# REPORT

# GEOLOGIC HAZARDS EVALUATION

## EASTWOOD ESTATES LOTS 28 AND 29

## 5973-5995 SOUTH 2950 EAST

## OGDEN, WEBER COUNTY, UTAH

***Prepared for***

GSH Geotechnical
1596 West 2650 South, Suite 107
Ogden, Utah 84401

September 1, 2015

***Prepared by***

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

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

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

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

September 1, 2015

Andrew M. Harris, PE
Senior Geotechnical Engineer
GSH Geotechnical, Inc.
1596 West 2650 South, Suite 107
Ogden, Utah 84401

**SUBJECT:** Geologic Hazards Evaluation
Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

Dear Mr. Harris:

This report presents results of an engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for Eastwood Estates Lots 28 and 29, 5973-5995 South 2950 East, Ogden, Weber County, Utah, Utah (Figure 1 – Project Location). The site is in the foothills at the western base of the Wasatch Range north of Bybee Reservoir (Pond) and northwest of the mouth of Spring Creek Canyon, and is located in Section 24, Township 5 North, Range 1 West (Salt Lake Base Line and Meridian; Figure 1). Elevation of the site ranges from about 5,050 feet to 5,210 feet above sea level. It is our understanding that the current intended site use is for development of one residential home in the eastern (upper) part of the site (Figure 2).

## PURPOSE AND SCOPE

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

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;

- Excavation and logging of three test pits to evaluate subsurface conditions in the area of the proposed home at the site;

- 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 following generally accepted professional engineering geologic principles and practice in Utah, and the Guidelines for Preparing Engineering Geologic reports in Utah (Utah Section of the Association of Engineering Geologists, 1986.

## HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Ogden Quadrangle shows no natural springs in the Project vicinity, and no active streams are mapped crossing the site. Spring Creek Canyon is to the south, Dry Canyon is to the north, and an unnamed ephemeral drainage flows southwestward to near the northeast site corner. The ephemeral drainage flows beneath 2950 East Street and discharges about 160 feet to the southwest north of the property.

The 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 local groundwater flow is expected to be to the southwest.

Elevation of the shallow aquifer varies somewhat based on seasonal and climatic fluctuations. No significant groundwater was encountered in any of the borings conducted by GSH at the site or in any of the test pits conducted for this report. Perched conditions may be found at depth, but were not evident in the borings or test pits. We anticipate the depth to groundwater to be greater than 50 feet in the area.

## GEOLOGY

### 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 main trace of the Weber segment is mapped slightly west of the Project near the intersection of 2925 East Street and Melanie Lane (Figures 2 and 3). The western part of the Project extends into the Surface Fault Rupture Special Study Area on Weber County maps, although no structures are currently planned in this area (Figure 2).

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). Previous paleoseismic studies indicate four large-magnitude surface-faulting earthquakes have occurred on the Weber segment since mid-Holocene time. Nelson and others (2006) report finding evidence for four events 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) report 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.

Lund (2005) indicates preferred earthquake timing for the last four surface-faulting earthquakes on the Weber segment is: (1) an event Z between 200 to 800 years ago (partial segment rupture) and/or between 500 and 1,400 years ago (complete segment rupture), (2) an event Y between 2,300 and 3,700 years ago, (3) an event X between 3,800 and 5,200 years ago, and (4) an event W between 5,400 and 6,800 years ago. The consensus preferred recurrence interval for the Weber segment, as determined by the Utah Quaternary Fault Working Group, is 1,400 years for the past four surface-faulting earthquakes (Lund, 2005).

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.

### Surficial Geology

The site is located within the Wasatch Front Valley System, a deep sediment-filled, structural basin flanked by the Wasatch Range to the east and the Lakeside Mountains to the west. The Project is located at and below the highest (Bonneville) shoreline of Lake Bonneville. Surficial geology of the site is mapped by Yonkee and Lowe (2004) as alluvial-fan deposits graded to the Bonneville shoreline, and lacustrine sand and gravel from Pleistocene Lake Bonneville (units Qaf4 and Qlg4; Figure 3). Further west is Holocene alluvium and colluvium (units Qaf1 and Qc; Figure 3). Yonkee and Lowe (2004) also map a queried landslide deposit (Qms5?; Figure 3) northeast of the Project. The main trace of the Weber segment is mapped near the southwest site corner (Figure 3).

Yonkee and Lowe (2004) describe surficial units in the site vicinity, from youngest to oldest in age, as follows:

> ***Qaf – Alluvial-fan deposits, undivided.*** Mixture of clast-supported, moderately sorted, pebble to cobble gravel and sand deposited by streams, and matrix-supported, poorly sorted, pebble to boulder gravel to diamicton deposited by debris flows; mapped where deposits lack cross-cutting relations and relative age is uncertain; exposed thickness less than 9 meters (30 ft).
>
> ***Qc – Colluvium.*** Weakly to non-layered, variably sorted, matrix- to clast-supported, pebble to boulder gravel and diamicton of local origin; contains angular to sub-angular clasts in variable amounts of clay, silt, and sand matrix; deposits formed mostly by creep and slope wash, also includes small landslides, talus, debris cones, minor alluvium, and small bedrock exposures; found mostly along vegetated slopes in Wasatch Range, and locally covering scarps along the Wasatch fault zone; thickness probably less than 15 meters (50 ft) in most areas.
>
> ***Qmf – Debris-flow deposits, undivided.*** Matrix- to clast-supported cobble and boulder gravel, with variable amounts of sand, silt, and clay matrix; surfaces variably rubbly and commonly have levees and channels; includes multiple events graded to various levels above modern channels; unit grades into alluvial fans at mouths of canyons, and into colluvium, talus, and slide deposits at higher elevations in source areas; thickness probably less than 9 meters (30 ft).

***Qms – Landslide deposits, undivided.*** Unsorted, unstratified deposits of angular boulders, sand, silt, clay, and bedrock blocks; deposits generally found on steeper slopes that are covered by thick vegetation and display hummocky topography; deposits formed by single to multiple slides, slumps, and flows; mapped where lack of cross-cutting relations prevents relative age determination; queried where hummocky topography is more subdued; thickness uncertain.

***Qaf1 – Younger alluvial-fan deposits, Holocene.*** Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; forms fans having distinct levees and channels at mouths of mountain-front canyons; exposed thickness less than 6 meters (20 ft).

***Qms1 – Younger landslide deposits, Holocene.*** Unsorted, unstratified mixtures of gravel, sand, silt, and clay redeposited by slides, slumps, and flows; deposits display distinctly hummocky topography and fresh scarps, and are currently or have been recently active; many of these deposits are within older slide complexes.

***Qaf2 – Older alluvial-fan deposits, Holocene***. Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; forms fans with poorly preserved levees that are slightly incised by modern stream channels; exposed thickness less than 6 meters (20 ft).

***Qaf3 – Alluvial-fan deposits, Bonneville regressive.*** Mixture of gravel and sand deposited by streams, and diamicton deposited by debris flows; contains mostly angular to subrounded clasts plus some recycled, well-rounded lacustrine clasts; forms fans having subdued morphology that are graded to the Provo or other regressive shorelines and are incised by modem stream channels; exposed thickness less than 9 meters (30 ft).

***Qaf4 – Alluvial-fan deposits, Bonneville transgressive.*** Mixture of gravel deposited by streams and diamicton deposited by debris flows; gravel contains mostly angular to subrounded clasts; locally weakly cemented with calcite; fans have subdued morphology, display top surfaces graded to the Bonneville shoreline, and are deeply incised by modern stream channels; total thickness of some composite fans as much as 60 meters (200 ft).

***Qd4 – Deltaic deposits, Bonneville transgressive.*** Topset beds of clast-supported, moderately to well-sorted, pebble gravel and gravelly sand; contains abundant subrounded to rounded basement clasts; deposited as Lake Bonneville was near a transgressive shoreline at an elevation of about 1,520 meters (5,000 ft); thickness of topset beds 2 to 4 meters (7 - 13 ft).

