REPORT

GEOLOGIC HAZARDS EVALUATION

WAJ ENTERPRISES PROPERTY

ABOUT 2050 NORTH BIG SKY DRIVE

LIBERTY, WEBER COUNTY, UTAH

Prepared for

Brandon Janis
562 South 1100 West
Farmington, UT 84025

October 4, 2018

Prepared by

Western GeoLogic, LLC
2150 South 1300 East, Suite 500
Salt Lake City, Utah 84106

Voice: 801.359.7222
Fax: 801.990.4601
Web: www.westerngeologic.com

WESTERN GEOLOGIC, LLC
2150 SOUTH 1300 EAST, SUITE 500
SALT LAKE CITY, UT 84106 USA

Phone: 801.359.7222 Fax: 801.990.4601 Email: cnelson@westerngeologic.com

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Brandon Janis
562 South 1100 West
Farmington, UT 84025

SUBJECT: Geologic Hazards Evaluation
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

Dear Mr. Janis:

This report presents the results of an engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for the WAJ Enterprises LLC Property at about 2050 North Big Sky Drive in Liberty, Utah (Figure 1 – Project Location). The Project straddles Coal Hollow in northwestern Ogden Valley about 1.03 miles southeast of Nordic Valley Ski Area, and is in the SW1/4, Section 33, Township 7 North, Range 1 East (Salt Lake Base Line and Meridian; Figure 1). The property does not have a formal address and consists of a 27.8-acre parcel identified as Weber County Assessor parcel number 22-040-0024. Elevation of the site ranges from about 5,480 feet to 5,640 feet above sea level. Based on current plans, it is our understanding that the site is proposed for development of an eight lot residential subdivision.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret surficial geologic conditions at the site to identify potential risk from geologic hazards to the Project. This investigation is intended to: (1) provide preliminary geologic information and assessment of geologic conditions at the site; (2) identify potential geologic hazards that may be present and qualitatively assess their risk to the intended site use; and (3) provide recommendations for additional site- and hazard-specific studies or mitigation measures, as may be needed based on our findings. Such recommendations could require further multi-disciplinary evaluations, and/or may need design criteria that are beyond our professional scope.

The following services were performed in accordance with the above stated purpose and scope:

- A site reconnaissance conducted by an experienced certified engineering geologist to assess the site setting and look for adverse geologic conditions;

- Review of readily-available geologic maps, reports, and air photos;

- Logging of ten test pits at the site in conjunction with a geotechnical evaluation conducted by Christensen Geotechnical (the Project geotechnical engineer);

- Preparation of three geologic cross sections based on LIDAR and subsurface data; and

- Evaluation of available data and preparation of this report, which presents the results of our study.

The engineering geology section of this report has been prepared in accordance with Bowman and Lund (2016) and current generally accepted professional engineering geologic principles and practice in Utah, and meets specifications provided in Chapter 27 of the Weber County Land Use Code within the above stated scope. We do not include discussion of radon hazard potential, as recommended in Bowman and Lund (2016), because radon gas poses an environmental health hazard and indoor levels are heavily influenced by several post-construction, non-geologic factors. The hazard from radon should be evaluated by long-term testing following construction.

HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Huntsville Quadrangle shows the site is on the northwest margin of Ogden Valley straddling Coal Hollow (Figure 1). Coal Hollow Creek flows from southwest to northeast across the central part of the Project and downslope into the valley, where it merges with the North Fork of the Ogden River. Various ephemeral drainages that feed Coal Hollow Creek are also at the property. Coal Hollow Creek was flowing at the time of our investigation, but all the ephemeral feeder drainages appeared dry. No springs are shown at the site on Figure 1, but a seasonal seep area was observed in the southwest part of the Project that drains into Coal Hollow Creek. The seep area was also dry at the time of our investigation.

The site is on the northwestern margin of Ogden Valley about 1.2 miles northwest of the north arm of Pineview Reservoir. The valley bottom to the east is dominated by unconsolidated lacustrine and alluvial basin-fill deposits, whereas slopes in the site area are mainly in weathered Tertiary-age tuffaceous bedrock and landslide colluvium from a complex series of overlapping failures since Late Pleistocene time. The Utah Division of Water Rights Well Driller Database shows three water wells in the site vicinity about 1,270 feet to the west, 2,615 feet to the northwest, and 3,290 feet to the east of the property (Figure 1). Reported depths to static groundwater for these wells is 50 feet, 132 feet, and 30 feet respectively (Figure 1). Given the above and site observations, we anticipate groundwater at the site is generally from 30 to 50 feet deep. However, test pits TP-3 and TP-8 on the edge of the seasonal seep area and in lower slopes in the north part of the site west of Coal Hollow Creek (respectively) encountered static groundwater at depths of 8.9 feet and 9.9 feet below the ground surface (bgs). These areas thus have localized shallower groundwater depths of less than 10 feet bgs. No groundwater was encountered in the remaining test pits to their explored depths. Groundwater depths may vary annually from climatic fluctuations, and also seasonally from snowmelt runoff and man-made sources such as landscape irrigation. Seasonal variations would be typical for an alpine environment. Perched conditions above less-permeable, clay-rich bedrock layers may also be present in the subsurface that could cause locally shallower groundwater levels. Groundwater flow should be generally to the northeast into Ogden Valley.

Avery (1994) indicates groundwater in Ogden Valley occurs under perched, confined, and unconfined conditions in the valley fill to depths of 750 feet or more. A well-stratified lacustrine silt layer forms a leaky confining bed in the upper part of the valley-fill aquifer. The aquifer below the confining beds is the principal aquifer, which is in primarily fluvial and alluvial-fan deposits. The principal aquifer is recharged from precipitation, seepage from surface water, and subsurface inflow from bedrock into valley fill along the valley margins (Avery, 1994). The confined aquifer is typically overlain by a shallow, unconfined aquifer recharged from surface flow and upward leakage. Groundwater flow is generally from the valley margins into the valley fill, and then toward the head of Ogden Canyon (Avery, 1994).

GEOLOGY

Surficial Geology

The site is located on the northwestern margin of Ogden Valley, a sediment-filled intermontane valley within the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986). Surficial geology of the site is mapped by Coogan and King (2016; Figure 2) as Tertiary Norwood Formation on the northwest and along on the eastern site boundary, and mainly younger landslide deposits in the area between (unit Qms). These landslide deposits likely represent a mixture of deposits from multiple failures of varying ages.

Coogan and King (2016) describe surficial geologic units in the site area on Figure 2 as follows:

> ***Qh, Qh?*** - *Human disturbances (Historical).* Mapped disturbances obscure original deposits or rocks by cover or removal; only larger disturbances that pre-date the 1984 aerial photographs used to map the Ogden 30 x 60- minute quadrangle are shown; includes engineered fill, particularly along Interstate Highways 80 and 84, the Union Pacific Railroad, and larger dams, as well as aggregate operations, gravel pits, sewage-treatment facilities, cement plant quarries and operations, brick plant and clay pit, Defense Depot Ogden (Browning U.S. Army Reserve Center), gas and oil field operations (for example drill pads) including gas plants, and low dams along several creeks, including a breached dam on Yellow Creek.
>
> ***Qay, Qa2, Qa2?, Qa3, Qa3?, Qa4, Qa4?, Qa4-5, Qa5, Qa6*** - *Alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in stream and alluvial-fan deposits that are not close to late Pleistocene Lake Bonneville and are geographically in the Huff Creek and upper Bear River drainages; variably sorted; variably consolidated; composition depends on source area; deposits lack fan shape of Qaf and are distinguished from terraces (Qat)

based on upper surface sloping toward adjacent streams from sides of drainage, or are shown where fans and terraces are too small to show separately at map scale; Qay is at to slightly above present drainages and not incised by active drainages, so is the youngest unit; generally 6 to 20 feet (2-6 m) thick.

Age-number and letter suffixes on alluvium (undivided, channel, flood plain, terrace, and fan) that is not close to late Pleistocene Lake Bonneville are relative and only apply to the local drainage, with suffix 2 being the second youngest; the relative age is queried where age uncertain, generally due to the height not fitting into the typical order of surfaces. The various numbered deposits listed, Qa2 through Qa6, are 20 to 180 feet (6-55 m) above the Bear River, Saleratus Creek, and Yellow Creek. Qa5 and Qa3? are only used in stacked units (Qa5/Tfb and Qa3?/Tfb).

Qal, Qal1, Qal2, Qal2? - *Stream alluvium and flood-plain deposits (Holocene and uppermost Pleistocene).* Sand, silt, clay, and gravel in channels, flood plains, and terraces typically less than 16 feet (5 m) above river and stream level; moderately sorted; unconsolidated; along the same drainage Qal2 is lower than Qat2 and has likely been subject to flooding, at least prior to dam building; present in broad plains along the Bear, Ogden, and Weber Rivers and larger tributaries like Deep, Cottonwood, East Canyon, Lost, and Saleratus Creeks, along Box Elder, Heiners, and Yellow Creeks, and in narrower plains of larger tributary streams; locally includes muddy, organic overbank and oxbow lake deposits; composition depends on source area, so in back valleys typically contains many quartzite cobbles recycled from the Wasatch Formation; mostly Holocene, but deposited after regression of Lake Bonneville from the late Pleistocene Provo shoreline; width in Morgan Valley is combined flood plain of Weber River and East Canyon and Deep Creeks; 6 to 20 feet (2-6 m) thick and possibly as much as 50 feet (15 m) along Weber River and thinner in the Kaysville quadrangle; greater thicknesses (>50 feet [15 m]) are reported in Morgan Valley (Utah Division of Water Rights, well drilling database), but likely include Lake Bonneville and older Pleistocene deposits.

Suffixes 1 and 2 indicate ages where they can be separated, with 1 including active channels and 2 including low terraces 10 to 20 feet (3-6 m) above the Weber and Ogden Rivers, and the South Fork Ogden River that may have been in the flood plain prior to damming of these waterways. Qal2 queried in low terraces above Bear River, Saleratus Creek, and Dry Creek where deposits may not be in the flood plain.

Qaf, Qafy, Qaf3, Qaf3?, Qaf4, Qaf4?, Qaf5 **-** *Alluvial-fan deposits (Holocene and Pleistocene).* Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and that is not close to late Pleistocene Lake Bonneville and is geographically in the Huff Creek and upper 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. 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.

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes) and relative ages only apply to the local drainage, with unit Qafy being the lowest (youngest) fans and unit 3 may or may not post-date Lake Bonneville. Relative ages of these fans are partly based on heights above present drainages at drainage-eroded edge of fan. The relative age is queried where the age is uncertain, generally due to the height not fitting into the typical order of surfaces. The various deposits listed, Qafy and Qaf3 through Qaf5, are 20 to 140 feet (6-40 m) above and west of Saleratus Creek, and also above Yellow Creek and the Bear River. Qafy fans are active, impinge on present-day floodplains, divert active streams, and overlie low terraces.

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 labeled Qafp and Qafb are related to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively, while unit Qafpb is used where fans may be related to the Provo or Bonneville shoreline (for example Qafpb is ~40 feet [12 m] above Lost Creek Valley), or where fans of different ages cannot be shown separately at map scale; Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted; generally 10 to less than 60 feet (3-18 m) thick. Lake Bonneville-age fans are queried where relative age is uncertain (see Qaf for details); fans labeled Qafpb? are above the Bonneville shoreline and might be Qafo or like Qafm; see the note under Qao about two possible ages of older alluvium (Qao, Qato, and Qafo).

Most of the Lake Bonneville-age fans in the James Peak quadrangle are far from the Bonneville shoreline and their age is inferred from their stratigraphic relationship(s) to coeval Pinedale glacial outwash (see age equality in Table 3).

The channels (Qafp/Qdlb) on the Weber River delta and Lake Bonneville fines (Qafp on Qlfb) probably record scour and fill during the rapid drawdown of the lake as it fell from the Bonneville shoreline to the Provo shoreline.

Qap, Qap?, Qab, Qab?, Qapb - *Lake Bonneville-age alluvium (upper Pleistocene).* Like undivided alluvium but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits, and unconsolidated to weakly consolidated; alluvium labeled Qap and Qab is related to Provo (and slightly lower) and Bonneville shorelines of Lake Bonneville (at ~4800 to 4840 feet [1463-1475 m] and 5180 feet [1580 m] in Morgan Valley), respectively; suffixes partly based on heights above adjacent drainages near Morgan Valley (see tables 1 and 2); Qap is typically about 15 to 40 feet (5-12 m) above present adjacent drainages, but is locally 45 feet (12 m) above; Qapb is used where more exact age cannot be determined, typically away from Lake Bonneville, or where alluvium of different ages cannot be shown separately at map scale; Qap is up to about 50 feet (15 m) thick, with Qapb and Qab, at least locally up to 40 and 90 feet (12 and 27 m) thick, respectively. Queried where classification or relative age uncertain (see Qa).

A prominent surface ("bench") is present on Qap and Qatp at about 4900 feet (1494 m) elevation and about 25 to 40 feet (8-12 m) above the Weber River in Morgan Valley and along the South Fork Ogden River.

In the Devils Slide quadrangle, the Qab that is mapped about 80 to 95 feet (24-29 m) above Round Valley and 40 to 50 feet (12-15 m) above adjacent drainages at the mouth of Geary Hollow appears unique. Based on heights above adjacent drainages, these deposits would be Qao (see table 1), but similar alluvial deposits to the east near Phil Shop Hollow have a Bonneville shoreline cut in them and are much thinner than 40 feet (12 m). The lack of a Bonneville shoreline, and small thickness and heights above drainages indicate the deposits could be a Bonneville shoreline fan-delta.

***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. Some deposits are "perched" on benches 80 feet (25 m) and more above present-day drainages like Left Fork Heiners Creek (Heiners Creek quadrangle) and Harris Canyon (Henefer quadrangle). In the Devils Slide quadrangle, some deposits are "perched" on benches about 60 to 130 feet (18-40 m) above Quarry Cottonwood Canyon indicating the alluvium is at least partly Lake Bonneville age and older (see Qab and Qao in tables 1 and 2).

