REPORT

GEOLOGIC HAZARDS RECONNAISSANCE

HIDDEN COVE SUBDIVISION

6260 SOUTH 2125 EAST

OGDEN, WEBER COUNTY, UTAH

Prepared for

Blue Mountain Homes
PO Box 65999
Salt Lake City, Utah 84165

April 27, 2018

Prepared by

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April 27, 2018

Donald Fulton
Blue Mountain Homes
PO Box 65999
Salt Lake City, Utah 84165

SUBJECT: Geologic Hazards Reconnaissance
Hidden Oak Subdivision
6260 South 2125 East
Ogden, Weber County, Utah

Dear Mr. Fulton:

This report presents results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for the proposed Hidden Oak Subdivision located at 6260 Jared Way (2125 East) in unincorporated Weber County, Utah (Figure 1 – Project Location). The Project consists of a 3.29-acre parcel identified as Weber County Assessor parcel number 07-665-0001. The site is located west of the mouth of Weber Canyon in the SW1/4 Section 23, Township 5 North, Range 1 West (Salt Lake Base Line and Meridian; Figure 1). Elevation of the site ranges between about 4,720 to 4,825 feet above sea level. The parcel is currently planned for development of a three-lot residential subdivision based on a November 2017 preliminary plat map prepared by Pinnacle Engineering.

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 exploration were conducted for our study.

Western GeoLogic previously assisted Earthtec Testing & Engineering in preparation of a combined geologic and geotechnical report for the site in February 2003 (ETE, 2003). The property at that time was named the Kunzler Subdivision. Geology and geologic hazards of the Project were discussed in Sections 9 and 10 of ETE (2003). The report herein updates and replaces our geologic and geologic hazard sections provided in ETE (2003). Earthtec

Engineering similarly prepared an updated geotechnical report for the proposed Hidden Oak Subdivision in December 2017 (Earthtec, 2017). No review of geotechnical data, analyses, findings, or recommendations, such as may be provided in ETE (2003) or Earthtec (2017), was conducted or considered within our professional scope.

The following services were performed:

- A site reconnaissance conducted by an experienced certified engineering geologist to assess the site setting and look for adverse or differing geologic conditions from those observed in 2003;

- Compilation and 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 Ogden Quadrangle shows the site is just below the crest of a south-facing terrace west of the Wasatch Range Front. The Weber River floodplain is several miles to the south. No active drainages or springs are shown at the site on Figure 1, and no springs or seeps were observed or reported at the site.

Subsurface hydrology in the area is dominated by the East Shore aquifer system. This aquifer system is comprised of a shallow, unconfined water table zone, and the deeper, often confined, Sunset and Delta aquifers (Feth and others, 1966). The depth to the shallow unconfined aquifer varies somewhat depending on topography and climatic and seasonal fluctuations. It is influenced by seepage from irrigation systems, and infiltration from precipitation and urban runoff. The Sunset aquifer (typical depth 250-400 feet) and Delta aquifer (typical depth 500-700 feet) provide water that generally meets the standards for public drinking water supply. Based on topography, the regional groundwater flow is expected to be to the south-southwest toward the Weber River floodplain.

No groundwater was encountered in ETE’s (2003) test pit excavations to an explored depth of 11 feet, but ETE (2006) conducted a subsequent boring in the northwest part of the Project that reportedly encountered groundwater at a depth of 18 feet. Given this, it is likely that groundwater at the site is between 15 and 20 feet deep. However, groundwater depth at the site likely varies seasonally from snowmelt runoff and annually from climatic fluctuations. Such variations would be typical for the region. Perched conditions may also be present in the subsurface that could cause locally shallower groundwater levels.

GEOLOGY

Surficial Geology

The site is located about a mile west of the western base of the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986). Coogan and King (2016; Figure 2) map the surficial geology of the Project as mainly younger Quaternary landslide deposits (unit Qmsy). The terrace north of the Project is mapped as lacustrine and deltaic deposits associated with the regressive stage of Pleistocene Lake Bonneville on the north (Qadp).

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.
>
> ***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.

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.

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).

