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Watts Enterprises
5200 South Highland Drive #101
Salt Lake City, Utah 84117
Attn: Mr. Rick Everson

IGES Project No. 01855-007

Subject: Reconnaissance Geologic Hazards Assessment
Trappers Ridge Phase 8 Subdivision at Wolf Creek
Eden, Utah

Mr. Everson:

At your request, IGES has performed a reconnaissance-level geologic hazard assessment for the Trappers Ridge Phase 8 Subdivision at Wolf Creek, located in the city of Eden in Weber County, Utah (Figure A-1). 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 and site reconnaissance conducted as part of this assessment.

INTRODUCTION

It is our understanding that the Trappers Ridge Phase 8 Subdivision at Wolf Creek project will involve the development of 18 lots with conventionally-framed, two to three-story residences, a clubhouse, and a pool across an area covering approximately 8.5 acres in Eden, Utah. The property is located within parts of the northwestern and southwestern quarters of Section 23 of Township 7 North, Range 1 East, approximately 2 miles north of Pineview Reservoir. The property is bound on all sides by partially completed residential neighborhoods containing intermittent developed and undeveloped lots.

PURPOSE AND SCOPE

This study was performed as a reconnaissance-level geologic hazards assessment 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; and

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

REVIEW OF GEOLOGIC LITERATURE

A number of pertinent publications were reviewed as part of this assessment. Sorensen and Crittenden, Jr. (1979) provides the most recent published 1:24,000 scale geologic mapping that covers the area in which the property of interest is located. Coogan and King (2016) provide more recent geologic mapping of the area, but at a 1:62,5000 scale; this map is an updated version of a previous map by the same authors (Coogan and King, 2001) that had long been used as the most recent geologic map of the area. A United States Geological Survey (USGS) topographic map for the Huntsville Quadrangle (2014) provides physiographic and hydrologic data for the project area. Two Federal Emergency Management Agency (FEMA) flood maps (both effective in 2015) that cover the project area were 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 EarthTec Engineering (EarthTec) geotechnical report (2016) for the subject property was reviewed.

General Geologic Setting

The Trappers Ridge Phase 8 at Wolf Creek property is situated along the eastern margin of the northern part of the Ogden Valley, along the foothills of the Wasatch Mountains and approximately 415 feet east of the Heinz Canyon drainage. 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.

Surficial Geology

According to Sorensen and Crittenden, Jr. (1979), the property is located entirely on Holocene-aged (~11,700 years ago to the present) colluvium and slopewash (Qcs) deposits (Figure A-2). The unit is likely underlain by the Norwood Tuff (Tn), as several small exposures of the Norwood Tuff is present within a one-mile radius of the property. Coogan and King (2016; Figure A-3) denote the approximately eastern half of the property as Qac (alluvium and colluvium deposits), which are described as including “stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale.” The approximately western half of the property is mapped as Qms (landslide deposits), which are described as including “slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks.” Two landslide scarps are mapped off the property upslope to the northeast within approximately 700 feet of the northeastern property margin.

In contrast to Sorensen and Crittenden, Jr. (1979), Coogan and King (2016) mapped the adjacent Heinz Canyon drainage approximately 0.1 mile upslope to the northwest as Qafy, younger (Holocene and uppermost Pleistocene) alluvial fan deposits on fans that are “active, impinge on present-day floodplains, divert active streams, overlie low terraces, and/or cap alluvial deposits related to the Provo and regressive shorelines.” Neither of the aforementioned geologic maps show any faults on the property, though Sorensen and Crittenden, Jr. (1979) show two faults that straddle the property and several additional faults that potentially project onto the property, all of which are cutting across the Holocene-aged colluvium. The faults that straddle the property trend northwest to southeast, and may be pass as close as 60 feet to the respective margins of the property (see Figure A-2). It should be noted that these faults are absent from the more recent (Coogan and King, 2016) publication, though two of the faults mapped to the northeast of the property in Sorensen and Crittenden, Jr. (1979) have been reinterpreted in Coogan and King (2016) as landslide headscarps.

Hydrology

The USGS topographic map for the Huntsville Quadrangle (2014) shows that the Trappers Ridge Phase 8 at Wolf Creek project area is situated within the broad northwest-southeast trending Ogden Valley and near the northeast-southwest trending Heinz Canyon drainage. Multiple generally northeast-southwest trending ephemeral stream drainages are found on the property, which were found to contain flowing water at least in part during the site visit. The largest of these ephemeral stream drainages forms the boundary between the property and the residential development to the south, and the other ephemeral drainages flow into this larger ephemeral drainage. 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 runoff.

Baseline groundwater depths for the Trappers Ridge Phase 8 at Wolf Creek property are currently unknown, but are anticipated to fluctuate both seasonally and annually. Groundwater was encountered in only one test pit (the southernmost test pit and therefore the closest to the main ephemeral stream drainage) excavated by EarthTec (2016) at a depth of approximately 8 feet below existing ground level in late January and early February. Groundwater flow from snowmelt is dependent upon the nature of the surface and subsurface materials, including the degree and orientation of fracturing of the bedrock. Given that the topography slopes generally downhill to the southwest, groundwater flow paths are anticipated to be generally to the southwest. Daylighting of this groundwater can be expected in the various ephemeral drainages and generally flat, low-lying parts of the property, especially during times of peak runoff as was encountered during the site visit.

The FEMA flood maps that covers the Trappers Ridge Phase 8 at Wolf Creek project area show that the property is outside of the 500-year flood floodplain for the Heinz Canyon drainage (FEMA, 2015a and 2015b).

Geologic Hazards

Based upon the available geologic literature, regional-scale geologic hazard maps that cover the Trappers Ridge Phase 8 at Wolf Creek 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.

