Geotechnical Investigation and Geologic Reconnaissance Proposed Well House Approximately 5665 East Elk Horn Drive, Eden, Weber County, Utah

September 27, 2022

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Proposed Well House
Approximately 5665 East Elk Horn Drive
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CG Project No.: 110-009

Prepared by:

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF WORK

This report presents the results of a geological hazards evaluation and a geotechnical investigation that were performed for the Proposed Well House which is to be located at approximately 5665 East Elk Horn Drive in the Eden area of Weber County, Utah. The site is located as shown on Plate 1, Vicinity Map. The proposed development site consists of an irregularly shaped parcel that includes an approximately 0.40-acre area, as shown on Plate 2, Site Plan. Plate 2 provides aerial coverage of the site and details of the current (2021) layout of the site vicinity.

In general, the purposes of this investigation were to provide a site-specific geological hazards study and a geotechnical engineering evaluation to support the proposed site development. The geological hazards study was conducted to evaluate the site relative to potential geologic hazards as outlined in the Weber County Code, Section 108-22 Natural Hazard Areas. These hazards include, but are not limited to: Surface-Fault Ruptures, Landslide, Tectonic Subsidence, Rock Fall, Debris Flows, Liquefaction Areas, Flood, or other Hazardous Areas (Weber County Code, 2022). The geotechnical engineering evaluation was conducted to evaluate the subsurface conditions and the nature and engineering properties of the subsurface soils, and to provide recommendations for general site grading and for the design and construction of floor slabs and foundations. This investigation included subsurface exploration, representative soil sampling, field and laboratory testing, and engineering analysis.

1.2 PROJECT DESCRIPTION

Based on conversations with our client, we understand that the proposed construction at the site is to consist of a well house. The plans and layout for the proposed structure have not been finalized at this time; however, we expect the structure to be a single-story structure with slab-on-grade floors at or near existing grade. The structural loads for the proposed building are anticipated to be on the order of 3 to 4 klf. If the actual structural loads are different from those anticipated, Christensen Geotechnical should be notified in order to reevaluate our recommendations.

1.3 WEBER COUNTY GEOLOGIC HAZARDS REGULATIONS

Because the proposed site appears to be located on a hillslope area in the vicinity of mapped landslide hazards, marginal soils, and FEMA floodplain areas, Weber County requires that a geological site reconnaissance be performed to assess whether all or parts of the site and the proposed improvements are exposed to the hazards that are included in the Weber County Code, Section 108-22 Natural Hazard Areas. These hazards include, but are not limited to: Surface-Fault

Ruptures, Landslide, Tectonic Subsidence, Rock Fall, Debris Flows, Liquefaction Areas, Flood, or other Hazardous Areas.

The purpose of the Geological Site Reconnaissance and Review is to evaluate whether the proposed development is either adjacent to or within areas identified as Natural Hazards Areas, and if within a hazard area, to recommend appropriate additional studies that comply with the purpose and intent of the Weber County Natural Hazards Area guidelines and standards in order to be "cleared" for building permit issuance by the county, as outlined by the Weber County Development Process packet provided by the Weber County Building Inspection Department (2022).

1.4 SCOPE OF WORK

The objectives and scope of this study were presented to Mr. Dan White, P.E. of Gardner Engineering (**Client**) in our Proposal for Geotechnical Investigation and Geologic Hazards Evaluation, dated June 22, 2022.

2.0 METHODS OF STUDY

2.1 LITERATURE AND RESOURCE REVIEW

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 (Bryant, 1988; King and McDonald, 2014; Coogan and King, 2016; and McDonald, 2020); a photogeologic analysis of 2012 and 2021 orthorectified imagery shown on Plate 2; a review of historical stereoscopic 1:20,000 scale imagery flown in 1946 (frames AAJ 2B-46 and AAJ 2B-47); a review of Google Earth® imagery sequence of the site between the dates of 1993 and 2022; a GIS analysis of elevation and geoprocessed 2020 LiDAR terrain data as shown on Plate 4, LIDAR Analysis; a field reconnaissance of the general site area; and the interpretation of the test pits made on the site as part of our field program, located as shown on Plate 5, Site Evaluation. Seismic hazards information was developed from United States Geologic Survey (USGS) databases (Petersen and others, 2014).

2.2 FIELD INVESTIGATION

The site was reconnoitered July 12, 2022 by Senior Geologist Dr. Gregory Schlenker, P.G. and Senior Engineer Mr. Mark Christensen, P.E. During the field reconnaissance, the mapped site geological conditions were confirmed and site surficial conditions were assessed.

The subsurface conditions at the site were explored by excavating two walk-in test pits to depths of 9 and 10 feet below the existing site grade. The approximate test pit locations are shown on Plate 5. The subsurface conditions as encountered in the test pits were recorded and logged at the time of excavation and are presented on the attached Test Pit Logs, Plates 6 and 7.

The test pits were excavated using an approximately 18-ton trackhoe excavator. Disturbed and undisturbed soil samples were collected from the test pit sidewalls at the time of excavation. The disturbed samples were collected and placed in bags and buckets. The undisturbed samples consisted of block samples which were placed in bags. The samples were visually classified in the field and portions of each sample were packaged and transported to our laboratory for testing. The classifications for the individual soil units are shown on the attached Plates 6 and 7.

2.3 LABORATORY TESTING

Of the soils collected during the field investigation, representative samples were selected for testing in the laboratory in order to evaluate the pertinent engineering properties. The laboratory testing included moisture content and density determinations, Atterberg limits evaluations, partial gradation analyses, and a consolidation test. A summary of our laboratory testing is presented in the table below:

Table No. 1: Laboratory Test Results

TEST HOLE NO.	DEPTH (ft.)	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE (%)	ATTERBERG LIMITS		GRAIN SIZE DISTRIBUTION (%)			SOIL TYPE
				LIQUID LIMIT	PLASTICITY INDEX	GRAVEL (+ #4)	SAND	SILT/ CLAY (- #200)	
TP-1	4	114.4	14.0	46	27	---	---	91.0	
TP-2	9		18.5	39	14	---	---	80.3	

The results of our laboratory tests are also presented on the Test Pit Logs, Plates 6 and 7, and more detailed laboratory results are presented on the laboratory testing plate, Plate 9.

Samples will be retained in our laboratory for 30 days following the date of this report, at which time they will be disposed of unless a written request for additional holding time is received prior to the disposal date.

2.4 SLOPE ANALYSIS

The elevation data for the site consisted of 2020 geoprocessed 0.5-meter bare earth LiDAR imagery data which was obtained from Utah Geospatial Resource Center (UGRC). These data were geoprocessed with the QGIS® GIS platform; and using the r.slope, r.shaded.relief and r.contour.level GRASS® (Geographic Resources Analysis Support System) modules, the slope percentages, surface renderings and elevation contours were calculated for the site area. Additionally, the referenced historical aerial photography was georeferenced to the GIS layering to support our geological interpretation of the site.

Plate 4, LiDAR Analysis, presents the results of the LiDAR slope analysis. Shown on Plate 4 are the slope percentage gradients over a rendered shaded relief surface. The surface of the site is shown to slope gently to moderately to the southwest. The site surface as shown on Plate 4, appears to have been locally steepened by the construction of the 5675 East Street stub. The site has undergone preliminary grading since the 2020 LiDAR scan of the site area, and thus steeper slope sections on the site as presented by the LiDAR have been reduced. The limiting steep slope gradient for site development considerations according to the Weber County Code is 25-percent (Weber County Code, 2022).

3.0 GENERAL SITE CONDITIONS

3.1 SURFACE CONDITIONS

As shown on Plate 2, the site is an approximately 0.40-acre area that is currently vacant and undeveloped. The site is located on the end of an incomplete roadway stub for 5675 East Street. The elevations across the site range from a low of 4492 feet on the southwest side to 4302 feet on the north side of the site. The surface of the site generally consists of gentle foothill slopes, with the surface generally sloping downward to the southwest. The surface vegetation consists of open areas of grasses with weeds, sage brush, and isolated hawthorn trees.

