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Geologic Hazards Screening Assessment
4400 North 2900 East, Liberty, Utah
Northern 5 Acres of Parcel ID# 22-008-0060

GeoStrata Job No. 1193-001

July 21, 2016

Prepared for:

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Prepared by:

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1.0 EXECUTIVE SUMMARY

The purpose of this investigation and report was to assess the proposed single family residential building lot located at approximately 4400 North 2900 East in Liberty, Utah for the presence of geologic hazards that may impact the cost and feasibility of the development of the subject site. As part of this assessment, we will identify and describe geologic hazards observed within or immediately adjacent to the subject site. Hazards assessed in this investigation include landslide, alluvial-fan flooding/debris flow, rockfall, surface fault rupture and stream flooding hazard. Hazards such as slope stability, shallow groundwater, soluble soils, and collapsible or expansive soils were not assessed in this investigation.

Landslide hazards that would potentially impact the site was assessed as part of our study. Based on the review of published geologic hazard maps a landslide deposit is mapped within the subject site and is characterized as a landslide undifferentiated from talus, colluvial, rock-fall, glacial, and soil creep (Elliot and Harty, 2010). No landslide deposits were observed within the subject site during our stereographic aerial photograph interpretation, our review of geologic maps, our review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR and our field observations. Therefore, the landslide hazards that may impact the subject site is considered low and it is considered unlikely that landslides will impact the proposed development.

The potential hazard of debris flow or alluvial-fan flooding within the subject site was also assessed as part of this study. No Holocene-aged alluvial fan or debris flow deposit is mapped or observed within or immediately adjacent to the subject site. Therefore, the debris flow or alluvial fan flooding hazards within the subject site is considered low and it is considered unlikely that debris flows or alluvial fan flooding will impact the proposed development.

No rock fall talus or debris resulting from rock fall were observed during our field investigation. Furthermore, sources of rockfall debris were not observed upslope of the subject site. It is our opinion that the rock fall hazard within the subject site is considered low and it is considered unlikely that rock falls will impact the proposed development.

There are no active faults mapped trending through or within the vicinity of the subject site. The nearest fault is the Quaternary age Ogden Valley North Fork Fault and is trending northwest approximately 1,550 feet northeast of the subject site. Given our field and office investigations, the surface fault rupture hazard within the subject site is considered low and it is considered unlikely that surface fault rupture will impact the proposed development.

The potential of stream flooding impacting the subject site was assessed as part of our investigation. Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 5 meter Auto-Corrected DEM from 2006 1 meter NAIP orthophotography and our field observations, no streams or drainages were observed within the subject site. Given our field and office investigations, the stream flooding hazard within the subject lot is considered low and it is considered unlikely that stream flooding will impact the proposed development. Proper site grading and drainage plans should be developed for the subject site as a part of the civil engineering design for the lot.

NOTICE: The scope of services provided within this report are limited to the assessment of the subsurface conditions for the proposed development. This executive summary is not intended to replace the report of which it is part and should not be used separately from the report. The executive summary is provided solely for purposes of overview. The executive summary omits a number of details, any one of which could be crucial to the proper application of this report.

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE OF WORK

The purpose of this investigation and report was to assess the proposed single family residential building lot located at approximately 4400 North 2900 East in Liberty, Utah for the presence of geologic hazards that may impact the cost and feasibility of the development of the subject site. As part of this assessment, we will identify and describe geologic hazards observed within or immediately adjacent to the subject site. The engineering and design of potential geologic hazards mitigation are out of the scope of this geological hazards assessment. Hazards such as slope stability, shallow groundwater, soluble soils, and collapsible or expansive soils will not be addressed as part of this investigation. If it is required that these hazards be assessed, then a site specific geotechnical investigation should be performed for the subject site.

The work performed for this report was performed in accordance with our proposal and your signed authorization dated May 13, 2016. Our scope of services included the following:

- Review of available references and maps of the area.
- Stereographic aerial photograph interpretation of aerial photographs covering the site area.
- Review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR from the State of Utah AGRC.
- Geologic reconnaissance of the site by an engineering geologist to observe and document pertinent surface features indicative of possible geologic hazards; and
- Evaluation of our observations combined with existing information and preparation of this written report with conclusions and recommendations regarding possible geologic hazards observed to affect the site.

The recommendations contained in this report are subject to the limitations presented in the Limitations section of this report.

2.2 PROJECT DESCRIPTION

The subject site is located along the northwestern margin of Ogden Valley and along the foothills east of North Ogden Peak at approximately 4400 North 2900 East in Liberty, Utah. We understand that the project site is currently an undeveloped single family residential building lot on a native hillside. Proposed development, as currently planned, will consist of a single family residential structure as well as associated driveway, utilities and landscape areas. The hillside in the area of the subject lot gently slopes generally to the east and toward Ogden Valley. It is our understanding that the general area of the subject lot was first developed in the 1960's. The subject site and much of the hillside south of the site remains in a native condition. The areas adjacent to the subject site remains in a native condition. The areas approximately 0.3 miles north, south, and east of the subject site are established residential building lots. The subject lot is shown on the Site Vicinity Map included in the Appendix of this report (Plate 1).

3.0 METHODS OF STUDY

3.1 OFFICE INVESTIGATION

To prepare for the investigation, GeoStrata reviewed pertinent literature and maps listed in the references section of this report, which provided background information on the local geologic history of the area and the locations of suspected or known geologic hazards (Elliot and Harty, 2010; Black and others, 2003; Crittenden and Sorensen, 1985; Coogan and King, 2001). The geologic hazards considered for this site include landslide, alluvial fan flooding/debris flow, rock fall, surface fault rupture and stream flooding. A stereographic aerial photograph interpretation was performed for the subject site using a set of stereo aerial photographs obtained from the UGS as shown in Table 1.

Table 1

Source	Photo Number	Date	Scale
USDA	AAJ-31K-211	September 19, 1953	20,000
USDA	AAJ-31K-212	September 19, 1953	20,000

GeoStrata also conducted a review of hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR from the State of Utah AGRC to assess the subject site for visible alluvial fan deposits, scarps associated with landslide geomorphology and lineations related to stream flooding hazards or surface fault rupture related geomorphology. The LiDAR elevation data was used to create hillshade imagery that could be reviewed for assessment of geomorphic features related to geologic hazards (Hillshade Map Plate 2).

