GeoStrata

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Geologic Hazards Assessment
Parcel No. 23-012-0082
Powder Ridge Road
Eden, Utah

GeoStrata Job No. 1236-001

November 1, 2016

Prepared for:

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Prepared by:

LICENSED PROFESSIONAL GEOLOGIST # 5242839 TIMOTHY J. THOMPSON 11/1/2016 STATE OF UTAH

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APPENDICES

1.0 EXECUTIVE SUMMARY

The purpose of this investigation and report was to assess the proposed multi-family residential building lot located on Powder Ridge Road in Eden, 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.

Landslide hazards that would potentially impact the site were assessed as part of our study. An undifferentiated landslide and colluvial deposits are mapped within the subject. However, 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 revealed no scarp features, hummocky topography, or other landslide related geomorphology features related to landslide deformation were observed. Based on our field observations and the location on the hillside of the subject site, it is the opinion of GeoStrata that the surficial deposits within the subject site are thin colluvial, slopewash or soil creep deposits. Based on our office and field investigation, the landslide hazard within the subject site is considered low and it is considered unlikely that landslides will impact the proposed development.

Slope stability of the subject site was not assessed as a part of this geological hazard assessment. Slopes in the eastern portion of the subject site were observed to be gently dipping approximately 3 to 10 degrees to the west and moderately to steeply dipping approximately 15 to 25 degrees to the west in the western portion of the subject. GeoStrata recommends that if the proposed development is planned to be located on slopes that are at a grade of 2.5:1 or greater, a site specific geotechnical investigation be performed to assess slope stability of the site prior to development. Recommendation for proper engineered site grading and drainage design should also be provided. It is the opinion of GeoStrata that landslide hazards should not preclude development at the subject lot as long as the previously stated recommendations are fulfilled.

Debris flow or alluvial-fan flooding hazards that would potentially impact the site were assessed as part of our study. No Holocene-aged alluvial fan or debris flow deposit are mapped within or adjacent to the subject site. Our office and field investigation revealed no indications that the subject lot has been subjected to Holocene-aged debris flows or alluvial fan flooding. 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.

Rock fall hazards that would potentially impact the site were assessed as part of our study. No rock fall or talus deposits are located within or immediately adjacent to the subject lot. 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.

Surface fault rupture hazards that would potentially impact the site were assessed as part of our study. No active surface ruptures are located near the subject site (Plate 7 UGS Quaternary Faults Map). The nearest fault is the southeast trending Ogden Valley Northeast Margin Fault and is undifferentiated Quaternary in age (less than 1.6 million years) with an undetermined reoccurrence interval and a slip rate of less than 0.2 mm/yr (Black and others, 2003). This fault is located approximately 2½ miles southwest 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.

Stream flooding hazards that would potentially impact the site were assessed as part of our study. No streams or drainages were observed within or adjacent to 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.

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 multi-family residential building lot located on Powder Ridge Road in Eden, 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 September 6, 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 5 meter auto-corrected DEM from 2006 1 meter NAIP orthophotography obtained 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 on the northeastern margin of Ogden Valley and within the foothills southeast of James Peak on Powder Ridge Road in Eden, Utah. The subject lot is shown on the Site Vicinity Map included in the Appendix of this report (Plate 1). We understand that the project site is currently an undeveloped multi-family residential building lot on a native hillside. Proposed development, as currently planned, will consist of multi-family residential structures as well as associated driveway, utilities and landscape areas. The hillside in the area of the subject lot gently to steeply slopes generally west toward Wolf Creek Canyon. It is our understanding that the general area of the subject lot was first developed in the late 1960's with the development of the Powder Mountain Ski Resort. The area north of the subject site is occupied by multi-family residential structures. The area south, east and west of the subject site remains in a native condition.

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; Utah Geological Survey, 2016; Sorensen and Crittenden, 1979; Coogan and King, 2016). 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 two sets of stereo aerial photographs obtained from the UGS as shown in Table 1.

Table 1

Source	Photo Number	Date	Scale
ASCS	AAI_3K-132	September 14, 1952	20,000
ASCS	AAI_3K-131	September 14, 1952	20,000

GeoStrata also conducted a review of hillshades derived from 5 meter Auto-Corrected DEM from 2006 1 meter NAIP orthophotography obtained 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 (Plate 2 Hillshade Map).

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 in Eden, Utah at an elevation of approximately 8,800 feet above mean sea level and along the northeastern margin of Ogden Valley and within the foothills southeast of James Peak. 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 Holocene age colluvium and slopewash as well as landslide deposits (Qcs-Qls) and as Holocene and Pleistocene age landslide and colluvial deposits (Qmc) typically mapped where landslides are difficult to distinguish and too difficult to map separately from slopewash or soil creep and where landslides are thin (Coogan and King, 2016). These deposits are mapped in the eastern portion of the subject site as overlying Eocene and upper Paleocene Wasatch Formation (TKwe, Tw) which is characterized as red to pale-reddish brown sandstone, siltstone, mudstone, and pebble, cobbles, and boulder conglomerate (Sorensen and Crittenden, 1979; Coogan and King, 2016). In the western portion of the subject site these deposits are mapped on the Geologic Map of the Huntsville Quadrangle, as shown on Plate 3a Site Vicinity Geologic Map) as overlying upper Cambrian St. Charles Limestone (Csd) which is characterized as thin- to thick-bedded, fine to medium crystalline and light to medium gray in color with white to light gray weathering (Sorensen and Crittenden, 1979). In the western portion of the subject site the Holocene and Pleistocene age deposits are mapped on the Interim Geologic Map of the Ogden 30' X 60' Quadrangle as overlying Cambrian age Nounan Dolomite (Cn) which is characterized as medium dark gray and thick-bedded dolomite and some limestone (Coogan and King, 2016).

