ENGINEERING • GEOTECHNICAL • ENVIRONMENTAL (ESA I & II)
MATERIALS TESTING • SPECIAL INSPECTIONS •
ORGANIC CHEMISTRY • PAVEMENT
DESIGN • GEOLOGY

## GEOTECHNICAL ENGINEERING AND GEOLOGIC SERVICES

# Proposed Highland Bluff Estates Lot 1 Subdivision

6224 South 2225 East
Ogden, Weber County, Utah
**CMT PROJECT NO. 13895**

FOR:
Randy Moore
Moore Homes
3838 South 8365 West
Magna, Utah 84044

January 13, 2020

Mr. Randy Moore
Moore Homes
3838 South 8365 West
Magna, Utah 84044

Subject: Geotechnical Engineering and Geologic Services
Proposed Highland Bluff Estates Lot 1 Subdivision
Weber County Assessor Parcel No. 07-335-0001
6224 South 2225 East
Ogden, Weber County, Utah
CMT Project No. 13895

Mr. Moore:

Submitted herewith is the report of our geotechnical engineering and geologic study for the subject site. This report contains the results of our findings and an interpretation of the results with respect to the available Project characteristics. It also contains recommendations to aid in the design and construction of the earth related phases of this project.

On December 3, 2019 CMT Engineering Laboratories (CMT) personnel were on-site and supervised the excavation of four test pits extending to depths of 6.6 to 8.1 feet below the existing ground surface. Soil samples were obtained during the field operations and subsequently transported to our laboratory for further testing and observation. Based on the findings of the subsurface explorations, conventional spread and continuous footings may be utilized to support the proposed residence, provided the recommendations in this report are followed. A detailed discussion of design and construction criteria is presented in this report.

We appreciate the opportunity to work with you on this project. CMT offers a full range of Geotechnical Engineering, Geological, Material Testing, Special Inspection services, and Phase I and II Environmental Site Assessments. With four offices throughout Northern Utah, and in Arizona, our staff is capable of efficiently serving your project needs. If we can be of further assistance or if you have any questions regarding the Project, please do not hesitate to contact us at (801) 870-6730. To schedule materials testing, please call (801) 381-5141.

Sincerely,
**CMT Engineering Laboratories**

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**APPENDIX**

# 1.0 INTRODUCTION

## 1.1 General

CMT Engineering Laboratories (CMT) was authorized by Mr. Randy Moore of Moore Homes to conduct a design-level geotechnical engineering and geologic study for a proposed 14-lot residential subdivision on a 4.59-acre property (Parcel #07-335-0001), located at 6224 South 2225 East in Ogden, Weber County, Utah. The site is located at the crest of a terrace northwest of the mouth of Weber Canyon, and is in the SW1/4 Section 23, Township 5 North, Range 1 West (Salt Lake Base Line and Meridian; Figure 1) at an elevation of from 4,800 to 4,823 feet above mean sea level. The Project location is shown on **Figure 1, Vicinity Map**. Regional geology of the Project and nearby area is provided on **Figure 2, Geologic Map**. Locations of test pits excavated for our subsurface investigation are shown on **Figure 3, Site Evaluation**. Slope-terrain information is provided on **Figure 4, LiDAR Analysis**.

## 1.2 Objectives, Scope and Authorization

The objectives and scope of our study were planned in discussions between Mr. Randy Moore of Moore Homes and Mr. Andrew Harris of CMT Engineering Laboratories (CMT) and are outlined in our proposal dated November 22, 2019. The proposal was authorized by Mr. Moore on November 23, 2019.

Our objectives and scope of work included:

1. Performing a site-specific geologic study, in accordance with Section 108-22 Natural Hazard Areas guidelines and standards of the Weber County Code of Ordinances (October 28, 2019), to assess whether all or parts of the site are exposed to natural hazards including, but not limited to: Surface-Fault Rupture, Landslides, Tectonic Subsidence, Rock Falls, Debris Flows, Liquefaction and Flooding.

2. Defining and evaluating site conditions, including: (a) a field program consisting of surficial observation and excavation, logging, and sampling of four walk-in test pits to evaluate subsurface conditions; (b) a laboratory soils testing program; and (c) an office program consisting of data compilation and correlation, applicable engineering and geological analyses, and preparation of this report summarizing our findings.

Based on the above, recommendations are provided herein to be utilized in appropriate site development and design and construction of the proposed home.

## 1.3 Description of Proposed Construction

We understand development of a residential subdivision is planned for the parcel. We project that single family residences are to be of wood-framed construction and founded on spread footings with basements (if conditions allow). Maximum continuous wall and column loads are anticipated to be 1,000 to 4,000 pounds per lineal foot and 10,000 to 40,000 pounds, respectively.

We anticipate that an asphalt-paved residential cul-de-sac will be constructed as part of the development. Traffic is projected to consist of a light volume of automobiles and pickup trucks, one or two daily medium-weight delivery trucks, a weekly garbage truck, and an occasional fire truck.

Site development will require some earthwork in the form of minor cutting and filling. A site grading plan was not available at the time of this report, but we project that maximum site grading cuts and fills may be on the order of 2 to 3 feet. If deeper cuts or fills are planned, CMT should be notified to provide additional recommendations, if needed.

## 1.4 Executive Summary

Proposed structures can be supported upon conventional spread and continuous wall foundations established on suitable natural soils or on structural fill extending to suitable natural soils. The most significant geotechnical/geological aspects of the site are:

1. The site is at the top of a terrace mapped by the Utah Geological Survey (UGS) as being underlain by deltaic deposits associated with the regressive stage of late Pleistocene Lake Bonneville. The land surface is flat to gentle. Except for a small (2,140 square-foot or 0.05-acre) area in the southeast corner of the property, slopes at the site dip an overall 2.57 degrees (4.5% gradient or 22.3:1 horizontal:vertical) to the southeast; the steep slope section, which is at the crest of the amphitheater, shows an overall dip of 29.1 degrees (55.7% gradient or 1.8:1). Groundwater was not observed in any of the test pits conducted for our study and is likely more than 50 feet below the ground surface (bgs) based on subsurface data from a study of the east-adjoining property (Western GeoLogic, 2017). However, groundwater depths may fluctuate seasonally, annually and locally. Soils encountered in the test pits appeared generally uniform and comprised of a mixture of gravel and sand.

2. The surface at each test pits is blanketed with sod and underlying topsoil ranging in thickness from about 6- to 12- inches which must be removed below new buildings and roadways.

A geotechnical engineer from CMT should be allowed to verify that all non-engineered/undocumented fill material and topsoil/disturbed soils have been completely removed from beneath proposed structures and roadways, and suitable natural soils encountered prior to the placement of structural fills, foundations, or concrete flatwork, and pavements.

In the following sections, detailed discussions pertaining to proposed construction, field exploration, the geologic setting and mapped hazards, geoseismic setting of the site, earthwork, foundations, lateral pressure and resistance, floor slabs, and pavements are provided.

# 2.0 FIELD EXPLORATION

Subsurface soil conditions at the site were explored by excavating four walk-in test pits (short trenches) located as shown on **Figure 4, Site Evaluation**. The test pits were excavated using a track-mounted excavator to depths of 6.6 to 8.1 feet for geologic/geotechnical logging and sampling. Deeper exploration was not conducted for safety reasons. During the course of the excavation operations, a continuous log of the subsurface conditions encountered was maintained. Undisturbed tube, block and disturbed bulk samples of representative soils encountered in the test pits were obtained for subsequent laboratory testing and examination. The representative soil samples were placed in sealed plastic bags and containers prior to transport to the laboratory.

The collected samples were logged and described in general accordance with ASTM D-2488, packaged, and transported to our laboratory. The soils were classified in the field based upon visual and textural examination. These classifications were supplemented by subsequent inspection and testing in our laboratory. The subsurface conditions encountered in the field exploration are discussed below in **Section 3.2**. Geologic logs of the test pits are illustrated on **Figures 5A through 5D, Test Pit Logs**. The logging methodology followed McCalpin (1996). The test pit locations were measured using a handheld GPS unit and by trend and distance methods. Location, trend, and other pertinent data and observations are provided on the logs.

When backfilling the test pits, only minimal effort was made to compact the backfill and no compaction testing was performed. Thus, the backfill must be considered as non-engineered and settlement of the backfill in the test pits over time must be anticipated.

# 3.0 SITE CONDITIONS

## 3.1 Surface Conditions

The site conditions and site geology were interpreted through an integrated compilation of data, including a review of literature and mapping from previous studies conducted in the area (Coogan and King, 2016; and Western GeoLogic, 2017); GIS analyses of elevation and geoprocessed 2013 LiDAR terrain data as shown on **Figure 3**; photogeologic analyses of 2012 imagery shown on **Figure 4**; field reconnaissance of the general site area; and interpretation of the test pits conducted at the site as part of our field program (**Figures 5A-D**). Seismic hazards information was developed from United States Geologic Survey (USGS) databases (Peterson and others, 2008).

As shown on **Figure 3**, topography of the site vicinity consists mainly of gentle slopes (in green) bordering the crest of a terrace; slopes below the terrace crest on **Figure 3** are steeper than 30% (in red). The site is currently a park developed for recreational uses. Vegetative cover consists mainly of grass and scattered landscape trees.

The surrounding areas on the north, west and south are generally developed for residential use. The area on the east is agricultural pastureland. Up to about five inches of snow covered the site surface at the time of our field investigation that limited surficial observation.

