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GEOTECHNICAL STUDY
POWDER 11 DEVELOPMENT
POWDER MOUNTAIN RESORT
EDEN, UTAH

Earthtec
Testing and Engineering, P.C.

PREPARED FOR:
GARDNER ENGINEERING
5875 S. ADAMS AVE. PARKWAY, SUITE 200
OGDEN, UT 84405

ETE JOB NO.: 04E-082

MAY 10, 2004

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Geotechnical Study
Powder 11 Development
Powder Mountain Resort
Eden, Utah
ETE Job No. 04E-082
May 11, 2004

1.0 INTRODUCTION

We understand that a residential development is planned for an approximate 9 acre parcel of land located on the north side of Powder Mountain Road, at the Powder Mountain Resort in Eden, Utah. The location is shown on the Vicinity Map, Figure 1.

This study was made to assist in evaluating the subsurface conditions and engineering characteristics of the foundation soils and in developing our opinions and recommendations concerning appropriate foundation types, floor slabs and pavement. This report presents the results of our geotechnical investigation including field exploration, laboratory testing, engineering analysis, and our opinions and recommendations. Data gathered are shown on Figures 2 through 5.

2.0 CONCLUSIONS

1. Based on the two test pits excavated for this investigation, native soils at this site consist of 1 to 2 ½ feet of organic topsoil underlain by dense to very dense clayey gravel with cobbles and boulders (GC) extending beyond the maximum depth explored of 8.5 feet. Perched groundwater was found in the test pits at depths of 3 to 3 ½ feet at the time of the excavations.

2. Lightly loaded spread footings founded on undisturbed native soils should provide adequate support for the proposed structures. A maximum allowable bearing capacity of 2000 psf should be used for footing designs.

3. Permanent cut and fill slopes should be graded no steeper than a 2 to 1 (horizontal to vertical) unless an engineered retainage system is used.

4. Footings should be placed at least 15 feet (measured horizontally) from the face of the slope.

3.0 PROPOSED CONSTRUCTION

We understand that the planned development will consist of 14 residential lots. The buildings will be wood frame structures possibly with basements. For design purposes, it was assumed that wall loads of the residential structures would be on the order of 2 to 3 klf. An asphalt access road and appurtenant concrete flatwork are also planned. A daily traffic load (18k equivalent axle loading) of 5, which is typical for residential access roads, was used in the pavement evaluation. If structural or traffic loads are different than those assumed, we should be notified and allowed to reevaluate our recommendations.

4.0 SITE CONDITIONS

The subject site is currently undeveloped land on a south facing slope. The ground slopes at grades of 20 to 45 percent and is covered with grasses and groves of aspen trees. A small runoff stream runs north to south at about the center of the property and was flowing at the time of the field investigation. The site is bound by Powder Mountain Road to the south, existing homes and undeveloped land to the north and undeveloped land to the east and west. The existing homes to the north of the property appear to be performing satisfactorily from a foundation viewpoint, based solely upon a limited exterior visual inspection.

5.0 FIELD INVESTIGATION

The field investigation consisted of excavating two test pits to depths of 7 to 8.5 feet below existing site grades at the approximate locations shown on Figure 2. The soils encountered at the site were continuously logged by the undersigned engineer. Samples were obtained and returned to our laboratory for closer examination.

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

6.0 SUBSURFACE CONDITIONS

Based on the two test pits excavated for this investigation, native soils at this site consist of 1 to 2 ½ feet of organic topsoil underlain by dense to very dense clayey gravel with cobbles and boulders (GC) extending beyond the maximum depth explored of 8.5 feet. Perched groundwater was found in the test pits at depths of 3 to 3 ½ feet at the time of the excavations. Graphical representations of the soil conditions encountered are shown on the Test Pit Logs, Figures 3A and 3B. Photos of the test pits are shown on Figure 4.

7.0 GEOLOGIC HAZARDS

A geologic hazards reconnaissance of the property was conducted by Western GeoLogic, LLC[1]. The report indicates that there are no geologic hazards on the site except the risk of avalanche which can be reduced through avalanche control. A copy of the geologic report is included in the appendix.

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1 Western GeoLogic, LLC, "Geologic Hazards Reconnaissance, Proposed 14-Lot Residential Subdivision, Near Powder Mountain Ski Area, Weber County, Utah.", January 22, 2004.

8.0 SLOPE STABILITY

The Geologic Hazards report indicates that there is no evidence of past instability on the site. To the west of the subject property a parking area at the base of a ski lift was constructed with a 50 foot high, 1 ½ horizontal to 1 vertical cut into the native slope (see Figure 6). Soils similar to those observed in the test pits was exposed. Using this data we back calculated a internal friction of the soil at 38°. To maintain stability at the site we recommend that cut or fill slopes be no steeper than 2:1 (h:v) unless engineered retainage systems are used.