***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.

Qls, Qls?, Qlsp, Qlsb, Qlsb? - *Lake Bonneville sand (upper Pleistocene).* Mostly sand with some silt and gravel deposited nearshore below and near the Provo shoreline (Qlsp) and between the Provo and Bonneville shorelines (Qlsb); Qls mapped downslope from slope break below Provo shoreline beach deposits where thin Lake Bonneville regressional sand may overlie transgressional sand; grades downslope into unit Qlf with decreasing sand content and laterally with more gravel into units Qdlp, Qdlb, and upslope with more gravel into unit Qlgb; Qls and Qlsb queried where grain size or unit identification uncertain; may be as much as 75 feet (25 m) thick, and thickest near Ogden; typically less than 20 feet (6 m) thick in Morgan Valley; may include small deltas and deltas that lack typical delta shape.

Qadb, Qadb? - *Transgressive and Bonneville-shoreline alluvial and deltaic deposits (upper Pleistocene).* Cobbly gravel, sand, silt, and clay deposited above (subaerial) and in Lake Bonneville (subaqueous); typically mapped where shorelines are obscure, so that line cannot be drawn between alluvial fan and delta; include rounded to subangular clasts in a matrix of sand and silt with interbeds of sand and silt; mapped above the Provo shoreline and deposited as lake transgressed to and was at the Bonneville shoreline; typically better sorted delta and lake deposits over poorly sorted alluvial-fan deposits; Qadb prominent along Deep Creek (Morgan quadrangle) and Strawberry Creek (Snow Basin quadrangle); 0 to at least 40 feet (0-12+ m) thick.

Note that the Bonneville-shoreline fan-delta unit (Qadb), at 80 to 100 feet (24-30 m) above present drainages, is typically higher than the related alluvial units (Qab, Qafb) (see table 1). A fan-delta is built when an alluvial fan enters a lake or ocean, and includes both the fan and the delta.

Qla, Qla? - *Lake Bonneville lacustrine deposits and post- and pre-Lake Bonneville alluvial deposits, undivided (Holocene and upper? Pleistocene).* Mostly poorly sorted and poorly bedded sand, silt, and clay, with some gravel; mapped where Lake Bonneville deposits are reworked by later stream action or covered by thin stream and fan deposits, and where lake deposits are thin and overlie older alluvial deposits; unit queried where may be dominantly alluvium; deposits typically eroded from shallow Norwood Formation; mostly mapped near Bonneville shoreline; also mapped in Peterson quadrangle along upper Deep Creek above Bonneville shoreline where lake deposits seem to indicate landslide dam of creek; thickness uncertain.

Qafo, Qafo? - *Older alluvial-fan deposits (mostly upper Pleistocene).* Incised and at least locally dissected fans of mostly sand, silt, and gravel that is poorly bedded and poorly sorted; includes debris flows, particularly in drainages and at drainage mouths (fan heads);

older fans are typically above the Bonneville shoreline, with an eroded bench at the shoreline; upstream and above the Bonneville shoreline, unit Qafo is topographically higher than fans graded to the Bonneville shoreline (Qafb), and is typically dissected; generally less than 60 feet (18 m) thick. In Mantua Valley, exposed thickness up to about 100 feet (30 m), but water wells (sections 26 and 27, T. 9 N., R. 1 W.) were still in gravelly to bouldery valley fill at depths of 505 and 467 feet (154 and 142 m), respectively, and red coloration that may indicate Wasatch Formation bedrock was not noted (see Bjorklund and McGreevy, 1973, p. 16).

Qafo queried where relative age is uncertain (see Qaf for details), for example in Mantua quadrangle where it is as high as Qafoe in Morgan Valley (see table 1). Qafo queried in East Canyon graben because the deposits are not dissected and some deposits mantle Qafoe (see also unit Qafm above), resulting in a reversal of relative height and only local incision. These irregular deposits are likely the result of salt movement in the East Canyon graben. Our Qafo is roughly shown to south by Bryant (1990) as Qgp (pediment gravel); farther south he showed Qoa (dissected alluvium) adjacent to the East Canyon fault, which may be the QTaf or Qafoe we mapped.

Amino-acid age estimates presented in Sullivan and Nelson (1992) imply Qafo north of Morgan considerably predates Lake Bonneville and is middle Pleistocene in age (>400 ka). However, the Bonneville shoreline is obscure on this fan, and soil-carbonate age estimates (>70-100 ka) and other amino-acid age estimates (~98-155 ka) in Sullivan and others (1988) imply these older fans are related to Bull Lake glaciation (95,000 to 130,000 years old; see Chadwick and others, 1997; Phillips and others, 1997). As noted under Qao, Qafo deposits may contain two ages (levels) of alluvial surfaces that are not easily recognized in Morgan Valley but are recognized upstream in the Henefer and Lost Creek Valleys (Devils Slide quadrangle) and along the North and South Forks of Ogden River.

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.

Zmcg, Zmcg? *- Maple Canyon Formation, Lower (green arkose) member (Neoproterozoic).* Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses up to 200 feet (60 m) thick; weathers darker gray to brown to greenish-gray and greenish-brown; 500 to 1000 feet (150-305 m) thick and lower thickness would eliminate the need for faulting in southwest part of Huntsville quadrangle. This unit is prone to slope failures.

Zpu, Zpu? *- Formation of Perry Canyon, Upper member (Neoproterozoic).* Olive drab to gray, thin-bedded slate to argillite to phyllite to micaceous meta-siltstone to meta-graywacke to meta-sandstone in variable proportions such that unit looks like both the "greywacke-sandstone" and "mudstone" members of previous workers; unit identification based on underlying diamictite in Mantua quadrangle; rare meta-gritstone and meta-diamictite (actually conglomerate?); locally schistose; meta-sandstone contains poorly sorted lithic, quartz, and feldspar grains in silty to micaceous matrix; meta-sandstone is quartzose in outcrops on west margin of Mantua quadrangle (Crittenden and Sorensen, 1985a) and medial zone of sandstone is feldspathic east of Ogden Valley, where mapped and described as argillite member of Maple Canyon Formation by Crittenden (1972) and Sorensen and Crittenden (1979); thickness uncertain, but appears to be about 600 feet (180 m) thick on west flank of Grizzly Peak in the Mantua quadrangle and about 1000 feet (300 m) thick between Ogden Canyon and North Ogden divide. In Ogden Valley typically non-resistant and tan weathering such that gray to green to dark-gray fresh color is seldom seen except in cut slopes and excavations. This unit is prone to slope failures.

Citations, tables, and figures above are not provided herein, but are in Coogan and King (2016).

Seismotectonic Setting

The property is located at the northwestern margin of Ogden Valley, a roughly 40-square mile back valley described by Gilbert (1928) as a structural trough similar to Cache and Morgan Valleys to the north and south, respectively. The back valleys of the northern Wasatch Range are in a transition zone between the Basin and Range and Middle Rocky Mountains provinces (Stokes, 1977, 1986). The Basin and Range is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is the prominent, west-facing escarpment along the Wasatch fault zone at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989). The back valleys are morphologically similar to valleys in the Basin and Range, but exhibit less structural relief (Sullivan and others 1988).

Ogden Valley occupies a structural trough created by up to 2,000 feet of vertical displacement on normal faults bounding the east and west sides of the valley. The Ogden Valley southwestern margin fault and North Fork fault (Black and others, 2003) are shown on Figure 2 trending northwestward along the western site boundary and about 3,700 feet to the northeast, respectively. The most recent movement on these faults is pre-Holocene (Sullivan and others, 1986). The faults are concealed where mantled by late Pleistocene and Holocene surficial deposits (Figure 2, dashed and dotted bold lines). Norwood Formation mapped in the site area (Figure 2, unit Tn) likely represents an in-place faulted block preserved between the faults (Jon King, Utah Geological Survey, verbal communication, February 2016).

The site is also situated near the central portion of the Intermountain Seismic Belt (ISB). The ISB is a north-south-trending zone of historical seismicity along the eastern margin of the Basin and Range province which extends for approximately 900 miles from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850, with the largest of these events the M_S 7.5 1959 Hebgen Lake, Montana earthquake. However, none of these events have occurred along the Wasatch fault zone or other known late Quaternary faults in the region (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events to the site was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake and south of the town of Snowville.

Lake Bonneville History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin consists of several topographically closed basins created by regional extension in the Basin and Range (Gwynn, 1980; Miller, 1990), and has been an area of internal drainage for much of the past 15 million years. Lake Bonneville consisted of numerous topographically closed basins, including the Salt Lake and Cache Valleys (Oviatt and others, 1992). Portions of Ogden Valley were inundated by Lake Bonneville at its highstand, and sediments from Lake Bonneville are mapped at lower elevations (below about 5,200 feet) in Ogden Valley.

Timing of events related to the transgression and regression of Lake Bonneville is indicated by calendar age estimates of significant radiocarbon dates in the Bonneville Basin (Oviatt, 2015). Approximately 30,000 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach, around 18,000 years ago. During the transgression and highstand, major drainages that emanate from within the Wasatch Range (such as the Weber River) formed large deltaic complexes in the lake at their canyon mouths. Headward erosion of the Snake River-Bonneville basin drainage divide then caused a catastrophic incision of the threshold and the lake level lowered by roughly 360 feet in fewer than two months (Jarrett and Malde, 1987; O'Conner, 1993). The Project is above the highest Bonneville shoreline, which is mapped on Figure 2 (blue line and B) about 4,500 feet to the north.

Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline between about 16,500 and 15,000 years ago. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Drainages that fed Lake Bonneville began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression around 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

SITE CHARACTERIZATION

Air Photo Observations

Black and white aerial photography from 1997, one-meter bare earth DEM LIDAR from 2011, and color high-resolution orthophotography from 2012 available from the Utah AGRC (Figures 3A-C) were reviewed to obtain information about the geomorphology of the Project area. The property is at the northwestern margin of Ogden Valley and straddles Coal Hollow on slopes overlooking the valley to the northeast. Coal Hollow Creek flows to the northeast across the middle of the Project and two ephemeral feeder drainages flow across the northwestern and eastern parts of the site into the creek. A seasonal seep area is also in the southwest part of the Project that drains into Coal Hollow Creek (Figures 3A-C). We note the seasonal seep area was heavily vegetated in 1997 (Figure 3A), but the tree cover had been cleared by 2012 (Figure 3C) for some unknown purpose. The northwest corner of the site is on a terrace underlain by Norwood Formation bedrock, which also forms the north-trending ridge along the eastern site boundary (Figures 3A-C). The western ephemeral drainage flows downslope and along the base of the terrace on the northwest, whereas the eastern drainage follows the western base of the ridge on the east. Slopes at the site range between about 3:1 (horizontal:vertical) and 12:1 in steepness; steepest areas are generally in the slopes bordering the terrace and those along the south property boundary.

The remainder of the Project between the bedrock areas on the northwest and east appears situated on various knobs of Norwood Formation bedrock surrounded by relatively gently sloping meadow areas. The bedrock knobs are inferred by Coogan and King (2016) to be rafted landslide blocks, although the source area for such a large slide is no longer evident. However, we note that the bedrock knobs along the southwestern site boundary also correspond to the trace of the Ogden Valley southwestern margin fault (Figure 2). Norwood Formation is similarly found in the area on the upthrown (southwest) side of this fault and as remnant knobs on the downthrown (northeast) side. Except for an arcuate-shaped scarp in the southeast part of the site that appears to be from a landslide that failed into one of the meadows, no evidence of recent or ongoing landsliding or other geologic hazards was observed on the photos.

Empirical Observations

On September 18-20, 2018, Mr. Bill D. Black of Western GeoLogic conducted a reconnaissance of the property in conjunction with subsurface exploration discussed below. Weather at the time of the site reconnaissance was clear to partly cloudy with temperatures in the 70's (°F). Native vegetation at the site consists mainly of mature pine trees, scrub oak, grasses, broadleaf weeds, and thistles. Coal Hollow Creek flows northeastward across the central part of the Project, and two ephemeral drainages that flow into the creek were observed near the eastern site margin and at the base of the slope bordering the terrace on the northwest. Coal Hollow was flowing at the time of our investigation, but the ephemeral drainages appeared dry. A large seep area was also observed in the southwest part of the site that was dry at the time of our reconnaissance.

As indicated in the Air Photo Observations Section above, the site straddles a series of heavily vegetated, remnant bedrock knobs surrounded by low-lying meadow areas where alluvial and colluvial deposits eroded from these knobs and upslope areas have accumulated since

Pleistocene time. The knobs are mantled by boulders and cobbles suggestive of tuffaceous conglomerate facies within the Norwood Formation. No evidence of recent or ongoing slope instability or other geologic hazards was observed or noted during the reconnaissance. Several piezometers and percolation test pits were observed at the site that suggest a prior geotechnical investigation was conducted at some point in the past, although no prior reports were reported in Weber County files or found.

Subsurface Investigation
Ten walk-in test pits were excavated at the property on September 18-20, 2018 to evaluate subsurface conditions. The test pit locations are shown on Figure 3C. Figures 4A-J are logs of the test pits at a scale of 1-inch equals five feet (1:60). Test pit locations were measured using a hand-held GPS unit and by trend and distance methods from known points. The test pits were logged following methodology in McAlpin (1996), and digitally photographed to document the exposures. The photos are not provided herein, but are available on request.

Test pits TP-1 and TP-9 (Figure 3C) in the terrace underlying the northwest part of the site both exposed tuffaceous conglomerate bedrock of the Tertiary Norwood Formation with bedding strike and dips of 345° N 12° NE and 355° N 12° NE, respectively (Figures 4A and 4I). Test pits TP-2, TP-3, TP-4, TP-6, TP-7, and TP-10 (Figure 3C) in the bedrock knobs exposed similar tuffaceous conglomerate bedrock, but with a thin veneer of slope colluvium at the surface. Bedding strike and dip measurements in these test pits were 290° N 15° NE, 322° N 19° NE, 306° N 18° NE, 320° N 12° NE, 322° N 20° NE, and 313° N 16° NE, respectively (Figures 3B-D, 3F, 3G, and 3J). Test pit TP-5 exposed a sequence of backtilted tuffaceous conglomerate bedrock from landslide deformation, although a B-horizon vertisol was observed forming at the surface that suggested the deposit is likely of late Pleistocene age. Test pit TP-8 in the north part of the site west of Coal Hollow Creek exposed mixed alluvium and colluvium with discontinuous gravel channels. Groundwater was observed in test pits TP-3 (near the seep area) and TP-8 (near Coal Hollow Creek) at static depths of 8.9 and 9.9 feet bgs, but was not observed in the remaining test pits.