5.0 GENERALIZED SITE CONDITIONS

5.1 SURFACE CONDITIONS

As stated previously, the project site is located within the foothills southeast of James Peak which is located along the northeastern margin of Ogden Valley and along Powder Ridge Road in Eden, Utah. The subject site is situated on a gently to steeply sloping hillside dipping generally to the west toward Wolf Creek Canyon. Slopes in the eastern portion of the subject site were observed to be gently dipping approximately 3 to 10 degrees and moderately to steeply dipping approximately 15 to 25 degrees in the western portion of the subject site (Plate 5 Site Specific Contour Map). Surficial deposits within the subject site consist of fine to coarse grained sand with gravel and partially buried, well-rounded to subrounded light pink and white boulder sized, between approximately 2 and 4 feet in diameter, sandstone and conglomerates of the Wasatch Formation (TKwe, Tw) and the Nounan Dlolmite (Cn). The site remains in a relatively natural state, and is lightly vegetated with native sagebrush, weeds, flowers, and grasses in the eastern portion of the subject site and heavily vegetated with mature aspens, few pines and native brush. No structures were observed within the subject site. The properties to the north is occupied by established multi-family residential structures and the areas to the east, west, and south are undeveloped native hillsides.

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 review of published geologic maps, undifferentiated landslide and colluvial deposits are mapped within the subject site (Plate 3a Site Vicinity Geologic Map, Plate 4 Site Vicinity 30' X 60' Geologic Map and Plate 6 Landslide Hazard Map). However, 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 revealed no scarp features, hummocky topography, or other landslide related geomorphology features related to landslide deformation were observed. During our field investigation we did observe curved tree trunks which would suggest soil creep or snow loading within the subject site and is consistent with published geologic maps that include the area of the subject site. Based on our field observations and the location on the hillside of the subject site, it is the opinion of GeoStrata that the surficial deposits within the subject site are thin colluvial, slopewash or soil creep deposits. These deposits are mapped as overlying Nounan Dolomite which is dipping between 25 and 30 degrees to the west and into the hillside. Based on our office and field investigation, the landslide hazard within the subject site is considered low and it is considered unlikely that landslides will impact the proposed development.

Slope stability of the subject site was not assessed as a part of this geological hazard assessment. Slopes in the eastern portion of the subject site were observed to be gently dipping approximately 3 to 10 degrees to the west and moderately to steeply dipping approximately 15 to 25 degrees to the west in the western portion of the subject site (Plate 5 Site Specific Contour Map). GeoStrata recommends that if the proposed development is planned to be located on slopes that are at a grade of 2.5:1 or greater, a site specific geotechnical investigation be performed to assess slope stability of the site prior to development. The geotechnical engineer should provide engineering recommendations regarding slope stability at the proposed building site. All cut and/or fill retaining structures should be designed by a geotechnical engineer. Recommendation for proper engineered site grading and drainage design should also be provided. It is the opinion of GeoStrata that landslide hazards should not preclude development at the subject lot as long as the previously stated recommendations are fulfilled.

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 5 meter auto-corrected DEM from 2006 1 meter NAIP orthophotography and our field observations, no Holocene-aged alluvial fan or debris flow deposit are mapped within or adjacent to the subject site (Plate 3a Site Vicinity Geologic Map and Plate 4 Site Vicinity 30' X 60' Geologic Map). The subject site is mapped as undifferentiated landslide and colluvial deposits overlying bedrock. Our office and field investigation revealed no indications that the subject lot has been subjected to Holocene-aged debris flows or alluvial fan flooding. 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 5 meter auto-corrected DEM from 2006 1 meter NAIP orthophotography and our field observations, no rock fall or talus deposits are located within or immediately adjacent to the subject lot. Boulders and cobbles observed on the subject lot as previously stated, were well-rounded to subrounded 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 5 meter auto-corrected DEM from 2006 1 meter NAIP orthophotography and our field observations, no active surface ruptures are located near the subject site (Plate 7 UGS Quaternary Faults Map). The nearest fault is the southeast trending Ogden Valley Northeast Margin Fault and is undifferentiated Quaternary in age (less than 1.6 million years) with an undetermined reoccurrence interval and a slip rate of less than 0.2 mm/yr (Black and others, 2003). This fault is located approximately 2½ miles southwest 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 or adjacent to the subject site (Plate 8 Drainage Map). 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 inch = 2,000 feet

Base Map:
Aerial imagery provided by ArcGIS Basemaps.