3.2 SUBSURFACE CONDITIONS

3.2.1 Soils

Based on the two test pits that were completed for this investigation, the subsurface materials at the site consist of approximately 1½ feet of surficial topsoil overlying stiff to very stiff Lean Clay (CL) containing varying amounts of sand extending to the 9-foot to 10-foot depths penetrated by the test pits. We ascertain that these soils are residually developed soils, likely derived from Norwood Formation claystone bedrock.

3.2.2 Groundwater

Groundwater was not encountered within our test pits at the time of excavation. It should be understood that groundwater may fluctuate in response to seasonal changes, precipitation, and irrigation.

4.0 GEOLOGIC CONDITIONS

4.1 Geologic Setting

The site is located in Ogden Valley which is a northwest trending fault bounded graben structure, with the Wasatch Range comprising the western flank of the valley and the Bear River Range the eastern flank (Avery, 1994). Topographically, the site is located on the east side valley margin near the lower reaches of Wolf Creek near where the creek joins the North Fork Ogden River. The elevation of the site is roughly 4300 feet, and is located on the transition of low gradient piedmont-foothill surfaces formed along margins of Ogden Valley, which are located at the base of 7000-foot-high mesa ridgelines that buttress James Peak which rises to 9424 feet approximately 5 miles northeast of the site.

The Ogden Valley is located on the east side of the Wasatch Range. On the west side of the range is the Wasatch Front which is marked by the Wasatch fault. The Wasatch fault is approximately 6.3 miles west of the site, and provides the basis of division between the Middle Rocky Mountain Physiographic Province on the east and the Basin and Range Physiographic Province on the west. The Basin and Range Physiographic Province is characterized by approximately north-south trending valleys and mountain ranges that have been formed by extensional tectonics and displacement along normal faults and extends from the Wasatch Range on the east to the Sierra Nevada Range on the west (Hunt, 1967).

The Middle Rocky Mountain province covers parts of Utah, Colorado, Wyoming, Idaho, and Montana. The geology of the province is an assemblage of sedimentary, igneous, and metamorphic rocks that have been folded, faulted, and uplifted. Mountain building (tectonic) activity commenced about 30 million years ago (Cretaceous time) and continues to the present. The province is characterized by mountainous terrain with deep canyons and broad intervening basins, with temperate semi-arid to mesic climatic conditions (Hunt, 1967).

The site is located within a setting of complex geological conditions wherein Pre-Cambrian and Paleozoic rocks were rafted over the same during a series of eastward thrust extensions, the last of which is named the Willard Thrust sheet, which is believed to have moved onto the vicinity during the Cretaceous Sevier orogeny, and occurred approximately 140 million years ago (Ma). This exposure was the result of movement along high-angle faults along the Wasatch fault during the late Tertiary and Quaternary age (Bryant, 1988). The Norwood Formation is mapped as outcropping in the site vicinity, and overlies parts of the older rocks, but is largely covered by the more recent Quaternary sediments in the area. The Norwood Formation is described as "light-gray to light brown, altered tuff (claystone), tuffaceous siltstone, sandstone, and conglomerate" derived from volcanic ash deposition that occurred during the lower Oligocene and upper Eocene Epochs (King and others, 2008). The current geological mapping of the site, as drawn from McDonald (2020), is shown on Plate 3, Geologic Mapping.

4.2 SURFICIAL GEOLOGY

The surficial geology of the site is presented on Plate 3 of this report and has been taken from mapping prepared by McDonald (2020). A summary of the mapping units identified on the site vicinity and described by McDonald (2020) are paraphrased below in relative age sequence (youngest-top to oldest bottom):

> **Qafy** - Younger alluvial-fan deposits (Holocene to upper Pleistocene) - Poorly to moderately sorted pebble to cobble gravel with silt, sand and minor clay matrix; angular to subangular grains; poorly to moderately bedded…includes debris flows, debris floods, and channel deposits…
>
> **Qms** - Landslide deposits, undifferentiated (Holocene to middle Pleistocene?) - Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks...
>
> **Qmso** - Landslide deposits, older (upper to middle Pleistocene?) - Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks…more subdued with increasing age and/or rate of movement...
>
> **Qafo** - Older alluvial-fan deposits (upper to middle Pleistocene?) - Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand and clay; subangular to subrounded clasts; poorly bedded; fans are typically eroded and incised locally…
>
> **Qac/BR** - Alluvium and colluvium over bedrock (Holocene to middle Pleistocene? over Neogene to Precambrian) - Unsorted to variably sorted silt, sand, gravel, clay, cobbles and boulders in variable proportions and roundness over Neogene to Precambrian bedrock…
>
> **Qafo/BR** - Older alluvial-fan deposits over bedrock (upper to middle Pleistocene? over Neogene to Precambrian) - Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand and clay over Neogene to Precambrian bedrock…

The site is shown on Plate 3 to be located primarily upon "Younger alluvial-fan deposits," of Holocene to upper Pleistocene age (**Qafy**); however, the exposures observed in the two test pits consisted of residual claystone soils, which would be more consistent with the **Qac/BR** - alluvium and colluvium over bedrock geologic classification, which is mapped nearby the site, as shown on Plate 3. The **Qac/BR** deposits are considered relatively ancient, and are believed to be no longer subject to active geologic processes.

4.3 SEISMIC HAZARDS/CHARACTERIZATION

4.3.1 Strong Ground Motion

Strong ground motion originating from the Wasatch Fault or other nearby seismic sources is 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). Based on probabilistic estimates (Petersen and others, 2014) queried for the site (41.3230º N -111.8121º E), the expected peak horizontal ground acceleration on rock from a large earthquake with a ten-percent probability of exceedance in 50 years is as high as 0.18g, and from an earthquake with a two-percent probability of exceedance in 50 years, as high as 0.40g.

The ten-percent probability of exceedance in 50 years event has a return period of 475 years. The 0.18g acceleration for this event corresponds "strong" perceived shaking with "light" potential damage based on instrument intensity correlations. The two-percent probability of exceedance in 50 years event has a return period of 2475 years, and the 0.40g acceleration for this event corresponds with "severe" perceived shaking with "moderate to heavy" potential damage based on instrument intensity correlations (Wald and others, 1999).

4.3.2 Active Earthquake Faults

Based upon our review of available maps and literature, no active faults are known to pass through or immediately adjacent to the site. The nearest active (Holocene) earthquake fault to the site is the Weber segment of the Wasatch Fault Zone (UT2351E) which is located 6.3 miles west of the site (Black and others, 2004). Accordingly, fault rupture hazards are not considered present on the site. The Ogden Valley northeastern margin fault (UT2379) is located much closer to the site, approximately 1.2 miles to the northeast; however, the most recent movement along this fault is estimated to be pre-Holocene (<1.6 Ma ybp), and is not considered an active risk to the site (Black and Hecker, 1999).

4.3.3 Liquefaction Potential Hazards

In conjunction with the ground-shaking potential of large magnitude seismic events as discussed previously, certain soil units may also possess a potential for liquefaction during a large-magnitude event. 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 conditions exist. The primary factors affecting the 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.

Liquefaction potential hazards have not been studied in detail or mapped for the Ogden Valley area, as has occurred in other parts of northern Utah (Anderson and others, 1994). Liquefaction more commonly occurs in saturated, non-cohesive, finer-grained soils such as floodplain alluvium and lacustrine sediments (Anderson and others, 1994), which are not present on the site. Consequently, the conditions susceptible to liquefaction do not appear to be present at the site.

4.3.4 Site Seismic Response

The State of Utah and Utah municipalities have adopted the 2018 International Building Code (IBC) for seismic design. The IBC seismic design is based on seismic hazard maps which depict probabilistic ground motions and spectral response; the maps, ground motions, and spectral response having been developed by the United States Geological Survey (USGS). Seismic design values, including the design spectral response, may be calculated for a specific site using the web-based application by the Applied Technology Council (ATC), the project site's approximate latitude and longitude, and its Site Class. Based on our field exploration, it is our opinion that this location is best described as a Site Class C, which represents a "very dense soil and soft rock" profile. The spectral acceleration values obtained from the ATC web-based application are shown below.

