GCS Geoscience

Report Professional Geologist Site
Reconnaissance and Review
Proposed Lift 5 and Snowmaking Expansion
Parcel #22-029-0010
Nordic Valley Ski Resort, 3567 Nordic Valley Way
Eden, Weber County, Utah

For:

Mountain Capital Partners
PO Box 17000
Durango, Colorado
81302

By:

GCS Geoscience
554 South 7700 East Street
Huntsville, Utah 84317

April 2, 2020
GCS File No: 2020.11

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Mountain Capital Partners
PO Box 17000
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ATTN: Gloryann Linch

Subject: **Report**
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INTRODUCTION

In response to your request, GCS Geoscience (GCS) has prepared this Professional Geologist site reconnaissance review for the above referenced improvements for the proposed expansion parcel at Nordic Valley Resort. The expansion parcel consists of a 346.78-acre property that is to become part of the existing Nordic Valley Resort in Weber County, Utah, as shown on attached Figure 1. Figure 2 provides aerial coverage of the site and detail of the current (2014) layout of the site vicinity.

The parcel is generally open and undeveloped ground at this time. The adjacent properties to the north have been developed for lift-served skiing, and comprise the current operating Nordic Valley Ski Resort. The subject parcel and surrounding properties are zoned by Weber County as Open Space Zone O-1, and Forest Valley FV-3 land-use zones. It is our understanding that the subject parcel is currently in review for Conditional Use permitting for this proposed use with Weber County.

It is our understanding that resort is proposing to increase skiable area by expanding snowmaking and its lift network onto the subject parcel. The proposed Lift 5 is an aerial lift that will span approximately 4000 feet as shown on Figure 2, and will lift skiers approximately 1375 feet in elevation. The proposed snowmaking will include approximately 28,000 lineal feet of supply line and cover roughly 50 acres of skiable terrain, as shown on Figure 2.

Because the proposed improvements appear to be located in part on a hillslope area in the vicinity of mapped landslide hazards, marginal soils, and/or FEMA floodplain areas, Weber County is requesting that a geological site reconnaissance be performed to assess whether all or parts of the site 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 this **Professional Geologist Site Reconnaissance Review** is to evaluate if the proposed improvements are outside or within areas identified as Natural Hazards Overlay District, 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 permitted for Conditional Use by Weber County. Because the proposed expansion, and expansion construction is likely to involve or overlap with geologically hazardous areas, and areas of slopes greater than 25-percent; the reporting and documentation to be provided by the studies herein will be used to guide Civil Engineering and Geotechnical engineering design for Hillside Review studies; as specified in Chapter 108-14 Hillside Development Review Procedures and Standards for hillside terrain and environmentally sensitive areas by the Weber County Code (2020).

LITERATURE AND RESOURCE REVIEW

To evaluate the potential exposure of sites to geological hazards that impact sites or site improvements, Weber County has compiled a series of Geographic Information Systems (GIS) data mapping layers of geological hazard related information. These data may be queried on-line using the Weber County Geo-Gizmo web server application at:

http://www.co.weber.ut.us/gis/maps/gizmo/.

Using the Geo-Gizmo application, under the Engineering Layers category, is listed geological hazard related layers that may be toggled on and off to determine potential hazards exposure to sites in the county. These mapping layers include the following categories; *Quake Epicenters, FEMA Flood Zone Line, FEMA Base Flood Elevation, Wasatch Faults, Landslide Scarps, Geologic Faults, Faults, Quaternary Faults, FEMA Flood Zone, FEMA LOMR, Engineering Problems; Liquefaction Potential, Landslide, FEMA Letters of Map Change, and FEMA Flood Zones.* These layers have been compiled from the respective agencies including the Federal Emergency Management Agency (FEMA), the Utah Geological Survey (UGS), and the U.S. Geological Survey (USGS). These mapping layers consist of regional compilation hazards data but are not compiled at scales that are necessarily applicable for site specific usage and planning. When hazard layer data on the Geo-Gizmo are found to interact with Permit Applicant site improvement locations, Weber County Engineers and Planners will request that the Permit Applicant have a Professional Geologist Site Reconnaissance Review, such as presented herein, conducted for the site.

In addition to the Geo-Gizmo site screening, the Weber County Engineers and Planners rely on recently published UGS geological mapping (Coogan and King, 2016), that includes much of Weber County for determining if a site is located upon a potentially hazardous geological mapping unit, thus requiring a geological reconnaissance. This mapping may be viewed on-line at:

> https://weber.maps.arcgis.com/apps/webappviewer/index.html?id=bd557ebafc0e4ed58471342bb03fdac5

Our preliminary review of the Geo-Gizmo web server indicated that the expansion parcel was partially overlapped with area classified as Landslide layer, however our review of the Weber County Geologic Map indicated that the property is located upon a geological mapping units designated as **Qms**, **Qms?(Zpu)**, and **Qms(ZYp)** which are mass movement deposits considered potentially hazardous because of indications of past landslide movement; and **Qafy** and **Qmdf** units which are younger alluvial fan and debris flow deposits that are considered potentially hazardous because of the potential for debris flow/debris flood processes on these areas, thus requiring this reconnaissance and review.

Our site specific review consisted of a GIS data integration effort that included:

1. Reviews of previous mapping and literature pertaining to site and regional geology including and Sorensen and Crittenden (1979), Mulvey (1992), USGS and UGS (2016), Elliott and Harty (2010), King and McDonald (2014), and Coogan and King (2016).

2. An analysis of vertical and stereoscopic aerial photography for the site including a 1947 1:20,000 stereoscopic sequence, 2012 5.0 inch digital HRO coverage, and 2014 1.0 meter digital NAIP coverage of the site.

3. A GIS analysis using the QGIS® GIS platform to geoprocess and analyze merged 2011 1.0 meter and 2018 0.5 meter LiDAR digital elevation data made available for the site by the Utah Automated Geographic Reference Center (AGRC). The GIS analysis included using the QGIS® platform Geospatial Data Abstraction

Library (GDAL, 2013) Contour; the GRASS® (Geographic Resources Analysis Support System, 2013) r.slope and r.shaded.relief modules.

For the best site-specific documentation for this review we relied on geologic mapping by Coogan and King (2016), which provided the most up-to-date rendering of geological mapping for the site location. Supporting documentation by King and McDonald (2014), and Sorensen and Crittenden (1979) was also used to support this review. The geological mapping for this review is provided on Figure 3, Geologic Mapping. Topographic, slope, and elevation data for this review was supported through the aforementioned LiDAR analysis which is presented on Figure 4, LiDAR Analysis.