3.2 FIELD INVESTIGATION

An engineering geologist investigated the geologic conditions within the general site area. A field geologic reconnaissance was conducted to observe existing geologic conditions and to assess existing geomorphology for surficial evidence of geologic hazards. During our fieldwork we conducted site observations to assess geologic hazards that might impact the lot. We used our field observations to confirm the observations made during our office research and to observe any evidence of geologic hazards that were not evident in our office research, but which could be observed in the field.

4.0 GEOLOGIC CONDITIONS

4.1 GEOLOGIC SETTING

The site is located along the northwestern margin of Ogden Valley and within the foothills of North Ogden Peak in Liberty, Utah at approximately 5,250 feet above sea level. The Ogden Valley is a northwest trending deep, lacustrine sediment-filled structural basin of Cenozoic age bounded on the northeast and southwest by two normal faults that dip towards the center of the valley. The Ogden Valley is a fault graben flanked by two uplifted blocks, the Wasatch Range on the west and unnamed flat-topped mountains to the east (King and others 2008). The Wasatch Range is the easternmost expression of pronounced Basin and Range extension in north-central Utah (Stokes, 1986).

The near-surface geology of the Ogden Valley is dominated by lake sediments which were deposited within the last 30,000 years during the high stand of the Lake Bonneville Cycle when water inundated Ogden Canyon and formed a small lake in Ogden Valley (Scott and others, 1983; Hintze, 1993; Leggette and Taylor, 1937; King and others, 2008). As the lake receded, streams began to incise large deltas that had formed at the mouths of major canyons along the Wasatch Range and the unnamed flat-topped mountains bounding the eastern margins of Ogden Valley. The eroded material was then deposited in shallow lakes and marshes in the basin and in a series of recessional deltas and alluvial fans. Sediments toward the center of the valley are predominately deep-water deposits of clay, silt and fine sand whereas sediments closer to the mountain fronts are shallow-water deposits of coarse sand and gravel. However, these deep-water deposits are in places covered by a thin post-Bonneville alluvial cover.

4.2 SITE GEOLOGY

Surface sediments within the subject site, as shown on Plate 3a Site Vicinity Geologic Map and Plate 4 Site Vicinity 30’ X 60’ Geologic Map, are mapped as upper or middle Proterozoic Graywacke-siltstone Member of the Perry Canyon Formation (ZYpg) and characterized as medium to dark grey or grey to dark green, weathering to tan, micaceous siltstone (Crittenden and Sorensen, 1985). Quaternary age Lake Bonneville deposits (Qbs) are mapped as overlying ZYpg in the eastern edge of the subject lot and are described as gravel, sand, and silt deposited during the high stand of Lake Bonneville.

5.0 GENERALIZED SITE CONDITIONS

5.1 SURFACE CONDITIONS

As stated previously, the project site is located along the northwestern margin of Ogden Valley and within the foothills of North Ogden Peak at approximately 4400 North 2900 East in Liberty, Utah. The subject site is situated on a gently sloping hillside dipping to the east toward Ogden Valley. Graywacke-siltstone formation of Perry Canyon is mapped within the subject site, however, no outcroppings were observed. Surficial deposits within the subject site were observed to consist of silty to clayey soils and patches of well-rounded light purple to pink cobble sized quartzite. Given the geologic history of Ogden Valley and the similarity in processes that were at work in the Salt Lake Valley during the Lake Bonneville Cycle, it is the opinion of GeoStrata that these are likely Pleistocene age lacustrine, alluvial fan, and/or deltaic deposits deposited along the Lake Bonneville shoreline and related to the transgressive and regressive phases of the Lake Bonneville Cycle. The site remains in a relatively natural state, and is heavily vegetated with mature scrub oaks and snowberry shrubs with open patches of sagebrush, grasses, weeds, and wildflowers. No structures were observed on the subject property. The properties approximately 0.3 miles to the north, south, and east of the subject site are occupied by established residential developments. The area to the west of the subject site remains in a relatively natural state.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 LANDSLIDE HAZARD

There are several types of landslides that should be considered when evaluating geologic hazards at a site with moderately to steeply sloping terrain. These include shallow debris slides, deep-seated earth or rock slumps and earth flows. Landslides, slumps and other mass movements can develop on moderate to steep slopes where the slope has been altered or disturbed. Movement can occur at the top of a slope that has been loaded by fill placement, at the base of a slope that has been undercut, or where local groundwater rises resulting in increased pore pressures within the slope. Slopes that exhibit prior failures and large landslide deposits are particularly susceptible to instability and reactivation.

Based on the review of published geologic hazard maps a landslide deposit is mapped within the subject site as shown on the Plate 5 Landslide Hazard Map and is characterized as a landslide undifferentiated from talus, colluvial, rock-fall, glacial, and soil creep (Elliot and Harty, 2010). No landslide deposits were observed within the subject site during our stereographic aerial photograph interpretation, our review of geologic maps, our review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR and our field observations. Furthermore, no landslide deposits are mapped within the subject site as indicated on the Geologic Map of the North Ogden Quadrangle and part of the Ogden and Plain City Quadrangles compiled by Crittenden and Sorensen (Plate 3a Site Vicinity Geologic Map) and on the Progress Report Geologic Map of the Ogden 30’ X 60’ Quadrangle compiled by Coogan and King (Plate 4 Site Vicinity 30’ X 60’ Geologic Map). Given our field and office investigation, it is the opinion of GeoStrata that the deposit delineated within the subject site by Elliot and Harty is an alluvial deposit related to the transgressive and regressive phases of the Lake Bonneville cycle. Therefore, the landslide hazard within the subject site is considered low and it is considered unlikely that landslides will impact the proposed development. It is the opinion of GeoStrata that landslide hazard should not preclude development at the subject lot.

Slope stability of the subject site was not assessed as a part of this geological hazard assessment. Slopes within and immediately adjacent to the subject lot were observed to be gently dipping to the east and toward Ogden Valley between approximately 6 and 10 degrees.

