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December 2, 2016

Wolf Creek Resort
3718 N. Wolf Creek Drive
Eden, Utah 84310
Attn: Mr. Eric Householder

IGES Project No. 02348-002

Subject: Geologic Hazards Assessment
The Retreat Subdivision
Eden, Utah

Mr. Householder:

At your request, IGES has performed a geologic hazards assessment for The Retreat Subdivision, located in the City of Eden in Weber County, Utah. This letter report identifies the nature and associated risk of the applicable geologic hazards associated with the property, based upon the results of the literature review, site reconnaissance, and subsurface investigation conducted as part of this assessment.

1.0 INTRODUCTION

The property is located in the City of Eden, Utah, approximately 2.5 miles north of Pineview Reservoir in the northeastern quarter of Section 22, Township 7 North, Range 1 East (see Appendix A, Figure A-1). The property is bound on the north and west by undeveloped lands, and on the east and south by partially completed residential neighborhoods containing intermittent developed and undeveloped lots. Elkhorn Drive runs along the southern margin of the property. We understand that The Retreat Subdivision consists of 45 lots to be developed as one to two-story wood-framed single-family residences, possibly with basements. It is also our understanding that of the 45 lots, 14 are currently unsold and 3 have already been developed. The development will cover a total of approximately 36 acres, and will include open space, community trails, and residential lots. The subject property is located within an area that is mapped as landslide deposits possibly associated with the Norwood Tuff, and as such is required to have a geologic hazard assessment prior to development in order to adequately meet the requirements of the Weber County Code. The following assessment has been produced to meet these requirements.

2.0 PURPOSE AND SCOPE

This study was initially performed as a reconnaissance-level geologic hazards assessment of the property, which was subsequently expanded to include subsurface investigation. The purpose of this assessment was to identify any surficial or subsurface geologic hazards that may be extant on the property or have the capability to adversely impact the property. Specifically, this study was conducted to:

- Analyze the existing geologic conditions present on the property and relevant adjacent areas;

- Assess the geologic hazards that pose a risk to development across the property, and determine an associated risk for each hazard; and

- Identify the most significant geologic hazard risks, and provide recommendations for appropriate additional studies and/or mitigation practices, if necessary.

In order to achieve the purpose and scope outlined above, the following services were performed as part of this investigation:

- Review of available published geologic reports and maps for the subject property and surrounding areas;

- Stereoscopic review of aerial photographs and analysis of additional available aerial imagery, including LiDAR;

- Site reconnaissance by an engineering geologist licensed in the state of Utah to map the surficial geology, determine site conditions, and assess the property for geologic hazards;

- Geologic logging of subsurface excavations, soil sampling, and slope stability analyses; and

- Preparation of this report, based upon the data reviewed and collected in this investigation.

3.0 REVIEW OF GEOLOGIC LITERATURE

A number of pertinent publications were reviewed as part of this assessment. Sorensen and Crittenden, Jr. (1979) provides the only 1:24,000 scale geologic mapping that covers the area in which the property of interest is located, in the form of the Huntsville Geologic Quadrangle. Coogan and King (2001) provide more recent geologic mapping of the area, but at a regional (1:100,000) scale. An updated Coogan and King (2016) regional geologic map (1:62,500 scale) provides the most recent published geologic mapping that covers the project area. A United States Geological Survey (USGS) topographic map for the Huntsville Quadrangle (2014) provides physiographic and hydrologic data for the project area. A Federal Emergency Management Agency (FEMA) flood map (effective in 2015) that covers the project area was reviewed. Regional-scale geologic hazard maps pertaining to landslides (Elliott and Harty, 2010; Colton, 1991), faults (Christenson and Shaw, 2008a; USGS and Utah Geological Survey (UGS), 2006), debris-flows (Christenson and Shaw, 2008b), liquefaction (Christenson and Shaw, 2008c; Anderson et al., 1994), and radon (Solomon, 1996) that cover the project area were also reviewed. More site-specific, the geotechnical report for the subject property (EarthTec, 2008) was reviewed.

3.1 General Geologic Setting

The Retreat Subdivision property is situated in the northern part of the Ogden Valley, along the foothills of the Wasatch Mountains, between two southwest-flowing unnamed ephemeral drainages. Ogden Valley separates the western part of the Wasatch Range from the Bear River Range to the east, a subgroup of mountains that are part of the parent Wasatch Range. The Wasatch Mountains contain a broad depositional history of thick Precambrian and Paleozoic sediments that have been subsequently modified by various tectonic episodes that have included thrusting, folding, intrusion, and volcanics, as well as scouring by glacial and fluvial processes (Stokes, 1987). The uplift of the Wasatch Mountains occurred relatively recently during the Late Tertiary Period (Miocene Epoch) between 12 and 17 million years ago (Milligan, 2000). Since uplift, the Wasatch Front has seen substantial modification due to such occurrences as movement along the Wasatch Fault and associated spurs, the development of the numerous canyons that empty into the current Salt Lake Valley and Utah Valley and their associated alluvial fans, erosion and deposition from Lake Bonneville, and localized mass movement events (Hintze, 1988). The Wasatch Mountains, as part of the Middle Rocky Mountains Province (Milligan, 2000), were uplifted as a fault block along the Wasatch Fault (Hintze, 1988). Ogden Valley itself is a fault-bounded trough that was occupied by Lake Bonneville (Sorensen and Crittenden, Jr, 1979) before being cut through by the Ogden River and subsequently dammed to form the Pineview Reservoir.

3.2 Surficial and Subsurface Geology

According to Sorensen and Crittenden, Jr. (1979), the property is located entirely on Holocene-aged (~11,700 years ago to the present) colluvium[1] and slopewash (Qcs) deposits (Figure A-2). The Qcs unit is underlain by the Norwood Tuff (Tn) across the property, and outcrops of the Norwood Tuff are present approximately 0.15 miles west of the property and 0.3 miles east of the property. Though two unnamed ephemeral drainages bound eastern and western margin of the property, no alluvial deposits were mapped in association with these drainages. Approximately 0.14 miles north of the northern margin of the property, an outcrop of the Lower Member of the Geertsen Canyon Quartzite (Cgcl) is present. A single northwest-southeast trending fault was mapped in the southern portion of the property near the southern margin. Additionally, a number of northwest-southeast trending faults were mapped to the south and east of the property, all within ¼ mile of the property, with some projecting onto the property (Sorensen and Crittenden, Jr., 1979).

Coogan and King (2001) denoted the area underlying the subject property entirely as Qmso, older (Pleistocene-aged; between 11,700 and 2.6 million years old) landslide and slump deposits, which are described as “poorly sorted clay to boulder-sized material; locally includes flow deposits.” In contrast to Sorensen and Crittenden, Jr. (1979), Coogan and King (2001) do not show the faults on, near, or projecting onto the property.

Most recently, Coogan and King (2016) displays the subject property to be predominantly underlain by a large lobe of old (Pleistocene-aged) landslide deposits (Qmso), with some younger (Holocene-aged) landslide deposits (Qms) mapped along the southern and

[1] Colluvium: A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides. (AGI, 2005)

southeastern portion of the property (Figure A-3). This map reinserts some of the linear features to the south and east of the property identified as faults by Sorensen and Crittenden, Jr. (1979), but reinterprets most of them to be landslide scarps, including the one near the southern margin of the property. One Holocene-aged normal fault is mapped as passing northwest-southwest approximately 0.1 miles south of the southern margin of the property. Older eroded alluvial fan deposits (Qafoe) are found adjacent to the Qmso deposits near the western margin of the property, in association with the larger of the two ephemeral drainages that bound the property.

As part of the geotechnical assessment for the property, EarthTec excavated a total of 7 test pits (EarthTec, 2008). The property was found to be largely devoid of topsoil, no groundwater was encountered in any of the test pits, and the soils largely consisted of dense clayey gravel with sand overlying elastic silt produced by the weathering of Norwood Tuff bedrock. A single occurrence of fat clay was noted in a test pit near the eastern margin of the property. Norwood Tuff bedrock was noted in only 2 of the 7 test pits.

3.3 Hydrology

The USGS topographic map for the Huntsville Quadrangle (2014) shows that The Retreat Subdivision project area is situated within the broad northwest-southeast trending Ogden Valley and straddled by two northeast-southwest trending ephemeral stream drainages which form the eastern and western margins of the property, respectively (see Figure A-1). Neither of these drainages were found to contain flowing water during the site reconnaissance. Multiple generally northeast-southwest trending gullies pass onto and across the property from the upslope area to the northeast. No springs are known to occur on the property, though it is possible that springs may occur on various parts of the property during peak spring runoff. A number of springs are found within ¼ mile downslope of the property.

Baseline groundwater depths for The Retreat Subdivision property are currently unknown, but are anticipated to fluctuate both seasonally and annually. Groundwater was not encountered in any of the test pits excavated by EarthTec (2008) for the geotechnical investigation of the property, conducted in late August.

The FEMA flood map that covers the project area shows that the property is in Zone X, located outside of the 500-year flood floodplain for any nearby drainage (FEMA, 2015).

3.4 Geologic Hazards

Based upon the available geologic literature, regional-scale geologic hazard maps that cover The Retreat Subdivision project area have been produced for landslide, fault, debris-flow, liquefaction, and radon hazards. The following is a summary of the data presented in these regional geologic hazard maps.

3.4.1 Landslides

Two regional-scale landslide hazard maps have been produced that cover the project area. Colton (1991) shows the property to be partially located within a large area that is queried as a possible landslide deposit. More recent mapping by Elliott and Harty (2010) refined the area queried by Colton (1991) and show the property to be located within an area classified as a "Deep or unclassified landslide," with individual landslide deposits generally greater than 10 feet thick and exhibiting characteristic landslide morphology.

3.4.2 Faults

Neither Christensen and Shaw (2008a) nor the Quaternary Fault and Fold Database of the United States (USGS and UGS, 2006) show any Quaternary-aged (~2.6 million years ago to the present) faults to be present on or projecting towards the subject property. The Ogden Valley North Fork Fault is located approximately 1.7 miles to the southwest of the property, and the Ogden Valley Northeastern Margin Fault is located approximately 0.8 miles to the northeast of the property. These faults represent the closest Quaternary-aged faults to the property (UGS, 2016a). The Weber County Natural Hazards Overlay Districts defines an active fault to be “a fault displaying evidence of greater than four inches of displacement along one or more of its traces during Holocene time (about 11,000 years ago to the present)” (Weber County, 2015). The closest active fault to the property is the Weber Segment of the Wasatch Fault Zone, located approximately 6.1 miles west of the western margin of the property (USGS and UGS, 2006). Coogan and King (2016) map a northwest-trending, southwest-dipping normal fault approximately 0.1 miles south of the southern margin of the property, though this fault is not included in either the Utah Quaternary Fault and Fold Database (UGS, 2016a) or the Quaternary Fault and Fold Database of the United States (USGS and UGS, 2006).

3.4.3 Debris-Flows

Christensen and Shaw (2008b) do not show the project area to be located within a debris-flow hazard special study area.

3.4.4 Liquefaction

Anderson, et al. (1994) and Christensen and Shaw (2008c) both show the project area to be located in an area with very low potential for liquefaction.

3.4.5 Radon

Solomon (1996) has part of the project area located in an area with moderate radon levels.

4.0 REVIEW OF AERIAL IMAGERY

A series of aerial photographs that cover project area were taken from the UGS Aerial Imagery Collection (UGS, 2016b) and analyzed stereoscopically for the presence of adverse geologic conditions across the property. This included a review of photos collected from the years 1946 and 1963 that were taken prior to the development of the nearby neighborhoods. A table displaying the details of the aerial photographs reviewed can be found in the *References* section at the end of this report.

No geologic lineaments, fault scarps, landslide headscarps, or landslide deposits were observed in the aerial photography on the subject property. However, upslope of the property to the northeast a prominent landslide headscarp and associated highly irregular, hummocky topography was observed. This is consistent with the older landslide deposit mapped by Coogan and King (2001 and 2016) and Elliott and Harty (2010).

Google Earth imagery of the property from between the years of 1993 and 2016 were also reviewed. No clear landslide scarps or deposits or other geological hazard features were noted in the imagery on the property, though the property was seen to be slightly hummocky in places. Most of the project area was observed to be covered in grasses and small bushes with a mantling of scattered cobbles and boulders; few trees were observed on the property. The southern part of the property exhibited the most irregular, possibly hummocky topography. Northeast of the property, the prominent landslide headscarp and associated landslide deposits noted in the aerial photographs were readily observed. The headscarp is located approximately 0.6 miles northeast of the northern margin of the property, and the two ephemeral drainages that bound the property were seen to originate (at least in part) from the edges of the scarp. Approximately ¼ mile northeast of the property in the vicinity of a water tank, the ground becomes noticeably hummocky, with the hummocky topography extending upslope to the northeast to the headscarp. The area between the hummocky topography near the water tank and the northern margin of the property was observed to be highly gullied, though generally with a consistent slope.

Utah Geological Survey 1 meter LiDAR data (UGS, 2011) for the project area was reviewed. The property was shown to contain a number of the gullies evident in the Google Earth imagery, though the property was largely not observed to be irregular or hummocky. The most irregular ground surface was observed near the northern margin of the property.

5.0 SITE RECONNAISSANCE

Mr. Peter E. Doumit, P.G., C.P.G., of IGES conducted reconnaissance of the site and the immediate adjacent properties on September 8, 2016. The site reconnaissance was conducted with the intent to assess the general geologic conditions present across the property, with specific interest in those areas identified in the geologic literature and aerial imagery reviews as potential geologic hazard areas. Additionally, the site reconnaissance provided the opportunity to geologically map the surficial geology of the area. Figure A-4 is a site-specific geologic map of The Retreat Subdivision property and adjacent areas, and Figure A-5 depicts the surficial geology on an aerial image, with reference to the landslide referenced above.

Much of the property was found to have been disturbed by human activity, largely in the form of existing asphalted roads and cul-de-sacs, and differentiating between the natural and human-altered modern topography was difficult to discern in places. In general, the existing terrain was largely sloping to the southwest and covered with quartzite cobbles and boulders. Road cuts in cul-de-sacs displayed as much as 10 feet of what appeared to be colluvial cover overlying weathered Norwood Tuff bedrock. The colluvial cover was observed to decrease in thickness downslope towards the southern parts of the property. The colluvium consisted of subangular to subrounded rock clasts up to 5 feet in diameter, though the mode average size was generally between 1 and 1.5 feet in diameter.

Three distinct lithologies were observed in the colluvial clasts:

1. Tan to white to orange, massive to banded quartzite; cherty in places. This lithology constituted approximately 80% of the clasts on the property.
2. Medium light gray pebbly conglomeratic quartzite. This lithology constituted approximately 15% of the clasts on the property.
3. Medium gray to dark yellow orange, well-indurated sandstone; largely oxidized, though still very hard and competent. This lithology constituted approximately 5% of the clasts on the property.

It should be noted that while it was originally assumed that weathered Norwood Tuff bedrock was seen in the cul-de-sac road cuts, Norwood Tuff clasts were not observed on the surface in association with the colluvium and neither Norwood Tuff clasts nor Norwood Tuff bedrock were encountered in any of the test pits excavated as part of this investigation.

The highly hummocky topography northeast of the property near the water tank was observed to contain a number of internal scarps and small landslide toes. However, none of the landslide scarps were observed to display evidence of recent or historic movement (the soil profile was not freshly exposed at the scarps). Between the hummocky topography and the northern margin of the property, a notable geomorphic change was observed in which the highly irregular, hummocky ground gave way downslope to generally even, consistently-sloping ground.

Four surficial geologic units were differentiated on and adjacent to the property (see Figures A-4 and A-5), as well as areas that have been modified by human activity. Each of these units are discussed in turn below.

Qal (Recent alluvium)

This unit was mapped along the western and eastern margins of the property in association with the unnamed northeast-southwest trending ephemeral drainages. The unit is characterized by the presence of abundant subrounded to subangular quartzite and sandstone clasts as described above, up to 5 feet in diameter, which litter the base and banks of the drainage. It is possible that some of this unit was deposited via a series of debris-flows during major storm events. This surficial alluvial unit was not observed in the subsurface, but the unit is likely to be less than 10 feet thick.

Qc (Holocene-Pleistocene colluvium)

This unit underlies nearly all of The Retreat property, and is found to extend from approximately the water tank north of the property to Elkhorn Drive to the south. The unit was observed in the subsurface in all 5 of the test pits, and consists of abundant cobbles and boulders of quartzite up to 2 feet in diameter loosely consolidated within a topsoil matrix comprised of a lean clay gradational to fat clay. The USCS classification of this unit graded between gravelly lean clay (CL) to lean clay with gravel (CL), and was found to be between 1 and 3 feet thick.

Qlso (Holocene to Pleistocene landslide deposits)

This unit was mapped to the northeast of the property, extending northeast from the approximate location of the water tank to the prominent headscarp at the head of the valley. In the area underlain by this unit, the surface was characterized by significant hummocky, irregular topography exhibiting several internal scarps. However, the subdued nature of the headscarp and the absence of internal scarps exhibiting recent movement suggest a Late Pleistocene/Early Holocene age for these deposits. In the subsurface, this unit was found underlying the Qc unit in 4 of the 5 test pits, and consisted of fat clay with gravel (CH) that commonly exhibited a basal shear zone. The unit was found range between 2.5 and 12 feet thick.

Cgcl (Cambrian Geertsen Canyon Quartzite, Lower Member)

This bedrock unit was found to outcrop northwest of the property, on the western side of the unnamed ephemeral drainage that bounds the western margin of the property. The unit consisted of a white to brown, amorphous to sugary quartzite that commonly exhibited an orange weathering rind. In contrast to the Coogan and King (2016) bedding orientation, which displays a northerly strike and dip of approximately 26°E for this bedrock outcrop, the outcrop was observed to display a strike of S70°E and dip of between 65 and 77°SW, based on internal bedding and laminations. This bedrock unit was not encountered in any of the test pits, though as much as 15 feet of outcrop was exposed at the surface.

5.1 Surface Water/Groundwater

At the time of the site visit, neither of the ephemeral stream drainages that bound the property were observed to be presently transporting surface water, though the surficial soils in the drainages were observed to be slightly moist.

No springs were identified on the property, and an absence of hydrophilic plants on the property suggests that groundwater is not shallow.

5.2 Geologic Hazards

Based on the fact that the property is located within a mapped landslide deposit and is possibly underlain by the landslide-prone Norwood Tuff, combined with the observation of significant landslide deposits upslope of the property and some uneven ground on the property, it was determined that there is substantial reason to believe that a landslide hazard exists for the property. As such, a subsurface component of the geologic hazard assessment was required to assess the nature and extent of the landslide deposits and associated hazard.

6.0 SUBSURFACE INVESTIGATION

A subsurface investigation of the property was performed between October 7 and 10, 2016. Five test pits were excavated by way of a Komatsu PC300LC tracked excavator to depths between 13 and 16 feet below existing grade (see Figures A-4 and A-5). The subsurface excavations were logged and photographed in detail; the logs are displayed in Figures A-6 through A-10. Practical refusal in hard bedrock was not encountered in any of the excavations. Additionally, groundwater was not observed in any of the test pits.

The common stratigraphic section encountered in the test pits included a thin topsoil between 3 inches and 1 foot thick, weathering upon a colluvial unit between 1 and 3 feet thick. The colluvial unit was overlying a shallow landslide deposit between 2.5 and 12 feet thick, and the shallow landslide unit was underlain by an alluvial deposit consisting of gravelly sand (SW). Both TP-1 and TP-2 were found to have a 3- to 5-foot-thick transitional unit between the shallow landslide and alluvial unit, consisting of sandy fat clay with gravel (CH). TP-3 was found to contain a sandy gravel (GW) fluvial deposit at least 2 feet thick in the base of the test pit, representing an ancient river channel that passed through the property. TP-4 was anomalous in that it contained two distinct landslide units situated upon a thin shear plane, though the basal landslide deposit was a gravelly sand with clay (SC-GC) that appeared similar to both the transitional unit observed in TP-1 and TP-2, as well as the alluvial unit observed in the other test pits underlying the upper landslide clay. No landslide deposits were encountered in TP-5, as the colluvial unit was found to be underlain by gravelly sand gradational to sandy gravel (SW-GW) in what resembled the Wasatch Formation, but may be alluvial deposits.

6.1 Laboratory Testing

Geotechnical laboratory tests were conducted on selected soil samples obtained during our subsurface investigation. The laboratory testing program was designed to evaluate the engineering characteristics of onsite earth materials and to assist in classification. Laboratory tests conducted during this investigation included:

- In situ moisture content (ASTM D7263)
- Atterberg Limits (ASTM D4318)
- Fines Content (% passing the #200 sieve) (ASTM D1140)
- Gradation (ASTM D6913)
- Direct Shear and Residual Shear Test (ASTM D3080)

Results of the laboratory testing are included with this report in Appendix B.

7.0 GEOLOGIC HAZARD ASSESSMENT

Geologic hazard assessments are necessary to determine the potential risk associated with particular geologic hazards that are capable of adversely affecting a proposed development area. As such, they are essential in evaluating the suitability of an area for development and provide critical data in both the planning and design stages of a proposed development. The geologic hazard assessment discussion below is based upon a qualitative assessment of the risk associated with a particular geologic hazard, based upon the data reviewed and collected as part of this investigation.

A “low” hazard rating is an indication that the hazard is either absent, is present in such a remote possibility so as to pose limited or little risk, or is not anticipated to impact the project in an adverse way. Areas with a low-risk determination for a particular geologic hazard generally do not require additional site-specific studies or associated mitigation practices with regard to the geologic hazard in question. A “moderate” hazard rating is an indication that the hazard has the capability of adversely affecting the project at least in part, and that the conditions necessary for the geologic hazard are present in a significant, though not abundant, manner. Areas with a moderate-risk determination for a particular geologic hazard may require additional site-specific studies and associated mitigation practices in the areas that have been identified as the most prone to susceptibility to the particular geologic hazard. A “high” hazard rating is an indication that the hazard is very capable of adversely affecting the project, that the geologic conditions pertaining to the particular hazard are present in abundance, and/or that there is geologic evidence of the hazard having occurred at the area in the historic or geologic past. Areas with a high-risk determination generally always require additional site-specific hazard investigations and associated mitigation practices. For areas with a high-risk geologic hazard, simple avoidance is often considered.