REVIEW FINDINGS

The site is located in Ogden Valley on the eastern flank of Lewis Peak. The valley 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, 1995). Topographically the site is located on valley margin slopes positioned between Lewis Peak on the west and floodplains of the North Fork of the Ogden River on the east. The expansion parcel is located on gentle to steep valley margin slopes that buttress Lewis Peak which rises to 8031 feet, approximately 2.6 miles southwest of the site. The surface of the site is located upon a valley margin slopes formed on Precambrian and Paleozoic rocks that have been incised and eroded by past alluvial processes, that have oversteepened slopes insomuch as to cause mass movement of susceptible slopes. Two established drainages flow generally southwest to northeast across the parcel area, with Pole Canyon on the southern margin of the site, and Pine Creek located on the northern part of the site, as shown on Figure 2.

The expansion parcel is located upon generally northeastern sloping ground with elevations ranging from 5576 feet on the northeast side of the site, to 7126 feet on the southwest side of the site, as shown on Figure 4. Slope surfaces on the expansion parcel range from near-level to steep, in excess of 30 percent, across much of the site.

Geological Mapping:

Figure 3 shows the location of the site relative to GIS overlays including geological mapping drawn from Coogan and King (2016). A summary of the geological mapping of the site vicinity, as paraphrased from Coogan and King (2016), is provided as follows:

> **Qmdf -** Debris- and mud-flow deposits (Holocene and upper and middle? Pleistocene) – Very poorly sorted, clay- to boulder-sized material in unstratified deposits characterized by rubbly surface and debris-flow levees with channels, lobes, and mounding...

Qafy, Qaf, Qaf2 - Alluvial-fan deposits (Holocene and Pleistocene) – Mostly sand, silt, and gravel that is poorly bedded and poorly...variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads)...with unit Qafy being the younger, and Qaf2 the older, and Qaf fans being undivided in age determination...

Qac - Alluvium and colluvium (Holocene and Pleistocene) – Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits...

Qms - Landslide deposits (Holocene and upper and middle? Pleistocene) – Poorly sorted clay- to boulder sized material; includes slides, slumps, and locally flows and floods...

Qafb, Qafp - Lake Bonneville-age alluvial-fan deposits (upper Pleistocene) – ...**Qafb** and **Qafp** fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted...

Qms(Tn) – Qms?(Tn) - Block landslide and possible block landslide deposits (upper and middle? Pleistocene) – Mapped where nearly intact block composed of Norwood Formation (**Tn**) is visible in landslide…

Qms?(Zpu) - Block landslide and possible block landslide deposits (upper and middle? Pleistocene) – Jumbled mass of formation, Formation of Perry Canyon bedrock; Upper member (**Zpu**) with blocks...

Qms(ZYp) - Qms?(ZYp) - Block landslide and possible block landslide deposits (upper and middle? Pleistocene) – Jumbled mass of formation of Perry Canyon (**ZYp**) with blocks...

Tn - Norwood Formation (lower Oligocene and upper Eocene) – Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate...

Zpu - Formation of Perry Canyon bedrock; Upper member (Neoproterozoic) – Olive drab to gray, thin-bedded slate to argillite to phyllite to micaceous meta-siltstone to meta-graywacke to meta-sandstone in variable proportions such that unit looks like both the “greywacke-sandstone” and “mudstone”...This unit is prone to slope failures...

Zpd - Formation of Perry Canyon bedrock; Diamictite member (Neoproterozoic) – Tan to gray weathering, gray to dark-gray meta-diamictite containing pebble to boulder-sized quartzite and granitoid (quartzo-feldspathic gneiss) clasts in dark-gray sandy (up to granule size) to micaceous argillite matrix...

Zmcg - Maple Canyon Formation bedrock; Lower unit (green arkose) member (Neoproterozoic) – Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses...is prone to slope failures...

Zarx - Argillite of lower member of Maple Canyon Formation or upper member of Formation of Perry Canyon (Proterozoic) – Greenish-gray argillite to meta-graywacke…This unit is prone to slope failures...

In summary the surface of the site is located upon older Precambrian and Paleozoic rocks that were thrusted from west to east roughly 80 million of years ago as part of what is called the Willard Thrust (Sorensen and Crittenden, 1979). Approximately 20 to 30 million years ago the thrusted rocks were locally covered by Tertiary volcanic deposits locally known as the Norwood Formation. Since the deposition of the Norwood Formation, orogenic mountain building processes have been occurring, resulting in the erosion and deposition of Quaternary age deposits on the surface vicinity during the past 1.6 million years. Most recently, in the past 19,000 to 15,000 years, ancient Lake Bonneville inundated parts of Ogden Valley leaving lake bed soil deposits, and adjusting the grade of alluvial soil deposition in the valley during and after the period of lake inundation (Currey and Oviatt, 1985). Since the regression of the ancient lake, stream erosion and incision of the mountain slopes has oversteepened slopes resulting in the mass movement, landsliding, of susceptible slopes on and in the vicinity of the expansion parcel.

Site Specific Geology:

Figure 3 indicates the expansion parcel is located upon the following geological sequence of rocks and deposits:

1. Older thrust-faulted and folded Neoprotoerozic rock units of **Zarx**, **Zmcg?**, **Zmcc?**, **Zpd**, and **Zpu** of the Willard thrust sheet that appear to be inclined to the northeast.

2. Block landslide deposits of **Qms(ZYp), Qms?(ZYp**), and **Qms(Zpu)** of the formation of Perry Canyon rocks that overlie the Neoprotoerozic rocks. On the

basis of the morphostratigraphic position of bounding and overlying younger **Qac**, **Qmdf**, and **Qms** deposits, we believe the time of movement for the **Qms(ZYp), Qms?(ZYp)**, and **Qms(Zpu)** deposits at the site to be no more recent than upper Pleistocene age.

3. Covering in part the sloping areas over the older Neoprotoerozic rocks and the Block Landslide deposits, are Holocene to middle? Pleistocene age landslide slump and creep deposits classified as **Qms.** The **Qms** deposits are the most recently active mass movement features on the site.

4. On the southeast and east margins of the site along the Pole Canyon and Pine Creek drainageways, alluvial deposits of **Qafb**, **Qafy**, and **Qmdf** have been deposited, with the **Qafy** and **Qmdf** deposits comprising the most recently active deposits on the site.

