REPORT

GEOLOGIC HAZARDS RECONNAISSANCE

SUMMIT MOUNTAIN HOLDING GROUP

POWDER MOUNTAIN RESORT PARCELS

WEBER AND CACHE COUNTIES, UTAH

Prepared for

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February 28, 2014

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SUBJECT: Geologic Hazards Reconnaissance
Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

Dear Mr. Everson:

This report presents results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for the Summit Mountain Holding Group parcels at Powder Mountain Resort in Weber and Cache Counties, Utah (Figures 1A-B – Project Location). The Project is located about 5.0 miles north of Huntsville, Utah and is in all or portions of Sections 1-3 and 10-12, Township 7 North, Range 1 East; Sections 4-9, 16, 17, and 18, Township 7 North, Range 2 East; Sections 35 and 36, Township 8 North, Range 1 East; and Sections 28-33, Township 8 North, Range 2 East. The Project encompasses a total area of about 15,350 acres and includes 31 parcels in Weber County and 21 parcels in Cache County, some of which are non-contiguous. Given the large Project size, Figures 1 through 3 each encompass two sheets dividing the Project into north and south halves.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret surficial geologic conditions at the Project and identify potential risk from geologic hazards. This investigation is intended to: (1) provide preliminary geologic information and assessment of geologic conditions; (2) identify potential geologic hazards that may be present and qualitatively assess their risks to the intended project; and (3) provide recommendations for additional site- and hazard-specific studies or mitigation measures as may be needed based on our findings. Given the large Project size and scale of the mapping included with this investigation, small variations in surficial conditions and geologic hazards risk may occur and should be expected.

This report is intended to be a reconnaissance-level tool to assist with Project planning, and reduce and minimize impacts from high-risk geologic hazards. The following services were performed in accordance with the above stated purpose and scope:

- Review of readily-available geologic maps, reports, and 2011 aerial photography; and

- Evaluation of available data and preparation of this report, which presents the results of our study.

The engineering geology section of this report was prepared in general accordance with the Guidelines for Preparing Engineering Geologic reports in Utah (Utah Section of the Association of Engineering Geologists, 1986). Western GeoLogic (2012) previously prepared a similar reconnaissance-level study for the proposed Area 1 development at Powder Mountain Resort, which encompasses a smaller area in the south half of the Project. We anticipate the Project area will have similar geologic hazards and risk, although both reports should be considered stand-alone documents.

HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the James Peak, Sharp Mountain, Huntsville, and Browns Hole Quadrangle show the Project straddles the Wolf Creek, Wellsville Creek, and Geertsen Canyon drainage basins, as well as numerous smaller subsidiary drainages of these basins. Wolf Creek and Geertsen Canyon Creek flow southward into Ogden Valley, whereas Wellsville Creek flows northward into Cache Valley. The Project generally straddles drainage head areas at the divide between Ogden and Cache Valleys, which is marked by the county line. Depth to groundwater at the site is unknown, but likely varies from near surface to substantially greater than 50 feet. Based on topography, we anticipate groundwater in the area flows multi-directionally through bedrock and unconsolidated colluvium toward the major drainages and then toward the valleys. Springs are shown in Sections 32 and 33, Township 8 North, Range 2 East (Figure 1A), and in Sections 4, 7, and 8, Township 7 North, Range 2 East (Figure 1B). Western Geologic (2012) observed one of these spring areas in parcel W18.

Groundwater depths in the Project area likely fluctuate seasonally from snowmelt, and also locally depending on bedrock flow patterns. Groundwater from snowmelt likely infiltrates through surficial colluvium, and then flows through bedrock fractures or on top of less-permeable bedrock layers. Fracture flow would likely be dominant in areas of Paleozoic sedimentary bedrock; whereas surface water at ridge tops underlain by Tertiary Wasatch Formation bedrock may perch and daylight where gently dipping bedrock layers meet steep slopes. We expect canyon bottoms and spring areas will likely have shallowest groundwater levels.

GEOLOGY

Structural Setting

The site is located at the divide between Ogden and Cache Valleys, which are to the south and north, respectively. Cache Valley is a major sediment-filled, north-south-trending intermontane valley flanked by the Bear River Range to the east and the Wellsville Mountains to the west. Ogden Valley is a roughly 40-square mile back valley within the Wasatch Range described by Gilbert (1928) as a structural trough similar to

Cache and Morgan Valleys to the north and south, respectively. Both valleys are in a transition zone between the Basin and Range and Middle Rocky Mountains provinces (Stokes, 1977, 1986). The Basin and Range is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is the prominent, west-facing escarpment along the Wasatch fault zone at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989).

Ogden and Cache Valleys are morphologically similar to valleys in the Basin and Range, but exhibit less structural relief (Sullivan and others 1988). Ogden Valley occupies a structural trough created by vertical displacement on normal faults bounding the east and west sides of the valley. The most recent movement on these faults is pre-Holocene (Sullivan and others, 1986). Cache Valley is a similar structural trough, and is bounded by the active West Cache fault zone at the base of the Malad Range and Wellsville Mountains on the west, and the East Cache fault zone at the base of the Bear River Range on the east. The most-recent, large-magnitude surface faulting earthquake on the West Cache fault zone occurred between 4,400 and 4,800 years ago (Black and others, 2000), whereas the most-recent event on the East Cache fault zone occurred about 4,000 years ago (McCalpin, 1994).

No active faults (those with evidence for Holocene activity) are mapped at the Project. However, the Project is situated near the central portion of the Intermountain Seismic Belt (ISB). The ISB is a north-south-trending zone of historical seismicity along the eastern margin of the Basin and Range province which extends for approximately 900 miles from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850, with the largest of these events the M_S 7.5 1959 Hebgen Lake, Montana earthquake. However, none of these events have occurred along the Wasatch fault zone or other known late Quaternary faults in the region (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events to the site was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake and south of the town of Snowville.

Surficial Geology

Geology of the Project area is shown on Figures 2A-B at a scale of 1:24,000 (1 inch equals 2,000 feet) based on mapping by Coogan and King (2001). Due to the scale of the mapping and size of the project area, Figure 2 covers two 11 inch x 17 inch sheets. UTM NAD83 coordinates for the Project corners are provided on Figure 2 to facilitate georeferencing. Figure 2 shows surficial geology of the Project area consists of various Paleozoic to Cambrian-age bedrock units (denoted by Z and C prefixes, respectively), Tertiary-age bedrock of the Wasatch Formation (unit Tw), and various Pleistocene- to

Holocene-age colluvial, landslide, and alluvial deposits. Coogan and King (2001) also map numerous bedrock faults in the Project area that are Cenozoic in age, including thrust faults of the Willard thrust.