## 3.2 Subsurface Soils

Four test pits were excavated throughout the property to evaluate subsurface soil conditions at the locations indicated on **Figure 4**. All the test pits (**Figures 5A-D**) exposed a similar sequence of lacustrine and deltaic sand and gravel deposits underlying a relatively thin surface layer of silty and clay soils encountered within the upper about 2.0 to 3.5 feet, which correlates well with the surficial geologic mapping on **Figure 2**. A surface layer of sod and topsoil blanketed each test pit ranging in thickness from about 6- to 12-inches. No groundwater was encountered in any of the test pits to their explored depths of 8.5 feet below surrounding grades. Detailed stratigraphic unit descriptions are shown on the test pit logs.

## 3.3 Groundwater

No groundwater was encountered in the test pits conducted at the site within 8.5 feet of existing grades (the maximum explored depth). Western GeoLogic (2017) reported groundwater in the amphitheater to the southeast was at depths of 18 to 59 feet bgs, but believed groundwater in the terrace further north and west was likely deeper than 50 feet bgs. However, groundwater levels may vary locally, annually from climatic fluctuations, and seasonally from snow-melt runoff or from man-made sources such as landscape irrigation. Although some groundwater fluctuations may occur, we do not anticipate groundwater will significantly affect the proposed construction.

## 3.4 Site Subsurface Variations

Based on the results of the subsurface explorations and our experience, some variations in the continuity and nature of subsurface conditions should be anticipated. Due to the heterogeneous characteristics of natural soils, care should be taken in interpolating or extrapolating subsurface conditions between or beyond the exploratory locations.

Also, when logging and sampling of the test pits was completed, the test pits were backfilled with the excavated soils but minimal to no effort was made to compact these soils. Thus, the backfill must be considered as non-engineered fill and settlement of the backfill in the test pits over time should be anticipated.

# 4.0 ENGINEERING GEOLOGY

## 4.1 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 0.8 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, a fifth event from 5,500 to 7,530 years ago, and a sixth event about 7,810 to 9,930 years ago. The preferred recurrence interval (mean time between events) based on this chronology is 1,500 years (DuRoss and others, 2009). Timing for events at the Rice Creek site was reportedly similar to those at the Garner Canyon, East Ogden, and Kaysville sites, except for one previously undiscovered event.

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 MS 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 (MS 6.6) event north of the Great Salt Lake.

## 4.2 Surficial Geology

The property is at the top of a terrace northwest of the mouth of Weber Canyon that was downcut by the Weber River following the retreat of late Pleistocene Lake Bonneville. The terrace overlooks the Weber River floodplain to the south. Coogan and King (2016) map the surficial geology of the Project as lacustrine and deltaic deposits associated with the regressive stage of Pleistocene Lake Bonneville (unit Qadp, **Figure 2**). Further southeast is an amphitheater formed by instability in slopes bordering the terrace and underlain by younger Quaternary-age mass wasting deposits (unit Qmsy, **Figure 2**).

Coogan and King (2016) describe surficial geologic units in the area 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 (slopewash 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 slopewash 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).*

## 4.3 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 in higher slopes to the east (**Figure 2**, blue line and B).

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).

## 4.4 Seismic Hazards

### 4.4.1 Strong Ground Motions

Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60-mile radius of the Project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. The Utah Geological Survey Quaternary Fault Database (Black and others, 2003; January 2017 update) shows numerous class A faults within 60 miles of the Project that may pose potential seismic sources. Strong ground motions originating from the Wasatch fault or other near-by seismic sources are capable of impacting the site. The Wasatch fault zone is considered active and capable of generating earthquakes as large as magnitude 7.3 (Arabasz and others, 1992).

### 4.4.2 Site Class

Utah has adopted the 2018 International Building Code (IBC), which determines the seismic hazard for a site based upon 2014 mapping of bedrock accelerations prepared by the United States Geologic Survey (USGS) and the soil site class. The USGS values are presented on maps incorporated into the IBC code and are also available based on latitude and longitude coordinates (grid points). For site class definitions, IBC 2018 Section 1613.2.2 refers to Chapter 20, Site Classification Procedure for Seismic Design, of ASCE[1] 7-16. Given the subsurface soils encountered at the site, it is our opinion the site best fits Site Class D – Stiff Soil Profile (without data), which we recommend for seismic structural design.

### 4.4.3 Seismic Design Category

The 2014 USGS mapping utilized by the IBC provides values of peak ground, short period and long period accelerations for the Site Class B/C boundary and the Maximum Considered Earthquake (MCE). This Site Class B/C boundary represents average bedrock values for the Western United States and must be corrected for local soil conditions. The Seismic Design Categories in the International Residential Code (IRC 2018 Table R301.2.2.1.1) are based upon the Site Class discussed in the previous section. For Site Class D at site grid coordinates of 41.14986 degrees north latitude and 111.92369 degrees west longitude, $\mathbf{S_{DS}}$ is 0.87 and the **Seismic Design Category** is $D_2$.

### 4.4.4 Surface Faulting

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

No evidence of active surface faulting is mapped or was evident at the site. The nearest active (Holocene-age) fault to the site is the Weber segment of the Wasatch fault zone about 0.8 miles to the east. Surface faulting is not therefore considered to pose a risk to the site.

### 4.4.5 Liquefaction

Liquefaction is a phenomenon whereby loose, saturated, granular soil units lose a significant portion of their shear strength due to excess pore water pressure buildup resulting from dynamic loading, such as that caused by an earthquake. Among other effects, liquefaction can result in densification of such deposits causing settlements of overlying layers after an earthquake as excess pore water pressures are dissipated. Horizontally continuous liquefied layers may also have a potential to spread laterally where sufficient slope or free-face

[1] American Society of Civil Engineers

conditions exist. The primary factors affecting liquefaction potential of a soil deposit are: (1) magnitude and duration of seismic ground motions; (2) soil type and consistency; and (3) occurrence and depth to groundwater.

Anderson and others (1982) and Christenson and Shaw (2008) map the subject site in an area classified as having a "Low-Moderate" liquefaction potential. The test pits at the site did not expose sediments likely susceptible to liquefaction, although sandy layers could be present deeper in the subsurface and the Project is subject to strong ground shaking. However, groundwater was not encountered in any of the test pits at the site and is likely more than 50 feet deep. The mapped liquefaction potential therefore appears appropriate for the known and expected onsite subsurface conditions. Given all the above, we do not anticipate that liquefaction will pose a significant risk to the proposed development.

### 4.4.6 Tectonic Subsidence

Tectonic subsidence is surface tilting subsidence that occurs along the boundaries of normal faults in response to surface-faulting earthquakes (Keaton, 1986). The site is not located adjacent to and the on the downthrown side of any active earthquake faults. Tectonic subsidence is not therefore considered to pose a significant risk.

## 4.5 Landslide and Slump Deposits

Landslides, slumps, and other mass movements are gravity-induced downslope movements of rock or soil. Such failures may be both deep and shallow seated. Deep-seated failures include rotational and translational slides and associated earthflows where the failure plane is more than 10 feet deep (Varnes, 1978; Cruden and Varnes, 1996). Landslides can develop in 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.

No landslides are mapped at the site and no evidence for recent or ongoing slope instability was observed during our field investigation. However, the amphitheater further southeast is a feature related to prior landsliding; the steep slopes in the southeast corner of the Project are from erosional degradation of the head scarp of this failure. Western GeoLogic (2017) inferred the landslide may have been a prehistoric liquefaction-induced flow failure concurrent with a large magnitude earthquake on the Weber segment of the WFZ. CMT completed a study including a slope stability for a property just east and south and below the head scarp dated June, 13, 2017[2]. This study indicated that where the existing slope analyzed would not be significantly modified is currently met the minimum required factors of safety of 1.5 for static conditions and 1.0 for seismic conditions. Given the above, landslides do not generally to pose a risk to the site.

## 4.6 Other Geologic Hazards

Other potential geologic hazards at the site are addressed in the following subsections.

[2] Geotechnical Engineering Study, Proposed Single Family Residence 2360 East 6200 South Ogden, Weber county, Utah; CMT Project Number 9587.

### 4.6.1 Sloping Surfaces

Surface slopes at the Project developed from our LiDAR analysis, as shown on **Figure 3**, are mainly gentler than 25% (in green). Slopes steeper than 30% on **Figure 3** (in red) are found only in a small part of the southeast corner of the Project. Slopes at the site dip an overall 2.57 degrees (4.5% gradient or 22.3:1 horizontal:vertical) to the southeast; the steep slope section, which is along the crest of the amphitheater further southeast (**Figure 3**), shows an overall dip of 29.1 degrees (55.7% gradient or 1.8:1).

### 4.6.2 Alluvial Fan Flooding

Alluvial-fan flooding refers to a continuum of processes that includes debris slides, debris flows, debris floods, and flash flooding on alluvial fans (National Research Council, 1996). Debris flows and related sediment-enriched floods and flows are fast moving flow-type landslides comprised of a slurry of rock, mud, organic matter, and water that move down drainage-basin channels onto alluvial fans (Giraud, 2005). Debris flow hazards are commonly associated with areas underlain by Holocene alluvial-fan deposits at the mouths of range-front drainages, such as those along the Wasatch Range.

The Project is not in an area subject to alluvial-fan flooding and no debris-flow channels, levees, or other debris-flow features were observed. Debris flows and floods are not therefore considered to pose a risk to the site.

### 4.6.3 Stream Flooding Hazards

No active drainages were observed crossing the Project and Federal Emergency Management Agency flood insurance rate mapping (Map Number 49057C0443F) classifies the Project in "Zone X - Area of Minimal Flood Hazard". Given the above, stream flooding is not considered to pose a risk to the site.

### 4.6.4 Rockfall and Avalanche Hazards

The site is not located downslope from steep slopes with source areas where rockfalls and avalanches may originate.

