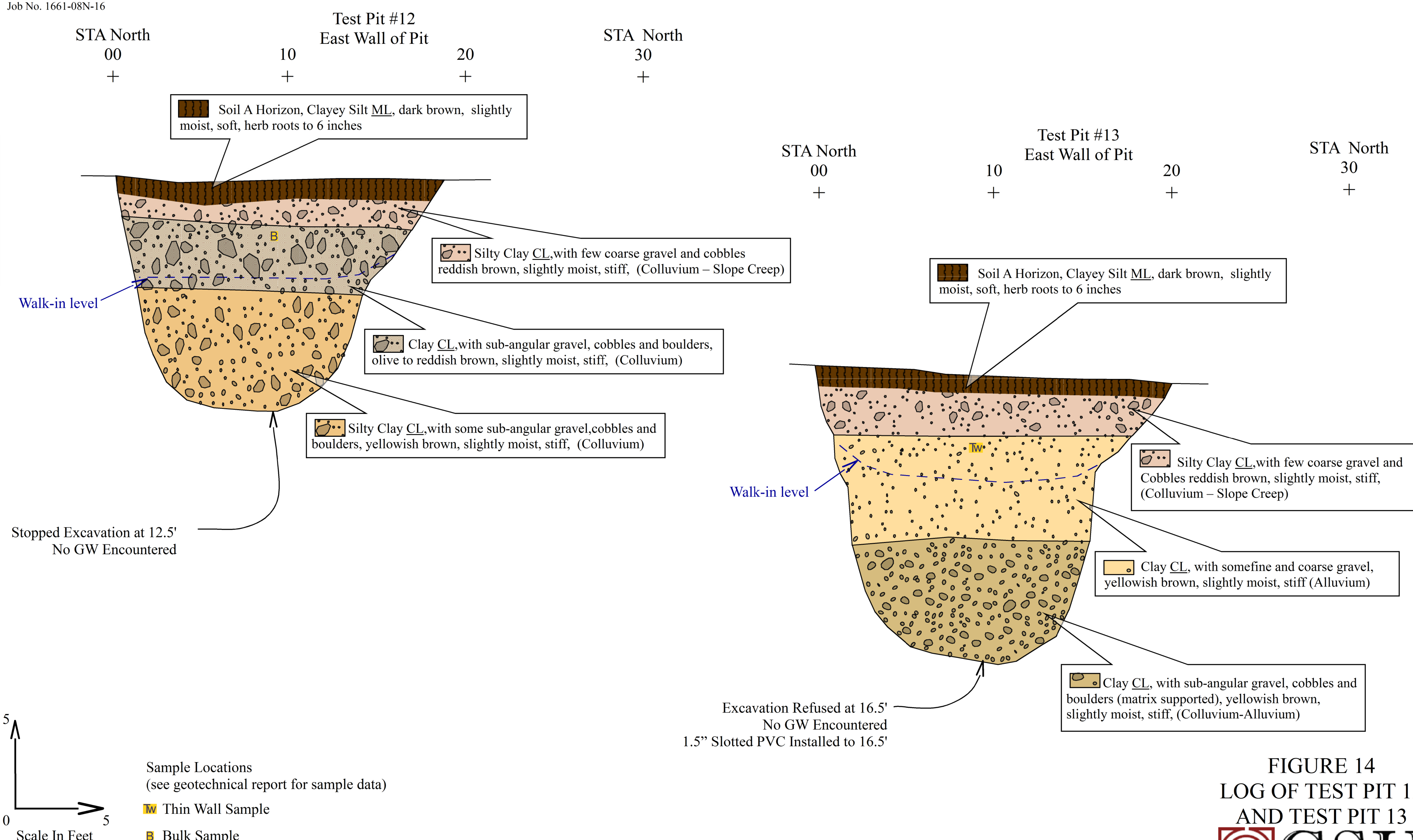
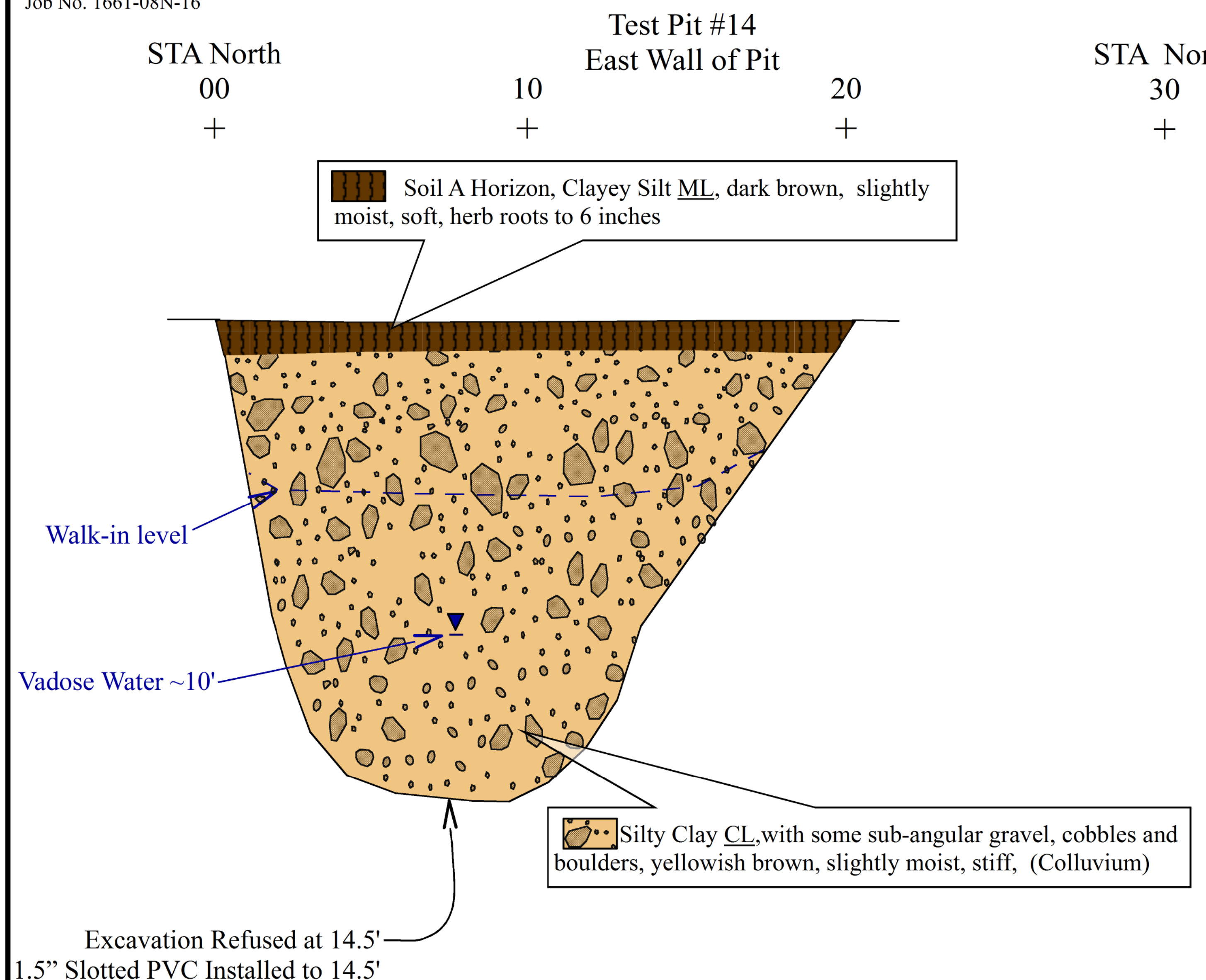