Coogan and King (2001) describe geologic units at the site and in the vicinity (from youngest to oldest in age) as follows:

> **Qa1, Qa2, Qa[p], Qab, Qay, Qao – *Stream and fan alluvium.*** Sand, silt, clay, and gravel. Alluvium labeled Qa[p] and Qab are graded to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively. Near former Lake Bonneville, units labeled 1 and 2 are younger than Lake Bonneville; elsewhere relative-age numbers only apply to local drainages.
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> **Qal1, Qal2 – *Stream alluvium, Holocene***. Sand, silt, clay, and gravel in channels and floodplains; composition depends on source area; suffixes 1 and 2 indicate ages where they can be separated in the area of former Lake Bonneville, with 2 including low terraces.
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> **Qaf1, Qaf2, Qafy, Qafp, Qafb, Qaf3, Qafo – *Alluvial-fan deposits***. Mostly sand, silt, and gravel that is poorly bedded and poorly sorted. Fans labeled Qafp and Qafb are graded to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively; unit Qaf3 is used where these fans can't be separated. Near former Lake Bonneville, units with suffixes 1 and 2 are younger than Lake Bonneville and are shown as Qafy where they can't be separated; here, unit Qafo is older than Lake Bonneville. Elsewhere relative-age numbers and letters only apply to local drainages.
>
> **Qac – *Alluvium and colluvium***. Includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits.
>
> **Qc – *Colluvium***. Includes slopewash and soil creep; composition depends on local bedrock.
>
> **Qm, Qmo – *Mass-movement deposits, undivided.*** Includes slides, slumps, and flows, as well as colluvium, talus, and alluvial fans that are mostly debris flows; composition depends on local sources. Qmo locally used where younger mass-movements (including landslides and slumps) are mapped.
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> **Qms, Qms1, Qms2, Qms3, Qmsy, Qms4, Qmso – *Landslide and slump deposits*** *(locally, unit involved is shown in parentheses).* Poorly sorted clay to boulder-sized material; locally includes flow deposits. Near former Lake Bonneville units with relative-age number suffixes were: 1) emplaced in the last 80 to 100 years; 2) are post Lake Bonneville in age; 3) were emplaced during or shortly after Lake Bonneville regression; and 4) were emplaced before Lake Bonneville transgression; extensive deposits in Lake Bonneville sediments in North Ogden and Kaysville quadrangles include earthquake liquefaction features. Suffixes y (as well as 1&2) and o (as well as 3&4) indicate probable Holocene and Pleistocene ages, respectively.

Qmt – *Talus, and lesser colluvium.* Angular debris at the base of and on steep slopes. Includes rock glaciers that form lobate mounds in cirques in the Wasatch Range; probably inactive.

Qg, Qgw – *Glacial till and outwash.* Mostly Pinedale (~15,000 to 30,000 yrs old) but probably includes Little Ice Age (1500 to 1800 A.D.) and may include Bull Lake (~130,000 to 150,000 yrs old) deposits; locally includes rock glaciers. Unit Qgw is outwash and, possibly, alluvially reworked outwash that obscures older deposits and bedrock.

Tw – *Wasatch Formation (Eocene and uppermost Paleocene)*. Typically red sandstone, siltstone, mudstone, and conglomerate with minor gray limestone.

Ogc – *Garden City Formation (Ordovician).* Dark-gray to gray, thin- to medium-bedded, silty limestone; intraformational, flat-pebble conglomerate common in lower half; weathers light bluish-gray with yellow/tan-weathering, wavy, siltstone layers; forms resistant ridges; commonly structurally thickened on leading margin of thrust sheet; usually about 400 to 1,200 feet (120-365 m) thick, thins to south and missing over Tooele arch.

Cn – *Nounan Formation (Middle and Upper Cambrian)* -- Medium-gray, very thick- to thick-bedded dolostone; with subordinate dark-gray, medium- to thick-bedded dolostone that weathers very dark gray with medium-gray, crude laminae and mottling; about 500 to 1,150 feet (150-350 m) thick, thins to south and possibly to east.

Ꞓbo – *Bloomington Formation (Middle Cambrian).* Olive to tan shale and gray, nodular limestone; about 500 to 900 feet (150-275 m) thick; divided into members (descending), except in Mantua quadrangle:

> **Ꞓbc – *Calls Fort Shale Member.*** Olive-gray to tan-gray, thin bedded, micaceous shale and argillite with minor, thin-bedded, dark-gray, silty limestone; 75 to 125 feet (35 to 40 m) thick on leading edge of thrust sheet.
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> **Ꞓbm – *Middle limestone member.*** Dark gray, thick- to thin-bedded limestone with tan, yellow, and red-weathering, wavy, silt layers; contains subordinate olive-gray and tan-gray, thin-bedded, micaceous shale and argillite; thickens southward from 425 to 850 feet (130-260 m) on leading edge of thrust sheet.
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> **Ꞓbh – *Hodges Shale Member.*** Olive-gray to tan-gray, thin-bedded, micaceous shale and argillite and thin- to thick-bedded, dark-gray limestone with tan-, yellow-, and red-weathering, wavy, silt layers; thickens southward from 410 to 600 feet (125-180 m) along leading edge of thrust sheet.

Ꞓu – *Ute Formation (Middle Cambrian).* Gray to dark-gray, thin- to thick- bedded limestone with tan-, yellow-, and red-weathering, wavy, silt layers, and olive-gray to tan-gray, thin-bedded, micaceous shale and argillite; and minor, medium-bedded, gray to light-gray dolostone; estimate 450 to 800 feet (140-245 m) thick; may be thinner on leading edge of thrust sheet.

Ꞓgc – *Geertsen Canyon Quartzite (Middle and Lower Cambrian and possibly upper Proterozoic).* In west mostly buff quartzite, with some brown-weathering argillite locally and common at top; upper part (Ꞓgcu) 2,400 to 2,700 feet (730-825 m) thick; lower part (Ꞓgcl) mostly arkosic, 1,640 feet (500 m) thick; total about 4,200 feet (1,280 m) thick. Divided in east into different members.

> **Ꞓgu – *Upper member.*** Tan, white, and light-gray, medium- to coarse-grained, crossbedded, thick-bedded quartzite in upper part; becomes increasingly conglomeratic and arkosic in lower part; base of member is marked by a resistant, purple weathering, quartz-pebble conglomerate containing white and pink quartz and rare jasper clasts; about 3,200 feet (975 m) thick in Horse Ridge and Dairy Ridge quadrangles. This is likely the entire Geertsen Canyon with the Browns Hole absent and the base being the Mutual Formation.
>
> **Ꞓgl – *Lower member.*** White, fine- to coarse-grained, locally vitreous, thick-bedded quartzite in upper part; lower part contains interbeds of red and green argillite; up to 1,500 feet (460 m) thick, but base is truncated by Willard thrust in Horse Ridge and Dairy Ridge quadrangles. This is likely the Caddy Canyon Quartzite with the Inkom absent and grading, at the base, into the Kelley Canyon Formation.

Zb – *Browns Hole Formation (upper Proterozoic).* Upper part quartzite, 60 to 285 feet (20-85 m) thick; lower part metavolcanic rocks, 0 to 460 feet (0-140 m) thick.

Zm – *Mutual Formation (upper Proterozoic).* Purplish quartzite, locally arkosic; 435 to 2,600 feet (135-790 m) thick; thins to southeast and thinnest in Browns Hole.

Zcc – *Caddy Canyon Quartzite (upper Proterozoic).* Mostly vitreous, almost white quartzite; 1,000 to 2,500 feet (305-760 m) thick, thickest near Geertsen Canyon.