9.0 SITE GRADING

9.1 General Site Grading

Topsoil, man-made fill, and soils loosened by construction activities should be removed (stripped) from the building pads, concrete flatwork and pavement areas prior to foundation excavation and placement of site grading fills. Following stripping and any additional excavation required to achieve design grades, the subgrade should be proof rolled to a firm, non-yielding surface. Soft areas detected during the proof-rolling operation should be removed and replaced with structural fill. If the soft soils extend more than 18 inches deep, stabilization may be considered. The use of stabilization should be approved by the geotechnical engineer and would likely consist of over-excavating the area by 18 inches, placing a geo-grid, such as Tensar BX-1100, at the bottom of the excavation over which a stabilizing fill consisting of angular coarse gravel with cobbles is placed up to the design subgrade.

9.2 Structural Fill and Compaction

The fill placed below the buildings, concrete flatwork, and pavements should be structural fill. All other fills should be considered as backfill. Structural fill may consist of the native gravels or imported fill. Imported material should consist of well-graded sands and gravels with a maximum particle size of 3 inches and 5 to 15 percent fines (materials passing the No. 200 sieve). The liquid limit of the fines should not exceed 35 and the plasticity index should be below 15. All fill soils should be free from topsoils, highly organic material, frozen soils, and other deleterious materials. Structural fill should be placed in maximum 8-inch thick loose lifts at a moisture content within 2 percent of optimum and compacted to at least 95 percent of maximum density (ASTM D 1557) under the buildings and 90 percent under concrete flatwork and pavements. If fill exceeds 5 feet in depth the required density should be increased to 98 percent.

9.3 Backfill

The native soils may be used as backfill in utility trenches and against the outside foundation walls. Backfill should be placed in lift heights suitable to the compaction equipment used and compacted to at least 90 percent of the maximum dry density (ASTM D 1557). Trench backfill which exceeds 5 feet in depth should be compacted to at least 95 percent of the maximum density (ASTM D 1557).

9.4 Excavations

Temporary construction excavations at the site that are less than five feet deep should have slopes no steeper than ½ to 1 (horizontal to vertical). Excavations which are advanced deeper than five feet below site grades or where water is encountered should be sloped or braced in accordance with OSHA Health and Safety Standards, final rule, CFR 29, part 1926 for a type C soil.

10.0 SEISMIC CONSIDERATIONS

10.1 Faulting

Based on published data, no active faults are known to traverse the site but there are several inactive faults are located in the area, see geologic report in the appendix.

10.2 Seismic Design Criteria

The proposed structures should be designed in accordance with the IRC building code. According to the IRC maps, this site is classified as seismic design category D_2. Mapped S_s value for this site is 131.4 %g.

10.3 Liquefaction

Liquefaction is a phenomenon where soils lose their intergranular strength due to an increase of pore pressures during a dynamic event such as an earthquake. The potential for liquefaction is based on several factors, including 1) the grain size distribution of the soil, 2) the plasticity of the fine fraction of the soil (material passing the No. 200 sieve), 3) relative density of the soil, 4) earthquake strength (magnitude) and duration, and 5) overburden pressures. In addition, the soils must be near saturation for liquefaction to occur. Our investigation indicates the soils at this site have a relatively low risk of liquefaction because of the density of the soils and the percentage of fines.

11.0 FOUNDATIONS

10.1 Footing Design

The native soils found at this site are capable of supporting the planned structures if the recommendations presented in this report are followed. The recommendations presented below should be utilized during design and construction of this project:

1. Spread footings founded on undisturbed native soils should be designed for a maximum allowable soil bearing pressure of 2000 psf. A one-third increase is allowed for short term transient loads such as wind and seismic events.

2. Footings should be placed at least 15 feet from the face of any cut or fill slope (measured horizontally).

3. Footings should be uniformly loaded.

4. Continuous and spot footings should have minimum widths of 20 and 30 inches, respectively.

5. Exterior footings should be placed below frost depth which is determined by local building codes. Generally 40 inches is adequate in this area. Interior footings not subject to frost should extend at least 18 inches below the lowest adjacent final grade.

6. Foundation walls on continuous footings should be well reinforced both top and bottom. We suggest a minimum amount of steel equivalent to that required for a simply supported span of 12 feet.

7. The bottom of footing excavations should be cleaned of disturbed soils and should be proof rolled with a non-vibratory compactor to identify soft spots prior to placement of structural fill or construction of footings. Soft areas encountered during the compaction operation should be replaced with structural fill or stabilized as recommended in section 10.1.

8. Footing excavations should be observed by the geotechnical engineer prior to placement of structural fill and construction of footings to evaluate whether suitable bearing soils have been exposed and whether excavation bottoms are free of man made fill or loose or disturbed soils.

11.2 Estimated Settlement

If footings are designed and constructed in accordance with the recommendations presented above, the risk of total settlement exceeding 1 inch and differential settlement exceeding 0.5 inch for a 25-foot span will be low. Additional settlement should be expected during a strong seismic event.