## 5.0 LABORATORY TESTING

### 5.1 General

Selected samples of the subsurface soils were subjected to various laboratory tests to assess pertinent engineering properties, as follows:

1. Moisture Content, ASTM D-2216, Percent moisture representative of field conditions
2. Dry Density, ASTM D-2937, Dry unit weight representing field conditions
3. Atterberg Limits, ASTM D-4318, Plasticity and workability

4. Gradation Analysis, ASTM D-1140/C-117, Grain Size Analysis
5. One Dimension Consolidation, ASTM D-2435, Consolidation properties

## 5.2 Lab Summary

Laboratory test results are presented in the following Lab Summary table:

**LAB SUMMARY TABLE**

| TEST PIT | DEPTH (feet) | SOIL CLASS | SAMPLE TYPE | MOISTURE CONTENT(%) | DRY DENSITY (pcf) | GRADATION | | | ATTERBERG LIMITS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | GRAV. | SAND | FINES | LL | PL | PI |
| TP-1 | 1.5 | CL-ML | TW | 6.5 | 118 | | | | | | |
| | 8 | GP | Bag | 1.1 | | 88 | 9 | 2.6 | | | |
| TP-2 | 1 | ML | TW | 4.5 | 102 | | | | | | NP |
| | 4.5 | GP | Bag | 1.8 | | 78 | 18 | 4 | | | |
| TP-3 | 2 | CL | TW | 15.5 | 109 | | | | 25 | 15 | 10 |
| TP-4 | 1.5 | ML | TW | 16.2 | 100 | | | | | | NP |
| | 7.5 | GP-GM | Bag | 4 | | 71 | 22 | 7 | | | |

# 6.0 SITE PREPARATION AND GRADING

## 6.1 General

Site preparation will consist of the removal of any surface vegetation, topsoil, and any other deleterious materials from beneath an area extending out at least 3 feet beyond new structures and 2 feet beyond pavements. Trees and their associated root bulbs will require deeper removal depths.

All non-engineered fill, if/where encountered, must be removed below buildings but may remain below pavement areas if; free of debris and deleterious materials, nor more than 3 feet thick, subsequent site grading fills are not more than 3 feet thick, and if properly prepared. Proper preparation of existing fills below pavements will consist of the scarification of the upper 12 inches followed by moisture preparation and re-compaction to the requirements of structural fill. Onsite fine-grained soils (silts/clays) are moisture sensitive and may be difficult to control proper moisture content for recompacting especially during wet and cold periods of the year. Where compaction of onsite fine-grained soils becomes difficult the recommended 12-inches of prepared soils may be removed and replaced with imported granular structural fill. Even with proper preparation, pavements over some remaining thickness of non-engineered fill may experience some settlement over time. If this is not tolerable then the entire sequence of non-engineered fill must be removed.

Subsequent to stripping and prior to the placement of floor slabs, foundations, structural site grading fills, exterior flatwork, and pavements, the exposed subgrade must be proofrolled by passing moderate-weight rubber tire-mounted construction equipment over the surface at least twice. If excessively soft or otherwise unsuitable soils are encountered beneath footings, they must be completely removed. If removal depth required is greater than 2 feet below footings, CMT must be notified to provide further recommendations. In pavement, floor slab, and outside flatwork areas, unsuitable natural soils should be removed to a maximum depth of 2 feet and replaced with compacted granular structural fill. Fills must be handled as described above.

The site should be examined by a CMT geotechnical engineer to assess that suitable natural soils have been exposed and any deleterious materials, loose and/or disturbed soils have been removed/properly prepared, prior to placing site grading fills, footings, slabs, and pavements.

Any fill should be placed on relatively level surfaces and against relatively vertical surfaces. Thus, where the existing slope is steeper than about 5H:1V (Horizontal:Vertical), the existing ground should be benched to create horizontal and vertical surfaces for receiving the fill. We recommend maximum bench heights of about 2 feet.

## 6.2 Temporary Excavations

Temporary construction excavations in cohesive soil, not exceeding 4 feet in depth and above or below the groundwater table, may be constructed with near-vertical sideslopes. Temporary excavations up to 8 feet deep in fine-grained cohesive soils, above or below the water table, may be constructed with sideslopes no steeper than one-half horizontal to one vertical (0.5H:1V). Excavations deeper than 8 feet are not anticipated at the site.

For granular (cohesionless) soils, construction excavations above the water table, not exceeding 4 feet, should be no steeper than one-half horizontal to one vertical (0.5H:1V). Excavations encountering saturated cohesionless soils will be very difficult and will require very flat sideslopes and/or shoring, bracing and dewatering as these soils will tend to flow into the excavation.

To reduce disturbance of the natural soils during excavation, we recommend that smooth edge buckets/blades be utilized.

All excavations must be inspected periodically by qualified personnel. If any signs of instability or excessive sloughing are noted, immediate remedial action must be initiated. All excavations should be made following OSHA safety guidelines.

## 6.3 Fill Material

Structural fill is defined as all fill which will ultimately be subjected to structural loadings, such as imposed by footings, floor slabs, pavements, etc. Structural fill will be required as backfill over foundations and utilities, as site grading fill, and possibly as replacement fill below footings. All structural fill must be free of sod, rubbish, topsoil, frozen soil, and other deleterious materials.

Following are our recommendations for the various fill types we project will be used at this site:

| Fill Material Type | Description/Recommended Specification |
|---|---|
| Structural Fill | Placed below structures, flatwork and pavement. Well-graded sand/gravel mixture, with maximum particle size of 4 inches, a minimum 70% passing 3/4-inch sieve, a maximum 20% passing No. 200 sieve, and a maximum Plasticity Index of 10. |
| General Site Grading Fill | Placed over larger areas to raise the site grade, with a maximum particle size of 6 inches, a minimum 70% passing 3/4-inch sieve, a maximum 50% passing No. 200 sieve and Plastic Index less than 18 percent. |
| Non-Structural Fill | Placed below non-structural areas, such as landscaping. On-site soils, including silt/clay soils not containing excessive amounts of degradable/organic material (see discussion below). |
| Stabilization Fill | Placed to stabilize soft areas prior to placing structural fill and/or site grading fill. Coarse angular gravels and cobbles 1 inch to 8 inches in size. May also use 1.5- to 2.0-inch gravel placed on stabilization fabric, such as Mirafi RS280i or equivalent. |

Onsite soils may be re-utilized as structural site grading fill if processed to meet the requirements for such. Note that fine grained soils are generally moisture-sensitive, including on-site clay soils, and are inherently more difficult to work with and properly moisture condition (they are very sensitive to changes in moisture content), requiring very close moisture control during placement and compaction. This will be very difficult, if not impossible, during wet and cold periods of the year.

## 6.4 Fill Placement and Compaction

The various types of compaction equipment available have their limitations as to the maximum lift thickness that can be compacted. For example, hand operated equipment is limited to lifts of about 4 inches and most "trench compactors" have a maximum, consistent compaction depth of about 6 inches. Large rollers, depending on soil and moisture conditions, can achieve compaction at 8 to 12 inches. The full thickness of each lift should be compacted to at least the following percentages of the maximum dry density as determined by ASTM D-1557 (or AASHTO[3] T-180) in accordance with the following recommendations:

[3] American Association of State Highway and Transportation Officials

| Location | Total Fill Thickness (feet) | Minimum Percentage of Maximum Dry Density |
|---|---|---|
| Beneath an area extending at least 3 feet beyond the perimeter of structures, and below flatwork and pavement (applies to structural fill and site grading fill) | 0 to 5<br>5 to 8 | 95<br>98 |
| Site grading fill outside area defined above | 0 to 5<br>5 to 8 | 92<br>95 |
| Utility trenches within structural areas | -- | 96 |
| Roadbase and subbase | - | 96 |
| Non-structural fill | 0 to 5<br>5 to 8 | 90<br>92 |

Structural fills greater than 8 feet thick are not anticipated at the site. For best compaction results, we recommend that the moisture content for structural fill/backfill be within 2% of optimum. Field density tests should be performed on each lift as necessary to verify that proper compaction is being achieved.

## 6.5 Utility Trenches

For the bedding zone around the utility, we recommend utilizing sand bedding fill material that meets current APWA[4] requirements.

All utility trench backfill material below structurally loaded facilities (flatwork, floor slabs, roads, etc.) shall be placed at the same density requirements established for structural fill. If the surface of the backfill becomes disturbed during the course of construction, the backfill shall be proofrolled and/or properly compacted prior to the construction of any exterior flatwork over a backfilled trench. Proofrolling shall be performed by passing moderately loaded rubber tire-mounted construction equipment uniformly over the surface at least twice. If excessively loose or soft areas are encountered during proofrolling, they shall be removed to a maximum depth of 2 feet below design finish grade and replaced with structural fill.

Most utility companies and City-County governments are now requiring that Type A-1a or A-1b (AASHTO Designation – basically granular soils with limited fines) soils be used as backfill over utilities. These organizations are also requiring that in public roadways the backfill over major utilities be compacted over the full depth of fill to at least 96 percent of the maximum dry density as determined by the AASHTO T-180 (ASTM D-1557) method of compaction. We recommend that as the major utilities continue onto the site that these compaction specifications are followed.

In private utility areas, existing fill soils and natural soils may be re-utilized as trench backfill over the bedding layer provided that they are properly moisture prepared and compacted to the minimum requirements stated in **Section 6.4 Fill Placement and Compaction**.

[4] American Public Works Association

## 6.6 Soil Stabilization

To stabilize soft subgrade conditions (if encountered), a mixture of coarse, clean, angular gravels and cobbles and/or 1.5- to 2.0-inch clean gravel should be utilized. Often the amount of gravelly material can be reduced with the use of a geotextile fabric such as Mirafi RS280i, or equivalent. Its use will also help avoid mixing of the subgrade soils with the gravelly material. After excavating the soft/disturbed soils, the fabric should be spread across the bottom of the excavation and up the sides a minimum of 18 inches. Otherwise, it should be placed in accordance with the manufacturer's recommendation, including proper overlaps. The gravel material can then be placed over the fabric in compacted lifts as described above.