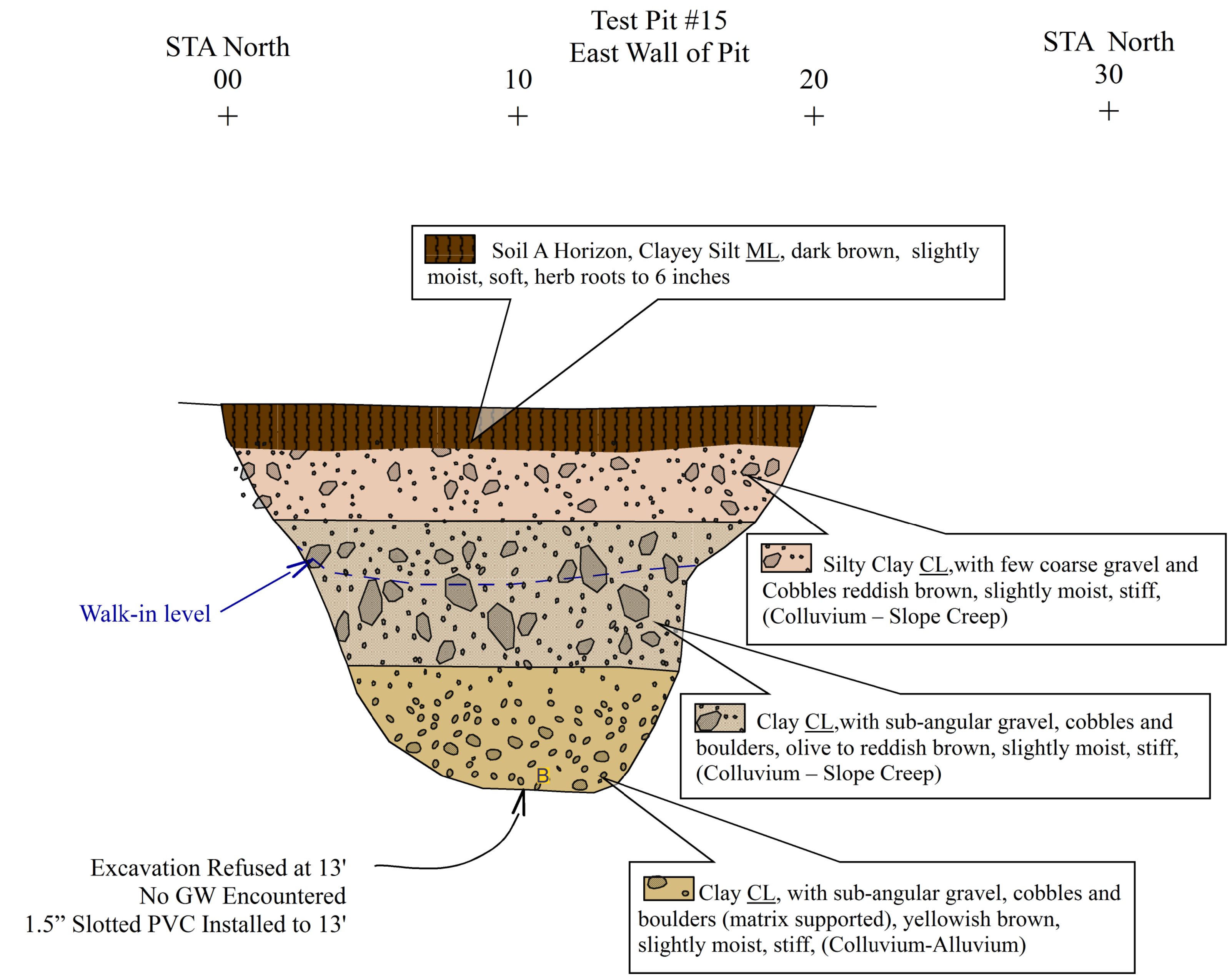
FIGURE 14
LOG OF TEST PIT 12
AND TEST PIT 13