12.0 BASEMENT AND RETAINING WALLS

12.1 Lateral Pressures

Below grade walls should be designed to resist the lateral loads imposed by the soils retained. The lateral earth pressures on the buried walls and the distribution of those pressures depends upon the type of structure, hydrostatic pressures, in-situ soils, backfill, and tolerable movements. Retaining and basement walls are usually designed with triangular stress distributions known as equivalent fluid pressure based on lateral earth pressure coefficients. Below grade walls may be designed using the following ultimate values:

Condition	Lateral Pressure Coefficient	Equivalent Fluid Weight (PCF)
At Rest	0.50	68
Active	0.24	32
Passive	4.20	462

We recommend that the lateral earth pressures for walls which allow little or no wall movement be based on "at rest" conditions. Walls allowed to rotate 0.4 percent of the wall height may be designed with "active" pressures. These values assume level backfill extending horizontally for a distance at least as far as the wall height and that water will not accumulate behind walls. Backfill should be placed in accordance with the requirements discussed in Section 9.3. Any surcharge loads in excess of the soil weight applied to the backfill should be multiplied by the appropriate lateral pressure coefficient and added to the soil pressure. Lateral pressures approximately 30 percent higher will occur during backfill placement and bracing may be called for until the backfilling operation is completed.

12.2 Resisting Loads

Lateral building loads will be resisted by frictional resistance between the footings and the foundation soils and by passive pressure developed by backfill against the wall. For footings on native soils we recommend a friction coefficient of 0.30 be used. Because the table shows ultimate values, an appropriate factor of safety should be applied to the values presented above when determining lateral resistance.

12.3 Retaining Wall Considerations

Several areas may require retaining walls because cut or fill slopes of 2:1 cannot be achieved. Several options may be considered: (1) Rock Retained Slopes, (2) Mechanically Stabilized Earth (MSE), or (3) Standard Concrete Retaining walls. We have briefly discussed these options below.

12.3.1 Rock Retained Slopes

The use of large rocks as retainage in this area is popular because it offers a natural looking face. The large rock provide sufficient weight to protect the slope against erosion and shallow slumps. If rock retainage is used it should be understood that rock retained slopes are a man made structure based on a natural system. Rock retained slopes are subject to natural processes that may adversely affect the system. Such processes include rocks used for facing can topple during earthquake events, wildlife can burrow and disturb facing, rock facing can erode over time, trees and vegetation can disturb facing and other processes. If these conditions are not acceptable, a rock retained slope should not have been used. Rock facing should not extend higher that 8 feet unless a tiered system is used.

If rock facing is used they should meet the following recommendations:

1. Rock retained slopes should have a maximum height of 8 feet. The rock face should slope at a 4 to 1 (vertical to horizontal) or flatter.

2. If more than 8 feet of retainage is required, the rock retained slope should be broken into tiers with a bench in between the tiers or a mechanically stabilized earth (MSE) wall may be used behind the rocks. The bench should be at least as wide as the height of the wall below it. The MSE system is discussed in Section 12.3.2.

3. The base rock should have an average nominal diameter of not less than 40 inches. The base rocks should be set at least 18 inches below final grade. The second row of rock should have an average nominal diameter of not less than 30 inches. Rocks above the second layer should have an average a nominal diameter of not less than 24 inches. Smaller rocks may be used to "chink" in larger voids.

4. The rocks should be placed with the largest diameter set horizontally into the slope. No rock should be placed with the largest dimension parallel to the slope.

5. Rocks should have good three point rock to rock contact and no rocks should bear on a downward sloping face of the supporting rock. Larger gaps should be "chinked" with smaller rock or sealed with a cement grout.

6. All rocks should consist of durable material. Sandstones, which are susceptible to weathering, and rocks which may dissolve, such as limestone, should not be used.

7. Grading to avoid concentrated runoff or ponding of water at the top or base of the rock face should be performed.

8. Footings for any structure should be no closer than 15 feet from the top of the retained slope.

9. Structures below the rock retained slope should be constructed at least 20 feet from the base of the rocks.

As a minimum periodic observation of the rock placement should be conducted by an experienced geotechnical engineer. If a letter of construction compliance is needed then full time observation would be required.

12.3.2 Mechanically Stabilized Earth

Mechanically Stabilized Earth (MSE) is a system where a gravity retaining structure is developed by placing reinforcing geo-grid within compacted granular soil. The spacing and length of the grid is determined based on height of wall and backfill material. Generally segmented block is used for facing but other alternatives such as formed facing or even large rock may be used as facing. If large rock is used, the potential of rockfall during earthquakes remain. We would be happy to work with the civil-structural engineer in developing individual walls once the design requirements are known.

12.3.3 Standard Concrete Retaining Walls

Standard concrete retaining walls using the lateral load and resistance values presented above may be used.