6.2 ALLUVIAL FAN FLOODING/DEBRIS FLOW

Alluvial fan flooding is a potential hazard that may exist in areas containing Holocene alluvial fan deposits. This type of flooding typically occurs as a debris flood consisting of a mixture of soil, organic material, and rock debris transported by fast-moving flood water. Debris floods and debris flows can be a hazard on or below alluvial fans or in stream channels above alluvial fans. Precipitation (rainfall and snowmelt) is generally viewed as a debris-flow “trigger”, but this represents only one of the many factors that contribute to debris-flow hazard. Vegetation, root depth, soil gradation, antecedent moisture conditions and long term climatic cycles all contribute to the generation of debris and initiation of debris-flows. Events of relatively short duration, such as a fire, can significantly alter a basin’s natural resistance to debris-flow mobilization for an extended period of time.

Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR and our field observations, no Holocene-aged alluvial fan or debris flow deposit is mapped or observed within or immediately adjacent to the subject site (Plate 3a Site Vicinity Geologic Map and Plate 4 Site Vicinity 30’ X 60’ Geologic Map). As stated above, it is the opinion of GeoStrata that the surficial deposits within the subject site are lacustrine, alluvial fan, and/or deltaic deposits related to the transgressive and regressive phases of the Lake Bonneville cycle. These are likely Pleistocene age deposits and not Holocene in age. Therefore, the debris flow or alluvial fan flooding hazards within the subject site is considered low and it is considered unlikely that debris flows or alluvial fan flooding will impact the proposed development. It is the opinion of GeoStrata that debris flow or alluvial fan flooding hazards should not preclude development at the subject lot.

6.3 ROCK FALL

Rock falls are the fastest moving mass movement that predominantly occur in mountains where a rock source exists along steep slopes and cliffs greater than 35 degrees. Rock falls are a result of a loss of support from beneath the rock mass that can be caused by freeze/thaw action, rainfall, weathering and erosion, and/or strong ground shaking resulting from seismic activity. Rockfalls result in the collection of rock fall material, referred to as talus, at the base of the slope. The presence of talus indicates that a rock fall hazard has occurred and may still be present at the site.

Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR and our field observations, no rock fall or talus deposits are located within or immediately adjacent to the subject lot. Cobbles observed on the subject lot as previously stated, were well-rounded and were not observed to be characteristic of a recent rock fall. Sources of rock fall debris were not observed up-slope of the subject site. Our field investigation revealed no indications that the subject lot has been subjected to previous rock fall. Therefore, the rock fall hazard within the subject site is considered low and it is considered unlikely that rock fall will impact the proposed development. It is the opinion of GeoStrata that rock fall hazard should not preclude development at the subject site.

6.4 SURFACE FAULT RUPTURE HAZARD

Movement along faults within the crustal rocks beneath the ground surface generates earthquakes. During large magnitude earthquakes (Richter magnitude 6.5 or greater) along the normal faults in the intermountain region, fault ruptures can propagate to the ground surface resulting in a surface fault rupture (Smith and Arabasz, 1991). The fault scarp formed during a surface fault rupture event along a normal fault is generally nearly vertical. A surface rupture fault may be comprised of a larger single surface rupture or several smaller surface ruptures across a fault zone. For all structures designed for human occupancy, a surface rupturing fault is considered active if it has experienced movement in approximately the past 10,000 years (Christenson and others, 2003).

Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR and our field observations, no active surface ruptures are located near the subject site (Plate 6 UGS Quaternary Fault Map). The nearest fault is the Ogden Valley North Fork Fault and is Quaternary in age with an undetermined reoccurrence interval and a slip rate of less than 0.2 mm/yr (Black and others, 2003). This fault is trending northwest approximately 1,550 feet northeast of the subject site. Given our field and office investigations, the surface fault rupture hazard within the subject site is considered low and it is considered unlikely that surface fault rupture will impact the proposed development. It is the opinion of GeoStrata that surface fault rupture hazard should not preclude development at the subject lot.

6.5 STREAM FLOODING HAZARD

Stream flooding can be caused by precipitation, snowmelt or a combination of both. Throughout most of Utah floods are most common in spring during the snowmelt. High flows in drainages can last for a few hours to several weeks. Factors that affect the potential for flooding at a site include surface water drainage patterns and hydrology, site grading and drainage design, and seasonal runoff.

Based on review of published geologic maps, our stereographic aerial photograph interpretation, our review of the hillshades derived from 5 meter Auto-Corrected DEM from 2006 1 meter NAIP orthophotography and our field observations, no streams or drainages were observed within the subject site. Given our field and office investigations, the stream flooding hazard within the subject lot is considered low and it is considered unlikely that stream flooding will impact the proposed development. It is the opinion of GeoStrata that stream flooding hazard should not preclude development at the subject lot. Proper site grading and drainage plans should be developed for the subject site as a part of the civil engineering design for the lot.

7.0 CLOSURE

7.1 LIMITATIONS

The conclusions and recommendations contained in this report, which include professional opinions and judgments, are based on the information available to us at the time of our evaluation, the results of our field observations and our understanding of the proposed site development. If any conditions are encountered at this site that are different from those described in this report, our firm should be immediately notified so that we may make any necessary revisions to recommendations contained in this report. In addition, if the scope of the proposed development changes from that described in this report, our firm should also be notified.

All services were completed in accordance with the current standard of care and generally accepted standard of practice at the time and in the place our services were completed. No other warranty, expressed or implied, is made. Development of property in the immediate vicinity of geologic hazards involves a certain level of inherent risk. It is impossible to predict where geologic hazards will occur. New geologic hazards may develop and existing geologic hazards may expand beyond their current limits.

All services were performed for the exclusive use and benefit of the above addressee. No other person is entitled to rely on GeoStrata's services or use the information contained in this letter without the express written consent of GeoStrata. We are not responsible for the technical interpretations by others of the information described or documented in this report. The use of information contained in this report for bidding purposes should be done at the Contractor's option and risk.