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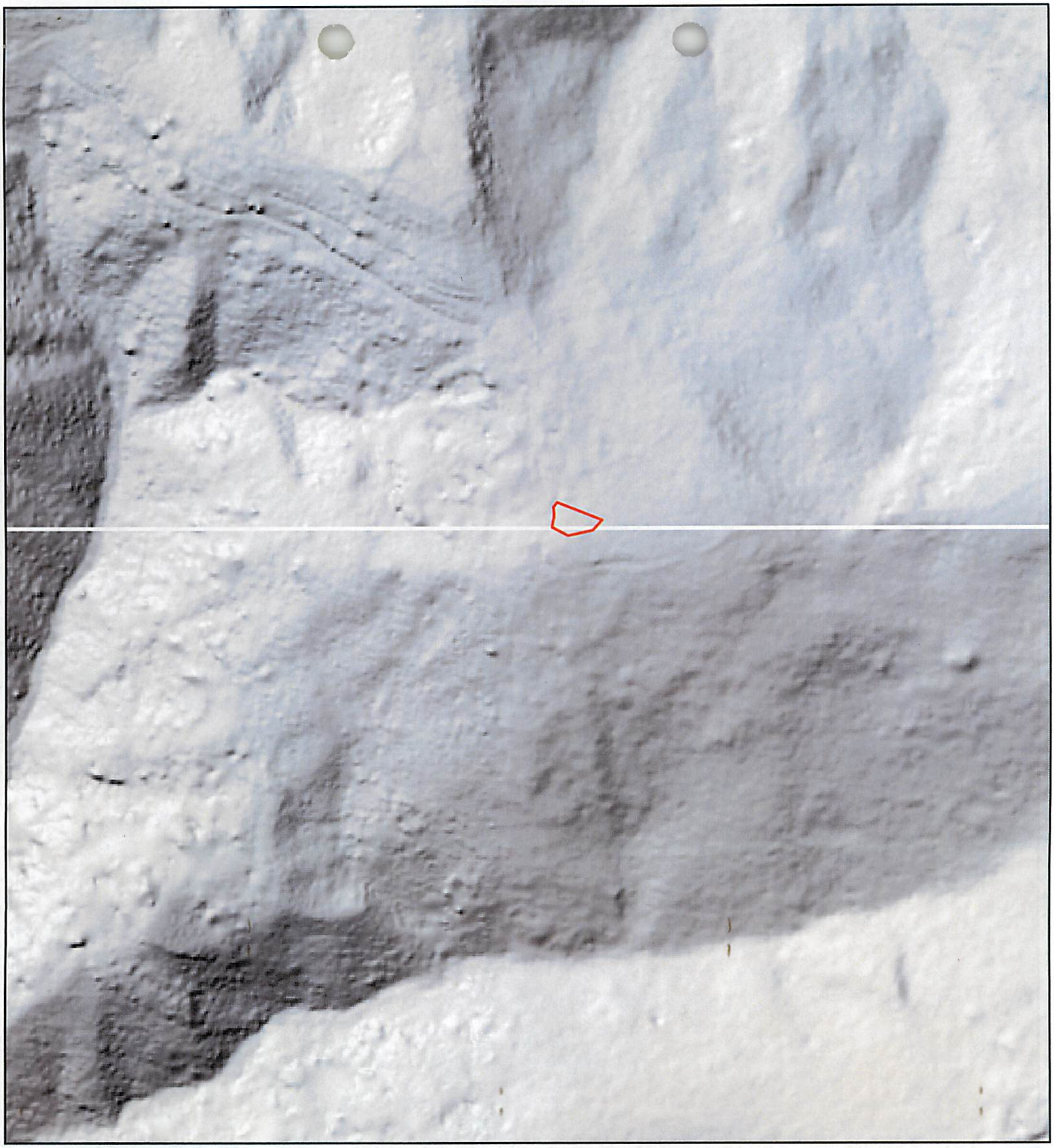
Site Vicinity Map

Plate 1



Legend

Approximate Site Boundary

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

1 inch = 1,000 feet

Base Map:
Hillshades derived from 5 meter auto-corrected DEMs from 2006 1 meter NAIP orthophotography obtained from the State of Utah AGRC.