***Qlg4 – Lacustrine gravel-bearing deposits, Bonneville transgressive.*** Clast-supported, moderately to well-sorted, pebble to cobble gravel, with some silt to sand in interfluve areas and away from mountain front; gravels contain rounded to subrounded clasts, and some subangular clasts derived from reworking of mass-wasting and alluvial-fan deposits; deposited in higher energy environments along shorelines and small fan deltas as Lake Bonneville was transgressing; grades westward away from shorelines into fine-grained lacustrine deposits (Qlf4); total thickness locally as much as 60 meters (200 ft).

***Qlf4 – Lacustrine fine-grained deposits, Bonneville transgressive.*** Intervals of calcareous clay to silt, and intervals of rhythmically interbedded fine to medium sand and silt near mouth of Weber Canyon; deposited in deeper water environments, and as delta bottomset beds during transgression of Lake Bonneville; total thickness, including subsurface deposits, locally as much as 150 meters (500 ft).

***Qms5 – Landslide deposits, pre-Bonneville to Bonneville transgressive.*** Unsorted, unstratified deposits of angular boulders, sand, silt, clay, and bedrock blocks; deposited by multiple slides, slumps, and flows; parts of these slides are covered by Lake Bonneville deposits and reworked along the Bonneville shoreline, and parts of some slides are interlayered with Bonneville-transgressive lacustrine deposits.

*Bedrock of the Farmington Canyon Complex:*

***Xfgh – Granitic gneiss of Ogden hanging wall.*** Light- to pink-gray, moderately to strongly foliated, fine- to medium-grained, hornblende-bearing granitic gneiss with rare orthopyroxene; gneiss is locally fractured and displays red hematite alteration; gneiss cut by variably deformed, light-colored pegmatitic dikes; unit also contains small pods of meta-gabbro and amphibolite; gradational contacts with migmatitic gneiss.

***Xfm – Migmatitic gneiss.*** Medium- to light-pink-gray, strongly foliated and layered, migmatitic, quartzo-feldspathic gneiss with widespread garnet and biotite; gneiss cut by widespread, variably deformed, pegmatitic dikes; unit also contains widespread amphibolite layers, granitic gneiss bands, and some thin layers of biotite-rich schist; gradational contacts with granitic gneiss.

***Xfb – Biotite-rich schist.*** 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; schist cut by variably deformed, garnet-bearing pegmatite dikes; unit also contains some thin layers of amphibolite, quartz-rich gneiss, and granitic gneiss; gradational contacts with migmatitic gneiss.

*References included in the above unit descriptions are not provided in this report, but are provided in Yonkee and Lowe (2004).*

## 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). Sediments from Lake Bonneville underlie the site and site vicinity.

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 (Donald Currey, University of Utah; written communication to the Utah Geological Survey, 1996; and verbal communication to the Utah Quaternary Fault Parameters Working Group, 2004). Approximately 32,500 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, after about 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. The lake remained at its highest level until 16,500 years ago, when headward erosion of the Snake River-Bonneville basin drainage divide 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. 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 experienced a brief transgression between 12,800 and 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

## SITE CHARACTERIZATION

### Air Photo Observations

A 1952 aerial photograph available from the U.S. Geological Survey (frame AAJ-3K-203, Figure 4) was reviewed to obtain information about the geomorphology of the site and surrounding area. The main trace of the Weber segment of the WFZ is evident on Figure 4 slightly west of the Project, and the highest (Bonneville) shoreline of Lake Bonneville is evident near the southeast corner of the site. The shoreline is obscured by a small post-lake alluvial fan emanating from the unnamed canyon to the east. The fan shows a bifurcated morphology that suggests past debris flows extended southward onto the shoreline and then turned northwestward back into the channel. The ephemeral drainage emanating from the unnamed canyon appears incised through the alluvial fan, indicating it may no longer be active. A younger Holocene fan formed by deposition from this drainage is downslope to the west of the Project. A northwest-trending bench about 50 to 75 feet wide crosses the western part of the Project, but is not evident further north or south. We infer this bench is an older shoreline formed at a lower elevation west of the canyon mouth as the Lake Bonneville transgressed to its highest shoreline.

No other geologic hazards are evident on the photo at the site or in the area, including the queried landslide east of the Project on Figure 3. The landslide morphology appears to be weak or nonexistent and its provenance is uncertain, although it could be an old rockslide similar to those found along the range front a few miles to the north (such as the Beus Canyon and College rockslides of Pashley and Wiggins, 1972)

**Empirical Observations**
On August 3, 2015, Mr. Bill D. Black of Western GeoLogic conducted a reconnaissance of the property and immediate vicinity. Weather at the time of the site reconnaissance was cloudy and raining with temperatures in the 70's (°F). The site is on southwest-facing slopes at the base of the Wasatch Range at and below the Bonneville shoreline. Vegetation at the site consists of scrub oak, sage brush, and grasses. Slopes in the upper (eastern part of the site) dip at about an overall 7:1 (horizontal:vertical) gradient, and then steepen southwestward to around 2:1. The steep slopes are heavily vegetated and showed no evidence for ongoing or recent instability. The steep slopes bound a narrow bench with about an 8:1 westward dip, corresponding to the sub-Bonneville shoreline discussed above, and then continue westward to Melanie Lane. The lower steep slope section (below the bench) is likely the upper part of the scarp of the main trace of the active Weber Segment of the WFZ, although it may be in part modified by road grading for Melanie Lane.

An unnamed drainage is northeast of the Project that flows from a small canyon to a small catchment basin on the east side of 2950 East Street. The drainage appears to be a possible source for debris flows, although it has been intercepted by fill materials emplaced for the street. The drainage is piped westward beneath the street and discharges north of the site back into its natural course. The drainage was dry at the time of our investigation, and appeared heavily vegetated and deeply incised west of 2950 East Street. No evidence for debris flow levees was observed, and no other geologic hazards were evident.

**Subsurface Investigation**
On August 3, 2015 three test pits were excavated at the site with a large trackhoe to evaluate subsurface conditions. Test pit locations are shown on Figure 5. Logs of the test pits at a scale of 1 inch equals 5 feet are shown on Figure 6. The test pits all exposed a similar sequence of near-shore lacustrine sand and gravel deposits from Lake Bonneville (unit 1) overlain by post-lake alluvium from a combination of debris flows and slope wash (unit 2, Figure 6). A weak paleosol A horizon was observed on the top of unit 1 in test pits 1 and 3 (unit 1A), but was not evident in test pit 2. A roughly one-foot thick modern A-horizon soil was evident on top of units 2 in all the test pits. Unit 2 has a maximum thickness in test pit 3 of about 5 feet, but no paleosols or stratigraphic contacts were evident to delineate individual debris flows. Based on soil carbonate in unit 2 and the paleosol A horizon on unit 1, we believe unit 2 to be latest Pleistocene to early Holocene in age. No groundwater was encountered in any of the test pits to their explored depths.

### Cross Section

Figure 7 shows one cross section (A-A') across the proposed home location at the site at a scale of 1 inch equals 40 feet, with no vertical exaggeration. The cross section location is shown on Figure 4. Unit contacts and dips are inferred from the test pit data, GSH boring logs, geologic mapping on Figure 3, and site observations. The cross section displays a thin veneer of alluvium overlying lacustrine sand and gravel from Lake Bonneville, which in turn overlies older alluvium and likely weathered Farmington Canyon Complex bedrock. The contact between the older alluvium and Lake Bonneville deposits is inferred to be at a depth of about 20 feet in GSH boring B-1, and the contact between the older alluvium and weathered bedrock is below the explored depth of B-1 (>50 feet). Further to the west, all these deposits would be down-dropped significantly across the WFZ.

