REPORT

GEOLOGIC HAZARDS RECONNAISSANCE

PROPOSED BUHRLEY SOUTH FORK RANCH LOT 4

W1/2 SECTION 20, T. 6 N., R. 2 E., HUNTSVILLE, WEBER COUNTY, UTAH

Prepared for

Peterson Builders Inc.
4794 East 2600 North
Eden, Utah 84310

September 14, 2020

Prepared by

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September 14, 2020

Erik Johnson, Project Manager
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SUBJECT: Geologic Hazards Reconnaissance
Proposed Buhrley South Fork Ranch Lot 4
W1/2 Township 6 North, Range 2 East
Huntsville, Weber County, Utah

Dear Mr. Johnson:

This report presents the results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western Geologic & Environmental LLC (Western Geologic) for the Proposed Buhrley South Fork Ranch Lot 4 in Huntsville, Utah (Figure 1 – Project Location). The Project consists of proposed 9.752-acre parcel currently within Weber County Assessor parcel numbers 21-032-0002 and 21-034-0034. The site is located in southern Ogden Valley on northeast-facing slopes overlooking Pineview Reservoir in the W ½ of Section 20, Township 6 North, Range 2 East (Salt Lake Base Line and Meridian; Figure 1). Elevation of the site is about 4,938 to 4.988 feet above sea level. Based on a Landmark Engineering site plan, the proposed development consists of a single-family residence in the southeast corner of the proposed parcel. The property is currently unaddressed.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret surficial geologic conditions at the site and 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. No hazard-specific evaluations or subsurface explorations were conducted for this report or within the scope of our study.

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; 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. However, 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 in southern Ogden Valley south and west of the south branch of South Fork Ogden River and east of Spring Hollow (Figure 1). The north and south branches of South Fork Ogden River flow into Pineview Reservoir about 3,200 to 3,500 feet northwest of the site. The Huntsville South Bench Canal crosses the south side of the Project and is a buried conveyance. Except for South Fork Ogden River, no other perennial, intermittent, or ephemeral drainages are mapped crossing the Project or were observed during our site reconnaissance.

The site is at the southern margin of Ogden Valley. Slopes in the area that bound the valley are in weathered tuffaceous bedrock mantled by mixed alluvium, colluvium and lacustrine sediments, whereas the valley floor is underlain by unconsolidated lacustrine and alluvial basin-fill deposits. The Utah Division of Water Rights Well Driller Database shows several water wells within a half mile of the Project that report static groundwater depths of 0 to 14 feet below the ground surface (Figure 1). Given the reported groundwater depths in these wells, we anticipate groundwater at the Project is 0 to 15 feet deep; groundwater in the area of the proposed home is likely 10 to 15 feet deep, but areas further north in the floodplain of South Fork Ogden River likely have shallower depths (0 to 10 feet). Groundwater depths at the site likely vary seasonally from snowmelt runoff and annually from climatic fluctuations. Such variations would be typical for an alpine environment.

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). Based on topography, we expect groundwater flow at the site to be to the north.

GEOLOGY

Surficial Geology

The site is located on the southern 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) as Holocene- to Pleistocene-age stream alluvium and alluvial fan deposits, and late Pleistocene-age lacustrine deposits from Lake Bonneville overlying Tertiary-age conglomerate (units Qal, Qafy and Ql/Tcg, Figure 2). The underlined units described below are those mapped at the site.

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

> ***Qlamh*** *– Lacustrine, marsh, and alluvial deposits, undivided (Historical).* Sand, silt, and clay mapped where streams enter Pineview Reservoir, and reservoir levels fluctuate such that lacustrine, marsh, and alluvial deposits are intermixed; thickness uncertain.
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> ***Qa2, Qa2?, Qay*** *– Younger alluvium (mostly Holocene).* Like undivided alluvium, with Qay at to slightly above present drainages, unconsolidated, and not incised by active drainages; likely mostly Holocene in age and postdates late Pleistocene Provo shoreline of Lake Bonneville; height above present drainages is low and is within certain limits, with suffix 1 (not present on this map) being the youngest and being at to slightly (<10 feet [3 m]) above drainages and suffix 2 being slightly higher and older, with y suffix where ages 1 and 2 cannot be separated; Qa2 is up to about 20 feet (6 m) above drainage on south side of Round Valley indicating unit includes slightly older post Provo-shoreline alluvium; generally 6 to 20 feet (2-6 m) thick. Mapped as Qa2 (queried) where about 20 feet (6 m) above incised stream in Stephens Canyon (Devils Slide quadrangle).
>
> <u>***Qal, Qal1, Qal2, Qal2?*** *– Stream alluvium and floodplain deposits (Holocene and uppermost Pleistocene)*</u>. Sand, silt, clay, and gravel in channels, floodplains, 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 floodplain 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 floodplain 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 floodplain.

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.

Qa, Qa? *– Alluvium, undivided (Holocene and Pleistocene)*. Sand, silt, clay, and gravel in stream and alluvial-fan deposits near late Pleistocene Lake Bonneville and are geographically in the Ogden and Weber River, and lower Bear River drainages; composition depends on source area; variably sorted; variably consolidated; 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; Qa with no suffix used where age uncertain or alluvium of different ages cannot be shown separately at map scale; Qa 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); generally 6 to 20 feet (2-6 m) thick.

Where possible, alluvium is subdivided into relative ages, indicated by number and letter suffixes. This alluvium is listed and described separately below. The relative ages of alluvium, including terraces and fans, are in part based on deposit heights above present adjacent drainages in Morgan and Round Valleys, and this 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 table 1 and 2). Alluvial deposits mapped in the Henefer quadrangle (Coogan, 2010b) and Lost Creek drainage (Coogan, 2004a-c) were revised during mapping of the Devils Slide quadrangle (see table 2). Comparable alluvium along Box Elder Creek in the northwest part of the map area (Mantua quadrangle) seems to be slightly higher than in Morgan Valley. Units Qa2, Qay, Qap, Qab, Qapb, Qao, and Qaoe described below are near Lake Bonneville. Their relative age is queried where age uncertain, generally due to height not fitting into ranges in table 1 and/or typical order of surfaces contradicts height-derived age.

Qat, Qat2, Qaty, Qatp, Qatp?, Qatpb, Qato – *Stream-terrace alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in terraces above floodplains near late Pleistocene Lake Bonneville and are geographically in the Ogden and Weber River, and lower Bear River drainages; moderately sorted; variably consolidated; upper surfaces slope gently downstream; locally includes thin and small mass-movement and alluvial-fan deposits; where possible, subdivided into relative ages, indicated by number and letter suffixes, with 2 being the lowest/youngest terraces, typically about 10 to 20 feet (3-6 m) above adjacent flood plains; Qat with no suffix used where age unknown or age subdivisions of terraces cannot be shown separately at map scale; 6 to at least 20 feet (2-6+ m) thick, with Qatp 50 to 80 feet (15-24 m) thick in Mantua Valley.

Relative ages are largely from heights above adjacent drainages in Morgan and Round Valleys. This 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). Despite the proximity to Lake Bonneville, terraces along and near Box Elder Creek in the northwest corner of the Ogden map area (Mantua quadrangle) seem to be slightly higher than comparable terraces in Morgan Valley. Terraces labeled Qat2 are post-Lake Bonneville and are likely mostly Holocene in age. A terrace labeled Qaty is up to 20 feet (6 m) above the South Fork Ogden River, but may be related to the Provo or regressional shorelines. Terraces labeled Qatp are likely related to the Provo and slightly lower shorelines of Lake Bonneville (at and less than ~4820 feet [1470 m] in area), and with Qap form “benches” at about 4900 feet (1494 m) along the Weber River and South Fork Ogden River. Qato terraces pre-date Lake Bonneville. Relative age queried (Qatp?) where age is uncertain, generally due to height not fitting into ranges in table 1 and/or typical order of surfaces contradicts height-derived age.