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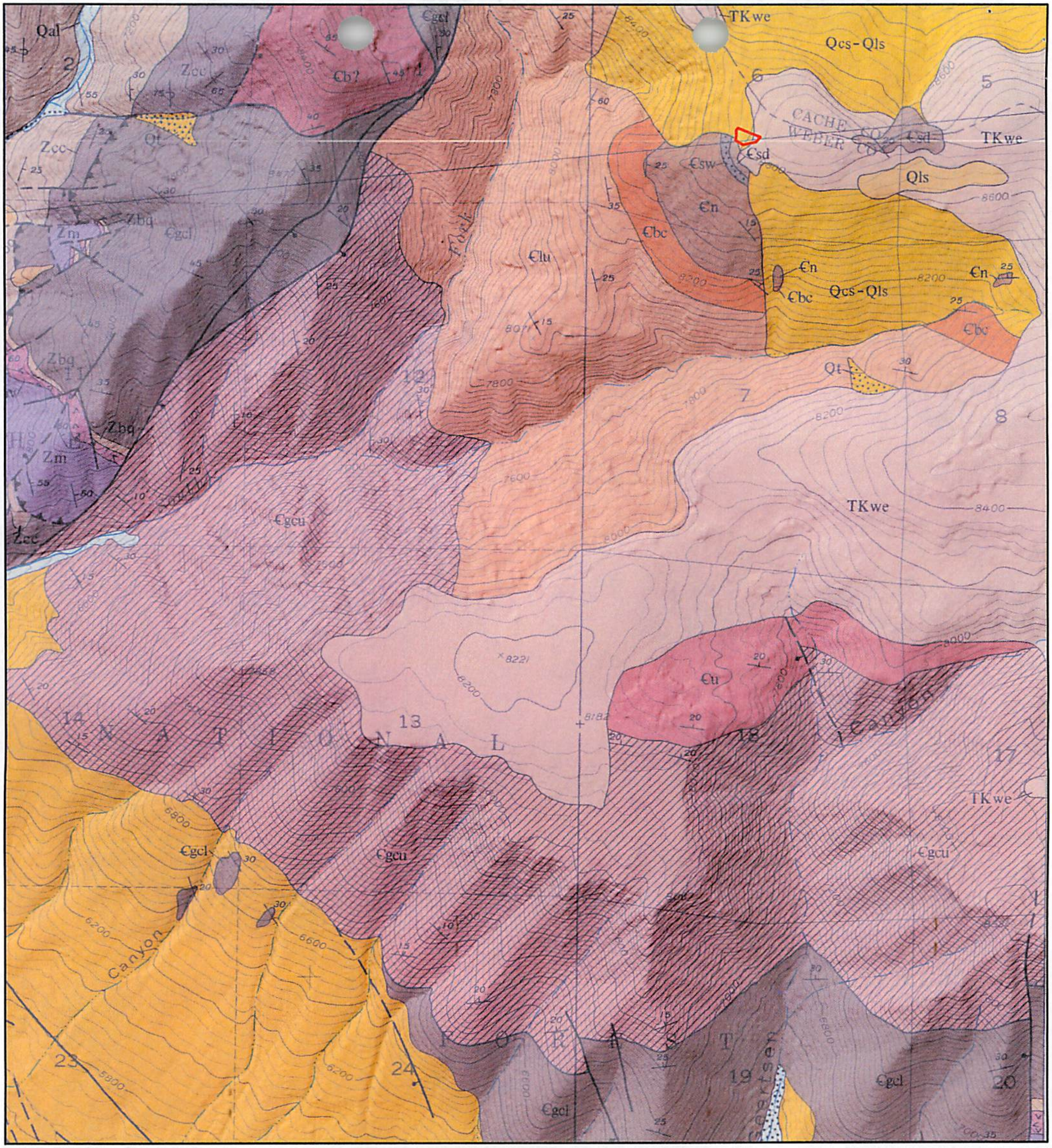
Hillshade Map

Plate 2



Legend

Approximate Site Boundary

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

1 inch = 2,000 feet

N

Base Map:
1:24,000 scale Geologic Map of the Huntsville Quadrangle, Weber and Cache Counties, Utah, Sorensen and Crittenden, 1979.
Hillshades derived from 5 meter auto-corrected DEMs from 2006 1 meter NAIP orthophotography obtained from the State of Utah AGRC.

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Site Vicinity Geologic Map

Plate 3a

Qal ALLUVIAL DEPOSITS, UNDIFFE[illegible]IATED (Holocene) – Unconsolidated gravel, sand, and silt deposits in presently active stream channels and floodplains; thickness 0-6 m

Qcs COLLUVIUM AND SLOPEWASH (Holocene) – Bouldery colluvium and slopewash chiefly along eastern margin of Ogden Valley; in part, lag from Tertiary units; thickness 0-30 m

Qf ALLUVIAL FAN DEPOSITS (Holocene) – Alluvial fan deposits; postdate, at least in part, time of highest stand of former Lake Bonneville; thickness 0-30 m

Qls LANDSLIDE DEPOSITS (Holocene) – thickness 0-6 m

Qt TALUS DEPOSITS (Holocene) – thickness 0-6 m

Qtd TERRACE AND DELTA(?) DEPOSITS (Pleistocene) – In North Fork Ogden River, gravel, sand, and silt in stream terraces graded to high stand of former Lake Bonneville; at mouth of Middle and South Fork Ogden River, pinkish-tan sand and silt in delta(?) remnants deposited during high stands of Lake Bonneville; thickness 0-45 m

Qs SILT DEPOSITS (Pleistocene) – Tan silt and sand forming extensive flats in Ogden Valley; deposited during high stands of Lake Bonneville, but may include older alluvial units; thickness 0-60 m

Qg GRAVEL AND COBBLE DEPOSITS (Pleistocene) – In Ogden Canyon, gravel and cobble terrace remnants, probably deposited after time of highest stand of Lake Bonneville; thickness 0-3 m

Qog OLDER GRAVEL DEPOSITS (Pleistocene) – North of Huntsville, cobble, gravel, and sand deposit that probably predates high stands of Lake Bonneville; thickness 21 m

Tn NORWOOD TUFF (lower Oligocene and upper Eocene) – Fine- to medium-bedded, fine-grained, friable, white- to buff-weathering tuff and sandy tuff, probably waterlain and in part reworked; thickness 0-450+(?) m

TKwe WASATCH AND EVANSTON(?) FORMATIONS, UNDIVIDED (Eocene, Paleocene, and Upper Cretaceous?) – Unconsolidated pale-reddish-brown pebble, cobble, and boulder conglomerate; forms boulder-covered slopes. Clasts are mainly Precambrian quartzite and are tan, gray, or purple; matrix is mainly poorly consolidated sand and silt; thickness 0-150 m

LOWER PLATE OF WILLARD THRUST

Mh HUMBUG FORMATION (Upper Mississippian) – Medium-bedded, commonly crossbedded, medium- to fine-grained, gray- to tan-weathering quartzite, commonly with thin beds and lenses of dark-gray to black chert; interbedded dark- to light-gray medium-bedded dolomite; thickness 300+ m