Geologic Hazards

The identified geologic hazards mapping units for the expansion parcel area are presented on Figure 5, Geologic Hazards Overlay Map. The hazard areas identified through this reconnaissance study should generally be studied in greater detail relative to specific affects and effects of the proposed project improvements to better define hazard margins, probabilities, and exposure detail relative to the proposed improvements. The units are broken down in to three hazard classifications and the basis of processes and morphology. The hazard classifications on Figure 5 are as follows:

- Alluvial fan and debris flow process hazards, which include active stream-flow, and floodplain areas, and potential and past active debris flow areas on the site. These include areas mapped as **Qafy**, and **Qmdf** on Figure 3, and are believed to have been subject to these processes as recently as Holocene time, between 12,000 years before present (ybp) to the present.
- Mass movement, slump, soil creep hazards, these include shallow and rotational landslide units, and areas where slope creep processes are likely. These include areas mapped as **Qms** on Figure 3, that are believed to have moved as recently as Holocene time, between 12,000 ybp to the present.
- Mass movement, block failures, these include likely deeper-seated landslide features where large intact bedrock blocks and surfaces have moved or shifted. These include areas mapped as **Qms(ZYp), Qms?(ZYp)**, and **Qms(Zpu)** on Figure 3, that are believed to have moved no more recently as upper Pleistocene age or approximately 12,000 ybp.

Sloping Surfaces

Figure 4, LiDAR Analysis presents the results of our slope analysis geoprocessing efforts described previously. The scene shown on Figure 4 shows the terrain and the steeper slope areas of the site, including 25 to 30 percent slopes, and greater than 30 percent slopes. Figure 6, Steep Slope Overlay Map illustrates the areas on the expansion parcel in excess of 25-percent. The average slope for the expansion area is 47.6-percent, with roughly 90-percent of the 346-acre parcel having slopes exceeding 25-percent. The Weber County Chapter 108-14 Hillside Development Review Procedures And Standards Sec 108-14-3 Applicability, specifies *…all parcels, subdivision lots, roads and accesses, where the natural terrain has average slopes at or exceeding 25 percent shall be reviewed by the Hillside Development Review Board as part of an application request for land use and building permits…*(Weber County Code, 2020).

Hazards Review:

This review includes discussions of the natural hazards included in the Weber County Code, Section 108-22 Natural Hazard Areas, and the exposure of the proposed site improvements to the potential affects and effects of the natural hazards. A summary of this review is provided as follows:

1. **Landsliding:** The active landslide units were not identified on the expansion parcel as part of this review. However presently inactive mass movement, slump, soil creep hazards (**Qms**) deposits, and mass movement, block failures including **Qms(ZYp), Qms?(ZYp)**, and **Qms(Zpu)**, consist of slopes that have moved during the past. Because of the past movement, the soils and rock structures that comprise these units have been weakened by the past movement and deformation, the areas mapped as mass movement on Figure 5 should be considered susceptible to renewed movement, and site development grading, cuts and fills, and foundations placement should not be conducted in these areas without specific design-level geotechnical engineering and supervision.

2. **Alluvial fan debris flow processes** including flash flooding and debris flow hazard: The **Qafy** and **Qmdf** deposits on the represent areas of potential future debris flow process hazards on the site. With the present layout plan for site improvements, we do not believe the potential debris flow hazards are an impact to the proposed site improvements.

3. **Seismic Hazards: Surface fault rupture hazards, strong earthquake ground motion, tectonic subsidence and liquefaction potential:**

Surface fault rupture hazards: The nearest active (Holocene) earthquake fault to the site is the Weber section of the Wasatch fault zone (UT2351E) which is located 3.0 miles west of the site, thus fault rupture hazards are not considered present on the site (Black and others, 2004). The Ogden Valley southwestern margin faults (UT2375) is shown to cross the northeastern side of the site, however the most recent movement along this fault is estimated to be pre-Holocene (>15,000 ybp), and therefore is presently is not considered an active fault rupture risk (Black and others, 1999). Active earthquake faults are generally considered to be faults which have disrupted the ground surface within the past 11,000 years of earth history (the Holocene epoch). Implied with this definition is that such faults are likely to disrupt the ground surface in the relatively near future (Lund and others, 2016).

Strong earthquake ground motion originating from the Wasatch fault or other near-by seismic sources is capable of impacting the site and surrounding region. 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 (Peterson, and others, 2008) queried for the site, 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 0.18*g,* and for a two-percent probability of exceedance in 50 years is as high as 0.42*g* for the site.

The ten-percent probability of exceedance in 50 years event has a return period of 475 years, and the 0.18*g* 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 0.42*g* acceleration for this event corresponds "severe" perceived shaking with "moderate to heavy" potential damage based on instrument intensity correlations (Wald and others, 1999).

Future ground accelerations greater than these are possible but will have a lower probability of occurrence.

Tectonic Subsidence is surface tilting subsidence that occurs along the boundaries of active 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.

Liquefaction potential hazards: In conjunction with strong earthquake ground motion 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 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 or mapped for the Ogden Valley area, as has occurred in other parts of northern Utah (Anderson and others, 1994). Liquefaction commonly occurs in saturated non-cohesive soils such as alluvium, conditions may be present where the **Qafy** and **Qmdf** deposits are located on the site as shown on Figure 5, however none of the proposed improvements are located where the **Qafy** and **Qmdf** deposits are mapped.

4. **Rockfall and avalanche hazards**: The expansion parcel is not located upon or downslope from steep sloping areas with source outcrops where rockfall hazards may originate.

   No existing process indices or set-up conditions for snow avalanche development, including starting zones, tracks, or runout zones (Perla and Martinelli, 1976) were observed to affect the expansion parcel during our analysis or reconnaissance of the expansion parcel. Although the snow avalanche hazard may not be presently apparent on the expansion parcel, the future clearing of slopes for the proposed improvements may increase the exposure or incidence of snow avalanche hazard on the site.

5. **Flooding:** No significant water ways pass in the vicinity of the site and flood insurance rate mapping by Federal Emergency Management Agency for the site vicinity indicates that the site is outside the 100-year Flood Zone (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.

SITE RECONNAISSANCE

The expansion was reconnoitered by foot (snowshoes) on March 12, 2020, and at the time of the reconnaissance the area was covered with approximately three of more feet of snow. The expansion parcel was accessed from the west end of 1950 North Street, and by following an established trail the location of the upper terminal for the proposed Lift 5 was reached. From the upper terminal location, the Lift 5 alignment was generally followed downslope to the approximate lower terminal location, and from the lower terminal location, a traversing trail was followed back to the 1950 North Street end. The surface of the expansion parcel consists of a moderate to steep slope down to the northeast, with steeper side-slopes trending from the ridges down into Pine Canyon and Pole Creek drainageways. Cover vegetation protruding from the snow generally consisted of moderately dense scrub oak, and maple trees, with aspen and fir trees clustered on north facing slopes. During the reconnaissance no conditions of imminent or active geologic hazards or hazard processes were observed at the site.