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.

***Qmc** – Landslide and colluvial deposits, undivided (Holocene and Pleistocene).* Poorly sorted to unsorted clay- to boulder-sized material; mapped where landslide deposits are difficult to distinguish from colluvium (slope wash and soil creep) and where mapping separate, small, intermingled areas of landslide and colluvial deposits is not possible at map scale; locally includes talus and debris flow and flood deposits; typically mapped where landslides are thin (“shallow”); also mapped where the blocky or rumpled morphology that is characteristic of landslides has been diminished (“smoothed”) by slope wash and soil creep; composition depends on local sources; 6 to 40 feet (2-12 m) thick. These deposits are as unstable as other landslide units (Qms, Qmsy, Qmso).

***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).

***Qcg** – Gravelly colluvial deposits (Holocene and Pleistocene).* Gravelly materials present downslope from gravel-rich deposits of various ages (for example units Keh, Tw, Tcg, Thv, QTaf, QTa, Qafoe, Qaoe, Qafo, and Qa); may contain residual deposits; typically differentiated from colluvium and residual gravel (Qc, Qng) by prominent stripes trending downhill on aerial photographs; stripes are concentrations of gravel up to boulder size; generally 6 to 20 feet (2-6 m) thick.

***Qng** – Colluvial and residual gravel deposits (Holocene and Pleistocene).* Poorly sorted pebble to boulder gravel in a matrix of silt and sand; gravel of uncertain origin, but probably includes colluvium and residuum, and at least locally glacial deposits (for example near Powder Mountain) and alluvium; mostly gravel-armored deposits on and near alluvial and colluvial deposits like units Qcg, QTay?, QTao?, and QTaf; locally on gravel-rich bedrock (Thv, Tcg, Tw, and Keh) and Paleozoic quartzite (Cgcu and Ct); typically have gently dipping upper surface; present on Durst Mountain, near high-level fans (QTaf) near head of Strawberry Creek (Snow Basin quadrangle), in northeast corner of Peterson quadrangle, and on benches above streams in east part of Peterson quadrangle; generally 6 to 20 feet (2-6 m) thick.

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.

Qdlb, Qdlb? *– Transgressive and Bonneville-shoreline deltaic and lacustrine deposits (upper Pleistocene).* Mostly sand, silty sand, and gravelly sand deposited near shore in Lake Bonneville; extensive at mouth of Weber Canyon; related to transgression to and occupation of the Bonneville shoreline with lacustrine deposits covering deltaic deposits; in Morgan Valley and near mouth of Coldwater Canyon (North Ogden quadrangle) contain more cobbles and overall more gravel; 0 to at least 40 feet (12 m) thick in Ogden and Morgan Valleys; about 400 feet (120 m) thick in bluff at the mouth of Weber Canyon. These deposits are prone to slope failures.

Ql, Ql? *– Lake Bonneville deposits, undivided (upper Pleistocene).* Silt, clay, sand, and cobbly gravel in variable proportions; mapped where grain size is mixed, deposits of different materials cannot be shown separately at map scale, or surface weathering obscures grain size and deposits are not exposed in scarps or construction cuts; thickness uncertain.

Qlf, Qlf?, Qlfb, Qlfb? *– Fine-grained lacustrine deposits (Holocene and upper Pleistocene).* Mostly silt, clay, and fine-grained sand deposited near- and off-shore in Lake Bonneville; typically mapped as Qlf below the Provo shoreline (P) because older transgressive (Qlfb) deposits are indistinguishable from younger regressive deposits; mapped as Qlfb above the Provo shoreline because these deposits can only be related to the Bonneville shoreline (B) and transgression; grades upslope with more sand into Qls or Qlsp; typically eroded from shallow Norwood Formation in Ogden and Morgan Valleys and at least 12 feet (4 m) thick near Mountain Green. Qlf and Qlfb queried where grain size is uncertain.

In the Kaysville quadrangle, Qlf deposits that are below the Gilbert (G) shoreline are at least partly the same age as this shoreline (Holocene-latest Pleistocene) and post-date late Pleistocene Lake Bonneville. Qlf deposits below the Holocene (H) highstand shoreline are Holocene. Both ages of deposits are generally less than 15 feet (5 m) thick.

Deeper water fine-grained deposits overlie older shoreline and delta gravels (Qlf/Qdlb) at the mouths of several drainages along the Weber River. These gravels were deposited above the Provo shoreline during transgression of Lake Bonneville to the Bonneville shoreline (see unit Qdlb).

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.

***Qao, Qao?** – Older alluvium (mostly upper Pleistocene).* Sand, silt, clay, and gravel above and likely older than the Bonneville shoreline; mapped on surfaces above Lake Bonneville-age alluvium (Qap, Qab, Qapb); deposits lack fan shape (Qaf) and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage; also shown where areas of fans and terraces are too small to show separately at map scale; composition depends on source area; at least locally up to 110 feet (34 m) thick. Queried where classification or relative age is uncertain (see Qa for details); for example near head of Saleratus Creek.

Older alluvium is likely older than Lake Bonneville and the same age as Qafo, so likely Bull Lake age, 95,000 to 130,000 years old (see Chadwick and others, 1997, and Phillips and others, 1997); see table 1 and note revision from Coogan and King (2006) and King and others (2008). From our work in the Henefer (Coogan, 2010b) and Devils Slide quadrangles and ages in Sullivan and Nelson (1992) and Sullivan and others (1988), older alluvium (Qao, Qafo, Qato) may encompass an upper (pre-Bull Lake) and lower (Bull Lake) alluvial surface that is not easily recognized in Morgan Valley (see tables 1 and 2).

***Thv?** – Fanglomerate of Huntsville area(?) (Pliocene and/or Miocene).* Brown to reddish-brown weathering sand, silt, and gravel (pebbles to boulders) on flat area near 7313-foot [2230 m] elevation hill on eastern margin of Mantua quadrangle; queried due to uncertain origin; located on Rendezvous Peak erosion surface of Williams (1948), so uncertain age (compare Williams, 1948 to 1958); similar patches on topographic highs to north and south are mapped as Salt Lake Formation conglomerate (Tslc); reddish color may be from erosion of Wasatch Formation and/or terra rossa development on underlying karstic carbonate rocks; may be post- or late-Salt Lake Formation age, like Thv on Durst Mountain.

***Tcg, Tcg?** – Unnamed Tertiary conglomeratic rocks (Oligocene?).* Characterized by rounded, cobble- to boulder-sized, quartzite-clast conglomerate with pebbles and less than 10 percent to more than 50 percent gray, tan, or reddish-gray to reddish-tan matrix; conglomerate clasts locally angular to subangular Tintic Quartzite and angular to rounded lower Paleozoic carbonate rocks; interbedded with tan, gray, and reddish-brown, pebble-bearing mudstone to sandstone and some claystone (altered tuff); most beds poorly indurated and poorly exposed; mudstone likely constitutes matrix of conglomeratic beds; in Morgan and Durst Mountain quadrangles, about 500 to 700 feet (150-210 m) thick and thickening northward to possibly 3000 feet (900 m), though faulting may make this estimate too large.