Md DESERET LIMESTONE (Upper and Lower Mississippian) – Medium- to thin-bedded, coarsely to finely crystalline, medium-gray- to pale-brown-weathering, dark- to light-gray dolomite and limestone, commonly with thin beds and lenses of dark-gray to black chert; 6 m dark-gray to black mudstone, shale, and oolitic phosphatic shale at base; thickness 60-75 m

Mg GARDISON LIMESTONE (Lower Mississippian) – Upper part finely to coarsely crystalline, thick-bedded to massive, dark-gray- to pale-brown-weathering, medium- to dark-gray fossiliferous dolomite with thin beds and lenses of light- to dark-gray chert. Lower part finely to medium crystalline, thin- to medium-bedded, commonly platy weathering, dark-gray to black, light-gray- to blue-gray-weathering fossiliferous dolomite; thickness 90-260 m

Db BEIRDNEAU SANDSTONE (Upper Devonian) – Medium-bedded to laminated, fine- to medium-grained sandstone, dolomitic sandstone, and dolomite with minor limestone, mudstone, shale, and quartzite; intraformational conglomerate common; weathers to 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 silty limestone; 5-12 m of medium-grained, buff- to tan-weathering dolomitic sandstone locally present in upper 30 m of unit; thickness 107 m

Dwc WATER CANYON(?) FORMATION (Lower? Devonian) – Thin-bedded to laminated, fine-grained, medium- to pale-gray, pale- to yellowish-gray-weathering dolomite, silty dolomite, and sandy dolomite; thickness 27 m

Ofh FISH HAVEN DOLOMITE (Upper Ordovician) – Medium- to thick-bedded, medium to finely 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 remna[illegible] corals and crinoid columnals common throughout unit; thickness 60-69 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 siltsone containing nodules and lenses of dolomite; thickness 60-75 m

ST. CHARLES LIMESTONE (Upper Cambrian) – Includes:

Ꞓsd Dolomite member – Thin- to thick-bedded, finely to medium crystalline, light- to medium-gray, white- to light-gray-weathering, cliff-forming dolomite; linguloid brachiopods common in basal 15 m; thickness 150-245 m

Ꞓsw Worm Creek Quartzite Member – Thin-bedded, fine- to medium-grained, medium- to dark-gray, tan- to brown-weathering calcareous quartzitic sandstone; detrital grains well-sorted and well-rounded; thickness 6 m

Ꞓn NOUNAN DOLOMITE (Upper and Middle Cambrian) – Thin- to thick-bedded, finely crystalline, medium-gray, light- to medium-gray-weathering, cliff-forming dolomite; white twiggy structures common throughout unit; thickness 150-230 m

Ꞓbc CALLS FORT SHALE MEMBER OF BLOOMINGTON FORMATION (Middle Cambrian) – Olive-drab to light-brown shale and light- to dark-blue-gray limestone with intercalated orange to rusty-brown silty limestone; intraformational conglomerate common throughout unit; thickness 23-90 m

Ꞓm MAXFIELD(?) LIMESTONE (Middle Cambrian) – Upper part thin-bedded, finely crystalline, medium- to dark-gray, ledge-forming dolomite, often with intercalated light-gray silty limestone; near top of unit, includes distinctive light-gray to white laminated dolomite, underlain by light- and dark-gray mottled limestone. Middle part dominantly olive-drab to greenish-brown micaceous shale, with interbedded medium- to dark-gray limestone, overlain by medium- to dark-gray, cliff-forming platy limestone. Lower part dark-blue-gray, light-gray-weathering, cliff-forming limestone and dolomite, with intercalated reddish-gray silty limestone; underlain by 30 m thin-bedded, light-blue-gray, slope-forming limestone and shaly limestone, with some greenish-olive-drab shale. Base of lower unit is finely crystalline, medium-blue-gray, light-gray-weathering limestone, commonly with intercalated tan to orange-brown silty limestone, and locally containing orange-brown oolites near top. Upper and middle parts of formation exposed in Huntsville quadrangle; lower part exposed in North Ogden quadrangle; thickness 290 m

UPPER PLATE OF WILLARD THRUST

ST. CHARLES LIMESTONE – See above

Ꞓsd Dolomite member – See above

Ꞓsw Worm Creek Quartzite Member – See above

Ꞓn NOUNAN DOLOMITE – See above

Ꞓbc CALLS FORT SHALE MEMBER OF BLOOMINGTON FORMATION – See above

Ꞓlu CAMBRIAN LIMESTONES, UNDIVIDED (Middle Cambrian) – Includes limestone and Hodges Shale Members of Bloomington Formation, and Blacksmith and Ute Limestones

Ꞓb BLACKSMITH LIMESTONE (Middle Cambrian)) – Medium- to thin-bedded, light-gray to dark-blue-gray limestone; thin-bedded, flaggy-weathering, gray to tan silty limestone and interbedded siltstone; light- to dark-gray dolomite, with some reddish siliceous partings; thickness 400? m

Ꞓu UTE LIMESTONE (Middle Cambrian) – Medium- to thin-bedded, finely crystalline, light- to dark-gray silty limestone with irregular wavy partings, mottled and streaked surfaces, worm tracks, and twiggy structures common throughout unit; oolites and *Girvanella* in many beds; olive-drab fissile shale interbedded throughout unit. Includes thin-bedded, gray-weathering, pale-tan to brown dolomite exposed at base of unit, 18-24 m at head of Geertsen Canyon and 0-3 m elsewhere; thickness 245? m

BRIGHAM GROUP (Crittenden and others, 1971) – Includes:

Ꞓgcu GEERTSEN CANYON QUARTZITE (Lower Cambrian) – Includes: Upper member – Pale-buff to white or flesh-pink quartzite, locally streaked with pale red or purple. Coarse-grained; small pebbles occur throughout unit and increase in abundance downward. Base marked by zone 30-60 m thick of cobble conglomerate in beds 30 cm to

1: 24,000 Geologic Map of the Hunstville Quadrangle, Weber and Cache Counties, Utah, Sorensen and Crittenden, 1979, Map Key.