Landslides

Two regional-scale landslide hazard maps have been produced that cover the project area. Colton (1991) shows the property to be 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 “Landslide and/or landslide undifferentiated from talus, colluvial, rockfall, glacial, or soil-creep deposits.” As noted above, the most recent geologic map of the area (Coogan and King, 2016; see Figure A-3) displays mapped landslide deposits on the approximately western half of the property and adjacent to the property on the north, east, and south.

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 closest Quaternary-aged fault to the property is the Ogden Valley Northeastern Margin Fault, located approximately 1.25 miles to the northeast of the property (USGS and UGS, 2006). 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 6.15 miles west of the western margin of the property (USGS and UGS, 2006).

Debris-Flows
Christensen and Shaw (2008b) do not show the project area to be located within a debris-flow hazard special study area, and Coogan and King (2016) do not show any mapped alluvial fan deposits on the property.

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.

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

REVIEW OF AERIAL IMAGERY

A series of aerial photographs that cover project area were taken from the UGS Aerial Imagery Collection (UGS, 2016) 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 which were all taken prior to the development of the nearby residences and their 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.

Google Earth imagery of the property from between the years of 1993 and 2015 were also reviewed. No landslide or other geological hazard features were noted in the imagery. The property was observed to contain abundant surficial gravel, cobbles, and boulders, as well as the several ephemeral drainages discussed above. Most of the project area was found to be covered in various forms of vegetation, with no bedrock exposures anywhere on the property.

Utah Geological Survey 1 meter LiDAR data (UGS, 2011) for the project area was reviewed. The southern half of the property was observed to be significantly gullied. No landslide or other geologic hazard features were readily identified on the property, though a couple lineaments potentially corresponding to the mapped landslide scarps in Coogan and King (2016) were observed on the slope to the northeast of the property.

SITE RECONNAISSANCE

Mr. Peter E. Doumit, P.G., C.P.G., of IGES conducted reconnaissance of the site and the immediate adjacent properties on May 13, 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 Trappers Ridge Phase 8 at Wolf Creek property and adjacent areas.

Variously-sized boulders and cobbles were found scattered across the property. These were typically subangular to subrounded, and were found to be as large as 5 feet in diameter. The rock clasts were found to be comprised of three distinct lithologies:

1. White to very light gray, finely laminated quartzite with occasional rounded pebbles
2. An orange-brown clast-supported conglomerate with subrounded to rounded quartzite pebble clasts
3. An orange to reddish-orange fine to medium-grained sandstone; well-indurated and gradational to quartzite; contains occasional rounded quartzite pebbles

In general, the proportion of these lithologies was fairly consistent across the property, with approximately 70% of the clasts comprised of quartzite, approximately 25% comprised of conglomerate, and approximately 5% comprised of sandstone. Where present, minor to moderate oxidation of the sandstone boulders was observed.

The presence or absence and setting within which these boulders were encountered provided the means by which the surficial geology was able to be mapped across the property. Three largely gradational geologic units were differentiated on the property, as well as areas that have been modified by human activity. Each of these units are discussed in turn below.

Qac (Quaternary alluvium and colluvium)

This unit was mapped in generally low-lying areas and straddling the multiple ephemeral stream drainages where there was a significantly greater proportion of alluvial (running water-deposited) material present than colluvial (gravity-deposited with the aid of rain; slopewash) material. This unit underlies much of the southern and eastern portions of the property where the property is highly gullied, and consists predominantly of an area in which relatively few boulders were encountered.

Qca (Quaternary colluvium and alluvium)

This unit was generally mapped in areas with gentle slopes, and represents a transitional unit between the predominantly alluvial deposits of the Qac unit and the almost exclusive colluvial deposits of the Qc unit. The unit was gradational in terms of the proportion of alluvial and colluvial material, with some areas having slightly more alluvial material than colluvial material, and vice versa. Much of the central and western parts of the property is underlain by the Qca unit.

Qc (Quaternary colluvium)
This unit was mapped in areas with steeper slopes with concentrated boulder fields and relatively few fines. The unit comprises the higher elevation knob found in the northern part of the property immediately southwest of the existing residences along Elkhorn Drive. Boulders in the boulder fields in this unit were commonly subangular to subrounded, and were as much as 5 feet in diameter, though the mode average boulder size was generally 1 to 1.5 feet in diameter.

Surface Water/Groundwater
At the time of the site visit, the ephemeral stream drainage that runs along the south margin of the property was found to be flowing with water, with a larger volume of water and stronger current further to the west. The low-lying south-central and southwestern portion of property contained several small gullies with flowing water and also ponded, marshy conditions associated with cattails and other hydrophilic plants (see Figure A-4).

No springs were identified on the property, though a shallow water table was found to be present across much of the south-central and southwestern parts of the property. The presence of the hydrophilic plants in these areas suggests that shallow groundwater conditions in this area are a common condition and not simply the product of being near the time of peak runoff.

Geologic Hazards
No mass-movement deposits, faults, or any additional geologic hazards were observed on the property during the site reconnaissance. However, two linear (northwest to southeast-trending) breaks in slope were noted on the hillslope to the northeast of the property, consistent with what was observed in the LiDAR and what is mapped as landslide scarps in Coogan and King (2016).

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 reconnaissance-level geologic hazard assessment for the Trappers Ridge Phase 8 at Wolf Creek property.

Landslides/Mass Movement/Slope Stability

The surficial geology of the property and adjacent areas have been interpreted in several ways. Sorensen and Crittenden, Jr. (1979) initially mapped the property as all Holocene-aged colluvium and slopewash, though had they showed several surficial faults cutting across this colluvium adjacent to the property. These faults were later interpreted as shallow landslide scarps (Black and Hecker, 1999), though these features (whether faults or landslide scarps) were not included in subsequent geologic mapping of the area (Coogan and King, 2001), which also mapped the units underlying the property entirely as alluvium and colluvium. Most recently, Coogan and King (2016) have reintroduced some of these features as headscarps adjacent to the property, and reinterpreted the approximately western half of the property as landslide deposits. Additionally, these surficial deposits are believed to be underlain by the Norwood Tuff, a geologic unit known to be landslide-prone (Ashland, 2010).