## 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 to the proposed development. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk or only impacts a small portion of the development. 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. High and moderate-risk hazards may require further studies or mitigation, whereas 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 | |
| **Radon** | 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). Peak ground, 0.2 second spectral, and 1.0 second spectral accelerations (percent of gravity, %g) at the site with 10% and 2% probabilities of exceedance in 50 years are estimated in Frankel and others (2002) as follows:

| *41.154026º N, -111.906968º W* | **10% PE in 50yr** | **2% PE in 50yr** |
|---|---|---|
| **PGA** | 19.77 | 60.91 |
| **0.2 sec SA** | 47.95 | 140.67 |
| **1.0 sec SA** | 16.97 | 57.84 |

Given the above information, earthquake ground shaking is a high risk to the site. The hazard from earthquake ground shaking can be adequately mitigated by prudent design and construction.

### 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 main trace of the Weber segment is mapped slightly west of the Project near the intersection of 2925 East Street and Melanie Lane (Figures 3-5), and the western part of the Project extends into the Surface Fault Rupture Special Study Area (SFRSSA) on Weber County maps. However, no structures are currently planned in the SFRSSA (Figure 2). No trenching was conducted to evaluate the hazard from surface faulting at the site given the current development plan and risk of destabilizing steep slopes in the western part of the site. Existing risk in the area of the proposed home footprint is low, but risk increases in the western part of the Project with proximity to the fault. Given the above, we rate the hazard from surface faulting at the site as moderate. No structures designed for human occupancy should be located in the SFRSSA (west of the boundary) without additional trenching to evaluate the risk from surface faulting.

### 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 lacustrine deposits possibly susceptible to liquefaction are present in the upper 30 feet of the site subsurface and the site is in an area of potentially strong shaking (as discussed in the Earthquake Ground Shaking Section above). However, groundwater at the site appears to be greater than 50 feet deep. Based on the above, we rate the hazard from liquefaction as low, although risk could vary depending on factors such as perched groundwater and seasonal conditions.

### Tectonic Deformation

Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of a normal fault. The site is not on the downthrown side of any mapped active faults, and therefore we rate that hazard from tectonic deformation 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 large bodies of water, the risk to the subject property from seismic seiches 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 cross the site or were evident during our reconnaissance. One ephemeral drainage is mapped in the unnamed canyon northeast of the site that is piped beneath 2950 East Street and discharges into its natural course downslope. This drainage does not enter the property. Given all the above, we rate the hazard from stream flooding as low. Site hydrology and runoff should be addressed in the civil engineering design and grading plan for the Project.

### Shallow Groundwater

No springs are shown on the topographic map for the Ogden quadrangle at the site and no springs were observed during our site reconnaissance. No groundwater was encountered in any of the borings conducted by GSH at the site to depths of 50 feet, or in any of the test pits conducted for this report. We anticipate the depth to groundwater to be greater than 50 feet in the area. Given the above, we rate the risk from shallow groundwater as low, although the risk may vary locally depending on factors such as perched groundwater and seasonal conditions.

### 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 western half of the site is on steep 2:1 (horizontal:vertical) slopes underlain by lacustrine sand and gravel deposits. Several Holocene landslides (unit Qms1) are shown in lacustrine deposits in the area, including in similar lacustrine gravel deposits as those underlying the site about 0.3 miles to the northwest (Figure 3). However, no existing landslides are mapped at the site and no evidence for ongoing or recent instability was observed. Given the above, we rate the hazard from landslides as moderate. We recommend stability of the slopes be evaluated in a geotechnical engineering evaluation prior to building based on site-specific data and subsurface information included in this report. Recommendations for reducing the risk from landsliding should be provided if factors of safety are determined to be unsuitable. Care should also be taken that site grading does not destabilize slopes in this area without prior geotechnical analysis and grading plans, that proper drainage is maintained, and no non-engineered cuts are made in slope toes.

### Debris Flows

Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front. Debris flows have historically significant damage in the Wasatch Front area.

An ephemeral drainage is in the unnamed canyon northeast of the site that flows southwestward to near the northeast site corner and forms an inverted Y-shaped alluvial fan emanating from the canyon mouth (Figure 4). The alluvial fan obscures (and is therefore younger than) the Bonneville shoreline (Figure 4). Figures 3 and 4 show the eastern and northern parts of the site are underlain by this alluvial fan. The ephemeral drainage currently flows from the canyon mouth to a small catchment basin on the northeast side of 2950 East Street, where it is piped beneath the road and discharges about 160 feet to the southwest roughly 20 feet north of the site (Figure 5). Fill materials emplaced for 2950 East Street appears to have blocked the natural drainage course (Figures 4 and 5). Prior to modification, the drainage appears to have incised a channel across the fan, suggesting the alluvial fan was no longer active (Figure 4). Deposition moved to lower slopes to the west and formed a younger alluvial fan (Figure 4). Test pit data confirm that one or more debris flows have emanated from the canyon and impacted the site since the lake retreat of Lake Bonneville (Figure 6). Individual flows could not be delineated, but the deposits have a maximum thickness of 5 feet in test pit 3 (unit 2, Figure 6) and appear to be latest Pleistocene to early Holocene in age based on soil development.

The drainage basin for the unnamed canyon covers an area of about 97 acres (0.39 $km^2$) and includes three ephemeral drainages with lengths of from 2,485 to 3,026 feet (Figure 1). Van Dine (1996; Figure 5) provides a correlation to estimate design magnitude debris flow volumes based on drainage basin area. Based on a drainage basin area of 0.39 $km^2$ (97 acres), Van Dine (1996, Figure 5) estimates a design magnitude volume of about 5,000 $m^3$ (6,540 $yd^3$). Hungr and others (1984) also provide a correlation to estimate design magnitude debris flow volumes based on drainage length (aka empirical bulking). Based on our observations, the drainages are in loose sediments over weathered bedrock, which would be a Hungr and others' (1984) Channel Type B drainage with a corresponding sediment bulking factor of 2 to 4 $yd^3$/ft. Giraud (2005) indicates bulking rates for intermittent and ephemeral streams are generally lower than rates for perennial streams, and similar ephemeral drainages have showed bulking rates of 1.5 to 5 $yd^3$/ft (Mulvey and Lowe, 1992; McDonald and Giraud, 2002). We believe a bulking rate of 2 $yd^3$/ft is appropriate. Given this bulking rate and a maximum length of 3,026 feet, Hungr and others' (1984) correlation would estimate a design magnitude volume of 6,052 $yd^3$, which is within 10% of the estimate based on drainage basin area (6,540 $yd^3$, above).

The unnamed canyon northeast of the Project thus appears capable of generating a significant flow. However, the fan underlying the site appears to have been inactive for several thousand years, and alluvial deposition appears to have moved to lower slopes to the west in Holocene time. Based on the above, we rate the risk from debris flows to the Project as moderate. Risk could vary if flow and deposition patters have been altered by development. Recommendations should therefore be provided in the civil engineering design for the proposed home to reduce the hazard from debris flows and floods. Such recommendations may include raising the building pad by at least the maximum past flow thickness (5 feet), eliminating north-facing below-grade entryways, grading routing channels and berms to direct debris and water away from the home, or a combination of the above. However, care should be taken that potential floodwaters and debris are not directed into adjoining properties.

### Rock Fall

No significant bedrock outcrops were observed in higher slopes east of the property, and no boulders from rock falls were observed at the site. Given this, we rate the hazard from rock falls as low.

### Radon

Radon comes from the natural (radioactive) breakdown of uranium in soil, rock, and water and can seep into homes through cracks in floor slabs or other openings. The site is located in an area of “High” radon-hazard potential (Black and Solomon, 1996). A high hazard potential indicates geologic factors are favorable for indoor radon concentrations exceeding 4 picocuries per liter of air, which would be above the EPA recommended level. Actual indoor radon levels can be affected by non-geologic factors such as building construction, maintenance, and weather. Long-term indoor testing following construction is the best method to characterize the radon hazard and determine if mitigation measures are required.