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

Bridges at Wolf Creek
Job No. 1661-08N-16





5
0 5
Scale In Feet

Sample Locations
(see geotechnical report for sample data)

TW Thin Wall Sample

B Bulk Sample

FIGURE 15
LOG OF TEST PIT 14
AND TEST PIT 15

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16

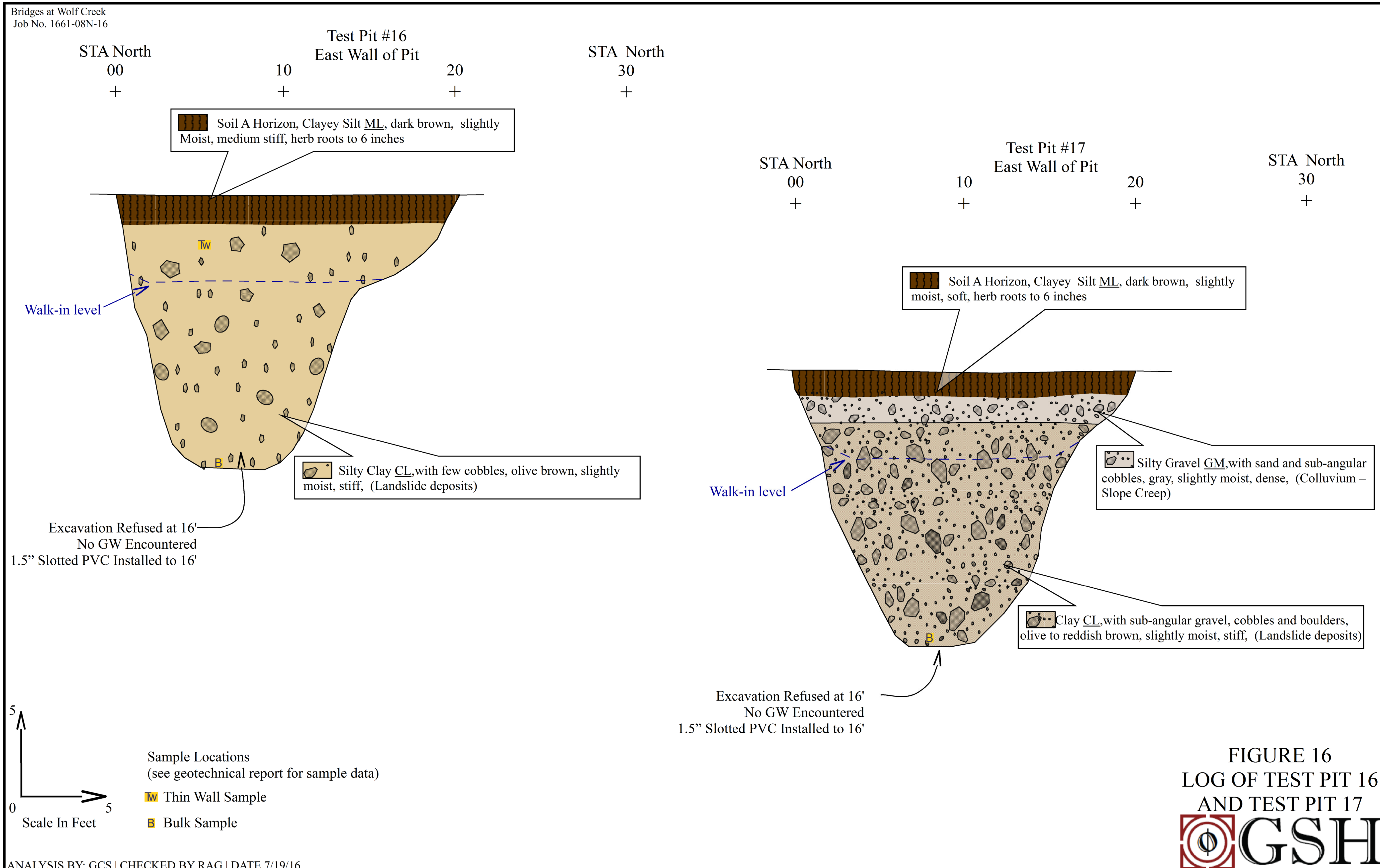
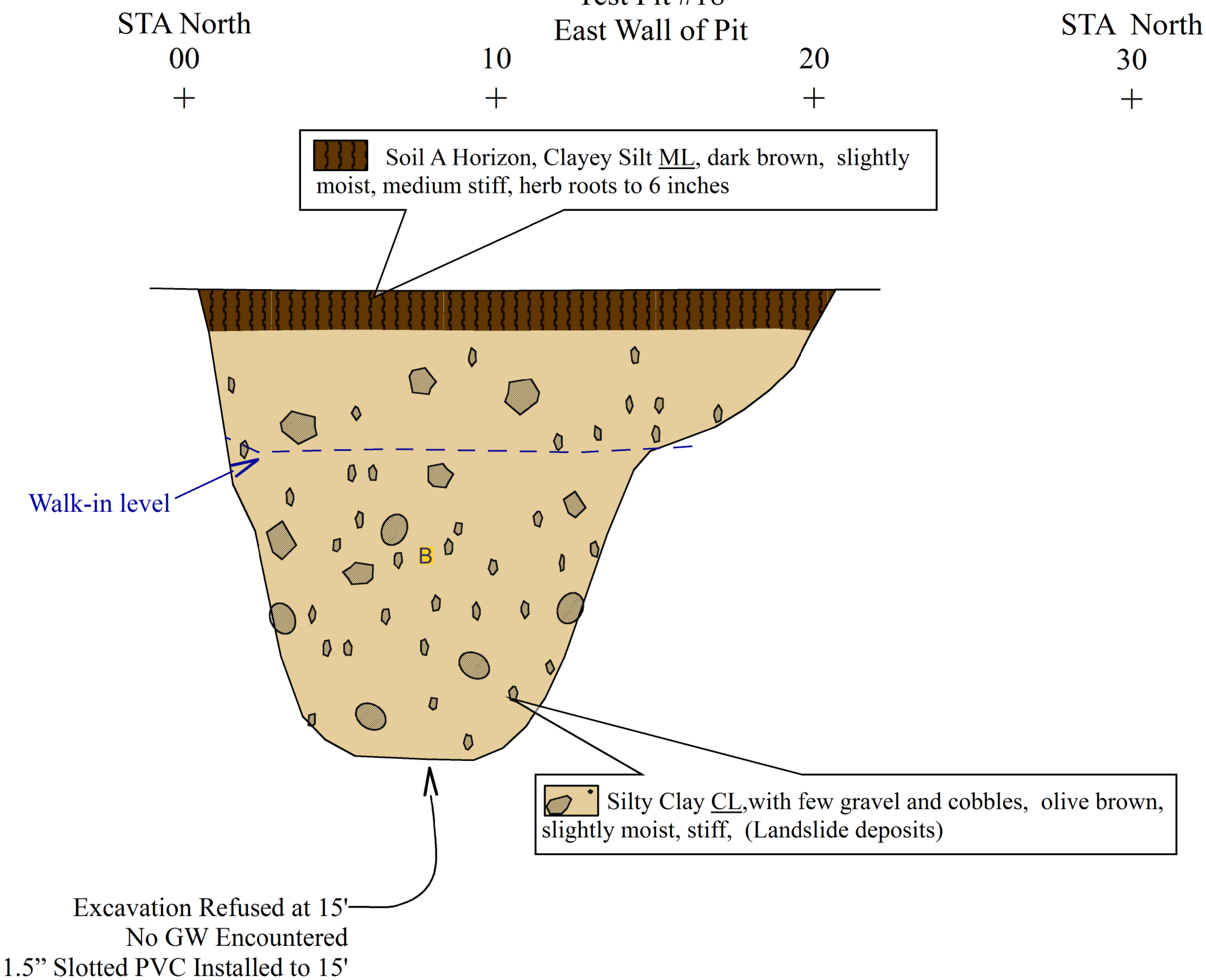
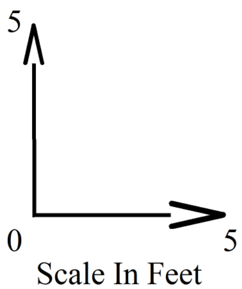