Reddish-hued Tcg strata mostly contain recycled Wasatch Formation clasts (quartzite and carbonate) with a distinct reddish patina in a reddish matrix. Some non-conglomeratic beds in Tcg look like gray upper Norwood Formation (Tn) and are locally tuffaceous, indicating the units are interbedded. Further, some Tcg pebble beds have carbonate and chert clasts (like the Norwood) and lesser quartzite clasts, and Tcg conglomerate includes rare altered tuff clasts from the Norwood Formation. Despite tuffaceous matrix, unit Tcg seems to be less prone to mass movements than Norwood strata.

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.

Keh, Keh? *– Hams Fork Member of Evanston Formation (Upper Cretaceous, Maastrichtian-Campanian).* Light gray to tan conglomerate with lesser conglomeratic sandstone, and sandstone, with quartzite and chert clasts, as exposed along South Fork Ogden River; lower Hams Fork markedly coarsens to cobble conglomerate dominated by Cambrian and Neoproterozoic quartzite clasts (not mapped separately here, but mapped as Kehc to southeast); about 300 to 1000 feet (140-300 m) thick along South Fork Ogden River, thinning to west; thins to absence to north and west along regional angular unconformities. DeCelles and Cavazza (1999, figure 7A) showed a basal conglomerate as 66 feet (20 m) thick in the Causey Dam quadrangle. Unconformably truncated beneath Wasatch Formation and overlies Cretaceous Weber Canyon Conglomerate and Paleozoic rocks, with angular unconformity, along Right Fork South Fork Ogden River, indicating northern Causey Dam quadrangle, northwestern Horse Ridge, and western Dairy Ridge quadrangles were areas of high paleotopography (after Coogan, 2006a-b).

The age of the Hams Fork here is based on Mullens (1969; 1971, p. 13) note of Late Cretaceous pollen in a sample (D3971) that is from upper part of our Keh unit.

These South Fork Ogden River Keh exposures are not the same lithologically as those near Devils Slide, in the Lost Creek drainage, and in Echo Canyon; but these outcrops form a nearly continuous band down the South Fork and along the east flank of Durst Mountain to Devils Slide and other exposures to the east. The lithology of Keh along the east flank of Durst Mountain also differs from that in the other areas mentioned.

Jn *– Nugget Formation (Lower Jurassic).* Pale-grayish-orange, pinkish-tan, and locally white, well cemented, cross-bedded, quartz sandstone with frosted sand grains; typically about 1000 to 1100 feet (300-335 m) thick in subsurface.

Numerous subsurface thicknesses have been reported because the Nugget is a reservoir rock in the gas and oil fields near the Utah-Wyoming state line. About 1050 feet (320 m) of Nugget was cut in the American Quasar Minnow Hill well (API 43-033-30018, Utah

DOGM; AMSTRAT log D-4952); about 1000 feet (300 m) of Nugget was cut in the Woodruff Narrows field Amoco 1-4H and Chevron-Amoco 1-32G wells (API 49-041-20289 and 49-041-20627 wells, WOGCC), with the 1-4H well just east of the Ogden map area. South of Woodruff Narrows 1011 feet (308 m) and 956 feet (291 m) of Nugget was cut in the Amoco Bradley and Chevron 1-35 wells (API 49-041-20509 and 49-041-20315, respectively, WOGCC), and 1040 feet (317 m) was cut in the Amoco A-MF-Chev well (after AMSTRAT log D-4943, API 43-033-30011). Farther south in the Yellow Creek field 1050 to 1150 feet (320-350 m) of Nugget was cut in the Champlin 375-Amoco C, Amoco Bradbury, Celsius [Mtn Fuel] 4-36, and Urroz wells, (API 49-041-20413, 49-041- 20421, 49-041-20578, and API 49-041-20321, WOGCC), and 1050 feet (320 m) of Nugget was cut in the Anschutz 14-33 well (API 43-043-30315, Utah DOGM). In the Cave Creek field about 1100 feet (335 m) of Nugget was cut in the Champlin 846-Amoco A (API 43-043-30100, Utah DOGM well file) and Fawcett & Son wells (AMSTRAT log D-5672, API 43-043-30078). In the Anschutz Ranch East field, 1145 feet, 1118 and 1056 feet (349, 340, and 322 m) of Nugget was cut in the ARE 30-10, U14-20, and Champlin 458-Amoco D1 wells (API 43-043-30215, 43-043-30145 and 43-043-30129, respectively, Utah DOGM). In the Anschutz Ranch (west) field 1096 and 1053 feet (334 and 321 m) of Nugget was cut in the Anschutz 28-1 and 34-2 wells (API 43-043-30032 and 43-043-30106, respectively, Utah DOGM), while the 1209 feet (369 m) of Nugget was cut in the Island Ranching D-1 well (API 43-043-30161, Utah DOGM) seems too large.

TRt *– Thaynes Formation, undivided (Lower Triassic).* Brownish-gray, thin-bedded, calcareous siltstone; gray, thin-bedded, silty shale; and thin- to medium-bedded, gray, fossiliferous limestone in upper and lower part; separated by a resistant ridge of gray, very thick- to medium-bedded, fossiliferous limestone in middle part (Coogan, 2004a, 2006a-b; this report); estimated thickness of 1850 feet (565 m) (upper tongue of Dinwoody not included) from several miles south of Weber River in Devils Slide quadrangle, about the same total thickness as to northeast in Lost Creek drainage, 1835 feet (560 m) (Coogan, 2006a-b; note about 1300 feet (400 m) in Dairy Ridge quadrangle (Coogan, 2006a).

In subsurface north of the map area, about 1930 feet (590 m) of Thaynes was cut in the American Quasar Putnam well in the Birch Creek fold belt (API 43-033-30002, Utah DOGM) and about 1700 to 1800 feet (510-540 m) was cut in the American Quasar Hoffman well near Randolph, Utah (API 43-033-30001, Utah DOGM). In the map area, estimate 2273 feet (693 m) of Thaynes penetrated in the Amoco Deseret WIU well, but not dip corrected (King after AMSTRAT log D-4948 and API 43-029-30009, Utah DOGM well file), and 2057 feet (627 m) of Thaynes was reportedly penetrated in the Champlin 432-Amoco C well in the Peck Canyon quadrangle (see API 043-29-30011, Utah DOGM well file). Member names are after Kummel (1954). Note that Kummel's (1954) members, from about 70 miles (110 km) to the north near Bear Lake in Idaho, are recognizable near Devils Slide and that most of these members are recognizable another 25 miles (40 km) to the southwest near Salt Lake City, Utah (see Mathews, 1931; Solien and others, 1979). Member descriptions from Coogan (2004a, 2006a-b) and this report.

Cn *– Nounan Formation (Cambrian).* Medium-dark-gray, thick-bedded dolomite and some limestone; estimated thickness 350 to 400 feet (105-120 m); see also Eardley (1944, his Cambrian units 6-8). The Nounan Formation does not appear to be present to the north of the map area in the Birch Creek fold belt (API 43-033-30042, 43-033-30043, 43-033-30028, and 43-033-30002, Utah DOGM), likely due to the unconformity that excised Silurian and Ordovician strata, and the Cambrian part of the St. Charles Formation elsewhere in the map area (see above).

***Cm, Cm?** – Maxfield Limestone (Middle Cambrian).* Limestone and calcareous siltstone; estimated thickness 300 feet (60 m); see also Eardley (1944, his Cambrian units 3-5). Queried where may be Nounan Formation (Cn). Bloomington Formation is not present on Durst Mountain. Strata in subsurface that are lithologically similar to Maxfield are called Gallatin Limestone (Cg) (Wyoming terminology).