### Swelling and Collapsible Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given the subsurface soil conditions observed at the site, we do not anticipate that any soils susceptible to swelling or collapse will be present. However, a geotechnical engineering evaluation should be performed to address soil conditions and provide specific recommendations for site grading, subgrade preparation, and footing and foundation design.

## CONCLUSIONS AND RECOMMENDATIONS

Geologic hazards posing a high relative risk to the site are earthquake ground shaking and radon. Moderate-risk hazards include surface faulting, landslides, and debris flows. The following recommendations are provided to address these hazards:

- Proposed homes should be designed and constructed to current seismic standards to reduce the potential ground-shaking hazard.

- No structures intended for human occupancy should be located in the SFRSSA (west of the boundary) on Figures 2 and 5 without additional trenching to evaluate if active faults may be present. It is generally accepted practice to allow streets, driveways, yards, tennis courts, and non-occupied, non-attached structures to be constructed within this area without further trenching studies.

- A design-level geotechnical engineering study should be conducted prior to construction to: (1) address soil conditions at the site for use in foundation design, site grading, and drainage; (2) provide recommendations regarding building design to reduce risk from seismic acceleration; and (3) evaluate stability of slopes at the site, including providing recommendations for reducing the risk of landsliding if the factors of safety are deemed unsuitable.

- Site grading and drainage should be addressed in the civil engineering design for the development, including providing recommendations to reduce risk from debris flows and floods to the proposed home.

The site appears suitable for the proposed development given the scope of this report and findings herein, and assuming our recommendations provided above are followed.

### Availability of Report

The report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. This 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

LICENSED PROFESSIONAL GEOLOGIST
9-1-2015
BILL DUANE BLACK
NO. 5224898-2250
STATE OF UTAH

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

Reviewed by:

LICENSED PROFESSIONAL GEOLOGIST
CRAIG V NELSON
5251804
STATE OF UTAH

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

**ATTACHMENTS**

- Figure 1. Location Map (8.5”x11”)
- Figure 2. Development Plan (8.5”x11”)
- Figure 3. Geologic Map (8.5”x11”)
- Figure 4. 1952 Air Photo (8.5”x11”)
- Figure 5. Site Plan (8.5”x11”)
- Figure 6. Test Pit Logs (11”x17”)
- Figure 7. Cross Section (11”x17”)

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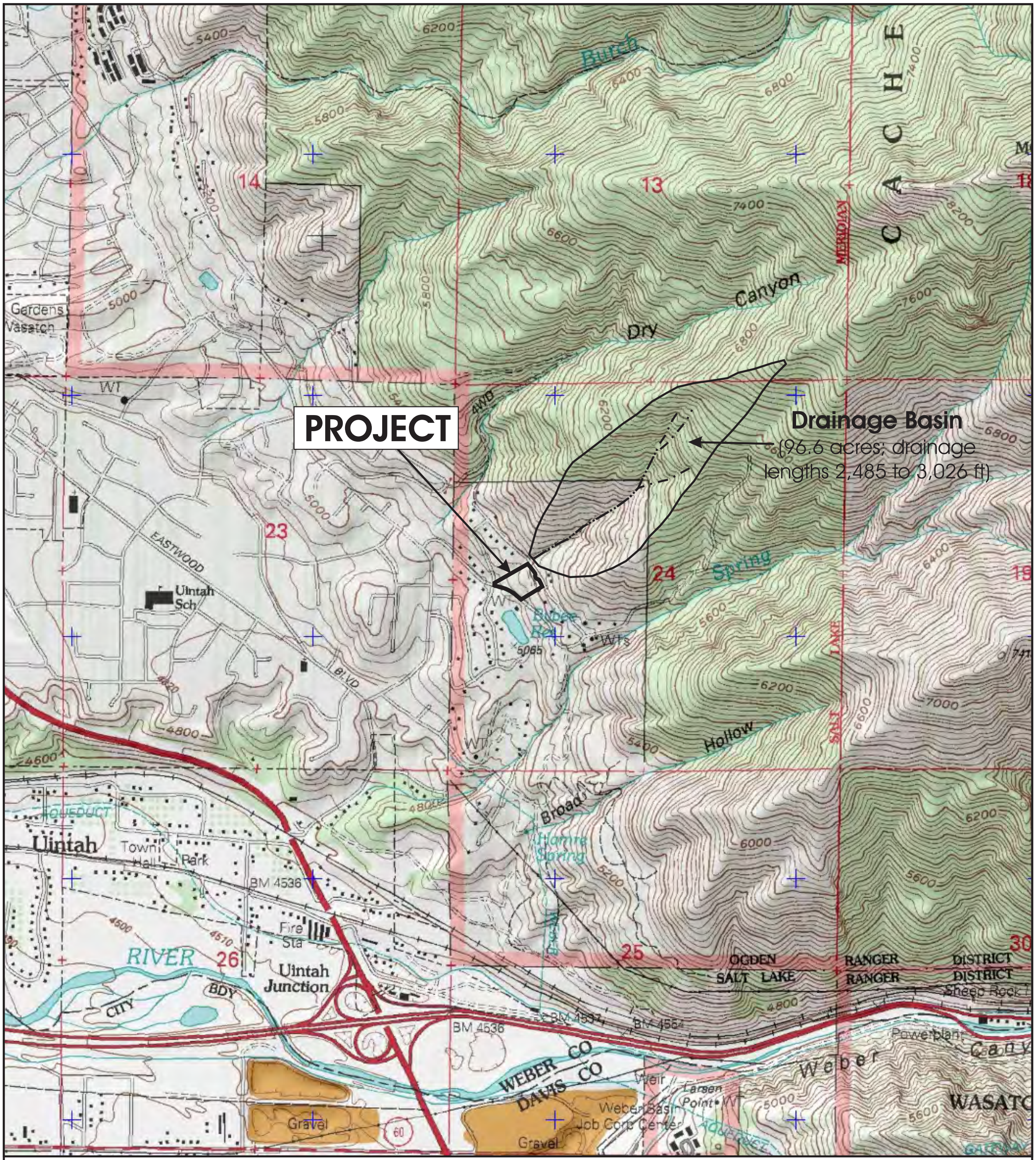


Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, UT - Ogden, 1998.