FIGURE 16
LOG OF TEST PIT 16
AND TEST PIT 17

Bridges at Wolf Creek
Job No. 1661-08N-16

Test Pit #18
East Wall of Pit





Sample Locations
(see geotechnical report for sample data)

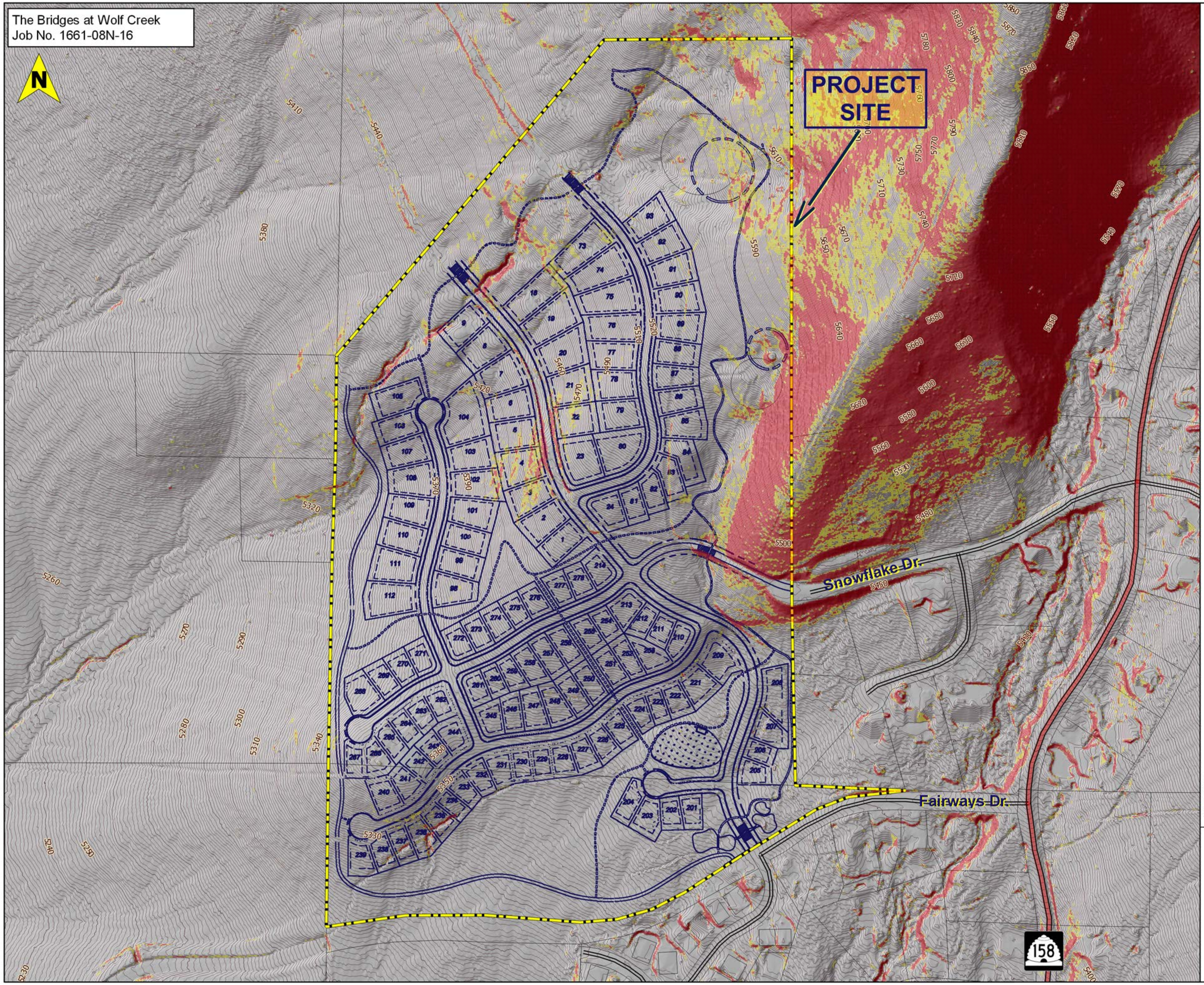
TW Thin Wall Sample

B Bulk Sample

FIGURE 17
LOG OF TEST PIT 18

GSH

ANALYSIS BY: GCS | CHECKED BY RAG | DATE 7/19/16



Explanation

- Phase Boundary
- Layout
  - Park Side 1,2 & 3
  - Mountainside 1,3, & 4