Zkc – *Kelley Canyon Formation (upper Proterozoic).* Argillite to phyllite, with rare metacarbonate; grades into overlying Caddy Canyon quartzite with increasing quartzite near Huntsville; only 600 feet (185 m) thick in Mantua quadrangle, where Papoose Creek takes up most of this interval, but 2,000 feet (610 m) thick near Huntsville.

Zmc, Zmcc, Zmcg – *Maple Canyon Formation (upper Proterozoic).* Upper (Zmcc): Quartzite to metaconglomerate at top and bottom with thin argillite in middle, 100 to 500 feet (30-150 m) thick; Lower (Zmcg): Green arkosic metasandstone with argillite partings and local quartzite, 500 to 1,000 feet (150-305 m) thick; 1,000 to 1,500 feet (305-460 m) total thickness.

Lake Bonneville and Glacial History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin is a regional, topographically closed basin comprised of several conjoined smaller basins created by crustal extension in the Basin and Range (Gwynn, 1980; Miller, 1990); the basin has been an area of internal drainage for much of the past 15 million years (Oviatt and others, 1992). Sediments from Lake Bonneville are not mapped in the Project area, but are found at lower elevations in Ogden and Cache Valleys.

Timing of events related to the transgression and regression of Lake Bonneville is indicated by calendar age estimates of significant radiocarbon dates in the Bonneville Basin (Donald Currey, University of Utah; written communication to the Utah Geological Survey, 1996; and verbal communication to the Utah Quaternary Fault Parameters Working Group, 2004). Approximately 32,500 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach, after about 18,000 years ago. The lake remained at this level until 16,500 years ago, when headward erosion of the Snake River-Bonneville basin drainage divide caused a catastrophic incision of the threshold and the lake level lowered by roughly 360 feet in fewer than two months (Jarrett and Malde, 1987; O’Conner, 1993). Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression between 12,800 and 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

Landsliding in the Project area possibly initiated in Pleistocene time following retreat of glacial ice in the region after the Pinedale glacial advance. The Pinedale glacial advance was the last major glaciation to appear in the Rocky Mountains in the United States. The Pinedale glacial advance lasted from approximately 30,000 to 10,000 years ago, was at its greatest extent between 23,500 and 21,000 years ago, and was composed of mountain glaciers that partly merged (to the east in Wyoming) into the Cordilleran Ice Sheet. Glaciers in Little Cottonwood and Bells Canyons advanced into eastern Salt Lake Valley from the Wasatch Range between 26,000 and 18,000 years ago (Personius and Scott, 1992). This is locally termed the Bells Canyon glacial advance, which is correlative to the Pinedale in Utah.

SITE CHARACTERIZATION

The Project area is in the Wasatch Range about 5.0 miles north of Huntsville and straddles the divide between Ogden and Cache Valleys to the south and north, respectively. The Project generally consists lightly to heavily forested slopes of various aspects. Wolf Creek heads in the northwest part of the Project and flows southward across parcels W1 and W7 (Figures 1A-B). South Fork Wolf Creek heads in the north-central part of the Project and flows southwestward across parcels W2, W3, W4, W1, W10, and W7 to its confluence with Wolf Creek south of the Project (Figures 1A-B). Geertsen Canyon Creek heads in the southeast of the Project and flows westward and southward across parcels W20 and W21 (Figure 1B). Wellsville Creek heads in the north-central part of the Project and flows northward across parcels C11, C17, C15, and C14 (Figure 1A).

Air Photo Observations

2011 aerial photography available from the U.S. Geological Survey was reviewed to obtain information about the geomorphology of the Project area. Figures 3A-B are annotated air photos for the Project at a scale of 1:24,000 (1 inch equals 2,000 feet), based on Western GeoLogic (2012), and prior mapping by Coogan and King (2001) and Elliot and Harty (2010). Due to the scale and size of the Project area, Figure 3 covers two 11 inch x 17 inch sheets (A-B). Figure 3 is at the same scale and registered to Figures 1 and 2.

Figure 3 shows several slope areas at the Project underlain by mixed slope colluvium and mass wasting deposits, including several Pleistocene- to Holocene-age landslides. These deposits are generally divided into three groups: (1) mixed mass-wasting deposits comprised of slope colluvium from surficial erosion, small shallow-seated slumps, and talus, which dominate most of the colluvial deposits in the area and likely thin near the ridge tops and thicken downslope into canyon bottoms; (2) older landslides of Pleistocene age with subdued morphology, likely eroded rotational and translational failures; and (3) younger landslides of Holocene to latest Pleistocene age with hummocky morphology generally comprised of shallow- and deep-seated slumps. The mass wasting deposits are generally found in slopes steeper than 5:1. Landslide deposits are found in parts of parcels C16, C20, C21, W2, W14, W15, W16, W18, W19, and W23. Based on the geologic mapping (Figures 2A-B), the landslides appear to be mainly sourced in Tertiary Wasatch Formation and Holocene to Pleistocene colluvium (units Tw and Qm).

No other geologic hazards are evident on the air photos.

GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the site for development. Table 1 below shows a summary of the geologic hazards reviewed at the site, as well as a relative (qualitative) assessment of risk to the Project for each hazard based on the discussions and evidence presented below. A “high” hazard rating (H) indicates a hazard that is present at the site (whether currently or in the geologic past), is likely to pose significant risk to the project, and/or may require further study or mitigation techniques. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk. Moderate-risk hazards may also require further studies or mitigation. A "low" hazard rating (L) indicates the hazard is not present, poses little or no risk, and/or is not likely to significantly impact the Project. Low-risk hazards typically require no additional studies or mitigation. We note that these hazard ratings represent a conservative assessment for the site.

Table 1. *Geologic hazards summary.*

Hazard	**H**	**M**	**L**	**…Hazard Rating**
Earthquake Ground Shaking	**X**			
Surface Fault Rupture			**X**	
Liquefaction and Lateral-spread Ground Failure			**X**	
Tectonic Deformation			**X**	
Seismic Seiche and Storm Surge			**X**	
Stream Flooding		**X**		
Shallow Groundwater		**X**		
Landslides and Slope Failures	**X**			
Debris Flows and Floods		**X**		
Rock Fall		**X**		
Radon		**X**		
Problem Soil		**X**		
Volcanic Eruption			**X**	

Earthquake Ground Shaking

Ground shaking refers to the ground surface acceleration caused by seismic waves generated during an earthquake. Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60 mile radius of the Project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. Nearest active fault to the site is the Weber section of the Wasatch fault zone about 7.0 miles to the west-southwest (Black and others, 2003).

The extent of property damage and loss of life due to ground shaking depends on factors such as: (1) proximity of the earthquake and strength of seismic waves at the surface (horizontal motions are the most damaging); (2) amplitude, duration, and frequency of ground motions; (3) nature of foundation materials; and (4) building design (Costa and Baker, 1981). Peak ground, 0.2 second spectral, and 1.0 second spectral accelerations (percent of gravity, %g) at the site with 10% and 2% probabilities of exceedance in 50 years are estimated in Frankel and others (2002) as follows:

41.368871° N, -111.777365° W	**10% PE in 50yr**	**2% PE in 50yr**
PGA	18.18	37.49
0.2 sec SA	43.84	91.53
1.0 sec SA	14.67	33.97

Given the above information, earthquake ground shaking is a high risk to the subject site. The hazard from earthquake ground shaking can be adequately mitigated by design and construction of homes in accordance with appropriate building codes. The Project geotechnical engineer, in conjunction with the developer, should confirm and evaluate the seismic ground-shaking hazard and provide appropriate seismic design parameters as needed.