The following are the results of the geologic hazard assessment for The Retreat Subdivision property.

7.1 Landslides/Mass Movement

Landslides and mass movement hazards pose the greatest risk to The Retreat Subdivision property. The property is entirely within an area previously mapped as an older (Pleistocene-aged) landslide (Coogan and King, 2016), aerial and LiDAR imagery indicated some hummocky topography, and the site reconnaissance observed hummocky topography northeast of the property and some irregular ground on the property (see Figures A-4 and A-5). This data was the basis for a subsequent subsurface investigation to assess the nature and extend of the landslide hazard on the property.

A correlative landslide unit approximately 2.5 to 6.5 feet thick consisting of brownish gray fat clay with gravel (CH) was observed in all test pits except TP-5. This unit commonly exhibited a heavily slickensided basal shear zone and occasional slickensides in the rest of the unit in TP-1 and TP-2, though the basal shear zone was absent and slickensides were less common in TP-3 and TP-4. In general, the landslide unit exhibited well-developed shear in the upslope (northeastern) test pits, while evidence of shear was significantly less common in the downslope (southwestern) test pits, and was altogether absent in the southeasternmost test pit (TP-5). These features are indicative of a translational slide, but may also represent post-deposition soil creep. A second landslide unit observed in TP-4, underlying the aforementioned correlative landslide unit, contained slickensides in clayey portions of the unit, but was generally much more granular than the overlying landslide deposit. This unit was more indicative of a debris-flow type landslide deposit, and represents a small, localized landslide that occurred prior to the more wide-spread, largely translational failure that subsequently covered most of the property.

Given this data, the landslide risk associated with the property is considered to be high for the unsold lots located in the northern ~1/3 of the property, including Lots 30, 31, 34, 38, 39, 42, 43, 44, and 45. The subsurface data indicate that these lots are most susceptible to mass movement, and are also at risk of the potential downslope movement from the large landslide deposit mapped northeast of the property above the water tank. The landslide risk associated with the remaining unsold lots (Lots 16, 19, 24, 28, and 29) is considered to be moderate, as the subsurface data indicate that less-developed and discontinuous shear planes are present within the shallow landslide deposit, and a well-developed basal shear zone was not observed in the test pits in this area. In both cases, the granular nature of the subsurface materials, including the generally high proportion of cobbles found in the shallow landslide unit (~15-20%), aids in reducing the propensity for mass movement.

7.2 Slope Stability Analysis

The stability of the existing natural slope has been assessed in general accordance with methodologies set forth in Blake, et al. (2002) with respect to Section A-A', illustrated on Figures A-4 and C-1. The stability of the slope was modeled using SLIDE, a computer application incorporating (among others) Spencer's Method of analysis. Calculations for stability were developed by searching for the minimum factor of safety for both translational-type and rotational-type failures. Homogeneous earth materials (colluvium, older landslide deposits) and both arcuate and planar failure surfaces were assumed. Analysis was performed for the following cases:

a) Static analysis of existing slope
b) Pseudo-static analysis of existing slope

Strength of earth materials was estimated based on direct observation of site earth materials (coarse granular colluvium and clayey landslide deposits) and the results of direct shear tests performed on representative remolded specimens. The results of the direct shear tests are presented in Appendix B, and are summarized in Table 1:

Table 1
Summary of Laboratory Soil Strength Testing

Sample	Description	Test	Friction Angle (deg.)	Cohesion (psf)
TP-2 at 9'	Colluvium, Clayey Sand (SC)	Direct Shear	33	673
TP-1 at 10'	Landslide, Sandy Clay (CH)*	Direct Shear, Residual	11.1	286

*sample obtained from landslide basal shear zone

Based on these test results, appropriate and reasonable soil strength parameters were selected.

Pseudo-static (seismic screening) analysis of the proposed slope was performed in general conformance with Blake, et al. (2002). The design seismic event was taken as the ground motion with a 2 percent probability of exceedance in 50 years (2PE50). Based on information provided in the geotechnical report (Earthtec, 2008), the Peak Ground Acceleration (PGA) associated with a 2PE50 event is taken as 0.44g. Half of the PGA was taken as the horizontal seismic coefficient (k_h = 0.22g) (Hynes and Franklin, 1984), and used in the pseudo-static seismic screen analysis.

Groundwater was not encountered during our investigation, and therefore was not modeled in our analysis.

Our slope stability analysis indicates that the subject property meets the minimum acceptable factors-of-safety of 1.5 (static) and 1.0 (seismic or pseudo-static). The results of the stability analyses are presented in Appendix C.

7.3 Rockfall

No bedrock is exposed upslope of the property. As such, the rockfall hazard associated with the property is considered to be low.

7.4 Surface-Fault-Rupture and Earthquake-Related Hazards

No faults are known to be present on or projecting towards the property, and the closest active fault to the property is the Weber Segment of the Wasatch Fault Zone, located approximately 6.1 miles to the west of the western margin of the property (USGS and UGS, 2006). Given this information, the risk associated with surface-fault-rupture on the property is considered low.

The entire property is subject to earthquake-related ground shaking from a large earthquake generated along the active Wasatch Fault. Given the distance from the Wasatch Fault, the hazard associated with ground shaking is considered to be moderate. Proper building design according to appropriate building code and design parameters can assist in mitigating the hazard associated with earthquake ground shaking.

7.5 Liquefaction

Given the generally clayey, though granular and dry nature of the surficial materials, and consistent with the existing geologic literature for the area, the risk associated with earthquake-induced liquefaction is expected to be low. However, we cannot preclude the possibility for liquefaction to occur onsite. A liquefaction study, which would include borings and/or CPT soundings to a depth of at least 50 feet or bedrock, whichever is shallower, was not performed for this project and is not a part of our scope of work.

7.6 Debris-Flows and Flooding Hazards

No alluvial fan deposits have been mapped on the property, though the property is flanked by ephemeral stream drainages. However, no active stream drainages pass through the property, and all lots on the property are elevated at least approximately 10 feet above the adjacent ephemeral drainages. The basal landslide deposit observed in TP-4 may have been deposited by way of a debris-flow, given its proximity to the ephemeral stream drainage. If so, it likely represents a Pleistocene-aged debris-flow produced under much wetter conditions and a larger available volume of source material than currently exists. Given this information, the debris-flow hazard for the property is considered to be low.

The FEMA flood map that covers the area (FEMA, 2015) shows the entire property to be located outside of the 500-year floodplain for any nearby drainage. Additionally, all of the lots are situated at least approximately 10 feet above the adjacent ephemeral drainages. Given this information, the flooding hazard for the property is considered to be low.

7.7 Shallow Groundwater

Groundwater was not encountered in any of the 7 test pits excavated as part of the original geotechnical investigation for the property (EarthTec, 2008), nor in the 5 test pits excavated as part of this investigation. The geotechnical test pits were excavated in late August, and the geologic hazard test pits were excavated in early to mid-October, so groundwater levels were likely to be dropping toward seasonal lows. The absence of surface water, springs, groundwater in the test pits, and hydrophilic plants on the property suggests that shallow groundwater conditions are not sustained across the property. As such, the risk associated with shallow groundwater hazards is considered to be low for the property. Nevertheless, it is expected that groundwater levels will fluctuate both seasonally and annually across the property. If present, shallow groundwater issues can be mitigated through appropriate grading measures and/or the avoidance of the construction of structures with basements (except where foundation drains are utilized), or through the use of land-drains.

7.8 Radon

Limited data is available to address the radon hazard across the property. However, at least one study (Solomon, 1996) shows the site situated within an area designated as having a moderate radon hazard. To be conservative, the radon hazard associated with the property is considered to be moderate. A site-specific radon hazard assessment is recommended to adequately address radon concerns across the property.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the data collected and reviewed as part of this assessment, IGES makes the following conclusions regarding the geological hazards present at The Retreat Subdivision project area:

- **The Retreat Subdivision project area does appear to have geological hazards that could potentially adversely affect significant portions of the development as currently proposed. Geological hazards in the form of landslides and other mass-movement processes, including soil creep, are capable of adversely affecting all of the remaining unsold lots on the property. IGES concludes, however, that the geologic conditions are such that appropriate mitigation practices (discussed in the *Recommendations* section below) can reduce the level of landslide/mass movement hazard risk to an acceptable level for development.**

- Landslide hazards are considered to be moderate for the northernmost ~1/3 of the property, including for unsold Lots 30, 31, 34, 38, 39, 42, 43, 44, and 45. This designation is based upon the presence of a shallow landslide unit exhibiting extensive shearing, and the proximity to the visible landslide deposits near the water tank northeast of the property. Landslide hazards are considered to be low to moderate for the remaining unsold lots on the property, including Lots 16, 19, 24, 28, and 29. Though the shallow landslide unit was observed in the test pits excavated near these lots, the shearing was found to be less prevalent and discontinuous.

- The preexisting landslide appears to be stable based on the current location of the slide, measured soil strengths, and limit equilibrium slope stability analysis performed for the existing conditions. Anticipated grading (construction of homes with basements, moderate cuts and fills for grading around the homes, etc.) is not expected to alter the stability of the slope in a meaningful way. Consequently, **the site is considered suitable for the proposed development of single-family residences across the property, provided the recommendations presented in the following paragraphs are followed.**

- Debris-flow and flooding, shallow groundwater, rockfall, and surface-fault-rupture hazards are all considered to be low for the property.

- Earthquake ground shaking and radon are the only hazards that may potentially affect all parts of the project area, while other hazards have the potential to affect only limited portions of the project area, or pose minimal risk.

- Published literature, the site-specific geotechnical report (EarthTec, 2008), and the laboratory results in this geologic hazard assessment indicate that the liquefaction potential for the site is appropriately considered low. However, due to the presence of some granular soils and the possibility of shallow groundwater, the potential for liquefaction occurring at the site cannot be ruled out.

Given the conclusions listed above, IGES makes the following recommendations:

- Foundations shall be placed on competent alluvial soils or structural fill extending to competent alluvial soils; this will require over-excavating below the base of the landslide (where present). Over-excavation need only be performed under exterior continuous foundation elements, not the entire building footprint. Prior to placement of steel or concrete, IGES should observe the foundation excavation to assess compliance with this recommendation and the recommendations for foundation subgrade preparation presented in the geotechnical report (EarthTec, 2008).

- Excavated foundation soils may be utilized for structural fill provided the soils meet the requirements of the referenced geotechnical report by EarthTec (2008). Over-size earth materials (more than 8 inches in greatest dimension) should not be incorporated into structural fill.

- All other recommendations presented in the referenced geotechnical report by EarthTec (2008) should be followed as applicable, except where superseded by site-specific recommendations presented in this report.

- It is recommended that the landscaping for this development consist of xeriscape, so as to minimize the amount of water introduced into the subsurface in these areas. Landscaping that requires intensive watering (e.g. grass or hydrophilic plants) should be avoided or minimized.

- It is critical to minimize the introduction of water into the subsurface to limit the potential for activation of new landslides or the re-activation of existing landslides. To this end, the inclusion of passive land drains as a part of the civil plans would be beneficial. On-site sewage or storm-drain disposal should not be allowed.

- To adequately address the radon hazard for the property, a site-specific radon assessment is recommended. This could be conducted either on a property-wide basis or a lot-by-lot basis.

- The property as a whole may be largely underlain by the Norwood Tuff, which is a known landslide-prone unit. Additionally, landslide deposits have been mapped on and near the property. Therefore, it is recommended that an IGES engineering geologist observe the foundation excavations for all of the proposed residences to assess the absence of landslide evidence or other adverse geologic conditions in these areas, and to assess compliance with the recommendations contained in this report.

9.0 LIMITATIONS

The conclusions and recommendations presented in this report are based on limited geologic literature review, site reconnaissance, subsurface investigation, laboratory testing, and our understanding of the proposed construction and landslide geometry. The subsurface data used in the preparation of this report were obtained from the explorations made for this investigation and the preceding geotechnical investigation for the property (Earthtec, 2008). It is possible that variations in the soil, geologic structure, and groundwater conditions exist between the points explored. The nature and extent of variations may not be evident until construction occurs. If any conditions are encountered at this site that are different from those described in this report, our firm should be immediately notified so that we may make any necessary revisions to recommendations contained in this report. In addition, if the mitigation measures described herein are altered from that described in this report, our firm should also be notified.

This report was prepared in accordance with the generally accepted standard of practice at the time the report was written; no warranty, expressed or implied, is made. Development of property on or adjacent to documented landslide deposits involves an inherent level of risk, regardless of recommended mitigation practices. In our professional opinion, the mitigation practices recommended in this report will reduce the landslide hazard risk to a reasonable level; however, development in a landslide-prone area always assumes some level of risk, and consequently the Client should understand and accept this risk and develop on this site at their own risk and option. It is not possible to predict whether or not other landslide slip surfaces within the landslide masses upon which the property is partially located will reactivate for currently unknown reasons.

Additional geologic hazards and/or geologic hazards initially concluded to pose low risk may be present that may not be identified until construction activities expose adverse geologic conditions. Therefore, the geologic hazard classifications as denoted in this report are potentially subject to change with data collected from additional excavations across the property.

It is the Client's responsibility to see that all parties to the project including the Contractor, Subcontractors, etc. are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the Contractor's option and risk.

10.0 CLOSURE

We appreciate the opportunity to provide you with our services. If you have any questions, please contact the undersigned at your convenience at (801) 748-4044.

Respectfully Submitted,
IGES, Inc.

Peter E. Doumit, P.G., C.P.G.
Senior Geologist

Reviewed by:

David A. Glass, P.E.
Senior Geotechnical Engineer

Attachments:

Section 11.0	References	
Appendix A	Figure A-1	General Location Map
	Figure A-2	Regional Geology Map 1
	Figure A-3	Regional Geology Map 2
	Figure A-4	Local Geology Map 1
	Figure A-5	Local Geology Map 2
	Figures A-6 to A-10	Exploration Logs
Appendix B		Laboratory Results
Appendix C		Slope Stability Analysis – Summary

11.0 REFERENCES

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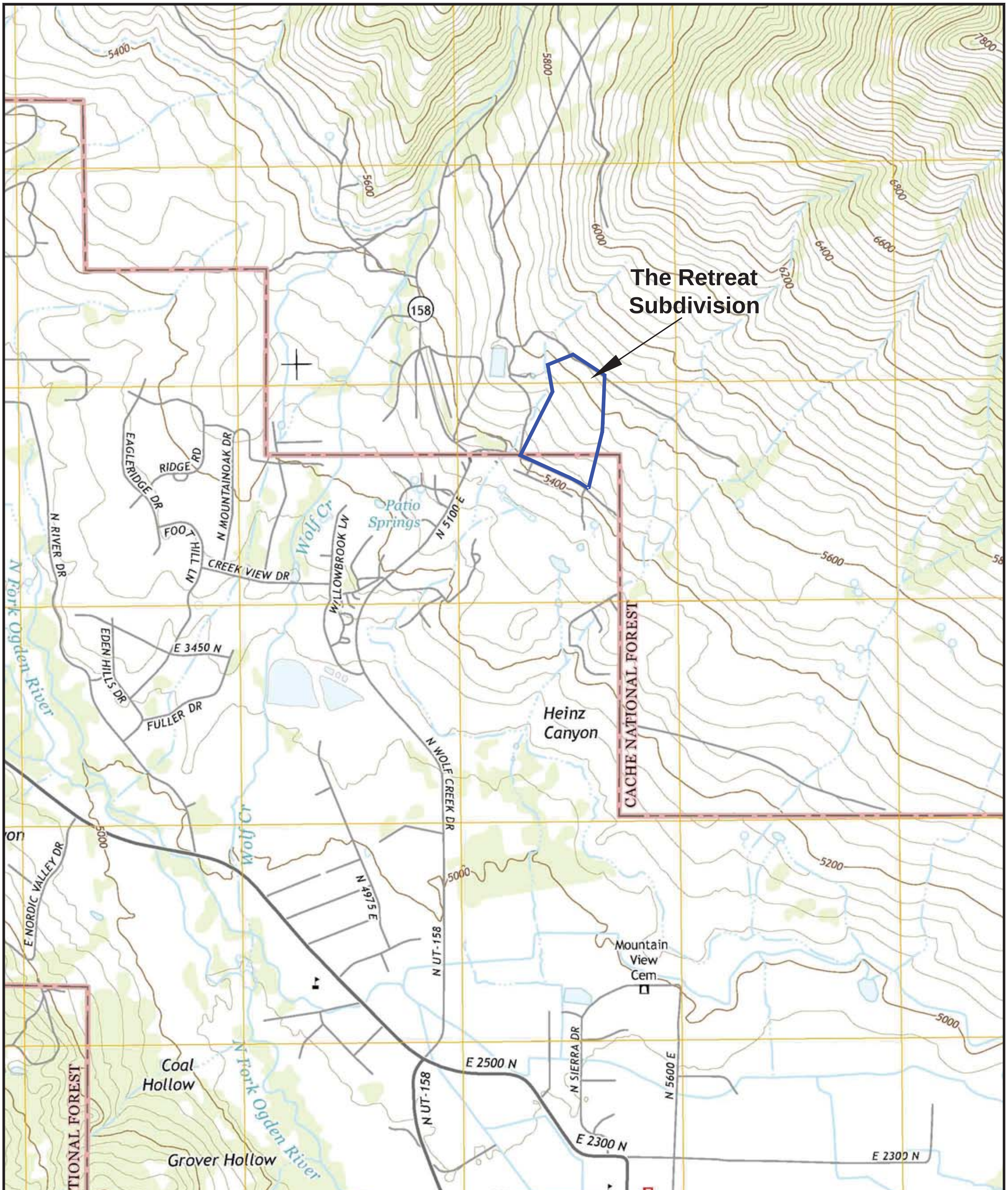
Data Set	Date	Flight	Photographs	Scale
1947 AAJ	August 10, 1946	2B	46, 47	1:20,000
1963 ELK	June 25, 1963	2	169, 170	1:15,840

*https://geodata.geology.utah.gov/imagery/

APPENDIX A



BASE MAP:

USGS Huntsville 7.5-Minute Topographic Quadrangle Map (2014)

QUADRANGLE LOCATION

N

0 1000 2000 3000

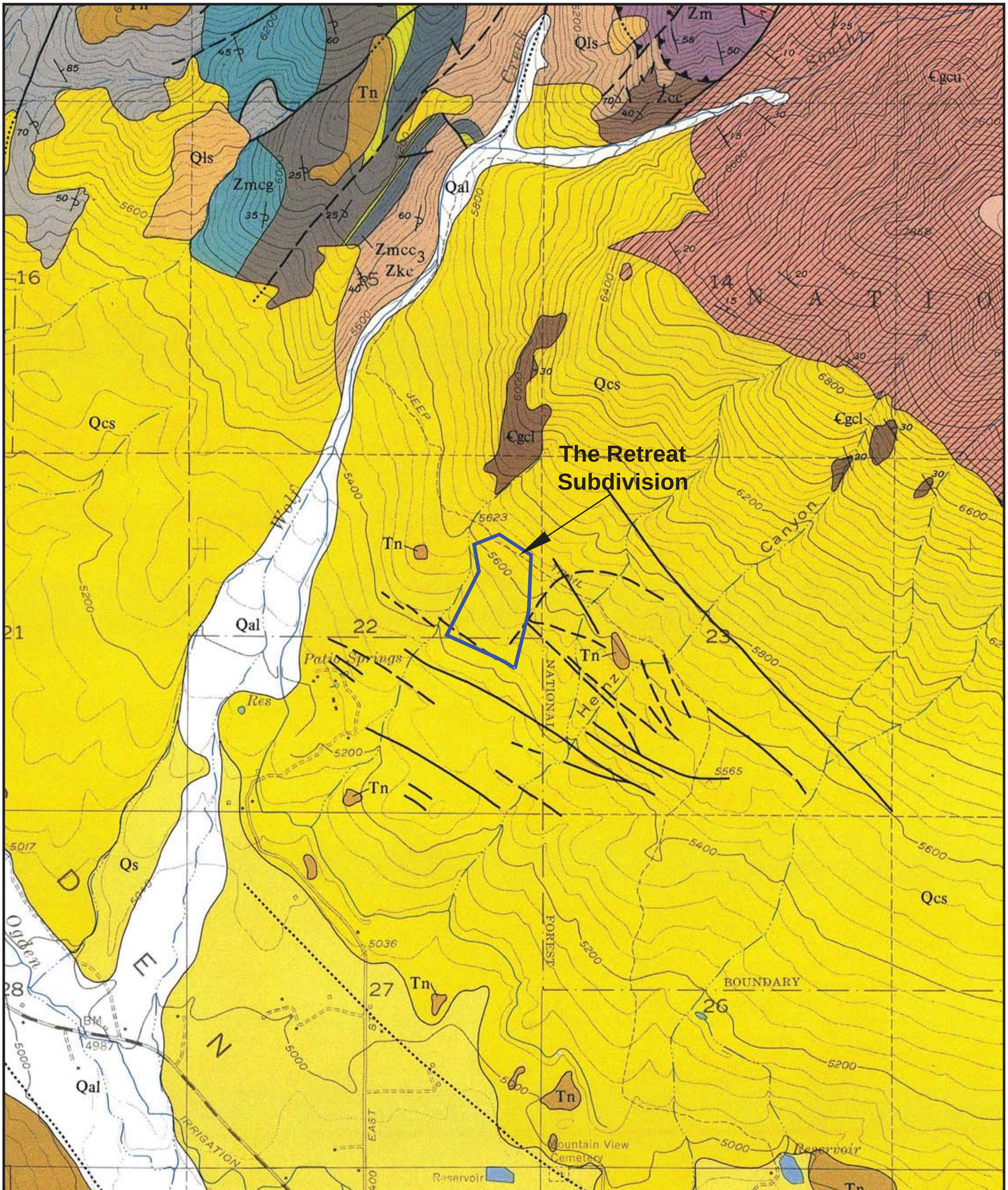
FEET

FIGURE A-1

GENERAL LOCATION MAP

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016
PROJECT:02348-002
SCALE: 1"=2,000'
IGES