Qat2, Qat3 – *Stream-terrace alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in terraces inset into late Pleistocene Weber River delta above Weber River flood plain; moderately to well-sorted, pebble and cobble gravel and gravelly sand with subangular to rounded clasts; unconsolidated to weakly consolidated; upper surfaces slope gently downstream; locally includes thin and small mass-movement and alluvial-fan deposits; subdivided into relative ages, indicated by number suffixes, with 2 being the lowest/youngest terraces and 3 divided by a scarp on the map into an upper and lower terrace; terraces 20 to 50 feet (6-16 m) above the Weber River; exposed thickness less than 20 to 50 feet (6-16 m) (after Yonkee and Lowe, 2004). These terraces do not fit into table 1 or 2 because they post-date the regression of Lake Bonneville from the Provo shoreline and appear to be graded to lake levels below the Gilbert shoreline.

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).

Qct *- Colluvium and talus, undivided (Holocene and Pleistocene).* Unsorted clay- to boulder-sized angular debris (scree) at the base of and on steep, typically partly vegetated slopes; shown mostly on steep slopes of resistant bedrock units; 6 to 30 feet (2-9 m) thick.

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).

Qadp, Qadp? *- Provo-shoreline and regressive 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; mapped below/near the Provo shoreline and related to the Provo and slightly lower regressional shorelines; deposits prominent east of Brigham City, at mouth of North Ogden Canyon, and on bench north of the Weber River; deposited as delta foreset beds with original dips of 30 to 35 degrees that allow separation from mixed lacustrine deposits (Qdlp); deltaic deposits at least 40 feet (12 m) thick and contain subrounded to well-rounded pebble and cobble gravel in a matrix of sand and silt with interbeds of sand and silt; capped by gently dipping alluvial-fan and stream topset beds that are less than 16 feet (5 m) thick, are poorly to moderately sorted, silty to sandy, subangular to well-rounded pebble and cobble gravel, and contain subangular to angular clasts in a matrix of sand and silt with interbeds of sand and silt (see units lpd and alp of Personius, 1990).

East of Brigham City at the mouth of Box Elder Canyon these deposits have been extensively excavated for sand and gravel. King estimates these deposits are about 200 feet (60 m) thick (from topographic contours) south of the mouth of Box Elder Creek, while Smith and Jol (1992) implied they are 400 feet (120 m) thick to the west of the Ogden map area.

The Provo shoreline fan-delta sediments were eroded from Bonneville-shoreline lacustrine and alluvial deposits, contain 20 to 70 percent rounded recycled Lake Bonneville clasts (Personius, 1990), and were redeposited during and soon after the Bonneville flood, which occurred during the drop of Lake Bonneville to the Provo shoreline. The Qadp unit probably includes Provo-stillstand deltaic deposits, sub-Provo-stillstand (regressional) alluvial-fan and lacustrine-deltaic deposits that contain abundant reworked materials from the Provo-shoreline delta, and locally overlying alluvial-fan deposits. Personius (1990) noted that deposits at the mouth of Box Elder Canyon are a fan-delta. A fan-delta is built when an alluvial fan enters a lake or ocean and includes both the fan and the delta.

Qlg, Qlg?, Qlgp, Qlgb, Qlgb? - *Lake Bonneville gravel and sand (upper Pleistocene).* Mostly interbedded pebble and cobble gravel and sand deposited along beaches and slightly offshore; varies from clast supported to only rare gravel clasts in a matrix of sand and silt; grades downslope and, locally, laterally into finer grained deposits (Qls, Qlsp, Qlsb); mapped as Qlg downslope from topographic slope break of Provo and regressive beaches (Qlgp) because gravel and sand may be related to Lake Bonneville transgression on this gentler slope; also mapped as Qlg where Provo shoreline not distinct or relationships to shorelines uncertain; Qlg and Qlgb queried where grain size or unit identification uncertain; up to about 100 feet (30 m) thick in gravel pits but less than 20 feet (6 m) thick on most valley slopes. Constructional landforms (beach ridges, bars, and spits) and transgressive (t) shorelines limited in Ogden map area.