13.0 FLOOR SLABS

The native soils below floor slabs should be proof rolled and soft areas should be stabilized as recommended in Section 8.1. A minimum 6 inch thick layer of free-draining gravel should be placed immediately below the floor slab to help distribute floor loads, break the rise of capillary water, aid in the concrete curing process and act as an underfloor drain. For slab design, we recommend a modulus of subgrade reaction of 150 psi/in be used. To help control normal shrinkage and stress cracking, the floor slabs should have adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints and contain frequent crack control joints.

Special precautions should be taken during placement and curing of all concrete slabs and flatwork. Excessive slump (high water-cement ratios) of the concrete and/or improper finishing and curing procedures used during hot or cold weather conditions may lead to excessive shrinkage, cracking, spalling, or curling of slabs. We recommend all concrete placement and curing operations be performed in accordance with American Concrete Institute (ACI) codes and practices.

14.0 SURFACE DRAINAGE

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

1. The ground surface should be graded to drain away from the structures in all directions. We recommend a minimum fall of 8 inches in the first 10 feet.

2. Roof runoff should be collected in rain gutters with down spouts designed to discharge well outside of the backfill limits.

3. Sprinkler heads, should be aimed away and kept at least 12 inches from foundation walls.

4. Provide adequate compaction of foundation backfill i.e. a minimum of 90% of ASTM D 1557. Water consolidation methods should not be used.

5. Where water concentration from surface drainage or from subsurface drains occurs, erosion protection should be provided.

6. Other precautions which may become evident during design and construction should be taken.

15.0 SUBSURFACE DRAINS

15.1 Foundation Drains

Although the shallow perched groundwater at this site will only occur in the spring months, the structures must be protected. We recommend that foundation drains be installed on all basement sections. The recommendations presented below should be followed during design and construction of basement:

1. The foundation drain should consist of a 4 inch diameter, slotted pipe encased in at least 12 inches of free draining gravel. The gravel should extend up the foundation wall to within 2

feet of the final ground surface and a filter fabric should separate the gravel from the native soils. The pipe should be graded to drain to a storm drain or other free gravity outfall. Gravel extending up the walls may be replaced by a fabricated drain panel such as Mirafi Micro drain, or equivalent.

2. The highest point of the 4 inch perforated pipe within the foundation drain should be placed at least 8 inches below the floor slab. The pipe should be graded to drain (minimum 2 percent grade) to a storm sewer or other free gravity outlet.

3. To facilitate basement drainage, clean gravel placed below the basement floor slabs should be at least 6 inches thick.

4. Connections through the foundation should be made between the subfloor gravel and the foundation drain. The connections should be made in such a way to allow any water collected below the floor slab to gravity flow to the foundation drain.

5. Clean outs should be installed so that the foundation drain pipes may be cleaned as necessary.

Drain operation is contingent upon proper drain construction and maintenance. Drains should be periodically inspected to verify that the drains are clear of blockages and are operating as envisioned.

15.2 General Drain Maintenance

Drain operation is contingent upon proper drain construction and maintenance. Drain pipe should be periodically inspected to verify that the drains are clear of blockages and operating as envisioned.

15.3 Water Proofing of Basement Walls

Because of the potential for perched groundwater at this site we recommend that the basements be water-proofed to prevent periodic basement seepage.

16.0 PAVEMENT

We understand that a flexible pavement is desired for the access road in this development. Unless a more stringent local code is required, we recommend a pavement section consisting of 3 inches of asphaltic concrete over 9 inches of untreated aggregated base. The design recommendations were based on an assumed CBR value of 14%, AASHTO design methods and the following assumptions:

1. The subgrade is proof rolled to a firm non-yielding condition and soft areas are stabilized, as discussed in Section 8.1;
2. Grading fills below the pavements meet structural fill material and placement requirements as defined in Section 8.2 of this report;
3. Asphaltic concrete and aggregate base meet UDOT specification requirements;
4. Aggregate base is compacted to at least 95 percent of maximum dry density (ASTM D 1557);
5. Asphaltic concrete is compacted to at least 97 percent of the laboratory Marshal mix design density (ASTM D 1559);
6. Traffic loads are typical for light commercial traffic as discussed in Section 3.0 of this report; and
7. Pavement design life of 20 years.

17.0 GENERAL CONDITIONS

The exploratory data presented in this report were collected to provide geotechnical design recommendations for this project. Test pits were widely spaced and may not be indicative of subsurface conditions between the points explored or outside the study area and thus have limited value in depicting subsurface conditions for contractor bidding. If it is necessary to define subsurface conditions in sufficient detail to allow accurate bidding we recommend an additional study be conducted which is designed for that purpose.

Variations from the conditions portrayed in the test pits often occur which are sometimes sufficient to require modifications in the design. If during construction, conditions are found to be different than those presented in this report, please advise us so that the appropriate modifications can be made. An experienced geotechnical engineer or technician should observe fill placement and conduct testing as required to confirm the use of proper structural fill materials and placement procedures.