Zkc, Zkc? – Kelley Canyon Formation (Neoproterozoic). Dark-gray to black, gray to olive-gray-weathering argillite to phyllite, with rare metacarbonate (for example basal meta-dolomite); grades into overlying Caddy Canyon quartzite with increasing quartzite; gradational interval mapped as Papoose Creek Formation (Zpc); 1000 feet (300 m) thick in Mantua quadrangle (this report), where Papoose Creek Formation is mapped separately, and reportedly 2000 feet (600 m) thick near Huntsville (Crittenden and others, 1971, figure 7), but only shown as about 1600 feet (500 m) thick to Papoose Creek transition zone by Crittenden (1972). The Kelley Canyon Formation is prone to slope failures.

***ZYp, ZYp? –** Formation of Perry Canyon (Neoproterozoic and possibly Mesoproterozoic).* Argillite to metagraywacke upper unit, middle meta-diamictite, and basal slate, argillite, and meta-sandstone; phyllitic at least south of Pineview Reservoir; due to overturned folding, only one diamictite unit (Adolph Yonkee, Weber State University, February 2, 2011, email communication) rather than two (see Crittenden and others, 1983); total thickness likely less than 2000 feet (600 m) (this report). Queried in knob west of North Fork Ogden River in North Ogden quadrangle because rock is quartzite that may be in this unit or the Papoose Creek Formation. The formation of Perry Canyon is prone to slope failures.

Balgord’s (2011; Balgord and others, 2013) detrital zircon uranium-lead and lead-lead maximum depositional ages (~950-1030 Ma) on the basal mudstone unit straddle the Upper and Middle Proterozoic boundary, but other maximum ages (925 Ma) on this mudstone unit are Upper Proterozoic; her maximum ages on the upper unit are about 640, 660, and 690 Ma.

Lower part of formation not measured where thick in the Wasatch Range and stratigraphy not worked out, because upper and lower parts incompletely measured and at least locally the upper and lower parts in the Wasatch Range are lithologically indistinguishable. Unit (“member”) thicknesses vary due to syndepositional faulting (see Balgord and others, 2013). The best stratigraphic section of the lower unit (ZYpm), volcanic unit (Zpb), and diamictite (Zpd) is 30 miles (50 km) to the southwest on Fremont Island in Great Salt Lake, but the base of ZYpm is not exposed (see Balgord, 2011, figure 14, p. 51; Balgord and others, 2013, figure 5). The Fremont Island section is likely in a different Proterozoic faulted basin; compare thicknesses and lithologies between Fremont Island and Willard Peak shown by Balgord (2011, Balgord and others (2013). Also, although both localities are shown on the

> Willard thrust sheet by Yonkee and Weil (2011), they may be on different thrust sheets. Therefore, the formal term Perry Canyon Formation is not used. Where possible divided into several lithosomes which have been called members.

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

Seismotectonic Setting

The property is located at the northeastern 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 physiographic 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 marked by 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 northeastern and southwestern margins of the valley. Coogan and King (2016) and the Utah Geological Survey Quaternary Fault Database (Black and others, 2003; January 2017 update) map these faults several miles to the northeast and west, respectively. Both faults were most-recently active more than 10,000 years ago (Sullivan and others, 1986). The nearest active (Holocene-age) fault to the site is the Weber segment of the Wasatch fault zone about 9.0 miles to the west.

The site is also in the central portion of the Intermountain Seismic Belt (ISB), a generally north-south trending zone of historical seismicity along the eastern margin of the Basin and Range province extending 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; the largest of these earthquakes was a M 7.5 event in 1959 near Hebgen Lake, Montana. None of these earthquakes occurred along the Wasatch fault or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest event was the 1934 Hansel Valley (M 6.6) event north of the Great Salt Lake. The March 18, 2020 M 5.7 earthquake north of Magna, Utah reportedly showed a style, location, and slip depth consistent with an earthquake on the Wasatch fault system (https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/executive). Despite being moderate in size (less than magnitude 6.0), this earthquake was felt from southern Idaho to south-central Utah and caused serious damage to multiple buildings (https://www.ksl.com/article/46731630/).

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. The highest (Bonneville) shoreline is mapped on Figure 2 (blue line and B) about 1,500 feet to the southwest north of the Project at an elevation of roughly 5,160 feet.

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).

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

Empirical Observations

On September 9, 2020 Bill D. Black, P.G. of Western Geologic conducted a brief reconnaissance of the property and nearby area. Weather at the time of the site visit was partly cloudy with a temperature of about 57 °F. A photographic record of our reconnaissance is included in the Appendix. The site is in southern Ogden Valley on slopes overlooking the south branch of South Fork Ogden River, which flows westward and northward along parts of the eastern and northern site boundaries. The Project straddles the valley basin-hillslope interface. The south part of the site slopes gently to the north-northeast, whereas the north part is nearly flat. Much of the site has been graded for agricultural use. Native vegetation appeared to consist of grasses and weeds, with mature cottonwood trees along the perimeter. Surficial soils appeared sandy with silt and gravel in some areas. Except for South Fork Ogden River, which was flowing at the time of our reconnaissance, no other evidence for perennial, intermittent or ephemeral drainages was observed. No seeps, springs, ongoing slope instability, characteristic debris flow features, bedrock outcrops or evidence for other geologic hazards was also observed.

Air Photo Observations

Black and white aerial photography from 1997, high-resolution orthophotography from 2012, and bare earth LIDAR (Light Imaging Detection and Ranging) digital elevation mapping from 2016 available from the Utah AGRC were reviewed to obtain information about the geomorphology of the Project area. Site-specific surficial geologic mapping for the area is shown on Figures 3A-C based on our air photo interpretations and mapping in Coogan and King (2016; Figure 2).

The site straddles the interface between slopes on the south and the floodplain of South Fork Ogden River on the north. Slopes on the south are underlain by lacustrine deposits from Lake Bonneville, which in turn overlie weathered Tertiary-age conglomerate. A post-Lake Bonneville alluvial fan underlies the southwest part of the site that appears to be inactive. The remainder of the site is on floodplain alluvium from South Fork Ogden River. The area of the proposed home is on gentle slopes underlain by lacustrine deposits. A heavily vegetated steep stream-cut slope is northeast of the proposed home location that is about 12 to 16 feet high and marks the approximate extent of the floodplain in this area. A dirt road follows the southern site boundary and marks the location of the Huntsville South Bench Canal, which is a buried conveyance. Several small runoff channels are evident from surface structures along the canal. No evidence for other geologic hazards was observed on the air photos at the site.

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. S denotes overall risk to the site, whereas H denotes risk to the specific area of the proposed home.

Table 1. *Geologic hazards summary.*

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

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. The Utah Geological Survey Quaternary Fault Database (Black and others, 2003; January 2017 update) shows numerous class A faults within 60 miles of the Project that may pose potential seismic sources.