# 7.0 FOUNDATION RECOMMENDATIONS

Based on our geotechnical engineering analyses, the proposed structures may be supported upon conventional spread and/or continuous wall foundations placed on suitable, undisturbed natural soils and/or on structural fill extending to suitable natural soils. Footings may be designed using a net bearing pressure of 1,500 psf if placed on suitable, undisturbed, natural soils or structural fill extending to suitable natural soils.

The term "net bearing pressure" refers to the pressure imposed by the portion of the structure located above lowest adjacent final grade, thus the weight of the footing and backfill to lowest adjacent final grade need not be considered. The allowable bearing pressure may be increased by 1/3 for temporary loads such as wind and seismic forces.

We also recommend the following:

1. Exterior footings subject to frost should be placed at least 30 inches below final grade.
2. Interior footings not subject to frost should be placed at least 16 inches below grade.
3. Continuous footing widths should be maintained at a minimum of 18 inches.
4. Spot footings should be a minimum of 24 inches wide.

## 7.2 Installation

Under no circumstances shall foundations be placed on undocumented fill, topsoil with organics, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

Deep, large roots may be encountered where trees and larger bushes are located or were previously located at the site; such large roots should be removed. If unsuitable soils are encountered, they must be completely removed and replaced with properly compacted structural fill. Excavation bottoms should be examined by a qualified geotechnical engineer to confirm that suitable bearing materials soils have been exposed.

All structural fill should meet the requirements for such, and should be placed and compacted in accordance with **Section 6** above. The width of structural replacement fill below footings should be equal to the width of the footing plus 1 foot for each foot of fill thickness. For instance, if the footing width is 2 feet and the structural fill depth beneath the footing is 2 feet, the fill replacement width should be 4 feet, centered beneath the footing.

## 7.3 Estimated Settlement

Foundations designed and constructed in accordance with our recommendations could experience some settlement, but we anticipate that total settlements of footings founded as recommended above will not exceed 1 inch, with differential settlements on the order of 0.5 inches over a distance of 20 feet. We anticipate approximately 50% of the total settlement to initially take place during construction.

## 7.4 Lateral Resistance

Lateral loads imposed upon foundations due to wind or seismic forces may be resisted by the development of passive earth pressures and friction between the base of the footings and the supporting soils. In determining frictional resistance, a coefficient of 0.30 for natural clay soils or 0.40 for granular structural fill, may be utilized for design. Passive resistance provided by properly placed and compacted granular structural fill above the water table may be considered equivalent to a fluid with a density of 250 pounds per cubic foot.

A combination of passive earth resistance and friction may be utilized provided that the friction component of the total is divided by 1.5.

# 8.0 LATERAL EARTH PRESSURES

For basement walls/retaining walls or utility boxes up to about 8 feet tall the following lateral pressure discussion is provided. Parameters, as presented within this section, are for backfills which will consist of drained soil placed and compacted in accordance with the recommendations presented herein.

The lateral pressures imposed upon subgrade facilities will, therefore, be basically dependent upon the relative rigidity and movement of the backfilled structure. For active walls, such as retaining walls which can move outward (away from the backfill), backfill may be considered equivalent to a fluid with a density of 40 pounds per cubic foot in computing lateral pressures. For more rigid walls (moderately yielding), backfill may be considered equivalent to a fluid with a density of 50 pounds per cubic foot. For very rigid non-yielding walls, granular backfill should be considered equivalent to a fluid with a density of at least 60 pounds per cubic foot. The above values assume that the surface of the soils slope behind the wall is horizontal and that the fill within 3 feet of the wall will be compacted with hand-operated compacting equipment.

For seismic loading of retaining/below-grade walls, the following uniform lateral pressures, in pounds per square foot (psf), should be added based on wall depth and wall case.

| Uniform Lateral Pressures | | | |
|---|---|---|---|
| **Wall Height (Feet)** | **Active Pressure Case (psf)** | **Moderately Yielding Case (psf)** | **At Rest/Non-Yielding Case (psf)** |
| 4 | 26 | 52 | 79 |
| 6 | 39 | 79 | 118 |
| 8 | 52 | 105 | 158 |

# 9.0 FLOOR SLABS

Floor slabs may be established upon suitable, undisturbed, natural soils and/or on structural fill extending to suitable natural soils (same as for foundations). Under no circumstances shall floor slabs be established directly on any topsoil, non-engineered fills, potentially collapsible soil, loose or disturbed soils, sod, rubbish, construction debris, other deleterious materials, frozen soils, or within ponded water.

In order to facilitate curing of the concrete, we recommend that floor slabs be directly underlain by at least 4 inches of “free-draining” fill, such as “pea” gravel or 3/4-inch to 1-inch minus, clean, gap-graded gravel. To help control normal shrinkage and stress cracking, the floor slabs may include the following features:

1. Adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints;
2. Frequent crack control joints; and
3. Non-rigid attachment of the slabs to foundation walls and bearing slabs.

# 10.0 DRAINAGE RECOMMENDATIONS

## 10.1 Surface Drainage

It is important to the long-term performance of foundations and floor slabs that water not be allowed to collect near the foundation walls and infiltrate into the underlying soils. We recommend the following:

1. All areas around the structure should be sloped to provide drainage away from the foundations. We recommend a minimum slope of 4 inches in the first 10 feet away from the structure. This slope should be maintained throughout the lifetime of the structure.

2. All roof drainage should be collected in rain gutters with downspouts designed to discharge at least 10 feet from the foundation walls or well beyond the backfill limits, whichever is greater.

3. Adequate compaction of the foundation backfill should be provided. We suggest a minimum of 90% of the maximum laboratory density as determined by ASTM D-1557. Water consolidation methods should not be used under any circumstances.

4. Landscape sprinklers should be aimed away from the foundation walls. The sprinkling systems should be designed with proper drainage and be well-maintained. Over watering should be avoided.

5. Other precautions that may become evident during construction.

# 11.0 PAVEMENTS

All pavement areas must be prepared as discussed above in **Section 6.1**. We anticipate the natural silt/clay soils will exhibit poor pavement support characteristics when saturated or nearly saturated. Based on our laboratory testing experience with similar soils, our pavement design utilized a California Bearing Ratio (CBR) of 3 for the natural silt/clay soils.

Site pavements are anticipated to consist primarily of flexible (asphalt concrete) pavement. Some Concrete aprons may be necessary for loading/unloading zones. All pavement areas must be prepared as discussed above in **Section 6.1**.

Given the projected traffic as discussed above in **Section 1.3**, the following pavement sections are recommended for approximately 4 ESAL's (18-kip equivalent single-axle loads) per day:

| MATERIAL | PAVEMENT SECTION THICKNESS (inches) | | |
|---|---|---|---|
| Asphalt | **3** | **3** | **---** |
| Rigid Concrete (PCC) | **---** | **---** | **5** |
| Road-Base | **11** | **6** | **6** |
| Subbase | **0** | **7** | **---** |
| Total Thickness | **14** | **16** | **11** |

Untreated base course (UTBC) should conform to city specifications, or to 1-inch-minus UDOT specifications for A–1-a/NP, and have a minimum CBR value of 70%. Subbase shall consist of a granular soil with a minimum CBR of 30%. Roadbase and subbase material should be compacted as recommended above in **Section 6.4** Fill Placement and Compaction of this report. Asphalt material generally should conform to APWA requirements, having a ½-inch maximum aggregate size, containing no more than 15% of recycled asphalt (RAP) and a PG58-28 binder. The asphalt pavement should be compacted to 96% of the maximum density for the asphalt material.

Rigid pavement sections are for non-reinforced Portland cement concrete. Pavement and site concrete should be designed in accordance with the American Concrete Institute (ACI) and joint details should conform to the Portland Cement Association (PCA) guidelines. The concrete should have a minimum 28-day unconfined compressive strength of 4,000 pounds per square inch and contain 6 percent ±1 percent air-entrainment.

# 12.0 QUALITY CONTROL

We recommend that CMT be retained to as part of a comprehensive quality control testing and observation program. With CMT on-site we can help facilitate implementation of our recommendations and address, in a timely manner, any subsurface conditions encountered which vary from those described in this report. Without such a program CMT cannot be responsible for application of our recommendations to subsurface conditions which may vary from those described herein. This program may include, but not necessarily be limited to, the following:

## 12.1 Field Observations

Observations should be completed during all phases of construction such as site preparation, foundation excavation, structural fill placement and concrete placement.

## 12.2 Fill Compaction

Compaction testing by CMT is required for all structural supporting fill materials. Maximum Dry Density (Modified Proctor, ASTM D-1557) tests should be requested by the contractor immediately after delivery of any fill materials. The maximum density information should then be used for field density tests on each lift as necessary to ensure that the required compaction is being achieved.

## 12.3 Excavations

All excavation procedures and processes should be observed by a geotechnical engineer from CMT or their representative. In addition, for the recommendations in this report to be valid, all backfill and structural fill placed in trenches and all pavements should be density tested by CMT. We recommend that freshly mixed concrete be tested by CMT in accordance with ASTM designations.

# 13.0 LIMITATIONS

The recommendations provided herein were developed by evaluating the information obtained from the subsurface explorations and soils encountered therein. The exploration logs reflect the subsurface conditions only at the specific location at the particular time designated on the logs. Soil and ground water conditions may differ from conditions encountered at the actual exploration locations. The nature and extent of any variation in the explorations may not become evident until during the course of construction. If variations do appear, it may become necessary to re-evaluate the recommendations of this report after we have observed the variation.

Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

We appreciate the opportunity to be of service to you on this Project. If we can be of further assistance or if you have any questions regarding the Project, please do not hesitate to contact us at (801) 870-6730. To schedule materials testing, please call (801) 381-5141.

## 14.0 REFERENCES

Anderson, R.E., 1989, Tectonic evolution of the intermontane system--Basin and Range, Colorado Plateau, and High Lava Plains, in Pakiser, L.C., and Mooney, W.D., editors, Geophysical framework of the continental United States: Geological Society of America Memoir 172, p. 163-176.

Arabasz, W.J., Pechmann, J.C., and Brown, E.D., 1992, Observational seismology and evaluation of earthquake hazards and risk in the Wasatch Front area, Utah, in Gori, P.L. and Hays, W.W., editors, Assessment of Regional Earthquake Hazards and Risk along the Wasatch Front, Utah: Washington, D.C, U.S. Geological Survey Professional Paper 1500-D, Government Printing Office, p. D1-D36.

Black, B.D., Hecker, Suzanne, Hylland, M.D., Christenson, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193DM, CD-ROM.

Bowman, S.D., and Lund, W.R., 2016, Guidelines for conducting engineering-geology investigations and preparing engineering-geology reports in Utah, in Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geo¬logic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah: Utah Geological Survey Circular 122, p. 15–30.

Coogan, J.C., and King, J.K., 2016, Interim Geologic Map of the Ogden 30' x 60' Quadrangle, Box Elder, Cache, Davis, Morgan, Rich, and Summit Counties, Utah, and Uinta County, Wyoming: Utah Geological Survey Open-File Report 653DM, scale 1:100,000, 141 p. with appendices.

Cruden, D.M. and Varnes, D.J., 1996, Landslide Types and Processes, in Turner, A.K. and Shuster, R.L., editors, Landslides--Investigation and Mitigation: Washington D.C., Transportation Research Board Special Report No. 247, 36-75.

DuRoss, C.B., Personius, S.F., Crone, A.J., McDonald, G.N., and Lidke, D.J., 2009, Paleoseismic Investigation of the Northern Weber Segment of the Wasatch Fault Zone at the Rice Creek Trench Site, North Ogden, Utah: Utah Geological Survey Special Study 130, Paleoseismology of Utah Volume 18, 37 p. with trench logs.

Feth, J.H., Barker, D.A., Moore, L.G., Brown, R.J., and Veirs, C.E., 1966, Lake Bonneville—Geology and hydrology of the Weber delta district, including Ogden, Utah: U.S. Geological Survey Professi9onal Paper 518, 76 p.

Gilbert, G.K., 1928, Studies of Basin and Range Structure: U.S. Geological Survey Professional Paper 153, 89 p.

Gwynn, J.W. (Editor), 1980, Great Salt Lake--A scientific, historical, and economic overview: Utah Geological Survey Bulletin 166, 400 p.

Jarrett, R.D., and Malde, H.E., 1987, Paleodischarge of the late Pleistocene Bonneville flood, Snake River, Idaho, computed from new evidence: Geological Society of America Bulletin, v. 99, p. 127-134.

Lund, W.R. (Editor), 1990. Engineering geology of the Salt Lake City metropolitan area, Utah: Utah Geological and Mineral Survey Bulletin 126, 66 p.

McCalpin, J.P., Forman, S.L., and Lowe, Mike, 1994, Reevaluation of Holocene faulting at the Kaysville site, Weber segment of the Wasatch fault zone, Utah: Tectonics, v. 13, no. 1, p. 1-16.

Miller, D.M., 1990, Mesozoic and Cenozoic tectonic evolution of the northeastern Great Basin, in Shaddrick, D.R., Kizis, J.R., and Hunsaker, E.L. III, editors, Geology and Ore Deposits of the Northeastern Great Basin: Geological Society of Nevada Field Trip No. 5, p. 43-73.

Nelson, A.R., Lowe, Mike, Personius, Stephen, Bradley, Lee-Ann, Forman, S.L., Klauk, Robert, and Garr, John, 2006, Holocene earthquake history of the northern Weber segment of the Wasatch fault zone, Utah: Utah Geological Survey Miscellaneous Publication 05-08, 39 p.

O'Connor, J.E., 1993, Hydrology, hydraulics, and geomorphology of the Bonneville flood: Geological Society of America Special Paper 274, 83 p.

Oviatt, C.G., 2015, Chronology of Lake Bonneville, 30,000 to 10,000 yr B.P.: Quaternary Science Reviews, v. 110 (2015), p. 166-171.

Oviatt, C.G., Currey, D.R., and Sack, Dorothy, 1992, Radiocarbon chronology of Lake Bonneville, Eastern Great Basin, USA: Paleogeography, Paleoclimatology, Paleoecology, v. 99, p. 225-241.

Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, S.C., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Y., Boyd, O.S., Perkins, D.M., Luco, N., Field, E.H., Wills, C.J., and Rukstales, K.S., 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps: USGS Open-File Report 2008-1128, 128p.

Sbar, M.L., Barazangi, M., Dorman, J., Scholz, C.H., and Smith, R.B., 1972, Tectonics of the Intermountain Seismic Belt, western United States--Microearthquake seismicity and composite fault plane solutions: Geological Society of America Bulletin, v. 83, p. 13-28.

Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the Intermountain Seismic Belt, in Slemmons, D.B., Engdahl, E.R., Zoback, M.D., and Blackwell, D.D., editors, Neotectonics of North America: Geological Society of America, Decade of North American Geology Map v. 1, p. 185-228.

Smith, R.B. and Sbar, M.L., 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the Intermountain Seismic Belt: Geological Society of America Bulletin, v. 85, p. 1205-1218.

Stewart, J.H., 1978, Basin-range structure in western North America, a review, in Smith, R.B., and Eaton, G.P., editors, Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 341-367.

____, 1980, Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4.

Stokes, W.L., 1977, Physiographic subdivisions of Utah: Utah Geological and Mineral Survey Map 43, scale 1:2,400,000.

____, 1986, Geology of Utah: Salt Lake City, University of Utah Museum of Natural History and Utah Geological and Mineral Survey, 280 p.

Varnes, D. J., 1978, Slope movement types and processes, in Schuster, R.L and Krizek, R.J, editors, Landslides Analysis and control: Washington D.C., Transportation Research Board Special Report 176, p. 11-33.

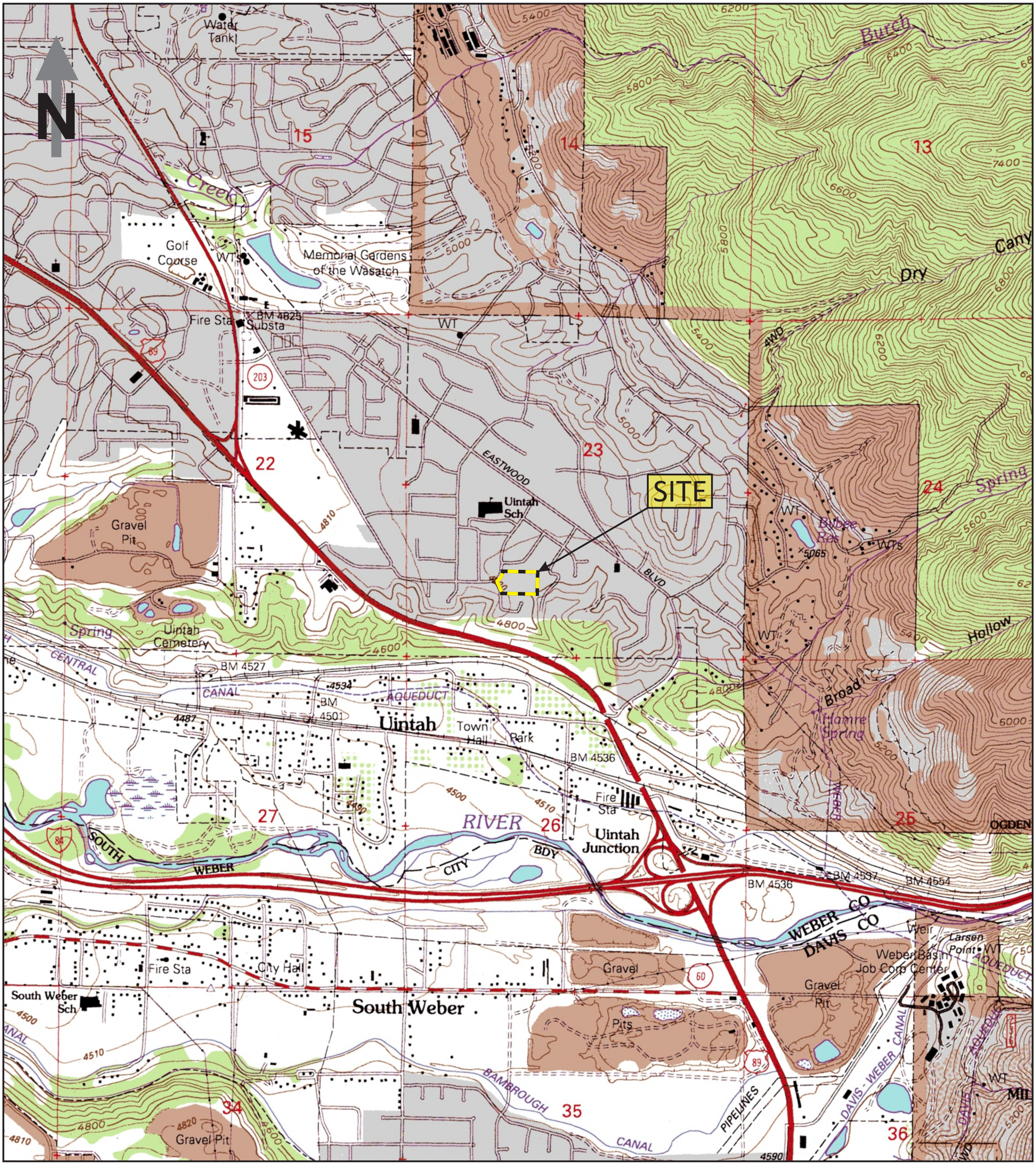
Western GeoLogic, 2017, Geologic Hazards Evaluation--McSwain Property, 2360 East 6200 South, Ogden, Weber County, Utah: unpublished consultant's report prepared for Mr. Colton McSwain dated April 22, 2017, 21 p. with test pits logs and geologic cross section.