Surface Fault Rupture

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

No active faults are mapped at the Project or evident on air photos. Nearest active fault to the site is the Weber section of the Wasatch fault zone about 8.5 miles to the southwest (Black and others, 2003). Given this, the existing risk from surface faulting in the Project area is low.

Liquefaction and Lateral-spread Ground Failure

Liquefaction occurs when saturated, loose, cohesionless, soils lose their support capabilities during a seismic event because of the development of excessive pore pressure. Earthquake-induced liquefaction can present a significant risk to structures from bearing-capacity failures to structural footings and foundations, and can damage structures and roadway embankments by triggering lateral spread landslides. Earthquakes of Richter magnitude 5 are generally regarded as the lower threshold for liquefaction. Liquefaction potential at the site is a combination of expected seismic (earthquake ground shaking) accelerations, groundwater conditions, and presence of susceptible soils.

No sandy soils possibly susceptible to liquefaction are likely present in the Project area given the mapped colluvial veneers and bedrock. Given the above, we rate the hazard from liquefaction as low.

Tectonic Deformation

Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). No active faults are mapped in the Project area, and therefore the risk from tectonic deformation is low.

Seismic Seiche and Storm Surge

Earthquake-induced seiche presents a risk to structures within the wave-oscillation zone along the edges of large bodies of water, such as the Great Salt Lake or similar large lakes or reservoirs. No large bodies of water are in the Project area. Given the above, the risk to the project from seismic seiches is rated as low.

Stream Flooding

Stream flooding may be caused by direct precipitation, melting snow, or a combination of both. In much of Utah, floods are most common in April through June during spring snowmelt. High flows may be sustained from a few days to several weeks, and the potential for flooding depends on a variety of factors such as surface hydrology, site grading and drainage, and runoff.

The Project straddles the Wolf Creek, Wellsville Creek, and Geertsen Canyon drainage basins, as well as numerous smaller subsidiary drainages of these basins. Wolf Creek heads in the northwest part of the Project and flows southward across parcels W1 and W7 (Figures 1A-B). South Fork Wolf Creek heads in the north-central part of the Project and flows southwestward across parcels W2, W3, W4, W1, W10, and W7 to its confluence with Wolf Creek south of the Project (Figures 1A-B). Geertsen Canyon Creek heads in the southeast of the Project and flows westward and southward across parcels W20 and W21 (Figure 1B). Wellsville Creek heads in the north-central part of the Project and flows northward across parcels C11, C17, C15, and C14 (Figure 1A). Canyon bottom areas within 50 feet of active and ephemeral drainages may have a high risk from seasonal stream flooding, but represent very limited portions of the Project. Given the above, we rate the risk from stream flooding as moderate. Site hydrology and runoff should be addressed in the civil engineering design for the development.

Shallow Groundwater

Groundwater in the Project area is likely locally and seasonally variable. Areas in and adjacent to canyon bottoms and spring areas will likely have shallowest groundwater levels, but represent very limited portions of the Project. Groundwater elsewhere may be at substantial depth. Given the above, we rate the risk from shallow groundwater as moderate. However, we do not anticipate that shallow groundwater will pose a significant constraint to the Project. Evaluation of and recommendations regarding shallow groundwater should be provided in the Project geotechnical engineering evaluation.

Landslides and Slope Failures

Slope stability hazards such as landslides, slumps, and other mass movements can develop along moderate to steep slopes where a slope has been disturbed, the head of a slope loaded, or where increased groundwater pore pressures result in driving forces within the slope exceeding restraining forces. Slopes exhibiting prior failures, and also deposits from large landslides, are particularly vulnerable to instability and reactivation.

Substantial portions of the Project have slopes underlain by mixed slope colluvium and mass wasting deposits comprised of slope colluvium from surficial erosion, small shallow-seated slumps, and talus, which dominate most of the colluvial deposits in the area and likely thin near the ridge tops and thicken downslope into canyon bottoms; older landslides of Pleistocene age with subdued morphology, likely eroded rotational and translational failures; and younger landslides of Holocene to latest Pleistocene age with hummocky morphology generally comprised of shallow- and deep-seated slumps. Landslides are found in parts of parcels C16, C20, C21, W2, W14, W15, W16, W18, W19, and W23, whereas mass wasting deposits appear common throughout the eastern half of the Project in slope areas with gradients steeper than 5:1. Landsliding in the area has likely been ongoing since Pleistocene time, possibly following the Pinedale (Bells Canyon) glacial advance. A combination of clayey surficial colluvium, weathered Wasatch Formation bedrock, unstable landslide deposits, and/or perched groundwater appears to be the likely cause for the failures. Landslides in the Project area may be slow-moving, creeping failures.

All the above evidence suggests portions of the Project have slopes with marginal stability and a high risk from landslides. Given the large areas involved, we rate the risk from landsliding to the Project as high. Landslide risk can be minimized by avoiding mapped landslides and steep slopes in the Project area, particularly at a planning level. Mapped colluvial and landslide areas in the Project area appear to be in slopes steeper than 20%. We therefore recommend that stability of slopes be evaluated in a site-specific geotechnical engineering evaluation prior to construction for any development in slope areas exceeding 20% (5:1) steepness. Recommendations for reducing the risk from landsliding should be provided if factors of safety are determined to be unsuitable. Groundwater is a significant contributor to slope instability, and stability evaluations should conservatively assume near-surface conditions. Care should also be taken that site grading does not destabilize slopes in the project area without prior geotechnical analysis and grading plans, and that proper drainage is maintained.

Development of steeper slope areas, and some areas in mapped landslides adjacent to ridge crests, may be feasible if shallow bedrock can be encountered and proved stable in the geotechnical evaluation. This would likely require drilling, and may also require expensive structural mitigation techniques to reduce risk from slope instability (such a drilled piers), as deemed necessary by the Project geotechnical engineer. If drilling is conducted, the borings should be carefully logged to note discontinuities such as clay gouge zones or abrupt lithologic changes that may indicate weak bedrock zones.

Debris Flows

A debris flow is a fast moving, liquefied landslide of unconsolidated, saturated debris that can carry material ranging in size from clay to boulders, and may entrain a large amount of woody debris. Debris flows typically form when unconsolidated sediments become saturated and unstable on a steep slope or mountain stream channel, accelerate downhill by gravity, and entrain further debris as they scour steep mountain channels. Debris from a flow is deposited when velocities fall, such as in channel margins, pulse surges, and gentler slope areas below a critical threshold. Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front in Utah.

No evidence of debris-flow features such as channels or levees, or debris flow deposits, was observed on air photos or is mapped at the Project. However, the Project is in an area where debris flows may initiate. Deposition from such a flow would be in canyon bottom areas that have less than about a 15% gradient. These areas do not appear common at the Project, suggesting the risk is low. However, we rate the risk from debris flows as moderate given that risk may be higher in some canyon bottom deposition areas.