BASE MAP:

USGS Huntsville 7.5-Minute Geologic Quadrangle Map (GQ-1503) Sorensen and Crittenden, Jr., 1979

QUADRANGLE LOCATION

N

0 1000 2000 3000

FEET

FIGURE A-2a

REGIONAL GEOLOGY MAP 1

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016
PROJECT:02348–002
SCALE: 1"=2,000'
IGES

MAP LEGEND

Qal — ALLUVIAL DEPOSITS, UNDIFFERENTIATED (Holocene) – Unconsolidated gravel, sand, and silt deposits in presently active stream channels and floodplains; thickness 0-6 m

Qcs — COLLUVIUM AND SLOPEWASH (Holocene) – Bouldery colluvium and slopewash chiefly along eastern margin of Ogden Valley; in part, lag from Tertiary units; thickness 0-30 m

Qf — ALLUVIAL FAN DEPOSITS (Holocene) – Alluvial fan deposits; postdate, at least in part, time of highest stand of former Lake Bonneville; thickness 0-30 m

Qls — LANDSLIDE DEPOSITS (Holocene) – thickness 0-6 m

Qt — TALUS DEPOSITS (Holocene) – thickness 0-6 m

Qtd — TERRACE AND DELTA(?) DEPOSITS (Pleistocene) – In North Fork Ogden River, gravel, sand, and silt in stream terraces graded to high stand of former Lake Bonneville; at mouth of Middle and South Fork Ogden River, pinkish-tan sand and silt in delta(?) remnants deposited during high stands of Lake Bonneville; thickness 0-45 m

Qs — SILT DEPOSITS (Pleistocene) – Tan silt and sand forming extensive flats in Ogden Valley; deposited during high stands of Lake Bonneville, but may include older alluvial units; thickness 0-60 m

Qg — GRAVEL AND COBBLE DEPOSITS (Pleistocene) – In Ogden Canyon, gravel and cobble terrace remnants, probably deposited after time of highest stand of Lake Bonneville; thickness 0-3 m

Qog — OLDER GRAVEL DEPOSITS (Pleistocene) – North of Huntsville, cobble, gravel, and sand deposit that probably predates high stands of Lake Bonneville; thickness 21 m

Tn — NORWOOD TUFF (lower Oligocene and upper Eocene) – Fine- to medium-bedded, fine-grained, friable, white- to buff-weathering tuff and sandy tuff, probably waterlain and in part reworked; thickness 0-450+(?) m

BASE MAP:
USGS Huntsville 7.5-Minute Geologic Quadrangle Map (GQ-1503), Sorensen and Crittenden, Jr. (1979)

QUADRANGLE LOCATION

N

0 1000 2000 3000
FEET

FIGURE A-2b

REGIONAL GEOLOGY MAP 1

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016 | PROJECT:02348–002 | SCALE: 1"=2,000' | IGES

MAP LEGEND

€gcu — GEERTSEN CANYON QUARTZITE (Lower Cambrian) — Includes:
Upper member — Pale-buff to white or flesh-pink quartzite, locally streaked with pale red or purple. Coarse-grained; small pebbles occur throughout unit and increase in abundance downward. Base marked by zone 30-60 m thick of cobble conglomerate in beds 30 cm to 2 m thick; clasts, 5-10 cm in diameter, are mainly reddish vein quartz or quartzite, sparse gray quartzite, or red jasper; thickness 730-820 m

€gcl — Lower member — Pale-buff to white and tan quartzite with irregular streaks and lenses of cobble conglomerate decreasing in abundance downward. Lower 90-120 m strongly arkosic, streaked greenish or pinkish. Feldspar clasts increase in size to 0.6-1.3 cm in lower part of unit; thickness 490-520 m

Zkc ls — KELLEY CANYON FORMATION (Precambrian Z) — Upper part interbedded olive-drab siltstone and thin-bedded, tan- or brown-weathering quartzite, generally in wavy or contorted beds cut by small sandstone dikelets; contact with overlying unit may be marked by zone of thin-bedded quartzite (0.5-2-cm beds) with red-weathering wavy laminae of shale and siltstone. Middle part is gray to lavender argillite enclosing and intercalated with thin-bedded pinkish-gray silty limestone (at Middle Fork Ogden River, shown on map as ls). Lower part is lavender-gray, purple-gray, or olive-drab shale, with thin beds of greenish fine-grained sandstone at top. Base of unit marked by 3-m thin-bedded to laminated, tan-weathering, fine-grained dolomite; thickness 600 m

MAPLE CANYON FORMATION (Precambrian Z) — Includes:

Zmcc — Conglomerate member — Total thickness 30-150 m. Includes:

$Zmcc_3$ — Upper conglomerate — Coarse-grained, locally conglomeratic, white quartzite

Recently active normal fault — Dashed where inferred. Ticks on downthrown side

Pre-Tertiary normal fault — Dotted where concealed Bar and ball on downthrown side

Thrust fault — Dashed where inferred Sawteeth on upper plate

BASE MAP:
USGS Huntsville 7.5-Minute Geologic Quadrangle Map (GQ-1503), Sorensen and Crittenden, Jr. (1979)

QUADRANGLE LOCATION

N

0 1000 2000 3000
FEET

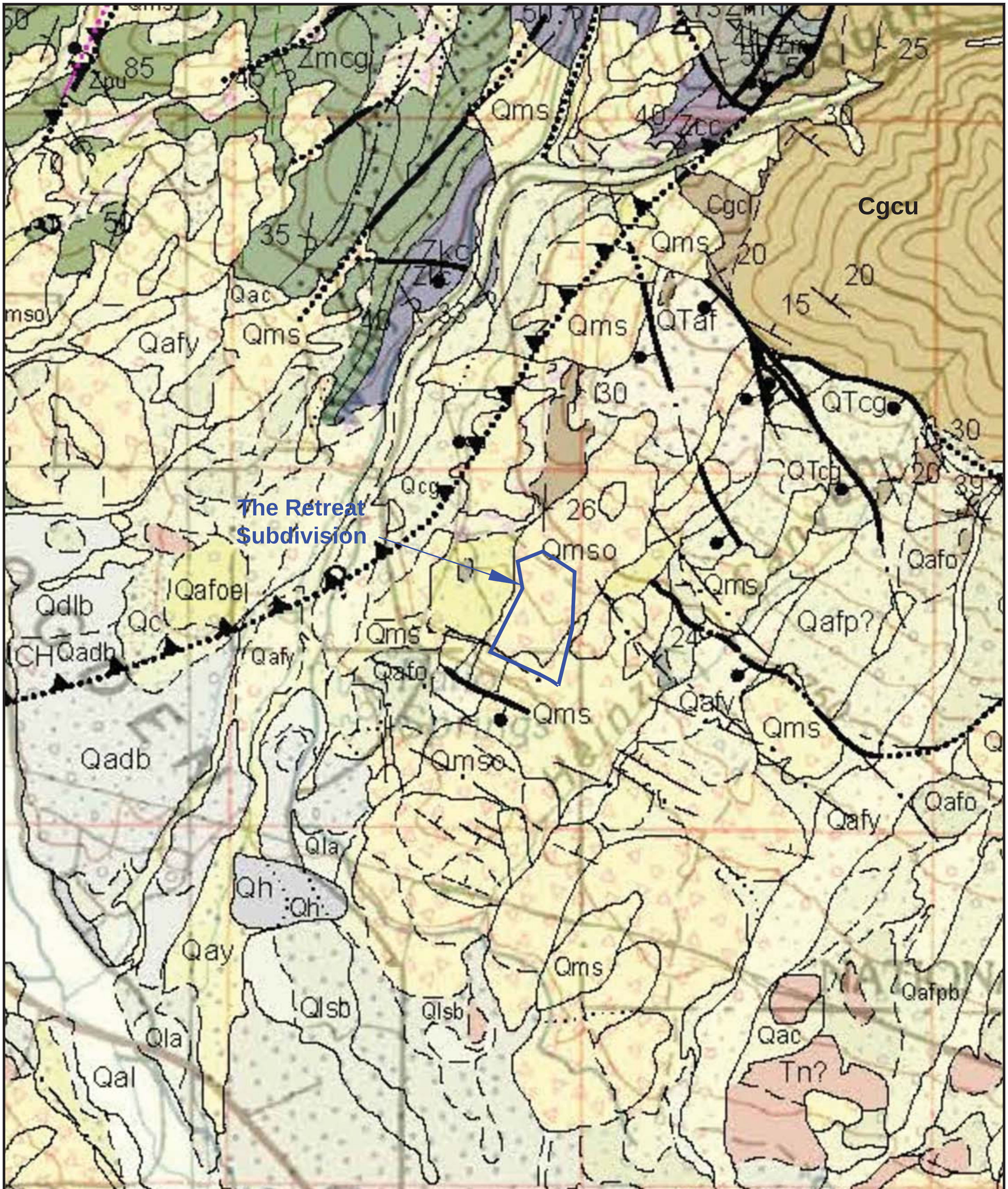
FIGURE A-2c

REGIONAL GEOLOGY MAP 1

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016 | SCALE: 1"=2,000'
PROJECT:02348–002

IGES



BASE MAP:

UGS Ogden 30-Minute x 60-Minute Geologic Quadrangle Map (OFR-653) Coogan and King, 2016

UTAH

QUADRANGLE LOCATION

N

0 1000 2000 3000

FEET

FIGURE A-3a

REGIONAL GEOLOGY MAP 2

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016
PROJECT: 02348-002
SCALE: 1"=2,000'
IGES

MAP LEGEND

Qaf1, Qaf2, Qaf2?, Qafy, Qafy?

Younger alluvial-fan deposits (Holocene and uppermost Pleistocene) – Like undivided alluvial fans, but all of these fans are unconsolidated and should be considered active; height above present drainages is low and is within certain limits; generally less than 40 feet (12 m) thick; near former Lake Bonneville, fans are shown as Qafy where Qaf1 and Qaf2 cannot be separated, and all contain well-rounded recycled Lake Bonneville gravel. Younger alluvial fan deposits are queried where relative age is uncertain (see Qaf for details).

Qaf1 fans are active because they impinge on and deflect present-day drainages. Qaf2 fans appear to underlie Qaf1 fans but may be active. Qafy fans are active, impinge on present-day floodplains, divert active streams, overlie low terraces, and/or cap alluvial deposits (Qap) related to the Provo and regressive shorelines. Therefore, Qafy fans are younger than the Provo shoreline and likely mostly Holocene in age, but may be as old as latest Pleistocene and may be partly older than Qaf1 fans.

Qms, Qms?, Qmsy, Qmsy?, Qmso, Qmso?

Landslide deposits (Holocene and upper and middle? Pleistocene) – Poorly sorted clay- to boulder-sized material; includes slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with time and amount of water in material during emplacement; Qms may be in contact with Qms when landslides are different/distinct; thickness highly variable, up to about 20 to 30 feet (6-9 m) for small slides, and 80 to 100 feet (25-30 m) thick for larger landslides. Qmsy and Qmso queried where relative age uncertain; Qms queried where classification uncertain. Numerous landslides are too small to show at map scale and more detailed maps shown in the index to geologic mapping should be examined.

Qms without a suffix is mapped where the age is uncertain (though likely Holocene and/or late Pleistocene), where portions of slide complexes have different ages but cannot be shown separately at map scale, or where boundaries between slides of different ages are not distinct. Estimated time of emplacement is indicated by relative-age letter suffixes with: Qmsy mapped where landslides deflect streams or failures are in Lake Bonneville deposits, and scarps are variably vegetated; Qmso typically mapped where deposits are "perched" above present drainages, rumpled morphology typical of mass movements has been diminished, and/or younger surficial deposits cover or cut Qmso. Lower perched Qmso deposits are at Qao heights above drainages (95 ka and older) and the higher perched deposits may correlate with high level alluvium (QTa_) (likely older than 780 ka) (see table 1). Suffixes y and o indicate probable Holocene and Pleistocene ages, respectively, with all Qmso likely emplaced before Lake Bonneville transgression. These older deposits are as unstable as other slides, and are easily reactivated with the addition of water, be it irrigation or septic tank drain fields.

- Contact, approximately located
- Contact, approximately located, queried
- Contact, concealed
- Contact, concealed, queried
- Contact, scratch, used where map units combined
- Contact, well located

- Fault, uncertain sense of movement, approximately located
- Fault, uncertain sense of movement, approximately located, queried
- Fault, uncertain sense of movement, concealed
- Fault, uncertain sense of movement, concealed, queried
- Fault, uncertain sense of movement, well located
- Scarp, landslide
- Scarp, terrace
- Scarp, undefined

BASE MAP:

UGS Ogden 30-Minute x 60-Minute Geologic Quadrangle Map (OFR-653) Coogan and King, 2016

N

0 1000 2000 3000

FEET

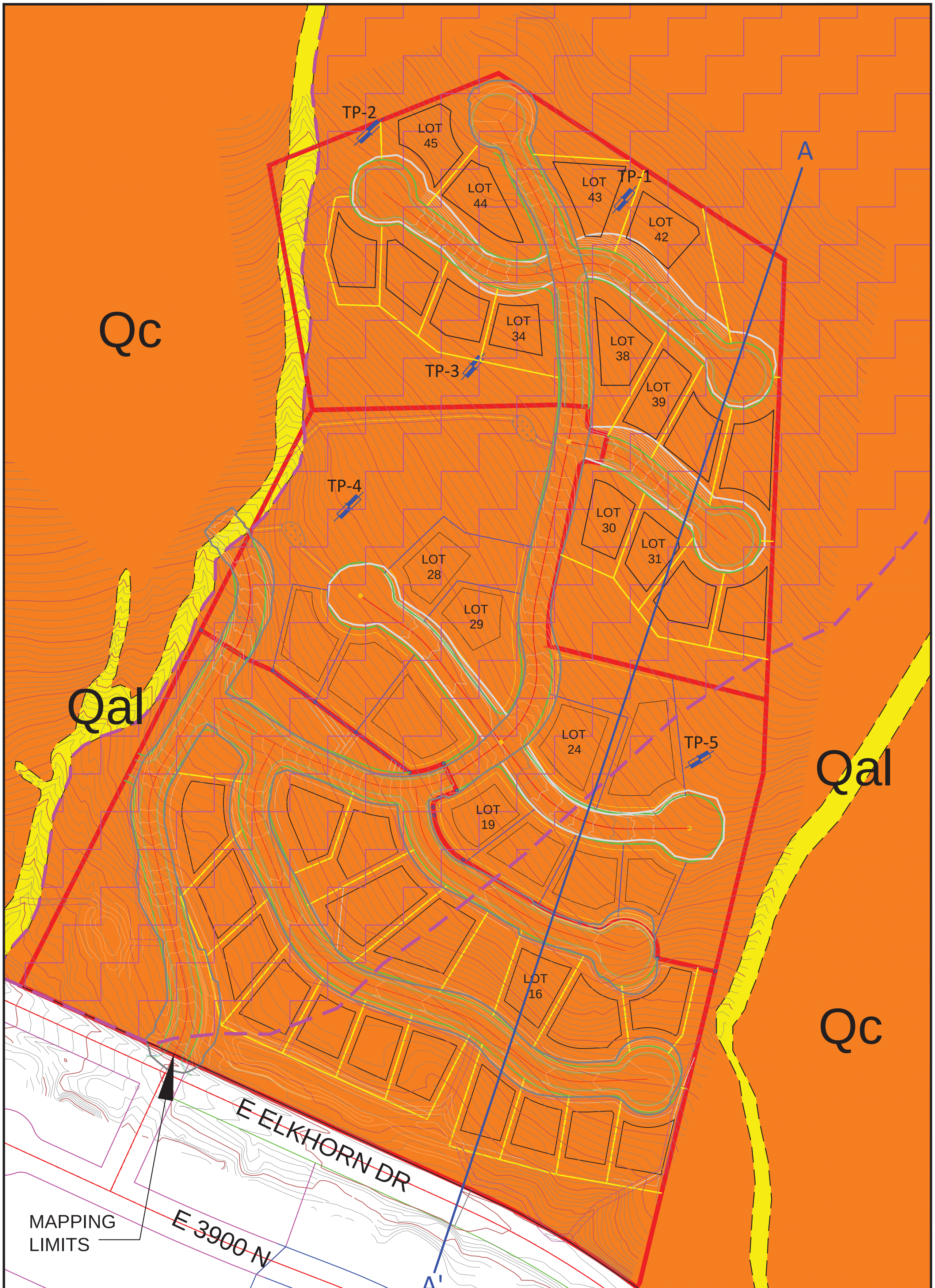
FIGURE A-3b

REGIONAL GEOLOGY MAP 2

THE RETREAT SUBDIVISION
WOLF CREEK RESORT
GEOLOGIC HAZARDS ASSESSMENT

DATE: 11/17/2016 | SCALE: 1"=2,000'
PROJECT:02348-002

IGES



LEGEND

Qal RECENT ALLUVIUM

Qc COLLUVIUM (HOLOCENE-PLEISTOCENE)

Qlso SHALLOW LANDSLIDE DEPOSITS (PLEISTOCENE); IN SUBSURFACE ONLY

THE RETREAT PROPERTY BOUNDARY

TP-3 TEST PIT LOCATION

ALL CONTACTS APPROXIMATE

A A' CROSS-SECTION LINE

N

0 150 FEET

Basemap provided by Gardner Engineering

FIGURE A-4

LOCAL GEOLOGY MAP

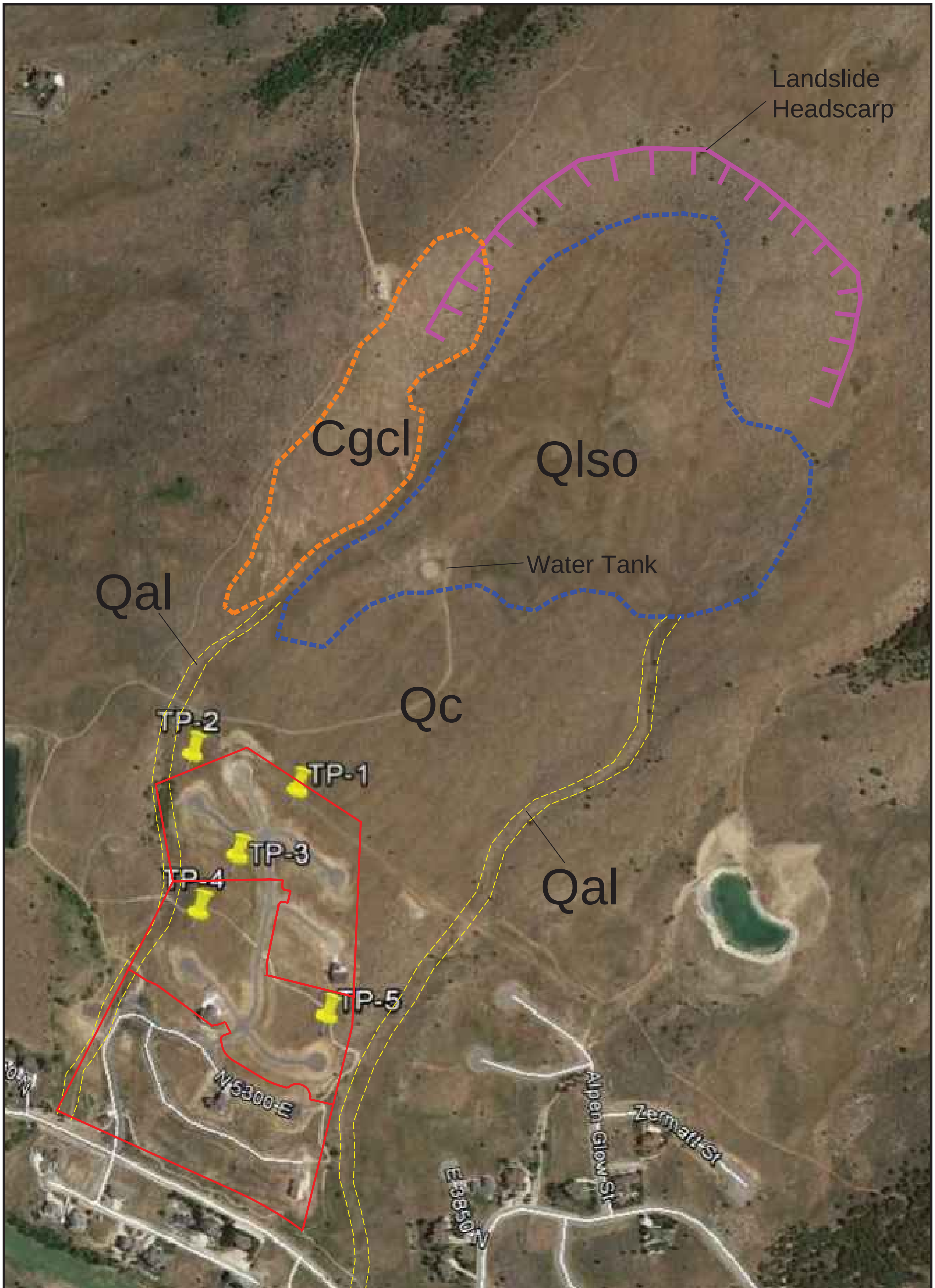
THE RETREAT SUBDIVISION

GEOLOGIC HAZARD ASSESSMENT
WOLF CREEK RESORT
EDEN, UTAH

DATE: 11/21/2016
PROJECT: 02348-002

SCALE: 1"=150'

IGES



LEGEND

Qal RECENT ALLUVIUM

Qc COLLUVIUM (HOLOCENE - PLEISTOCENE)

Qlso SHALLOW LANDSLIDE DEPOSITS (HOLOCENE - PLEISTOCENE)

Cgcl GEERTSEN CANYON QUARTZITE, LOWER MEMEBER (CAMBRIAN)