Zoback, M.L., 1989. State of stress and modern deformation of the northern Basin and Range province: Journal of Geophysical Research, v. 94, p. 7105-7128.

Zoback, M.L. and Zoback, M.D., 1989. Tectonic stress field of the conterminous United States: Boulder, Colorado, Geological Society of America Memoir, v. 172, p. 523-539.

# APPENDIX

**SUPPORTING**
DOCUMENTATION




Base:
USGS 7.5-minute topographic quadrangle, Utah; OGDEN, 1998.

0 2,000 ft 4,000 ft

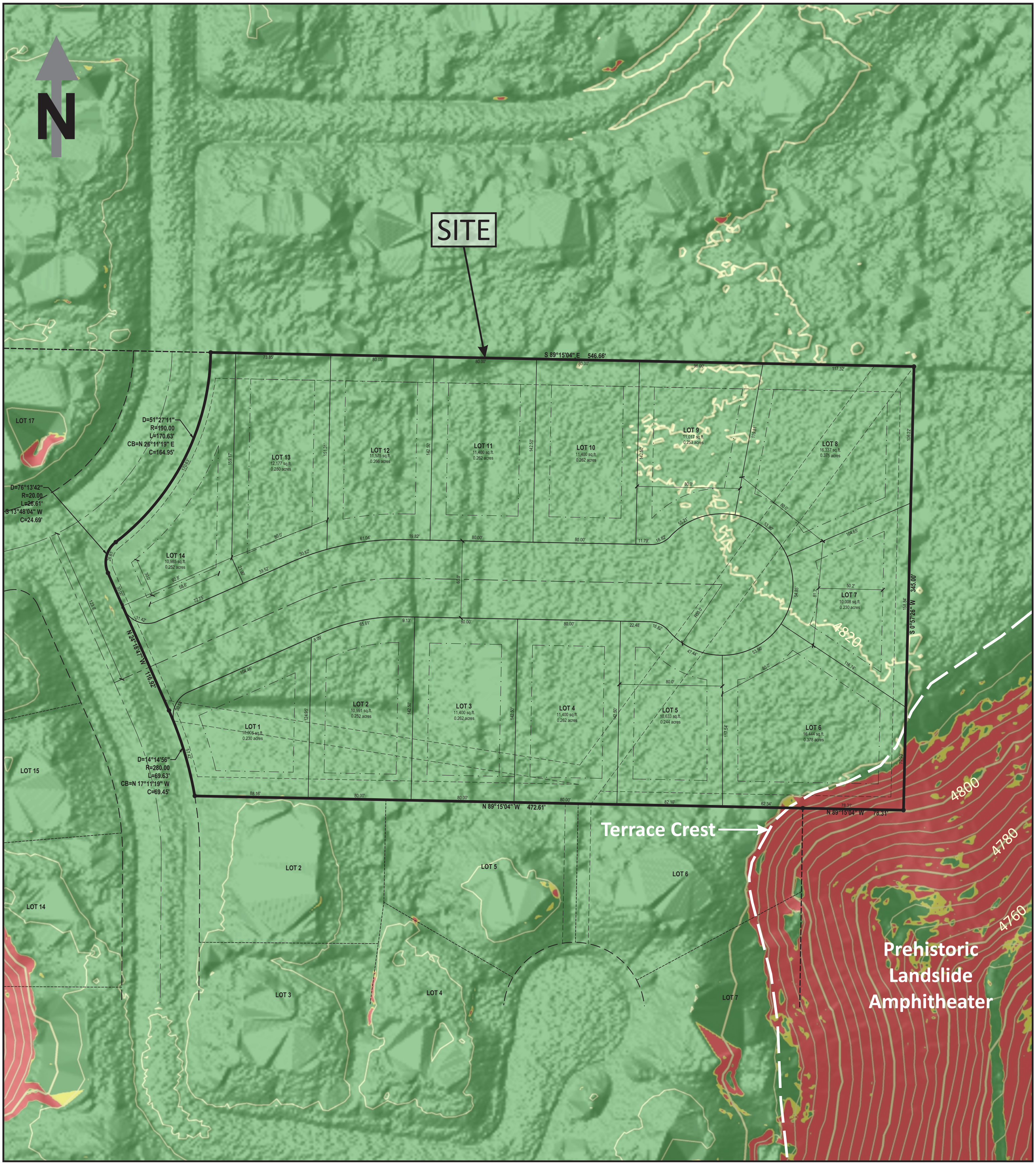
1:24,000 (1 inch equals 2,000 feet)

| | | | |
|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | Figure 1 |
| | **Vicinity Map** | Date: 23-Dec-2019<br>Job #: 13895 | |


Base:
Interim Geologic Map of the Ogden 30' x 60' Quadrangle (Coogan and King, 2016).

0 2,000 ft 4,000 ft
1:24,000 (1 inch equals 2,000 feet)

| Proposed Highland Bluff Estates Lot 1 Subdivision<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | Figure 2 |
|---|---|---|---|
| | Geologic Map | Date: 23-Dec-2019<br>Job # 13895 | |




Base:
2013 LIDAR, 50cm resolution; slopes <25% shaded in green, 25-30% in yellow, and >30% in red; 4-foot contour interval.

0 100 ft 200 ft
1:1,200 (1 inch equals 100 feet)

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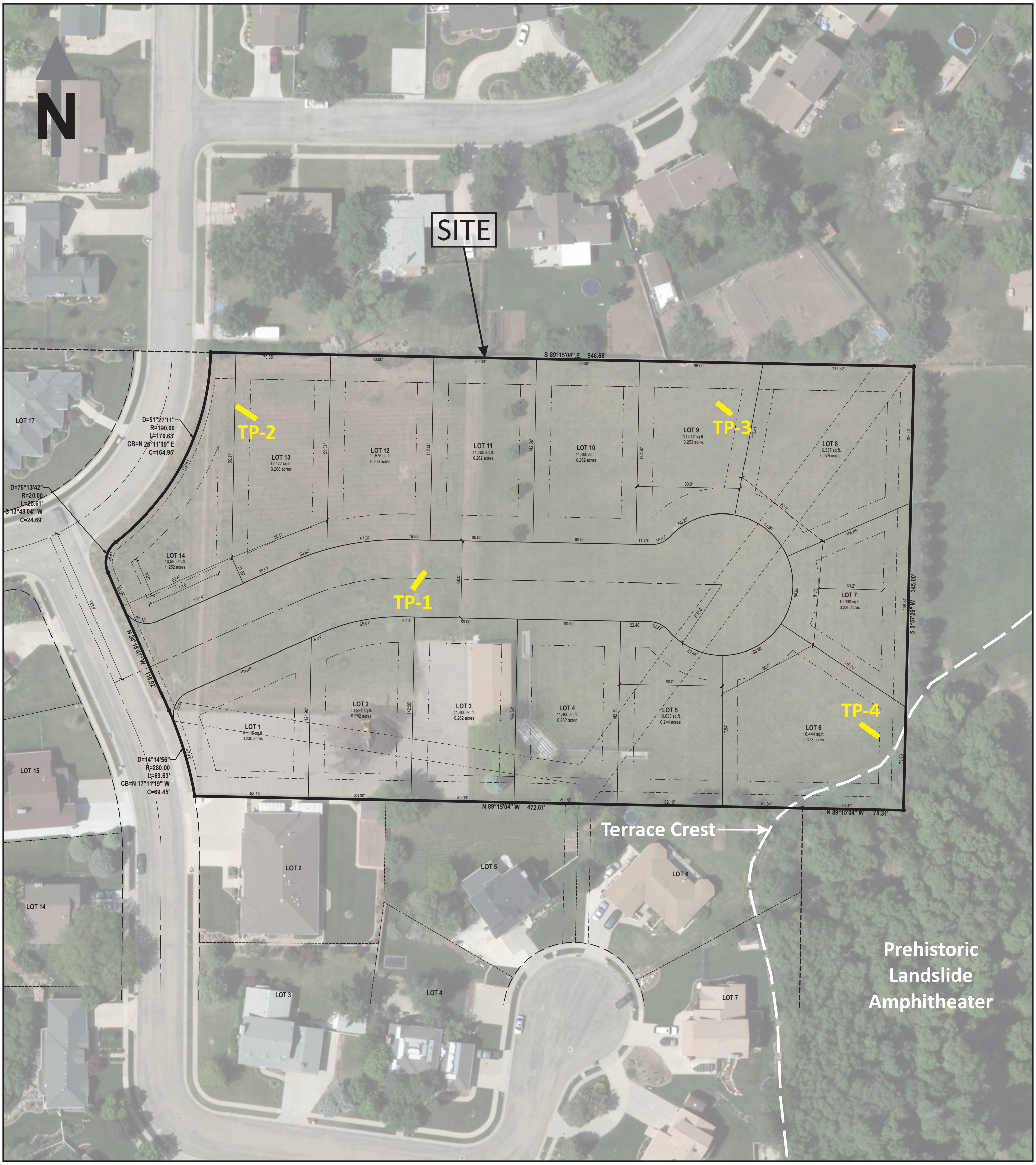
|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | Figure |
| | **LIDAR Analysis** | Date: 23-Dec-2019 | 3 |
| | | Job # 13895 | |




Base:
Utah AGRC High Resolution Orthophoto,
12.5 cm resolution.