Qlgp is mapped in beaches near and below the erosional bench at the Provo shoreline (P); gravel typically subrounded to rounded, but locally along bedrock mountain fronts marked by a carbonate-cemented, poorly sorted, angular pebble to boulder gravel in a sandy matrix.

Qlgb is mapped in beaches mostly just downslope from Bonneville shoreline (B), typically an eroded bench, and above Provo shoreline; deposited during transgression to and occupation of the Bonneville shoreline; clasts typically subrounded to rounded but contains subangular to angular clasts on steep bedrock mountain fronts; mountain front Bonneville shoreline benches covered by locally mappable (> 6 feet [2 m] thick) colluvium and talus (Qmt, Qc, Qct).

Xfcb, Xfcb? - *Biotite-rich schist (Paleoproterozoic).* Medium-gray to dark-brown, strongly foliated, biotite-rich schist with widespread garnet and sillimanite; displays alternating biotite-rich and quartz-feldspar-rich bands that are rotated into complex fold patterns; cut by garnet-bearing pegmatite dikes; also contains some thin layers of amphibolite, quartz-rich gneiss, and granitic gneiss; gradational contacts with migmatitic gneiss.

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

Seismotectonic Setting

The property is located along the western base of the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes, 1977, 1986). The Basin and Range province 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 (WFZ) 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 WFZ is one of the longest and most active normal-slip faults in the world and extends for 213 miles along the western base of the Wasatch Range from southeastern Idaho to north-central Utah (Machette and others, 1992). The fault zone generally trends north-south and, at the surface, can form a zone of deformation up to several hundred feet wide containing many subparallel west-dipping main faults and east-dipping antithetic faults. Previous studies divided the fault zone into 10 segments, each of which rupture independently and are capable of generating large-magnitude surface-faulting earthquakes (Machette and others, 1992). The central five segments of the fault (Brigham City, Weber, Salt Lake, Provo, and Nephi) have each produced two or more surface-faulting earthquakes in the past 6,000 years (Black and others, 2003).

The Weber segment of the WFZ extends for about 35 miles from the southern edge of the Plain View salient near North Ogden to the northern edge of the Salt Lake salient near North Salt Lake (Machette and others, 1992). The main trace of the Weber segment is mapped about 0.9 miles east of the Project (Figure 2, heavy black line). Several paleoseismic studies have been conducted on the Weber segment to evaluate its Holocene earthquake history. Nelson and others (2006) report finding evidence for four large-magnitude earthquakes at the Garner Canyon and East Ogden sites, including what they infer was a partial segment rupture (with 1.6 feet of displacement) around 500 years ago. This partial segment rupture was not evident at the Kaysville site of McCalpin and others (1994), although chronologic intervals for the remaining three earthquakes were similar. DuRoss and others (2009) indicate that paleoseismic data from the 2007 Rice Creek site support a preferred scenario of six surface-faulting earthquakes in Holocene time, with four events since about 5,400 years ago, and confirm Nelson and others' (2006) partial segment rupture timing.

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_S 7.5 event in 1959 near Hebgen Lake, Montana. However, 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 of these events was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake.

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).

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 site is located below the Bonneville shoreline, which is to the east (blue line and B, Figure 2). The Provo shoreline is not mapped in the area but would be at an elevation similar to the terrace north of the site.

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. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Drainages that fed Lake Bonneville began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. 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 April 26, 2018, Bill D. Black, P.G. of Western GeoLogic conducted a reconnaissance of the property. Weather at the time of the site reconnaissance was clear and sunny with temperatures in the low 60's (°F). The site is at the crest of a south-facing deltaic terrace stranded by downcutting by the Weber River following the retreat of Pleistocene Lake Bonneville. Vegetation at the Project consists mainly of mature oak trees, heavy oak brush, and grasses.