Table 2: IBC Seismic Response Spectrum Values

Site Location: 41.323065° N -111.812044° W	
Name	**Response Spectral Value**
S_S	**0.908**
S_1	**0.321**
S_{MS}	**1.089**
S_{M1}	**0.481**
S_{DS}	**0.726**
S_{D1}	**0.321**
PGA	**0.402**
PGA_M	**0.482**

4.4 ENGINEERING GOLOGY

The engineering geology findings presented in this section pertain to the natural and geological hazards included in the potential geologic hazards as outlined in the Weber County Code, Section 108-22 Natural Hazard Areas. These hazards include, but are not limited to: Surface-Fault

Ruptures, Landslide, Tectonic Subsidence, Rock Fall, Debris Flows, Liquefaction Areas, Flood, or other Hazardous Areas (Weber County Code, 2022).

4.4.1 Landsliding - Slope Stability

The nearest potentially active Holocene landslide units are mapped as **Qms** - landslide deposits, undifferentiated, Holocene to middle Pleistocene? by McDonald (2020). These deposits are located approximately 970 feet to the southwest of the site as shown on Plate 3. These **Qms** deposits are relatively distant and should not potentially impact the site or the proposed improvements.

4.4.2 Tectonic Subsidence

Tectonic subsidence is surface tilting subsidence that occurs along the boundaries of normal faults in response to surface-faulting earthquakes (Keaton, 1986). Because the site is not located in near proximity to active earthquake faults, tectonic subsidence hazards are not considered a risk to the site.

4.4.3 Sloping Surfaces

The site vicinity slopes developed from our LiDAR analysis range from level to well over 30 percent as shown on Plate 4. The calculated average slope gradient for the 0.40-acre site is 29.2 percent.

The threshold gradient for slope development considerations and hillside review according to the Weber County Section 108-14-3 includes slopes greater than 25 percent (Weber County Code, 2022). As previously indicated, the site surface as shown on Plate 4, appears to have been locally steepened by the construction of the 5675 East Street stub. The site has undergone preliminary grading since the 2020 LiDAR scan of the site area; thus, steeper slope sections on the site as presented by the LiDAR have been reduced.

4.4.4 Alluvial Fan - Debris Flow Processes

Alluvial fan/debris flow processes include flash flooding and debris flow hazards. The mapping on Plate 3 indicates that the site is located upon alluvial fan deposits **Qafy** which are considered potential debris flow process deposits. However, the soils exposed within the two test pits excavated for this study did not expose alluvial deposits, but rather residual claystone soils, which indicate that alluvial fan/debris flow processes are not present for the site location.

4.4.5 Surface Fault Rupture Hazards and Liquefaction

These hazards were discussed previously in Section 4.3.2 of this report.

4.4.6 Flooding Hazards

No significant waterways pass in the vicinity of the site, and flood insurance rate mapping by Federal Emergency Management Agency for Weber County classifies the site location as within "Zone X - Area of Minimal Flood Hazard" (FEMA, 2015).

Local sheet flow, slope wash, and seasonally perched soil water typical of sloping areas should be anticipated for the site and site improvements.

4.4.7 Rockfall and Avalanche Hazards

The site is not located directly below steep rock outcrops where rockfall hazards may originate, and no indices or set-up conditions for snow avalanche development (Perla and Martinelli, 1976) were observed for the site vicinity during our analysis or reconnaissance of the site.

5.0 ENGINEERING ANALYSIS AND RECOMMENDATIONS

5.1 GENERAL CONLUSIONS

Based on the results of our field and laboratory investigations, it is our opinion that the subject site is suitable for the proposed construction provided that the recommendations contained in this report are incorporated into the design and construction of the project.

5.2 EARTHWORK

5.2.1 General Site Preparation and Grading

Prior to site grading operations, all vegetation, topsoil, undocumented fill soils, and loose or disturbed soils should be stripped (removed) from the building pad and flatwork concrete areas. Following the stripping operations, the exposed soils should be proof rolled to a firm, unyielding condition. Site grading may then be conducted to bring the site to design grade. Where over-excavation is required, the excavation should extend at least 1 foot laterally for every foot of over-excavation. A Christensen Geotechnical representative should observe the site grading operations.

5.2.2 Soft Soil Stabilization

Once exposed through excavation, all subgrade soils should be proof rolled with a relatively large-wheeled vehicle to a firm, unyielding condition. Where localized soft areas are encountered, they should be removed and replaced with granular structural fill. If soft areas extend more than 18 inches deep, or if large areas are encountered, stabilization may be considered. The use of stabilization should be approved by the geotechnical engineer, but would likely consist of over-excavating the area by at least 18 inches and then placing a geofabric (such as Mirafi RS280i) at the bottom of the excavation. Over this, a stabilizing fill, consisting of angular coarse gravel with cobbles, would be placed to the design subgrade.

5.2.3 Temporary Construction Excavations

Based on OSHA requirements and the soil conditions encountered during our field investigation, we anticipate that temporary construction excavations at the site that have vertical walls that extend to depths of up to 5 feet may be occupied without shoring; however, where groundwater or fill soils are encountered, flatter slopes may be required. Excavations that extend to more than 5 feet in depth should be sloped or shored in accordance with OSHA regulations for a type C soil. The stability of construction excavations is the contractor’s responsibility. If the stability of an excavation becomes questionable, the excavation should be evaluated immediately by qualified personnel.

5.2.4 Structural Fill and Compaction

All fill placed for the support of structures and concrete flatwork should consist of structural fill. Due to its expansive nature, we do not recommend that the native clay soils at the site be used as structural fill. Imported structural fill, if required, should consist of a relatively well-graded granular soil with a maximum particle size of 4 inches, with a maximum of 50 percent passing the No. 4 sieve and a maximum of 30 percent passing the No. 200 sieve. The liquid limit of the fines (material passing the No. 200 sieve) should not exceed 35 and the plasticity index should be less than 15. Additionally, all structural fill, whether native soils or imported material, should be free of topsoil, vegetation, frozen material, particles larger than 4 inches in diameter, and any other deleterious materials. Any imported materials should be approved by the geotechnical engineer prior to importing.

The structural fill should be placed in loose lifts that are a maximum of 8 inches thick. The moisture content should be within 3 percent of optimum and the fill should be compacted to at least 95 percent of the maximum density as determined by ASTM D 1557. Where fill heights exceed 5 feet, the level of compaction should be increased to 98 percent.

5.3 FOUNDATIONS

Due to the presence of swelling soils at the site, the foundations for the planned structure may consist of conventional continuous and/or spread footings established on at least 2 feet of properly placed and compacted granular structural fill which extends down to undisturbed native soil. The footings for the proposed structure should be a minimum of 20 inches and 30 inches wide for continuous and spot footings, respectively. The exterior footings should be established at a minimum of 30 inches below the lowest adjacent grade to provide frost protection and confinement. Interior footings that are not subject to frost should be embedded a minimum of 18 inches for confinement.

Continuous and spread footings that are established on undisturbed native soil, bedrock, or structural fill may be proportioned for a maximum net allowable bearing capacity of 2,000 psf. A one-third increase may be used for transient wind or seismic loads. All footing excavations should be observed by the geotechnical engineer prior to the construction of footings.

5.4 ESTIMATED SETTLEMENT

If the foundations are designed and constructed in accordance with the recommendations presented in this report, there is a low risk that total settlement will exceed 1 inch and a low risk that differential settlement will exceed ½ inch for a 30-foot span.