0 100 ft 200 ft

1:1,200 (1 inch equals 100 feet)

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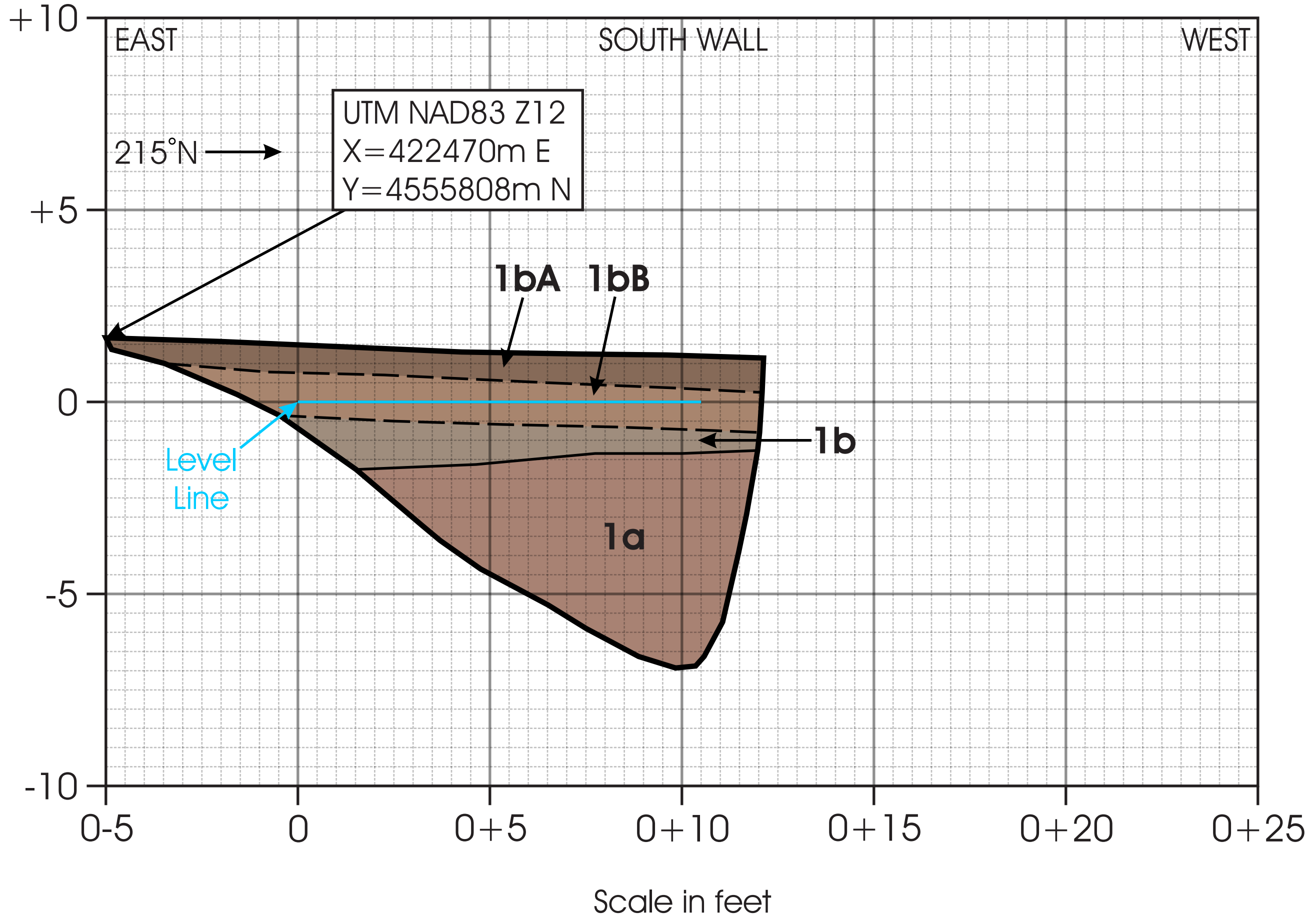
|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | Figure |
| | **Site Evaluation** | Date: 6-Dec-2019 | 4 |
| | | Job # 13838 | |

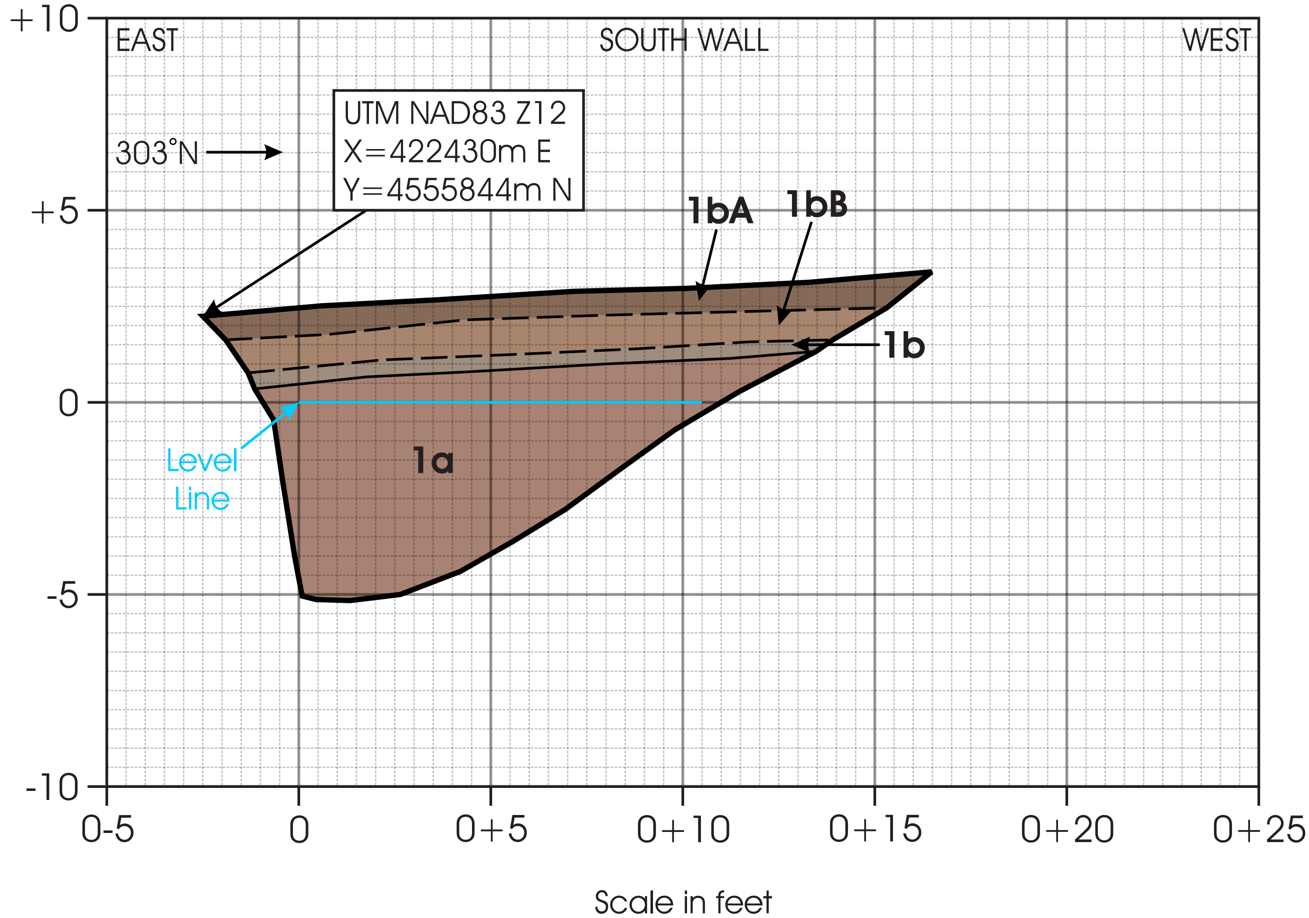



**UNIT DESCRIPTIONS**

**Unit 1.** *Lacustrine deltaic sediments related to the regressive stage of Lake Bonneville* - Sequence of gravel to sand comprised of a lower (**unit 1a**) reddish-brown, poorly bedded, low density, gravel with poorly graded sand (GP); and an upper (**unit 1b**) reddish-brown to brown, poorly to well bedded, moderate density, silty sand (SM) with trace gravel; Bw and modern A soil horizons formed in unit 1b at surface (**units 1bB and 1bA**, respectively).