CONCLUSIONS

It is our opinion that the proposed expansion parcel improvements can proceed in concept without adversely affecting the geological condition of the site, provided that the procedures outlined in Section 108-14 Weber County Hillside Development Review Procedures and Standards are appropriately followed and applied (Weber County, 2020), and the provisions of Utah State rules pertaining to ski lift construction safety prescribed by rule R920-50. Ropeway Operation Safety, which *…establishes regulations, requirements, and provides standards for the design, construction, and operation of a passenger ropeway*… are also followed (Utah Administrative Code, 2020).

Based on our understanding of the project and proposed improvements, the primary construction activities affecting the geological condition of the expansion parcel would include: 1) the construction of temporary and permanent construction access roadways (cuts, fills and grading) for the construction of the of the Lift 5 terminals and towers, and for the placement of the snowmaking water supply lines; 2) the construction of foundation systems for the Lift 5 terminals and towers; and 3) permanent cuts, fills and grading for ski trails and maintenance vehicles. Operational activities potentially affecting geological condition of the expansion parcel are anticipated to include augmented snowpack from the snowmaking activities, and potential failure of the snowmaking water supply lines, and the effects these activities may have on excessive soil moisture and susceptible slopes.

Based upon the findings of this review we believe for preliminary site development planning and design should undergo procedures outlined in Section 108-14 Weber County Hillside Development Review Procedures and Standards (Weber County, 2020). With respect to steep slope limitations, the excavation, grading and filling guidelines provided in Section 108-14-8 of the Weber County Code should be followed for site development planning and implementation. For preliminary site development guidance and planning, we recommend the following procedures be applied for site development based upon the areal classifications provided on Figure 5 and Figure 6:

1. **Steep Slope Overlay areas on Figure 6:** These areas should undergo the requirements of Section 108-14 - Hillside Development Review Procedures and Standards, with specific attention to excavation, grading and filling guidelines provided in Section 108-14-8. These standards should also be supported by site specific geotechnical engineering studies including slope stability analysis as outlined by Weber County Natural Hazards Overlay Districts - Section 104-27-2.

2. **Combined Mass Movement Hazards and Steep Slope Overlay areas on Figure 5 and Figure 6:** For areas that are shown on Figure 5 and Figure 6 to be exposed to both Mass Movement Hazards and Steep Slope conditions, we recommend that these areas be considered for avoidance where practical, however specific engineered design for the improvements in these areas, such as slope retention structures, and deep foundations, may be considered for mitigating the effects of the improvements and exposure to the natural hazards in these areas.

The Hillside Review and Natural Hazards Overlay studies will likely require additional specific geological, geotechnical and slope stability studies, and construction observations for proposed design and construction for the expansion parcel improvements and development.

LIMITATIONS

Our services were limited to the scope of work discussed in the introduction section of this report. The results provided by this study are limited to geological hazards included in the Weber County Code, Section 108-22 Natural Hazard Areas (Weber County, 2020). The reporting provided here is not based upon any subsurface observations, and should in no way preclude the results of a geotechnical engineering soils and groundwater studies for foundations, earthwork, and geoseismic design prepared by a professional engineer licensed in the State of Utah.

Although risk can never be eliminated, more detailed and extensive studies yield more information, which may help understand and manage the level of risk. The recommendations contained in this report are based on our site observations, available data, probabilities, and our understanding of the facilities investigated. This report was prepared in accordance with the generally accepted standard of practice at the time the report was written. No warranty, express or implied, is made.

This report may be used only by the client and only for the purposes stated within a reasonable time from its issuance. The regulatory requirements and the "state of practice" can and do change from time to time, and the conclusions presented herein may not remain current. Based on the intended use of the report, or future changes to design, GCS Geoscience may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else, unless specifically agreed to in advance by GCS Geoscience in writing will release GCS Geoscience from any liability resulting from the use of this report by any unauthorized party.

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CLOSING

We appreciate the opportunity to work with you on this project and look forward to assisting you in the future. If you have any questions or need additional information on this or other reporting, please contact the undersigned at (801) 745-0262 or (801) 458-0207.