8.0 REFERENCES CITED

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Appendix

Legend

Approximate Site Boundary

0 750 1,500 3,000 4,500 6,000 Feet

1:24,000

N

Base Map:
Aerial imagery provided by the ArcGIS Basemaps. Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

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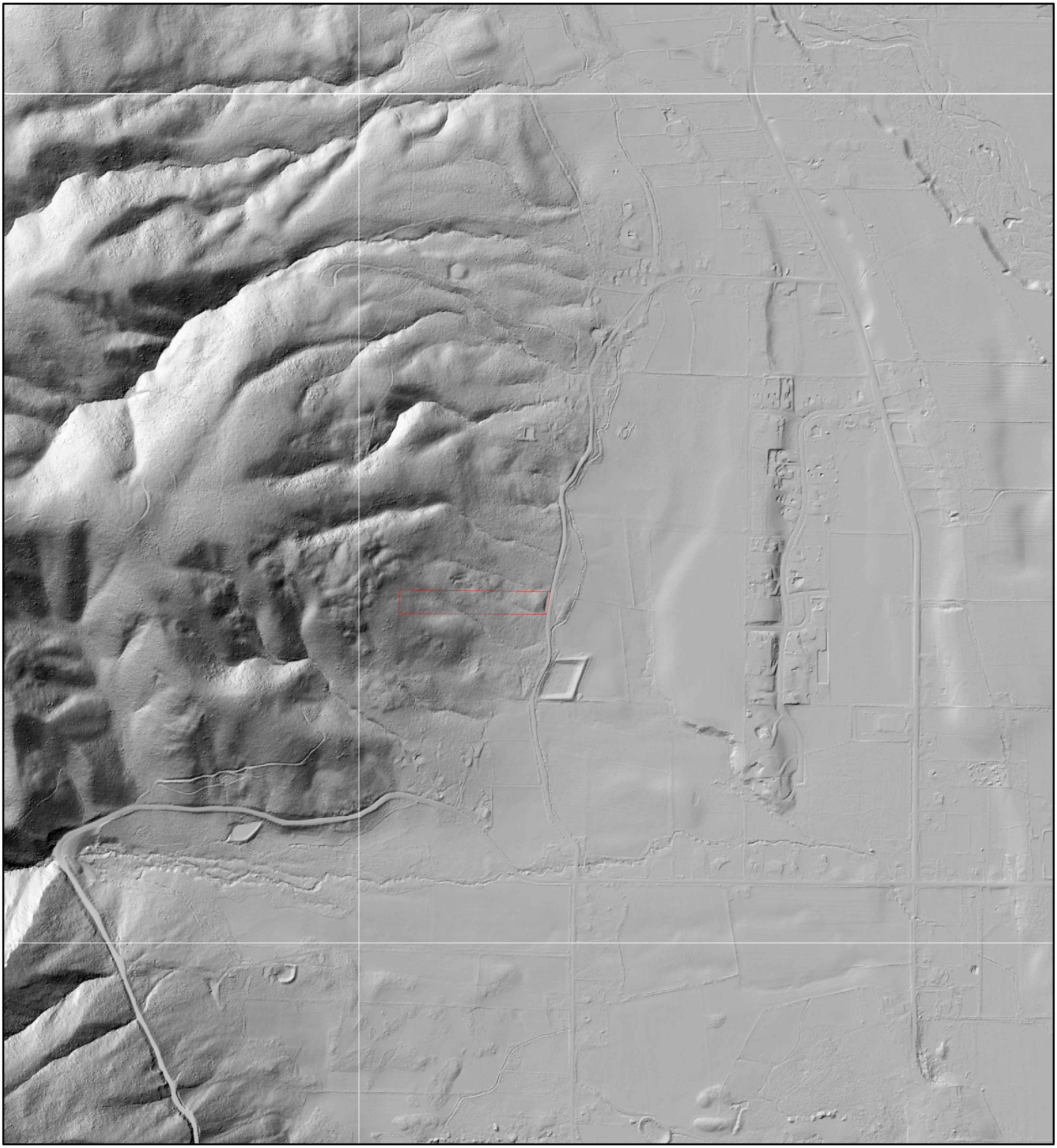
Site Vicinity Map