THE RETREAT PROPERTY BOUNDARY

ALL CONTACTS APPROXIMATE

N

0 200 400

FEET

Base image from Google Earth, dated 7/8/16

FIGURE A-5

LOCAL GEOLOGY MAP 2

THE RETREAT SUBDIVISION

GEOLOGIC HAZARD ASSESSMENT

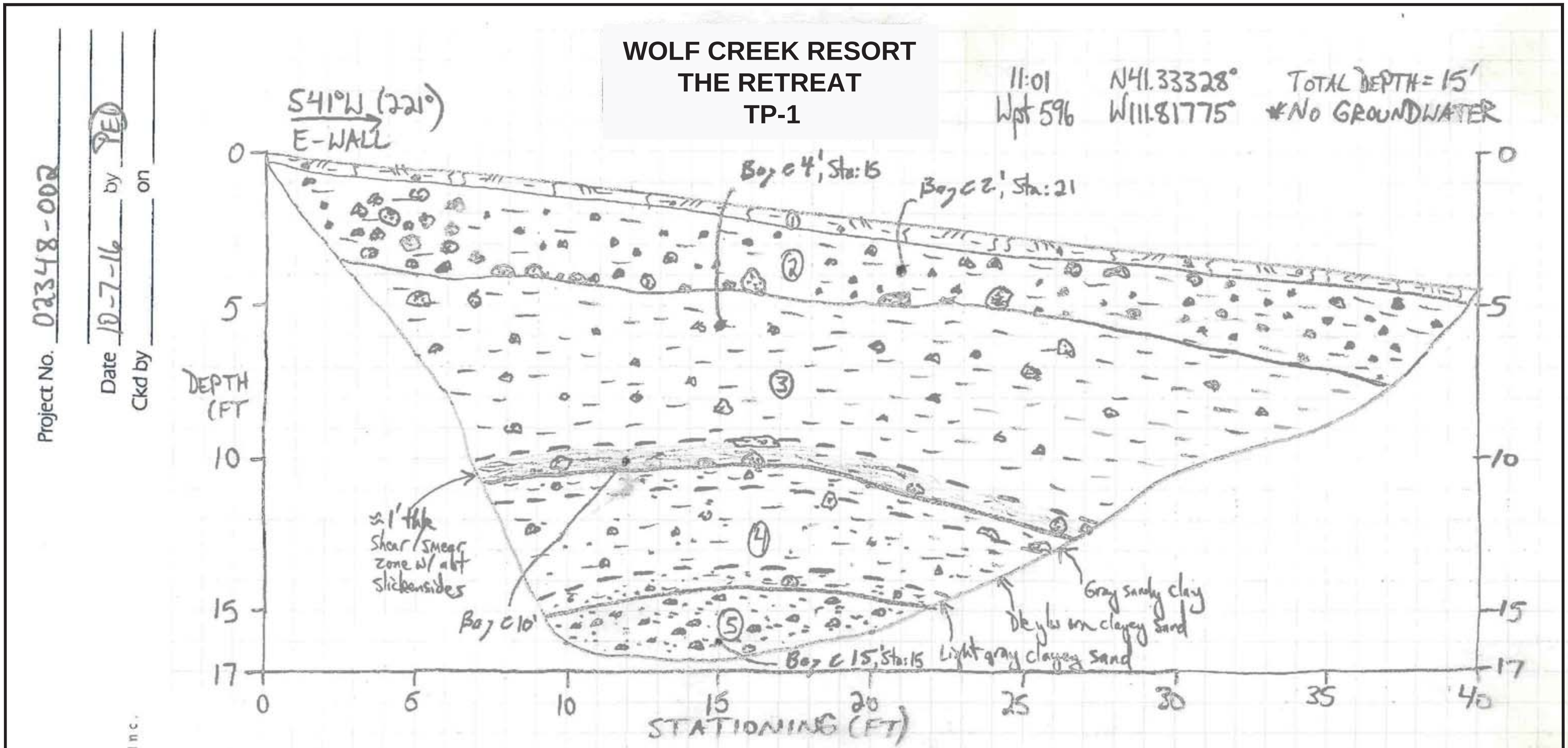
WOLF CREEK RESORT
EDEN, UTAH

DATE: 11/22/2016

PROJECT: 02348-002

SCALE: 1"=350'

IGES



LITHOLOGIC UNIT DESCRIPTIONS:

1. A/B Soil Horizon: ~3-6" thick; brownish black (5YR 2/1) to grayish brown (5Y 3/2) lean CLAY with gravel (CL), loose, slightly moist, low plasticity, massive; gravel and larger sized clasts comprise ~10-20% of unit; clasts entirely subrounded to subangular moderate orange pink (10R 7/4) to medium gray (N5) quartzite up to 9" in diameter; abundant plant and tree roots.

2. Colluvium: ~2-3' thick; dark yellowish brown (10YR 4/2) to grayish brown (5Y 3/2) gravelly lean CLAY (CL) gradational to clayey GRAVEL (GC), loose to medium stiff, moist, low plasticity, massive; gravel and larger sized clasts comprise ~40-50% of unit; clasts entirely quartzite as above, up to 14" in diameter, though mode size is ~2-4"; appears to have topsoil between clasts as matrix; matrix-supported, though clasts-supported in places; poorly sorted; basal ~6" of unit is medium stiff and dark reddish brown (10R 3/4), with a low to moderate plasticity; common plant and tree roots; sharp, irregular basal contact with large clasts commonly found at contact.

3. Shallow Landslide: ~6-6.5' thick; light gray (N7) to medium light gray (N6) fat CLAY with gravel (CH), very stiff, slightly moist, high plasticity, massive; basal ~1' is brownish gray (5YR 4/1) and is shear/slide plane littered with natural slickensides and linear shear features, though a single basal slide plane not observed; occasional slickensides noted throughout rest of unit; gravel and larger sized clasts comprise ~30% of unit, and increase in frequency with depth; clasts are predominantly white (N9) to light gray (N7) massive quartzite, though some white possibly hydrothermally altered sandstone; clasts are subangular to subrounded, and up to 1' in diameter, though mode size ~4-6"; sharp, irregular basal contact.

4. Transitional: ~4' thick; medium light gray (N6) to dark yellowish orange (10YR 6/6) to pale yellowish orange (10YR 8/6) sandy fat CLAY with gravel (CH) gradational to clayey SAND with gravel (SC), stiff, slightly moist, moderate plasticity, thickly bedded; gravel and larger sized clasts comprise ~10-15% of unit; clasts as above, up to 7" in diameter, though mode size 3"; becomes sandier with depth; occasional slickensides, though not continuous; sharp, planar basal contact.

5. Alluvium: >2.5' thick; dark yellowish orange (10YR 6/6) to moderate reddish orange (10R 6/6), gravelly SAND (SW), very dense, slightly moist, possibly faintly thinly bedded; gravel and larger sized clasts comprise ~40-50% of unit; clasts entirely quartzite as above, up to 6" in diameter, though mode size 1-3"; moderately sorted; sand is fine to medium-grained.

FIGURE A-6
TP-1 LOG

THE RETREAT SUBDIVISION

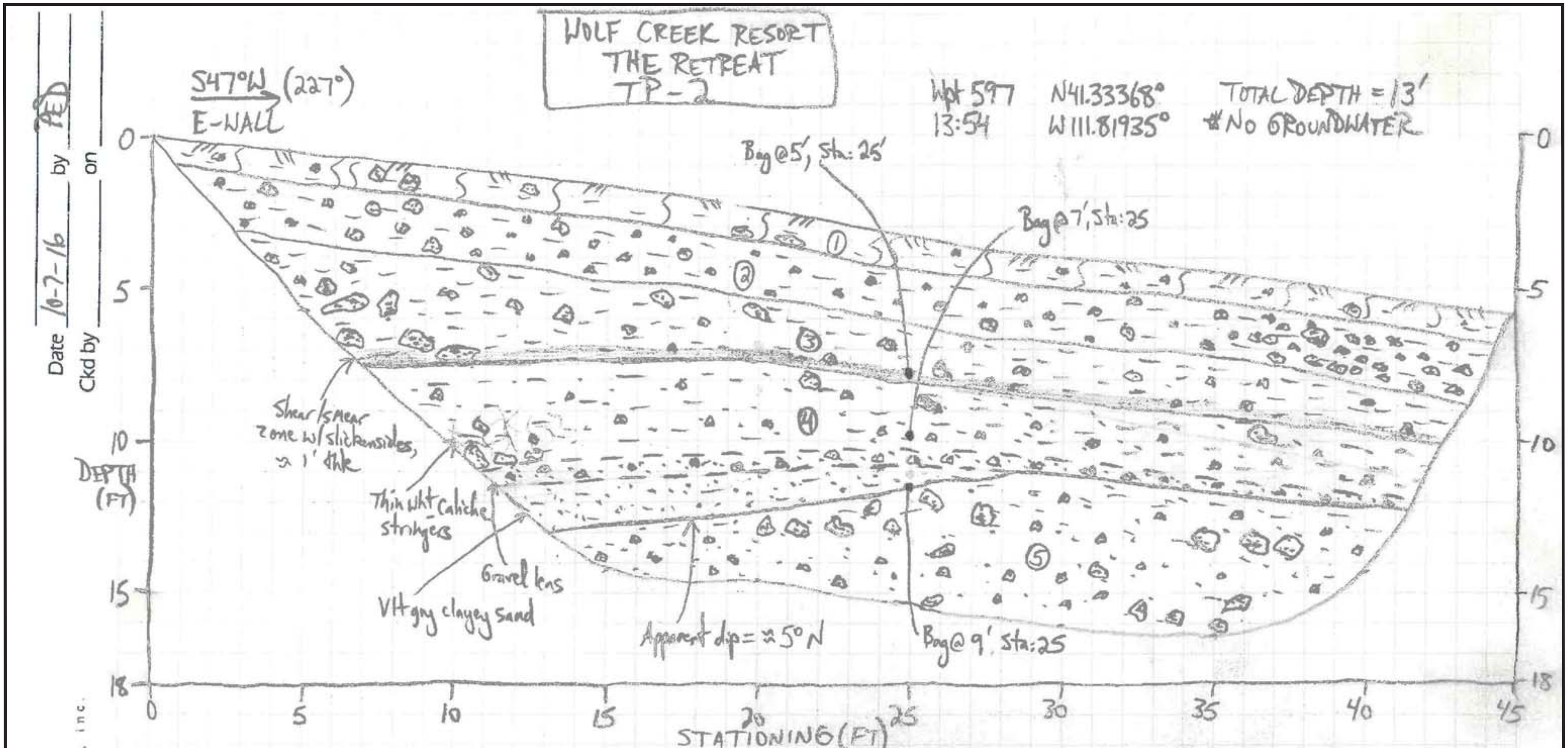
GEOLOGIC
HAZARD ASSESSMENT

WOLF CREEK RESORT

EDEN, UTAH

DATE: 11/17/2016 | SCALE: 1"=5'
PROJECT: 02348-002

IGES



LITHOLOGIC UNIT DESCRIPTIONS:

1. A/B Soil Horizon: ~1' thick; brownish black (5YR 2/1) to grayish brown (5Y 3/2) lean CLAY with gravel (CL), loose, slightly moist, low plasticity, massive; gravel and larger sized clasts comprise ~5-10% of unit; clasts entirely subrounded to subangular moderate orange pink (10R 7/4) to medium gray (N5) quartzite up to 3' in diameter; abundant plant and tree roots.

2. Colluvium: ~2-2.5' thick; brownish black (5YR 2/1) to dark reddish brown (10R 3/4) gravelly fat CLAY (CH), medium stiff to loose, slightly moist, moderate plasticity, massive; gravel and larger sized clasts comprise ~30-40% of unit; clasts entirely moderate orange pink (10R 7/4) to medium gray (N5) quartzite, subrounded to subangular, up to 16" in diameter, though mode size ~3-4"; largely same as seen in TP-1, except clay is fatter and red component comprises basal ~1-1.5' of unit, with topsoil matrix above; sharp, irregular basal contact.

3. Shallow Landslide: ~2.5-3.5' thick; brownish gray (5YR 4/1) to dark yellowish brown (10YR 4/2) fat CLAY with gravel (CH), very stiff, slightly moist, high plasticity, massive; as seen in TP-1, except darker colored, thinner, and exhibits less prevalent slickensides; shear/smear zone seen in basal ~1' of unit; gravel and larger sized clasts comprise ~15-20% of unit; clasts are entirely subangular to subrounded quartzite as above, up to 14" in diameter; irregularly sorted and largely variable clasts sizes; unit thins downslope; sharp, largely planar basal contact.

4. Transitional: ~3-5' thick; dark yellowish orange (10YR 6/6) to very light gray (N8); uppermost ~1.5-3' is dark yellowish orange sandy fat CLAY with gravel (CH), stiff to very stiff, slightly moist, moderate to high plasticity, massive; contains occasional natural slickensides, though highly variable clay and sand component and slickensides are discontinuous; gravel and larger sized clasts comprise ~5% of this uppermost subunit; middle of the unit is ~4-6" of dark yellowish orange, coarse-grained gravelly SAND (SP) that appears alluvial in origin; basal ~1-1.5' of unit is very light gray fine-grained clayey SAND (SC) that pinches out downslope; this basal subunit contains no clasts, though it appears like a slab of highly weathered quartzite bedrock.

5. Alluvium: >7' thick; dark yellowish orange (10YR 6/6) gravelly SAND (SW), very dense, slightly moist, massive to finely bedded; sand is coarse-grained and largely derived from weathered quartzite; appears generally reversely-graded; gravel and larger sized clasts comprise ~40-50% of unit; clasts entirely subrounded to subangular quartzite up to 13" in diameter, though mode size ~1-3"; slightly clayey in uppermost ~6" of unit; becomes less gravelly (sandier) and finely bedded with depth.

FIGURE A-7
TP-2 LOG

THE RETREAT SUBDIVISION

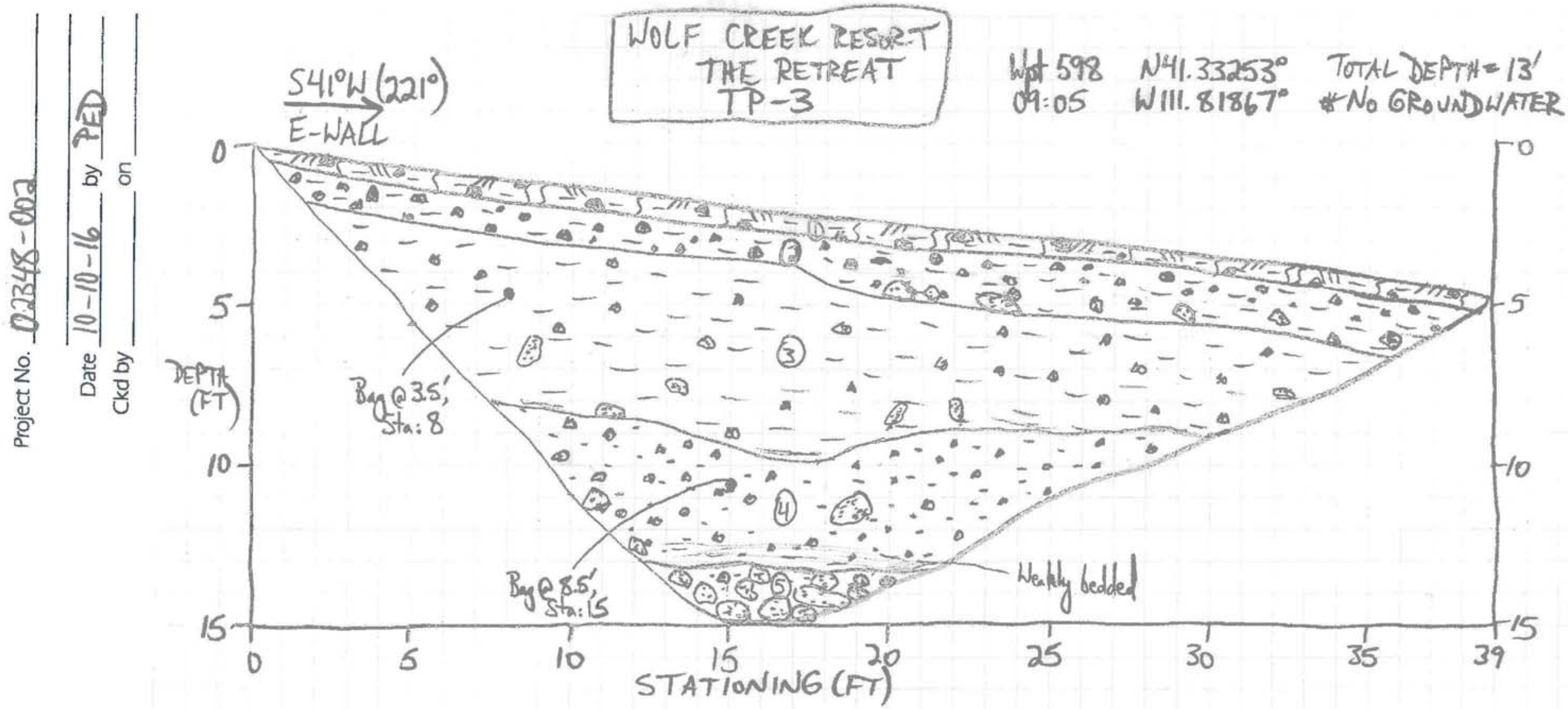
GEOLOGIC
HAZARD ASSESSMENT

WOLF CREEK RESORT

EDEN, UTAH

DATE: 11/18/2016 | SCALE: 1"=5'
PROJECT: 02348-002

IGES



LITHOLOGIC UNIT DESCRIPTIONS:

1. A/B Soil Horizon: ~3-6" thick; brownish black (5YR 2/1) to grayish brown (5Y 3/2) gravelly lean CLAY (CL), loose, slightly moist, low plasticity, massive; gravel and larger sized clasts comprise ~20-25% of unit; clasts entirely subrounded to subangular pale yellowish orange (10YR 8/6) to medium gray (N5) quartzite up to 1.5' in diameter, though mode size ~3-6"; silty; abundant plant and tree roots.

2. Colluvium: ~1-2' thick; dark reddish brown (10R 3/4) to dark yellowish brown (10YR 4/2) gravelly fat CLAY (CH), stiff to medium-stiff, slightly moist, moderate plasticity, massive; gravel and larger sized clasts comprise ~40% of unit; clasts entirely quartzite as above up to 1.5' in diameter, though mode size ~2-4"; matrix-supported; uppermost ~6"-1' matrix is topsoil, though becomes clayey with depth and clay component is fat; poorly sorted; thickens downslope; occasional plant and tree roots; sharp, irregular basal contact.

3. Shallow Landslide: ~3-5' thick; light gray (N7) to light brownish gray (5YR 6/1) fat CLAY with gravel (CH), very stiff to stiff, slightly moist, high plasticity, massive; gravel and larger sized clasts comprise ~20% of unit; clasts consist of medium gray (N5) to moderate orange pink (10R 7/4) to pale yellowish orange (10YR 8/6) quartzite and white (N9), possibly hydrothermally altered sandstone; clasts are subrounded to subangular and up to 2' in diameter, though mode size ~3-6"; blocky texture; occasional natural slickensides, though no clear basal shear zone as seen in TP-1 and TP-2; thins downslope; sharp, irregular basal contact.

4. Alluvium: ~3-4' thick; mottled dark yellowish orange (10YR 6/6) to moderate reddish brown (10R 4/6) to white (N9) gravelly SAND (SW), very dense to dense, slightly moist, finely bedded in basal ~1', otherwise massive; gravel and larger sized clasts comprise ~30-40% of unit and increase in frequency with depth; clasts are roughly equal proportion of medium light gray (N6) massive quartzite and white (N9) hydrothermally altered fine-grained to medium-grained sandstone; clasts are subangular to subrounded and up to 14" in diameter, though mode size ~1-2"; poorly sorted, though basal ~1' is dark reddish brown (10R 3/4) sandy gravel bed with minor clay and is moderately sorted; sand is medium-grained to fine-grained; sharp, wavy basal contact.

5. Fluvial: >2' thick; very light gray (N8) sandy GRAVEL (GW), dense to very dense, dry, possibly faintly bedded; river channel gravel deposits, clast-supported; gravel and larger sized clasts comprise ~85-90% of unit; clasts are a combination of quartzite and sandstone as above up to 2' in diameter, though mode size ~1-3"; clasts are subrounded to subangular; moderately sorted; matrix is fine-grained sand and unit is largely devoid of fines.