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Plate 3b

BRIGHAM GROUP (Crittenden and others, 1971) – Includes:

GEERTSEN CANYON QUARTZITE (Lower Cambrian) – Includes:

Ꞓgcu Upper member – Pale-buff to white or flesh-pink quartzite, locally streaked with pale red or purple. Coarse-grained; small pebbles occur throughout unit and increase in abundance downward. Base marked by zone 30-60 m thick of cobble conglomerate in beds 30 cm to 2 m thick; clasts, 5-10 cm in diameter, are mainly reddish vein quartz or quartzite, sparse gray quartzite, or red jasper; thickness 730-820 m

Ꞓgcl Lower member – Pale-buff to white and tan quartzite with irregular streaks and lenses of cobble conglomerate decreasing in abundance downward. Lower 90-120 m strongly arkosic, streaked greenish or pinkish. Feldspar clasts increase in size to 0.6-1.3 cm in lower part of unit; thickness 490-520 m

BROWNS HOLE FORMATION (Precambrian Z) – Includes:

Zbq Quartzite member – Medium- to fine-grained, locally friable-weathering, well-rounded, well-sorted, terra-cotta-colored quartzite, with some small- to large-scale crossbedding; thickness 30-45 m

Zbv Volcanic member – Unit comprises volcanic rocks ranging in composition from basalt or andesite to trachyte. Includes gray-weathering, fine-grained basaltic flows and a variety of black to red, scoriaceous to amygdaloidal volcanic breccias, all locally reworked as volcanic conglomerate. K/Ar age of hornblende from cobble of alkali trachyte is 570 ± 7 m.y. (Crittenden and Wallace, 1973); thickness 55-140 m

Zm MUTUAL FORMATION (Precambrian Z) – Coarse- to medium-grained, commonly gritty, locally pebbly, grayish-red to pale-purple or pink quartzite and feldspathic quartzite with abundant cross-bedding; thickness 370 m

Zi INKOM FORMATION (Precambrian Z) – Thin-bedded purple and olive-drab to light-green siltstone, argillite and thin-bedded quartzite. Upper half of unit dominantly purple; lower half of unit olive-drab to pale green, and includes thin zone of silver-weathering tuff and sandy tuff; thickness 120 m

Zcc CADDY CANYON QUARTZITE (Precambrian Z) – Medium-grained, vitreous, white to tan quartzite; unit is dominantly light-colored near top and tan- to pale-brown-weathering in lower part, with abundant intercalated red siltstone at base; thickness 460-600 m

Zkc **ls** KELLEY CANYON FORMATION (Precambrian Z) – Upper part interbedded olive-drab siltstone and thin-bedded, tan- or brown-weathering quartzite, generally in wavy or contorted beds cut by small sandstone dikelets; contact with overlying unit may be marked by zone of thin-bedded quartzite (0.5-2-cm beds) with red-weathering wavy laminae of shale and siltstone. Middle part is gray to lavender argillite enclosing and intercalated with thin-bedded pinkish-gray silty limestone (at Middle Fork Ogden River, shown on map as ls). Lower part is lavender-gray, purple-gray, or olive-drab shale, with thin beds of greenish fine-grained sandstone at top. Base of unit marked by 3-m thin-bedded to laminated, tan-weathering, fine-grained dolomite; thickness 600 m

MAPLE CANYON FORMATION (Precambrian Z) – Includes:

Zmcc Conglomerate member – Total thickness 30-150 m. Includes:

$Zmcc_3$ Upper conglomerate – Coarse-grained, locally conglomeratic, white quartzite

$Zmcc_2$ Argillite – Olive-drab to silvery-gray laminated argillite

$Zmcc_1$ Lower conglomerate – White to pale-gray conglomeratic quartzite, with pebble- to cobble-size clasts of white quartz and white, gray, or pale-pink quartzite

Zmcg Green arkose member – Massively bedded pale-green arkosic sandstone, with K-feldspar content locally to 40 percent. Zone of siliceous arkosic quartzite locally present approximately 60 m below top of unit; intercalated quartzitic conglomerates locally present near base of unit; thickness 150-300 m

Zmca Argillite member – Olive-drab, locally gray, thin-bedded siltstone and silty argillite, with a medial zone of greenish-gray arkosic sandstone. Argillite commonly shows small-scale folding and marked schistosity. May include rocks of Precambrian Y age near base of unit; thickness 150 m

FORMATION OF PERRY CANYON (Precambrian Z or Precambrian Y)

ZYpg Graywacke-siltstone member – Medium- to fine-grained, medium- to dark-gray, tan-weathering graywacke; gray to dark-green, tan-weathering, micaceous siltstone; thickness 460 m

ZYpd Diamictite member – Gray to black, tan-weathering diamictite, consisting of pebble- to boulder-size quartzitic and granitic clasts set in a black, medium- to fine-grained sandy matrix; thickness 0-120 m

Xf FORMATION OF FACER CREEK (Precambrian X) – Green, purple, and black slate and phyllite; thickness 0-15 m (section incomplete, present only in fault slice)

Axial trace of recumbent syncline, showing direction of dip of limbs

Approximate location of Lake Bonneville shoreline

1: 24,000 Geologic Map of the Hunstville Quadrangle, Weber and Cache Counties, Utah, Sorensen and Crittenden, 1979, Map Key.