## LOCATION MAP

### GEOLOGIC HAZARDS EVALUATION

Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

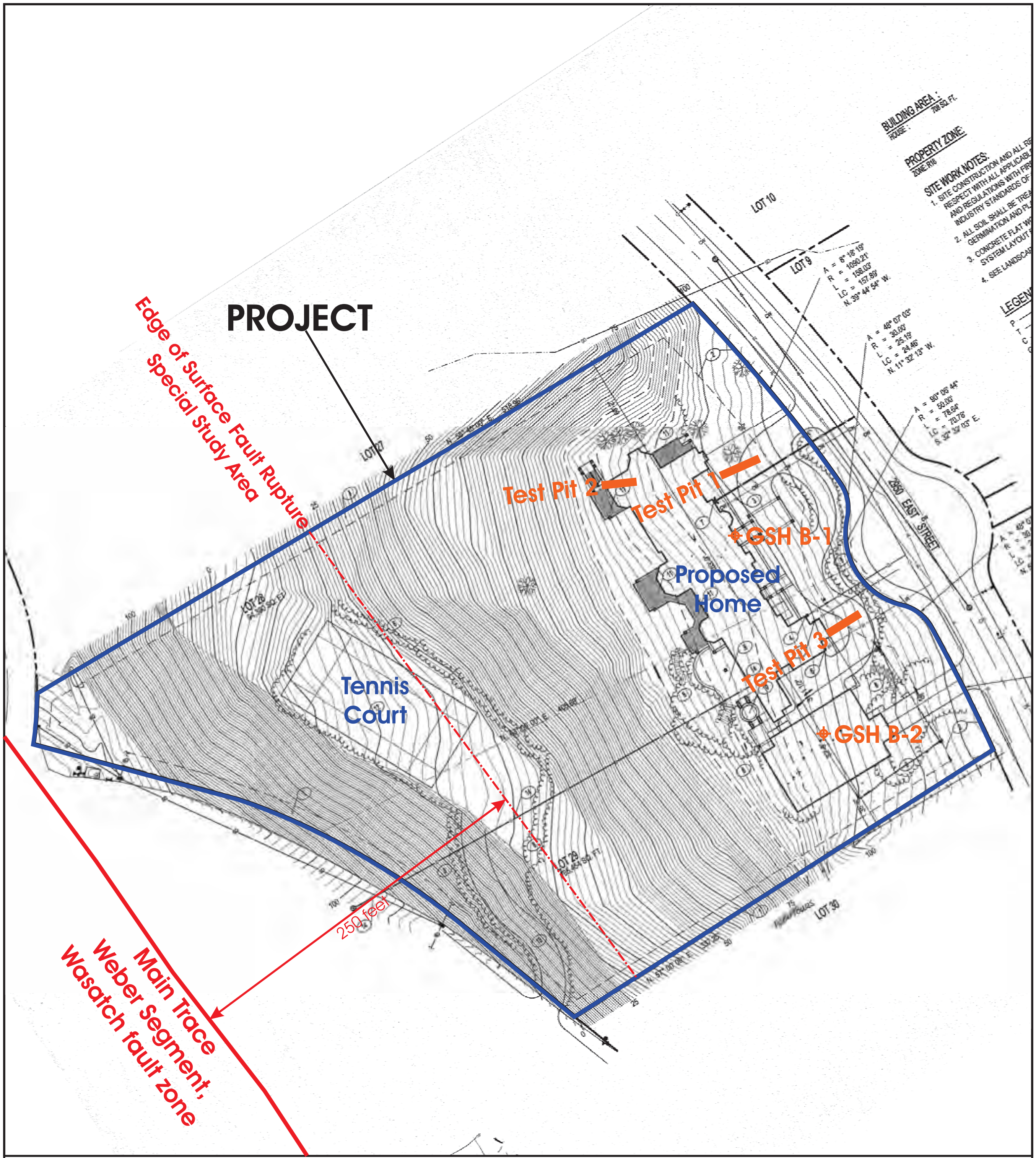
**FIGURE 1**

WESTERN GeoLogic

N
W E
S

0 1000 2000 feet

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



Source: undated Design Source Site Plan prepared for Herb & Carol Christian.

WESTERN GEOLOGIC

N
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S

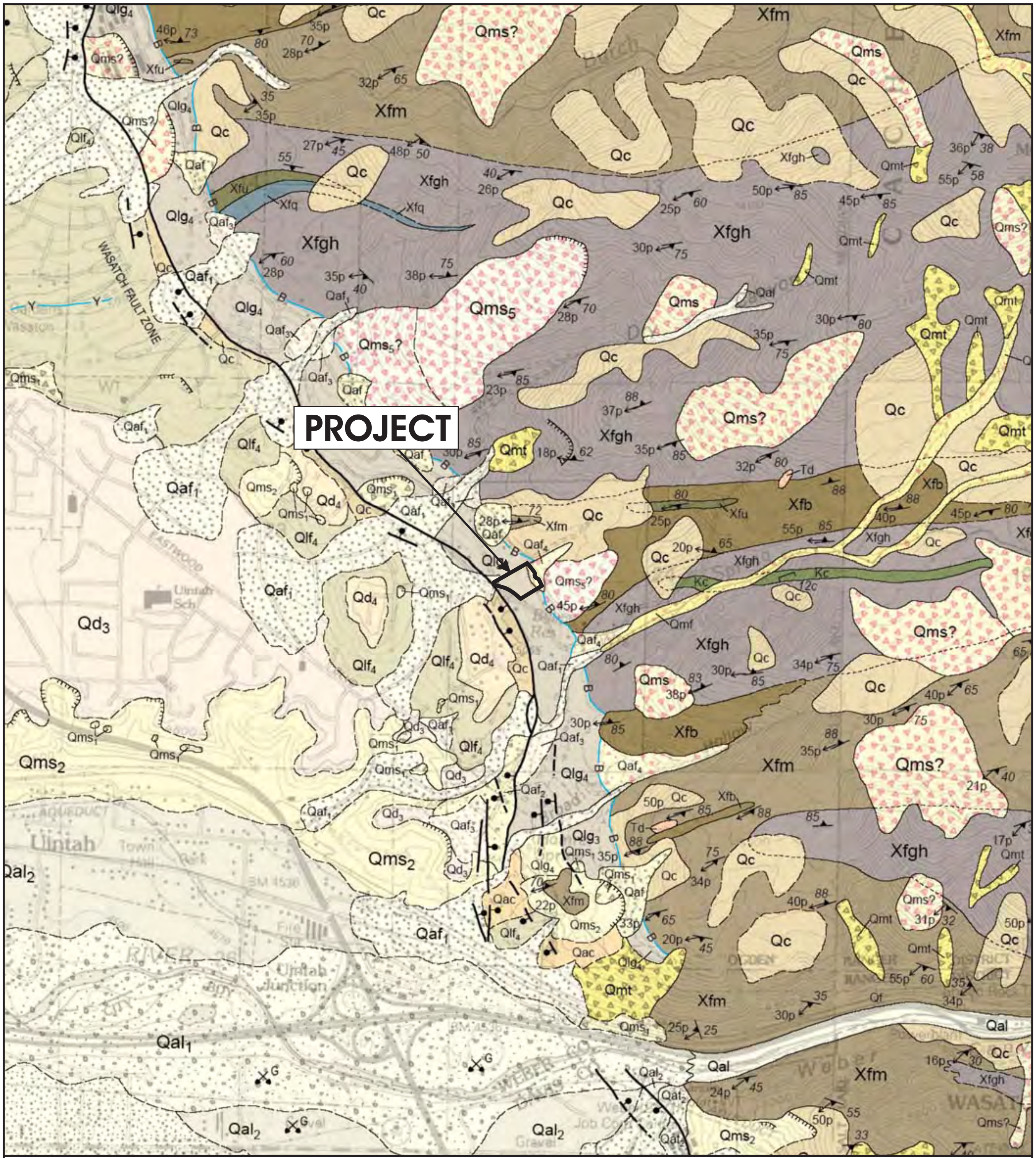
0 50 100 feet

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

## DEVELOPMENT PLAN

**GEOLOGIC HAZARDS EVALUATION**
Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 2**



Source: Yonkee and Lowe (2004).