FIGURE A-8

TP-3 LOG

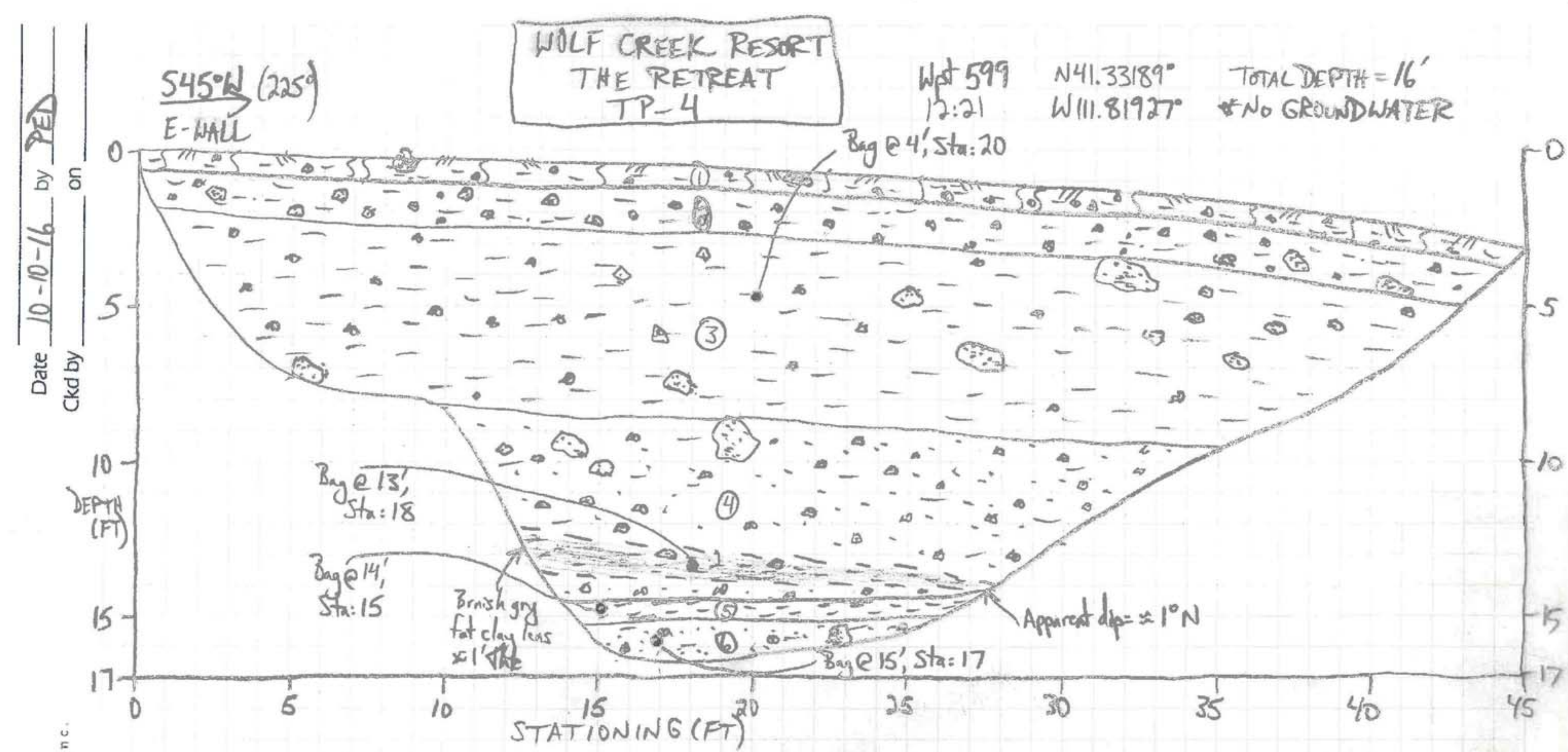
THE RETREAT SUBDIVISION

GEOLOGIC
HAZARD ASSESSMENT

WOLF CREEK RESORT

EDEN, UTAH

DATE: 11/18/2016	SCALE: 1"=5'	IGES
PROJECT: 02348-002		



LITHOLOGIC UNIT DESCRIPTIONS:

1. A/B Soil Horizon: ~6" thick; brownish black (5YR 2/1) lean CLAY with gravel (CL), loose to medium-stiff, moist, low plasticity, massive; silty; gravel and larger sized clasts comprise ~15% of unit; clasts entirely subrounded to subangular moderate orange pink (10R 7/4) to medium gray (N5) quartzite up to 2' in diameter, though mode size ~6"; abundant plant and tree roots; gradational, irregular basal contact.

2. Colluvium: ~1-1.5' thick; grayish brown (5Y 3/2) to dark yellowish brown (10YR 4/2) lean CLAY with gravel (CL) gradational to gravelly fat CLAY (CH), medium stiff to loose, moist, moderate plasticity, massive; no reddish brown component as seen in other test pits, though some fat clay present; gravel and larger sized clasts comprise ~30% of unit; clasts entirely quartzite as above up to 2' in diameter, though mode size ~4-6"; matrix-supported, with matrix largely topsoil; silty; occasional to common plant and tree roots; sharp, irregular basal contact.

3. Shallow Landslide 1: ~5-5.5' thick; light brownish gray (5YR 6/1) fat CLAY with gravel (CH), very stiff to stiff, slightly moist, high plasticity, massive; sandy in part, associated with oxidized sandstone clasts which give a dark yellowish orange (10YR 6/6) mottled appearance; very similar to as seen in other test pits, except sandier; poorly sorted; gravel and larger sized clasts comprise ~15-20% of unit; clasts are subangular to subrounded quartzite as above and white (N9) hydrothermally altered sandstone up to 14" in diameter, though mode size ~2-4"; blocky texture and occasional natural slickensides, though not well developed; becomes darker and sand/gravel component increases with depth; gradational, irregular basal contact.

4. Shallow Landslide 2: ~5.5-6' thick; dark yellowish brown (10YR 4/2) to brownish gray (5YR 4/1) to moderate reddish orange (10R 6/6) gravelly SAND with clay (SC) gradational to sandy GRAVEL with clay (GC), dense to very dense, slightly moist, massive; appears like a combination of both transitional and alluvial units underlying shallow landslide clay seen in other test pits, except more chaotic and clayey throughout; gravel and larger-sized clasts comprise ~50-60% of unit, and are up to 1.5' in diameter; clasts entirely quartzite and sandstone as above; slickensides are present where clayey, but discontinuous; largely reversely graded; sharp, planar basal contact.

5. Shear Plane: ~1' thick; light brownish gray (5YR 6/1) sandy fat CLAY (CH), very stiff, moist, high plasticity, massive; blocky texture; well-developed slide surfaces with slickensides at top and bottom contacts; common organic smear; sharp, planar basal contact.

6. Alluvium: >1.5' thick; dark yellowish orange (10YR 6/6) clayey SAND with gravel (SC), dense, moist, low to moderate plasticity, weakly bedded; gravel and larger sized clasts comprise ~15-20% of unit and are up to 1' in diameter; clasts are subangular quartzite and sandstone as above, and commonly highly oxidized and bleached to white (N9) and light brownish gray (5YR 6/1); poorly sorted; clay component is partly fat.

FIGURE A-9
TP-4 LOG

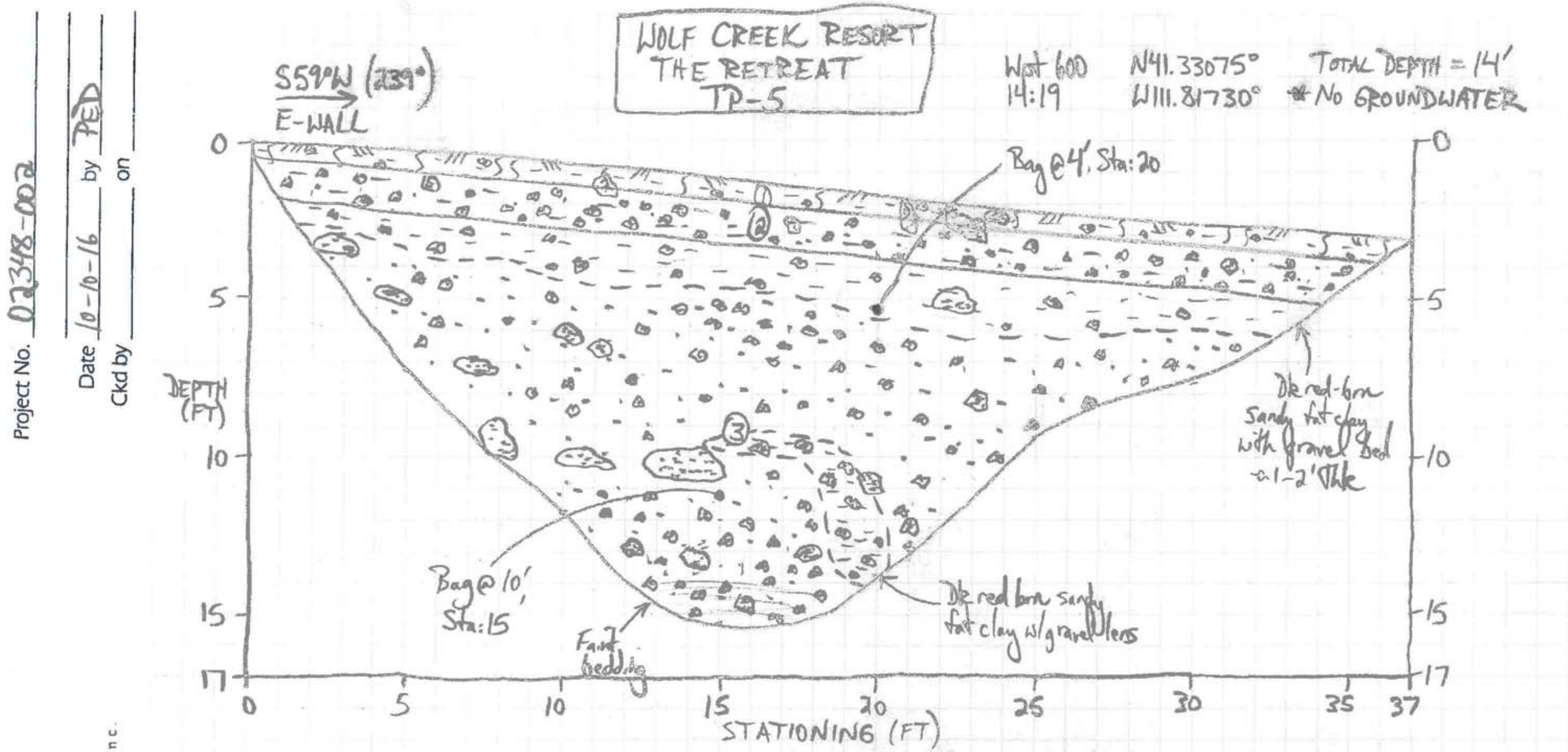
THE RETREAT SUBDIVISION

GEOLOGIC
HAZARD ASSESSMENT

WOLF CREEK RESORT

EDEN, UTAH

DATE: 11/18/2016	SCALE: 1"=5'	IGES
PROJECT: 02348-002		



LITHOLOGIC UNIT DESCRIPTIONS:

1. A/B Soil Horizon: ~4-6" thick; brownish black (5YR 2/1) lean CLAY with gravel (CL), loose to medium-stiff, moist, low plasticity, massive; silty; gravel and larger sized clasts comprise ~30% of unit; clasts entirely subrounded to subangular moderate orange pink (10R 7/4) to medium gray (N5) quartzite up to 2' in diameter, though mode size ~6"; abundant plant and tree roots; gradational, irregular basal contact.

2. Colluvium: ~1-1.5' thick; dark yellowish brown (10YR 4/2) to dark reddish brown (10R 3/4) lean CLAY with gravel (CL), medium stiff to loose, moist, low to moderate plasticity, massive; top ~1/2 of unit is topsoil matrix, while basal ~1/2 of unit is dark reddish brown sandy clay that looks and feels like Wasatch Formation; gravel and larger sized clasts comprise ~40% of unit; clasts entirely subrounded to subangular medium gray (N5) to moderate orange pink (10R 7/4) quartzite up to 1.5' in diameter, though mode size ~3-4"; common plant and tree roots; gradational, planar basal contact.

3. Wasatch Formation?: >12' thick; dark reddish brown (10R 3/4) to dark yellowish orange (10YR 6/6) gravelly SAND (SW) gradational to sandy GRAVEL (GW), dense to very dense, slightly moist, massive; gravel and larger sized clasts comprise ~50-75% of unit; clasts entirely subrounded to subangular quartzite as above and white (N9) hydrothermally altered sandstone up to 2' in diameter, though mode size ~3-6" and tend to be coarser; moderately sorted and weakly bedded with depth; dark reddish brown sandy fat clay with gravel lenses found at top of unit and as irregular lens in middle of unit, and may represent depositional facies changes; gravel content increases with depth; though some fat clay present, no natural slickensides observed.

FIGURE A-10
TP-5 LOG

THE RETREAT SUBDIVISION

GEOLOGIC HAZARD ASSESSMENT

WOLF CREEK RESORT

EDEN, UTAH

DATE: 11/18/2016
PROJECT: 02348-002
SCALE: 1"=5'
IGES

APPENDIX B

Water Content and Unit Weight of Soil

(In General Accordance with ASTM D7263 Method B and D2216)

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/26/2016
By: BSS & BRR

Sample Info.	Boring No.	TP-1	TP-2	TP-2	TP-4				
	Sample								
	Depth	10.0'	5.0'	9.0'	14.0'				
	Split	Yes	No	Yes	No				
	Split sieve	No.4		No.4					
	Total sample (g)	2148.00		3384.76					
	Moist coarse fraction (g)	1221.83		126.39					
	Moist split fraction (g)	926.17		3258.37					
	Sample height, H (in)								
	Sample diameter, D (in)								
	Mass rings + wet soil (g)								
	Mass rings/tare (g)								
	Moist unit wt., γ_m (pcf)								
Coarse Fraction	Wet soil + tare (g)	1534.68		247.88					
	Dry soil + tare (g)	1522.61		245.66					
	Tare (g)	312.85		121.49					
	Water content (%)	1.0		1.8					
Split Fraction	Wet soil + tare (g)	1222.50	551.92	478.15	540.16				
	Dry soil + tare (g)	1064.01	470.50	402.44	409.61				
	Tare (g)	328.29	126.94	121.43	123.06				
	Water content (%)	21.5	23.7	26.9	45.6				
	Water Content, w (%)	**8.9**	**23.7**	**25.8**	**45.6**				
	Dry Unit Wt., γ_d (pcf)								

Entered by:___________

Reviewed:___________

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

(ASTM D4318)

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: BRR

Boring No.: TP-1
Sample:
Depth: 10.0'
Description: Reddish brown fat clay

Preparation method: Wet
Liquid limit test method: Multipoint

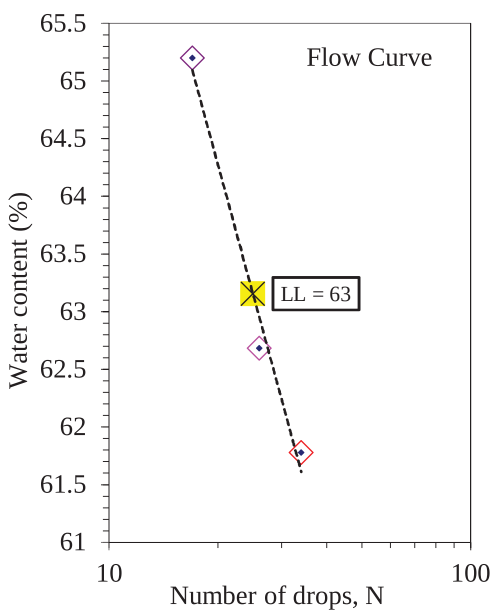
Plastic Limit

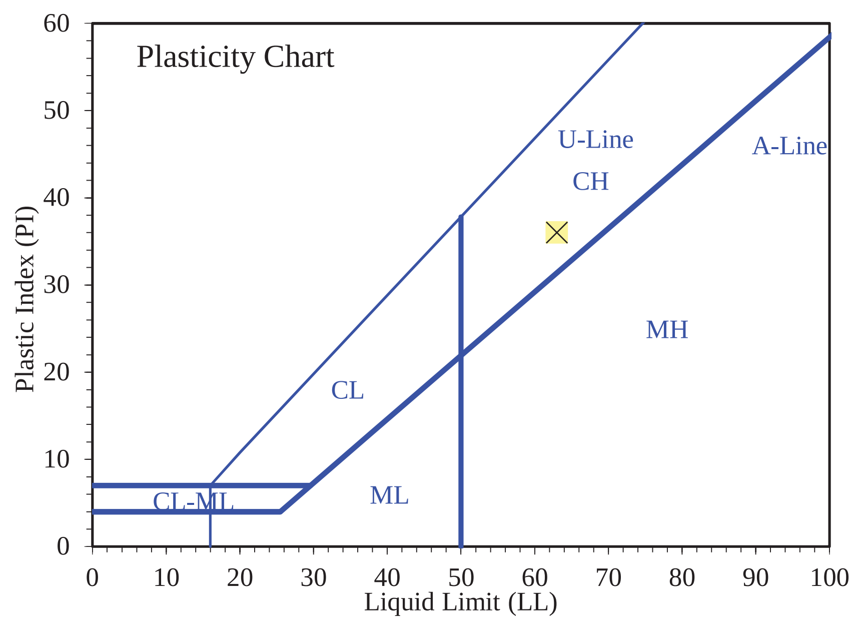
Determination No	1	2				
Wet Soil + Tare (g)	28.84	27.88				
Dry Soil + Tare (g)	27.39	26.59				
Water Loss (g)	1.45	1.29				
Tare (g)	21.96	21.75				
Dry Soil (g)	5.43	4.84				
Water Content, w (%)	26.70	26.65				

Liquid Limit

Determination No	1	2	3			
Number of Drops, N	34	26	17			
Wet Soil + Tare (g)	28.25	29.82	29.81			
Dry Soil + Tare (g)	25.89	26.83	26.55			
Water Loss (g)	2.36	2.99	3.26			
Tare (g)	22.07	22.06	21.55			
Dry Soil (g)	3.82	4.77	5.00			
Water Content, w (%)	61.78	62.68	65.20			
One-Point LL (%)		63				

Liquid Limit, LL (%)	**63**
Plastic Limit, PL (%)	**27**
Plasticity Index, PI (%)	**36**





Entered by:___________
Reviewed:___________

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

(ASTM D4318)

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: BRR

Boring No.: TP-2
Sample:
Depth: 5.0'
Description: Brown fat clay

Preparation method: Wet
Liquid limit test method: Multipoint

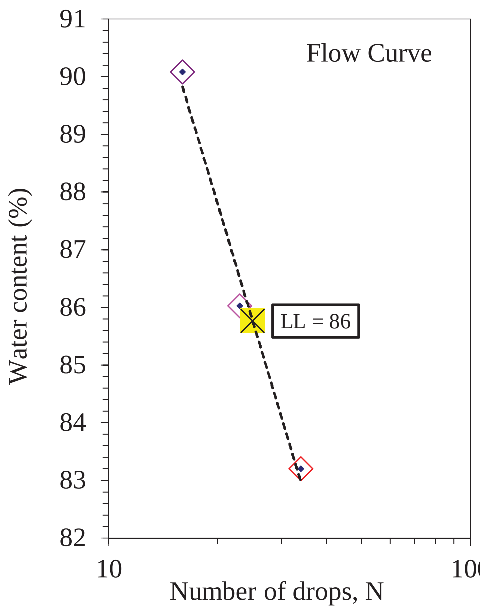
Plastic Limit

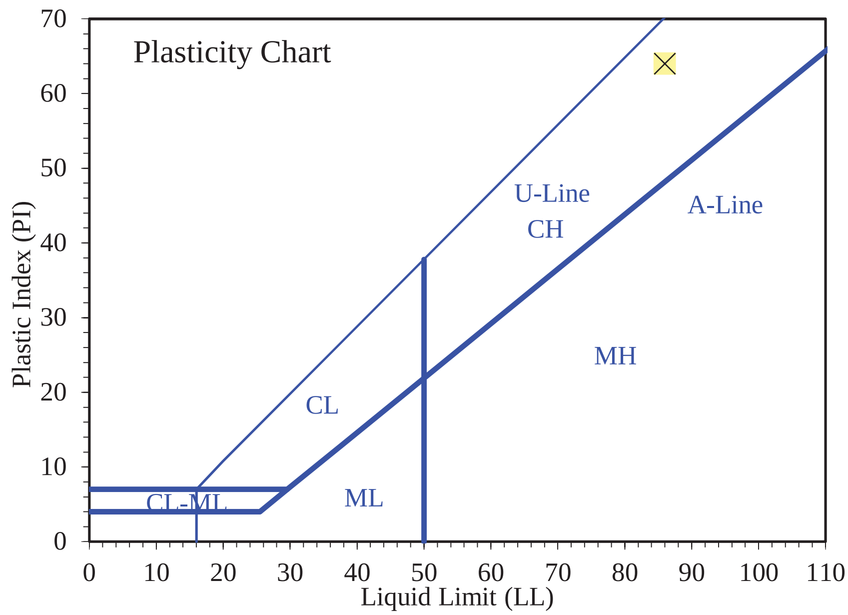
Determination No	1	2				
Wet Soil + Tare (g)	28.07	28.43				
Dry Soil + Tare (g)	26.92	27.27				
Water Loss (g)	1.15	1.16				
Tare (g)	21.52	22.02				
Dry Soil (g)	5.40	5.25				
Water Content, w (%)	21.30	22.10				

Liquid Limit

Determination No	1	2	3			
Number of Drops, N	34	23	16			
Wet Soil + Tare (g)	28.81	28.93	29.07			
Dry Soil + Tare (g)	25.59	25.79	25.80			
Water Loss (g)	3.22	3.14	3.27			
Tare (g)	21.72	22.14	22.17			
Dry Soil (g)	3.87	3.65	3.63			
Water Content, w (%)	83.20	86.03	90.08			
One-Point LL (%)		85				

Liquid Limit, LL (%)	**86**
Plastic Limit, PL (%)	**22**
Plasticity Index, PI (%)	**64**





Entered by:___________
Reviewed:___________

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Liquid Limit, Plastic Limit, and Plasticity Index of Soils

(ASTM D4318)