However, the aerial imagery evaluation and site reconnaissance did not identify landslide deposits on the property, though two possible landslide scarps were observed on the slope to the northeast of the property consistent with the Coogan and King (2016) geologic map. Also, the steepest slopes on the property are found to be greater than 5:1 (horizontal:vertical), which do not warrant site-specific slope stability analyses. Given this information, the risk associated with landslide/mass movement and slope stability hazards on the property is considered to be low to moderate.

Rockfall

No bedrock is exposed upslope of the property, and it is approximately 270 feet to the northeast of the northeastern property margin before there is a significant increase in slope with sizable boulders exposed at the surface. As such, the rockfall hazard associated with the property is considered to be low.

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 6.15 miles to the west 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.

Liquefaction

Given the generally very coarse and likely relatively thin 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, both shallow groundwater and granular soils are likely to be present on the property; therefore, 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, was not performed for this project and is not a part of our scope of work.

Debris-Flows and Flooding Hazards

Young alluvial fan deposits (Qafy) have been mapped approximately 0.1 mile north of the property by Coogan and King (2016) in association with the Heinz Canyon drainage. However, no part of the property is within this alluvial fan deposit, the Heinz Canyon drainage at its closest is approximately 415 feet to the west of the property, and the property is not located on the Heinz Canyon floodplain. Given this situation, the debris-flow hazard associated with the property is considered to be low.

The ephemeral stream drainages found on the property are generally small (generally 2 to 5 feet wide by 1 to 3 feet deep), though water was flowing within the main ephemeral drainage that forms the southern border of the property at the time of the site reconnaissance. Most of the property is located at an elevation at least 5 feet above the bank of the main ephemeral drainage, such that only the southernmost proposed lots are potentially capable of being adversely impacted by a cloudburst flooding event. Given this data, the flooding hazard for the property is considered to be low for all but the southernmost proposed lots adjacent to the main ephemeral stream drainage. This is consistent with the FEMA flood maps that covers the area (FEMA, 2015a and 2015b). The flooding hazard for the southernmost lots is considered low to moderate, though this could be reduced to low by way of appropriate grading and the installation of land-drains.

Shallow Groundwater

Groundwater was encountered in only one (the southernmost) of the five tests geotechnical test pits excavated on the property, located at approximately 8 feet below ground level (EarthTec, 2016). These test pits were excavated in late January and early February, and the groundwater level observed in the test pit is likely to be at or near seasonal lows. With the site reconnaissance occurring in mid-May near the expected peak runoff and seasonal high for groundwater, shallow groundwater was noted to be prevalent on the property. Extensive shallow groundwater was observed via the presence of abundant hydrophilic plants in the southern part of the property in areas of gentle topography and near the multiple ephemeral stream drainages and gullies found in the area, though no springs were observed.

Given the existing data, it is expected that groundwater levels will fluctuate both seasonally and annually in the southern part of the property between approximately 8 feet below the existing ground surface and ground level. As such, the risk associated with shallow groundwater hazards near the southern margin of the property is considered high, moderate for the eastern one-third of the property (between two ephemeral drainages), and low for the rest of the property, However, shallow groundwater issues can be easily mitigated through appropriate grading measures and/or the avoidance of the construction of residences with basements, or through the use of land-drains.

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, though this study only covered a portion of the property. 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.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the data collected and reviewed as part of this assessment, IGES makes the following reconnaissance-level conclusions regarding the geological hazards present at the Trappers Ridge Phase 8 at Wolf Creek project area:

- **From a reconnaissance-level perspective, the Trappers Ridge Phase 8 at Wolf Creek project area does not appear to have major geological hazards that would adversely affect significant portions of the development as currently proposed. As such, no subsurface geologic hazards investigative methods are considered to be necessary for the property preceding development.**

- 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.

- Shallow groundwater is considered to be a high hazard for those lots that are adjacent to the main ephemeral stream drainage that flows along the southern border of the property, moderate for the eastern one-third of the property, and low for the remainder of the property.

- Rockfall, surface-fault-rupture, and debris-flow hazards are considered to be low for the property.

- Landslide hazards are considered to be low to moderate for the property. Though no landslide deposits were observed on the property during the site reconnaissance, possible landslide scarps present upslope to the northeast of the property may indicate the possibility of material moving downslope and adversely impacting the Trappers Ridge Phase 8 property at a later date.

- Published literature and the site-specific geotechnical report (EarthTec, 2016) indicate that the liquefaction potential for the site is expected to be low. However, due to the likely presence of granular soils and shallow groundwater and the unknown character of the soils underlying those examined in the geotechnical report, the potential for liquefaction occurring at the site cannot be ruled out.

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

- The prevalence of shallow groundwater across the property makes necessary mitigation practices to adequately address this potential hazard. Appropriate grading measures in low-lying areas susceptible to near-surface groundwater conditions is recommended, as is the construction of the proposed residences without basements.

- 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.

- Though no landslide features were observed on the property, the alluvial and colluvial deposits present on the property are likely underlain by the Norwood Tuff, which is a known landslide-producing unit. Additionally, features interpreted as landslide scarps have been noted on nearby properties and are present on the barren hillslope upslope to the northeast of the property. Therefore, it is recommended that an IGES engineering geologist observe the lot foundation excavations to confirm the absence of landslide evidence on the property. It is also recommended that landslide and slope stability analyses be conducted on the barren hillslope to the northeast of the property preceding any development on the hillslope to identify the risk that development on the hillslope would have on the Trappers Ridge Phase 8 development.