Plate 1



Legend

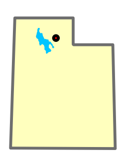
Approximate Site Boundary

0 375 750 1,500 2,250 3,000 Feet

1 inch equals 1,000 feet

Base Map:
Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

N



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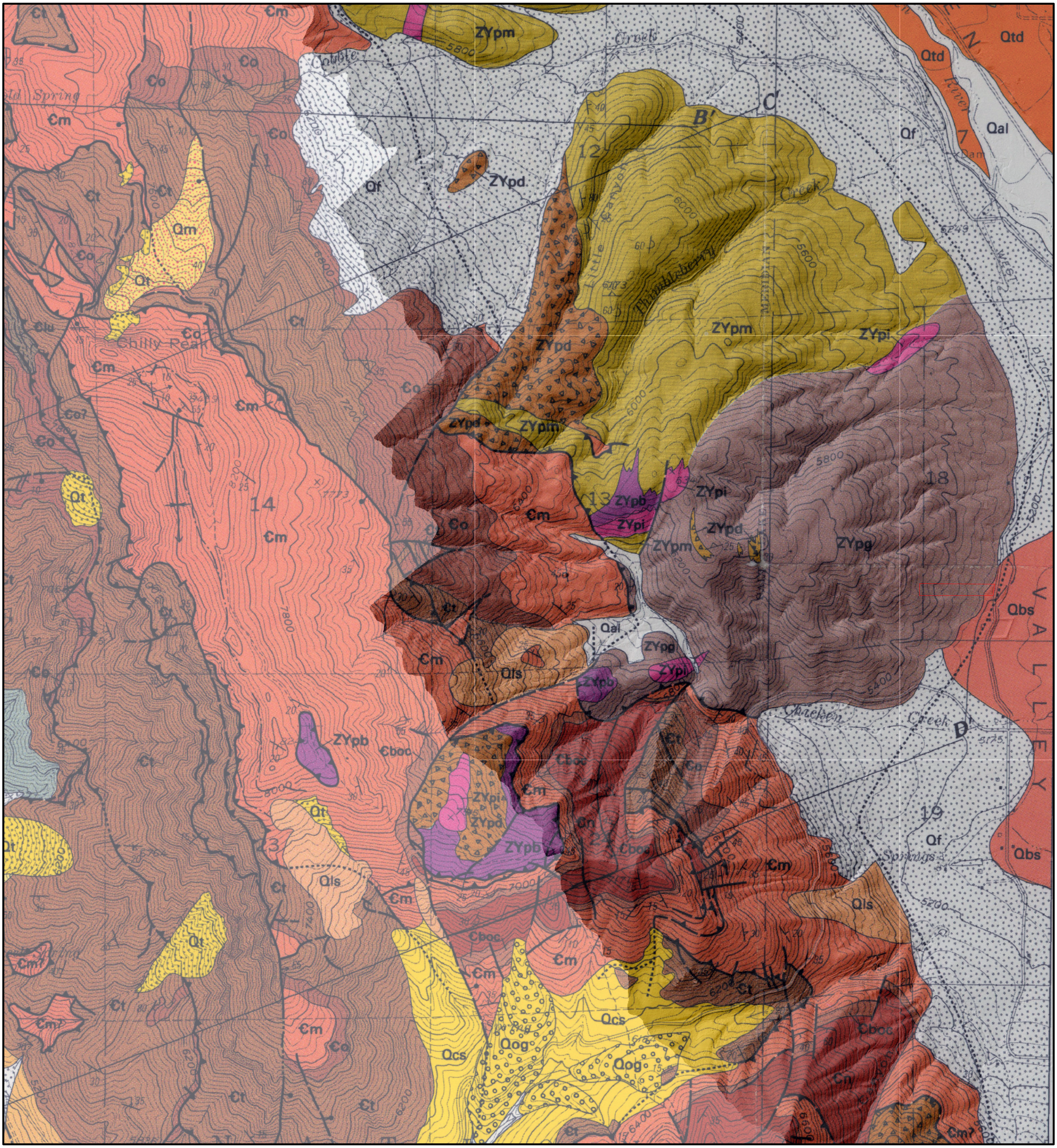
Hillshade Map

Plate 2



Legend

Approximate Site Boundary

Refer to Plate 3b for geologic unit descriptions

0 750 1,500 3,000 4,500 6,000 Feet

1:24,000

Base Map:
Geologic Map of the North Ogden Quadrangle and Part of the Ogden and Plain City Quadrangles, Box Elder and Weber Counties, Utah, Crittenden and Sorensen, 1985. Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

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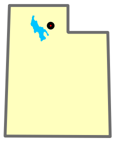

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Site Vicinity Geologic Map

Plate 3a

DESCRIPTION OF MAP UNITS

Qal ALLUVIAL DEPOSITS (HOLOCENE)—Unconsolidated deposits of gravel, sand, and silt in active stream channels and flood plains; thickness 0-6 m

Qt TALUS DEPOSITS (HOLOCENE)—Coarse angular locally derived rock fragments; thickness 0-6 m

Qf ALLUVIAL FAN DEPOSITS (HOLOCENE)—Boulder- to pebble-size gravel, sand, and silt in alluvial fans along Wasatch front and along west edge of Ogden Valley. Deposited after high stand of Lake Bonneville; thickness 0-60 m

Qls LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)—Mostly angular debris of boulder to sand size; thickness 0-30 m. Locally, includes:

Qlsm Mudflows (Pleistocene)—Deposited below surface of Lake Bonneville

Qu SURFICIAL DEPOSITS, UNDIVIDED (HOLOCENE AND PLEISTOCENE)

Qcs COLLUVIUM AND SLOPEWASH (HOLOCENE AND PLEISTOCENE?) — Locally derived accumulations of cobbles, sand, and silt; thickness 0-10 m

Qb LAKE BONNEVILLE DEPOSITS (PLEISTOCENE)—Gravel, sand, and silt deposited mainly during high stands of Lake Bonneville; thickness 0-60 m. Locally, includes:

Qbs Silt deposits

Qtd TERRACE DEPOSITS (PLEISTOCENE)—Gravel, sand, and silt in stream terraces graded to high stand of Lake Bonneville; thickness 0-35 m

Qo OUTWASH(?) DEPOSITS (PLEISTOCENE)—Unsorted deposits consisting mainly of gravel, sand, and silt; thickness 0-10 m

Qm MORAINE(?) DEPOSITS (PLEISTOCENE)—Unsorted deposits consisting of abundant locally derived cobbles, sand, and silt; thickness 0-30 m

Qog OLDER GRAVEL DEPOSITS (PLEISTOCENE)— Deposits of boulders, cobbles, and sand in low-angle alluvial cones along the Wasatch front and locally in stream canyons. Mostly older than high stand of Lake Bonneville; thickness 0-100? m

QTu SURFICIAL DEPOSITS, UNDIVIDED (QUATERNARY AND TERTIARY)—Shown only in cross sections

Tn NORWOOD TUFF (LOWER OLIGOCENE AND UPPER EOCENE)—Pale-gray to greenish-white, thin-bedded tuff, tuffaceous silt, and sandstone, locally interbedded with lenses of pebble-size gravel. Tuffs are extensively altered to zeolites or bentonite. Commonly covered with black deeply cracked soil in areas of poor exposure. In the type locality, about 35 km southeast of the mapped area, unaltered tuff of this unit yielded K/Ar ages of 38.4, 38.3, and 36.9 m.y. on biotite, sanidine, and glass, respectively (Evernden and others, 1964, recalculated to new isotopic decay constants); thickness in this quadrangle 0-50? m; in type area may attain 500 m

LOWER PLATE OF WILLARD THRUST

All stratigraphic units between the Beirdneau Sandstone and the top of the Tintic Quartzite may be drastically thinned or thickened by the tectonic effects of the overriding Willard thrust. This is particularly evident in the limbs of the overturned fold exposed on the steep north slopes of Ogden Canyon.