The Project is situated in an amphitheater formed by erosional degradation of a prehistoric landslide that initiated in the south-facing slopes below the terrace crest from a combination of steep slopes, unstable sediments, shallow groundwater, and/or liquefaction from a prior large-magnitude earthquake on the Wasatch fault zone. The landslide is part of a discontinuous complex of overlapping, historic and prehistoric landslides of various failure mechanisms, including shallow and deep-seated rotational slides as well as flow failures. The landslide complex extends westward along the south-facing terrace between Uintah and Washington Terrace (unit Qmsy, Figure 2); a corresponding landslide complex is also in the north-facing slopes south of the Weber River. Surficial soils at the Project appeared to consist mainly of sandy gravel to gravelly sand with silt and subround to round cobbles. A mound from landslide deposition and/or post-landslide scarp degradation was observed at the mouth of the amphitheater that appeared to consist mainly of sand at the surface. Based on this and our experience in the area, it is likely that colluvium mantling the slopes at the Project is shallow but thickens downslope in the amphitheater bottom and to the south. Fill materials from construction of U.S. 89 may also be present at the amphitheater mouth, although we anticipate that most of the material from road grading would have been emplaced on the downslope (south) side of the highway. No evidence of springs, seeps, surface water drainage channels, recent or ongoing slope instability, or other geologic hazards was observed during our reconnaissance.

Air Photo Observations
Black and white and color orthophotography from 1997 and 2012, and Bare Earth DEM LIDAR imagery from 2013 available from the Utah AGRC (Figures 3A-3C) were reviewed to obtain information about the geomorphology of the Project area. The site is at and below the crest of a stranded deltaic terrace overlooking the Weber River floodplain in an amphitheater bounded by steep slopes on the north, west, and east. The amphitheater was created by a prehistoric landslide that was subsequently eroded, and slopes bounding the amphitheater are heavily vegetated and show about a 2:1 to 4:1 (horizontal:vertical) steepness. Shallowest slopes are found along a gentle swale in the northeast part of the Project. No other geologic hazards were observed at the site or in the area on the photos.

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	…Hazard Rating
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). Assuming 2015 IBC design codes, 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: 41.1488° N, -111.9261° W)

S_S	*1.316 g*
S_1	*0.490 g*
S_{MS} (F_a x S_S)	*1.316 g*
S_{M1} (F_v x S_1)	*0.740 g*
S_{DS} (2/3 x S_{MS})	*0.877 g*
S_{D1} (2/3 x S_{M1})	*0.494 g*
Site Coefficient, F_a	*=1.000*
Site Coefficient, F_v	*=1.510*

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

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 WFZ about 0.9 miles to the east (Figure 2), and no evidence of active surface faulting is mapped or was evident at the site. Based on this, the hazard from surface faulting is rated as 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.

Sandy soils may be present in the subsurface that could be susceptible to liquefaction, the site is in an area of potentially strong ground shaking, and groundwater appears to be between 15 to 20 feet deep. Although these factors would suggest the risk may be high, subsurface conditions are not known and may vary. We therefore rate the risk from liquefaction as moderate. The hazard should be confirmed in a geotechnical engineering evaluation conducted prior to construction, and recommendations provided as needed. Liquefaction in the slopes at the site will likely manifest as landsliding.

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 adjacent to any mapped active faults and we therefore rate the hazard 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 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.

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.

No active drainages subject to stream flooding cross the Project or were observed during our reconnaissance, and Weber County hazard maps do not show the site in a FEMA hazard zone subject to flooding. Given the above, we rate the risk from stream flooding as low. Site hydrology and drainage should be addressed in the civil engineering design or grading plan, in accordance with all applicable local government development guidelines.

Shallow Groundwater
Based on limited boring data, groundwater in the amphitheater at the site appears to be between 15 to 20 feet deep. However, groundwater depths may vary locally and seasonally, or if perched conditions are present. We therefore rate the risk from shallow groundwater as moderate. The hazard should be confirmed in a geotechnical engineering evaluation conducted prior to construction, and recommendations provided as needed to maintain proper foundation drainage.

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.

The Project is at and below the crest of a deltaic terrace formed by downcutting by the Weber River following the retreat of Lake Bonneville. This terrace has been subsequently impacted by a landslide triggered in the oversteepened slopes, which formed an amphitheater bounded by slopes of from 2:1 to 4:1 in steepness. No evidence for recent or ongoing slope instability was observed during our reconnaissance and the slopes are heavily vegetated. Colluvium from the landslide and/or post-scarp degradation likely increases in thickness downslope into the amphitheater bottom and to the south and appears to comprise (at least in part) a mound present at the amphitheater mouth.