LIMITATIONS

The conclusions and recommendations presented in this report are based on limited geologic literature review and site reconnaissance, and our understanding of the proposed construction. It should be noted that these conclusions are based solely upon the geological hazards investigated for this report, and do not pertain to other potential geologic hazards that may be present on the property. Additional geologic hazards 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 site-specific excavations across the property. 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.

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

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

Attachments:
References
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

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U.S. Geological Survey, 2014, Topographic Map of the Huntsville Quadrangle, Huntsville, Utah: Scale 1:24,000.

U.S. Geological Survey and Utah Geological Survey, 2006, Quaternary fault and fold database for the United States, accessed 5-16-16, from USGS website: http://earthquakes.usgs.gov/regional/qfaults

Utah Geological Survey, 2016, Utah Geological Survey Aerial Imagery Collection https://geodata.geology.utah.gov/imagery/

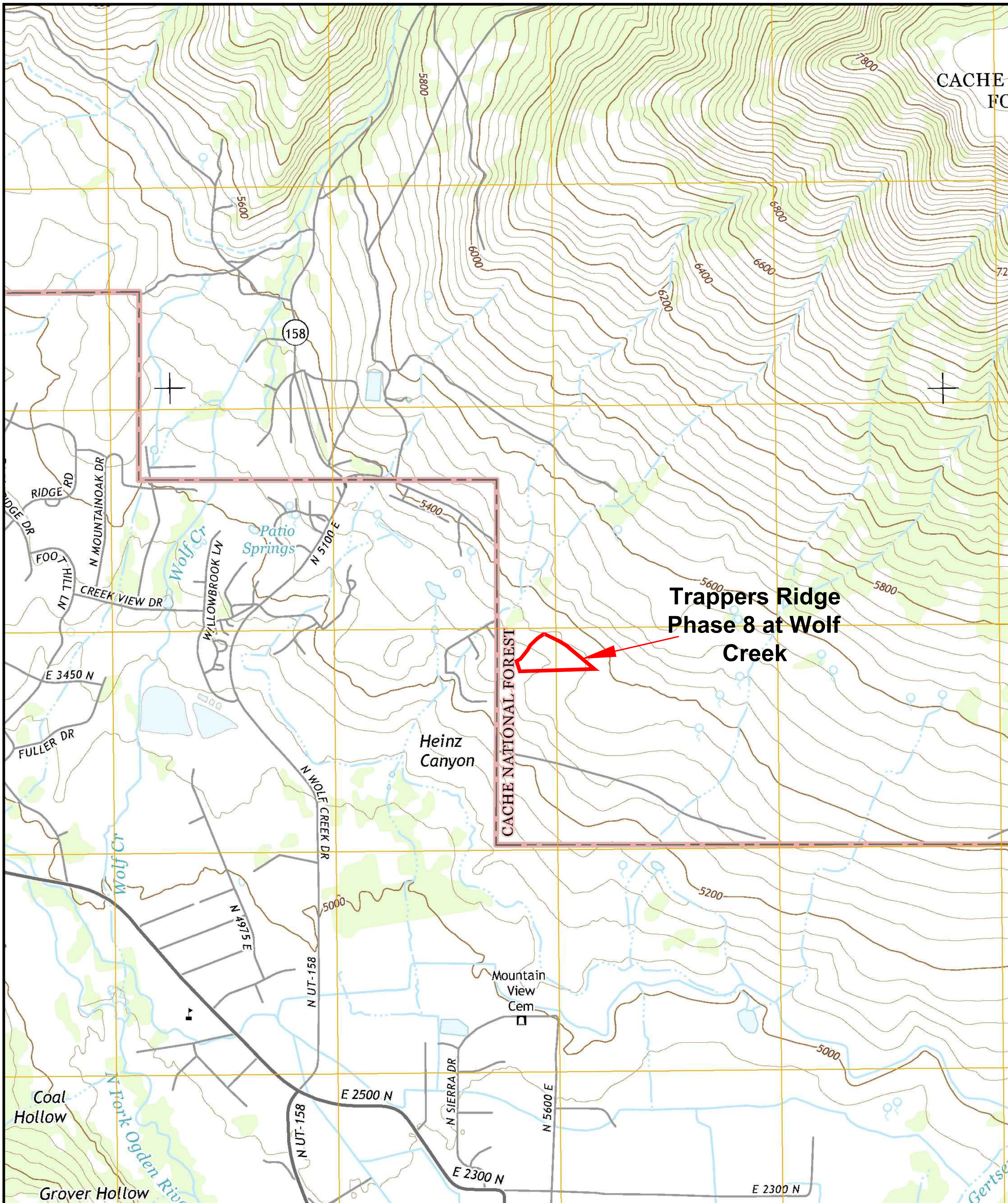
AERIAL PHOTOGRAPHS

Data Set	Date	Flight	Photographs	Scale
1947 AAJ	August 10, 1946	2B	46, 47, 48	1:20,000
1963 ELK	June 25, 1963	2	82, 169, 170	1:15,840

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

Utah Geological Survey, 2011, Utah Geological Survey 1-Meter Lidar: data downloaded from opentopography.org.

Weber County, 2015, Natural Hazards Overlay Districts, Chapter 27 of Title 104 of the Weber County Code of Ordinances, adopted on December 22, 2015.