The geotechnical study as presented in this report was conducted within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession in the area. No other warranty or representation, either expressed or implied, is intended in our proposals, contracts or reports.

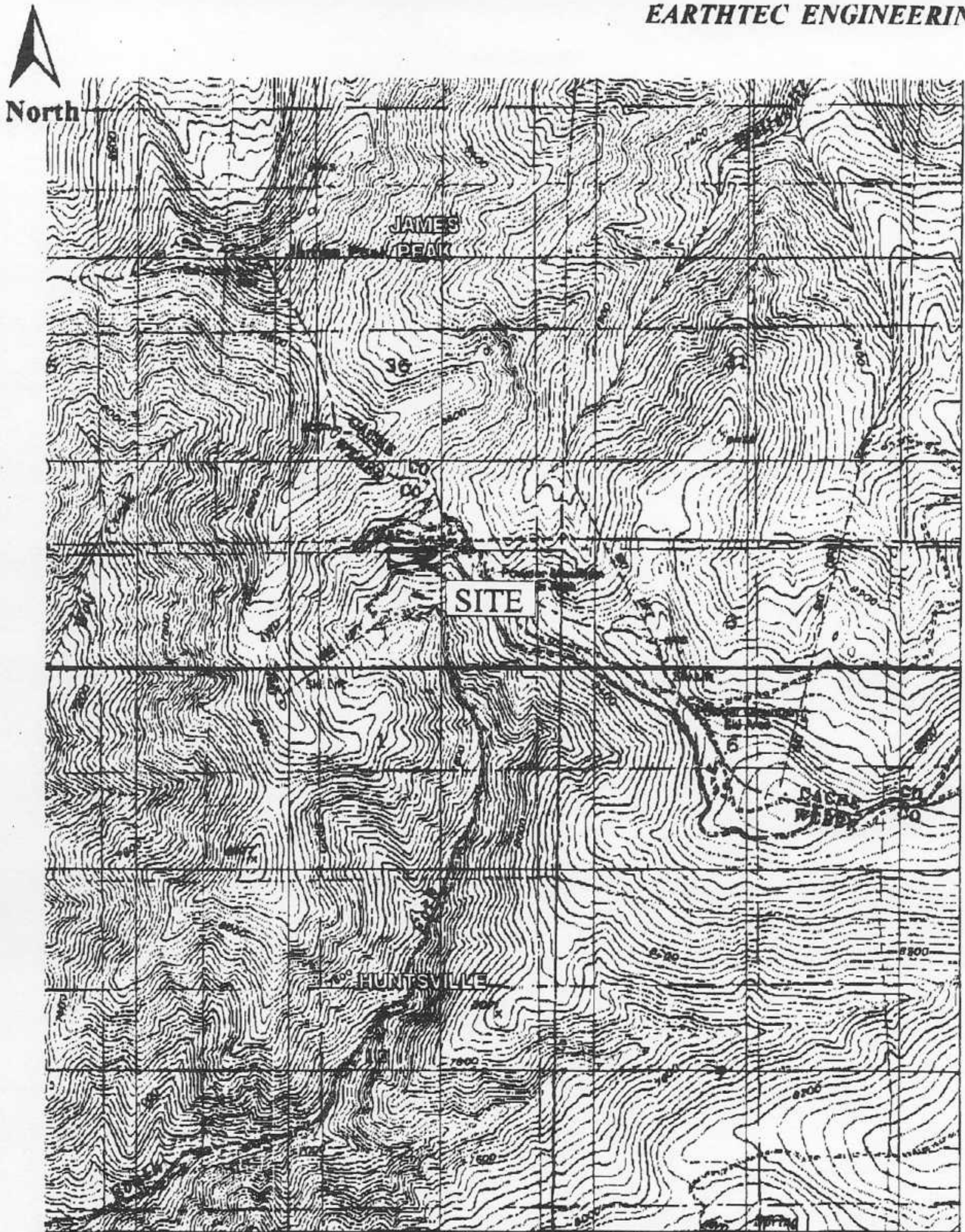
We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please call.

Respectfully;
EARTHTEC ENGINEERING, P.C.