Geology and Cross Sections
Average bedding strike and dip from bedrock exposures in test pits TP-1 to 4, TP-5 to 7, and TP-9 and 10 is 322° N 16° NE, which appears similar to nearby strike and dip measurements on Figure 2. Given this, we infer the bedrock knobs at the Project are intact remnants of Norwood Formation rather than rafted blocks, and the meadows are surrounding low-lying erosional areas where a mixture of alluvial and colluvial sediments eroded from the knobs and upslope areas has accumulated since Pleistocene time. Figure 3C shows the surficial geology of the Project based on our air photo, empirical, and subsurface observations above. One area of landsliding is mapped in the southeastern part of the Project, though most of the Project is underlain by either mixed alluvial and colluvial deposits or undeformed Tertiary Norwood Formation bedrock with a thin veneer of slope colluvium. Figures 5A-C shows three geologic cross sections across the site (A-A', B-B', and C-C') at a scale of 1-inch equals 30 feet (Figure 5A) or 1-inch equals 60 feet (Figures 5B-C) with no vertical exaggeration. Units and contacts are based on subsurface data from the test pits (Figures 4A-J) and inferred the site-specific surficial geologic mapping (Figure 3C). Topographic profiles are based on 2011 LIDAR data.

GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the site for development. Table 1 below shows a summary of the geologic hazards reviewed at the site, as well as a relative (qualitative) assessment of risk to the Project for each hazard. A "high" hazard rating (H) indicates a hazard is present at the site (whether currently or in the geologic past) that is likely to pose significant risk and/or may require further study or mitigation techniques. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk. Moderate-risk hazards may also require further studies or mitigation. A "low" hazard rating (L) indicates the hazard is not present, poses little or no risk, and/or is not likely to significantly impact the Project. Low-risk hazards typically require no additional studies or mitigation. We note that these hazard ratings represent a conservative assessment for the entire site and risk may vary in some areas. Careful selection of development areas can minimize risk by avoiding known hazard areas.

Table 1. *Geologic hazards summary.*

Hazard	H	M	L
Earthquake Ground Shaking	X		
Surface Fault Rupture			X
Liquefaction and Lateral-spread Ground Failure			X
Tectonic Deformation			X
Seismic Seiche and Storm Surge			X
Stream Flooding		X	
Shallow Groundwater		X	
Landslides and Slope Failures	X		
Debris Flows and Floods			X
Rock Fall			X
Problem Soil		X	

Earthquake Ground Shaking

Ground shaking refers to the ground surface acceleration caused by seismic waves generated during an earthquake. Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60 mile radius of the project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. Mapped active faults within this distance include the East and West Cache fault zones; the Brigham City, Weber, Salt Lake, and Provo segments of the Wasatch fault zone; the East Great Salt Lake fault zone; the Morgan fault; the West Valley fault zone; the Oquirrh fault zone; and the Bear River fault zone (Black and others, 2003).

The extent of property damage and loss of life due to ground shaking depends on factors such as: (1) proximity of the earthquake and strength of seismic waves at the surface (horizontal motions are the most damaging); (2) amplitude, duration, and frequency of ground motions; (3) nature of foundation materials; and (4) building design (Costa and Baker, 1981). Based on 2015 IBC provisions, a site class of D (stiff soil), and a risk category of I-III, USGS calculated uniform-hazard and deterministic ground motion values with a 2% chance of exceedance in 50 years are as follows:

Table 2. *Seismic hazards summary.*
(Site Location: 41.29562º N, -111.84197º W)

S_S	*0.960 g*
S_1	*0.330 g*
S_{MS} (F_a x S_S)	*1.072 g*
S_{M1} (F_v x S_1)	*0.574 g*
S_{DS} (2/3 x S_{MS})	*0.714 g*
S_{D1} (2/3 x S_{M1})	*0.382 g*
Site Coefficient, F_a	*= 1.116*
Site Coefficient, F_v	*= 1.741*

Given the above information, earthquake ground shaking poses a high risk to the site. The hazard from earthquake ground shaking can be adequately mitigated by design and construction of homes in accordance with appropriate building codes. The Project geotechnical engineer, in conjunction with the builder or architect, should confirm and evaluate the seismic ground-shaking hazard and provide appropriate seismic design parameters as needed. Earthquake ground shaking is a regional hazard. All of the prospective home sites therefore have a high risk.

Surface Fault Rupture

Movement along faults at depth generates earthquakes. During earthquakes larger than Richter magnitude 6.5, ruptures along normal faults in the intermountain region generally propagate to the surface (Smith and Arabasz, 1991) as one side of the fault is uplifted and the other side down dropped. The resulting fault scarp has a near-vertical slope. The surface rupture may be expressed as a large singular rupture or several smaller ruptures in a broad zone. Ground displacement from surface fault rupture can cause significant damage or even collapse to structures located on an active fault.

The nearest active fault to the site is the Weber segment of the Wasatch fault zone about 4.3 miles to the west, and no evidence of active surface faulting is mapped or was evident at the site. Given this, the risk from surface faulting appears to be low.

Liquefaction and Lateral-spread Ground Failure

Liquefaction occurs when saturated, loose, cohesionless, soils lose their support capabilities during a seismic event because of the development of excessive pore pressure. Earthquake-induced liquefaction can present a significant risk to structures from bearing-capacity failures to structural footings and foundations, and can damage structures and roadway embankments by triggering lateral spread landslides. Earthquakes of Richter magnitude 5 are generally regarded as the lower threshold for liquefaction. Liquefaction potential at the site is a combination of expected seismic (earthquake ground shaking) accelerations, groundwater conditions, and presence of susceptible soils.

The anticipated depth to groundwater at the Project is 30 to 50 feet, although shallower groundwater (less than 10 feet deep) was encountered in test pits TP-3 and 8 that suggest conditions may vary locally. The site is also in an area of potentially strong ground shaking. The NRCS (https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx) maps two soil units at the site comprised of very cobbly loam, gravelly clay, gravelly loam, and clay loam soils formed in colluvium derived from sandstone and quartzite on mountain slopes and mountain sides. Given this, we do not anticipate any soils susceptible to liquefaction are present at the site. We therefore rate the risk from liquefaction as low.

Tectonic Deformation
Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of a normal fault. The site is not on the downthrown side of any active faults. Given this, we rate the hazard from tectonic subsidence as low. All of the home sites have a low risk from tectonic subsidence.

Seismic Seiche and Storm Surge
Earthquake-induced seiche presents a risk to structures within the wave-oscillation zone along the edges of large bodies of water, such as the Great Salt Lake. Given the elevation of the subject property and distance from any large bodies of water, the risk from seismic seiches and storm surges is rated as low. All of the prospective home sites have a low risk from seiches.

Stream Flooding
Stream flooding may be caused by direct precipitation, melting snow, or a combination of both. In much of Utah, floods are most common in April through June during spring snowmelt. High flows may be sustained from a few days to several weeks, and the potential for flooding depends on a variety of factors such as surface hydrology, site grading and drainage, and runoff.

Coal Hollow Creek crosses the central part of the Project, and two ephemeral (seasonal) drainages that flow into the creek area are to the west and east on Figures 3A-C. Given this, we rate the risk from stream flooding as moderate. Site hydrology and drainage should therefore be addressed in the civil engineering design for the development, in accordance with all applicable local government development guidelines.

Shallow Groundwater
Groundwater at the site is likely between 30 to 50 feet deep, although test pits data indicate shallower levels are present in the seasonal seep area and along Coal Hollow Creek. Conditions may also fluctuate seasonally, and perched groundwater could be found in some areas over less-permeable layers. Given the above, we rate the risk from shallow groundwater as moderate. The potential for shallow groundwater should be assessed in a geotechnical engineering evaluation for the Project, with recommendations provided as needed regarding subsurface drainage. However, we do not anticipate shallow groundwater will pose a significant development constraint.

Landslides and Slope Failures
Slope stability hazards such as landslides, slumps, and other mass movements can develop along moderate to steep slopes where a slope has been disturbed, the head of a slope loaded, or where increased groundwater pore pressures result in driving forces within the slope exceeding restraining forces. Slopes exhibiting prior failures, and also deposits from large landslides, are particularly vulnerable to instability and reactivation.

Tertiary Norwood Formation bedrock, which is a known landslide-prone unit, is mapped in the terrace underlying the northwest part of the Project and the ridge bordering the eastern site boundary. The area between the terrace and ridge consists of several remnant Norwood Formation bedrock knobs that appear to be intact based on our subsurface data and are surrounded by gently sloping meadow areas where mixed alluvial and colluvial sediments have accumulated from local and upslope erosional processes. One landslide is in the southeast part of the Project that was confirmed by test pit TP-5, although no other evidence of landsliding or recent or ongoing slope instability was observed at the site on air photos or during our reconnaissance.

The Project is in an area underlain by landslide-prone bedrock surrounded by areas of mixed alluvial and colluvial deposition. Although the bedrock underlying the site appears to be mostly intact and undeformed, slopes bordering the terrace on the northwest and along the southern site boundary are steep and one Pleistocene-age landslide was found in these slopes in the southeast part of the site. Given the above, we conservatively rate the risk from landslides as high. We recommend that stability of slopes at the site be evaluated by the Project geotechnical engineer based on site-specific data and data provided in this report. Recommendations should be provided to reduce the landslide hazard risk if factors of safety are determined to be unsuitable. Water, steep man-made cuts, and non-engineered fill materials are often major contributors to slope instability. Care should therefore also be taken to maintain proper site drainage, that site grading does not destabilize slopes at the site without prior geotechnical analysis and grading plans, and that water from sources such as landscape irrigation is minimized in and adjacent to potentially unstable slope areas.

Debris Flows
Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front. Debris flows have historically significant damage in the Wasatch Front area. The site is not in any mapped alluvial-fan deposits, and no evidence of debris-flow channels, levees, or other debris-flow features was observed. Based on the above, we rate the hazard from debris flows at the site as low. All of the prospective home sites would appear to have a low risk.

Rock Fall
No bedrock outcrops were observed at the site or in higher adjacent slopes that could present a source area for rock fall clasts. Based on the above, we rate the hazard from rock falls as low. All of the prospective home sites would appear to have a low risk.

Swelling and Collapsible Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given observed subsurface conditions, clay-rich layers are present in the subsurface in some areas that may be susceptible to a low degree of swelling. We therefore rate the hazard from problem soils as moderate. The Project geotechnical engineering evaluation should address soil conditions and provide specific recommendations for site grading, subgrade preparation, and footing and foundation design.

CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking and landslides are identified as geologic hazards posing a high relative risk to the Project. Stream flooding, shallow groundwater, and problem soils also pose a moderate risk. The following recommendations are provided to reduce risk from these hazards and for proper site development:

- ***Seismic Design –*** All habitable structures developed at the property should be constructed to current seismic hazards to reduce the risk of damage, injury, or loss of life from earthquake ground shaking.

- ***Site Grading and Drainage –*** No unplanned cuts should be made in the slopes at the site without prior geotechnical analyses, and proper site drainage should be maintained.

- ***Excavation Backfill Considerations –*** The test pits may be in areas where a structure could subsequently be placed. However, backfill may not have been replaced the excavations in compacted layers. The fill could settle with time and upon saturation. Should structures be located in an excavated area, no footings or structure should be founded over the excavation unless the backfill has been removed and replaced with structural fill, if the fill is to support a structure.

- ***Geotechnical Evaluation –*** A design-level geotechnical engineering study should be conducted prior to construction to: (1) address soil conditions at the site for use in foundation design, site grading, and drainage; (2) evaluate and provide recommendations regarding shallow groundwater and subsurface drainage; and (3) evaluate stability of slopes at the site, including providing recommendations for reducing the risk of landsliding if the factors of safety are deemed unsuitable. The evaluation should be based on geologic characterizations in this report and site-specific geotechnical data, and provide recommendations for reducing the risk of landsliding if the factors of safety are deemed unsuitable. The stability evaluation should account for perched groundwater, seasonal fluctuations, and water from sources such as landscape irrigation and septic systems. We further recommend that no homes or septic systems be located within 30 feet of the landslide area mapped on Figure 3C without additional subsurface exploration to characterize the lateral extent and thickness of the deposit.

- ***Stream Flooding* –** The civil engineering design for the development should address site hydrology and drainage in accordance with all applicable Weber County development guidelines.

- ***Report Availability* –** This report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. The report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of Western Geologic and should not be copied, used, or modified without express permission of the authors.

LIMITATIONS

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western GeoLogic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western GeoLogic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

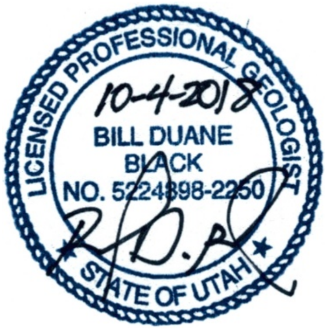
The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western GeoLogic.

In expressing the opinions stated in this report, Western GeoLogic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western GeoLogic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

It has been a pleasure working with you on this project. Should you have any questions, please call.