Rock Fall

Cliff areas possibly posing a risk from rock falls are found mainly in the western half of the Project. Figure 3A shows talus deposits in parcels C9, C14, and C15, and it is likely that smaller talus chutes also exist below bedrock source areas, such as in parcels W18 and 23 (Western GeoLogic, 2012). These areas would have a high risk from rock falls, as well as canyon bottom areas below steep slopes. Given the above, we rate the risk from rock falls as moderate.

Radon

Radon comes from the natural (radioactive) breakdown of uranium in soil, rock, and water and can seep into homes through cracks in floor slabs or other openings. The Project is located in an area of “Moderate” radon-hazard potential (Black, 1993). A moderate potential indicates that indoor radon concentrations would likely be between 2 and 4 picocuries per liter of air. However, actual indoor radon levels can be affected by non-geologic factors such as building construction, maintenance, and weather. Indoor testing following construction is the best method to characterize the radon hazard and determine if mitigation measures are required.

Swelling and Collapsible (Problem) Soils

Surficial soils that contain certain clays can swell or collapse when wet. Given the geologic mapping (Figures 2A-B), soils susceptible to swelling or collapse may be present. We anticipate that most bedrock areas will have only a shallow veneer of surficial soil, however colluvial and landslide areas may have deeper, possibly clay-rich soils. We therefore rate the risk from swelling and collapsible soils as moderate. A geotechnical engineering evaluation should be performed prior to construction to address soil conditions and provide specific recommendations for site grading, subgrade preparation, and structural and footing design.

Volcanic Eruption

No active volcanoes, vents, or fissures are mapped in the region. Based on this, no volcanic hazard likely exists in the Project area and the risk to the project is low.

CONCLUSIONS AND RECOMMENDATIONS

Geologic hazards posing a high risk to the Project are earthquake ground shaking and landslides. Moderate risk hazards include stream flooding, shallow ground water, debris flows, rock falls, radon, and problem soils. Except for earthquake ground shaking, not all hazards are present in every area of the Project. The risk may vary, as discussed above.

The following recommendations are provided:

- ***Seismic Design*** - The structures should be designed and constructed to current seismic standards to reduce the potential ground-shaking hazard.

- ***Geotechnical Investigation -*** A design-level geotechnical engineering study should be conducted prior to design and construction to: (1) address soil conditions at the Project for use in footing design, site grading, and drainage; (2) provide recommendations to reduce risk from seismic acceleration; and (3) evaluate and address potential shallow groundwater issues as warranted. Landslide risk can be minimized by avoiding mapped landslides and steep slope areas at the Project. We recommend structures be placed outside of mapped landslides, though these areas may be developable if future studies can demonstrate that bedrock is shallow and slopes are stable under static and dynamic conditions. We recommend that a slope stability evaluation be performed for any development on slopes steeper than 20%, including providing recommendations for reducing the risk from landsliding if static or dynamic factors of safety are unsuitable. Groundwater should conservatively be assumed to be at near-surface levels to represent seasonal alpine conditions.

- ***Other Investigations*** – Risk from stream flooding should be addressed in the civil engineering design for the Project for development in canyon bottom areas, in accordance with all applicable local government development guidelines. Risk from rock falls can be minimized by avoiding placing structures below steep slopes with bedrock outcrops, and in talus or runout zones. Risk from radon can be determined by indoor testing following construction.

- ***Availability of Report -*** The report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. This report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of Western Geologic and should not be copied, used, or modified without express permission of the authors.

LIMITATIONS

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western GeoLogic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western GeoLogic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western GeoLogic.

In expressing the opinions stated in this report, Western GeoLogic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western GeoLogic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

It has been a pleasure working with you on this project. Should you have any questions, please call.

Sincerely,
Western GeoLogic, LLC

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Craig V Nelson

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ATTACHMENTS

Figures 1A-B. Location Map, North and South Halves (11”x17”)
Figures 2A-B. Geologic Map, North and South Halves (11”x17”)
Figures 3A-B. Air Photo, North and South Halves (11”x17”)

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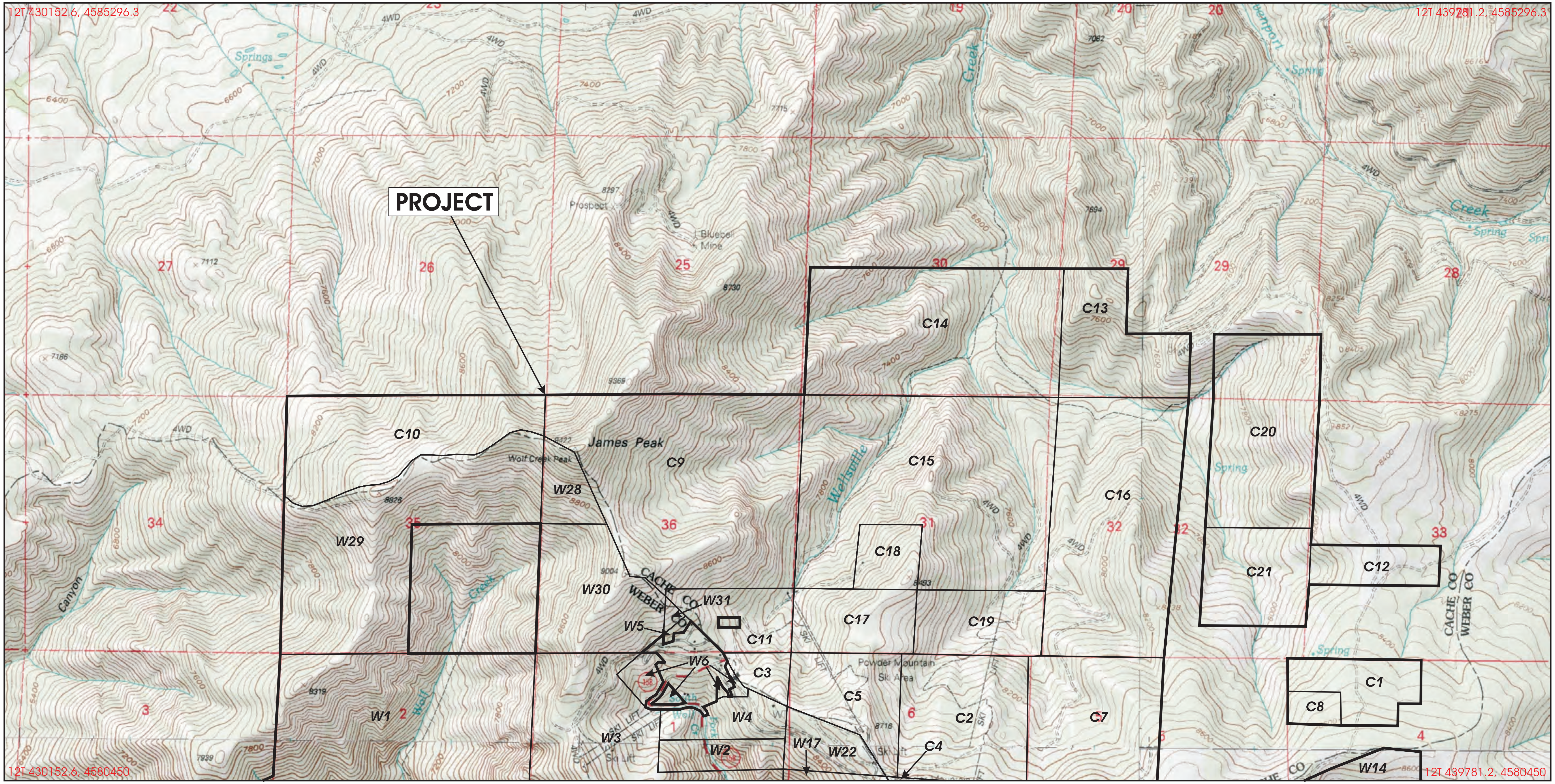

Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - James Peak, Sharp Mountain, Huntsville, and Browns Hole; 1998.