5.5 LATERAL EARTH PRESSURES

Buried structures, such as basement walls, should be designed to resist the lateral loads imposed by the soils retained. The lateral earth pressures on the below-grade walls and the distribution of those pressures will depend upon the type of structure, hydrostatic pressures, in-situ soils, backfill, and tolerable movements. Basement and retaining walls are usually designed with triangular stress distributions, which are based on an equivalent fluid pressure and calculated from lateral earth pressure coefficients. If soils similar to the native soils are used to backfill basement walls, then the walls may be designed using the following ultimate values:

Table No. 3: Lateral Earth Pressures

Condition	Lateral Pressure Coefficient	Equivalent Fluid Density (pcf)
Active Static	0.36	42
Active Seismic	0.15	17
At-Rest	0.53	61
Passive Static	2.77	319
Passive Seismic	-0.31	-36

We recommend that walls which are allowed little or no wall movement be designed using "at rest" conditions. Walls that are allowed to rotate at least 0.4 percent of the wall height may be designed with "active" pressures. The coefficients and densities presented above assume level backfill with no buildup of hydrostatic pressures. If anticipated, hydrostatic pressures and any surcharge loads should be added to the presented values. If sloping backfill is present, we recommend that the geotechnical engineer be consulted to provide more appropriate lateral pressure parameters once the design geometry is established.

The seismic active and passive earth pressure coefficients provided in the table above are based on the Mononobe-Okabe method and only account for the dynamic horizontal force produced by a seismic event. The resulting dynamic pressure should therefore be added to the static pressure to determine the total pressure on the wall. The dynamic pressure distribution may be approximated as an inverted triangle, with stress decreasing with depth and the resultant force acting approximately 0.6 times the height of the retaining wall, measured upward from the bottom of the wall.

Lateral building loads will be resisted by frictional resistance between the footings and the foundation soils and by passive pressure developed by backfill against the wall. For footings on native soils, we recommend that an ultimate coefficient of friction of 0.35 be used. If passive resistance is used in conjunction with frictional resistance, the passive resistance should be reduced by ½. Passive earth pressure from soils subject to frost or heave should usually be neglected in design.

The coefficients and equivalent fluid densities presented above are ultimate values and should be used with an appropriate factor of safety against overturning and sliding. A value of 1.5 is typically used.

5.6 CONCRETE SLAB-ON-GRADE CONSTRUCTION

The laboratory testing that was completed for this investigation indicates that the native clay soils at the site have a high swell potential with changes in moisture. Concrete slabs, including basement floor slabs and exterior flatwork, have a high risk of movement when placed on these soils due to their light loading. To reduce the risk of expansion and slab movement, we recommend placing at least 3 feet of imported structural fill below any concrete slabs. To help control normal shrinkage and stress cracking, the floor slabs should have adequate reinforcement for the anticipated floor loads with the reinforcement continuous through the interior joints. In addition, we recommend adequate crack control joints to control crack propagation.

5.7 MOISTURE PROTECTION AND SURFACE DRAINAGE

Any wetting of the foundation soils will likely cause some degree of volume change within the soil and should be prevented both during and after construction. We recommend that the following precautions be taken at this site:

1. The ground surface should be graded to drain away from the structures in all directions, with a minimum fall of 8 inches in the first 10 feet.
2. Roof runoff should be collected in rain gutters with downspouts that are designed to discharge well outside of the backfill limits.
3. Sprinkler heads should be aimed away from and placed at least 12 inches from foundation walls.
4. There should be adequate compaction of backfill around foundation walls, to a minimum of 90% density (ASTM D 1557). Water consolidation methods should not be used.

6.0 CONCLUSIONS

Based upon the findings of this study, we believe that the proposed site development will not be adversely exposed to the geological hazards addressed in this report. It is our opinion that the buildable area of the site as shown on Plate 5 is suitable for the proposed development from both a geological hazard and a geotechnical engineering perspective. Our conclusion assumes that the proposed construction is to occur as shown on Plate 5, that the geotechnical engineering recommendations provided herein are followed, and that the final site development and grading does not adversely affect the site's slope stability in its present condition.

7.0 LIMITATIONS

The recommendations contained in this report are based on limited field exploration, laboratory testing, and our understanding of the proposed construction. The subsurface data used in this report was obtained from the explorations that were made specifically for this investigation. It is possible that variations in the soil and groundwater conditions could exist between and beyond the points explored. The nature and extent of variations may not be evident until construction occurs. If any conditions are encountered at this site that are different from those described in this report, Christensen Geotechnical should be immediately notified so that we may make any necessary revisions to the recommendations contained in this report. In addition, if the scope of the proposed construction changes from that described in this report, Christensen Geotechnical should be notified.

This report was prepared in accordance with the generally accepted standard of practice at the time the report was written. No other warranty, expressed or implied, is made.

It is the client's responsibility to see that all parties to the project, including the designer, contractor, subcontractors, etc., are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk.

The recommendations presented within this report are based on the assumption that an adequate program of tests and observations will be followed during construction to verify compliance with our recommendations. We also assume that we will review the project plans and specifications to verify that our conclusions and recommendations are incorporated and remain appropriate (based on the actual design).

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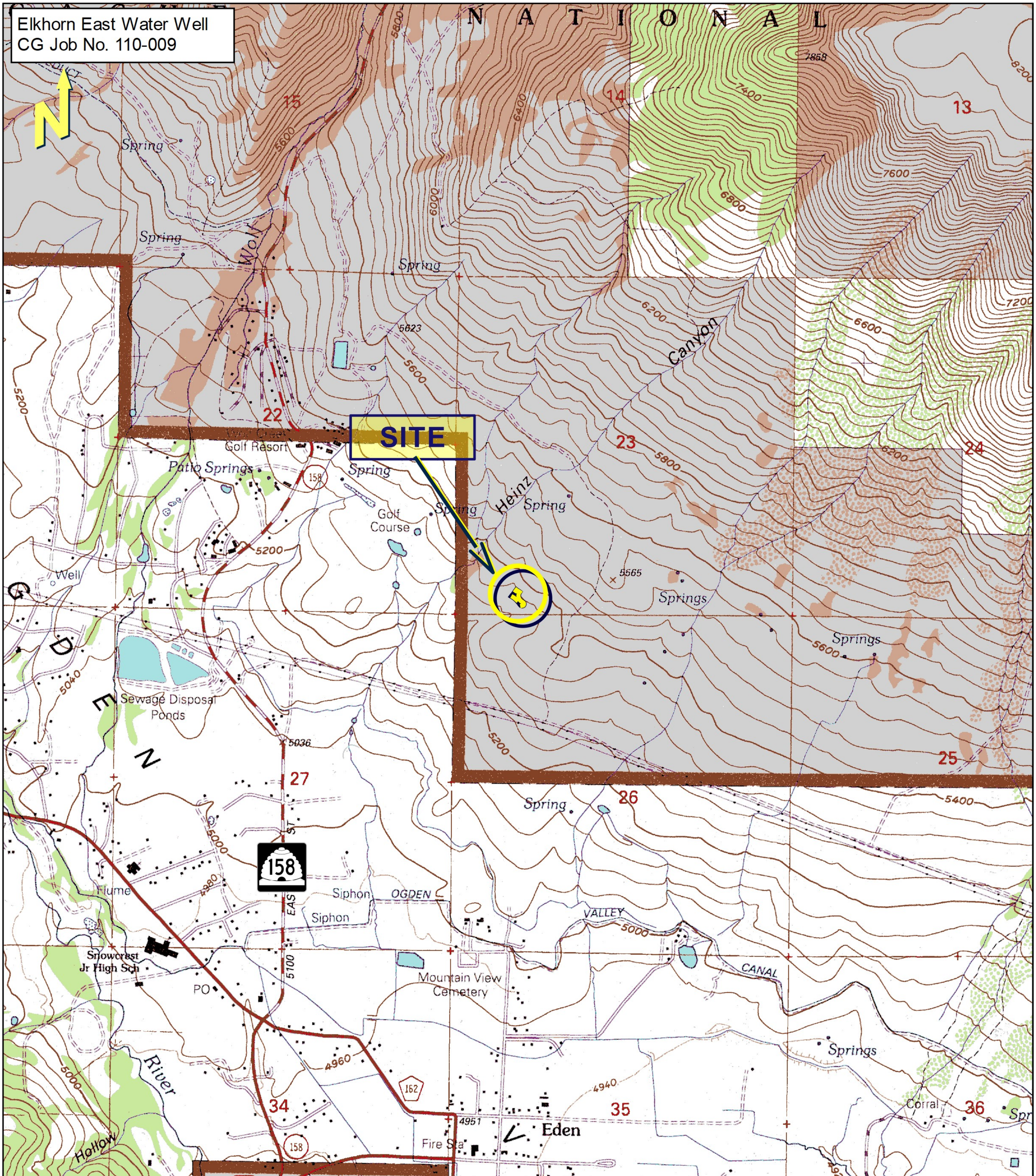