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: BRR

Boring No.: TP-4
Sample:
Depth: 14.0'
Description: Light brown fat clay

Preparation method: Wet
Liquid limit test method: Multipoint

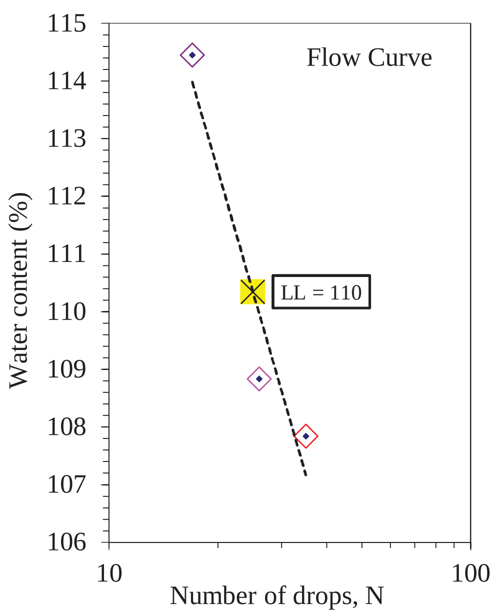
Plastic Limit

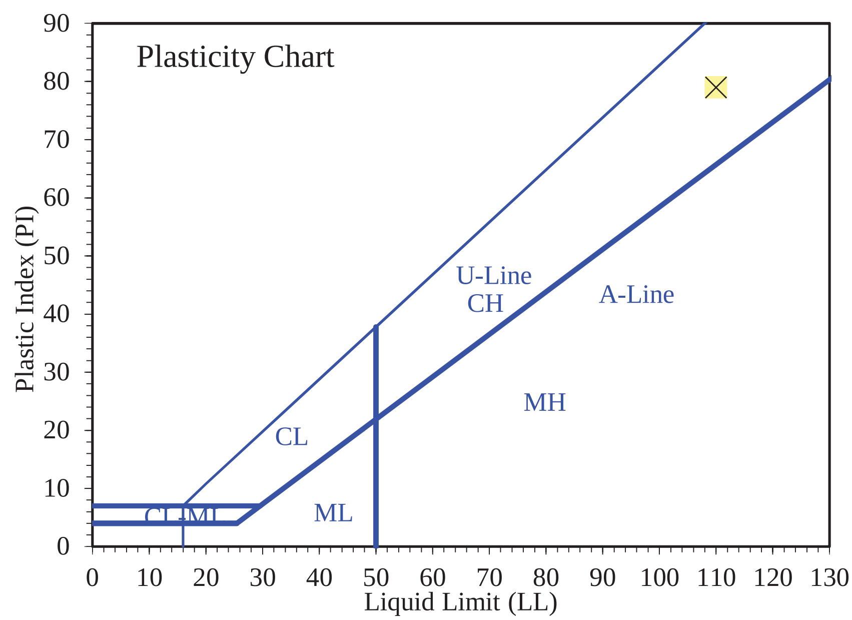
Determination No	1	2				
Wet Soil + Tare (g)	28.78	27.94				
Dry Soil + Tare (g)	27.15	26.53				
Water Loss (g)	1.63	1.41				
Tare (g)	21.85	21.91				
Dry Soil (g)	5.30	4.62				
Water Content, w (%)	30.75	30.52				

Liquid Limit

Determination No	1	2	3			
Number of Drops, N	35	26	17			
Wet Soil + Tare (g)	28.14	28.54	29.15			
Dry Soil + Tare (g)	24.84	25.09	25.19			
Water Loss (g)	3.30	3.45	3.96			
Tare (g)	21.78	21.92	21.73			
Dry Soil (g)	3.06	3.17	3.46			
Water Content, w (%)	107.84	108.83	114.45			
One-Point LL (%)		109				

Liquid Limit, LL (%)	**110**
Plastic Limit, PL (%)	**31**
Plasticity Index, PI (%)	**79**





Entered by:___________
Reviewed:___________

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Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

(ASTM D6913)

IGES

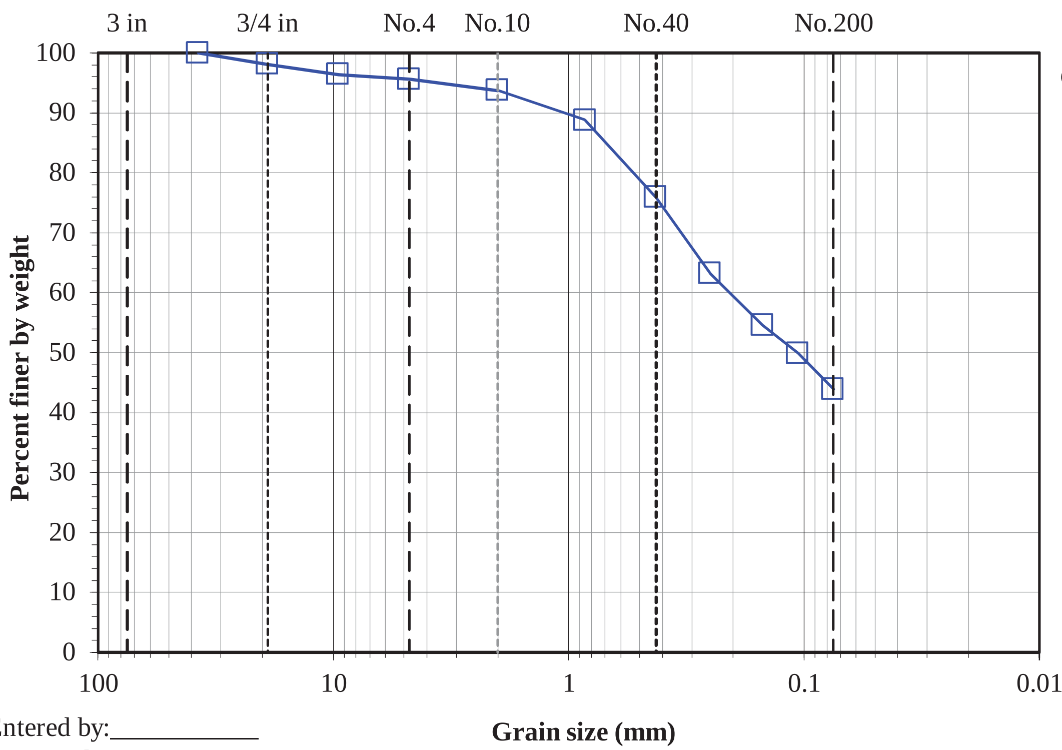
Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: JDF

Boring No.: TP-2
Sample:
Depth: 9.0'
Description: Brown clayey sand

Split:	Yes	
Split sieve:	#4	
	Moist	Dry
Total sample wt. (g):	3258.37	2589.35
+#4 Coarse fraction (g):	115.74	113.71
-#4 Split fraction (g):	356.72	281.01
Split fraction:	0.956	

Water content data	C.F.(+#4)	S.F.(-#4)
Moist soil + tare (g):	247.88	478.15
Dry soil + tare (g):	245.66	402.44
Tare (g):	121.49	121.43
Water content (%):	1.7879	26.9

Sieve	Accum. Wt. Ret. (g)	Grain Size (mm)	Percent Finer	
8"	-	200	-	
6"	-	150	-	
4"	-	100	-	
3"	-	75	-	
1.5"	-	37.5	100.0	
3/4"	48.97	19	98.1	
3/8"	93.63	9.5	96.4	
No.4	113.71	4.75	95.6	←Split
No.10	5.57	2	93.7	
No.20	20.11	0.85	88.8	
No.40	58.00	0.425	75.9	
No.60	95.41	0.25	63.1	
No.100	120.70	0.15	54.5	
No.140	134.41	0.106	49.9	
No.200	152.10	0.075	43.9	



Gravel (%): 4.4
Sand (%): 51.7
Fines (%): 43.9

Entered by:___________
Reviewed:___________

Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

(ASTM D6913)

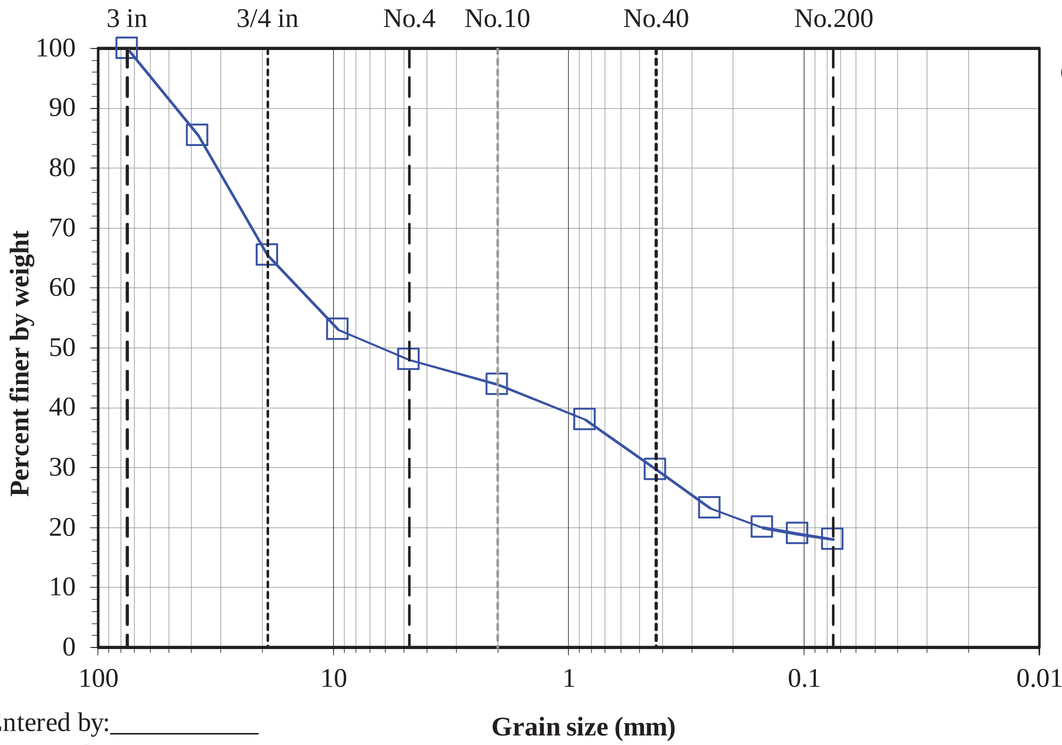
Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: BSS

Boring No.: TP-3
Sample:
Depth: 8.5'
Description: Reddish brown clayey gravel with sand

	Moist	Dry
Split:	Yes	
Split sieve:	3/8"	
Total sample wt. (g):	4585.19	4385.20
+3/8" Coarse fraction (g):	2069.59	2060.69
-3/8" Split fraction (g):	803.28	742.26
Split fraction:	0.530	

Water content data	C.F.(+3/8")	S.F.(-3/8")
Moist soil + tare (g):	2401.05	1113.92
Dry soil + tare (g):	2392.15	1052.90
Tare (g):	331.46	310.64
Water content (%):	0.4	8.2

Sieve	Accum. Wt. Ret. (g)	Grain Size (mm)	Percent Finer	
8"	-	200	-	
6"	-	150	-	
4"	-	100	-	
3"	-	75	100.0	
1.5"	637.27	37.5	85.5	
3/4"	1513.75	19	65.5	
3/8"	2060.69	9.5	53.0	←Split
No.4	70.30	4.75	48.0	
No.10	128.42	2	43.8	
No.20	210.37	0.85	38.0	
No.40	326.61	0.425	29.7	
No.60	416.92	0.25	23.2	
No.100	461.76	0.15	20.0	
No.140	477.25	0.106	18.9	
No.200	490.51	0.075	18.0	



Gravel (%): 52.0
Sand (%): 30.0
Fines (%): 18.0

Entered by:___________
Reviewed:___________

Amount of Material in Soil Finer than the No. 200 (75µm) Sieve

(ASTM D1140)

IGES

Project: **Wolf Creek Resort/The Retreat**
No: **02348-002**
Location: Eden, UT
Date: 10/27/2016
By: BSS

Sample Info.	Boring No.	TP-1	TP-4	TP-5					
	Sample								
	Depth	14.0'	15.0'	10.0'					
	Split	Yes	Yes	Yes					
	Split Sieve*	3/8"	3/8"	3/8"					
	Method	B	B	B					
	Specimen soak time (min)	420	450	430					
	Moist total sample wt. (g)	4027.60	2826.65	3143.99					
	Moist coarse fraction (g)	1720.60	1307.73	1593.99					
	Moist split fraction + tare (g)	878.97	767.62	711.73					
	Split fraction tare (g)	310.40	410.38	326.66					
	Dry split fraction (g)	536.70	300.31	361.48					
	Dry retained No. 200 + tare (g)	752.90	588.65	590.02					
	Wash tare (g)	310.40	410.38	326.66					
	No. 200 Dry wt. retained (g)	442.50	178.27	263.36					
	Split sieve* Dry wt. retained (g)	1708.75	1286.13	1581.63					
	Dry total sample wt. (g)	3886.44	2562.99	3036.67					
Coarse Fraction	Moist soil + tare (g)	2031.62	1739.12	2002.72					
	Dry soil + tare (g)	2019.77	1715.81	1990.36					
	Tare (g)	311.02	328.07	408.73					
	Water content (%)	0.69	1.68	0.78					
Split Fraction	Moist soil + tare (g)	878.97	767.62	711.73					
	Dry soil + tare (g)	847.10	710.69	688.14					
	Tare (g)	310.40	410.38	326.66					
	Water content (%)	5.94	18.96	6.53					
	Percent passing split sieve* (%)	**56.0**	**49.8**	**47.9**					
	Percent passing No. 200 sieve (%)	**9.8**	**20.2**	**13.0**					

Entered by:___________

Reviewed:___________

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Direct Shear Test for Soils Under Drained Conditions

(ASTM D3080)

© IGES 2009, 2016

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT
Date: 10/27/2016
By: JDF

Boring No.: TP-2
Sample:
Depth: 9.0'
Sample Description: Brown clayey sand
Sample type: Arbitrary remold

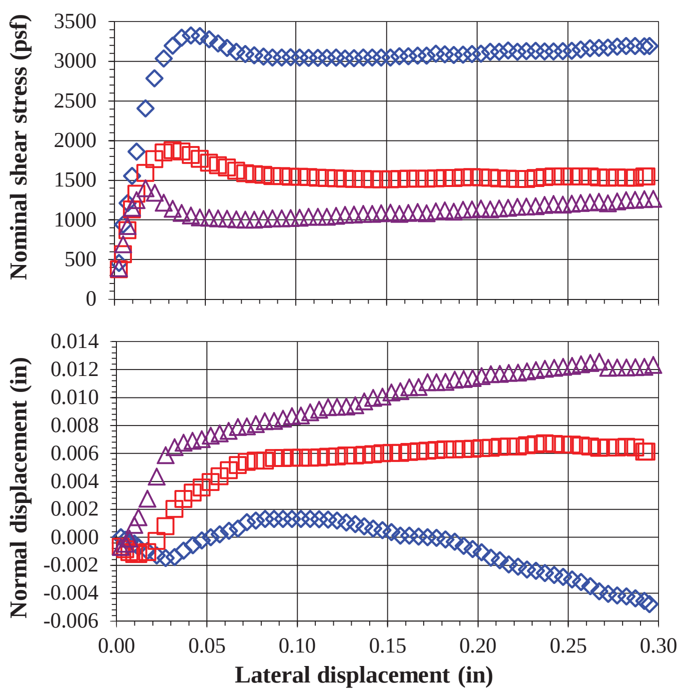
Test type: Inundated
Lateral displacement (in.): 0.3
Shear rate (in./min): 0.0007
Specific gravity, Gs: 2.70 Assumed

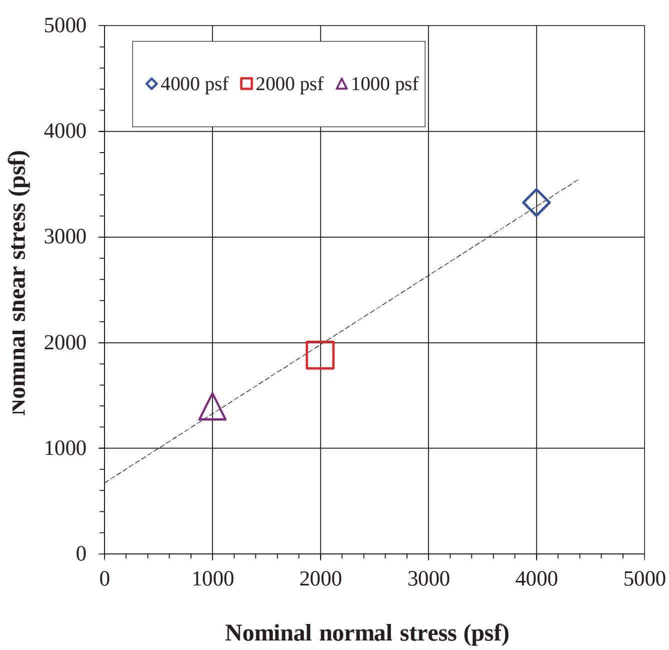
	Sample 1		Sample 2		Sample 3	
Nominal normal stress (psf)	4000		2000		1000	
Peak shear stress (psf)	3325		1879		1396	
Lateral displacement at peak (in)	0.042		0.032		0.017	
Load Duration (min)	896		935		965	
	Initial	Pre-shear	Initial	Pre-shear	Initial	Pre-shear
Sample height (in)	1.0000	0.9798	1.0000	0.9910	1.0000	0.9971
Sample diameter (in)	2.416	2.416	2.416	2.416	2.416	2.416
Wt. rings + wet soil (g)	184.32	187.27	183.34	187.14	183.03	187.29
Wt. rings (g)	44.14	44.14	43.16	43.16	42.85	42.85
Wet soil + tare (g)	478.15		478.15		478.15	
Dry soil + tare (g)	402.44		402.44		402.44	
Tare (g)	121.43		121.43		121.43	
Water content (%)	26.9	29.6	26.9	30.4	26.9	30.8
Dry unit weight (pcf)	91.8	93.6	91.8	92.6	91.8	92.0
Void ratio, e, for assumed Gs	0.84	0.80	0.84	0.82	0.84	0.83
Saturation (%)*	86.9	100.0	86.9	100.0	86.9	100.0

ϕ' (deg)	33
c' (psf)	673

Average of 3 samples	Initial	Pre-shear
Water content (%)	26.9	30.3
Dry unit weight (pcf)	91.8	92.7

*Pre-shear saturation set to 100% for phase calculations





Comments:
Specimens swelled upon inundation.

Entered by:___________
Reviewed:___________

IGES

Direct Shear Test for Soils Under Drained Conditions

(ASTM D3080)

Project: Wolf Creek Resort/The Retreat
Boring No.: TP-2
No: 02348-002
Sample:
Location: Eden, UT
Depth: 9.0'