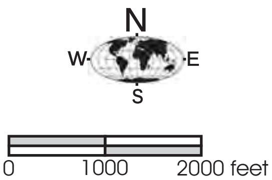
# GEOLOGIC MAP

## GEOLOGIC HAZARDS EVALUATION

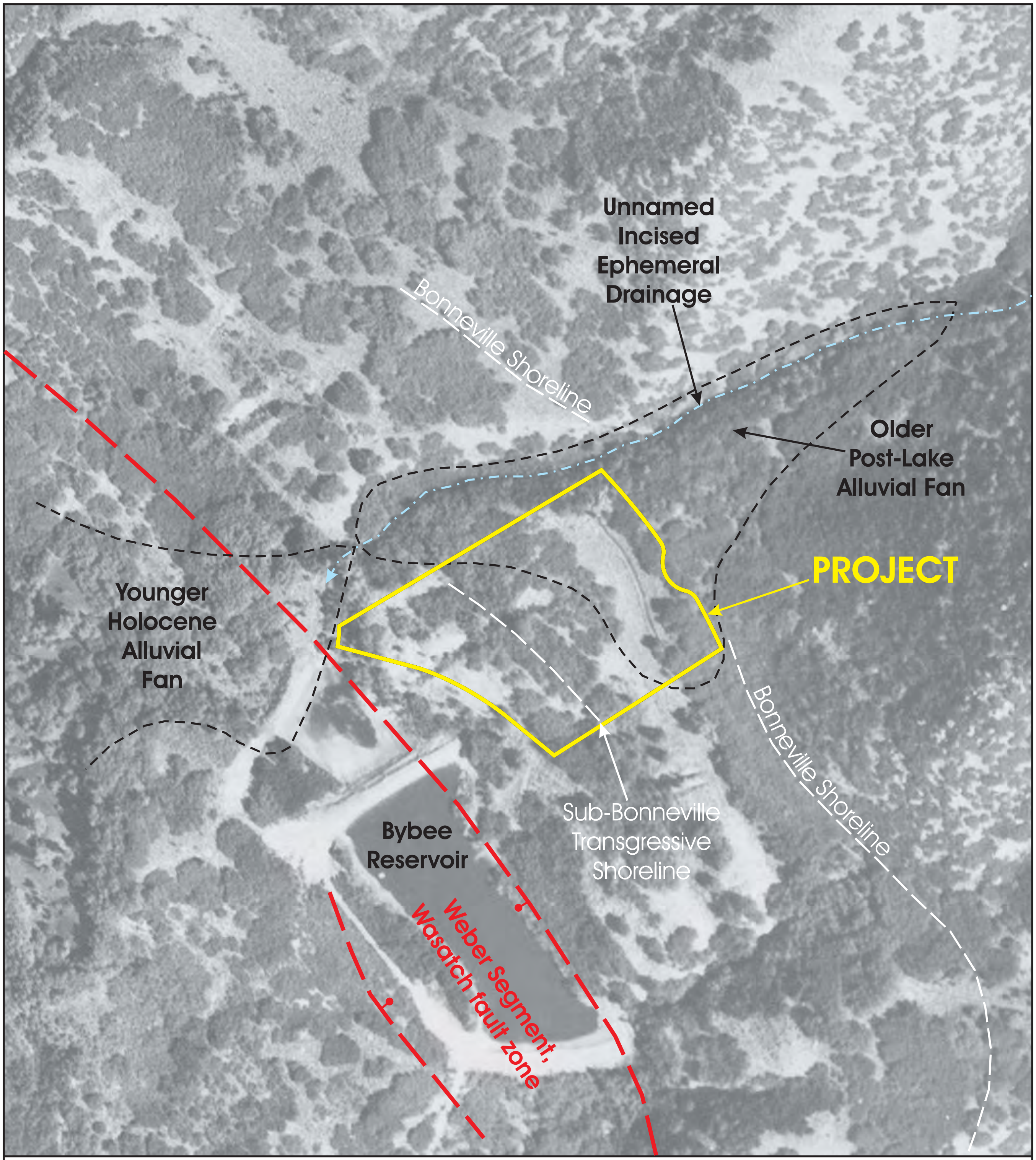
Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 3**

WESTERN GEOLOGIC



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



Air photo from U.S. Geological Survey, frame AAJ-3K-203, September 1952.

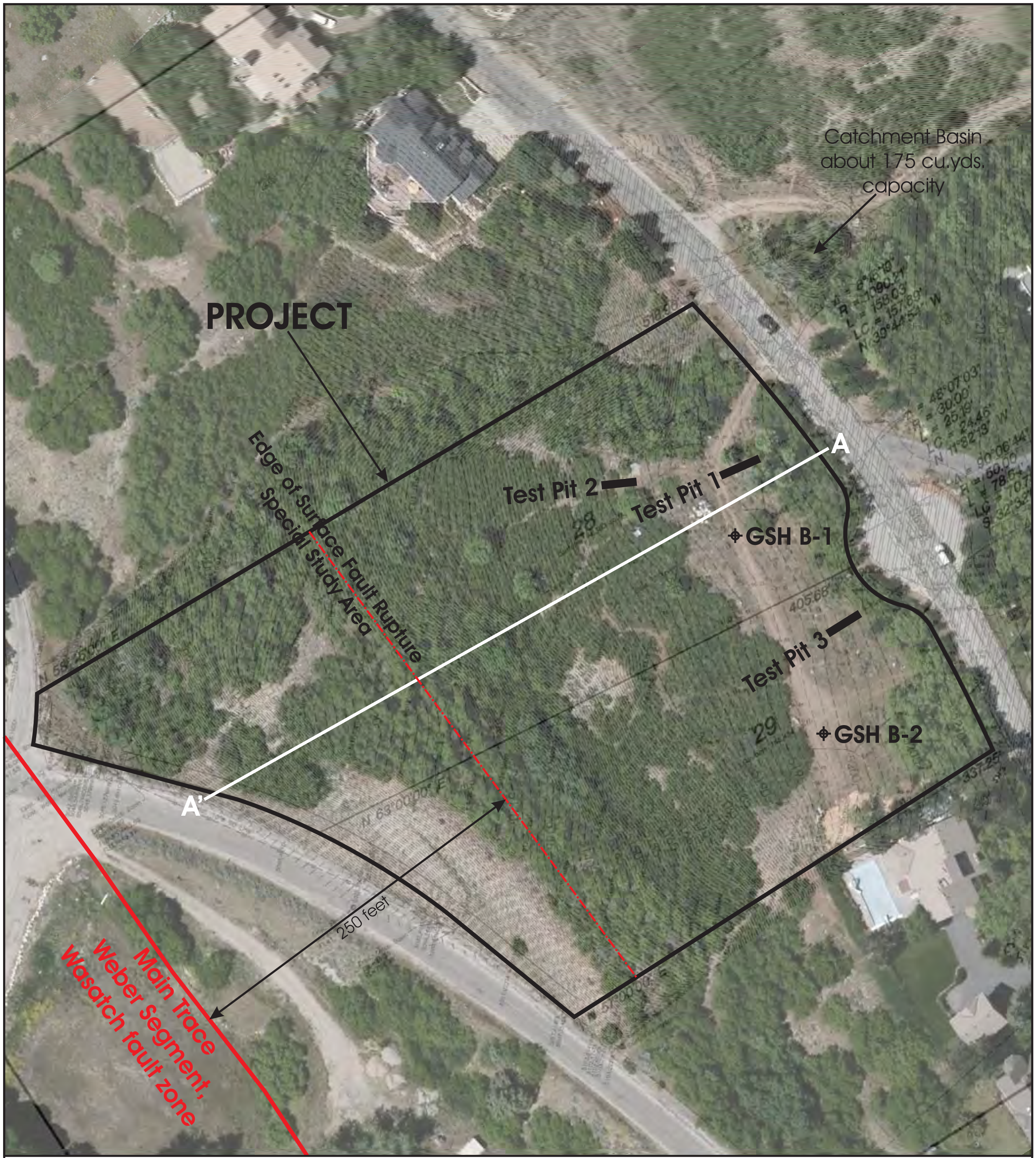
Scale 1:3,000
(1 inch = 250 feet)

## AIR PHOTO

## GEOLOGIC HAZARDS EVALUATION

Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 4**



Base map from Great Basin Engineering Topographic Survey, September 2008; aerial photo from Utah AGRC high-resolution orthophoto, 2012; fault location from Yonkee and Lowe (2004; Figure 2).