- SGID10_CADASTRE_Parcels_Weber

Slope Percentage Classification

- 25 to 30 percent
- 30 percent and greater
- Index contour (10ft)

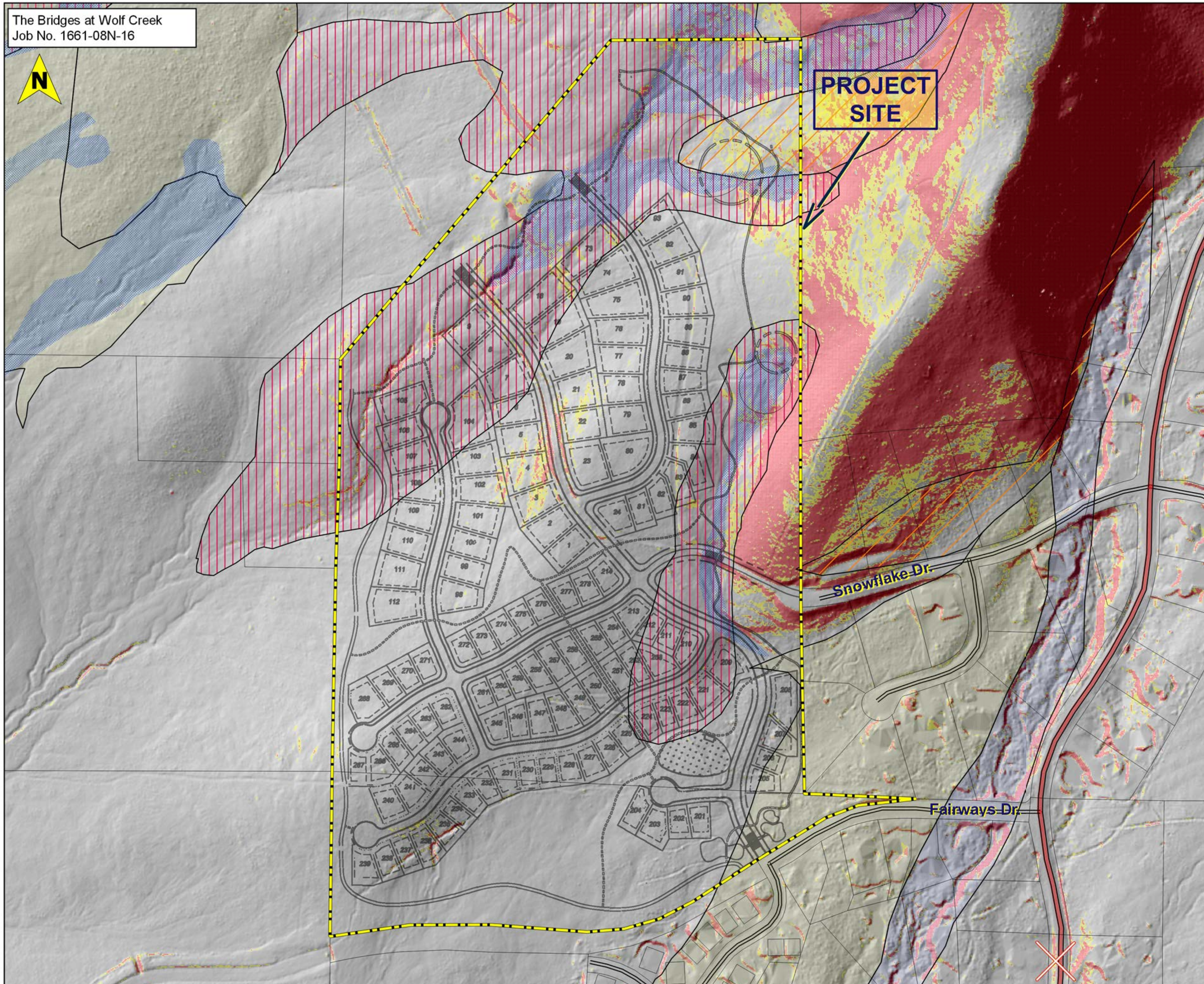
0 300 600 900 ft

1:3,600

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

FIGURE 18
LiDAR-SLOPE ANALYSIS

GSH



Explanation

- Phase Boundary
- Layout
  - Park Side 1,2 & 3
  - Mountainside 1,3, & 4
- SGID10_CADASTRE_Parcels_Weber
- Index contour (10ft)