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. Based on 2018 IBC provisions, a site class of D (stiff soil), and a risk category of II, calculated seismic values for the proposed home (centered on 41.238061° N, -111. 793482° W) are summarized below:

Table 2. *Seismic hazards summary.*

S_S	*0.778 g*
S_1	*0.27 g*
S_{MS} (F_a x S_S)	*0.925 g*
S_{M1} (F_v x S_1)	*See ASCE 7-16 Section 11.4.8*
S_{DS} (2/3 x S_{MS})	*0.617 g*
S_{D1} (2/3 x S_{M1})	*See ASCE 7-16 Section 11.4.8*
Site Coefficient, F_a	*= 1.189*
Site Coefficient, F_v	*See ASCE 7-16 Section 11.4.8*
Peak Ground Acceleration, PGA	*= 0.34 g*

Given the above information, we rate the hazard from earthquake ground shaking as high. Earthquake ground shaking is a regional hazard common to all Wasatch Front areas. The hazard is mitigated by design and construction of homes in accordance with the current adopted building code. We note that IBC 2018 provisions require calculation of the spectral acceleration value (S_{M1}), seismic design value (S_{D1}), and site coefficient (F_v) differently from IBC 2015. In municipalities where IBC 2018 has been adopted, the Project engineer or architect should determine these seismic values in accordance with ASCE 7-16 Section 11.4.8 guidelines.

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.

No evidence of active surface faulting is mapped or was evident at the site. The nearest active (Holocene-age) fault to the site is the Weber segment of the WFZ about 9.0 miles to the west. Given the above, the risk from surface faulting is 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 Natural Resources Conservation Service (NRCS) Web Soil Survey at https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx maps three soil types at the Project. The southeast part of the site and area of the proposed home is in “Hawkins-Collinston complex, 6 to 30 percent slopes”, which is described as a well-drained, hillslope soil formed in slope alluvium and/or colluvium derived from tuffaceous sandstone. A typical Hawkins-Collinston soil profile reportedly consists of silty clay to a depth of 13 inches, silty clay loam from 13 to 44 inches, and silty clay loam from 44 to 60 inches. The western part of the site is in “Nebeker clay loam, 3 to 6 percent slopes”, which is described as a well-drained, alluvial fan and terrace soil formed in lacustrine deposits. A typical Nebeker soil profile reportedly consists of clay loam to a depth of 20 inches, clay from 20 to 47 inches, and sandy clay loam and clay loam from 47 to 69 inches. The northern part of the site is in “Sunset loam, very gravelly substratum”, which is described as a somewhat poorly drained, floodplain and stream terrace soil formed in alluvium. A typical Sunset soil profile reportedly consists of loam to a depth of 24 inches, silt loam from 24 to 30 inches, very fine sandy loam from 30 to 36 inches, silt loam from 36 to 45 inches, and extremely gravelly sand from 45 to 63 inches.

Although the Project is in an area of potentially strong ground shaking and may have shallow groundwater is some areas, no subsurface soils likely susceptible to liquefaction appear to be present based on the soil descriptions above. We therefore rate the risk from liquefaction as low. Weber County hazard mapping also shows the site in an area of low liquefaction potential (code 1).

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. Given that the site is not on the downthrown side of any active faults, we rate the risk from tectonic subsidence as low.

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 relative elevations and distance to the nearest large body of water (Pineview Reservoir), we rate the risk from seismic seiches and storm surges as low.

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.

Except for South Fork Ogden River, no other perennial, intermittent or ephemeral drainages are mapped crossing the site, were evident on air photos, or were observed during our reconnaissance. Federal Emergency Management Agency flood insurance rate mapping (Map Number 49057C0457F, effective 06/02/2015) classifies the area along South Fork Ogden River as Zone AE, regulatory floodways with base elevation. However, most of the Project (including the area of the proposed home) is mapped in Zone X, areas of minimal flood hazard. Given the above, we rate the risk to the overall site as moderate and the risk to the area of the proposed home as low.

Shallow Groundwater

Given evidence discussed in the Hydrology Section above, groundwater in the area of the proposed home is likely from 10 to 15 feet deep, but groundwater may be 0 to 10 feet deep in the floodplain of South Fork Ogden River further north. Given the above, we rate the risk from shallow groundwater to the overall site as moderate, but rate the risk as low to the proposed home. Although shallower levels may occur seasonally, as would be expected for an alpine environment, we do not anticipate that groundwater will pose a significant development constraint. However, we conservatively recommend that a foundation drainage system be installed if the proposed home will include a basement given that anticipated footing depths and the seasonal water table depth may be close. The design should be provided or reviewed (and approved) by a licensed geotechnical engineer. Care should be taken that proper surface and subsurface drainage is maintained.

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. Steep slopes underlain by landslide-prone bedrock (such as the Norwood Formation), slopes exhibiting prior failures, and deposits from landslides are particularly vulnerable to instability.

No landslides are mapped at the Project, and no evidence for landsliding or ongoing slope instability was observed during our reconnaissance. Based on geoprocessed LIDAR data, slopes across the area of the proposed home dip to the northwest at about an overall 12.5% gradient (7.12 degrees, or 8:1 horizontal:vertical). Given the above, we rate the risk from landslides as low. However, a steep (1.5:1) stream-cut slope is about 24 feet northeast of the proposed home that is about 16 feet high; the slope toe is about 48 feet northeast of the proposed home. Although stability of this slope would need to be confirmed by a licensed geotechnical engineer, it is our opinion that the slope is not sufficiently high to pose a landslide risk if the proposed home includes a basement. The base of the footings for the proposed home would be at a 6:1 gradient from the slope toe if the footings extended to a depth of 8 feet below existing grade (which would be half the slope height).

Steep man-made cuts and non-engineered fill materials are also major contributors to slope instability. In addition to maintaining proper surface and subsurface drainage, care should be taken that no fill materials are emplaced beneath the structure footprint without engineered compaction and that no unplanned cuts are made in the slopes without prior geotechnical consultation.

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 caused significant damage in the Wasatch Front area. The proposed home is not in an area currently subject to alluvial-fan flooding and no debris-flow channels, levees, or other debris-flow features were observed. We therefore rate the hazard from debris flows to the Project as low.

Rock Fall

No bedrock outcrops were observed at the site or in higher slopes that could present a source area for rock fall clasts. We therefore rate the hazard from rock falls to the Project as low.

Problem Soil and Rock

Surficial soils that contain certain clays can swell or collapse when wet. No soils likely susceptible to swelling or collapse appear to be present based on the soil units mapped at the site by the NRCS and described in the Liquefaction Section above. Weber County hazard mapping also shows no areas of expansive soil or rock at the Project. Given the above, we rate the risk from problem soil and rock as low. However, it would be prudent to have a geotechnical engineer observe the foundation excavation for the home once it is open to check for subsurface conditions (such as problem soils) that could affect performance of the planned structure.

CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking is the only geologic hazard that poses a high relative risk to the Project. The hazard from ground shaking is common to all Wasatch Front areas. No other high-risk hazards were identified. We recommend the following:

- ***Seismic Design –*** All habitable structures developed at the property should be constructed to current adopted seismic building codes to reduce the risk of damage, injury, or loss of life from earthquake ground shaking. Earthquake ground shaking is a common hazard for all Wasatch Front areas.

- ***Foundation Drainage –*** We recommend the proposed home include a foundation drainage system to reduce risk from seasonal shallow groundwater and ensure that proper subsurface drainage is maintained. We recommend the design be provided or reviewed (and approved) by a licensed geotechnical engineer.

- ***Geotechnical Considerations –*** We recommend that a Utah-licensed geotechnical engineer observe the foundation excavation for the home once it is open to ensure no subsurface conditions are present that would affect performance of the planned structure. The purpose of the excavation observation is to evaluate the need for design-specific recommendations with regard to foundation conditions.

- ***Report Availability –*** This report and any subsequent reports regarding geologic conditions at the property should be made available to the architect and building contractor, as well as real estate agents and potential buyers in the event of a future sale. 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 the authors and should not be copied, used, or modified without their express permission.