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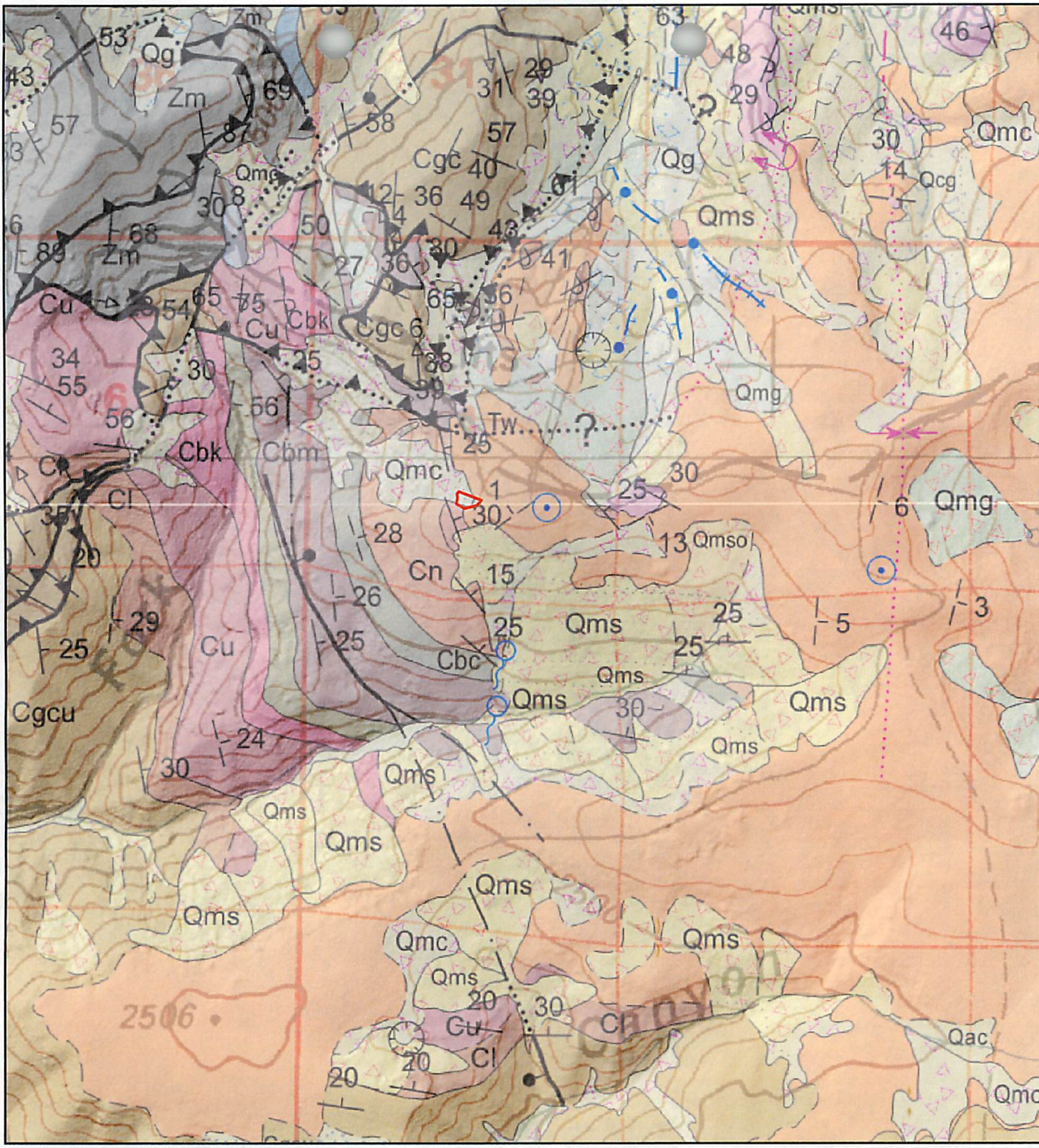
Plate 3c



Legend

Approximate Site Boundary

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

1 inch = 2,000 feet

Base Map:
Interim Geologic Map of the Ogden 30' x 60' Quadrangle, Box, Elder, Cache, Davis, Morgan, Rich, and Summit Counties, Utah and Uintah County, Wyoming, Coogan and King, 2001. Hillshades derived from 5 meter auto-corrected DEMs from 2006 1 meter NAIP orthophotography obtained from the State of Utah AGRC.

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Site Vicinity 30x60 Geologic Map

Plate 4

Legend

Approximate Site Boundary

10 Foot Contour

0 35 70 140 210 280 Feet

1 inch = 100 feet

Base Map:
Contours derived from 5 meter auto-corrected DEMs from 2006 1 meter NAIP orthophotography obtained from the State of Utah AGRC. 2006 25 cm HRO provided by that State of Utah AGRC.