Robert E. Barton, P.E.
Project Geotechnical Engineer

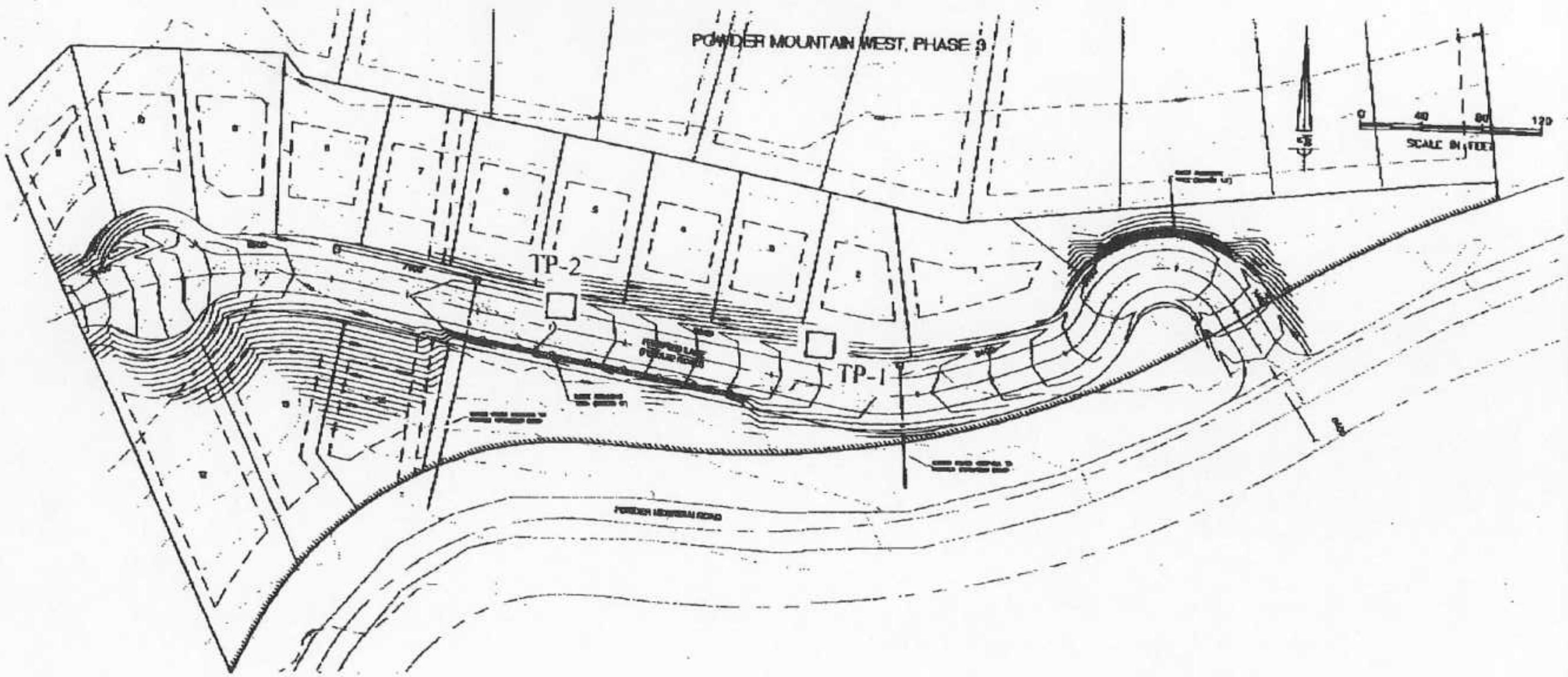
3 copies sent

EARTHTEC ENGINEERING



TOPOGRAPHIC MAP FROM
DOLORME "JAMES PEAK" AND
HUNTSVILLE QUADRANGLES

ETE Job No. 04E-082 VICINITY MAP Figure 1



SITE PLAN PROVIDED
BY GARDNER
ENGINEERING

SITE PLAN SHOWING LOCATION OF TEST PITS

ETE Job No. 04E-082

Figure 2

TEST PIT LOG

PIT NO.: TP-1

PROJECT: Powder 11 Development @ Powder Mountain
CLIENT: Gardner Engineering
LOCATION: See Figure 2
OPERATOR: S&S Excavation
EQUIPMENT: CAT 314 Trackhoe

PROJECT NO.: 04E-082
DATE: May 8, 2004
ELEVATION:
LOGGED BY: Robert Barton

Depth (Ft.)	Graphic Log	USCS	Description	Samples	Dry Dens. pcf	Water Cont. %	PL	LL	Gravel %	Sand %	Fines %	Other Tests
		SOIL	Organic topsoil comprised of loose silt, moist, dark brown.									
3		GC	Clayey gravel with sand containing cobbles with boulders below 6.5 feet, dense to very dense, moist becoming wet below 3 feet, reddish tan.									
6			Practical rig refusal at 7 feet									
9												
12												
15												

Notes:

Tests Key:
A = Atterberg Limits
C = Consolidation
G = Gradation
DS = Direct Shear
SO = Solubility
UC = Unconf. Compress. Strength

PROJECT NO. 04E-082

EARTHTEC ENGINEERING, P.C.