Respectfully submitted,

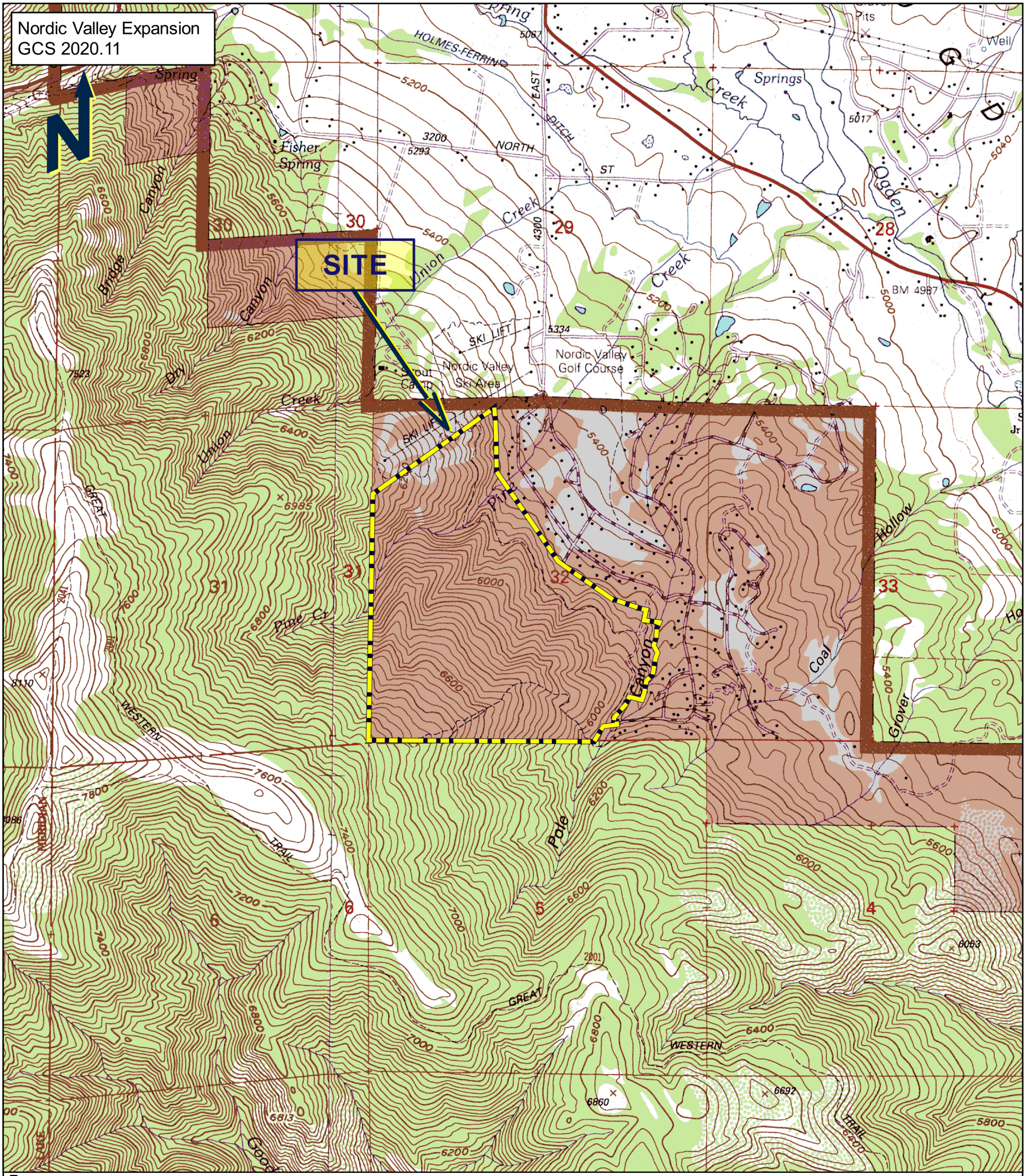
GCS Geoscience

LICENSED PROFESSIONAL GEOLOGIST
4/2/20
GREGORY C. SCHLENKER
5224720-2250
STATE OF UTAH

Gregory C. Schlenker, PhD, PG
State of Utah No. 5224720-2250
Principal Geologist

GCS Geoscience
554 South 7700 East Street
Huntsville, Utah 84317

Encl. Figure 1, Site Vicinity Map
Figure 2, Aerial Coverage
Figure 3, Geologic Mapping
Figure 4, LiDAR Analysis
Figure 5, Geologic Hazards Overlay Map
Figure 6, Steep Slope Overlay Map



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

0 2000 4000 ft

1:24,000

FIGURE 1
SITE VICINITY MAP

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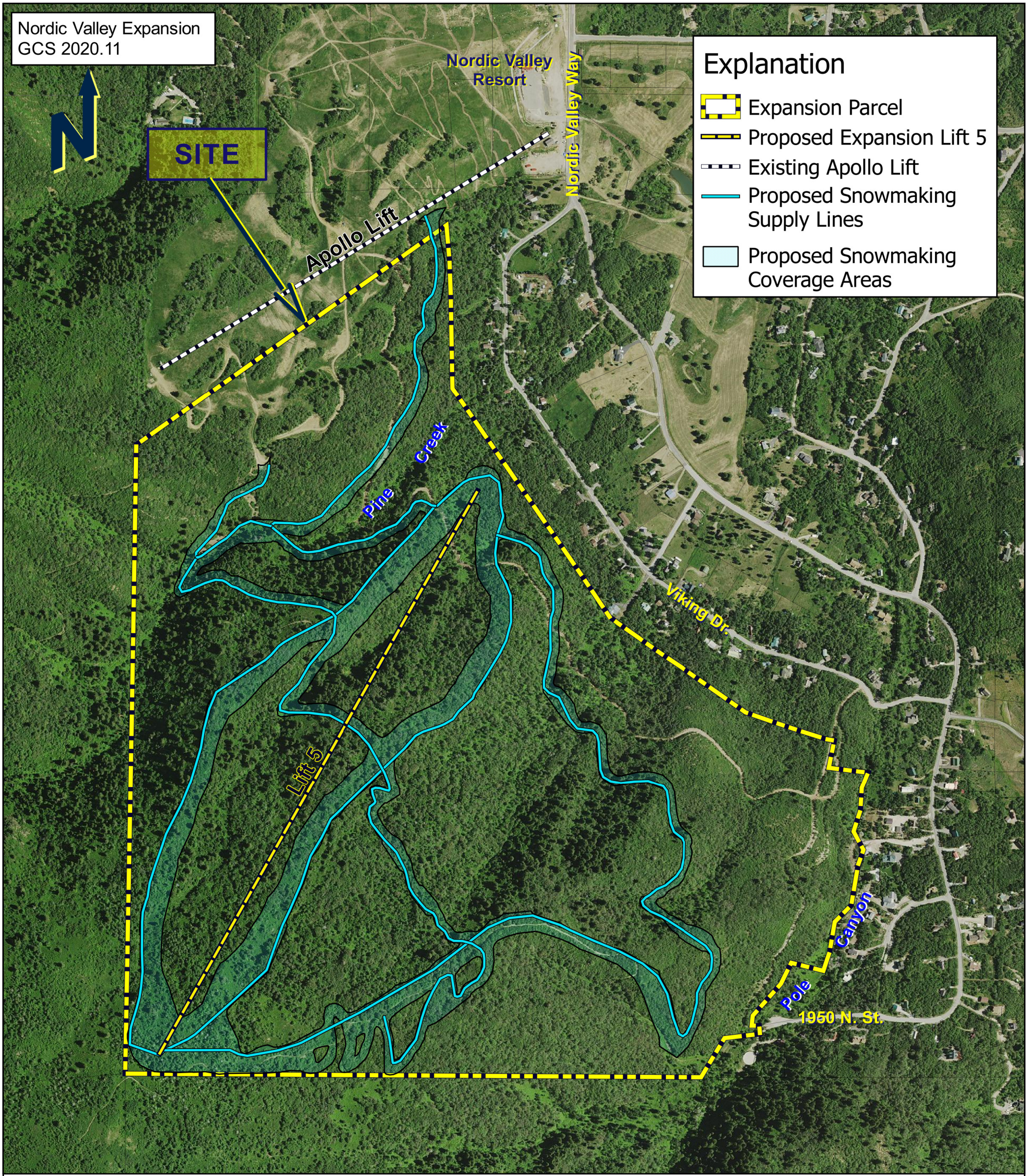