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 the Project. Should you have any questions, please call.

Sincerely,
Western Geologic & Environmental LLC

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09/14/2020
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Bill. D. Black, P.G.
Subcontract Engineering Geologist

Reviewed By:

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ATTACHMENTS
Figure 1. Location Map (8.5"x11")
Figure 2. Geologic Map (8.5"x11")
Figure 3A. 1997 Air Photo (8.5"x11")
Figure 3B. 2012 Air Photo (8.5"x11")
Figure 3C. LIDAR Analysis (8.5"x11")
Appendix. Photographic Record of Site Reconnaissance

C:\Users\GLENDA\Documents\WG&E\PROJECTS\Peterson Builders\Huntsville, UT - Geo Haz Recon - Buhrley South Fork Ranch Lot 4 #5495\Geo Haz Recon - Buhrley South Fork Ranch Lot 4 - Huntsville, UT.docx

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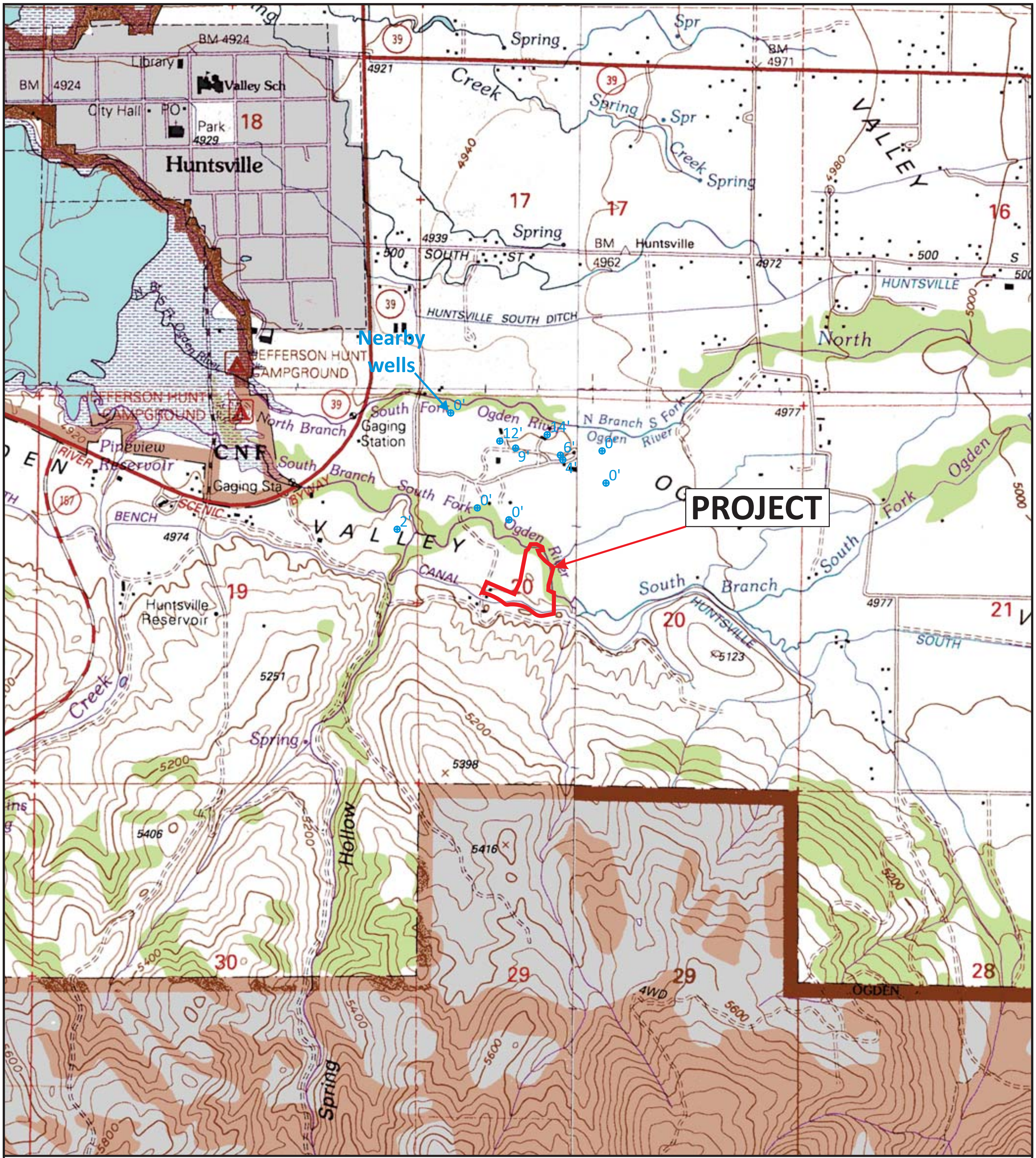
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Huntsville, Browns Hole, Durst Mountain and Snow Basin, 1998; Project location W1/2, Section 20, T6N, R2E (SLBM).

LOCATION MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E.
Huntsville, Weber County, Utah