Sincerely,
Western GeoLogic, LLC



Bill. D. Black, P.G.
Senior Engineering Geologist

Reviewed by:

Craig V. Nelson, P.G.
Principal Engineering Geologist

ATTACHMENTS

Figure 1. Location Map (8.5”x 11”)
Figure 2. Geologic Map (8.5”x 11”)
Figure 3A. 1997 Air Photo (8.5”x 11”)
Figure 3B. 2011 LIDAR Image (8.5”x 11”)
Figure 3C. Site Plan and Geology (17”x 22” landscape)
Figures 4A-4J. Test Pit Logs (ten 8.5”x 11” sheets)
Figures 5A-5C. Cross Sections (three 11” x 17” landscape sheets)

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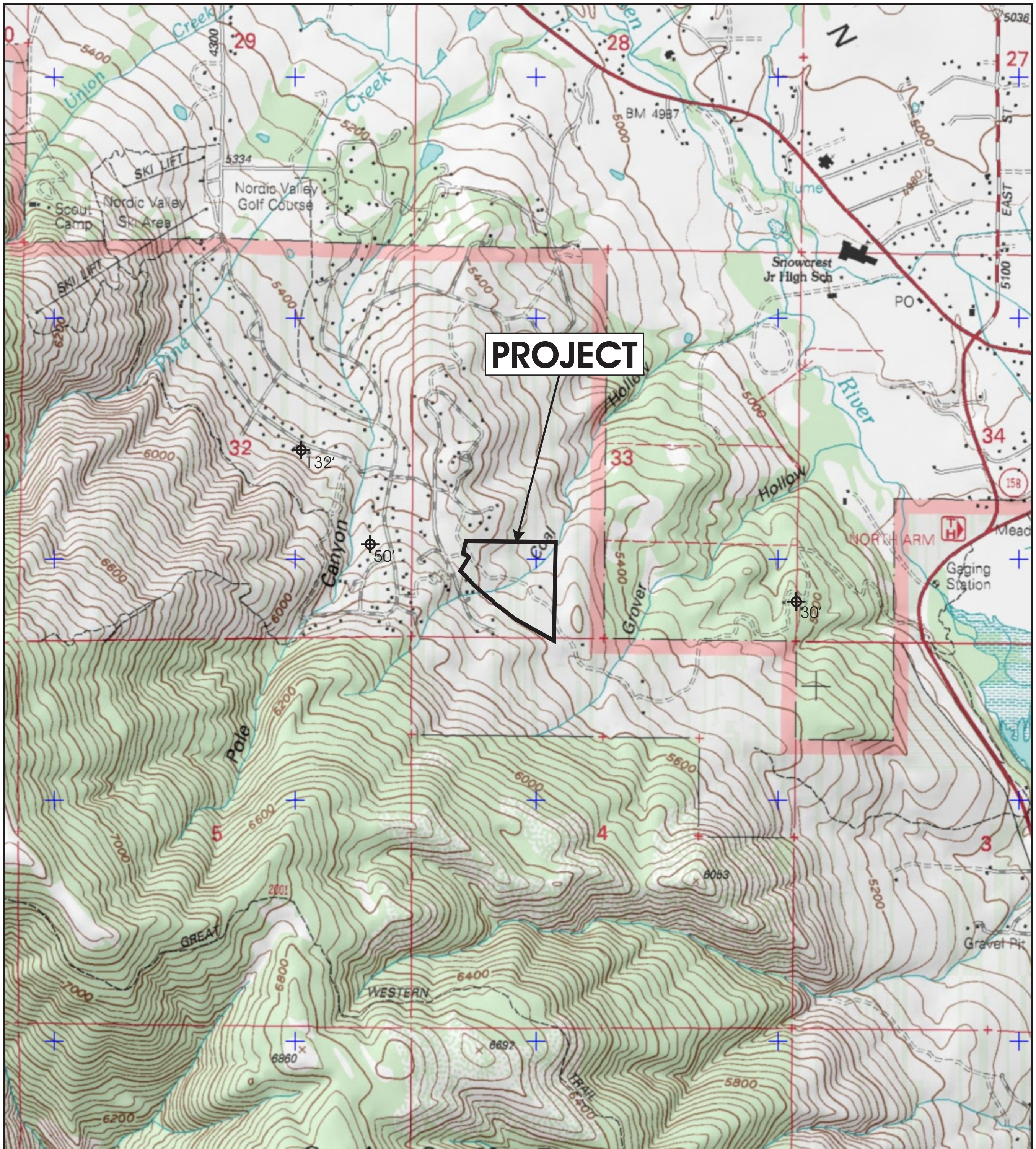
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Huntsville, 1998;
Project location SW1/4, Section 33, T7N, R1E (SLBM); about 5,480 to 5,640 feet elevation (ASL).

WESTERN GEOLOGIC

N
W E
S

0 1000 2000 feet

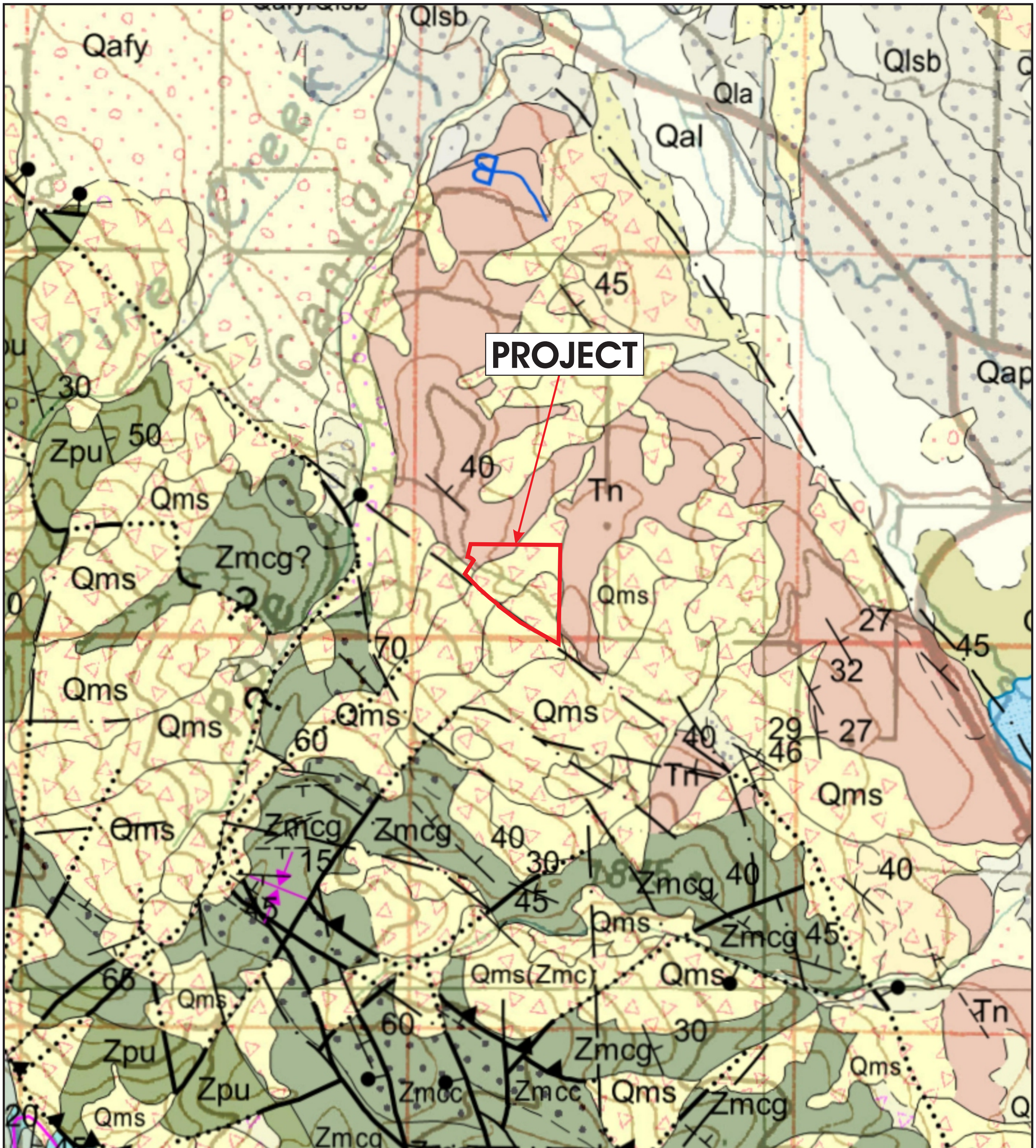
Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 1



Source: Coogan and King (2016); original map scale 1:100,000. See text for explanation of nearby surficial geologic units.

WESTERN GEOLOGIC

N
W E
S

0 1000 2000 feet

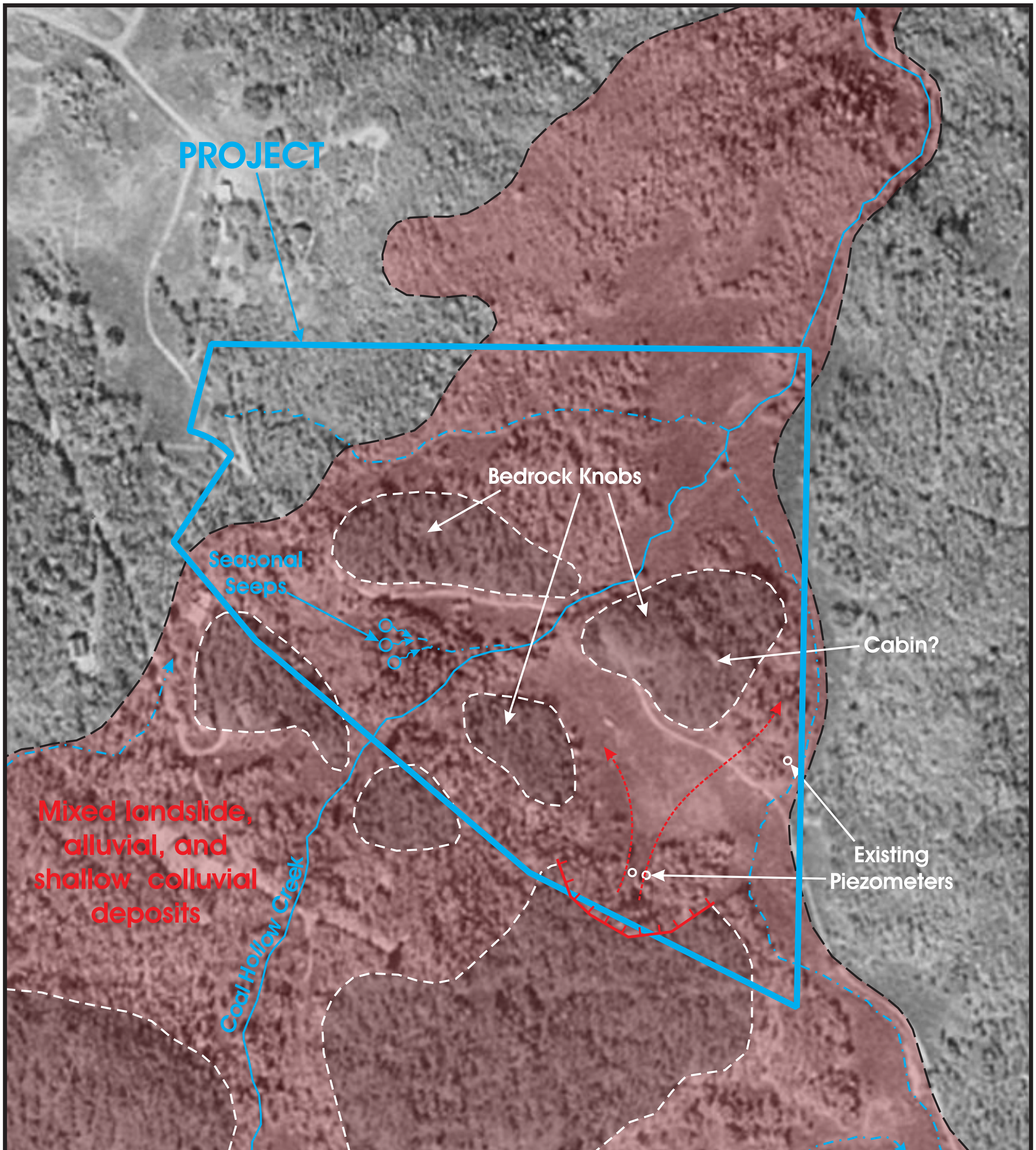
Scale 1:24,000
(1 inch = 2000 feet)

GEOLOGIC MAP

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 2



Source: Utah AGRC, 1990s Digital Orthophoto, 1 meter resolution.

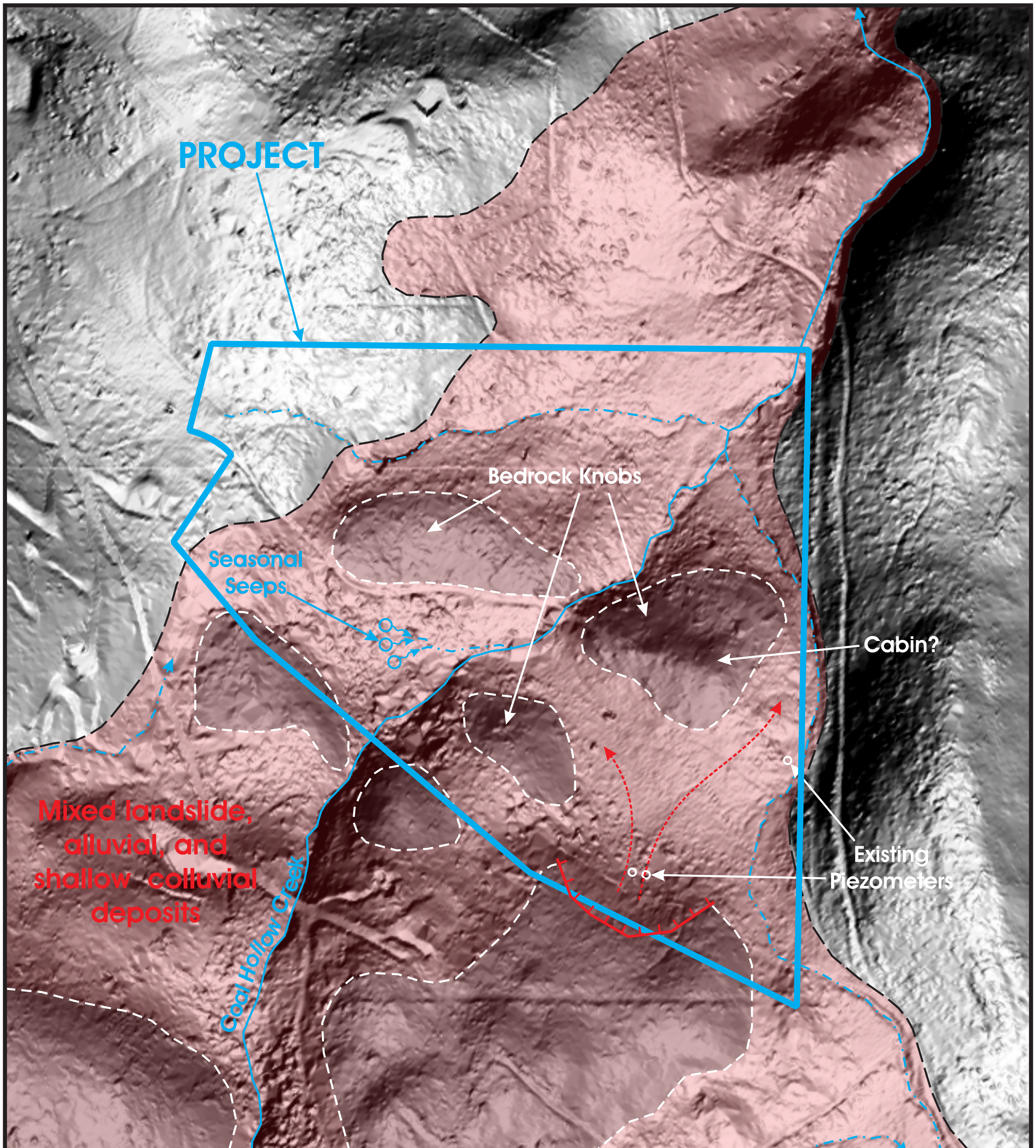
Scale 1:3,600
(1 inch = 300 feet)

WESTERN GEOLOGIC

1997 AERIAL PHOTO

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 3A



Source: Utah AGRC, 2011 LIDAR Bare Earth DEM, 1 meter resolution.