Logged by Bill D. Black, P.G. on December 3, 2019.
Scale 1 inch equals 5 feet (1:60) with no vertical exaggeration.

| | | | |
|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | Figure |
| **Test Pit 1 Log** | Date: | 23-Dec-2019 | 5A |
| | Job # | 13895 | |

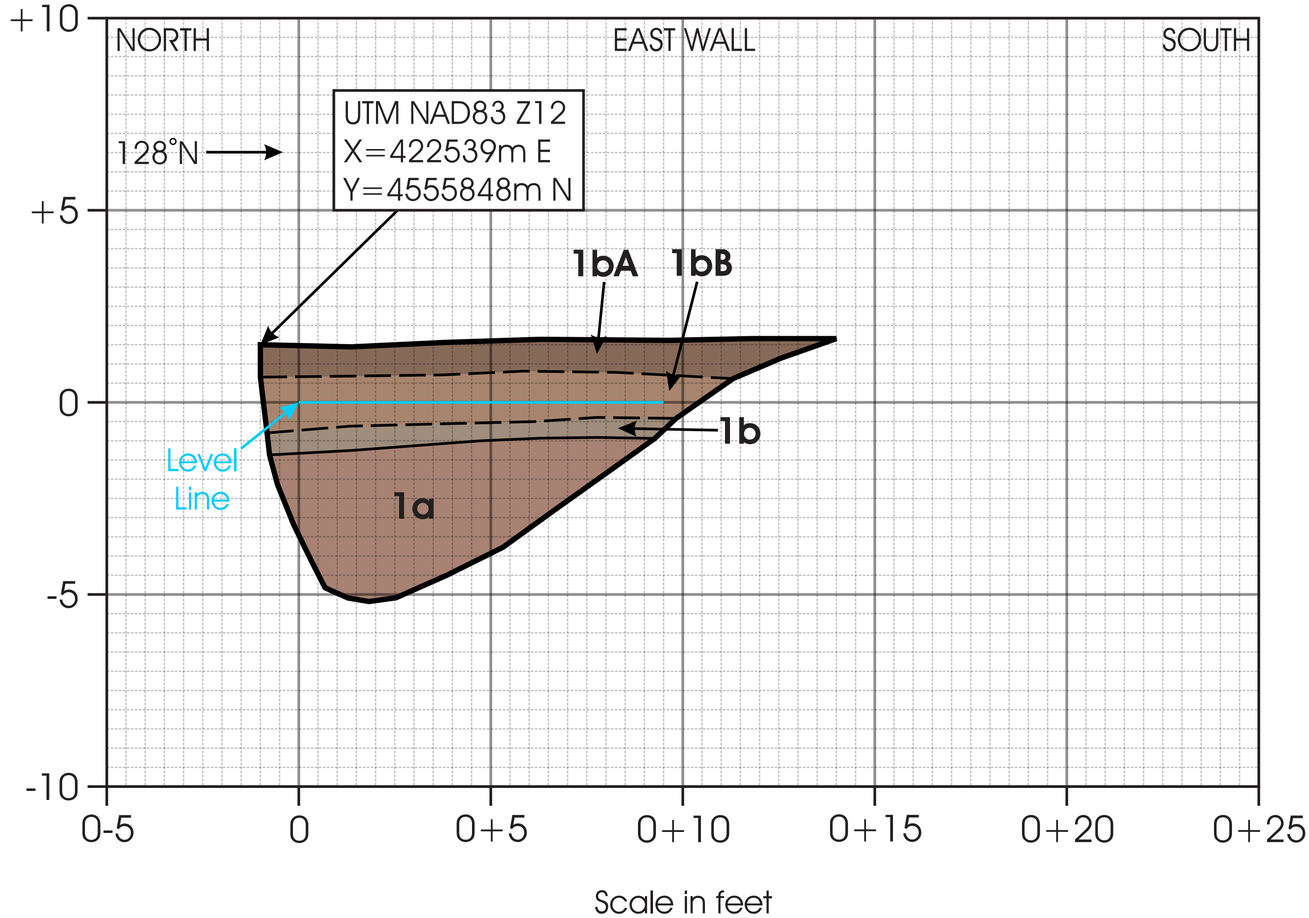



## UNIT DESCRIPTIONS

**Unit 1.** *Lacustrine deltaic sediments related to the regressive stage of Lake Bonneville* - Sequence of gravel to sand comprised of a lower (**unit 1a**) reddish-brown, well bedded, low density, gravel (GP) with poorly graded sand lenses; and an upper (**unit 1b**) reddish-brown to brown, poorly to well bedded, moderate density, silty sand (SM) with trace gravel; Bw and modern A soil horizons formed in unit 1b at surface (**units 1bB and 1bA**, respectively).

Logged by Bill D. Black, P.G. on December 3, 2019.
Scale 1 inch equals 5 feet (1:60) with no vertical exaggeration.

| | | | | |
|---|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | | Figure |
| | **Test Pit 2 Log** | Date: | 23-Dec-2019 | 5B |
| | | Job # | 13895 | |

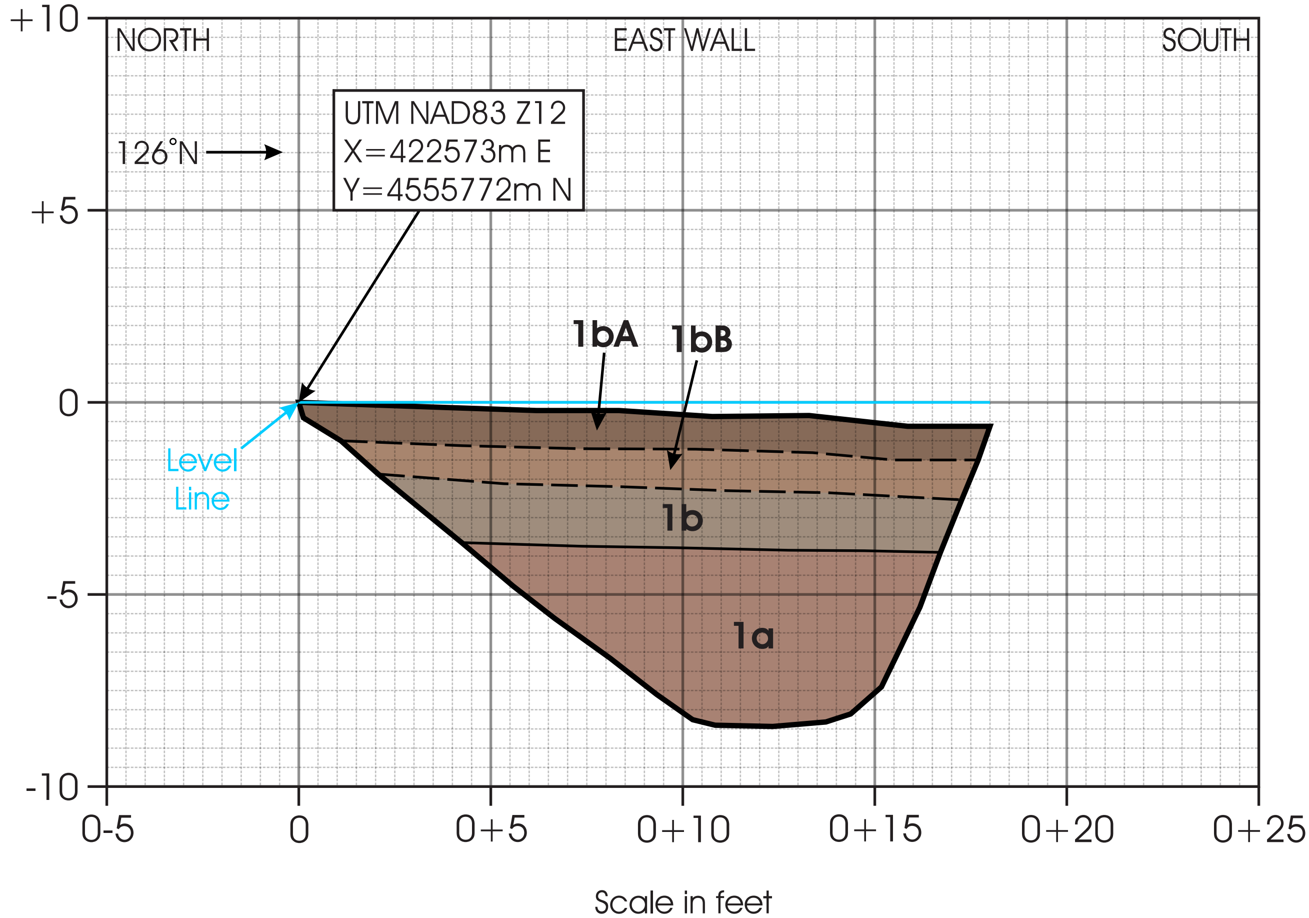



**UNIT DESCRIPTIONS**

**Unit 1.** *Lacustrine deltaic sediments related to the regressive stage of Lake Bonneville* - Sequence of gravel to sand comprised of a lower (**unit 1a**) reddish-brown, poorly bedded, low density, gravel with poorly graded sand and lesser silt (GP); and an upper (**unit 1b**) brown, poorly bedded to massive, moderate density, silty sand (SM), similar to but less dense and moister than TP-1 unit 1b; Bw and modern A soil horizons formed in unit 1b at surface (**units 1bB and 1bA**, respectively).

Logged by Bill D. Black, P.G. on December 3, 2019.
Scale 1 inch equals 5 feet (1:60) with no vertical exaggeration.

| Proposed Highland Bluff Estates Lot 1 Subdivision<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES | | | Figure |
|---|---|---|---|---|
| | Test Pit 3 Log | Date: | 23-Dec-2019 | 5C |
| | | Job # | 13895 | |




**UNIT DESCRIPTIONS**

**Unit 1.** *Lacustrine deltaic sediments related to the regressive stage of Lake Bonneville* - Sequence of gravel to sand comprised of a lower (**unit 1a**) reddish-brown, poorly bedded, low density, gravel with poorly graded sand and lesser silt (GP); and an upper (**unit 1b**) brown, poorly bedded to massive, moderate density, silty sand (SM), similar to but less dense and moister than TP-1 unit 1b; Bw and modern A soil horizons formed in unit 1b at surface (**units 1bB and 1bA**, respectively).

Logged by Bill D. Black, P.G. on December 3, 2019.
Scale 1 inch equals 5 feet (1:60) with no vertical exaggeration.

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|---|---|---|---|
| **Proposed Highland Bluff Estates Lot 1 Subdivision**<br>6224 South 2225 East, Ogden, Utah | CMT ENGINEERING LABORATORIES<br>**Test Pit 4 Log** | Date: 23-Dec-2019<br>Job # 13895 | Figure<br>5D |