Given that the site is in an area of prehistoric landsliding and slopes are relatively steep, we rate the risk from landsliding as high. We recommend that stability of the slopes be evaluated in a geotechnical engineering evaluation prior to building. Recommendations should be provided to reduce the landslide hazard risk if factors of safety are determined to be unsuitable. The geotechnical evaluation should be based on site-specific data and geologic characterizations. 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 and septic systems is minimized in and adjacent to steep slopes.

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. No evidence for debris-flow channels, levees, or other debris-flow features was observed at the site or on air photos. Based on the above, we rate the existing risk from debris flows at the site as low.

Rock Fall
No bedrock outcrops were observed at the site or in adjacent higher slopes that could present a source area for rock fall clasts. Given this, we rate the risk from rock falls as low.

Swelling and Collapsible Soils
Surficial soils that contain certain clays can swell or collapse when wet. Given anticipated subsurface conditions, such soils appear unlikely to be present and the risk from problem soils is rated as low. Subsurface soil conditions should be confirmed in the geotechnical engineering evaluation and recommendations provided as needed for site grading, subgrade preparation, and footing and foundation design.

FINDINGS AND RECOMMENDATIONS

Earthquake ground shaking and landslides are identified as geologic hazards posing a high relative risk to the Project. Liquefaction and shallow groundwater are identified as posing a moderate risk. We recommend the following:

- ***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.

- ***Geotechnical Evaluation*** **–** A design-level geotechnical engineering study should be conducted prior to construction to: (1) confirm subsurface soil conditions; (2) assess the potential for shallow groundwater and liquefaction, including providing recommendations to reduce risk from these hazards as needed; (3) provide recommendations regarding site grading, subgrade preparation, and footing and foundation design; (4) provide recommendations regarding building design to reduce risk from seismic acceleration; and (5) evaluate the stability of slopes at the site. The stability evaluation should be based on site-specific geotechnical data and geologic characterizations, account for possible varying groundwater conditions, and provide recommendations for reducing the risk of landsliding if the factors of safety are deemed unsuitable.

- ***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   Reviewed by:

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

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

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. 2011 LIDAR Image (8.5”x11”)
Figure 3C. 2012 Air Photo (8.5”x11”)
Appendix. Photographic Record of Site Reconnaissance

P:\Blue Mountain Homes\Ogden, UT - Geologic Hazards Recon - Hidden Oak Subdiv - 6260 South 2125 East #4649\Geologic Hazards Reconnaissance - Hidden Oak Subdivision - 6260 South 2125 East.docx