Geologic/Natural Hazards

- Shallow-Seasonal Groundwater
- Alluvial Fan - Debris Flow Hazards
- Landslide - Mass Movement Hazards
- Alluvial Fan - Debris Flow / Landslide - Mass Movement Hazards (combined)
- Slope Stability Hazards
- Flood Zone Hazards

Steep Slope Areas

- 25 to 30 percent
- 30 percent and greater

0 300 600 900 ft

1:3,600

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

FIGURE 19
GEOLOGIC/NATURAL HAZARD EXPOSURE

GSH

The Bridges at Wolf Creek
Job No. 1661-08N-16

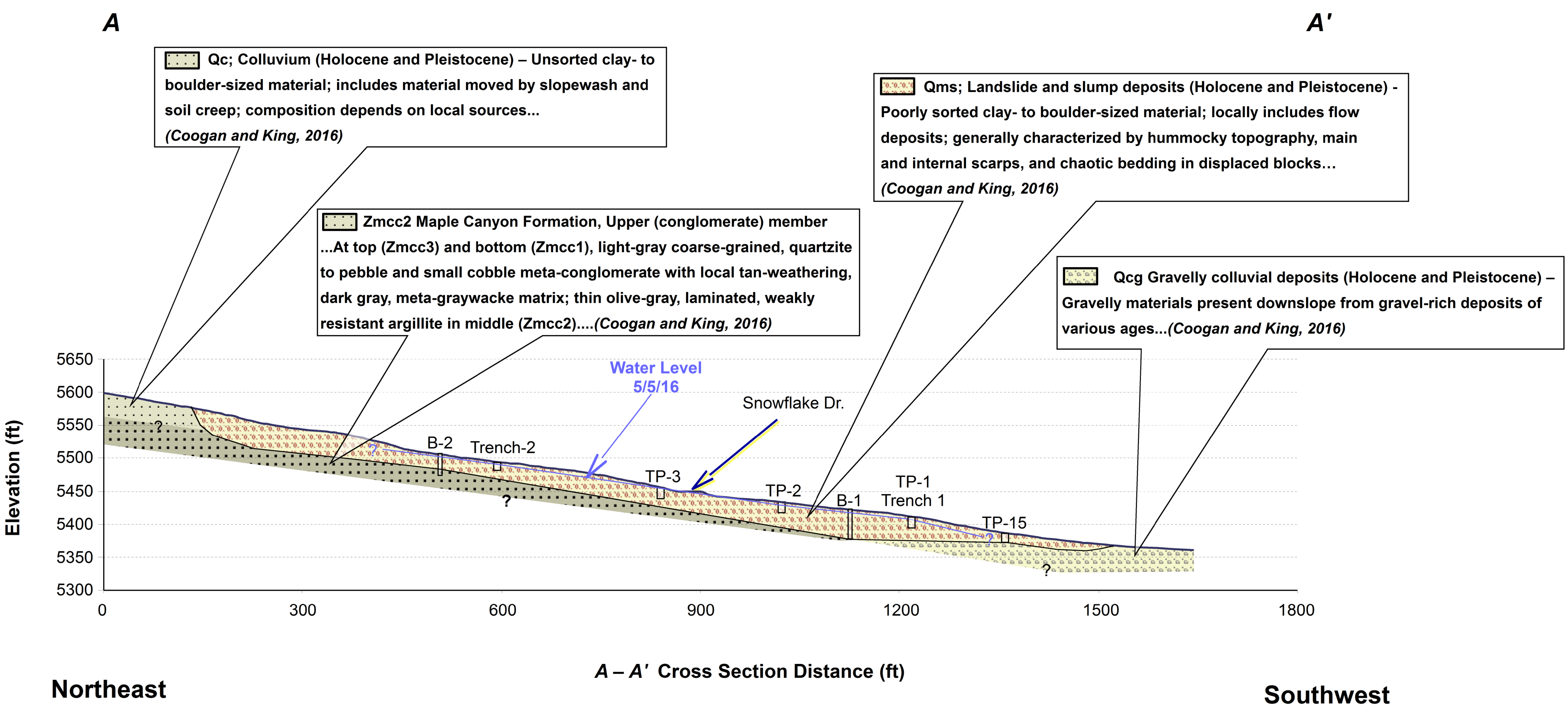


FIGURE 20
GEOLOGIC SLOPE
CROSS SECTION *A-A′*

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 06/24/16

* From Section Line Shown On Figure 3

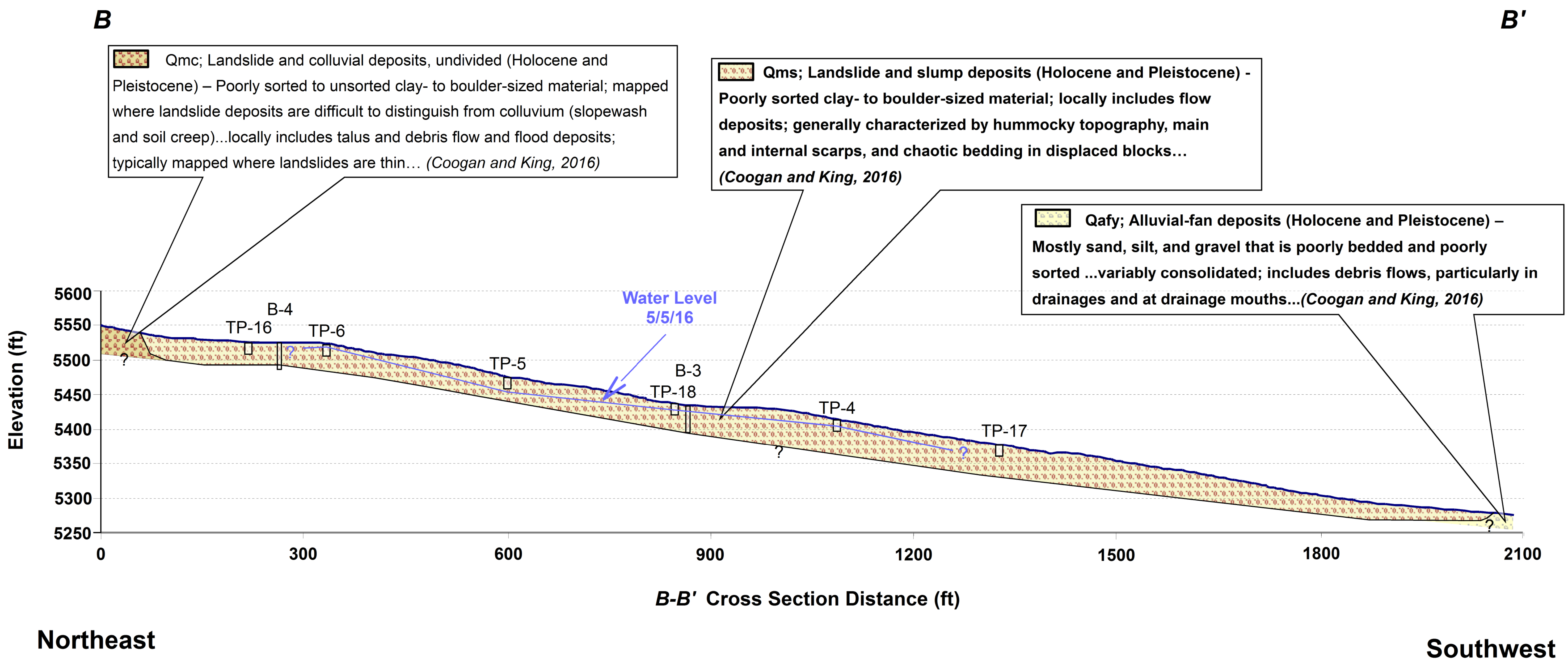


FIGURE 21
GEOLOGIC SLOPE
CROSS SECTION *B-B′*

GSH

ANALYSIS BY: GCS | CHECKED BY AH | DATE 06/24/16

* From Section Line Shown On Figure 3

APPENDIX

BORING LOG

BORING: B-1

CLIENT: Lewis Homes — PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I — DATE STARTED: 5/4/16 — DATE FINISHED: 5/4/16

LOCATION: Northwest of Fairway Drive, near Eden, Weber County, Utah — GSH FIELD REP.: AA

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

GROUNDWATER DEPTH: 5.0' (5/4/16), 5.6' (7/1/16) — ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CL	SILTY CLAY with some fine and coarse gravel; some fine to coarse sand; trace large to small cobbles; small boulders; trace organics; major roots (topsoil) to 3"; light reddish-brown	0								slightly moist hard
				71	X						
▼			5	50+	X						saturated
				50+	X						
	CL	FINE TO COARSE SANDY CLAY with some fine and coarse gravel; small to large cobbles; boulders; trace organics; light reddish-brown	10	50+	X						saturated hard
				46	X						
			15	45	X						