BASE MAP:

USGS Huntsville 7.5-Minute Topographic Quadrangle Map (2014)

UTAH

QUADRANGLE LOCATION

N

0 1000 2000 3000

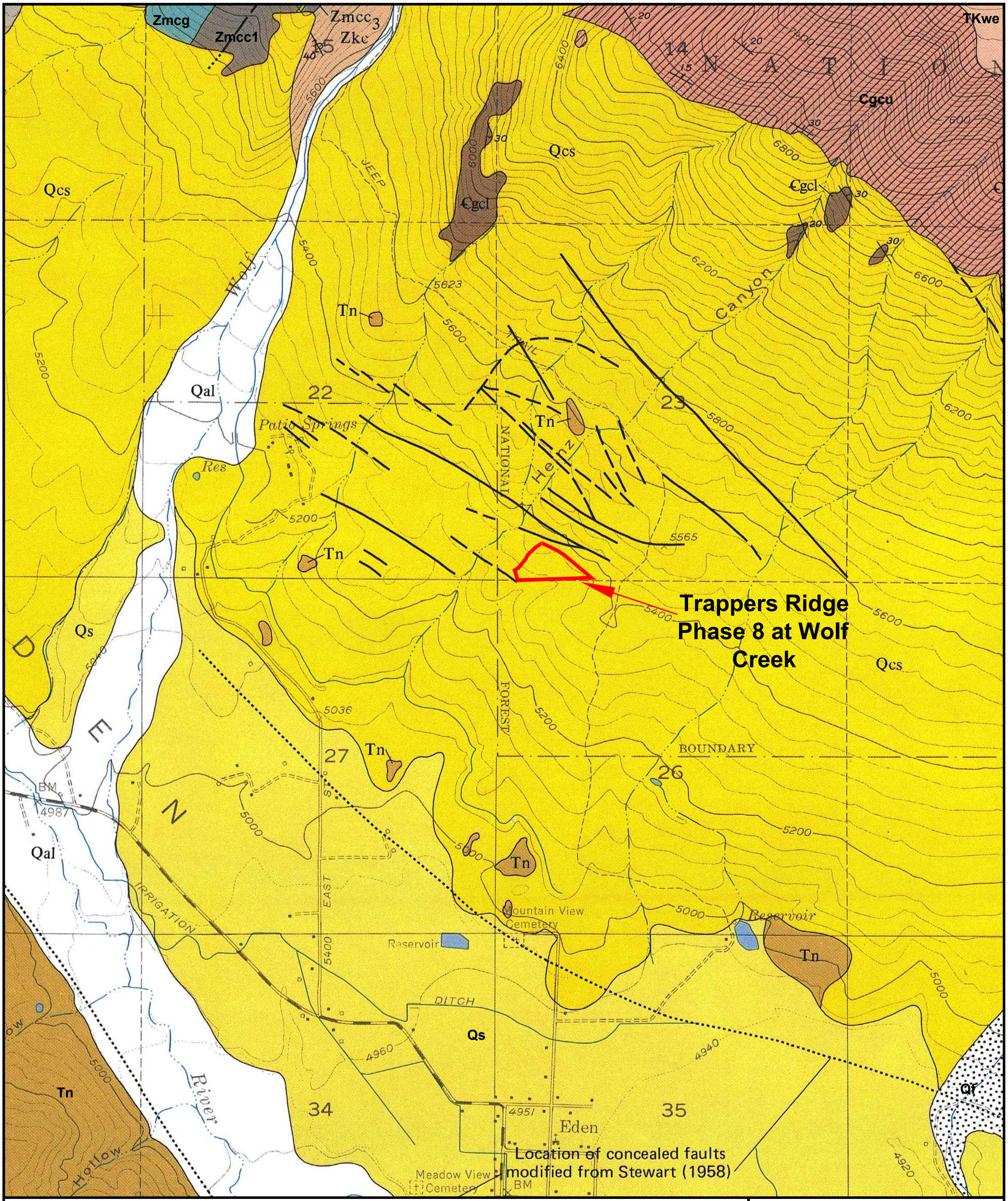
FEET

FIGURE A-1

GENERAL LOCATION MAP

TRAPPERS RIDGE AT WOLF CREEK SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 05/18/2016
PROJECT:01855-007
SCALE: 1"=2,000'
IGES



BASE MAP:

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

UTAH

QUADRANGLE LOCATION

FIGURE A-2a

REGIONAL GEOLOGY MAP 1

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASES 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 05/18/2016
PROJECT:01855–007
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

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

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

TKwe WASATCH AND EVANSTON(?) FORMATIONS, UNDIVIDED (Eocene, Paleocene, and Upper Cretaceous?) – Unconsolidated pale-reddish-brown pebble, cobble, and boulder conglomerate; forms boulder-covered slopes. Clasts are mainly Precambrian quartzite and are tan, gray, or purple; matrix is mainly poorly consolidated sand and silt; thickness 0-150 m

BRIGHAM GROUP (Crittenden and others, 1971) – Includes:

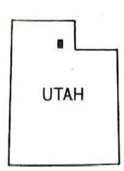
GEERTSEN CANYON QUARTZITE (Lower Cambrian) – Includes:

€gcu 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

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

TRAPPERS AT WOLF CREEK SUBDIVISION PHASE 8 GEOLOGIC HAZARDS ASSESSMENT

DATE: 05/18/2016 | SCALE: 1"=2,000' | IGES

PROJECT:01855-007

MAP LEGEND

Zmcc MAPLE CANYON FORMATION (Precambrian Z) – Includes:
Conglomerate member – Total thickness 30-150 m. Includes:

Zmcc3 Upper conglomerate – Coarse-grained, locally conglomeratic, white quartzite

Zmcc2 Argillite – Olive-drab to silvery-gray laminated argillite

Zmcc1 Lower conglomerate – White to pale-gray conglomeratic quartzite, with pebble- to cobble-size clasts of white quartz and white, gray, or pale-pink quartzite