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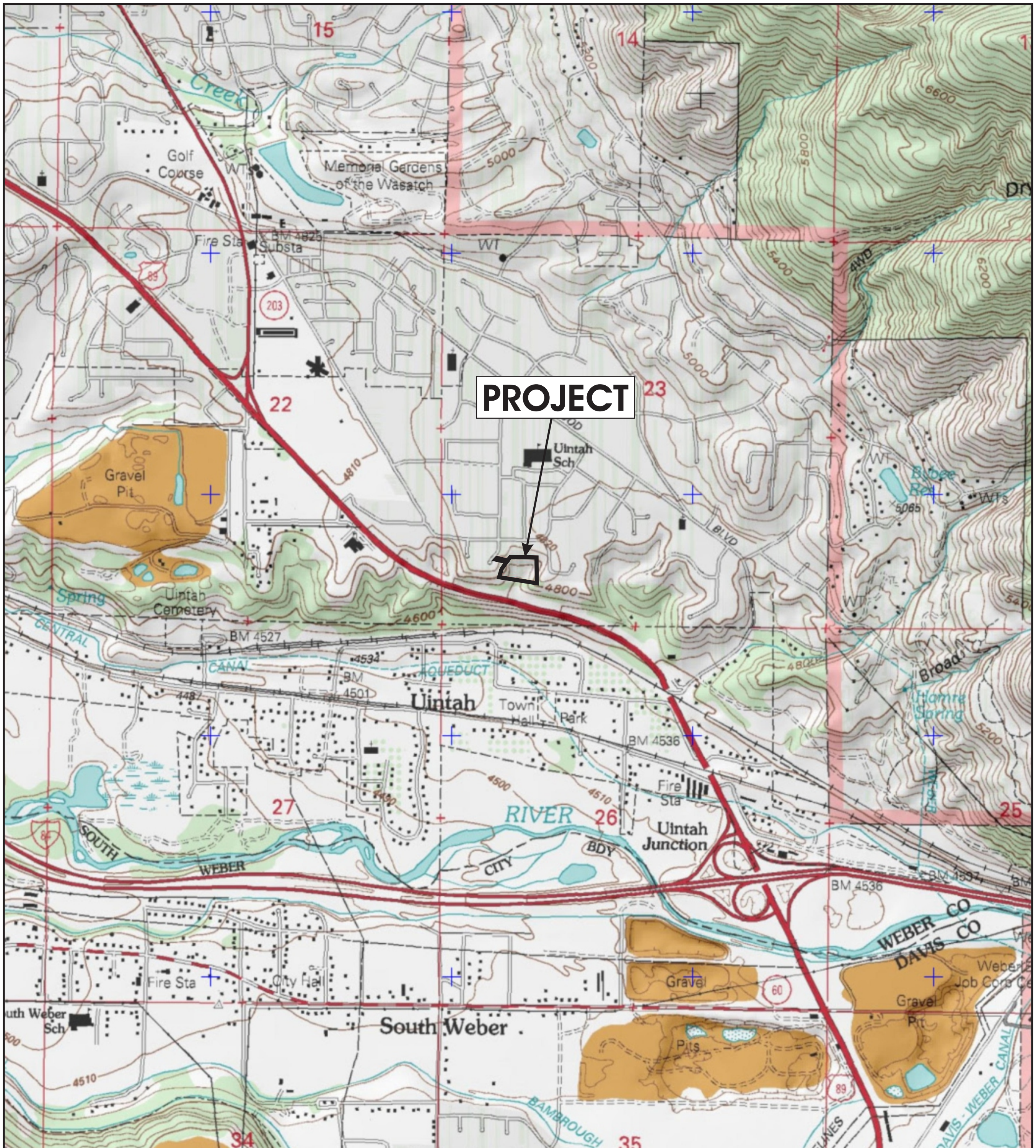
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Ogden, 1998;
Project location SW1/4, Section 23, T5N, R1W (SLBM); 41.11488° N, -111.9261° W.