Base:
2014 1.0m NAIP Color Orthoimagery,
from Utah AGRC; http://gis.utah.gov/

0 800 1600 ft

1:9,400

FIGURE 2
AERIAL COVERAGE

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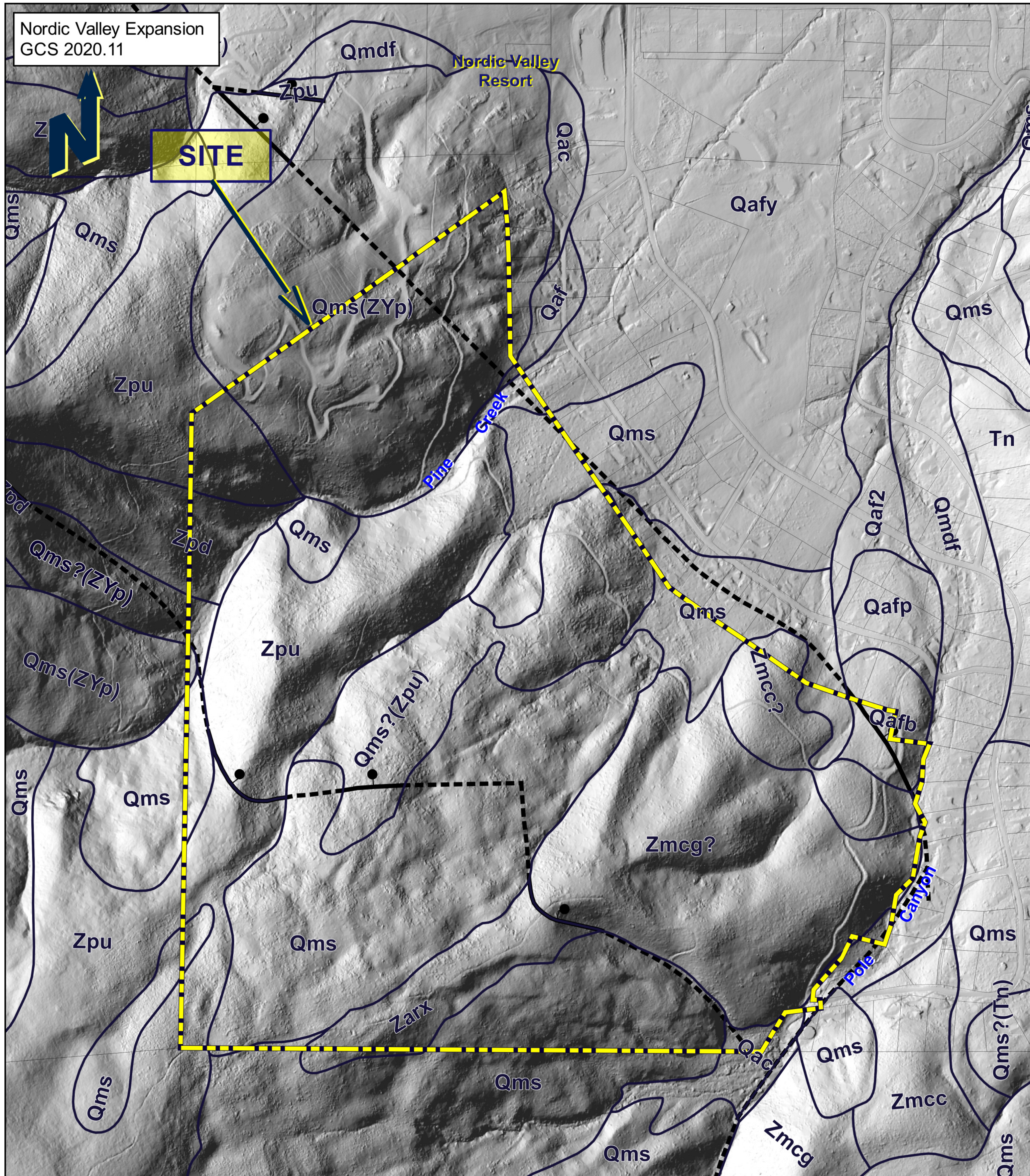

Base:
Merged 2018 0.5m (West side), and 2011 1.0m (East side) Bare Earth LiDAR Imagery from Utah AGRC; http://gis.utah.gov/

0 800 1600 ft

1:9,400

Geology (after Coogan and King, 2016)

Qmdf - Debris- and mud-flow deposits (Holocene and upper and middle? Pleistocene) – Very poorly sorted, clay- to boulder-sized material in unstratified deposits characterized by rubbly surface and debris-flow levees with channels, lobes, and mounding...

Qafy, Qaf, Qaf2 - Alluvial-fan deposits (Holocene and Pleistocene) – Mostly sand, silt, and gravel that is poorly bedded and poorly...variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads)...with unit Qafy being the younger, and Qaf2 the older, and Qaf fans being undivided in age determination...

Qac - Alluvium and colluvium (Holocene and Pleistocene) – Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits...

Qms - Landslide deposits (Holocene and upper and middle? Pleistocene) – Poorly sorted clay- to boulder sized material; includes slides, slumps, and locally flows and floods...

Qafb, Qafp - Lake Bonneville-age alluvial-fan deposits (upper Pleistocene) – ...Qafb and Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted...

Qms(Tn) – Qms?(Tn) Block landslide and possible block landslide deposits (Holocene and upper and middle? Pleistocene) – Mapped where nearly intact block composed of Norwood Formation (Tn) is visible in landslide…

Qms?(Zpu) - Block landslide and possible block landslide deposits (Holocene and upper and middle? Pleistocene) – Jumbled mass of formation Formation of Perry Canyon bedrock; Upper member (Zpu) with blocks...

Qms(ZYp), Qms?(ZYp) - Block landslide and possible block landslide deposits (Holocene and upper and middle? Pleistocene) – Jumbled mass of formation of Perry Canyon (ZYp) with blocks...

Tn - Norwood Formation (lower Oligocene and upper Eocene) – Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate...

Zpu - Formation of Perry Canyon bedrock; Upper member (Neoproterozoic) – Olive drab to gray, thin-bedded slate to argillite to phyllite to micaceous meta-siltstone to meta-graywacke to meta-sandstone in variable proportions such that unit looks like both the “greywacke-sandstone” and “mudstone”...This unit is prone to slope failures...

Zpd - Formation of Perry Canyon bedrock; Diamictite member (Neoproterozoic) – Tan to gray weathering, gray to dark-gray meta-diamictite containing pebble to boulder-sized quartzite and granitoid (quartzo-feldspathic gneiss) clasts in dark-gray sandy (up to granule size) to micaceous argillite matrix...

Zmcc? - Maple Canyon Formation, Upper (conglomerate) member (Neoproterozoic) – Light-gray coarse-grained, quartzite to pebble and small cobble meta-conglomerate with local tan-weathering, dark gray, meta-graywacke matrix; thin olive-gray, laminated, weakly resistant argillite in middle...