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(1 inch = 2000 feet)

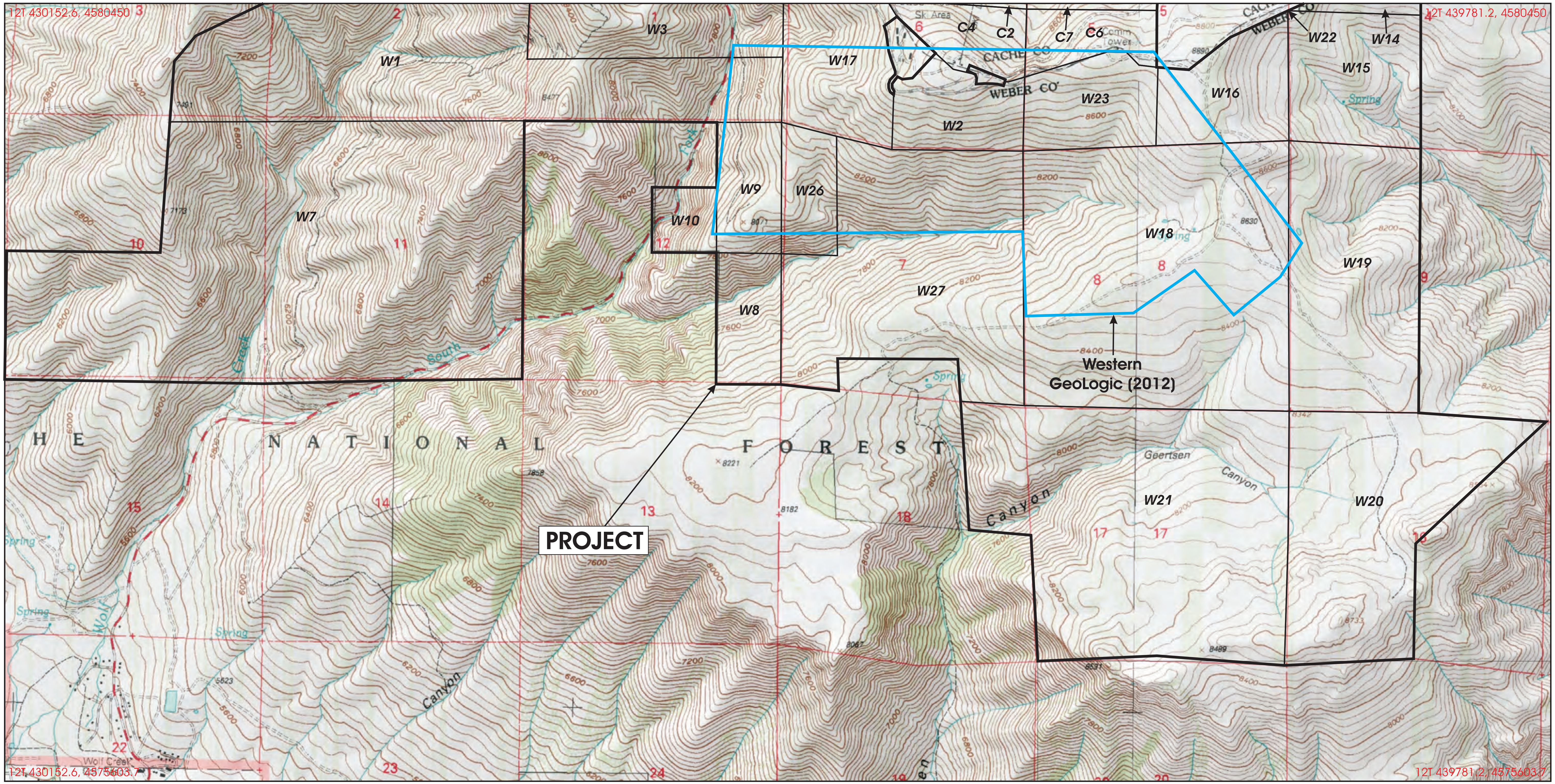
WESTERN
GEOLOGIC

LOCATION MAP, NORTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE

Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 1A



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Huntsville, and Browns Hole; 1998.

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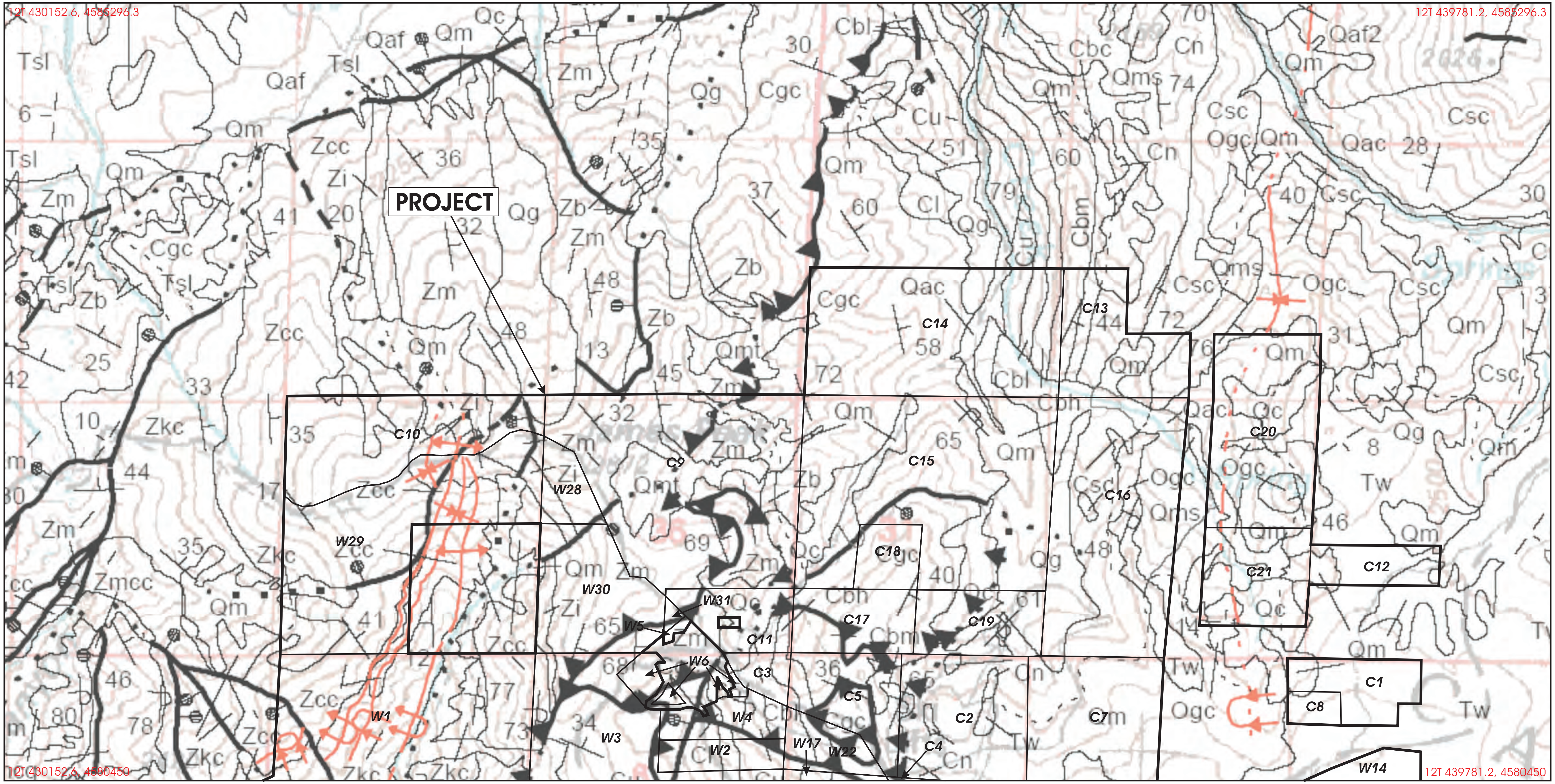
(1 inch = 2000 feet)