N
W E
S

0 1000 2000 feet

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

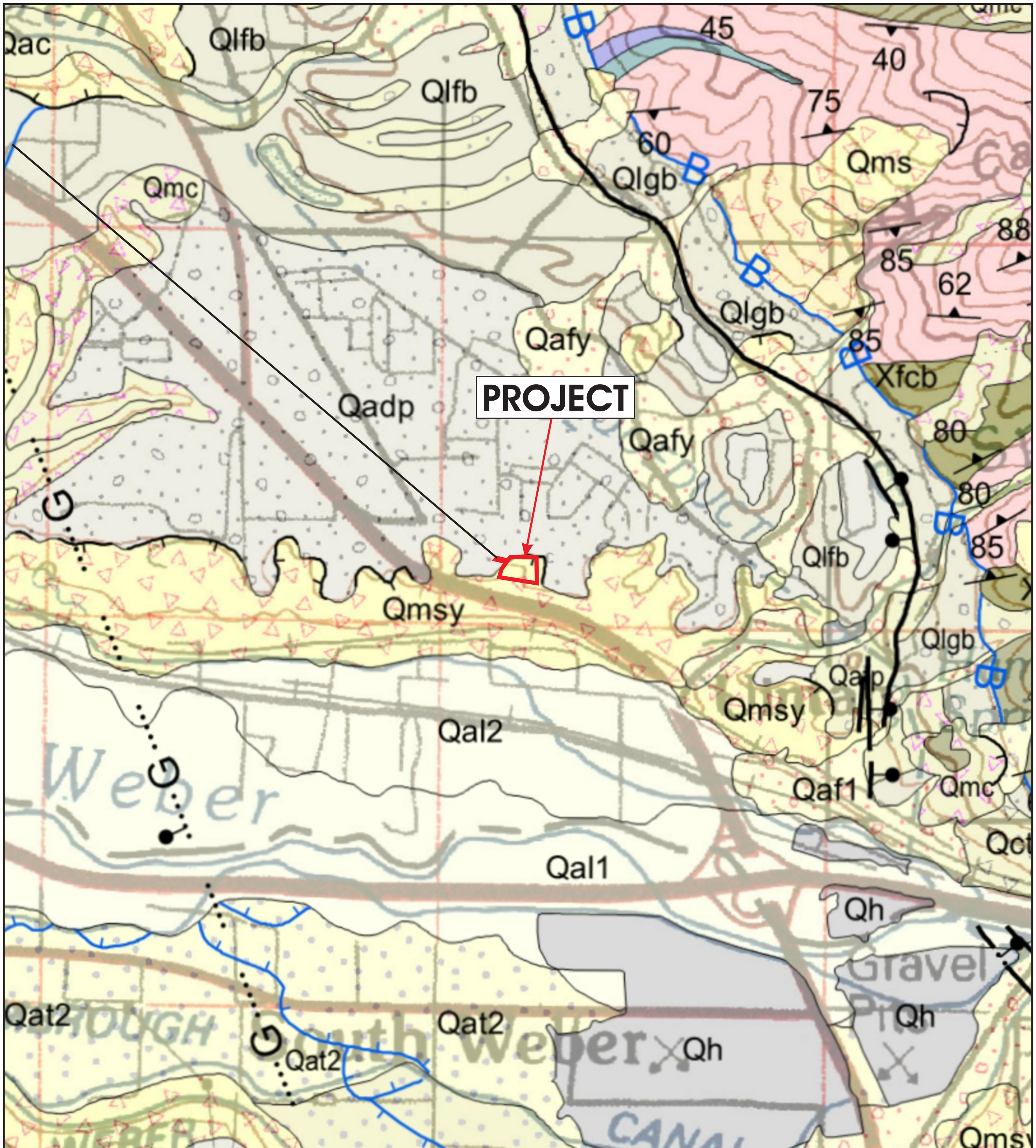
WESTERN GEOLOGIC

LOCATION MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Hidden Oak Subdivision
6260 South 2125 East
Ogden, 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.

N
W E
S

0 1000 2000 feet

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

WESTERN GEOLOGIC

GEOLOGIC MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Hidden Oak Subdivision
6260 South 2125 East
Ogden, Weber County, Utah

FIGURE 2

Source: Utah AGRC , 1997 digital orthophoto.

WESTERN GEOLOGIC

N W E S

0 100 200 feet

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

1997 AIR PHOTO

GEOLOGIC HAZARDS RECONNAISSANCE

Hidden Oak Subdivision
6260 South 2125 East
Ogden, Weber County, Utah

FIGURE 3A

Source: Utah AGRC high-resolution orthophoto, 2012.