Zmcg? - Maple Canyon Formation bedrock; Lower unit (green arkose) member (Neoproterozoic) – Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses...is prone to slope failures...

Zarx - Argillite of lower member of Maple Canyon Formation or upper member of Formation of Perry Canyon (Proterozoic) – Greenish-gray argillite to meta-graywacke…This unit is prone to slope failures...

Normal Fault Bar on downthrown dashed where concealed

Strike and Dip Long bar represents strike axis, numerical value equals dip angle

FIGURE 3
GEOLOGIC MAPPING

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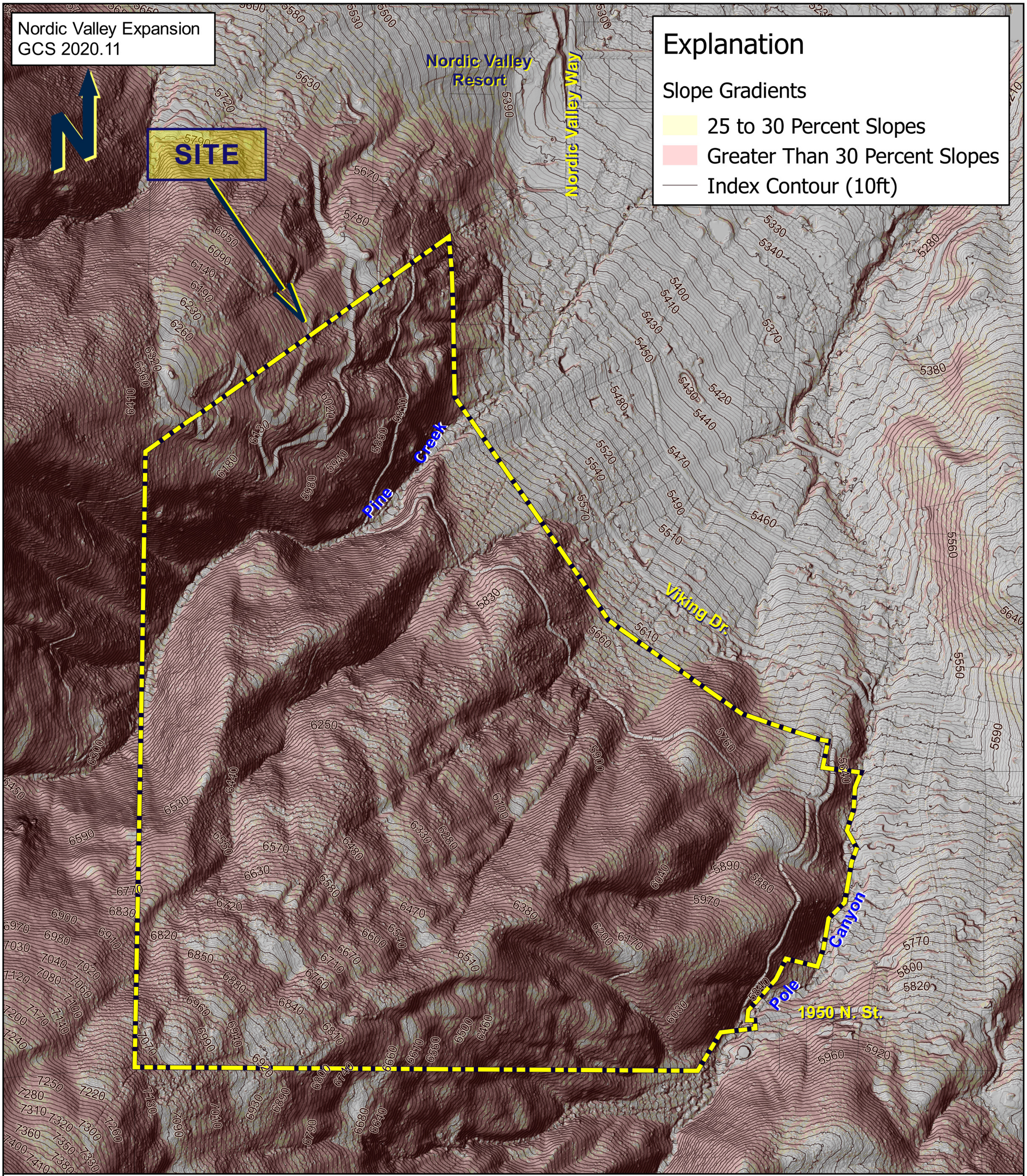

Base:
Merged 2018 0.5m (West side), and 2011 1.0m (East side) Bare Earth LiDAR Imagery from Utah AGRC; http://gis.utah.gov/