Zmcg Green arkose member – Massively bedded pale-green arkosic sandstone, with K-feldspar content locally to 40 percent. Zone of siliceous arkosic quartzite locally present approximately 60 m below top of unit; intercalated quartzitic conglomerates locally present near base of unit; thickness 150-300 m

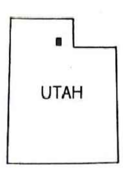
Zmca Argillite member – Olive-drab, locally gray, thin-bedded siltstone and silty argillite, with a medial zone of greenish-gray arkosic sandstone. Argillite commonly shows small-scale folding and marked schistosity. May include rocks of Precambrian Y age near base of unit; thickness 150 m

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

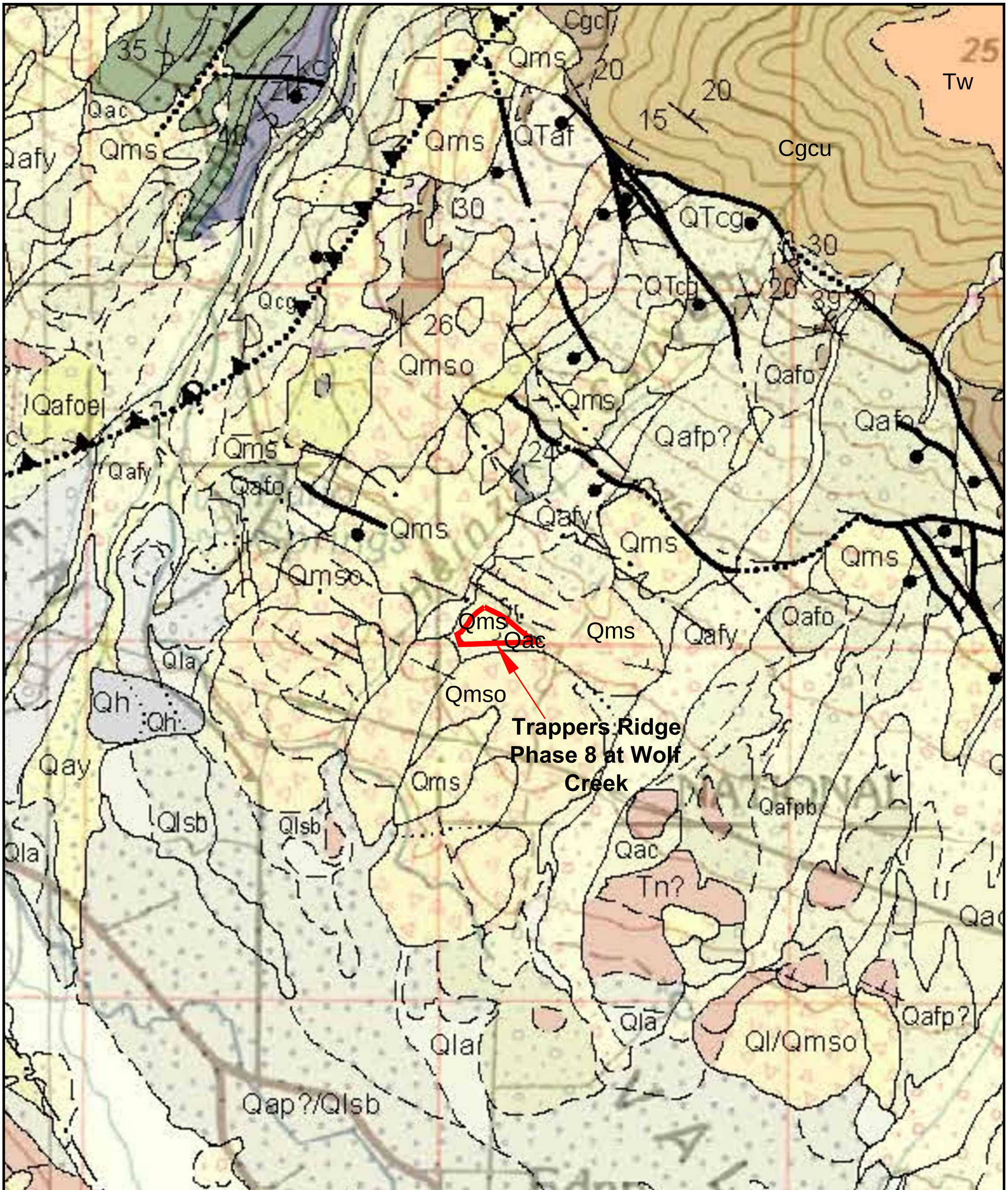
FIGURE A-2c

REGIONAL GEOLOGY MAP 1

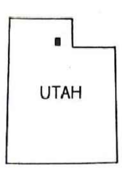
TRAPPERS AT WOLF CREEK
SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 05/18/2016 | SCALE: 1"=2,000'
PROJECT:01855-007

IGES



BASE MAP:
UGS Ogden 30' x 60' Interim Geologic Quadrangle Map (OFR-653), Coogan and King (2016)



QUADRANGLE LOCATION

N

0 1000 2000 3000
FEET

FIGURE A-3a

REGIONAL GEOLOGY MAP 2

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASES 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 06/20/2016
PROJECT: 01855-007
SCALE: 1"=2,000'
IGES

MAP LEGEND

Qaf, Qaf?

Alluvial-fan deposits, undivided (Holocene and Pleistocene) – Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and is near late Pleistocene Lake Bonneville and is geographically in the Ogden and Weber River, and lower Bear River drainages; variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads); generally less than 60 feet (18 m) thick; in subsurface, about 100 feet (30 m) thick in section 22, T. 9 N., R. 1 W. northwest of Mantua, and about 150 feet (45 m) thick beneath Qac in sections 9 and 16, T. 9 N., R. 1 W. (Utah Division of Water Rights website). Qaf with no suffix used where age uncertain or for composite fans where portions of fans with multiple ages cannot be shown separately at map scale; toes of some fans have been removed by human disturbances, so their age cannot be determined, for example in Upper Weber Canyon. Qaf queried where relative age uncertain, generally due to height not fitting into ranges in table 1 and/or typical order of surfaces contradicts height-derived age (see following paragraphs).