LOCATION MAP, SOUTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE
Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 1B



Source: Coogan and King, 2001; original map scale 1:100,000. See text for description of nearby surficial geologic units.

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(1 inch = 2000 feet)

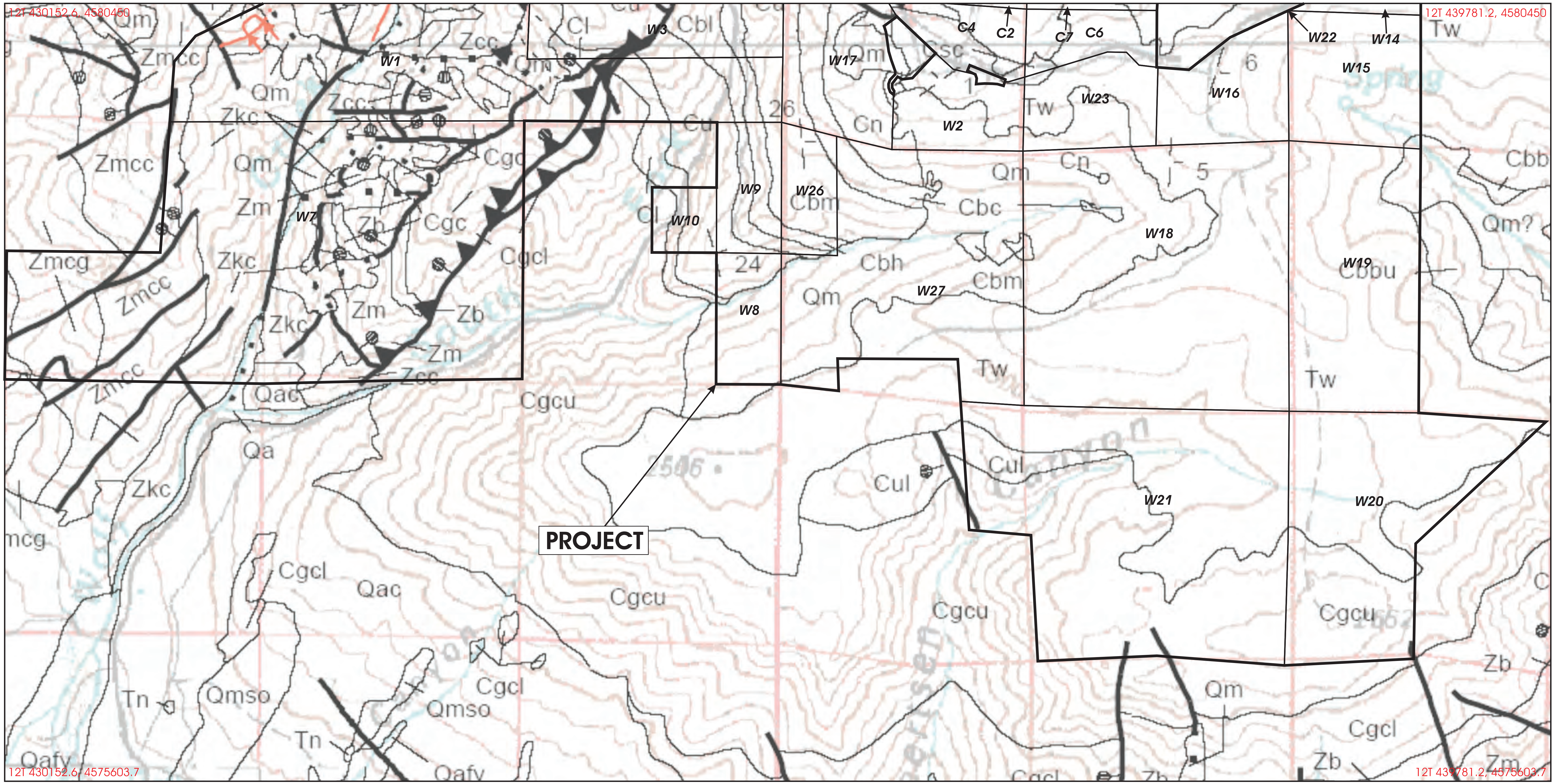
WESTERN
GEOLOGIC

GEOLOGIC MAP, NORTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE

Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 2A



Source: Coogan and King, 2001; original map scale 1:100,000. See text for description of nearby surficial geologic units.

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(1 inch = 2000 feet)