0 800 1600 ft

1:9,600

FIGURE 4
LiDAR ANALYSIS

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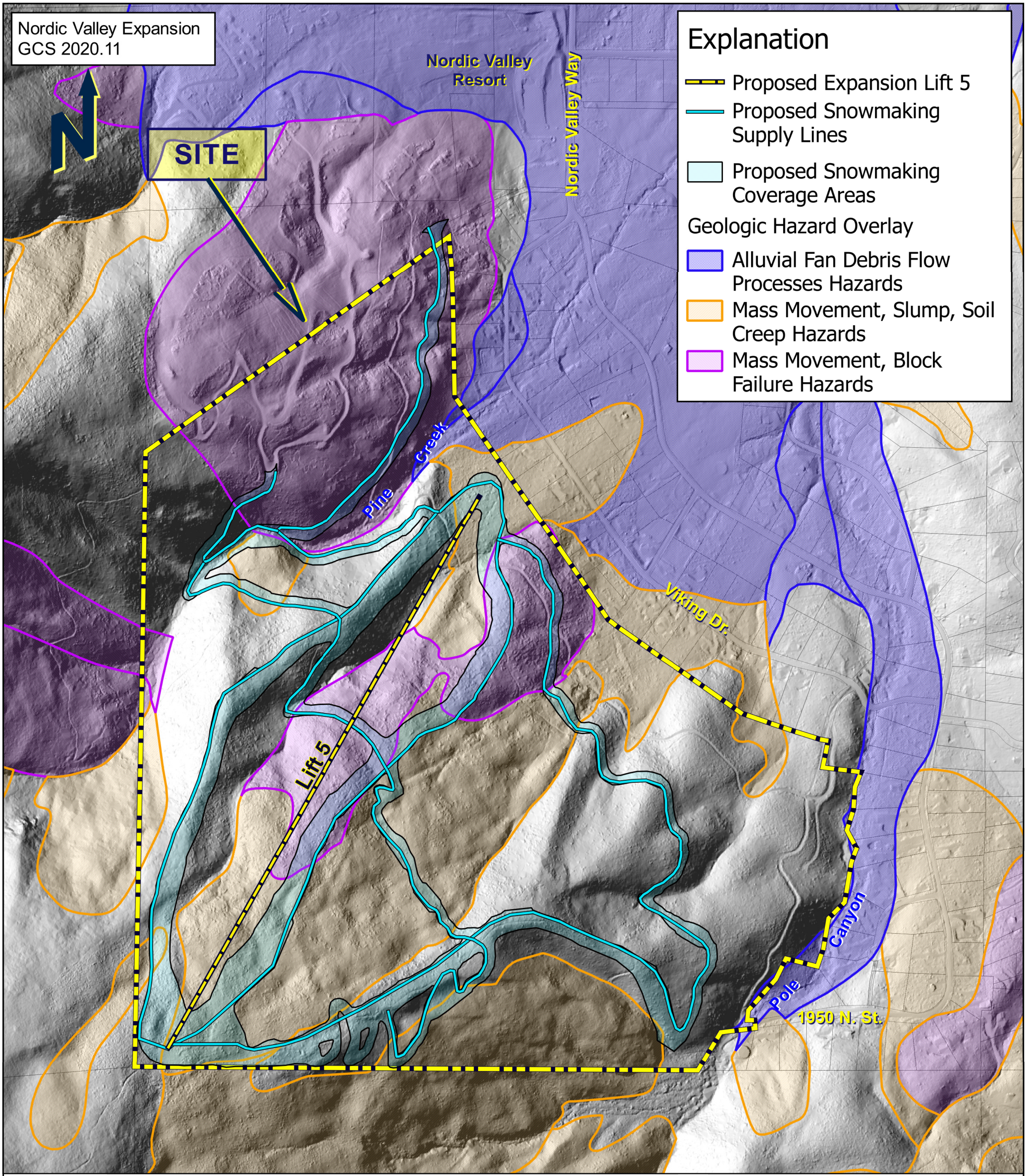

Base:
Merged 2018 0.5m (West side), and 2011 1.0m (East side) Bare Earth LiDAR Imagery from Utah AGRC; http://gis.utah.gov/

0 800 1600 ft

1:9,600

FIGURE 5
GEOLOGIC HAZARDS OVERLAY MAP

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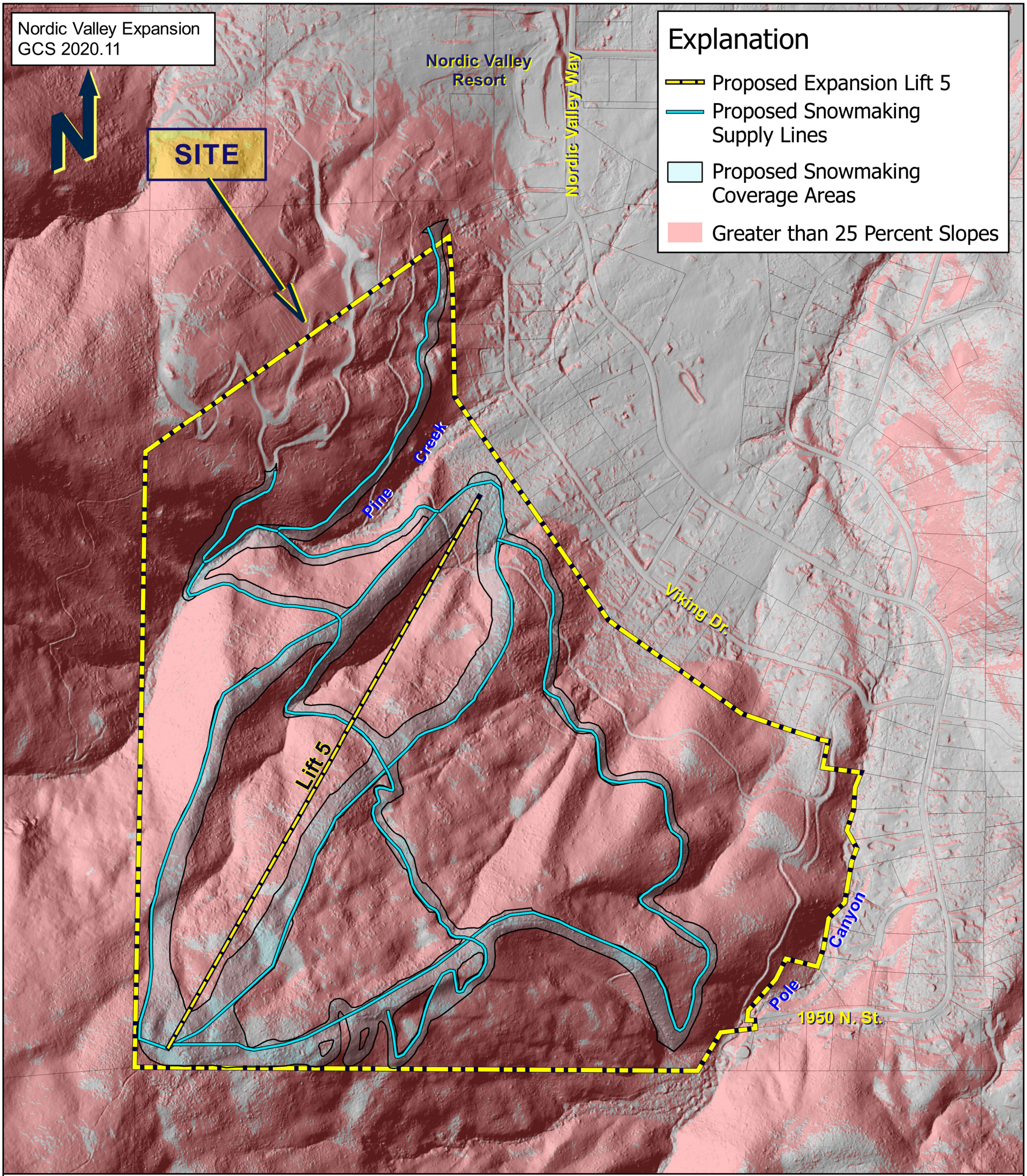

Base:
Merged 2018 0.5m (West side), and 2011 1.0m (East side) Bare Earth LiDAR Imagery from Utah AGRC; http://gis.utah.gov/

0 800 1600 ft

1:9,600

FIGURE 6
STEEP SLOPE OVERLAY MAP

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