WESTERN GEOLOGIC

N W E S

0 150 300 feet

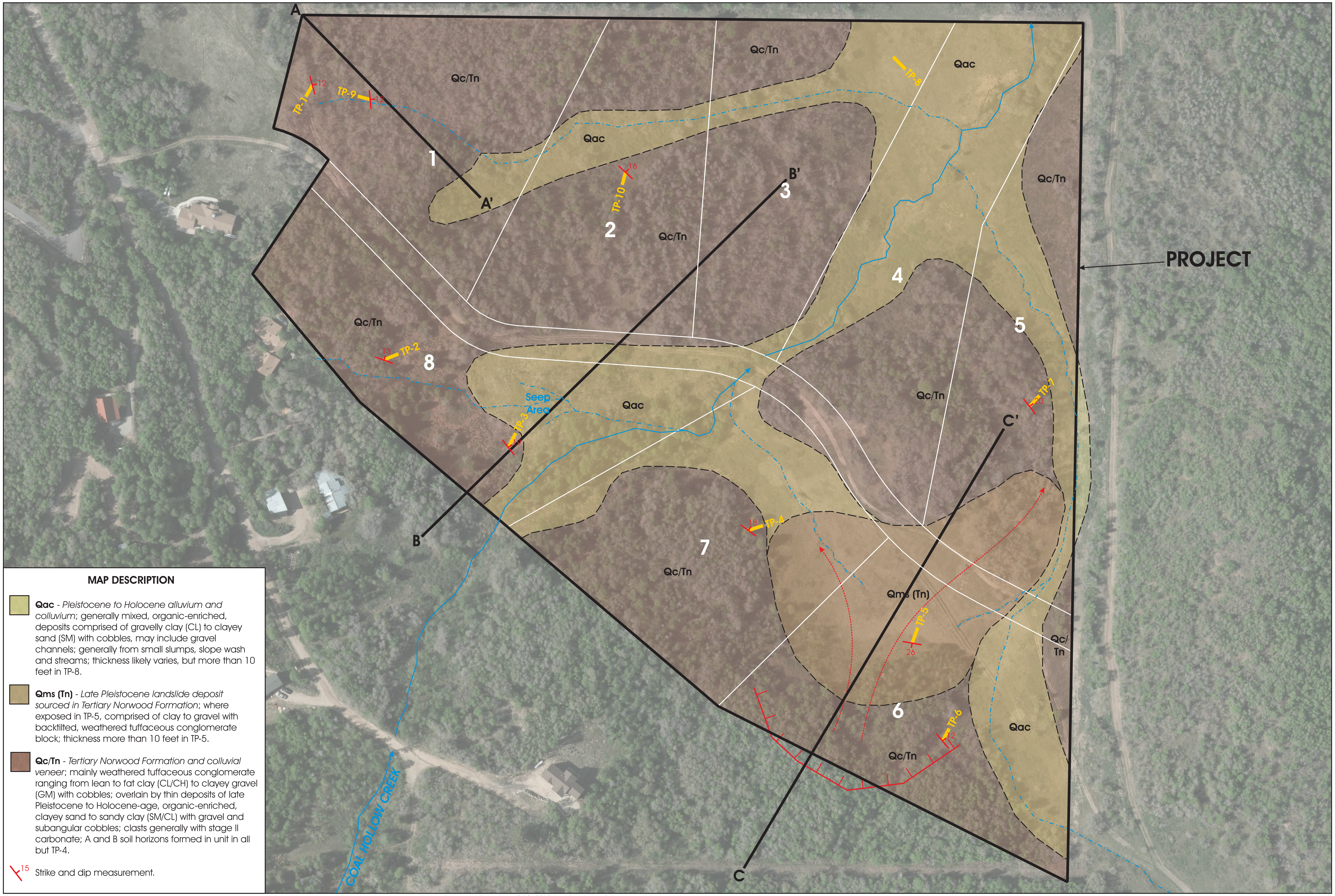
Scale 1:3,600
(1 inch = 300 feet)

2011 LIDAR IMAGE

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 3B



MAP DESCRIPTION

Qac - *Pleistocene to Holocene alluvium and colluvium*; generally mixed, organic-enriched, deposits comprised of gravelly clay (CL) to clayey sand (SM) with cobbles, may include gravel channels; generally from small slumps, slope wash and streams; thickness likely varies, but more than 10 feet in TP-8.

Qms (Tn) - *Late Pleistocene landslide deposit sourced in Tertiary Norwood Formation*; where exposed in TP-5, comprised of clay to gravel with backtilted, weathered tuffaceous conglomerate block; thickness more than 10 feet in TP-5.

Qc/Tn - *Tertiary Norwood Formation and colluvial veneer*; mainly weathered tuffaceous conglomerate ranging from lean to fat clay (CL/CH) to clayey gravel (GM) with cobbles; overlain by thin deposits of late Pleistocene to Holocene-age, organic-enriched, clayey sand to sandy clay (SM/CL) with gravel and subangular cobbles; clasts generally with stage II carbonate; A and B soil horizons formed in unit in all but TP-4.

15 Strike and dip measurement.

Base map from Utah AGRC, 2012 High-Resolution Orthophoto, 6-inch resolution.

N S W E

0 50 100 feet

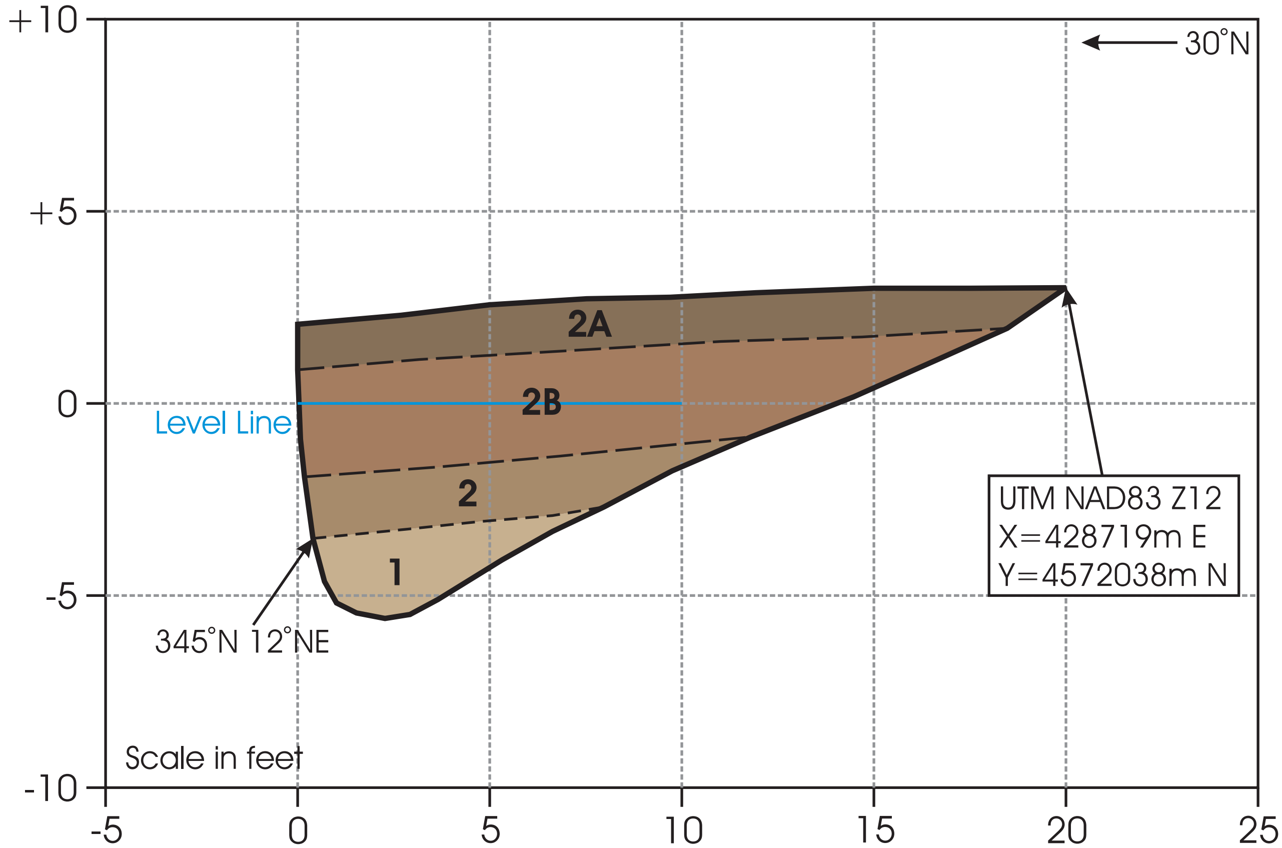
Scale 1:1,200
(1 inch = 100 feet)

WESTERN GEOLOGIC

SITE PLAN AND GEOLOGY

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 3C



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of brown, moderate-high density, poorly bedded, clayey gravel (GM) and subangular to subround cobbles with stage II carbonate.

Unit 2. *Tertiary Norwood Formation* - Weathered tuffaceous claystone comprised of orange- to dark-brown, poorly bedded to massive, lean to fat clay (CL/CH) with basal pebble gravel.

2B. Bt soil horizon formed in unit 2.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

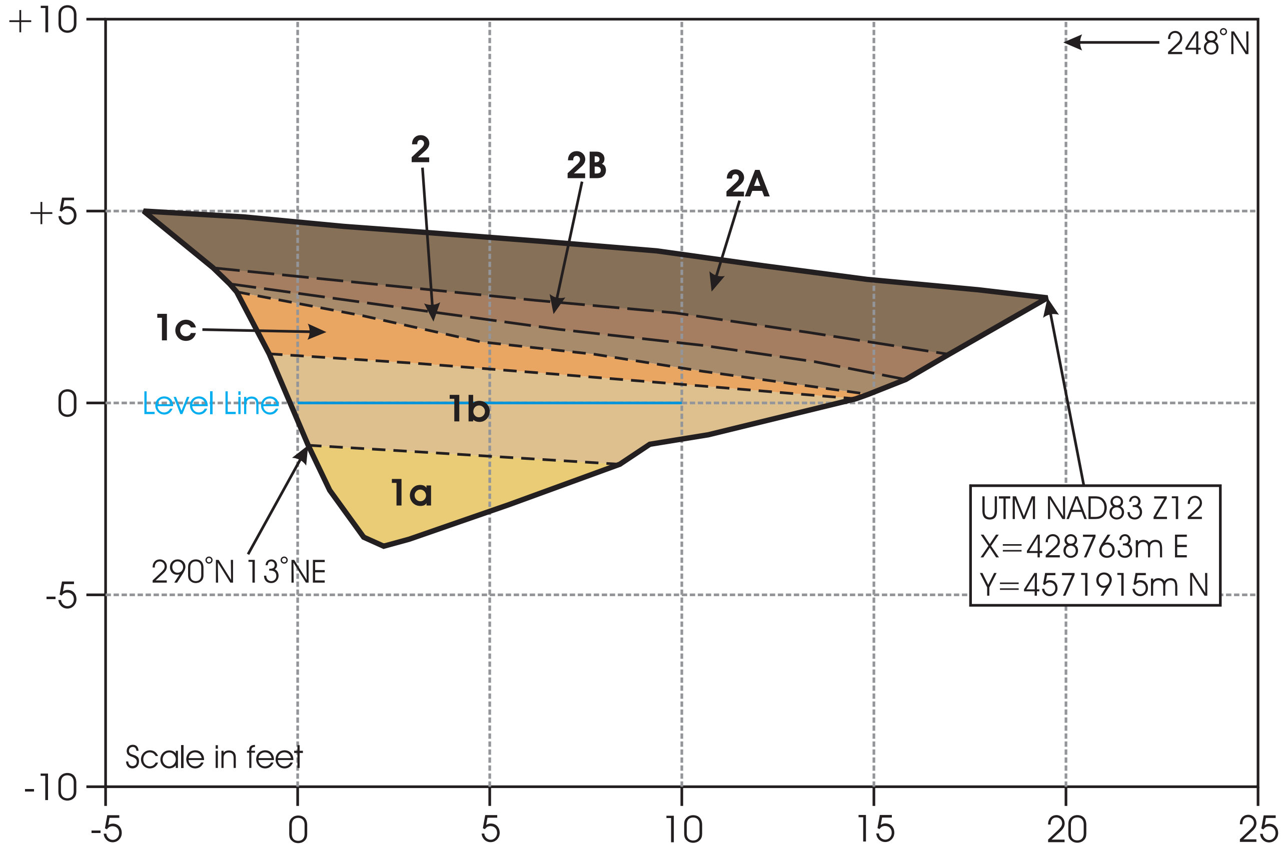
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 1 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4A



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), pale-brown, dense, well to poorly bedded, clayey gravel (GM) with sand and cobbles; a middle (**1b**), pale-brown, dense, poorly bedded, sandy to clayey gravel (GM) with cobbles and trace boulders; and an upper (**1c**), pale-orange-brown, dense, poorly bedded, gravelly lean to fat clay (CL/CH); clasts subangular to subrounded with stage II carbonate.