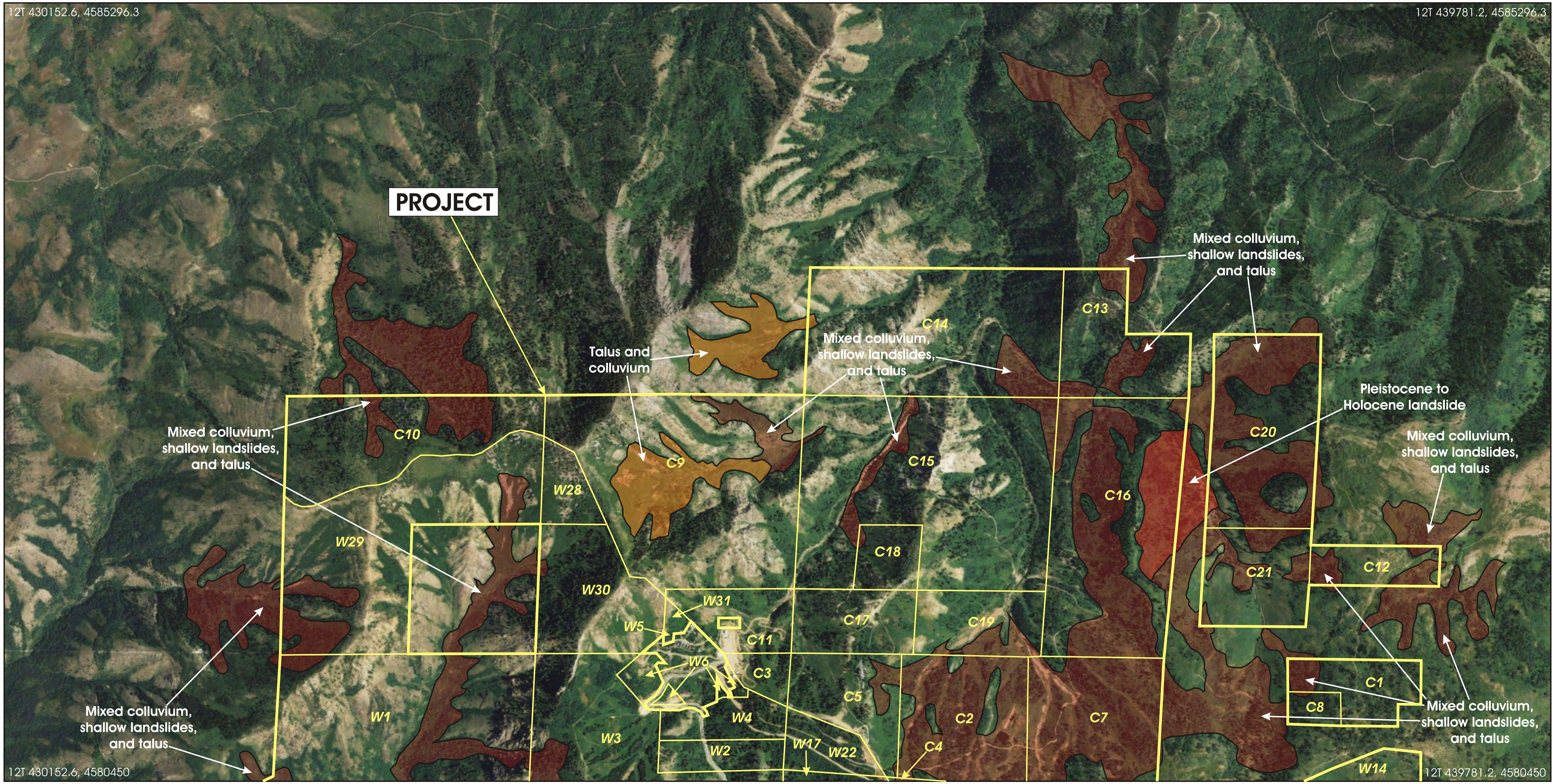
WESTERN
GEOLOGIC

GEOLOGIC MAP, SOUTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE

Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 2B



Source: Air photo from U.S. Geological Survey, 2011; landslide mapping modified from Coogan and King (2001) and Elliott and Harty (2010).

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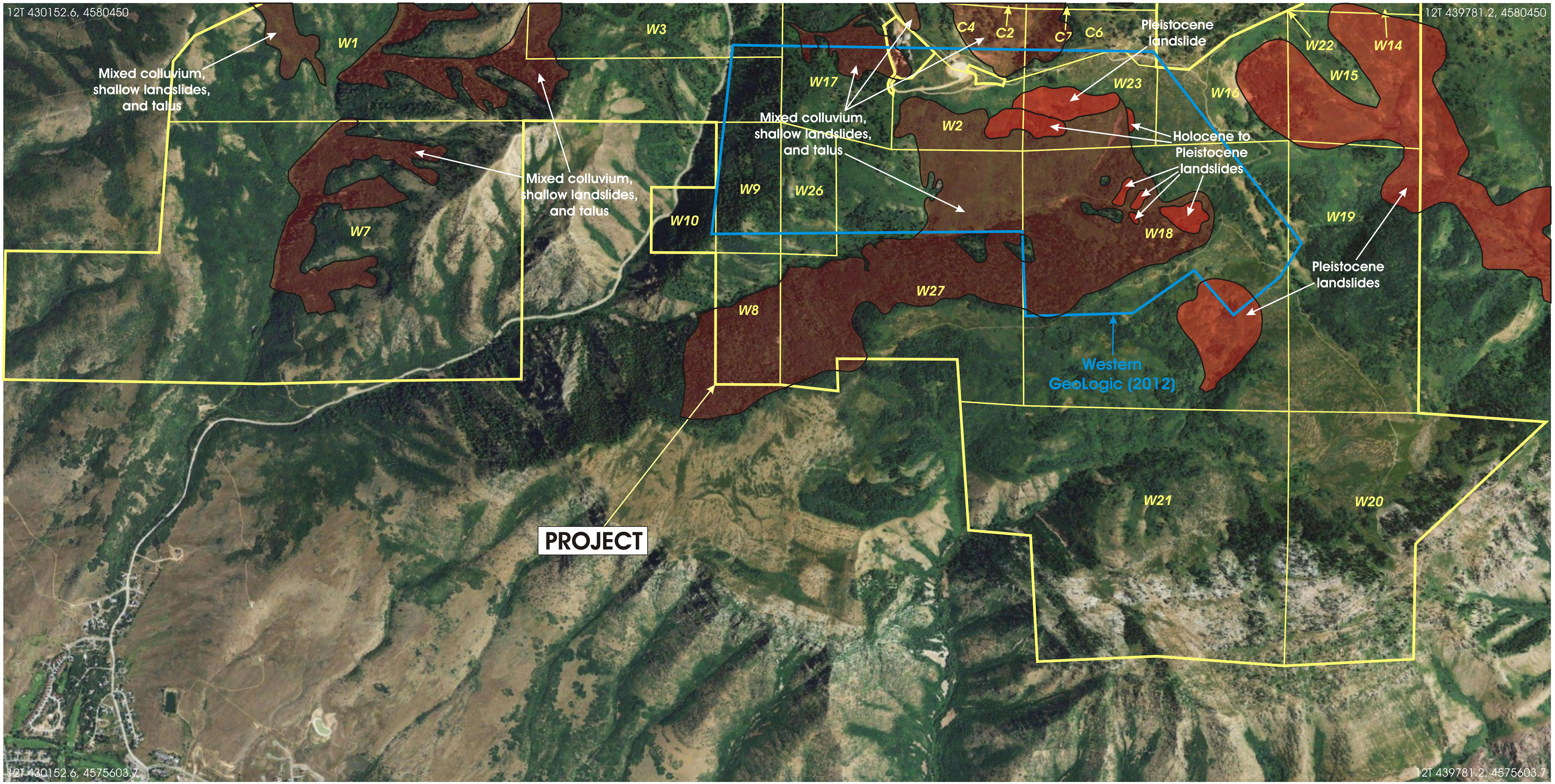
Scale 1:24,000
(1 inch = 2000 feet)

AIR PHOTO, NORTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE

Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 3A



Source: Air photo from U.S. Geological Survey, 2011; landslide mapping modified from Coogan and King (2001) and Elliott and Harty (2010).

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(1 inch = 2000 feet)

AIR PHOTO, SOUTH HALF

GEOLOGIC HAZARDS RECONNAISSANCE

Summit Mountain Holding Group
Powder Mountain Resort Parcels
Weber and Cache Counties, Utah

FIGURE 3B