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes). These alluvial fans near Lake Bonneville (Qaf1, Qaf2, Qafy, Qafp, Qafpb, Qafb, Qafm, Qafo, Qafoe) are listed and described separately below. Relative ages of these fans are partly based on heights above present drainages in Morgan Valley area, in this case at drainage-eroded edge of fan. This height-based subdivision apparently works in and is applied in Ogden, Henefer, and Lost Creek Valleys and above the North, Middle and South Forks of Ogden River (see tables 1 and 2) (note revisions from Coogan and King, 2006; King and others, 2008; Coogan, 2010a-b). Despite the proximity to Lake Bonneville, alluvial fans along and near Box Elder Creek in the northwest corner of the map area (Mantua quadrangle) do not fit into table 1 and overall appear to be higher than comparable fans in Morgan Valley. Their relative ages are queried where the age is uncertain, generally due to the height not fitting into the ranges in table 1 and/or the typical order of surfaces contradicts height-derived age.

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).

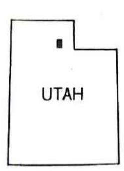
Qaf1 fans are active because they impinge on and deflect present-day drainages. Qaf2 fans appear to underlie Qaf1 fans but may be active. Qafy fans are active, impinge on present-day floodplains, divert active streams, overlie low terraces, and/or cap alluvial deposits (Qap) related to the Provo and 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.

Qafp, Qafp?, Qafb, Qafb?, Qafpb, Qafpb?

Lake Bonneville-age alluvial-fan deposits (upper Pleistocene) – Like undivided alluvial fans, but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits (see table 1); these fans are inactive, unconsolidated to weakly consolidated, and locally dissected; fans

BASE MAP:

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



QUADRANGLE LOCATION

N

0 1000 2000 3000

FEET

FIGURE A-3b

REGIONAL GEOLOGY MAP 2

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 06/20/2016
PROJECT:01855–007
SCALE: 1"=2,000'
IGES

MAP LEGEND

Mass-movement deposits

Qmdf, Qmdf?

Debris- and mud-flow deposits (Holocene and upper and middle? Pleistocene) – Very poorly sorted, clay- to boulder-sized material in unstratified deposits characterized by rubbly surface and debris-flow levees with channels, lobes, and mounding; variably vegetated; in drainages typically form mounds, an indication of more viscous Qmdf, rather than being flat like unit Qac; Qmdf queried where may not be mostly debris- and mud-flow deposits; many debris flows cannot be shown separately from alluvial fans at map scale; 0 to 40 feet (0-12 m) thick. Age(s) uncertain; deposits in drainages likely post-date the Provo shoreline of Lake Bonneville, while deposits above drainages, like north of the Right Hand Fork Peterson Creek, are likely as old as Bull Lake glaciation, but could pre-date Bull Lake glaciation and be middle Pleistocene.

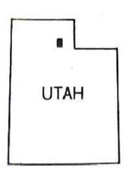
Qms, Qms?, Qmsy, Qmsy?, Qmso, Qmso?

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.

BASE MAP:

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



QUADRANGLE LOCATION

N

0 1000 2000 3000

FEET

FIGURE A-3c

REGIONAL GEOLOGY MAP 2

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 06/20/2016 | SCALE: 1"=2,000'
PROJECT:01855–007

IGES

MAP LEGEND

Mixed deposits

Qac **Alluvium and colluvium (Holocene and Pleistocene)** – Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale; typically mapped along smaller drainages that lack flat bottoms; more extensive east of Henefer where Wasatch Formation (Tw) strata easily weather to debris that "chokes" drainages; 6 to 20 feet (2-6 m) thick.

Tn, Tn? **Norwood Formation (lower Oligocene and upper Eocene)** – Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate; unaltered tuff, present in type section south of Morgan, is rare; locally colored light shades of red and green; variable calcareous cement and zeolitization; involved in numerous landslides of various sizes; estimate 2000-foot (600 m) thick in exposures on west side of Ogden Valley (based on bedding dip, outcrop width, and topography). Norwood Formation queried where poor exposures may actually be surficial deposits. For detailed Norwood Formation information see description under heading "Sub-Willard Thrust - Ogden Canyon Area" since most of this unit is in and near Morgan Valley and covers the Willard thrust, Ogden Canyon, and Durst Mountain areas.

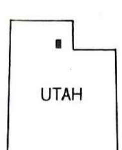
Tnf, Tnf?

Norwood and Fowkes Formation equivalent strata, undivided (Oligocene? and Eocene) – Light-colored, altered tuffaceous fine-grained rocks (claystone and mudstone) with at least local conglomerate, limestone, and sandstone as exposed in southern Cache Valley; extensive altered tuff (claystone), tuff, and tuffaceous sandstone higher in section may or may not be in these equivalent strata (see Tsl notes above); estimate 600 to 1250 feet (180-380 m) thick or may be less than 600 feet (180 m) thick adjacent to Ogden map area, since contact with underlying Wasatch Formation and overlying Salt Lake Formation uncertain; about 500 feet (150 m) exposed below angular unconformity in James Peak quadrangle east of Davenport Creek (from topography, bedding dip and contacts). When the angular unconformity between Tsl and Tnf is not visible the strata have been mapped as Salt Lake Formation over Norwood and Fowkes equivalent strata (Tsl/Tnf). Unit Tnf queried where it may be tuffaceous Salt Lake Formation (Tsl). This combined unit (Tnf) is prone to slope failures.