WESTERN GEOLOGIC

N W E S

0 100 200 feet

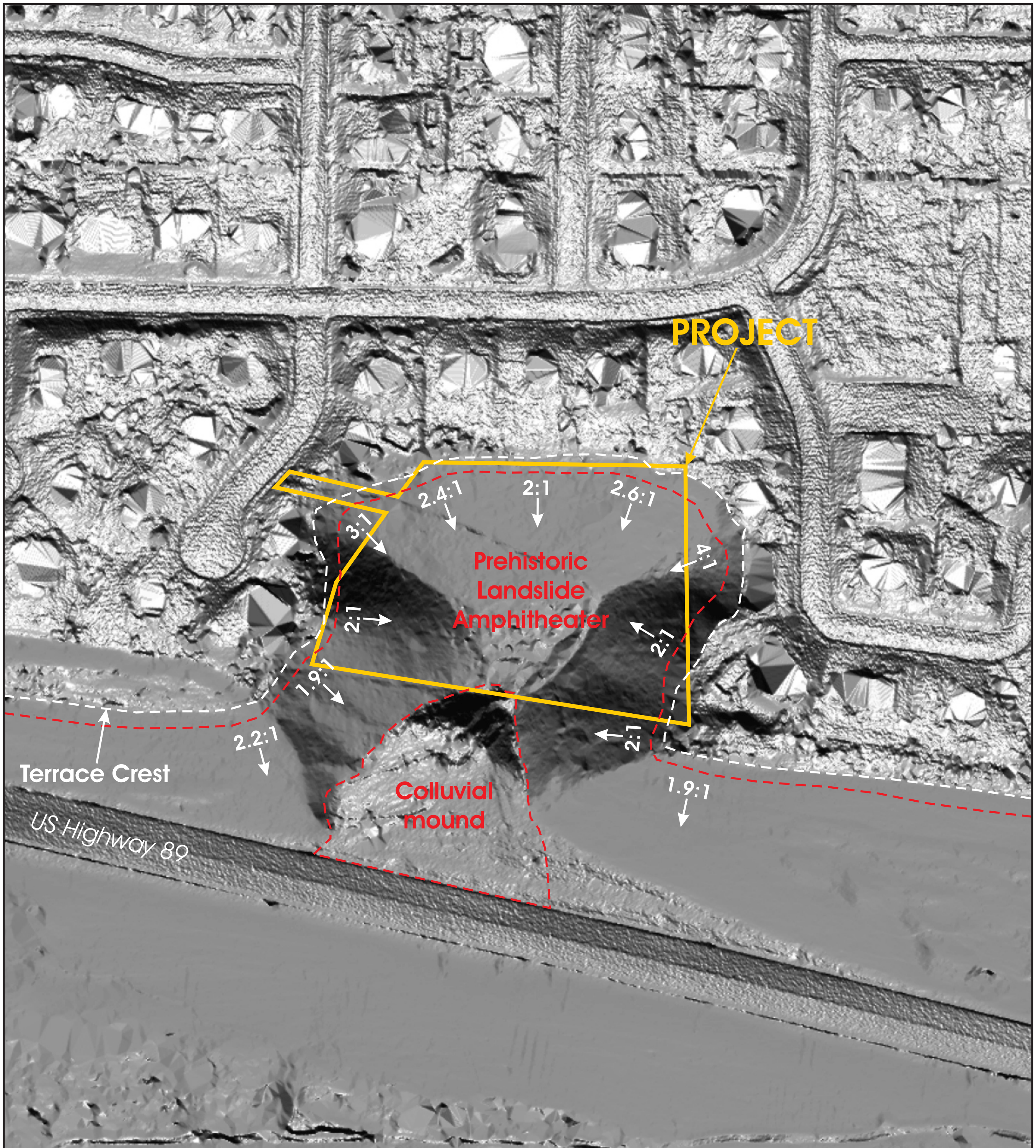
Scale 1:2,400
(1 inch = 200 feet)

2012 AIR PHOTO

GEOLOGIC HAZARDS RECONNAISSANCE

Hidden Oak Subdivision
6260 South 2125 East
Ogden, Weber County, Utah

FIGURE 3B



Source: Utah AGRC Bare Earth DEM, 2013, 0.5-meter resolution.

WESTERN GEOLOGIC

N S W E

0 100 200 feet

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

2013 LIDAR IMAGE

GEOLOGIC HAZARDS RECONNAISSANCE

Hidden Oak Subdivision
6260 South 2125 East
Ogden, Weber County, Utah

FIGURE 3C

APPENDIX

Photographic Record of Site Visit

Photographic Record of Site Reconnaissance
Hidden Cove Subdivision – 6260 South 2125 East – Ogden, Utah

Photo 1. Access road from Jared Way (2125 East).

Photo 2. Typical slopes in northwest part of Project.

Photo 3. Typical slopes in northeast part of Project.

Photo 4. Spoils from prior test pit excavation.

Photo 5. Mound at amphitheater mouth.

Photo 6. Overview of slopes bounding amphitheater.