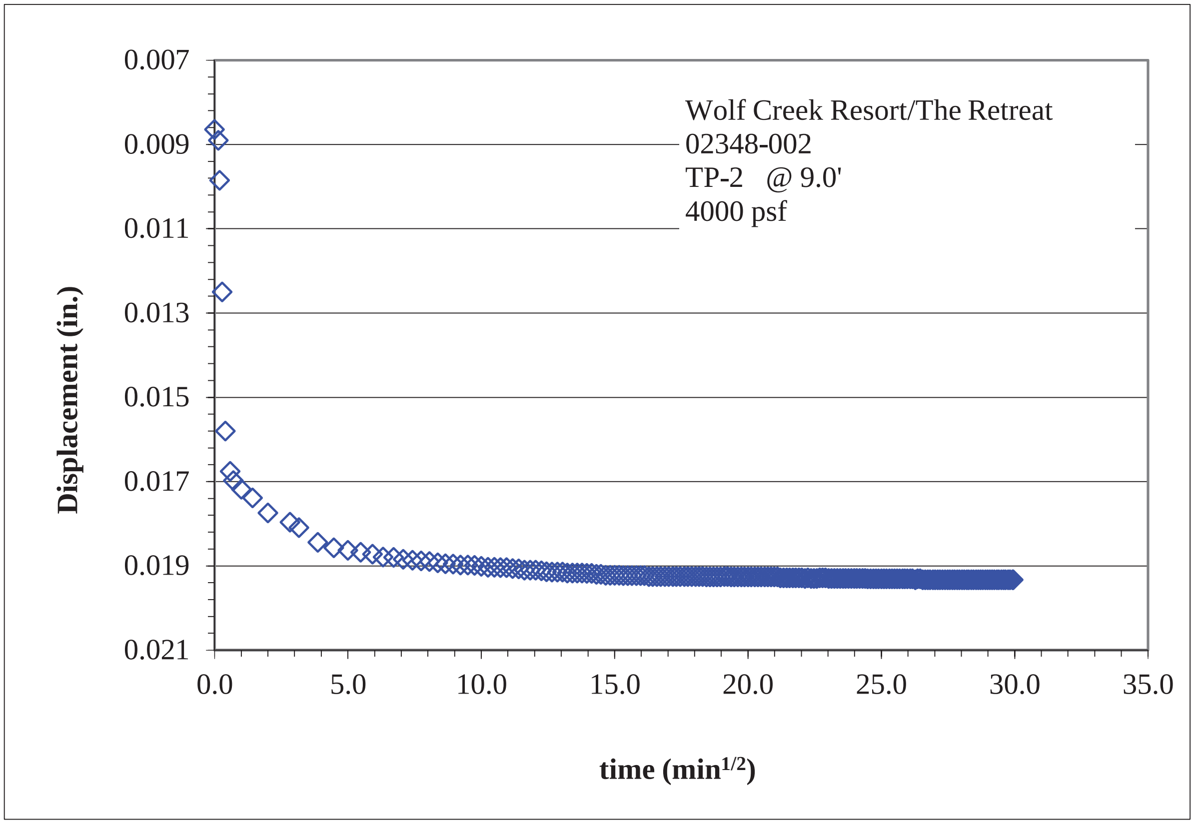
Nominal normal stress = 4000 psf			Nominal normal stress = 2000 psf			Nominal normal stress = 1000 psf		
Lateral Displacement (in.)	Nominal Shear Stress (psf)	Normal Displacement (in.)	Lateral Displacement (in.)	Nominal Shear Stress (psf)	Normal Displacement (in.)	Lateral Displacement (in.)	Nominal Shear Stress (psf)	Normal Displacement (in.)
0.002	457	0.000	0.002	375	-0.001	0.002	388	-0.001
0.005	942	0.000	0.005	566	-0.001	0.005	690	0.000
0.007	1210	0.000	0.007	870	-0.001	0.007	923	0.000
0.010	1553	0.000	0.010	1133	-0.001	0.010	1153	0.001
0.012	1860	-0.001	0.012	1329	-0.001	0.012	1249	0.001
0.017	2407	-0.001	0.017	1590	-0.001	0.017	1396	0.003
0.022	2784	-0.001	0.022	1765	0.000	0.022	1342	0.004
0.027	3034	-0.001	0.027	1849	0.001	0.027	1216	0.006
0.032	3196	-0.001	0.032	1879	0.002	0.032	1141	0.006
0.037	3297	-0.001	0.037	1862	0.003	0.037	1085	0.007
0.042	3325	-0.001	0.042	1817	0.003	0.042	1053	0.007
0.047	3320	0.000	0.047	1768	0.004	0.047	1032	0.007
0.052	3279	0.000	0.052	1722	0.004	0.052	1027	0.007
0.057	3225	0.000	0.057	1689	0.004	0.057	1017	0.007
0.062	3171	0.000	0.062	1659	0.005	0.062	1012	0.008
0.067	3122	0.001	0.067	1621	0.005	0.067	1006	0.008
0.072	3093	0.001	0.072	1588	0.005	0.072	1001	0.008
0.077	3075	0.001	0.077	1574	0.005	0.077	1003	0.008
0.082	3062	0.001	0.082	1566	0.005	0.082	1011	0.008
0.087	3049	0.001	0.087	1551	0.006	0.087	1017	0.008
0.092	3049	0.001	0.092	1549	0.006	0.092	1019	0.008
0.097	3052	0.001	0.097	1543	0.006	0.097	1023	0.009
0.102	3047	0.001	0.102	1542	0.006	0.102	1027	0.009
0.107	3042	0.001	0.107	1540	0.006	0.107	1037	0.009
0.112	3044	0.001	0.112	1529	0.006	0.112	1038	0.009
0.117	3044	0.001	0.117	1526	0.006	0.117	1037	0.009
0.122	3047	0.001	0.122	1521	0.006	0.122	1052	0.009
0.127	3036	0.001	0.127	1520	0.006	0.127	1063	0.009
0.132	3039	0.001	0.132	1514	0.006	0.132	1068	0.009
0.137	3047	0.001	0.137	1514	0.006	0.137	1074	0.010
0.142	3047	0.001	0.142	1511	0.006	0.142	1074	0.010
0.147	3047	0.001	0.147	1509	0.006	0.147	1081	0.010
0.152	3047	0.000	0.152	1512	0.006	0.152	1089	0.010
0.157	3065	0.000	0.157	1515	0.006	0.157	1076	0.010
0.162	3065	0.000	0.162	1517	0.006	0.162	1088	0.011
0.167	3072	0.000	0.167	1518	0.006	0.167	1098	0.011
0.172	3072	0.000	0.172	1519	0.006	0.172	1084	0.011
0.177	3096	0.000	0.177	1521	0.006	0.177	1106	0.011
0.182	3088	0.000	0.182	1526	0.006	0.182	1117	0.011
0.187	3080	0.000	0.187	1528	0.006	0.187	1103	0.011
0.192	3083	-0.001	0.192	1535	0.006	0.192	1126	0.011
0.197	3091	-0.001	0.197	1537	0.006	0.197	1133	0.011
0.202	3098	-0.001	0.202	1536	0.006	0.202	1145	0.012
0.207	3119	-0.001	0.207	1531	0.006	0.207	1131	0.012
0.212	3122	-0.002	0.212	1522	0.006	0.212	1142	0.012
0.217	3137	-0.002	0.217	1520	0.006	0.217	1152	0.012
0.222	3122	-0.002	0.222	1514	0.006	0.222	1162	0.012
0.227	3129	-0.002	0.227	1513	0.007	0.227	1166	0.012
0.232	3132	-0.002	0.232	1525	0.007	0.232	1170	0.012
0.237	3124	-0.003	0.237	1540	0.007	0.237	1187	0.012
0.242	3124	-0.003	0.242	1546	0.007	0.242	1199	0.012
0.247	3129	-0.003	0.247	1548	0.007	0.247	1190	0.012
0.252	3134	-0.003	0.252	1548	0.007	0.252	1204	0.012
0.257	3147	-0.003	0.257	1547	0.007	0.257	1211	0.012
0.262	3165	-0.004	0.262	1547	0.006	0.262	1221	0.012
0.267	3171	-0.004	0.267	1536	0.006	0.267	1226	0.013
0.272	3173	-0.004	0.272	1529	0.006	0.272	1209	0.012
0.277	3186	-0.004	0.277	1535	0.006	0.277	1230	0.012
0.282	3194	-0.004	0.282	1531	0.006	0.282	1248	0.012
0.287	3194	-0.004	0.287	1531	0.006	0.287	1253	0.012
0.292	3191	-0.005	0.292	1545	0.006	0.292	1262	0.012
0.295	3194	-0.005	0.293	1548	0.006	0.297	1265	0.012
						0.300	1266	0.012

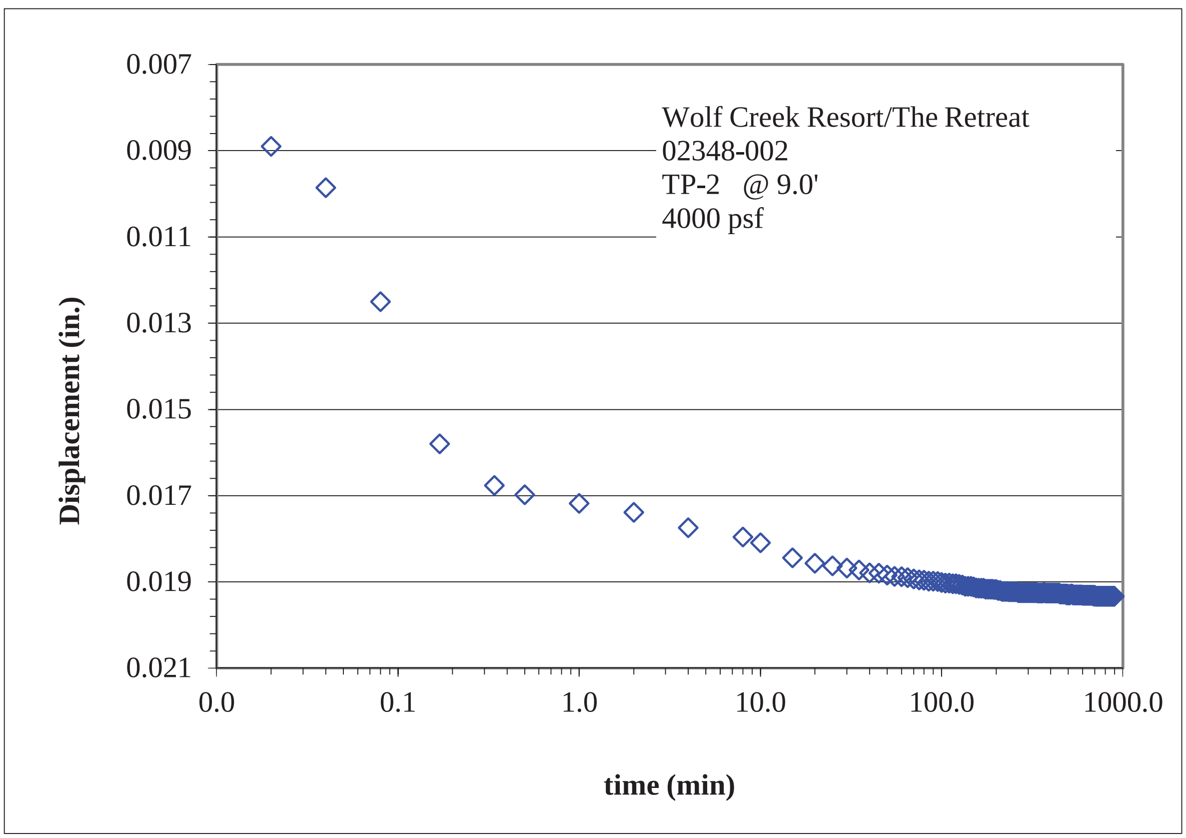
Direct Shear Test for Soils Under Drained Conditions

(ASTM D3080)

Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT

Boring No.: TP-2
Sample:
Depth: 9.0'





Drained Repeated Direct Shear

(In general accordance with ASTM D3080)

Project:	Wolf Creek Resort/The Retreat	**Boring No:**	TP-1
No:	02348-002	**Sample:**	
Location:	Eden, UT	**Depth:**	10.0'
Date:	11/9/2016	**Sample Description:**	Light brown clay
By:	JDF/NB	Specific gravity, Gs:	2.85 Assumed

	Sample 1		Sample 2		Sample 3	
	Initial	Pre-Shear	Initial	Pre-Shear	Initial	Pre-Shear
Sample height (in)	1.0000	0.9800	1.0000	0.9800	1.0000	0.9800
Wet unit weight (pcf)	106.2	120.6	106.2	120.6	106.2	120.6
Water content (%)	20.9	34.5	20.9	34.5	20.9	34.5
Dry unit weight (pcf)	87.9	89.7	87.9	89.7	87.9	89.7
Void ratio, e, for assumed Gs	1.02	0.98	1.02	0.98	1.02	0.98
Saturation (%)*	99.5	100.0	99.5	100.0	99.5	100.0

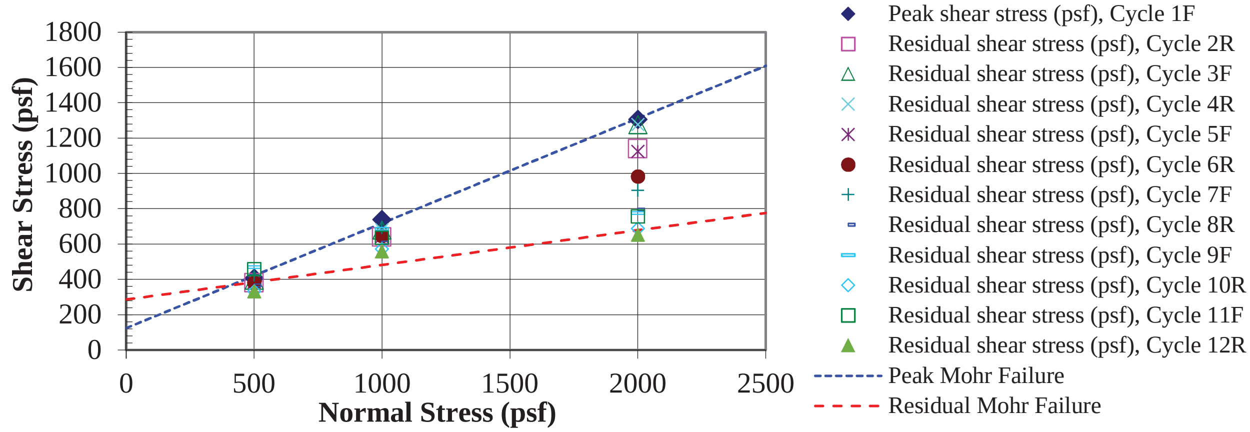
*Pre-shear saturation set to 100% for phase calculations

Average of 3 samples	Initial	Final
Water content (%)	20.9	34.5
Dry unit weight (pcf)	87.9	89.7
Shear rate (in/min)	3.47E-04	

Test specimens consist of minus No. 4 sieve material remolded to an arbitrary unit weight and water content.

Summary of Shear Strength Results	Sample 1	Sample 2	Sample 3	ϕ (deg)	c (psf)
Normal stress (psf)	2000	1000	500		
Peak shear stress (psf), Cycle 1F	1305	739.5	406.8	30.7	124.1
Residual shear stress (psf), Cycle 2R	1140	641.1	381.6	26.8	132.2
Residual shear stress (psf), Cycle 3F	1277	680.3	395.9	30.5	97.5
Residual shear stress (psf), Cycle 4R	1277	680.3	395.9	30.5	97.5
Residual shear stress (psf), Cycle 5F	1125	641.9	385.8	26.2	144.3
Residual shear stress (psf), Cycle 6R	982.9	646.9	381.6	21.4	213.6
Residual shear stress (psf), Cycle 7F	905.5	693.6	424.4	17.0	318.5
Residual shear stress (psf), Cycle 8R	797.1	610.2	366.5	15.3	273.1
Residual shear stress (psf), Cycle 9F	776.5	688.6	470.5	10.6	426.6
Residual shear stress (psf), Cycle 10R	688.8	572.7	333	12.4	275.0
Residual shear stress (psf), Cycle 11F	758.4	636.9	460.4	10.6	399.7
Residual shear stress (psf), Cycle 12R	652.7	558.6	333	11.1	286.0
Minimum shear stress (psf)	652.7	558.6	333	11.1	286.0

F - Forward cycle; R - Reverse cycle



Tested by:___________

Reviewed:___________

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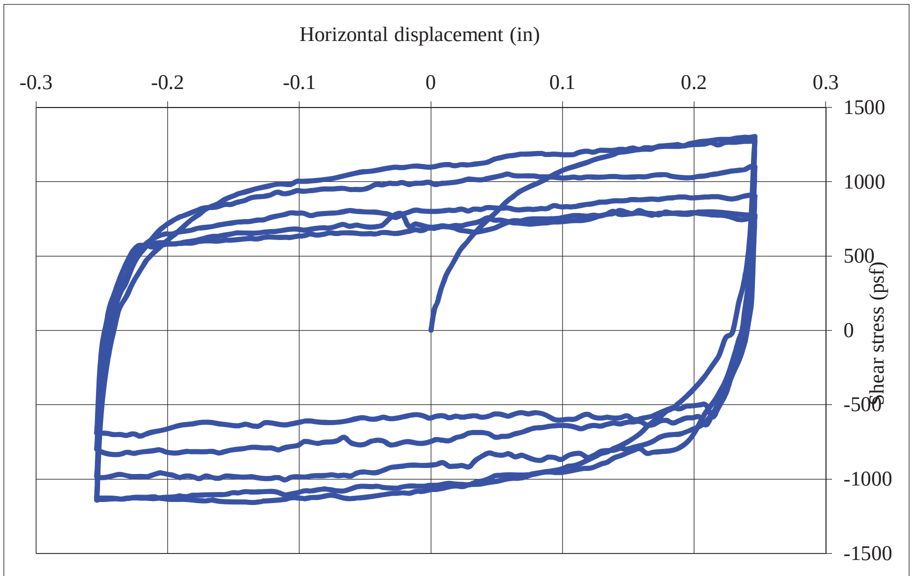
Drained Repeated Direct Shear

(In general accordance with ASTM D3080)

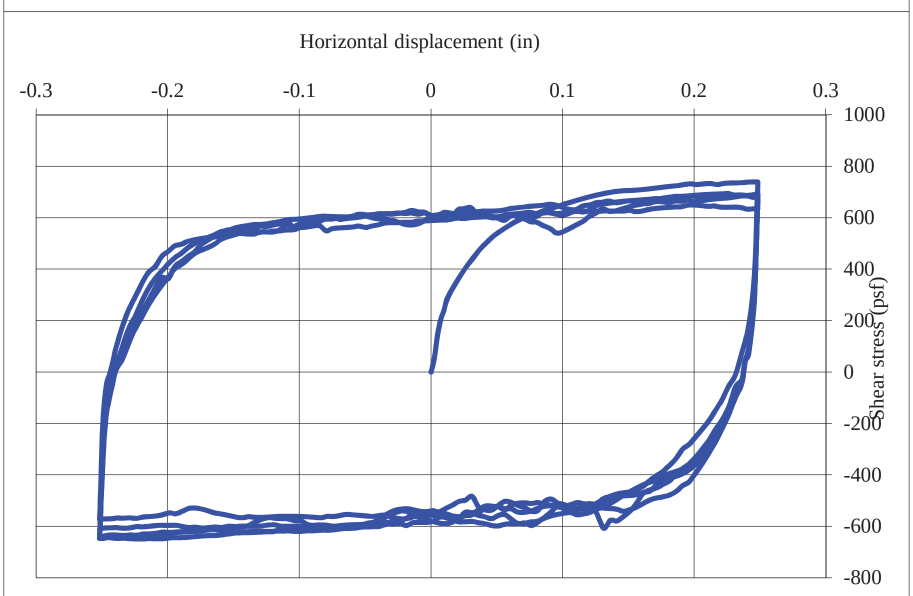
Project: Wolf Creek Resort/The Retreat
No: 02348-002
Location: Eden, UT

Boring No: TP-1
Sample:
Depth: 10.0'

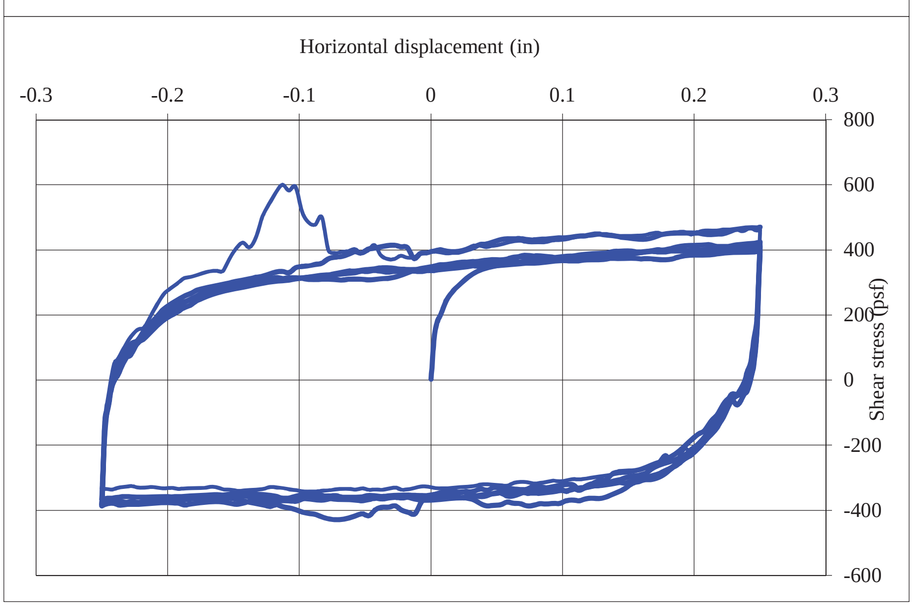
2000 (psf)



1000 (psf)



500 (psf)

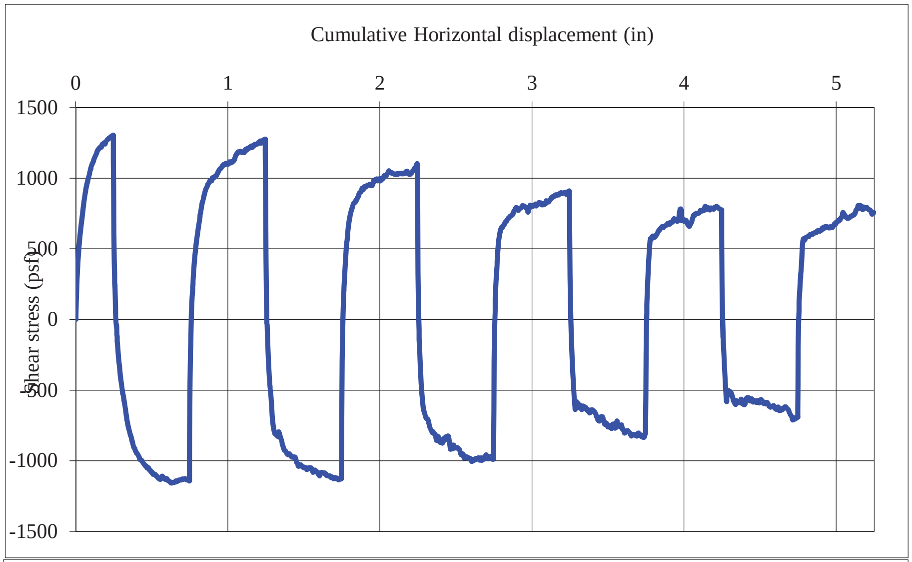


Drained Repeated Direct Shear

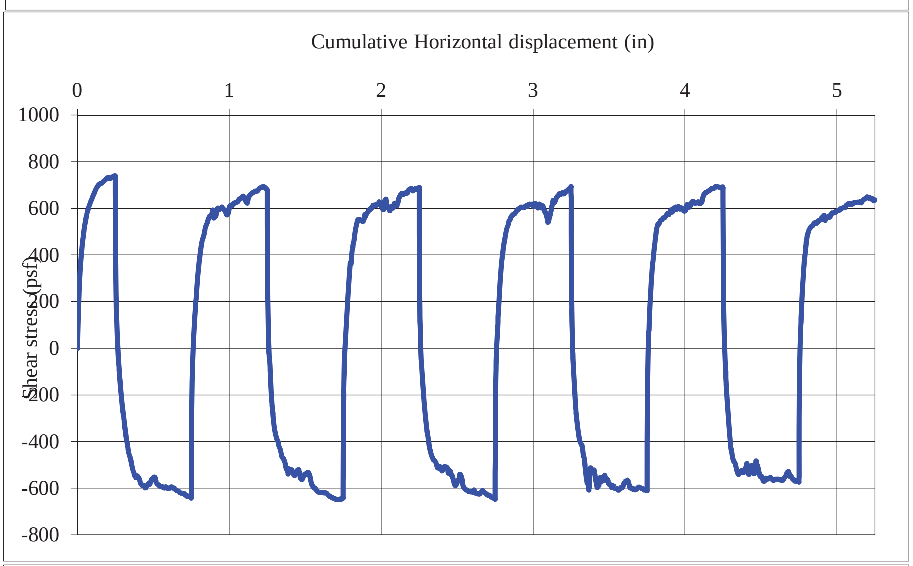
(In general accordance with ASTM D3080)

Project:	Wolf Creek Resort/The Retreat	**Boring No:**	TP-1
No:	02348-002	**Sample:**	
Location:	Eden, UT	**Depth:**	10.0'