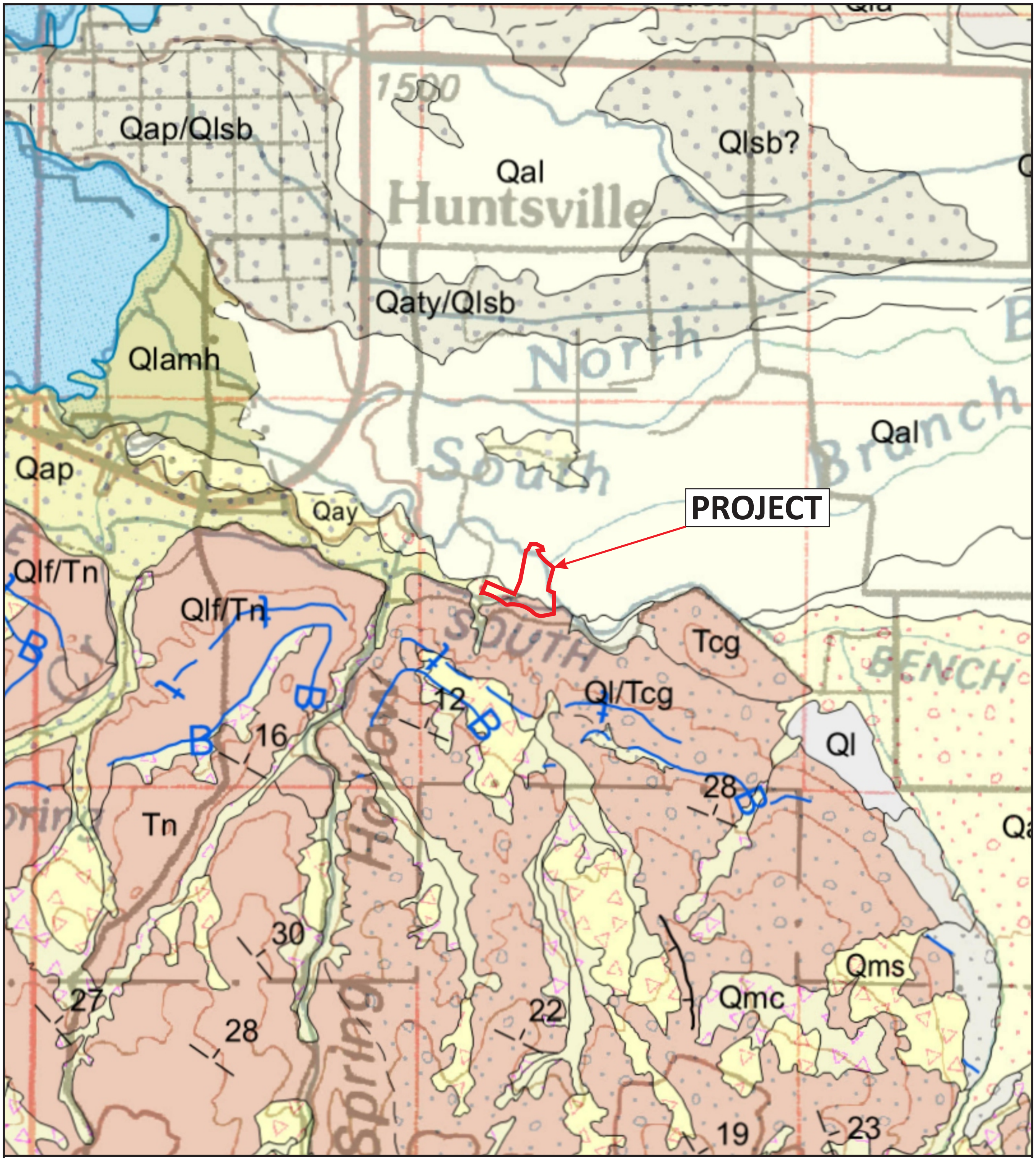
FIGURE 1

WESTERN GEOLOGIC

N
W E
S

0 1000 2000 feet

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



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

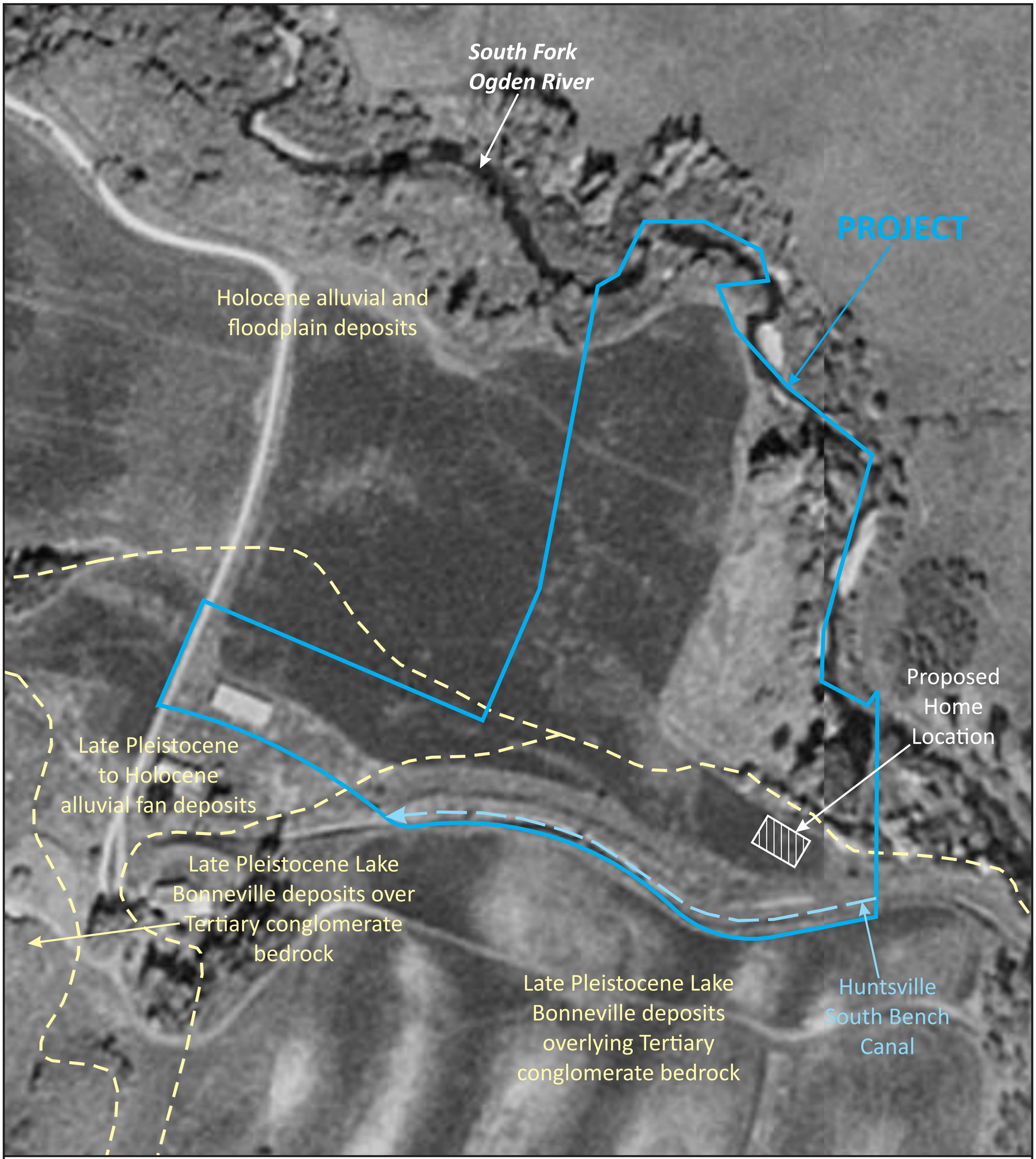
Scale 1:24,000
(1 inch = 2000 feet)

GEOLOGIC MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E.
Huntsville, Weber County, Utah

FIGURE 2



Source: Utah AGRC 1997 Digital Orthophoto, 1 m resolution.

Scale 1:2,400
(1 inch = 200 feet)