FIGURE NO.: 3A

TEST PIT LOG

PIT NO.: TP-2

PROJECT: Powder 11 Development @ Powder Mountain
CLIENT: Gardner Engineering
LOCATION: See Figure 2
OPERATOR: S&S Excavation
EQUIPMENT: CAT 314 Trackhoe

PROJECT NO.: 04E-082
DATE: May 8, 2004
ELEVATION:
LOGGED BY: Robert Barton

Depth (Ft.)	Graphic Log	USCS	Description	Samples	Dry Dens. pcf	Water Cont. %	PL	LL	Gravel %	Sand %	Fines %	Other Tests
		SOIL	Organic topsoil comprised of loose silt, moist, dark brown.									
3		GC	Clayey gravel with sand containing cobbles, dense, moist becoming wet below 3.5 feet, reddish tan. below 3 feet, reddish tan.									
6												
9												
12												
15												

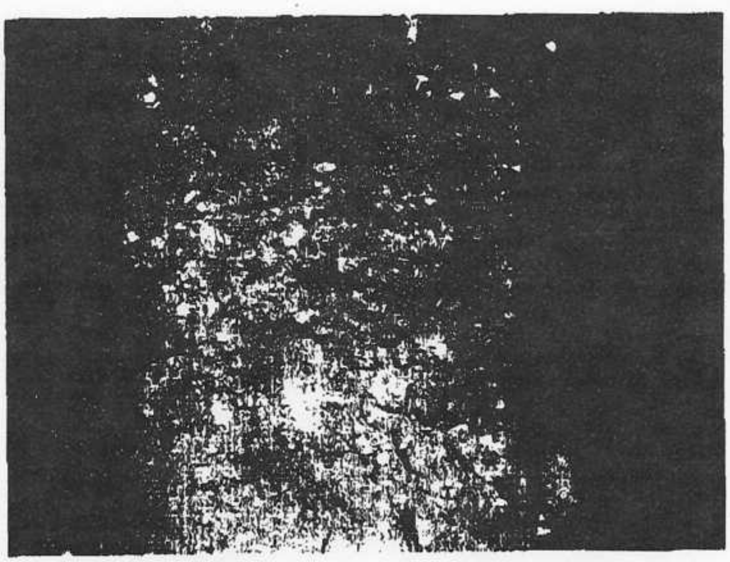
Notes:

Tests Key:
A = Atterberg Limits
C = Consolidation
G = Gradation
DS = Direct Shear
SO = Solubility
UC = Unconf. Compress. Strength

PROJECT NO. 04E-082 | EARTHTEC ENGINEERING, P.C. | FIGURE NO.: 3B

EARTHTEC TESTING AND ENGINEERING

TEST PIT TP-1



TEST PIT TP-2

ETE JOB NO. 04E-082

FIGURE 4

CUT SLOPE

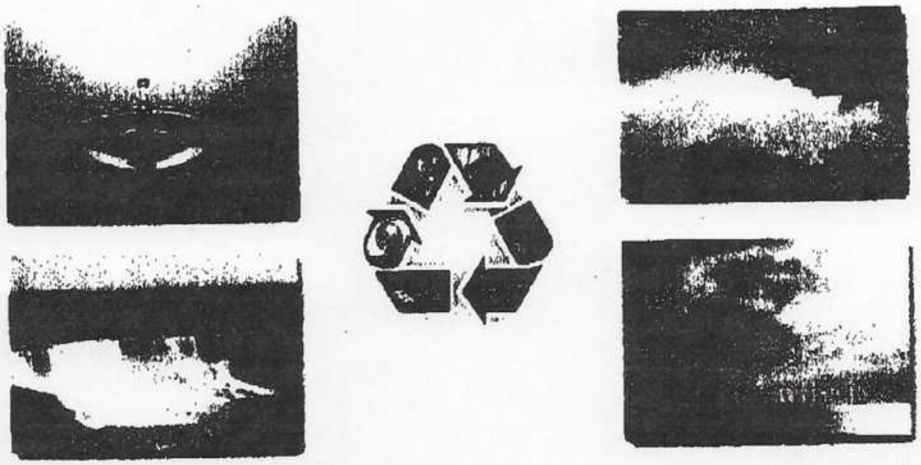
FIGURE 5

APPENDIX

GEOLOGIC HAZARDS REPORT
WESTERN GEOLOGIC, LLC

REPORT

Geologic Hazards Reconnaissance
Proposed 14-Lot Residential Subdivision
Near Powder Mountain Ski Area
Weber County, Utah



Prepared for

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January 22, 2004

Prepared by

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January 22, 2004

Mr. Robert Barton, P.E.
Earthtec Testing and Engineering, P.C.
1596 West 2650 South
Suite 108
Ogden, Utah 84401

SUBJECT: Geologic Hazards Reconnaissance
Proposed 14-lot Residential Development at Powder Mountain Ski Area
Weber County, Utah

Dear Mr. Barton:

Western Geologic is pleased to present this report describing our geologic hazards analysis for the proposed residential development in Weber County, Utah.