WESTERN GeoLogic

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0 50 100 feet

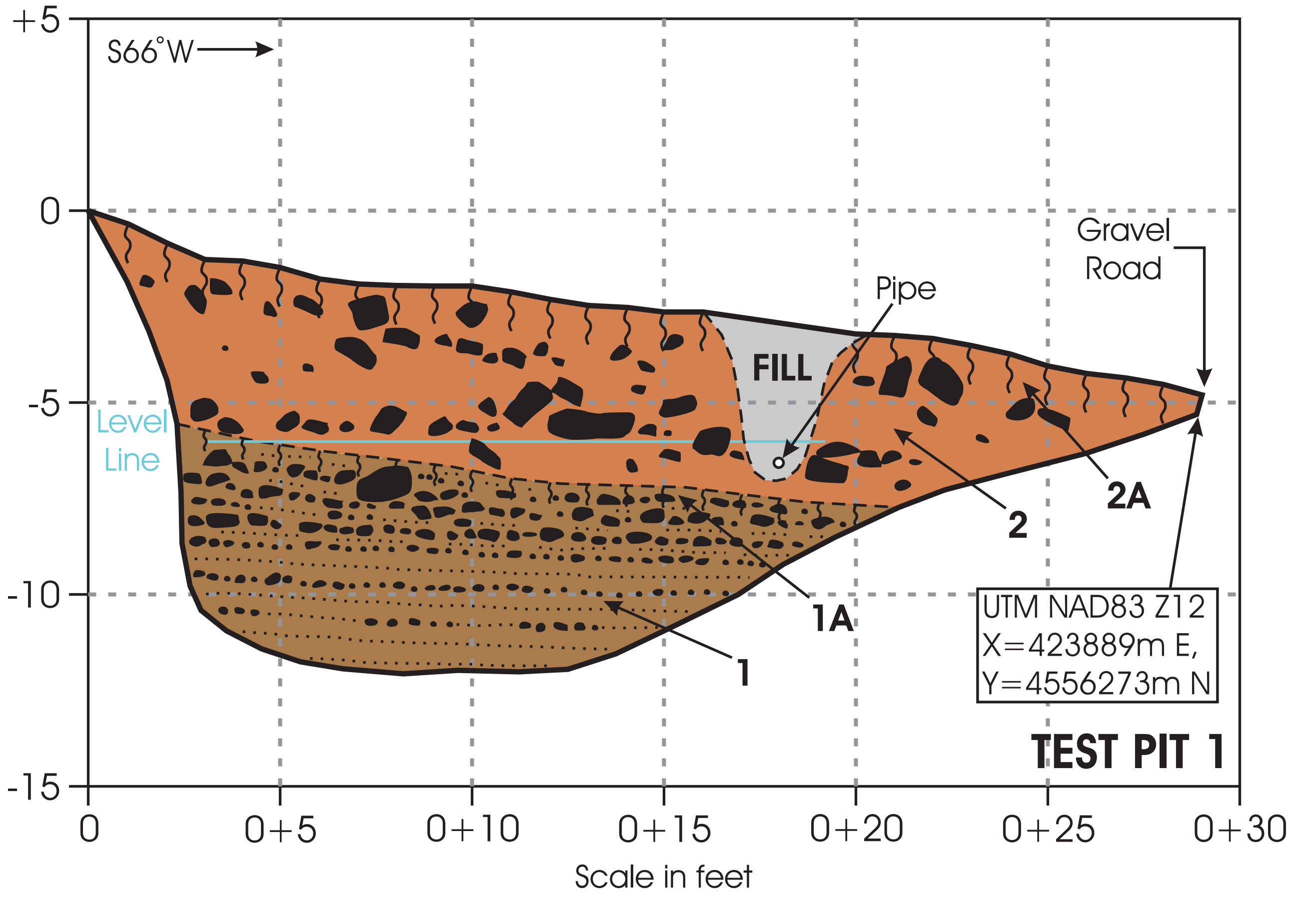
Scale 1:1,200
(1 inch = 100 feet)