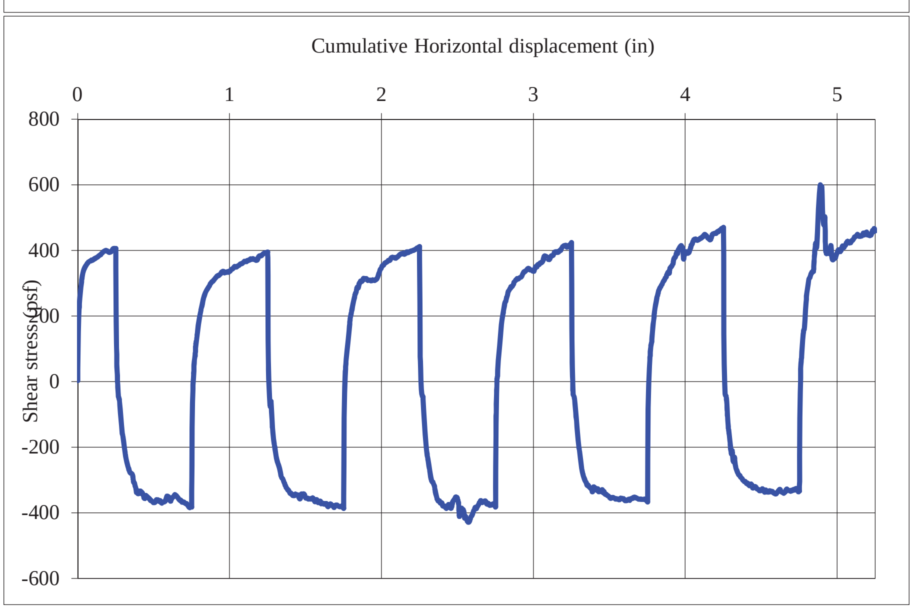
2000 (psf)



1000 (psf)

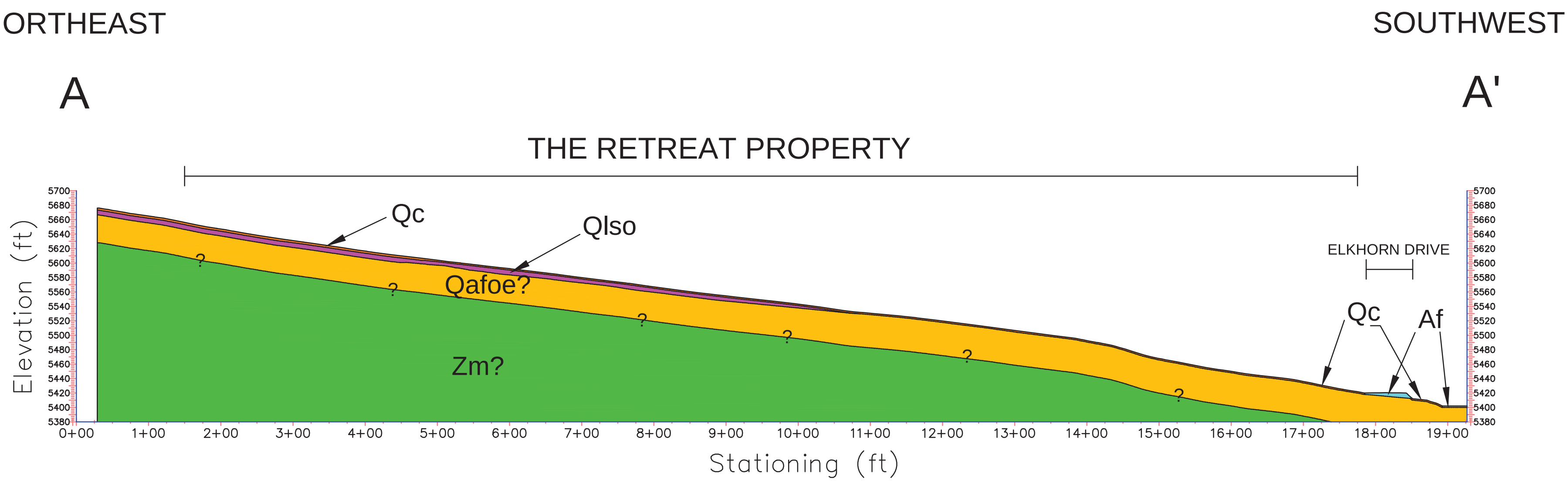


500 (psf)



APPENDIX C

CROSS-SECTION A - A'



Af ARTIFICIAL FILL

Qc COLLUVIUM (HOLOCENE-PLEISTOCENE)

Qlso SHALLOW LANDSLIDE DEPOSITS (PLEISTOCENE); IN SUBSURFACE ONLY

Qafoe? ERODED OLDER ALLUVIAL FAN DEPOSITS (PLEISTOCENE); IN SUBSURFACE ONLY

Zm? MUTUAL FORMATION (PRECAMBRIAN); IN SUBSURFACE ONLY

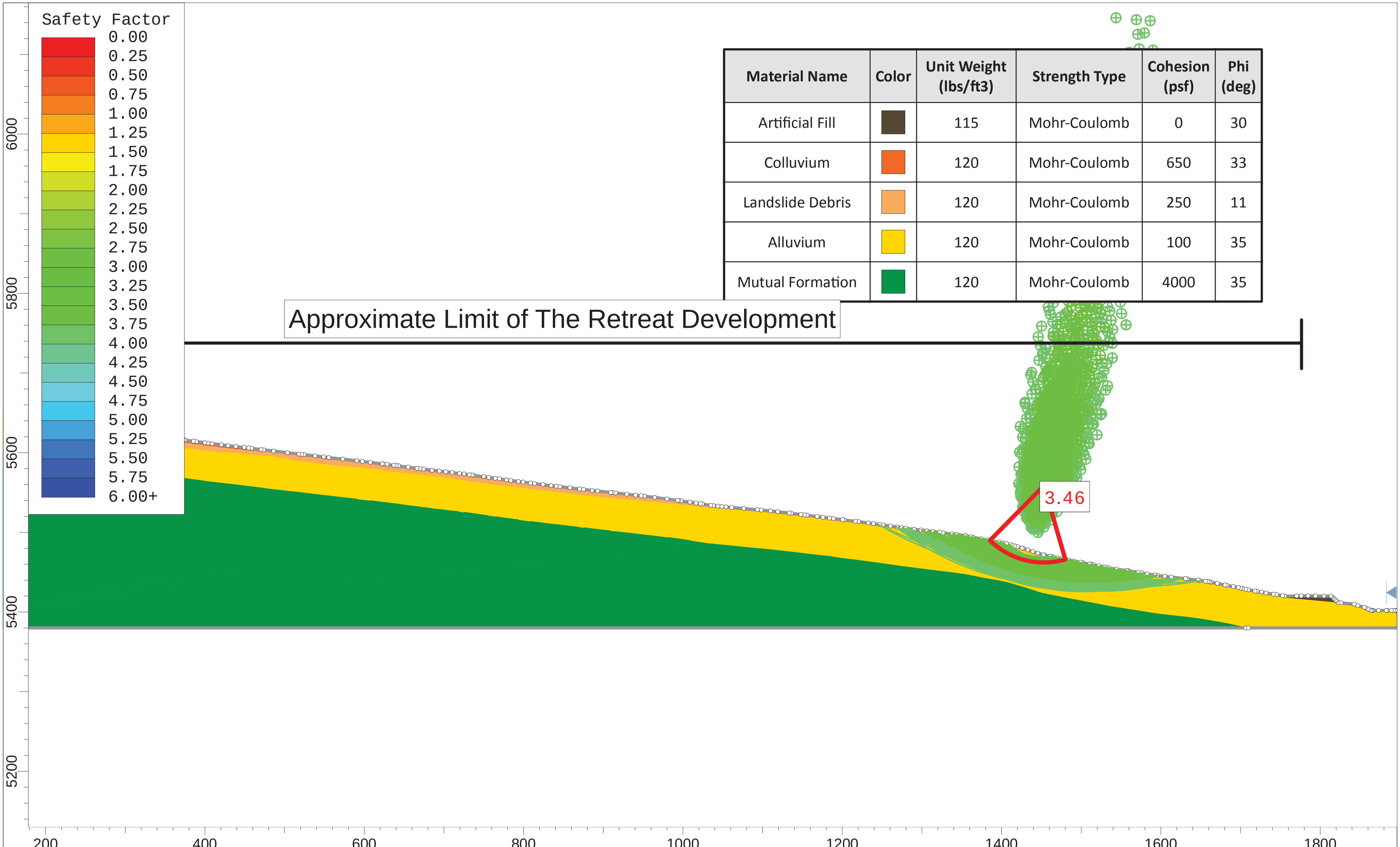
NO VERTICAL EXAGGERATION

0 150 300
FEET

FIGURE C-1

CROSS-SECTION A - A'
THE RETREAT SUBDIVISION
GEOLOGIC HAZARD ASSESSMENT
WOLF CREEK RESORT
EDEN, UTAH

DATE: 12/01/2016
PROJECT: 02348-002
SCALE: 1"=150'
IGES



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Artificial Fill		115	Mohr-Coulomb	0	30
Colluvium		120	Mohr-Coulomb	650	33
Landslide Debris		120	Mohr-Coulomb	250	11
Alluvium		120	Mohr-Coulomb	100	35
Mutual Formation		120	Mohr-Coulomb	4000	35

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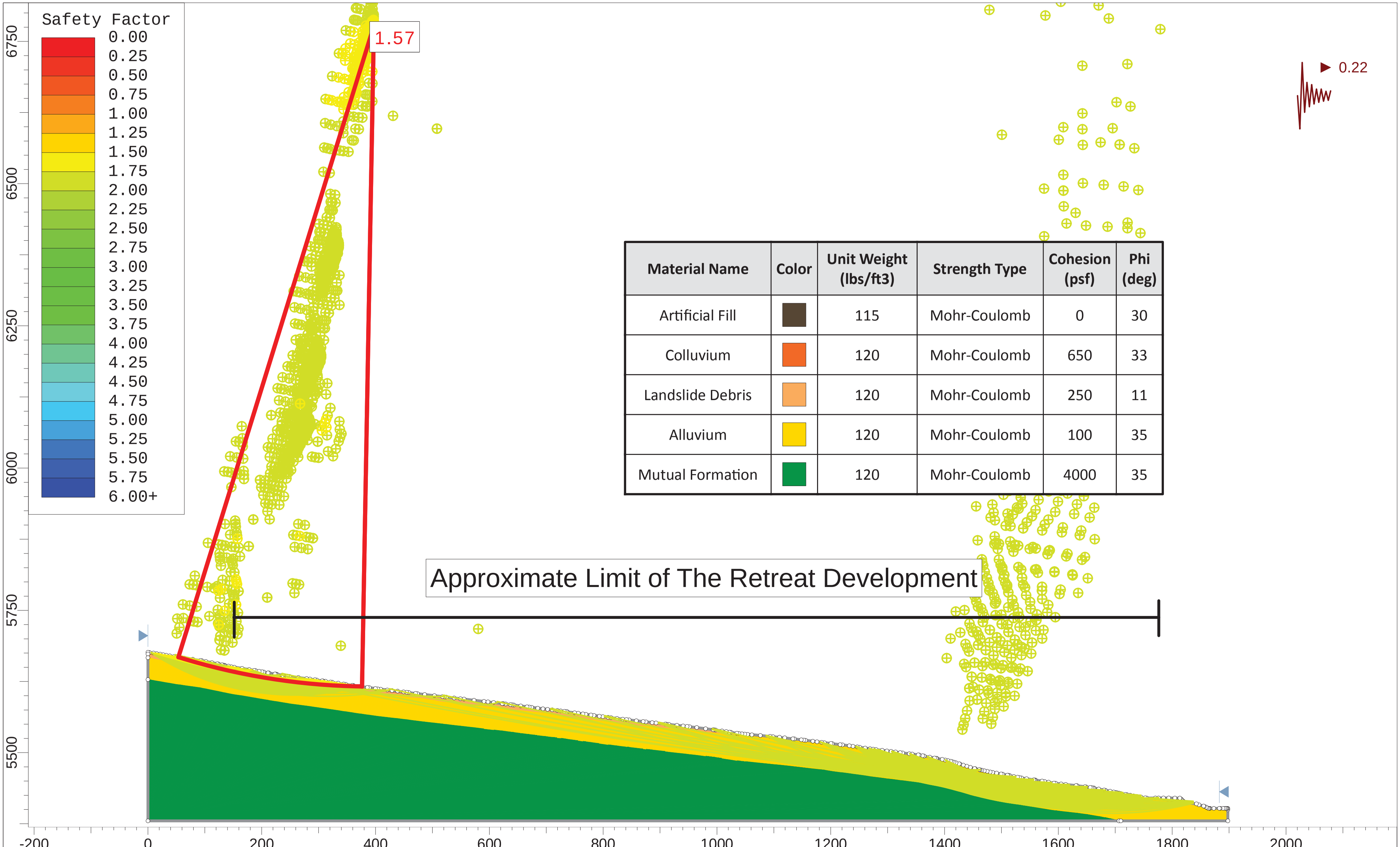
SLIDEINTERPRET 7.020

Project	The Retreat - Section A-A'		
Analysis Description	Global Stability - Circular		
Drawn By TQH	*Scale* 1:2000	*Company*	IGES, Inc.
Date	12/1/2016	*File Name*	The Retreat Global - Static.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Artificial Fill		115	Mohr-Coulomb	0	30
Colluvium		120	Mohr-Coulomb	650	33
Landslide Debris		120	Mohr-Coulomb	250	11
Alluvium		120	Mohr-Coulomb	100	35
Mutual Formation		120	Mohr-Coulomb	4000	35

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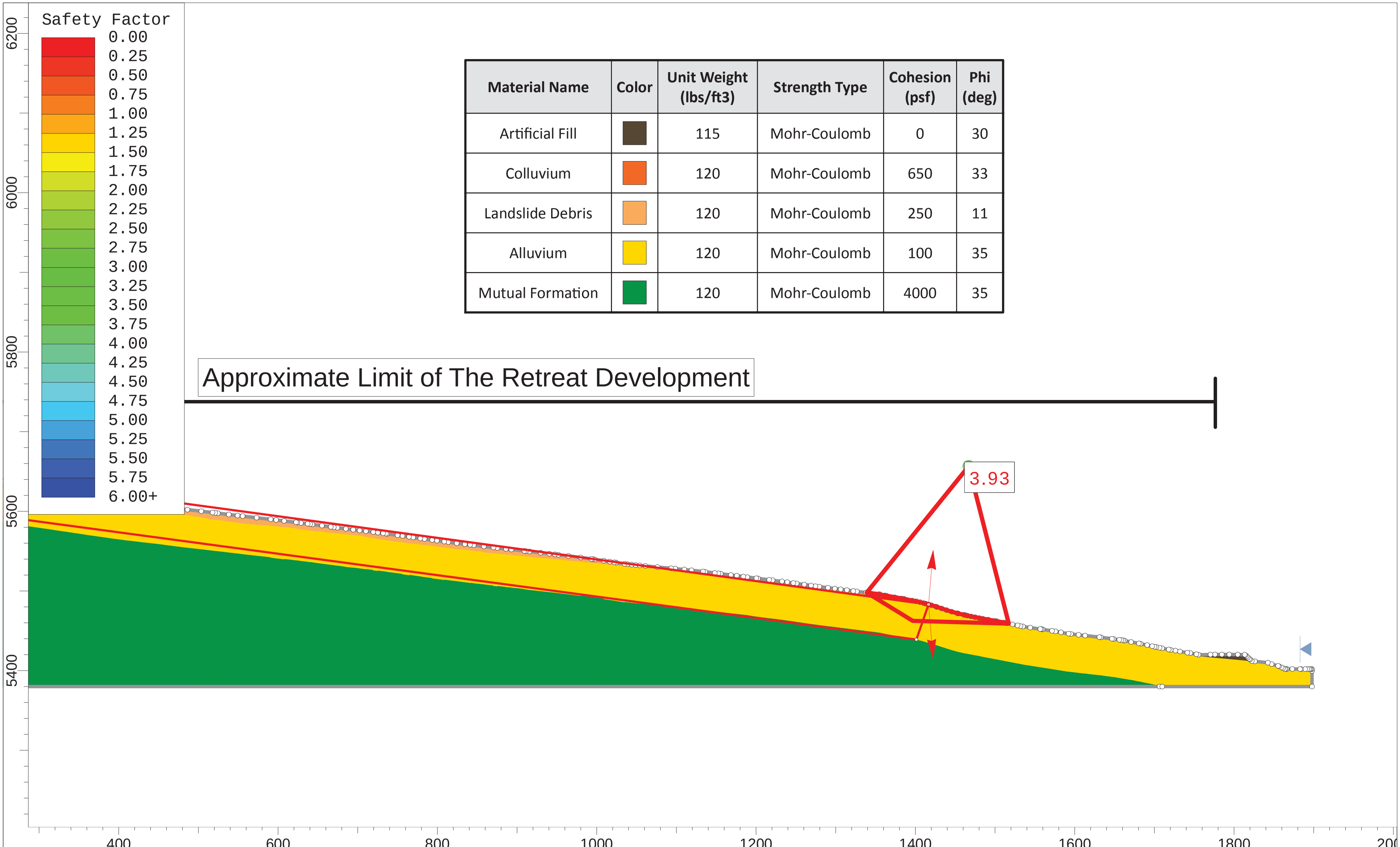
SLIDEINTERPRET 7.020

Project	The Retreat - Section A-A'
Analysis Description	Global Stability - Circular - Seismic
Drawn By	TQH
Scale	1:2800
Company	IGES, Inc.
Date	12/1/2016
File Name	The Retreat Global - Static.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Artificial Fill		115	Mohr-Coulomb	0	30
Colluvium		120	Mohr-Coulomb	650	33
Landslide Debris		120	Mohr-Coulomb	250	11
Alluvium		120	Mohr-Coulomb	100	35
Mutual Formation		120	Mohr-Coulomb	4000	35

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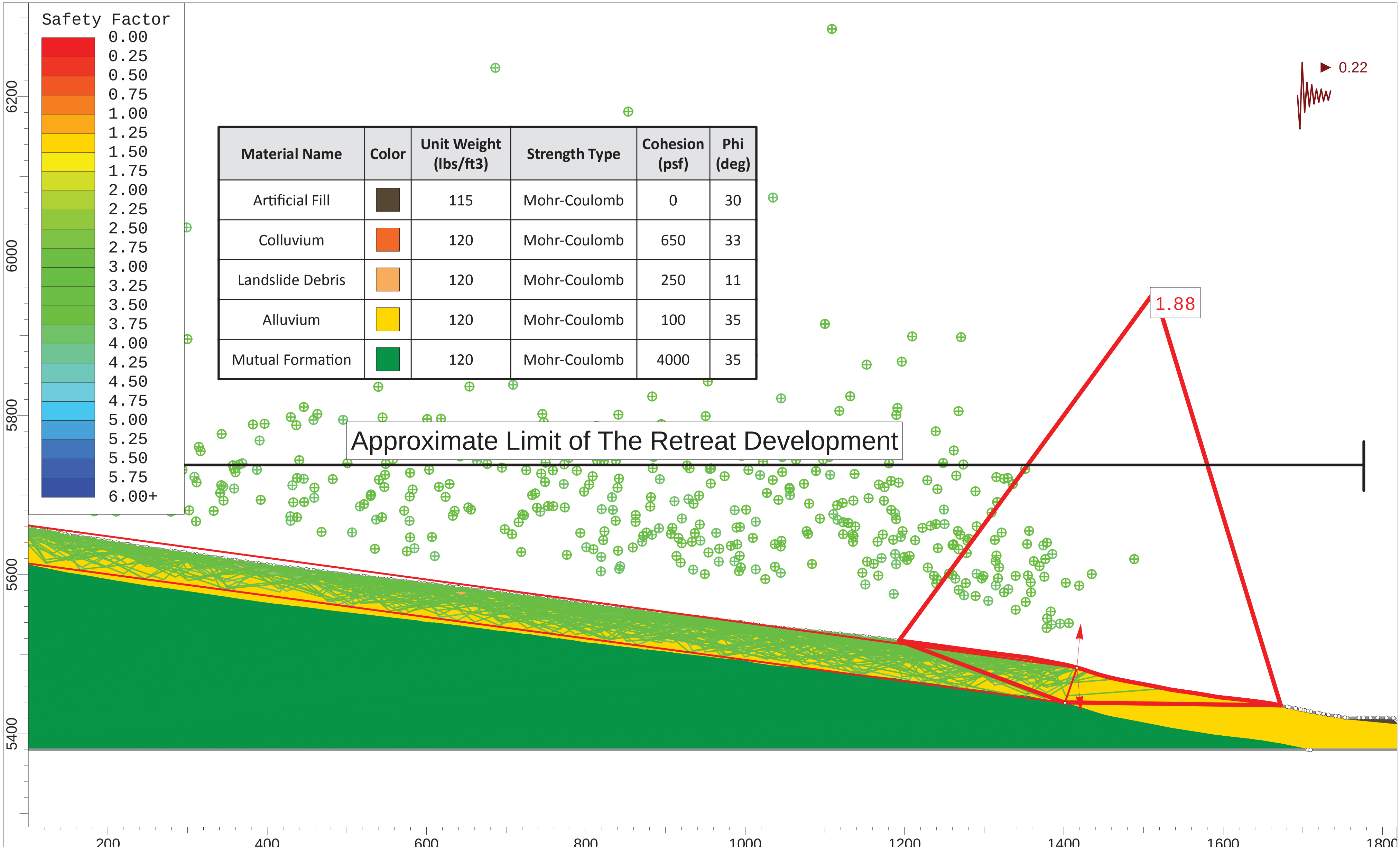
SLIDEINTERPRET 7.020

Project The Retreat - Section A-A'

Analysis Description Global Stability - Wedge

Drawn By TQH | *Scale* 1:2000 | *Company* IGES, Inc.

Date 12/1/2016 | *File Name* The Retreat Global - Static.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Artificial Fill		115	Mohr-Coulomb	0	30
Colluvium		120	Mohr-Coulomb	650	33
Landslide Debris		120	Mohr-Coulomb	250	11
Alluvium		120	Mohr-Coulomb	100	35
Mutual Formation		120	Mohr-Coulomb	4000	35

IGES®

SLIDEINTERPRET 7.020

Project	The Retreat - Section A-A'		
Analysis Description	Global Stability - Wedge - Seismic		
Drawn By TQH	*Scale* 1:2000	*Company*	IGES, Inc.
Date	12/1/2016	*File Name*	The Retreat Global - Static.slim