Unit 2. *Late Pleistocene to Holocene Colluvium* - Brown to dark brown, low to moderate density, massive, clayey sand to sandy clay (SM/CL) with gravel and subangular cobbles; root penetrated and organic enriched.

2B. Bt soil horizon formed in unit 2.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

SCALE: 1 inch = 5 feet
(no vertical exaggeration)

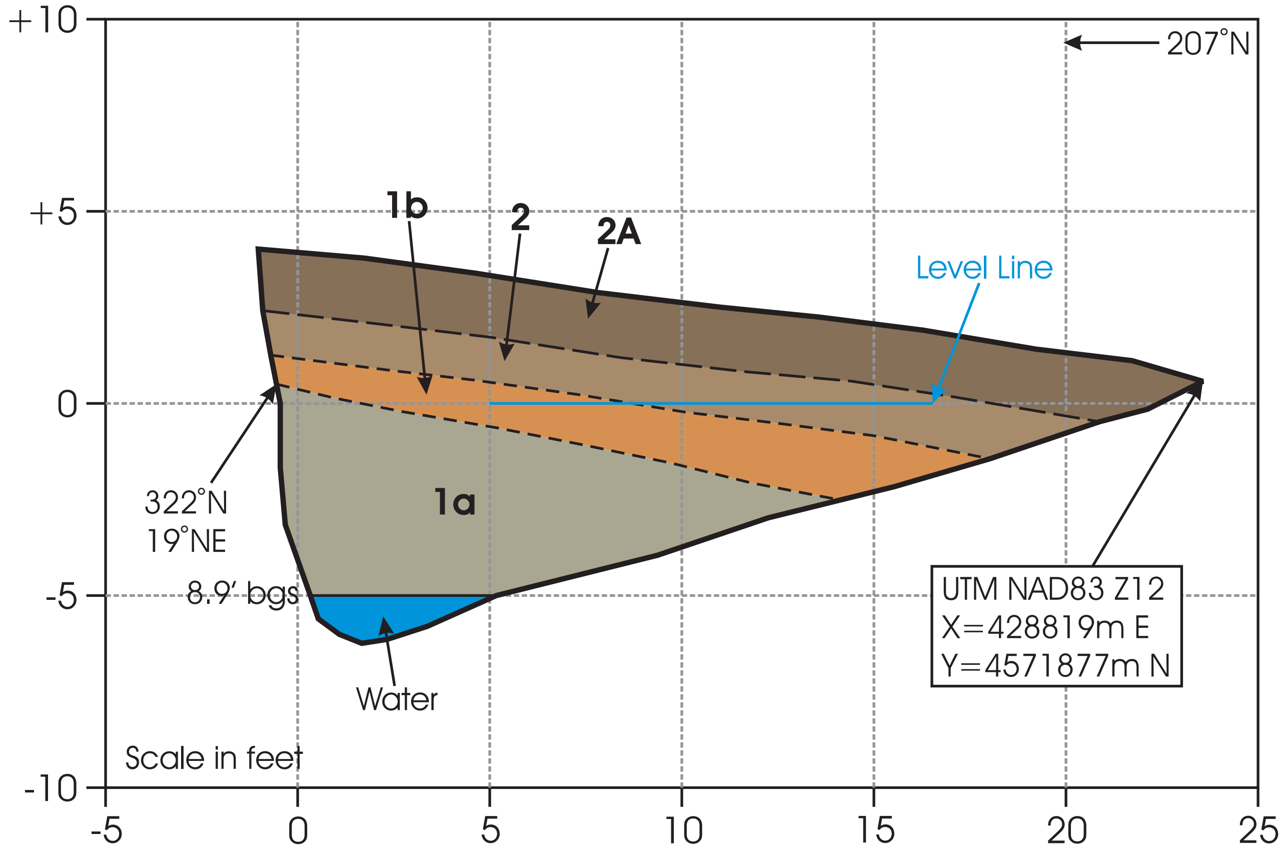
Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 2 LOG

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4B



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous claystone and sandstone comprised of a lower (**1a**), olive-gray to brownish-orange, moderate-high density, well to poorly bedded, lean to fat clay (CL/CH) in lower part; and an upper (**1b**), orange-brown, moderate density, poorly bedded, clayey sand (SM).

Unit 2. *Holocene Colluvium* - Brown to dark brown, low to moderate density, massive, clayey sand to sandy clay (SM/CL) with gravel; root penetrated and organic enriched.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

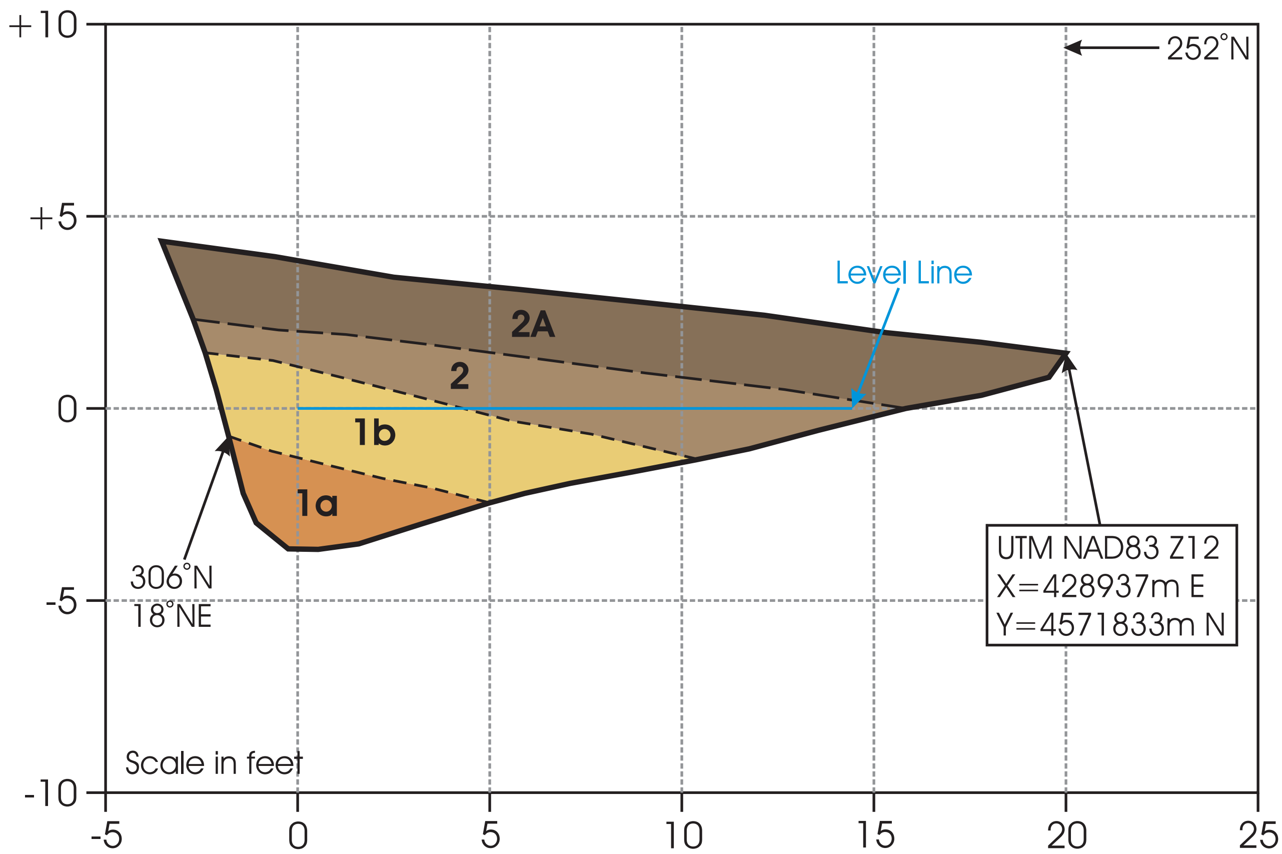
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 3 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4C



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), orange-brown, dense, massive, lean to fat clay (CL/CH) with gravel; and an upper (**1b**), pale-brown, dense, poorly bedded, clayey gravel with cobbles (GM); clasts subangular to subround with stage II carbonate.

Unit 2. *Holocene Colluvium* - Dark-grayish-brown, moderate density, massive, silty to clayey sand (SM) with gravel and trace cobbles; root penetrated and organic enriched.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

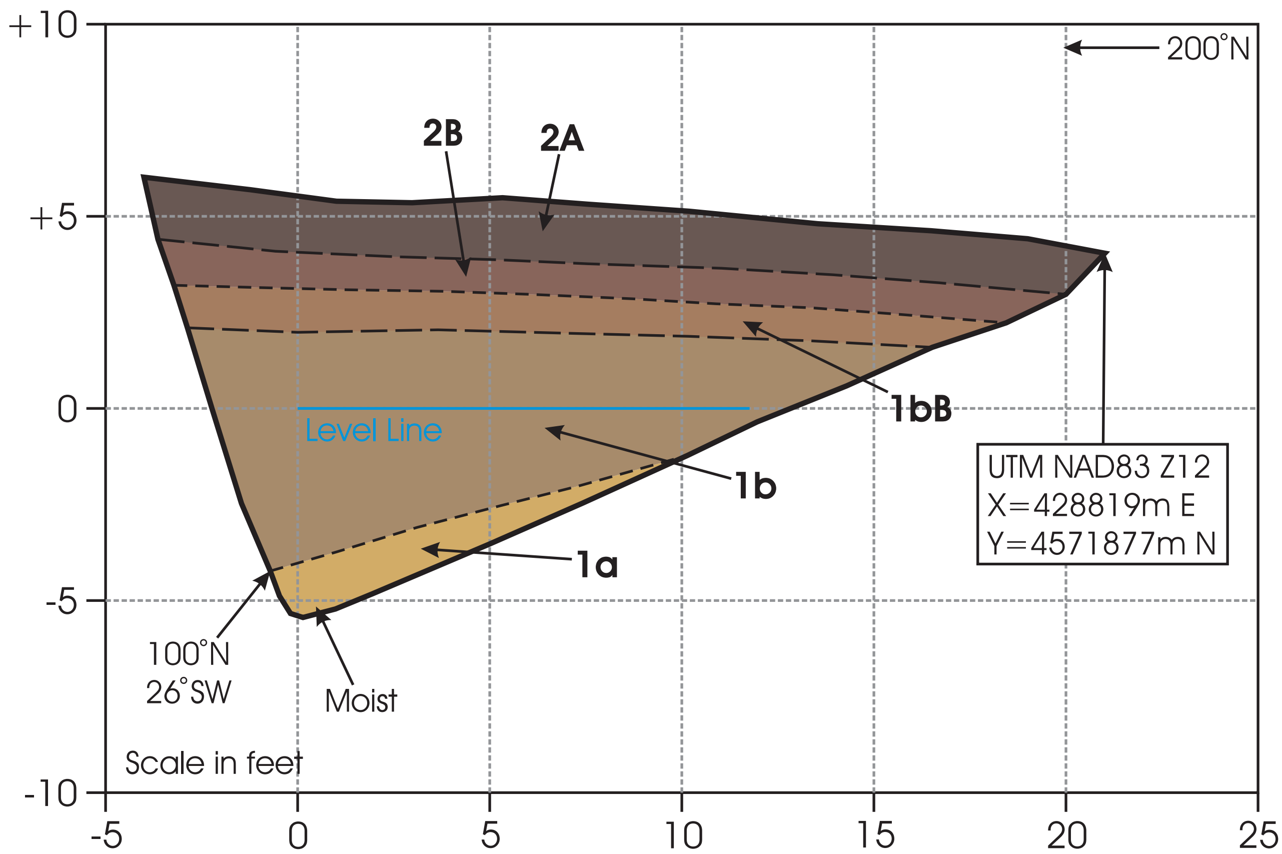
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 4 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4D



UNIT DESCRIPTIONS

Unit 1. *Late Pleistocene Landslide Colluvium* - Deformed, weathered tuffaceous conglomerate comprised of a lower (**1a**), backtilted block of grayish- to yellowish-brown, moderate-high density, massive, moist, clayey gravel (GM) with cobbles; and an upper (**1b**), brown, dense, massive, lean to fat clay (CL/CH) with trace pea gravel; clasts subangular to subround with stage II carbonate.

1bB. Slightly carbonate-enriched Bt vertisol formed in unit 1b.

Unit 2. *Late Pleistocene to Holocene Colluvium* - Dark-grayish-brown, moderate density, massive, clayey to silty sand (SM) with trace gravel; root penetrated and organic enriched.