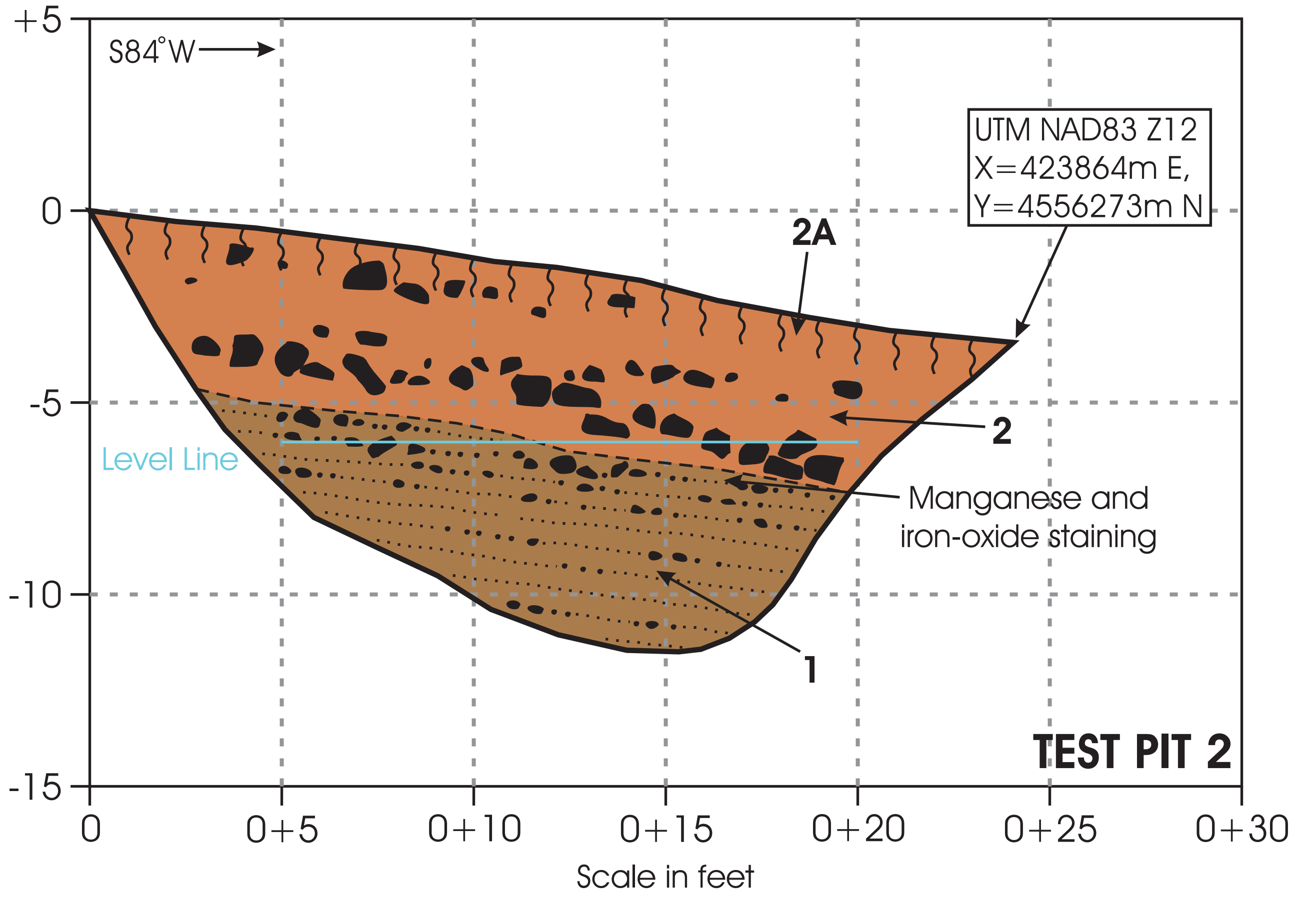
## SITE PLAN

## GEOLOGIC HAZARDS EVALUATION

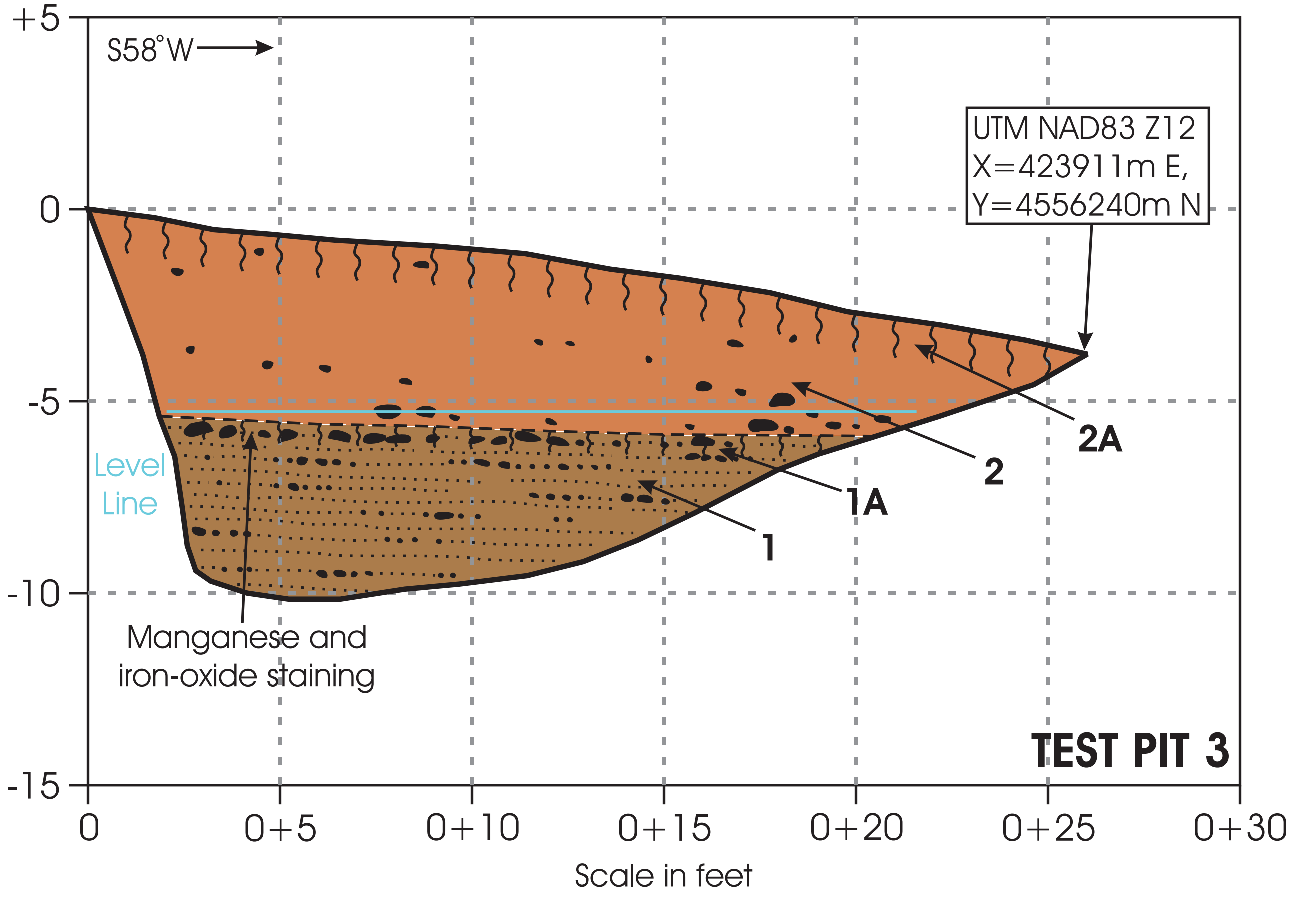
Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 5**





WESTERN GEOLOGIC



## UNIT DESCRIPTIONS

**Unit 1.** *Near-shore lacustrine deposits related to the transgressive stage of Lake Bonneville* - Brown to grayish-brown, generally well bedded, loose, mainly gravelly sand (SW) with rounded cobbles and rare boulders in upper part; root penetrated in zones in upper part; mainly coarse sand exposed in test pit 3.

**1A.** Thin paleosol A horizon formed in unit 1 in test pits 1 and 3, but not evident in test pit 2.

**Unit 2.** *Post-lake alluvium* - Brown to reddish-brown, massive, dense, silty to clayey sand with gravel, cobbles, and boulders (SM); slightly root penetrated; clasts subangular to subround quartzite with stage II carbonate, size up to about 2.5 feet; test pit 3 exposure is finer grained with less gravel, trace cobbles, and no boulders; likely represents latest Pleistocene to early Holocene-age debris flow deposits mixed with slope wash, individual flows are indistinct.

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

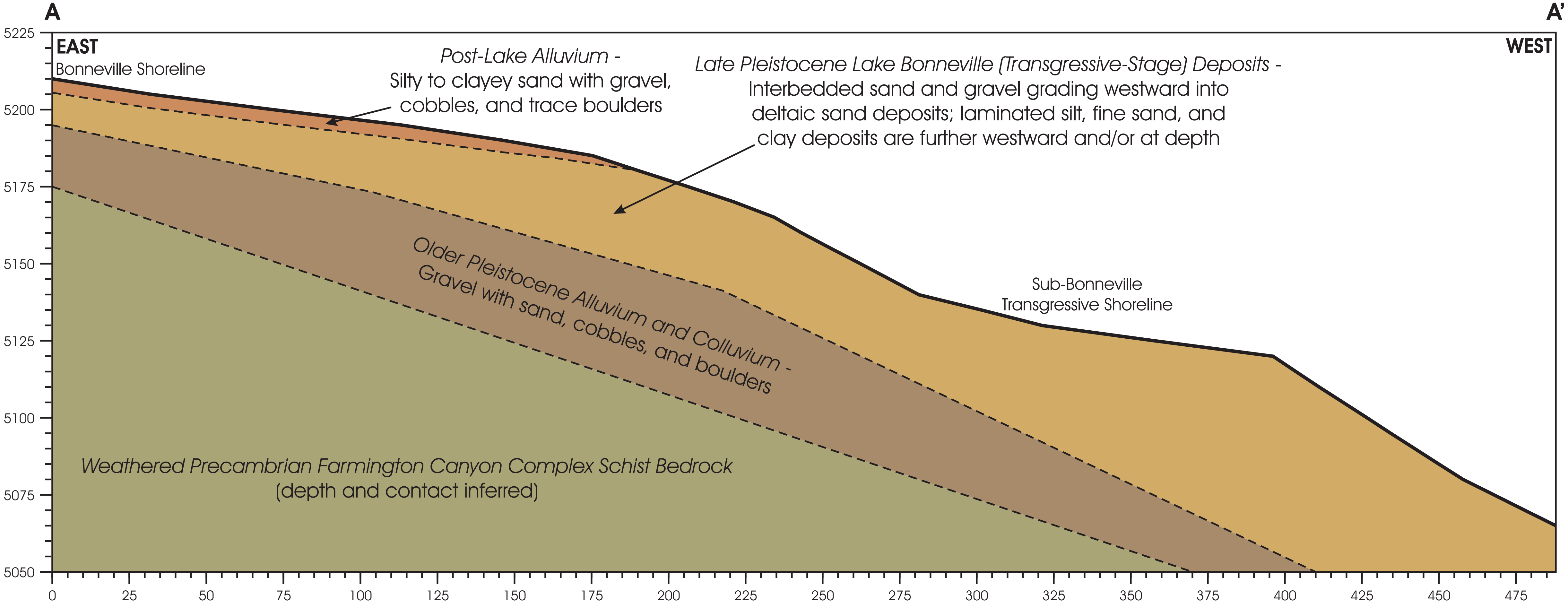
SCALE: 1 inch = 5 feet
(no vertical exaggeration)
Southeast Walls Logged, East to West

Test pits logged by Bill D Black, P.G. on
August 3, 2015
Reviewed by Craig V Nelson, P.G.

## TEST PIT LOGS

**GEOLOGIC HAZARDS EVALUATION**
Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 6**



Scale 1 inch equals 40 feet, no vertical exaggeration;
cross section location shown on Figure 3.

# CROSS SECTION

## GEOLOGIC HAZARDS EVALUATION

Eastwood Estates Lots 28 and 29
5973-5995 South 2950 East
Ogden, Weber County, Utah

**FIGURE 7**

WESTERN GEOLOGIC