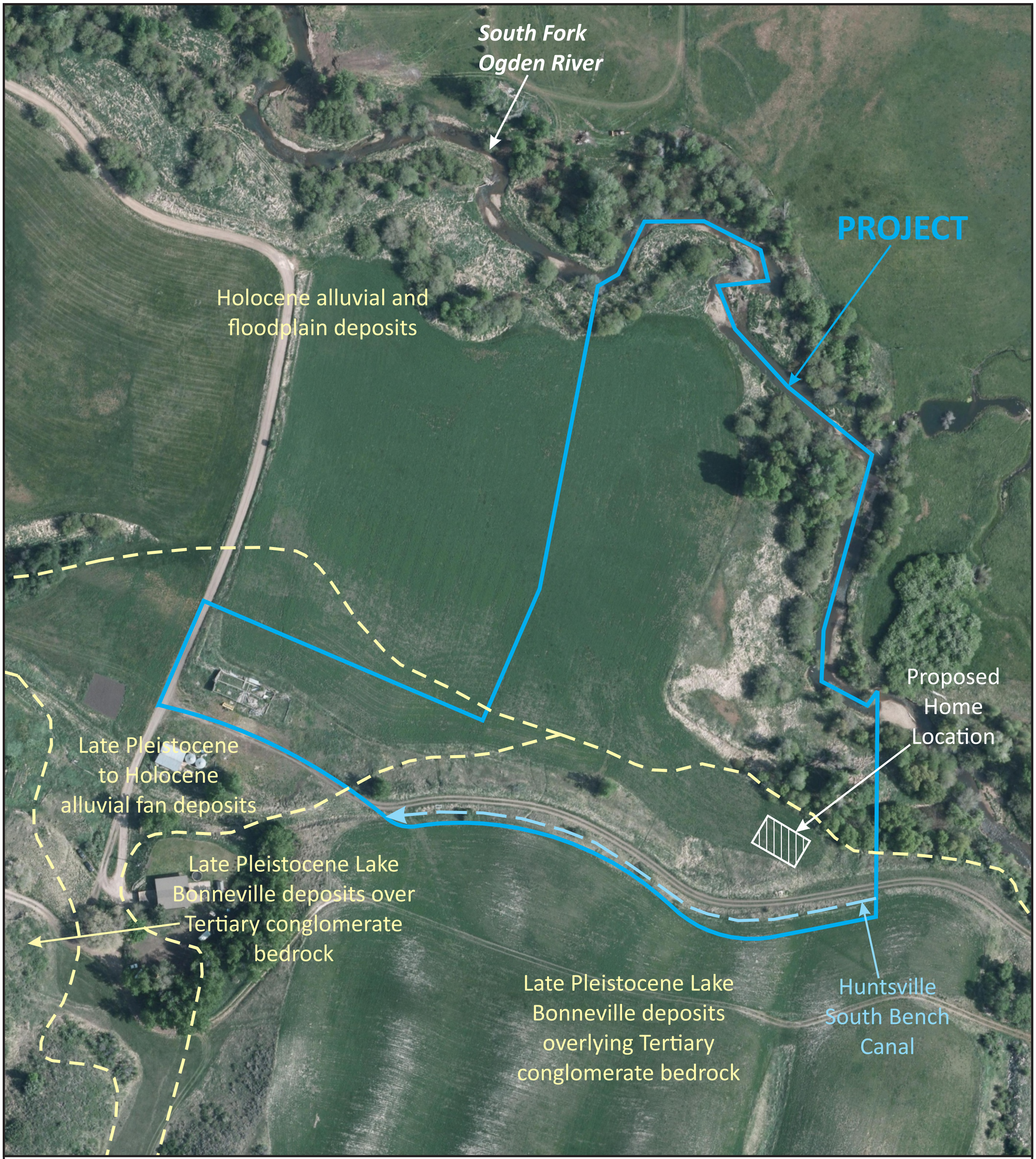
WESTERN GEOLOGIC

1997 AERIAL PHOTO

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E.
Huntsville, Weber County, Utah

FIGURE 3A



Source: Utah AGRC, 2012 High Resolution Orthophoto, 12.5 cm resolution.

Scale 1:2,400
(1 inch = 200 feet)

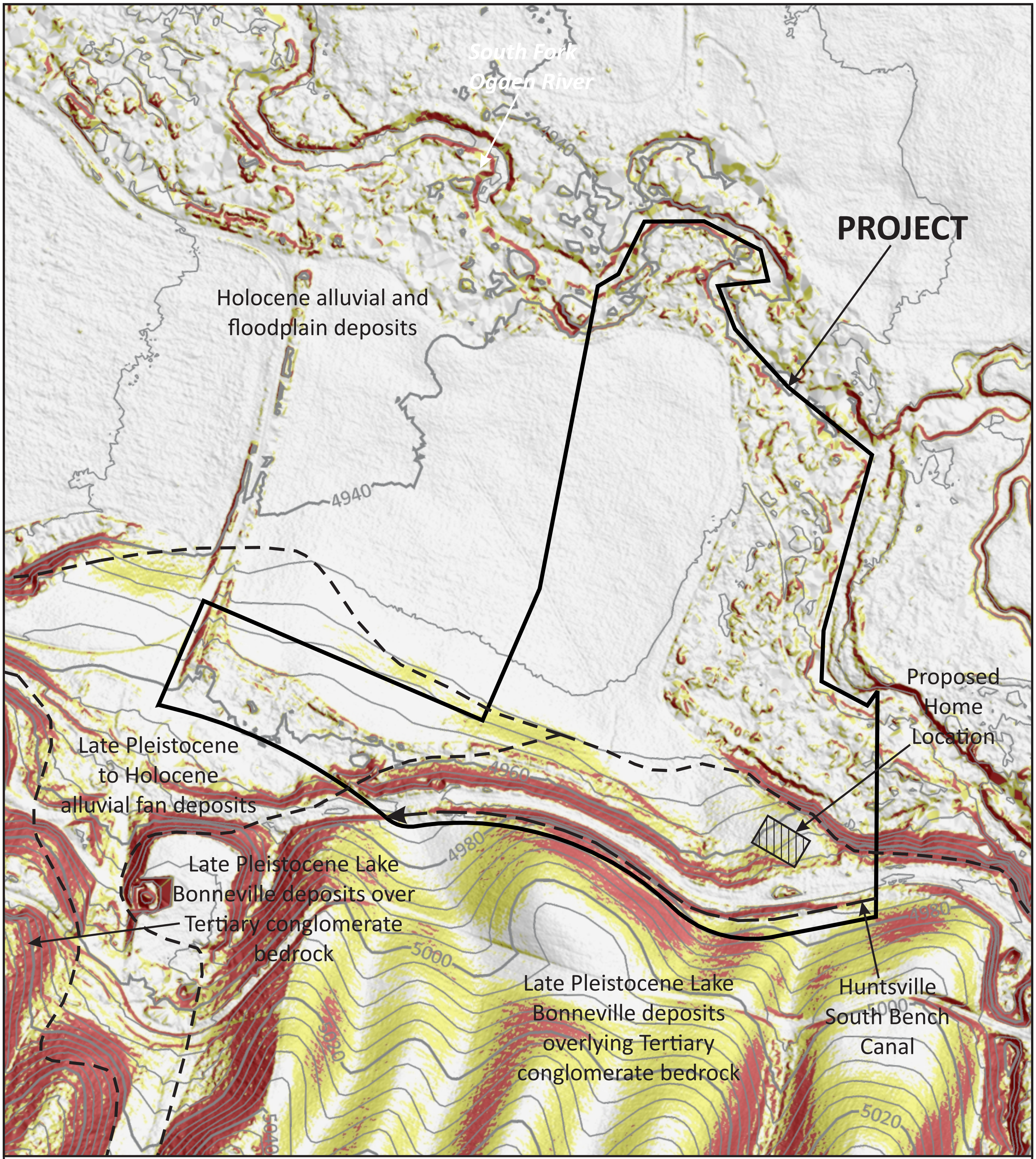
WESTERN GEOLOGIC

2012 AERIAL PHOTO

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E.
Huntsville, Weber County, Utah

FIGURE 3B



Source: Utah AGRC, 2016 LIDAR Bare Earth DEM, 50 cm resolution; 4-foot contour interval; slope gradients <15% unshaded, 15-25% in yellow, and >25% in red.

LIDAR ANALYSIS

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E.
Huntsville, Weber County, Utah

FIGURE 3C

N
W E
S

0 100 200 feet

Scale 1:2,400
(1 inch = 200 feet)

APPENDIX

Photographic Record of Site Reconnaissance
Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E., Huntsville, Weber County, Utah

Photo 1. View north across eastern part of site.

Photo 2. South branch, South Fork Ogden River, and area to the east.

Photographic Record of Site Reconnaissance
Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E., Huntsville, Weber County, Utah

Photo 3. View south across site.

Photo 4. View west across site.

Photographic Record of Site Reconnaissance
Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E., Huntsville, Weber County, Utah

Photo 5. Area of proposed home.

Photo 6. Slopes along southern site boundary, terrace at location of buried canal.

Photographic Record of Site Reconnaissance
Proposed Buhrley South Fork Ranch Lot 4
W1/2 Section 20, T. 6 N., R. 2 E., Huntsville, Weber County, Utah

Photo 7. Stream-cut slope northeast of (below) proposed home location.

Photo 8. View to northeast across site.