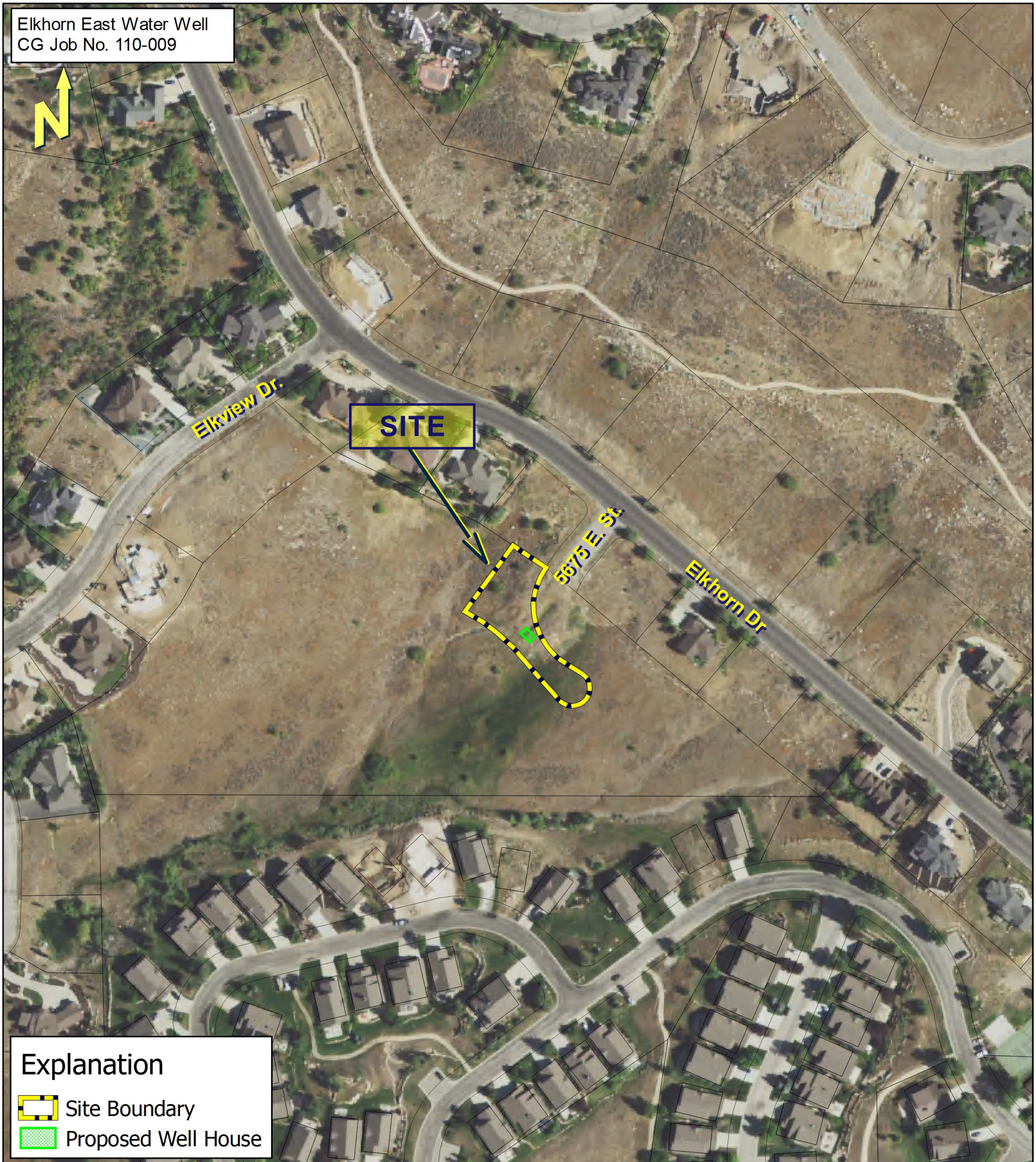
Base:
1998 USGS 7.5 Minute topographic map titled "Huntsville, Utah" from Utah AGRC; http://gis.utah.gov/

0 2000 4000 ft

1:24,000

PLATE 1
VICINITY MAP

Christensen Geotechnical



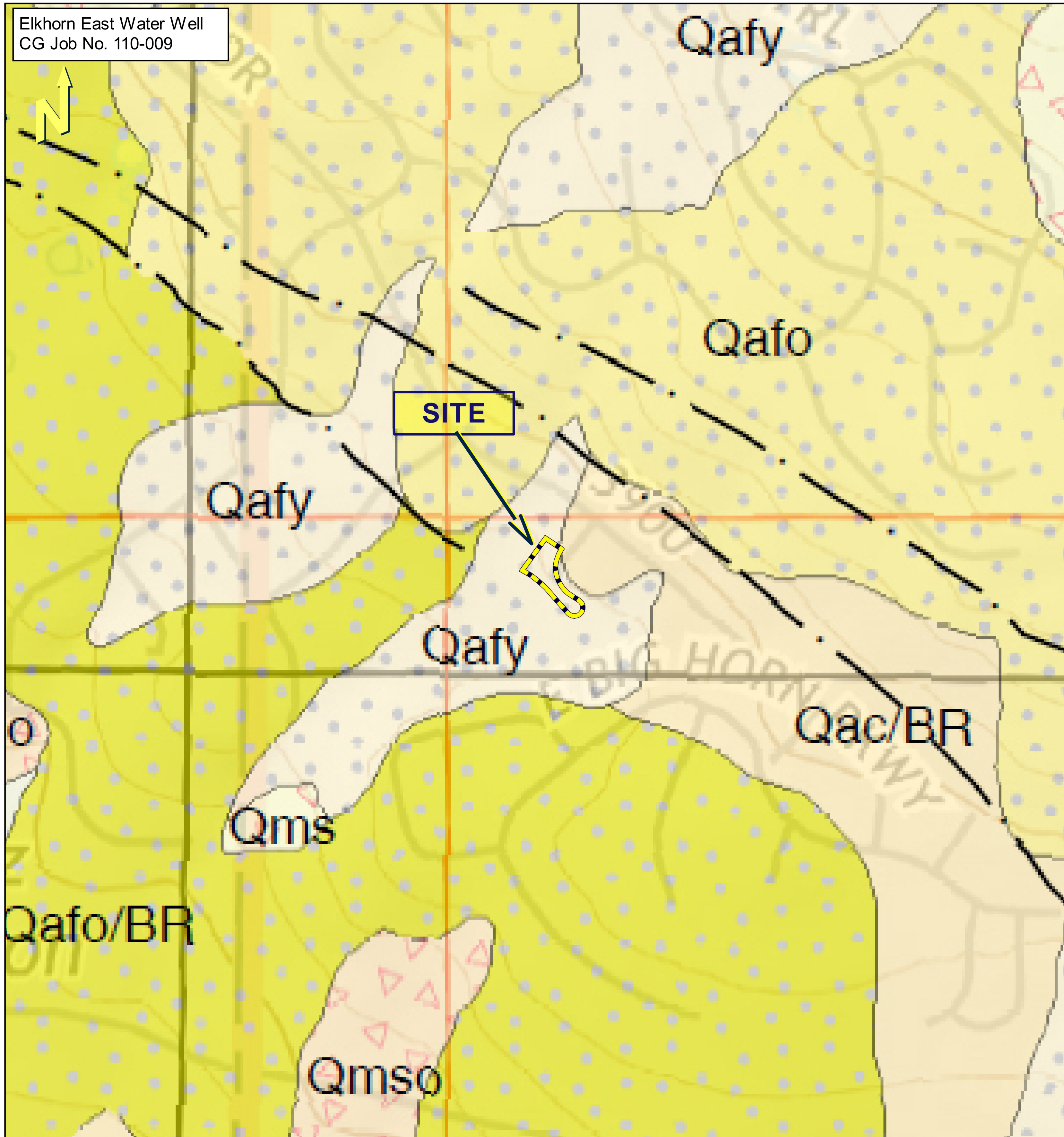
Base:
2021 0.6m NAIP Orthophotography,
from Utah UGRC; http://gis.utah.gov/

0 200 400 ft

1:2,400

PLATE 2
SITE PLAN

Christensen Geotechnical



Base:
McDonald, 2021

0 400 800 ft

1:4,800

GEOLOGCIAL CLASSIFICATION (after McDonald, 2020)

Qafy — **Qafy – Younger alluvial-fan deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted pebble to cobble gravel with silt, sand and minor clay matrix; angular to subangular grains; poorly to moderately bedded…includes debris flows, debris floods, and channel deposits…

Qms — **Qms – Landslide deposits, undifferentiated** (Holocene to middle Pleistocene?) – Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks...