Db BEIRDNEAU SANDSTONE (UPPER DEVONIAN)—Medium-bedded to laminated, fine- to medium-grained sandstone, dolomitic sandstone, and dolomite; weathers buff, tan, orange, and brown; thickness 75-90 m

Dh HYRUM DOLOMITE (UPPER AND MIDDLE DEVONIAN)—Thin- to thick-bedded, fine- to medium-grained, dark-gray to black, dark- to light-gray-weathering, cliff-forming dolomite. Minor intercalated gray limestone and limy siltstone; thickness 75-90 m

Dwc WATER CANYON(?) FORMATION (LOWER? DEVONIAN)—Thin-bedded to laminated, fine-grained, medium- to pale-gray, very pale gray- to yellowish-gray-weathering dolomite, silty dolomite, and sandy dolomite; thickness 30 m

Ofh FISH HAVEN DOLOMITE (UPPER ORDOVICIAN)—Medium- to thick-bedded, finely to medium-crystalline, medium- to light-gray, medium- to pale-gray-weathering, cliff-forming dolomite; upper 3 m weathers very pale gray to silver; small white twiggy structures and remnants of corals and crinoid columnals common throughout unit; thickness 60-70 m

Ogc GARDEN CITY FORMATION (MIDDLE AND LOWER ORDOVICIAN)—Thin- to medium-bedded, medium- to pale-gray and tan, tan- to buff-weathering dolomite, commonly with sandy streaks and lenses. Interbedded and intercalated with thinly laminated, medium-gray to tan, tan- to buff-weathering siltstone enclosing lenses of dolomite, resulting in a characteristic netted appearance; thickness 60-75 m

Ꞓs ST. CHARLES LIMESTONE , UNDIVIDED (UPPER CAMBRIAN)—Divided into:

Ꞓsd Dolomite member—Thin- to thick-bedded, finely to medium-crystalline, light- to medium-gray, light-gray-weathering, cliff-forming dolomite; linguloid brachiopods common in basal 15 m; thickness 120-185 m

Ꞓsw Worm Creek Quartzite Member—Thin-bedded, fine- to medium-grained, gray to tan, light-brown-weathering, calcareous to quartzitic sandstone; detrital grains well sorted and well rounded; thickness 2-10 m

Ꞓn NOUNAN DOLOMITE (UPPER AND MIDDLE CAMBRIAN)—Thin- to thick-bedded, finely crystalline, medium-gray, light- to medium-gray-weathering, cliff-forming dolomite; mottled by various shades of gray and with abundant twiggy structures locally; thickness 150-230 m

Ꞓsn ST. CHARLES LIMESTONE (UPPER CAMBRIAN) AND NOUNAN DOLOMITE, (UPPER AND MIDDLE CAMBRIAN), UNDIVIDED

BLOOMINGTON FORMATION (MIDDLE CAMBRIAN)—In this area, consists of:

Ꞓboc Calls Fort Shale Member—Olive-drab to light-brown shale and light- to dark-gray lime stone with intercalated orange to rusty-brown silty limestone; intraformational conglomerate common throughout unit; thickness 25-90 m

Ꞓm MAXFIELD LIMESTONE, UNDIVIDED (MIDDLE CAMBRIAN)—Divided into:

Ꞓmu Upper part—Thin-bedded, finely cystalline, medium- to dark-gray, ledge-forming dolomite; near top of unit includes distinctive light-gray to white laminated dolomite enclosed in medium-blue-gray limestone with lighter gray wavy laminae

Ꞓmm Middle part—Dominantly olive-drab micaceous shale intercalated with medium-gray, mottled, cliff-forming limestone

Ꞓml Lower part—Dark-blue-gray, light-gray-weathering, cliff-forming limestone and dolomite intercalated with greenish-olive-drab limy shale. Locally oolitic and pisolitic; thickness about 300 m, but it may be severely thinned or thickened in proximity to the Ogden and Willard thrusts

Ꞓo OPHIR FORMATION (MIDDLE CAMBRIAN)—Olive-drab fissile micaceous shale interbedded with thin pale-gray silty limestone and rare beds of glauconitic sandstone or quartzite. Includes thin beds of quartzite at the base; thickness 30-40 m, but may be tectonically thinned or thickened locally

Ꞓlu LIMESTONE, UNDIVIDED (MIDDLE CAMBRIAN)—Undivided Maxfield Limestone and limestone of the Ophir Formation

Ꞓt TINTIC QUARTZITE (MIDDLE AND LOWER CAMBRIAN)—Buff- to rusty-weathering, medium- to coarse-grained, well-bedded, cliff-forming orthoquartzite with abundant cross bedding. Pebbles of pale-gray vein quartz dispersed along bedding planes, increasing in abundance downward to form thin lenses of pebble conglomerate. Beds and lenses of cobble-size clasts present near the base. Locally the basal beds are friable, coarse-grained, grayish-red to white, arkosic sandstone that grades downward into gruss developed on the top of the underlying unit; thickness 335-400 m

Xfc FARMINGTON CANYON COMPLEX (LOWER PROTEROZOIC)—Medium- to coarse-grained quartz monzonite gneiss composed of quartz, plagioclase, and alkali feldspars in about equal amounts with minor biotite and ferrohastingsite hornblende. U/Pb dating of zircons and Pb/Sr dating of whole rocks indicate that the quartz monzonite was intruded about 1,790 m.y. ago (Hedge and others, 1983). May include lenses of gneiss and schist derived from sedimentary rocks of Archean age. South of map area, the complex consists mainly of gneissic metasedimentary rocks that may be as old as 3,000 m.y. into which the quartz monzonite and numerous masses of pegmatite were intruded (Bryant, 1979, 1980; Hedge and others, 1983). Unit is locally cut by numerous ptygmatically folded quartz veins generally 1 to 5 cm thick and by:

Xfca Plagioclase-hornblende amphibolite dikes—Dark-greenish-black dikes a few meters to 100 m long and as much as 20 m wide

Xfcp Pegmatite dikes

UPPER PLATE OF WILLARD THRUST

Zcc CADDY CANYON QUARTZITE (UPPER PROTEROZOIC)—Medium-grained, medium- to thick-bedded, vitreous quartzite. Colors are highly variable, ranging from white to tan, gray, green, bluish green or purple; often striped or streaked. A dull liver brown is particularly characteristic. Upper contact is commonly a hematite-stained shear zone atop 5-6 m of cliff-forming, white, brecciated quartzite; thickness 300-500 m