	CL/ CH	SILTY CLAY with trace fine and coarse gravel; some fine to coarse sand; trace organics; light reddish-brown		57	X	31	87	61	55	33	saturated hard
			20	20	X						
		grades with trace fine to coarse sand		18	X	29	93	66	45	28	very stiff
			25		X						

See Subsurface Conditions section in the report for additional information.

FIGURE 3A

BORING LOG

BORING: B-1

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/4/16 | DATE FINISHED: 5/4/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25	18	X						
				66	X						hard
			30	31	X	29	97	55	59	33	very stiff
				66	X						hard
			35	50+	X						
				41	X						very stiff
			40	48	X						hard
				50+	X						
			45	55	X						
		End of Exploration at 45.0' due to auger refusal Installed 1.25" diameter slotted PVC pipe to 45.0'									
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3A (continued)

GSH

BORING LOG

BORING: B-2

CLIENT: Lewis Homes — PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I — DATE STARTED: 5/5/16 — DATE FINISHED: 5/6/16

LOCATION: Northwest of Fairway Drive, near Eden, Weber County, Utah — GSH FIELD REP.: AA

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

GROUNDWATER DEPTH: 5.0' (5/5/16), 3.2' (7/1/16) — ELEVATION: ---

DEPTH (FT.)	WATER LEVEL	USCS	DESCRIPTION	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			Ground Surface								
0		CL	SILTY CLAY with some fine to coarse sand; cobbles and boulders; trace organics; major roots (topsoil) to 3"; brown								
				50+							
5	▽			29		21	99				saturated very stiff
			grades light reddish-brown	58							hard
10				50+							
				50+							
15			grades with some fine and coarse gravel	50+							
				25		30	92				very stiff
20				17		29	89		44	22	stiff
				50+							
25		BR	BEDROCK								

See Subsurface Conditions section in the report for additional information.