Qmso — **Qmso – Landslide deposits, older** (upper to middle Pleistocene?) – Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks…more subdued with increasing age and/or rate of movement...

Qafo — **Qafo – Older alluvial-fan deposits** (upper to middle Pleistocene?) – Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand and clay; subangular to subrounded clasts; poorly bedded; fans are typically eroded and incised locally…

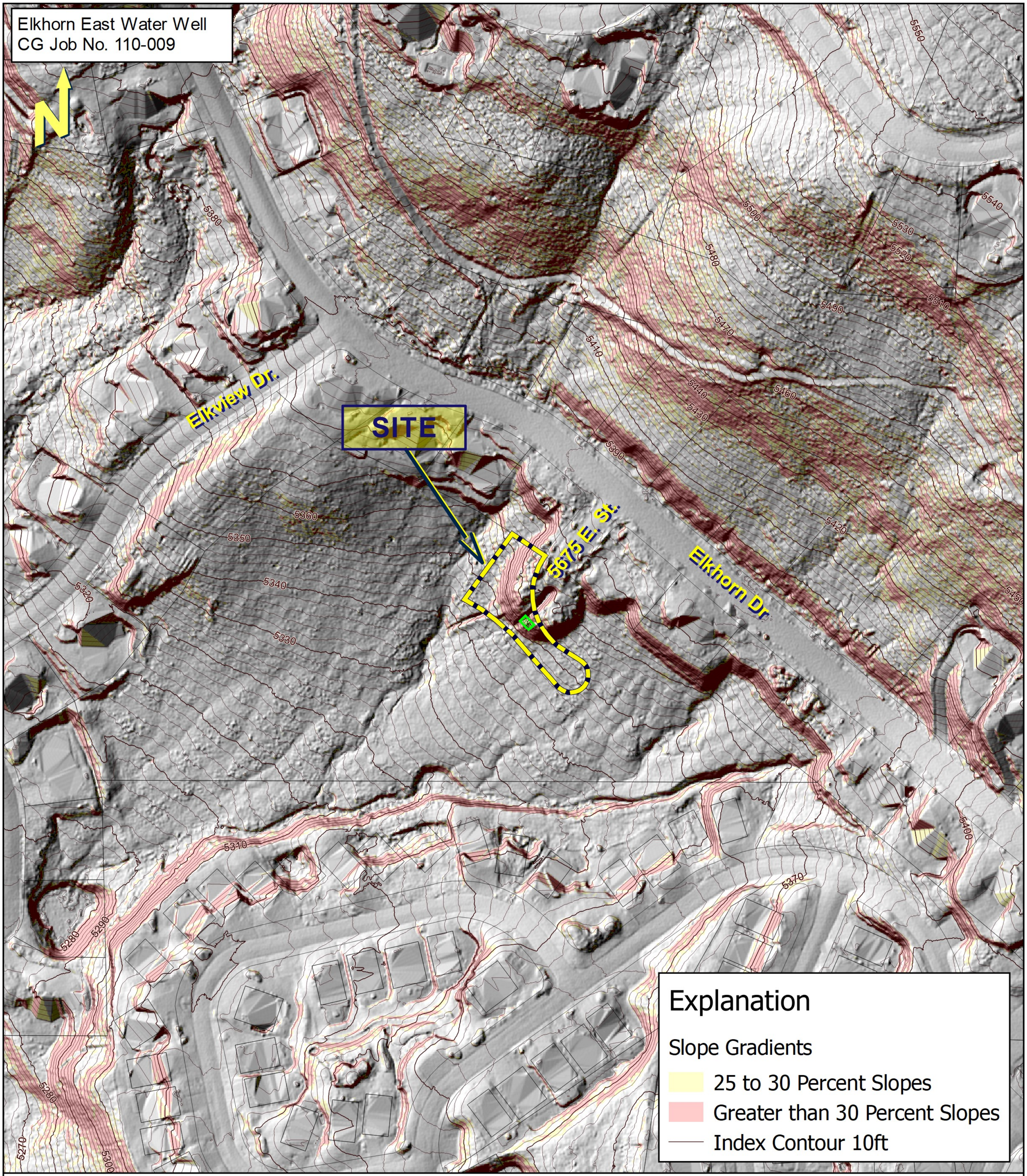
Qac/BR — **Qac/BR –** Alluvium and colluvium over bedrock (Holocene to middle Pleistocene? over Neogene to Precambrian) – Unsorted to variably sorted silt, sand, gravel, clay, cobbles and boulders in variable proportions and roundness over Neogene to Precambrian bedrock…

Qafo/BR — **Qafo/BR – Older alluvial-fan deposits over bedrock** (upper to middle Pleistocene? over Neogene to Precambrian) – Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand and clay over Neogene to Precambrian bedrock…

— · — **Lineament**

PLATE 3
GEOLOGIC MAPPING

Christensen Geotechnical



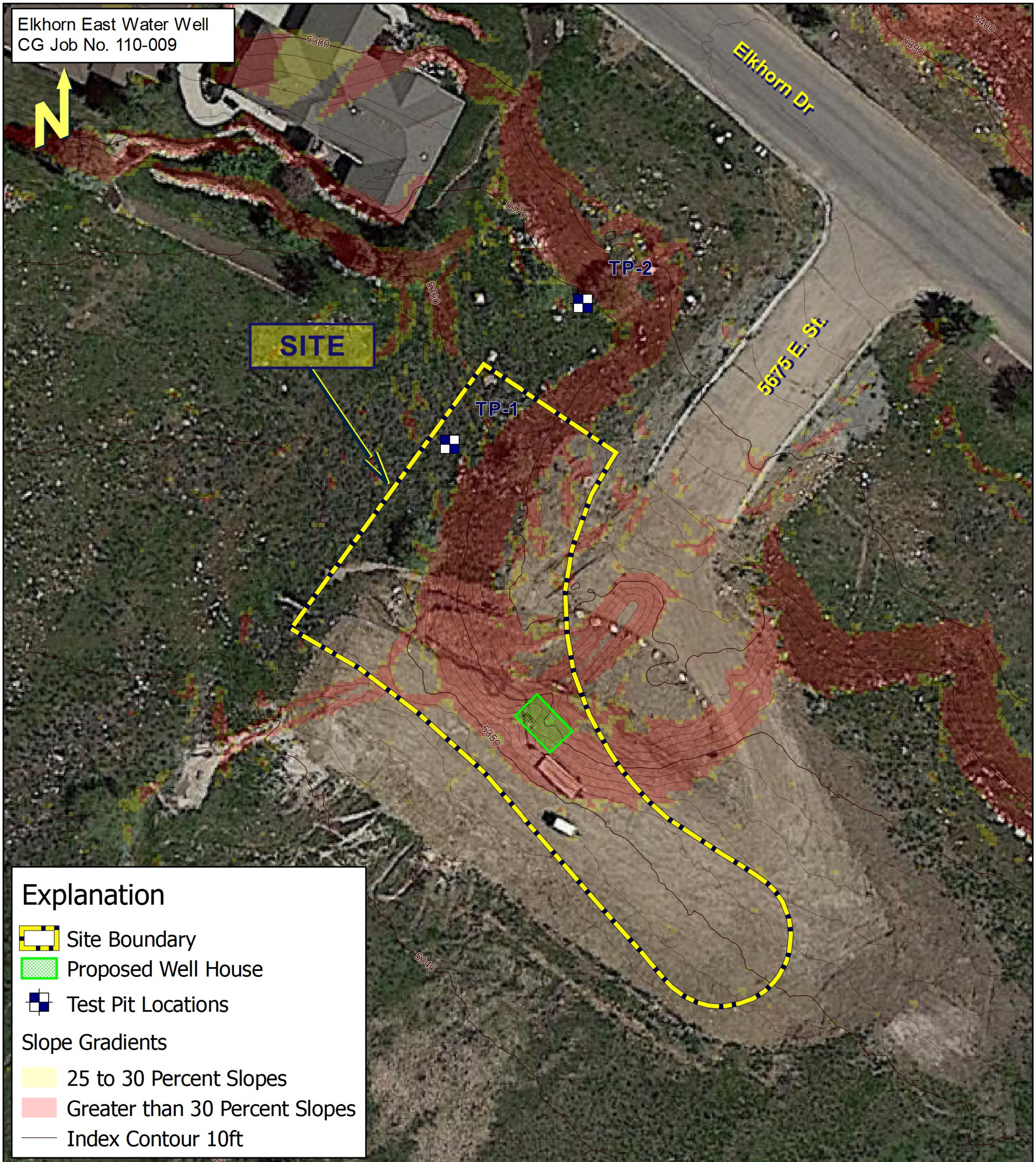
Base:
2020 0.5m LiDAR Imagery,
from Utah AGRC; http://gis.utah.gov/