Zkc KELLEY CANYON FORMATION (UPPER PROTEROZOIC)—Thin-bedded, dark-gray to black argillite, weathering to tan, dark gray, greenish gray, and silver; commonly has alternating dark-gray and greenish-gray interbeds. Brown-weathering, limonite-stained, chloritic lamprophyre dikes common throughout; thickness 180 m

FORMATION OF PERRY CANYON (UPPER OR MIDDLE PROTEROZOIC)—In this area, divided into:

ZYpm Carbonaceous mudstone—Thin- to thick-bedded, black, carbonaceous mudstone locally containing isolated lenses of black diamictite

ZYpg Graywacke-siltstone—Medium- to fine-grained, medium- to dark-gray, tan-weathering graywacke; gray to dark-green, tan-weathering, micaceous siltstone; laterally gradational, mainly in the adjoining Huntsville and Mantua quadrangles, with the carbonaceous mudstone (ZYpm)

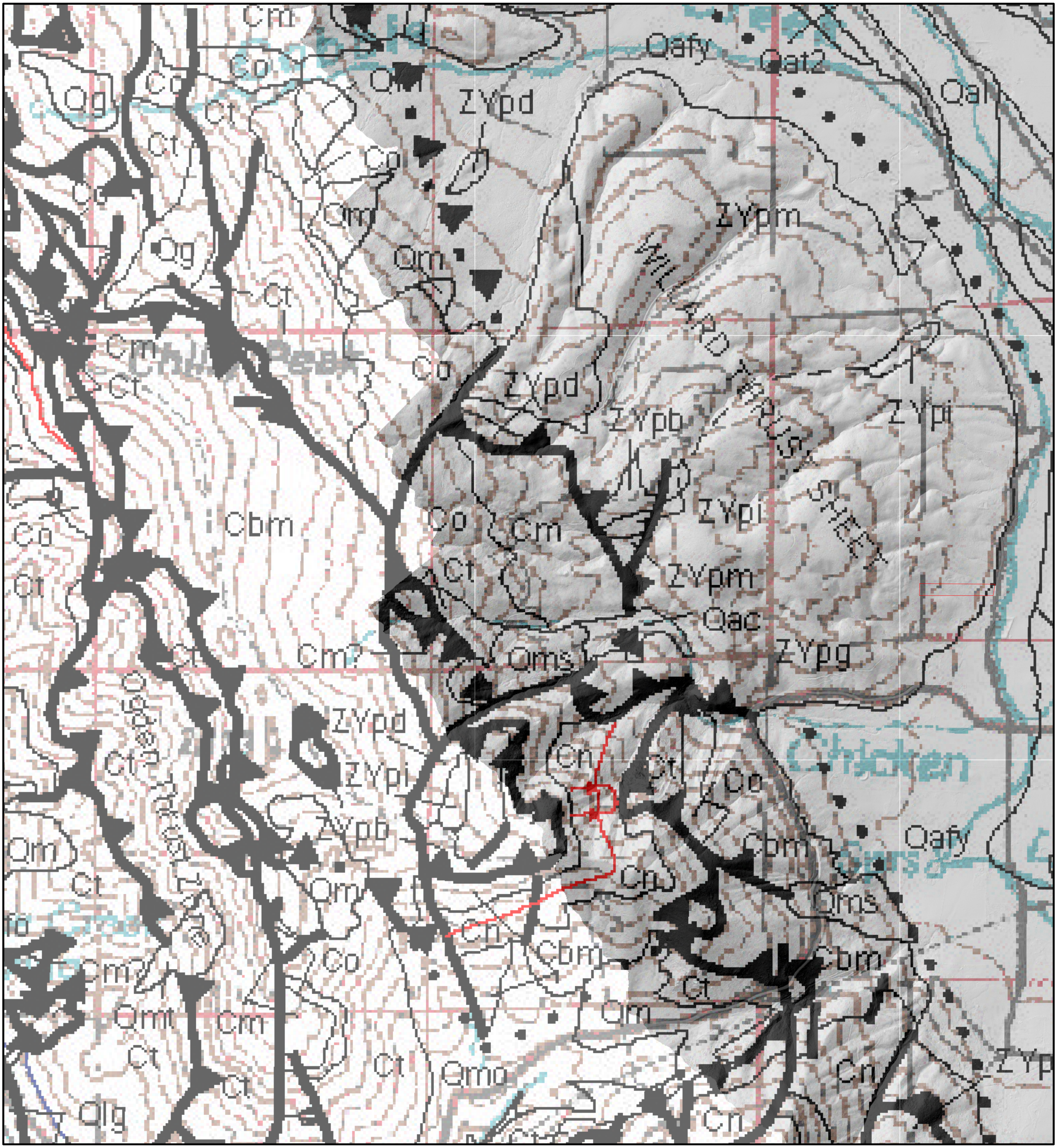
ZYpb Pillow basalt

ZYpi Altered intrusive diorite

ZYpd Diamictite—Unit is characterized by cobble- to boulder-size clasts enclosed in a voluminous matrix of black mudstone with abundant, partly angular clasts ranging from sand to granule size. Clasts are predominantly pale-gray quartzite and subordinate coarse-grained granitic rocks; in places, as large as 3 m in diameter. Clasts of bright apple-green, fuchsite-bearing quartzite are a minor but distinctive component. Diamictite is present as isolated lenses within the carbonaceous mudstone unit (ZYpm) and forms discrete beds at the base of the Perry Canyon unit, particularly near North Ogden Pass, where it is associated with altered intrusive diorite (ZYpi) and pillow basalt (ZYpb)

Xf FACER FORMATION, UNDIVIDED (LOWER PROTEROZOIC)—Green, blue-black, and purple slate and phyllite, locally containing fine-grained white to tan metaquartzite. Fine- to coarse-grained muscovite schist and thin amphibolite sills are present mainly north of this quadrangle (Crittenden and Sorensen, 1980) The best exposures are on Lewis Peak, but the unit also crops out east of Ben Lomond and forms sheared lenses too thin to map at other places along the Willard thrust; thickness 0-75 m. Locally divided into:

Xfls Limestone—Thin-bedded, buff-colored, aphanitic limestone



Legend

Approximate Site Boundary

Refer to map cited for geologic unit descriptions

0 750 1,500 3,000 4,500 6,000 Feet

1:24,000

N

Base Map:
Progress Report Geologic Map of the Ogden 30' X 60' Quadrangle, Utah and Wyoming - Year 3 of 3, Coogan and King, 2001. Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

GeoStrata

Geologic Hazards Assessment
4400 North 2900 East
Liberty, Utah
Project Number: 1193-001

Site Vicinity 30'X60' Geologic Map

Plate 4

Legend

- Approximate Site Boundary
- Debris Flow Paths
- Landslide Scarps
- deep or unclassified landslide
- landslide and/or landslide undifferentiated from talus, colluvial, rock-fall, glacial, and soil-creep deposits
- landslide undifferentiated from talus and/or colluvial deposits
- lateral spread and/or flow failure
- not classified
- shallow landslide

0 375 750 1,500 2,250 3,000 Feet

1 inch = 1,000 feet

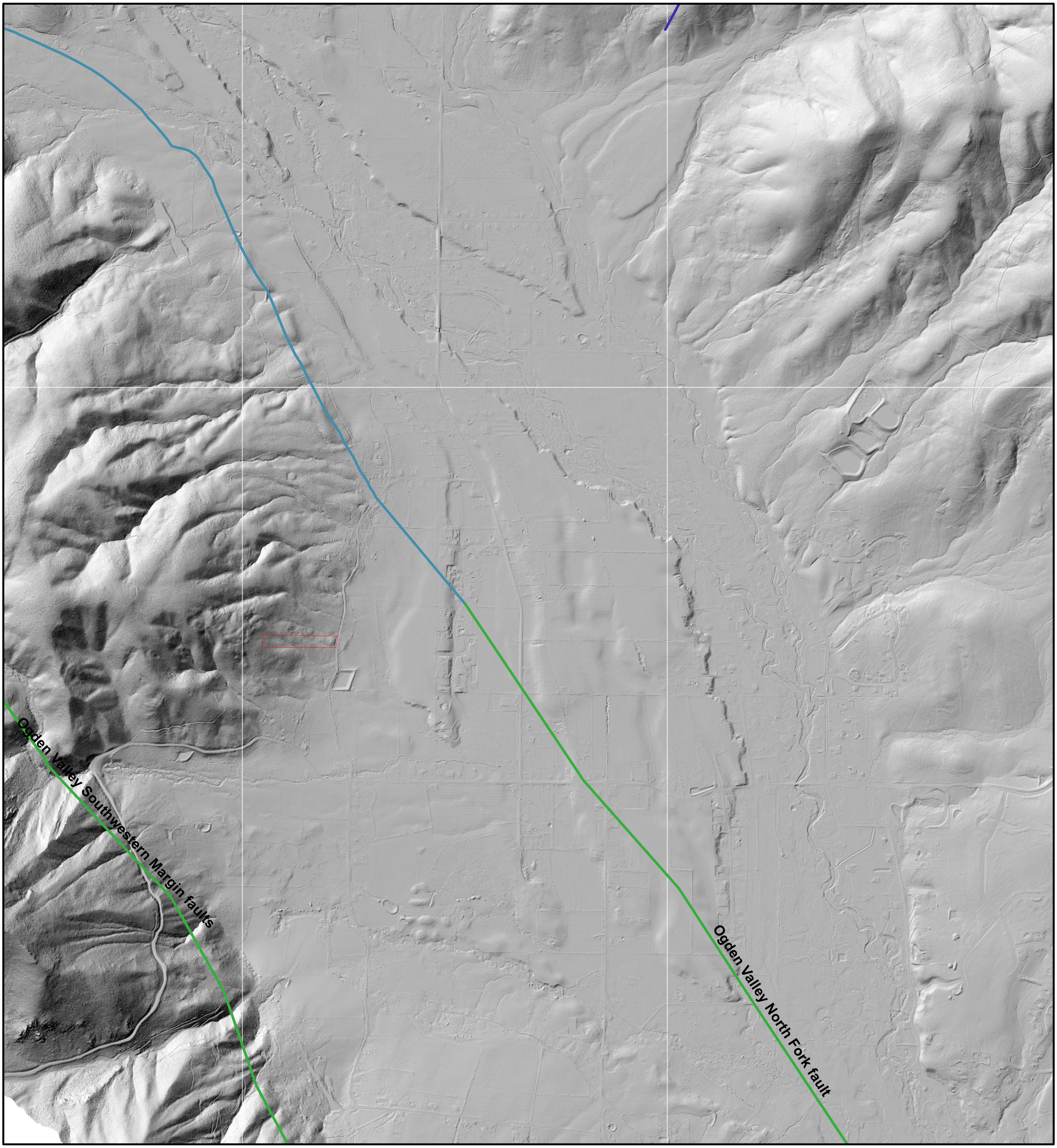
N

Base Map:
Landslide Maps of Utah, Ogden 30' X 60' Quadrangle, Elliot and Harty, 2010. Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

GeoStrata

Geologic Hazards Assessment
4400 North 2900 East
Liberty, Utah
Project Number: 1193-001
Landslide Hazard Map

Plate 5



Legend

Approximate Site Boundary

UGS Quaternary Faults

Fault Age

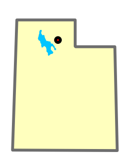
- <130,000
- <15,000
- <150
- <2,600,000
- <750,000

0 750 1,500 3,000 4,500 6,000 Feet

1 inch equals 2,000 feet

Base Map:
Hillshades derived from 2011 1 meter LiDAR and 2013-2014 0.5 meter LiDAR provided by the State of Utah AGRC.

N



GeoStrata

Geologic Hazards Assessment
4400 North 2900 East
Liberty, Utah
Project Number: 1193-001

UGS Quaternary Fault Map

Plate 6