2B. Bt soil horizon formed in unit 2.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

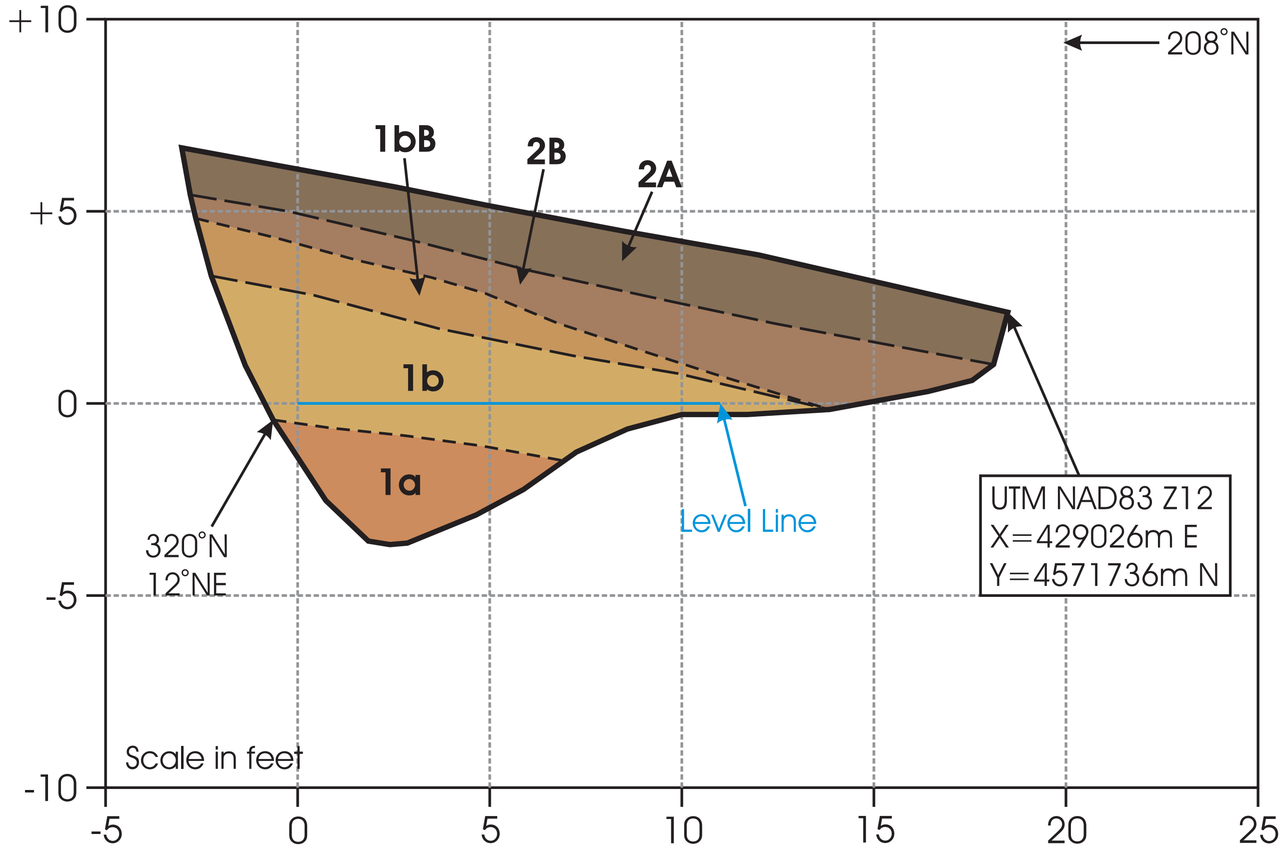
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 5 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4E



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), reddish-brown, dense, poorly bedded, lean to fat clay (CL/CH) with trace gravel; and an upper (**1b**), pale-orange-brown to pale-brown, dense, poorly bedded, clayey gravel to gravelly clay (GM/CL).

1bB. Bt vertisol formed in unit 1b.

Unit 2. *Late Pleistocene to Holocene Colluvium* - Brown to dark-grayish-brown, moderate density, clayey sand to sandy clay (SM/CL) with gravel, cobbles, and trace boulders; root penetrated and organic enriched; clasts subangular to subround with stage II carbonate.

2B. Bt soil horizon formed in unit 2.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

SCALE: 1 inch = 5 feet
(no vertical exaggeration)

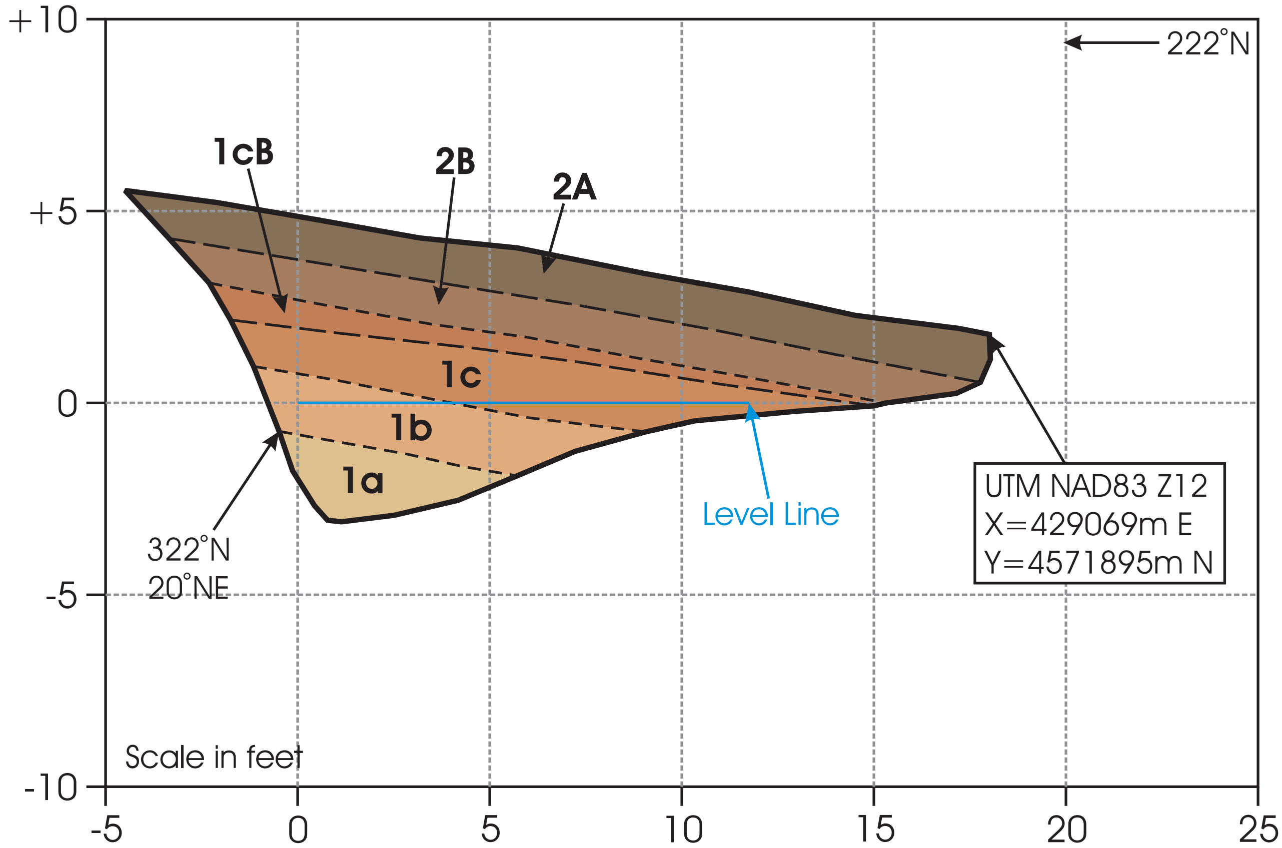
Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 6 LOG

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4F



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), pale-brown, dense, well to poorly bedded, clast-supported, clayey gravel (GM) with small cobbles; a middle (**1b**), orange-brown, dense, poorly bedded, clayey gravel (GM); and an upper (**1c**), brown, dense, poorly bedded, lean to fat clay (CL/CH) with trace gravel; clasts subangular to subrounded with stage II carbonate.

1cB. Bt vertisol formed in unit 1c.

Unit 2. *Holocene Colluvium* - Brown to dark brown, low to moderate density, massive, clayey sand to sandy clay (SM/CL) with gravel and trace cobbles; root penetrated and organic enriched.

2B. Bt soil horizon formed in unit 2.

2A. Modern A-horizon soil formed in unit 2.

WESTERN GEOLOGIC

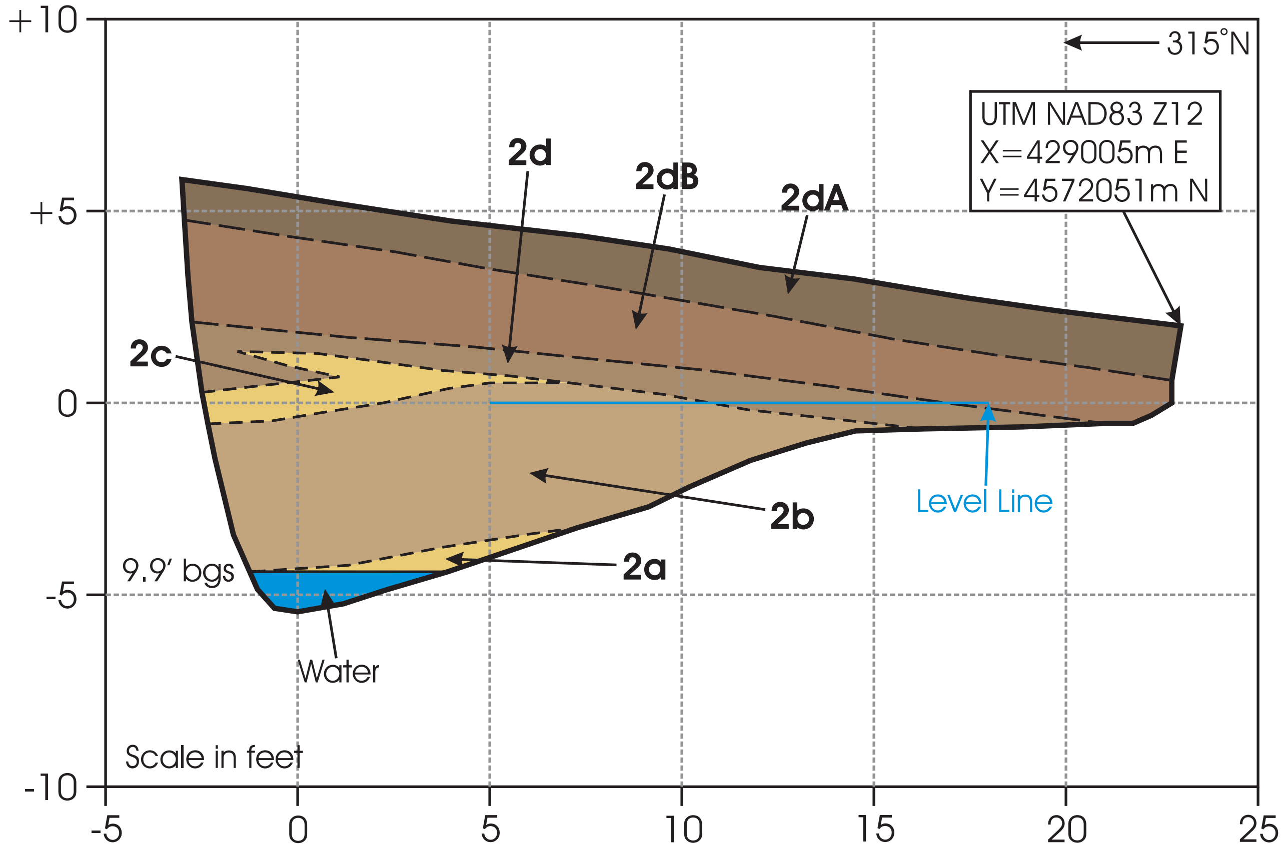
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 7 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4G



UNIT DESCRIPTIONS

Unit 1. *Late Pleistocene to Holocene Alluvium and Colluvium* - Sequence of moderate density, poorly bedded, mixed mudflow and stream deposits comprised of a lower (**2a**), channel comprised of pale-brown, clayey gravel (GM); a middle **(2b),** brown, sandy clay (CL) with gravel; and an upper **(2c)**, foreset channel comprised of brown, clayey to sandy gravel (GM/GW) in and underlying a **(2d)**, brown to dark-brown sandy clay to clayey sand (CL/SM).

2dB. Bt soil horizon formed in unit 2d.

2dA. Modern A-horizon soil formed in unit 2d

WESTERN GEOLOGIC

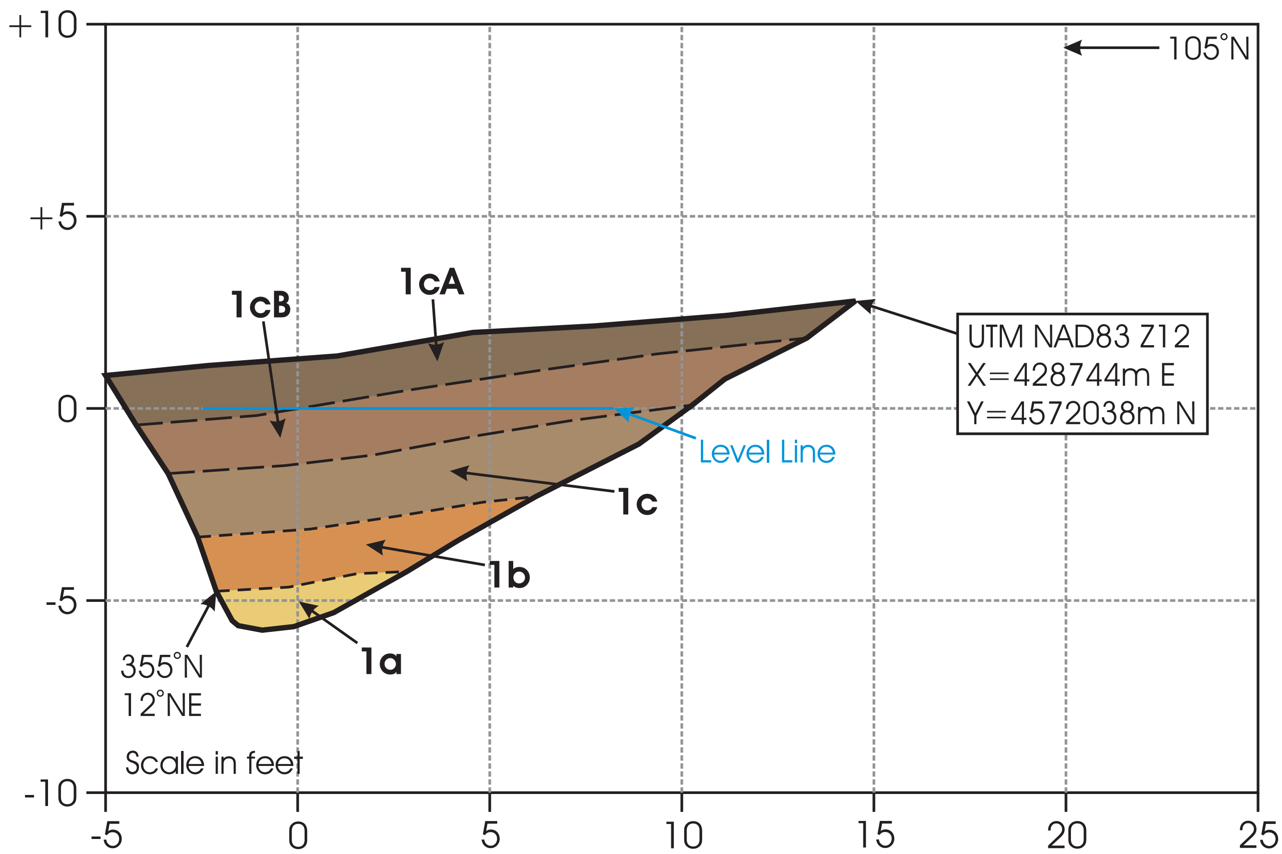
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 8 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4H



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), pale-brown, dense, poorly bedded, clayey gravel (GM) with cobbles; a middle (**1b**), pale-orange-brown, dense, poorly bedded, lean to fat clay (CL/CH) with trace gravel; and an upper (**1c**), orange-brown to brown, moderate-high density, poorly bedded, gravelly clay to clayey gravel (CL/GM) with cobbles; clasts subangular to subrounded with stage II carbonate.