FIGURE 3B

BORING LOG

BORING: B-2

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/5/16 | DATE FINISHED: 5/6/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
	BR	BEDROCK brown	25								
			30								
		End of Exploration at 33.0' due to auger refusal Installed 1.25" diameter slotted PVC pipe to 33.0'									
			35								
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3B
(continued)

GSH

BORING LOG

BORING: B-3

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/24/16 | DATE FINISHED: 5/24/16

LOCATION: Northwest of Fairway Drive, near Eden, 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: 5.0' (5/24/16), 5.5' (7/1/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CL	SILTY CLAY with trace fine and coarse gravel; trace fine to coarse sand; large cobbles; trace organics; brown	0								moist very stiff
▼			5	31							saturated
				48							
			10	36							
		grades light brown		13							stiff
		grades reddish-brown	15	27							
				51							hard
			20	65							
		grades gray		36							very stiff
			25								

See Subsurface Conditions section in the report for additional information.

FIGURE 3C

BORING LOG

BORING: B-3

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/24/16 | DATE FINISHED: 5/24/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25	30	X						
				28	X						
		grades whitish-gray	30	22	X						
				43	X						
		grades reddish-brown	35	46	X						hard
				85	X						
			40	80	X						
		End of Exploration at 41.5' due to auger refusal Installed 1.25" diameter slotted PVC pipe to 40.0'									
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3C
(continued)

BORING LOG

BORING: B-4

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/19/16 | DATE FINISHED: 5/19/16

LOCATION: Northwest of Fairway Drive, near Eden, Weber County, Utah | GSH FIELD REP.: AA/JM

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

GROUNDWATER DEPTH: 7.5' (5/19/16), 7.3' (7/1/16) | ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CL	SILTY CLAY with trace fine and coarse gravel; trace fine to coarse sand; trace organics; major roots (topsoil) to 2"; brown	0								moist very stiff
				21	X						
		grades brownish-gray	5	23	X						
▼				12	X						saturated
	GC	CLAYEY GRAVEL with trace fine to coarse sand; trace organics; brown to grayish-green	10	50+	X						saturated hard
				35	X				47	31	very stiff
			15	34	X						
	CL	SANDY CLAY with trace fine and coarse gravel; whitish-gray		7	X						saturated stiff
			20	12	X						
		grades with trace fine to coarse sand; reddish-brown		31	X						very stiff
			25		X						

BORING LOG

BORING: B-4

CLIENT: Lewis Homes — PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I — DATE STARTED: 5/19/16 — DATE FINISHED: 5/19/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
			25	35	X						
				55	X	25	96				hard
			30	53	X	21	100				
				94	X						
			35	65	X						
		End of Exploration at 36.5' Installed 1.25" diameter slotted PVC pipe to 36.0'									
			40								
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3D
(continued)

GSH

BORING LOG

BORING: B-5

CLIENT: Lewis Homes	PROJECT NUMBER: 1661-08N-16
PROJECT: The Bridges at Wolf Creek Phase I	DATE STARTED: 5/20/16 DATE FINISHED: 5/20/16
LOCATION: Northwest of Fairway Drive, near Eden, 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: 5.0' (5/20/16), 10.5' (7/1/16)	ELEVATION: ---

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
		Ground Surface									
	CL	SILTY CLAY with trace fine and coarse gravel; trace fine to coarse sand; trace organics; brown	0								moist very stiff
				37							
▼			5	69							saturated hard
				69							
			10	28		31		75			very stiff
				40							
			15	35							
				43							hard
			20	37							very stiff
		grades light gray to white		56							hard
	GC	CLAYEY GRAVEL	25								

See Subsurface Conditions section in the report for additional information.

FIGURE 3E

GSH

BORING LOG

Page: 2 of 2

BORING: B-5

CLIENT: Lewis Homes | PROJECT NUMBER: 1661-08N-16

PROJECT: The Bridges at Wolf Creek Phase I | DATE STARTED: 5/20/16 | DATE FINISHED: 5/20/16

WATER LEVEL	USCS	DESCRIPTION	DEPTH (FT.)	BLOW COUNT	SAMPLE SYMBOL	MOISTURE (%)	DRY DENSITY (PCF)	% PASSING 200	LIQUID LIMIT (%)	PLASTICITY INDEX	REMARKS
	GC	CLAYEY GRAVEL with trace fine to coarse sand; gray	25	38	X						moist very stiff
	CL/CH	SILTY CLAY with trace fine and coarse gravel; trace fine to coarse sand; brownish-gray		53	X						moist hard
			30	63	X						
				42	X						very stiff
			35	50+	X						hard
				57	X	22		71	59	35	
			40	50+	X						
		End of Exploration at 41.5' due to auger refusal Installed 1.25" diameter slotted PVC pipe to 40.0'									
			45								
			50								

See Subsurface Conditions section in the report for additional information.

FIGURE 3E
(continued)

CLIENT: Lewis Homes PROJECT: The Bridges at Wolf Creek Phase I PROJECT NUMBER: 1661-08N-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:	MODIFIERS:	MOISTURE CONTENT (FIELD TEST):
Weakly: Crumbles or breaks with handling or slight finger pressure.	**Trace** <5%	**Dry:** Absence of moisture, dusty, dry to the touch.
Moderately: Crumbles or breaks with considerable finger pressure.	**Some** 5-12%	**Moist:** Damp but no visible water.
Strongly: Will not crumble or break with finger pressure.	**With** > 12%	**Saturated:** Visible water, usually soil below water table.

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

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

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

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

STRATIFICATION:

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

Occasional: One or less per 6" of thickness

Numerous; More than one per 6" of thickness

TYPICAL SAMPLER GRAPHIC SYMBOLS

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

WATER SYMBOL

Water Level

FIGURE 5

GSH