North of the Ogden map area, Williams (1962) showed his tuff unit (Fowkes-Norwood strata of this report) as an irregular band next to Paleozoic rocks on the west side of Cache Valley, and described these strata as 1200 feet (360 m) of earthy gray tuff (actually altered, so claystone or mudstone), with two distinctive limestone beds near the base and a minor amount of pebble conglomerate. He described the upper limestone as stromatolitic (oncolitic, see Adamson, 1955, figure 11). Smith (1997) placed these limestones in her Norwood-Fowkes strata (Tfnx), while Oaks and others (1999) placed them in their Wasatch Formation (Twx) based on oncolites that are similar to those in the Wasatch Formation to the east in the Bear River Range (Oaks and Runnells, 1992). In the Pole Creek valley, east of Cache Valley, we mapped similar oncolitic limestones as undivided Tertiary rocks (Tu, see above).

BASE MAP:

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



QUADRANGLE LOCATION

N

0 1000 2000 3000

FEET

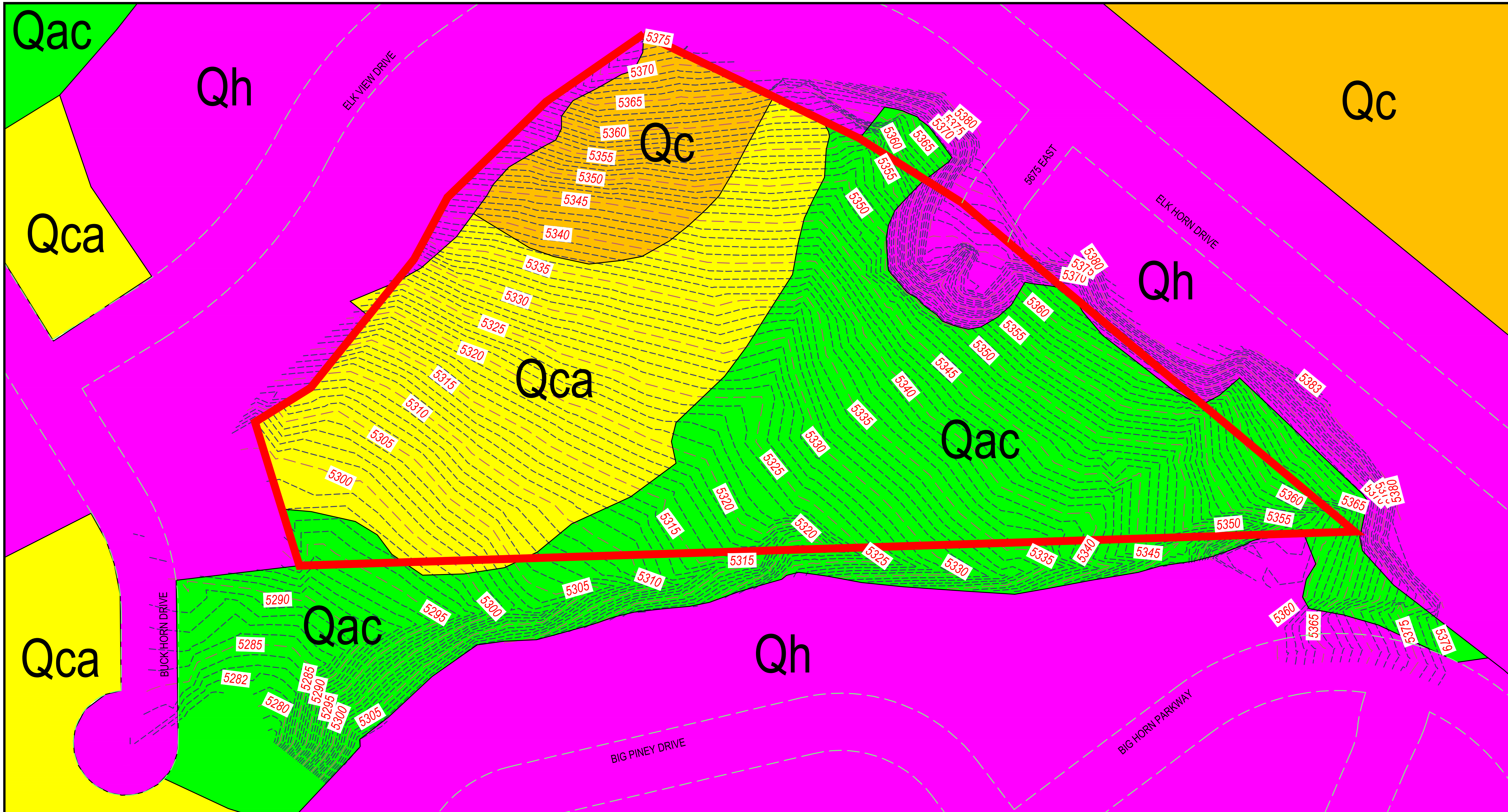
FIGURE A-3d

REGIONAL GEOLOGY MAP 2

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 06/20/2016 | SCALE: 1"=2,000'
PROJECT:01855–007

IGES



GEOLOGY LEGEND:

Qh	HUMAN DISTURBED
Qca	COLLUVIUM AND ALLUVIUM; GRADATIONAL
Qc	BOULDERY COLLUVIUM
Qac	ALLUVIUM AND COLLUVIUM

PROPERTY BOUNDARY

N

0 200
FEET

FIGURE A-4

LOCAL GEOLOGY MAP

TRAPPERS AT WOLF CREEK
SUBDIVISION PHASE 8
GEOLOGIC HAZARDS ASSESSMENT

DATE: 06/15/2016
FILE: 01855-007
SCALE: 1"=100'
IGES