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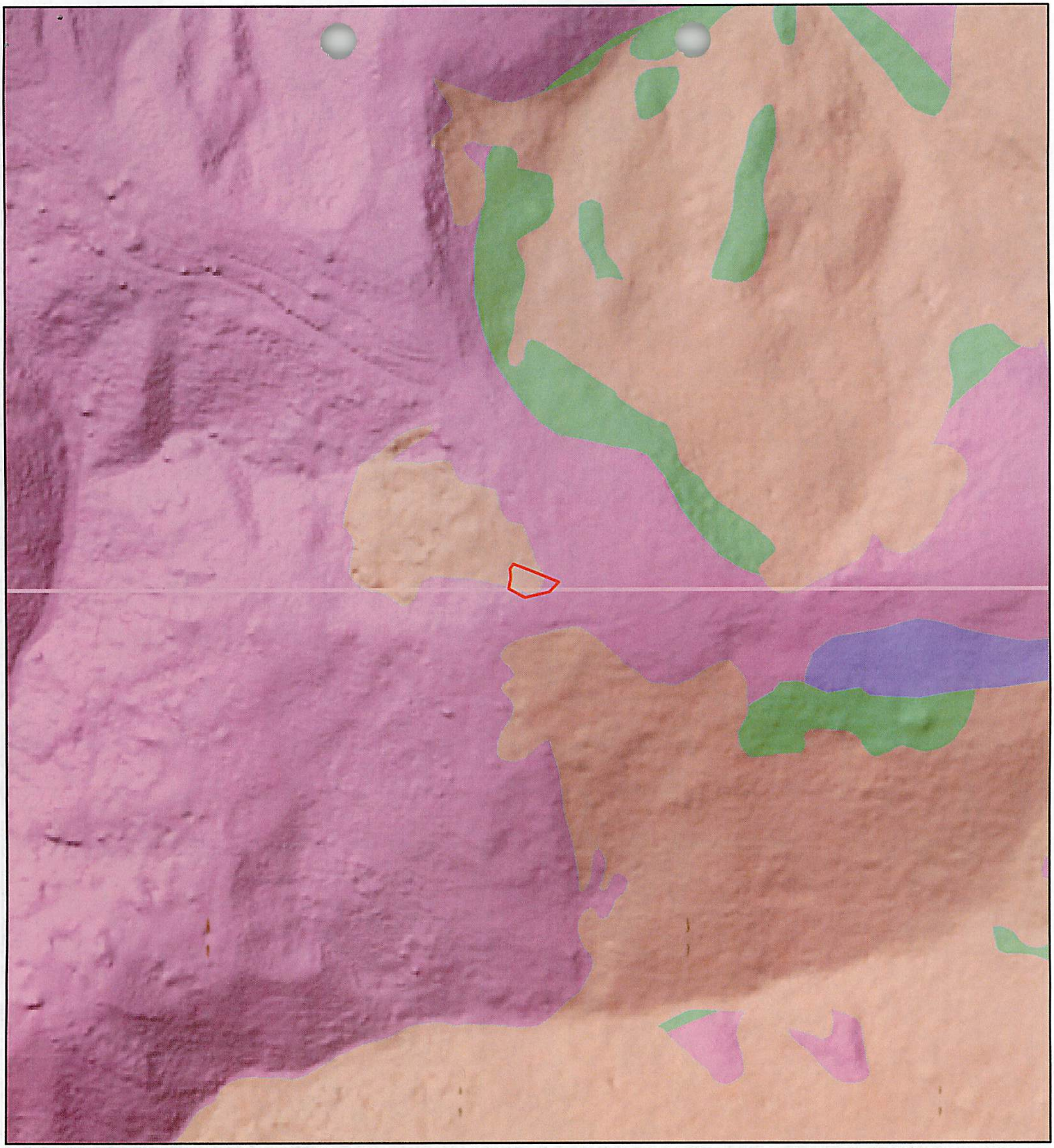
Contour Map

Plate 5



Legend

- Approximate Site Boundary
- LandslideScarps
- DebrisFlowPaths
- 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

Base Map:
Landslide Maps of Utah, Ogden 30' x 60' Quadrangle, Elliot and Harty, 2010. Hillshades derived from 5 meter auto-corrected DEMs from 2006 1 meter NAIP orthophotography obtained from the State of Utah AGRC.

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Site Vicinity 30x60 Geologic Map

Plate 6

Legend

Approximate Site Boundary

Quaternary Fault

- <150 Years, Well Constrained
- <15,000 Years, Well Constrained
- <15,000 Years, Moderately Constrained
- <15,000 Years, Inferred
- <130,000 Years, Well Constrained
- <130,000 Years, Moderately Constrained
- <130,000 Years, Inferred
- <750,000 Years, Well Constrained
- <750,000 Years, Moderately Constrained
- <750,000 Years, Inferred
- <2.6 Million Years, Well Constrained
- <2.6 Million Yeras, Moderately Constrained
- <2.6 Million Years, Inferred

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

1 inch = 2,000 feet

Base Map:
Aerial imagery provided by ArcGIS Basemaps.

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UGS Quaternary Faults Map

Plate 7

Legend

Approximate Site Boundary

Stream (National Hydrology Dataset)

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

1 inch = 1,000 feet

Base Map:
National Hydrology Dataset provided by the State of Utah AGRC. Aerial imagery provided by ArcGIS Basemaps.

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Drainage Map

Plate 8