0 200 400 ft

1:2,400

PLATE 4
LiDAR ANALYSIS

Christensen Geotechnical



Base:
2022 ~0.2m Google Earth Orthophotography,
from https://earth.google.com/

0 50 100 ft

1:600

PLATE 5
SITE EVALUATION

Christensen Geotechnical

TEST PIT LOG

Date	
Started:	7/12/2022
Completed:	7/12/2022
Backfilled:	7/12/2022

Logged By: M Christensen
Equipment: Trackhoe
Location: See Plate 5

Test Pit No.

TP-1

Sheet 1 of 1

Depth (feet)	Sample Type	Groundwater	Graphic Log	Group Symbol	Material Description	Dry Density (pcf)	Moisture Content (%)	Minus #200 (%)	Liquid Limit	Plasticity Index
0–1.5					Topsoil; Lean CLAY - moist, dark brown					
1.5					Lean CLAY - stiff to very stiff, moist, brown					
~4.2	Undisturbed					114.4	14.0	91.0	46	27
5				CL						
~6					- light brown					
~8	Undisturbed				- gray-brown					
9					Bottom of test pit at 9 feet					
10										
15										

⊠ Bulk/Bag Sample
▥ Undisturbed Sample
Stabllized Groundwater
Groundwater At Time of Excavation

Christensen Geotechnical

Gardner Engineering
Well House
Eden, Weber County, Utah
Project No.: 110-009

Plate
6

TEST PIT LOG

Date		
Started:	7/12/2022	
Completed:	7/12/2022	
Backfilled:	7/12/2022	

Logged By: M Christensen
Equipment: Trackhoe
Location: See Plate 5

Test Pit No. **TP-2**

Sheet 1 of 1

Depth (feet)	Sample Type	Groundwater	Graphic Log	Group Symbol	Material Description	Dry Density (pcf)	Moisture Content (%)	Minus #200 (%)	Liquid Limit	Plasticity Index
0–1.5					Topsoil; Lean CLAY - moist, dark brown					
1.5–10	Undisturbed (~3 ft), Undisturbed (~9 ft)			CL	Lean CLAY with sand - stiff to very stiff, moist, brown		18.5	80.3	39	14
10					Bottom of test pit at 10 feet					

Depth scale: 5, 10, 15

☒ Bulk/Bag Sample
▥ Undisturbed Sample
Stablllized Groundwater
Groundwater At Time of Excavation

Christensen Geotechnical

Gardner Engineering
Well House
Eden, Weber County, Utah
Project No.: 110-009

Plate
7

RELATIVE DENSITY – COURSE GRAINED SOILS

Relative Density	SPT (blows/ft.)	3 In OD California Sampler (blows/ft.)	Relative Density (%)	Field Test
Very Loose	<4	<5	0 – 15	Easily penetrated with a ½ inch steel rod pushed by hand
Loose	4 – 10	5 – 15	15 – 35	Difficult to penetrate with a ½ inch steel rod pushed by hand
Medium Dense	10 – 30	15 – 40	35 – 65	Easily penetrated 1-foot with a steel rod driven by a 5 pound hammer
Dense	30 – 50	40 – 70	65 – 85	Difficult to penetrate 1-foot with a steel rod driven by a 5 pound hammer
Very Dese	>50	>70	85 - 100	Penetrate only a few inches with a steel rod driven by a 5 pound hammer

CONSISTENCY – FINE GRAINED SOILS

Consistency	SPT (blows/ft)	Torvane Undrained Shear Strength (tsf)	Pocket Penetrometer Undrained Shear Strength (tsf)	Field Test
Very Soft	<2	<0.125	<0.25	Easily penetrated several inches with thumb
Soft	2 – 14	0.125 – 0.25	0.25 – 0.5	Easily penetrated one inch with thumb
Medium Stiff	4 – 8	0.25 – 0.5	0.5 – 1.0	Penetrated over ½ inch by thumb with moderate effort. Molded by strong finger pressure
Stiff	8 – 15	0.5 – 1.0	1.0 – 2.0	Indented ½ inch by thumb with great effort
Very Stiff	15 – 30	1.0 – 2.0	2.0 – 4.0	Readily indented with thumbnail
Hard	>30	>2.0	>4.0	Indented with difficulty with thumbnail

CEMENTATION

Weakly	Crumbles or breaks with handling or little finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

MOISTURE

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible water, usually below water table

GRAIN SIZE

Description		Sieve Size	Grain Size (in)	Approximate Size
Boulders		>12″	>12″	Larger than basketball
Cobbles		3″ – 12″	3″ – 12″	Fist to basketball
Gravel	Coarse	3/4″ - 3″	3/4″ - 3″	Thumb to fist
	Fine	#4 – 3″	0.19 – 0.75	Pea to thumb
Sand	Coarse	#10 - #4	0.079 – 0.19	Rock salt to pea
	Medium	#40 - #10	0.017 – 0.079	Sugar to rock salt
	Fine	#200 - #40	0.0029 – 0.017	Flour to sugar
Silt/Clay		<#200	<0.0029	Flour sized or smaller

STRATAFICATION

Occasional	One or less per foot of thickness
Frequent	More than one per foot of thickness