1cB. Bt vertisol formed in unit 1c.

1cA. Modern A-horizon soil formed in unit 1c.

SCALE: 1 inch = 5 feet
(no vertical exaggeration)

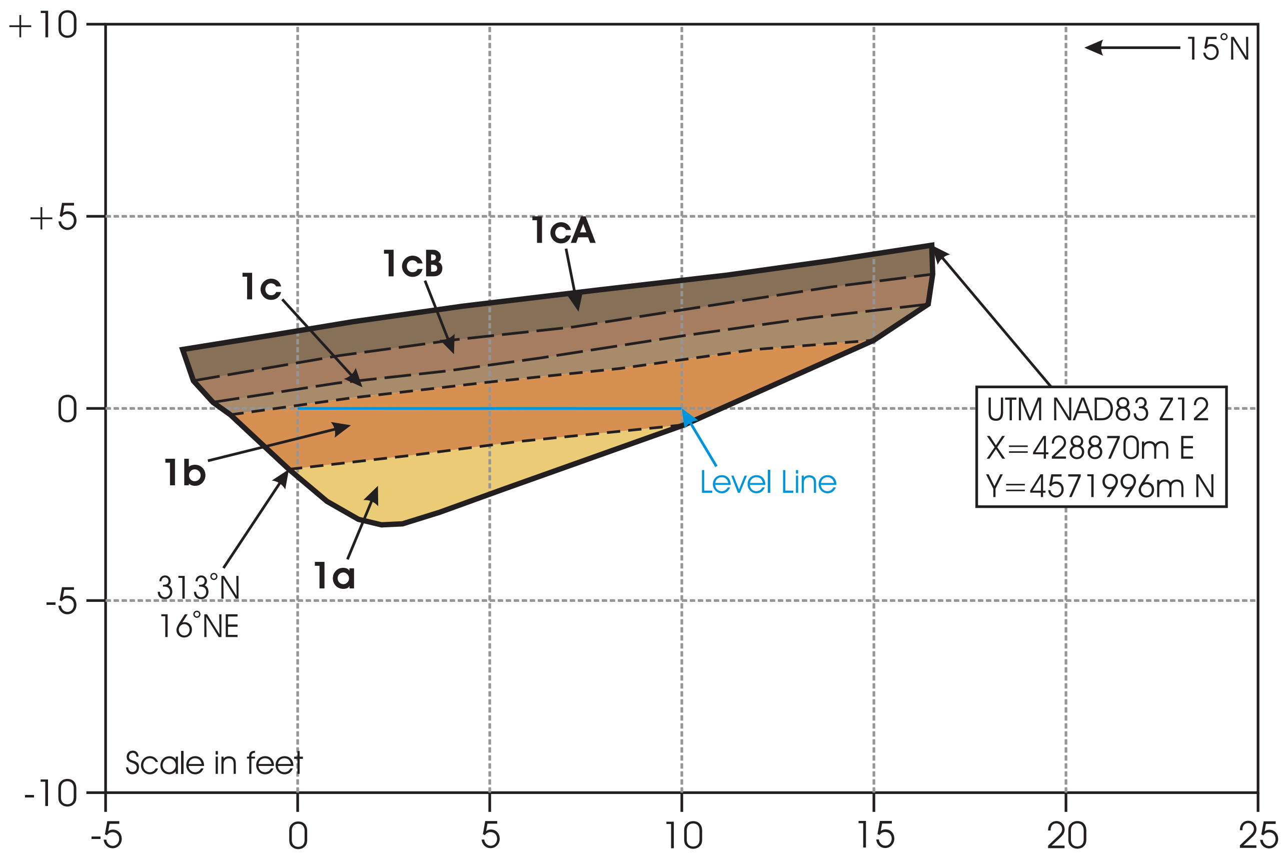
Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

WESTERN GEOLOGIC

TEST PIT 9 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4I



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - Weathered tuffaceous conglomerate comprised of a lower (**1a**), pale-brown, dense, poorly bedded, lean to fat clay (CL/CH) with trace gravel; a middle (**1b**), orange-brown, dense, poorly bedded, lean to fat clay (CL/CH) with trace gravel; and an upper (**1c**), brown, dense, poorly bedded, gravelly lean to fat clay (CL/CH) with trace cobbles; clasts subangular to subrounded with stage II carbonate.

1cB. Carbonate-enriched Bt soil horizon formed in unit 1c.

1cA. Modern A-horizon soil formed in unit 1c.

WESTERN GEOLOGIC

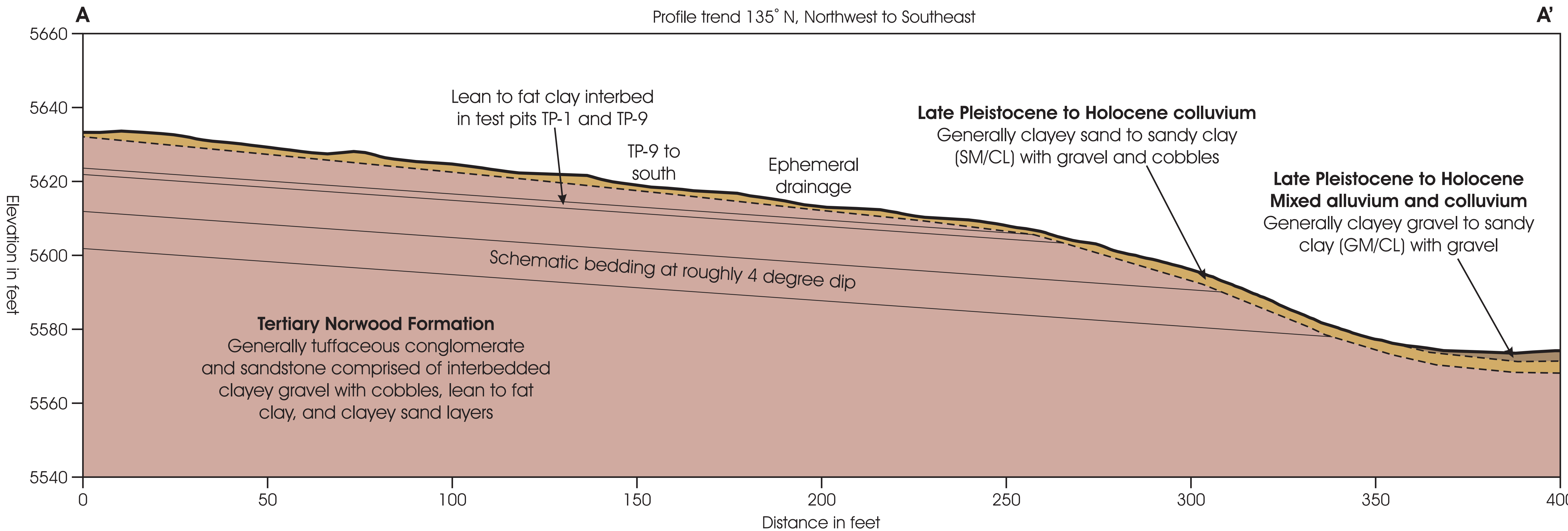
SCALE: 1 inch = 5 feet
(no vertical exaggeration)

Logged by Bill D. Black, P.G.
on September 18-20, 2018
Reviewed by
Craig V. Nelson, P.G.

TEST PIT 10 LOG

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 4J



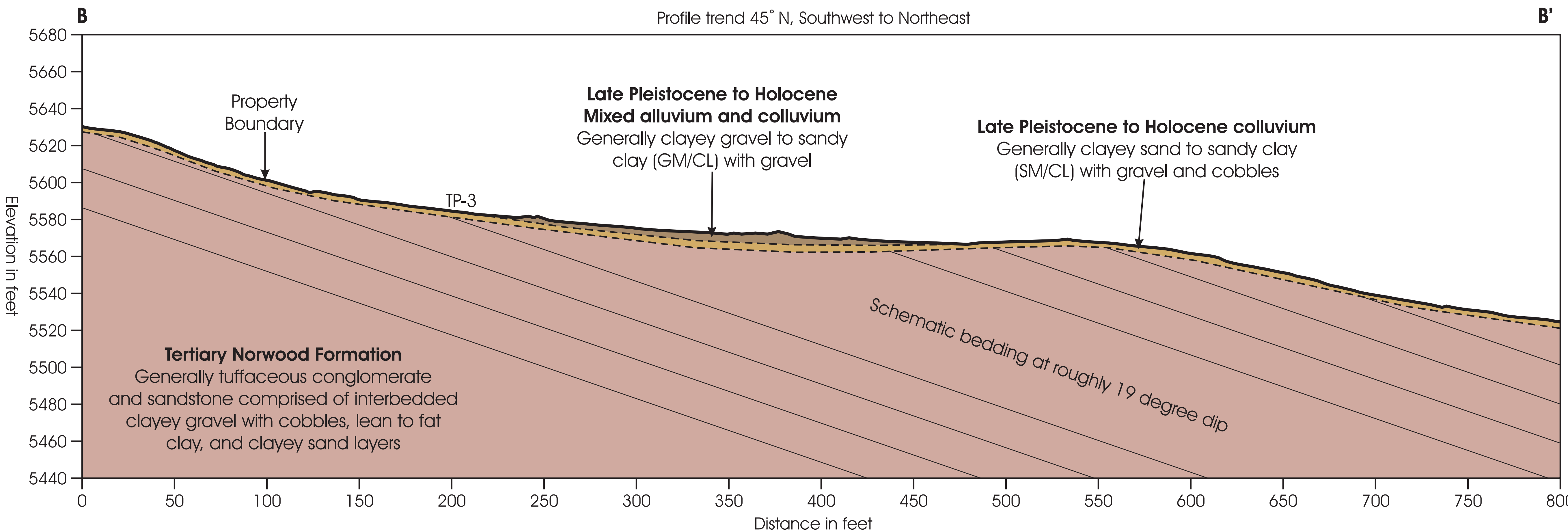
Scale 1 inch equals 30 feet, no vertical exaggeration.
Topographic profile from 2011 LIDAR data. Profile location on Figure 3C.
Units and contacts approximate based on subsurface information.

WESTERN GEOLOGIC

CROSS SECTION A-A'

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 5A



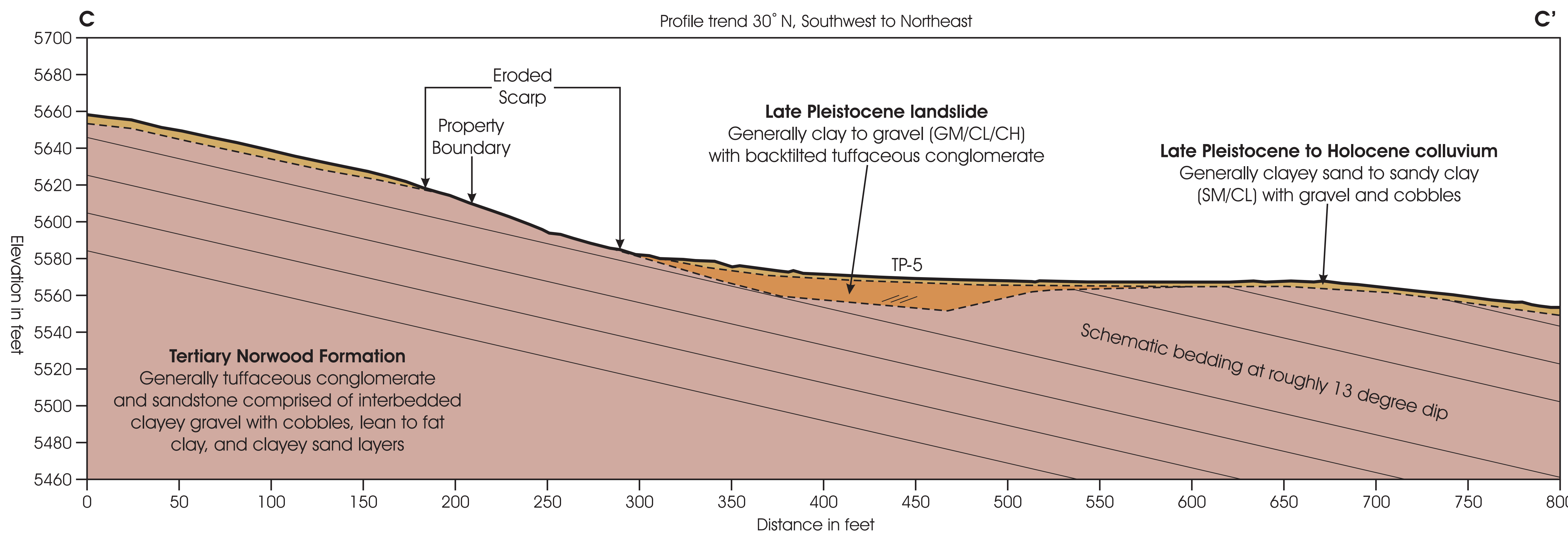
Scale 1 inch equals 60 feet, no vertical exaggeration.
Topographic profile from 2011 LIDAR data. Profile location on Figure 3C.
Units and contacts approximate based on subsurface information.

WESTERN GEOLOGIC

CROSS SECTION B-B'

GEOLOGIC HAZARDS EVALUATION
WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 5B



Scale 1 inch equals 60 feet, no vertical exaggeration.
Topographic profile from 2011 LIDAR data. Profile location on Figure 3C.
Units and contacts approximate based on subsurface information.

CROSS SECTION C-C'

GEOLOGIC HAZARDS EVALUATION

WAJ Enterprises Property
About 2050 North Big Sky Drive
Liberty, Weber County, Utah

FIGURE 5C