MODIFIERS

Trace	<5%
Some	5-12%
With	>12%

STRATIFICATION

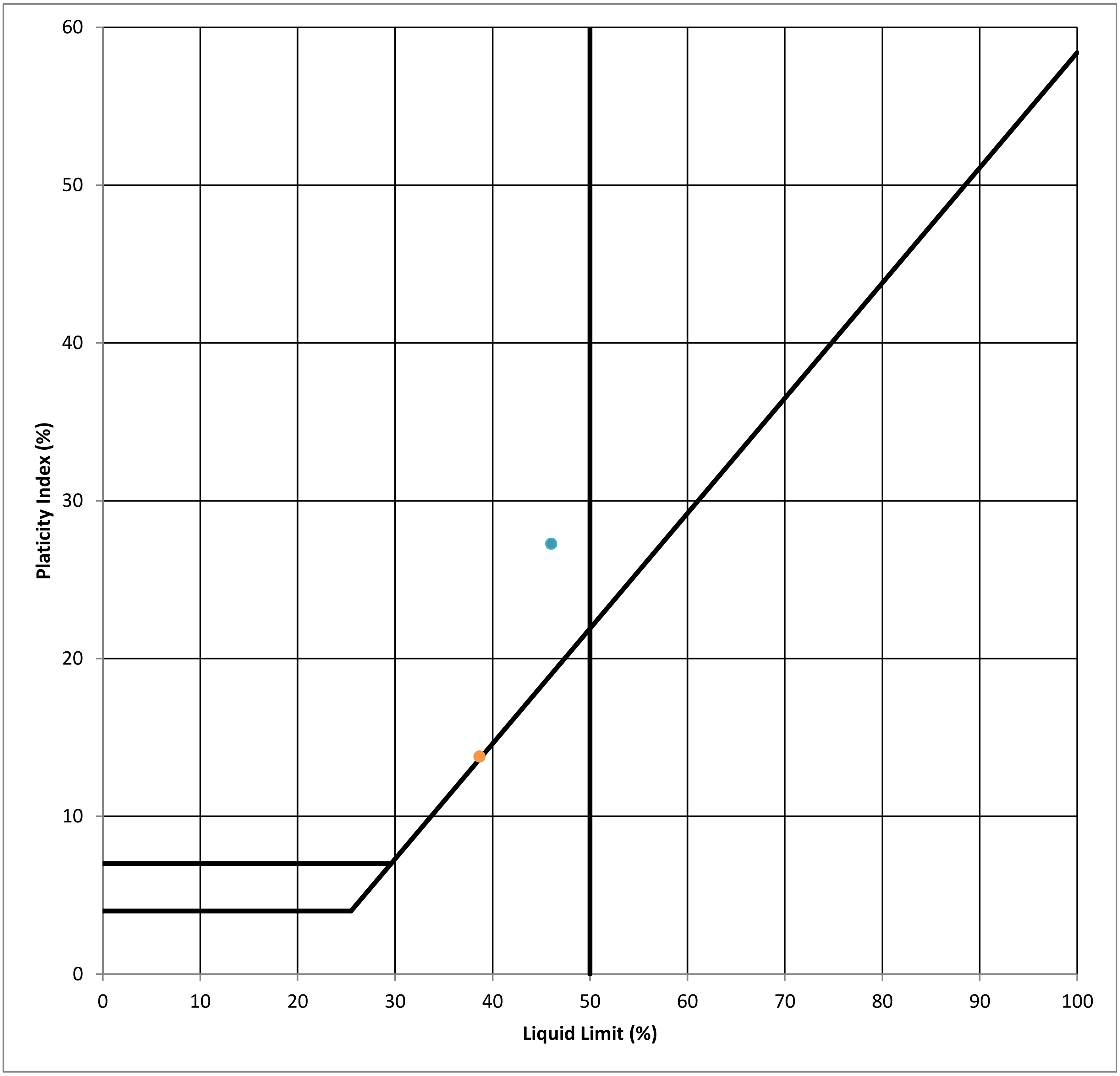
Seam	1/16 to 1/2 inch
Layer	1/2 to 12 inch

NOTES

1. The logs are subject to the limitations and conclusions presented in the report.
2. Lines separating strata represent approximate boundaries only. Actual transitions may be gradual.
3. Logs represent the soil conditions at the points explored at the time of our investigation.
4. Soils classifications shown on logs are based on visual methods . Actual designations (based on laboratory testing)may vary.

Christensen Geotechnical	**Soil Terms Key**	Plate 8

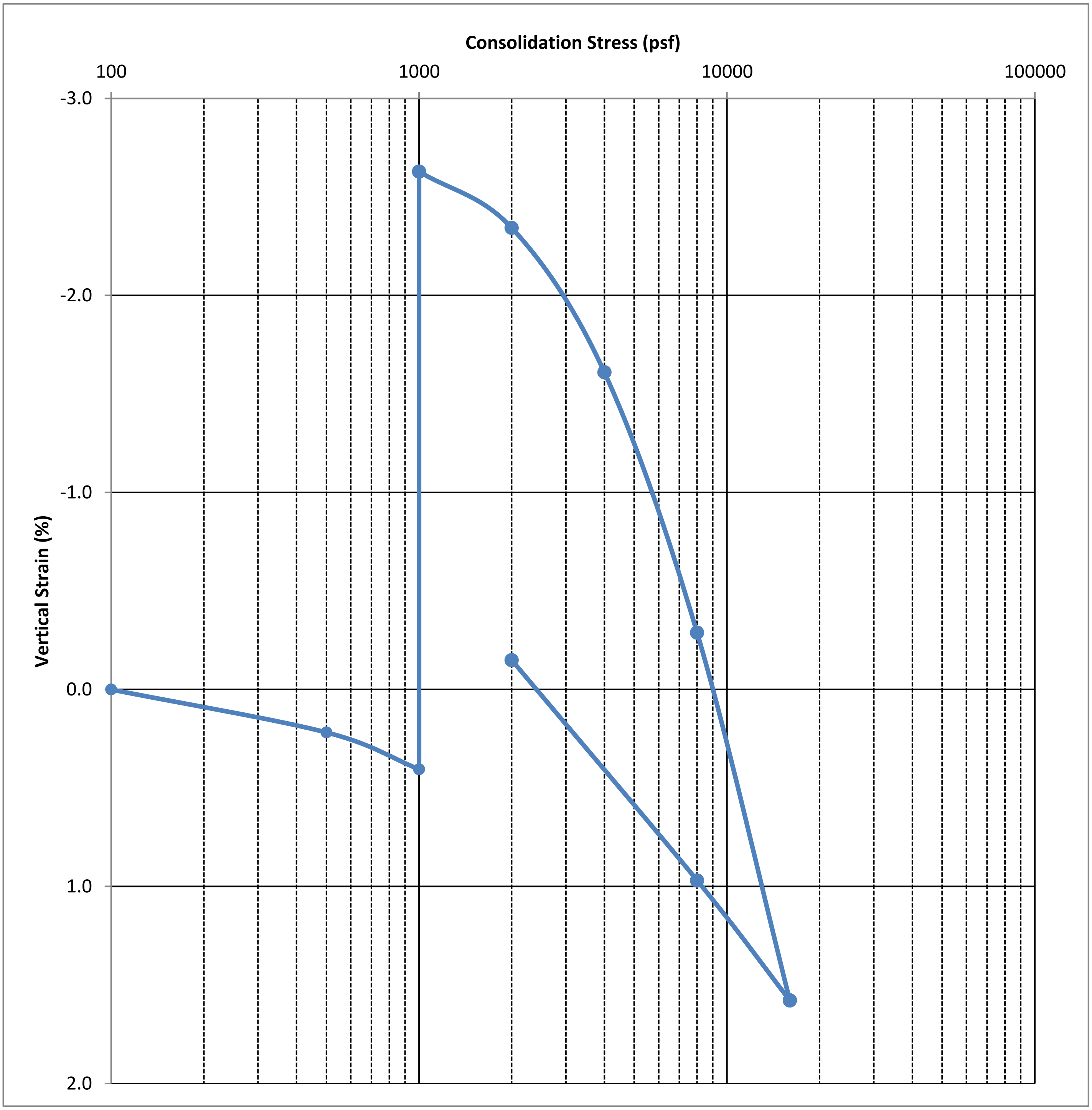
Atterberg Limits



Location	Depth (ft)		Classification	Liquid Limit	PI
TP-1	4	●	Lean CLAY	46	27
TP-2	9	●	Lean CLAY with sand	39	14

Christensen Geotechnical	Gardner Engineering Well House Eden, Weber County, Utah Project No.: 110-009	Plate 9

1-D Consolidation



Location	Depth (ft)	Dry Density (pcf)	Moisture Content (%)	σ_o (psf)	σ_p (psf)	C_c	C_r	OCR
TP-1	4	114.4	14.0	500	3,500	0.053	0.019	7.0

Christensen Geotechnical	Gardner Engineering Well House Eden, Weber County, Utah Project No.: 110-009	Plate 10