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

Sincerely,
Western GeoLogic, LLC

LICENSED PROFESSIONAL GEOLOGIST BILL DUANE BLACK NO. 5224898-2250 STATE OF UTAH

Bill. D. Black, P.G.
Associate Engineering Geologist

Reviewed by:

LICENSED PROFESSIONAL GEOLOGIST CRAIG V NELSON 5261804 STATE OF UTAH

Craig V Nelson, P.G., R.G., C.E.G.
Principal Engineering Geologist

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EXECUTIVE SUMMARY

Western GeoLogic, LLC conducted a geologic hazards reconnaissance of the proposed 14-lot residential development at Powder Mountain located about 8 miles north of Huntsville in Weber County, Utah (subject property). This assessment was accomplished by, and limited to, a review of readily available geologic information related to the subject property.

This assessment has revealed no evidence of adverse risk of geologic hazards in connection with the subject property except for the following:

1. Peak earthquake ground accelerations (%g) at the subject property area for 10% and 2% probabilities of exceedance in 50 years have been estimated at 20 to 25 %g, and 40 to 50 %g respectively for NEHRP B-C boundary (firm rock) sites (Frankel and others, 1996). Ground amplification is expected to be minimal given the relatively shallow bedrock at the subject site. Construction of the proposed dwellings to current seismic design standards should reduce this hazard to acceptable levels.

2. A hazard from snow avalanche is possible at the site, though proximity of the site to Powder Mountain Ski Area (which likely performs some avalanche control) may adequately reduce the hazard. The hazard should be disclosed to future buyers.

The site is considered suitable for the proposed development if the recommendations in this report are followed. Because of snow cover an on-site reconnaissance was not feasible during preparation of this report and it is therefore recommended that field conditions be verified prior to construction by a follow-up site visit when the site is accessible and not snow covered.

This Executive Summary is not intended to be a "stand-alone" document. It is intended to provide a summary of our findings described in the following report and should be used in conjunction with the scope of services and limitations described therein.

1.0 INTRODUCTION

This report presents results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western GeoLogic, LLC (Western GeoLogic) for a 14-lot residential development located about 8 miles north of Huntsville, Weber County, Utah (figure 1). The site is on generally south-facing slopes at the South Fork Ogden River drainage head, in the NE ¼ Section 1, Township 7 North, Range 1 East (Salt Lake Base Line and Meridian). Elevation of the site is about 8,200 feet above sea level.

2.0 PURPOSE AND SCOPE

The purpose of the investigation was to identify and interpret surficial geologic conditions at the site and to evaluate any potential geologic hazards to the project. The following services were performed in accordance with that purpose:

1. Examination of 1:20,000-scale aerial photos,
2. Review of available geologic maps and reports, and
3. Evaluation of available data and preparation of this report, which presents the results of our study.

No site reconnaissance was performed due to heavy snow cover at the time of the investigation. 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).

3.0 AERIAL PHOTOGRAPH REVIEW

Aerial photographs (U.S. Department of Agriculture, 1980) were reviewed to obtain information about the geomorphology of the site and surrounding area. The site is in an arcuate shaped bowl area opening eastward; slopes bordering the southern part of the bowl are occupied by Powder Mountain Ski Area. No slope failures are evident on air photos at the site, and no other geologic hazards are evident on the photos. No large bedrock outcrops are evident on the air photos.

4.0 HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the James Peak Quadrangle shows no surface-water impoundments or streams crossing the property. The site is at the head of the South Fork Ogden River drainage, which generally flows to the south. Groundwater flow in the area is likely toward the drainage head and downstream to the south through thin surficial sediments and bedrock.

5.0 GEOLOGY

5.1 Seismotectonic Setting

The property is located southeast of James Peak in a mountainous area bordering the northern end of Ogden Valley within the Wasatch Range. The Wasatch Range is a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes, 1977). Ogden Valley is a 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. The back valleys of the northern Wasatch Range are in a transition zone between the Basin and Range and Middle Rocky Mountains provinces (Stokes, 1977).

The Basin and Range province 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).

The site is also in the east-central portion of the Intermountain seismic belt (ISB), a generally north-south trending zone of historical seismicity along the eastern margin of the Basin and Range province extending 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; the largest of these earthquakes was a M_S 7.5 event in 1959 near Hebgen Lake, Montana. However, none of these earthquakes occurred along the Wasatch fault or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake.

5.2 Unconsolidated Deposits

Coogan and King (2001) show no surficial geologic units at the site, but unconsolidated deposits in the vicinity of the site include colluvium, man-made fill, and undifferentiated mass-movement deposits (figure 2). The mass-movement deposits are shown on slopes radiating away from the site about 0.5 to 1 mile distant (figure 2). Descriptions of these units, from youngest to oldest, are:

***Qf* – Man-made fill.** *Fill material about 1,000 feet east of the site.*

***Qc* – Colluvium.** *Includes slope wash and soil creep; composition depends on local bedrock.*

***Qm* – Mass-movement deposits (undivided).** *Includes slides, slumps, flows, colluvium, talus, and alluvial fans mapped where several mass-movement processes contribute to the deposit.*

5.3 Bedrock

Coogan and King (2001) show several bedrock units in the vicinity of the site (figure 2), described from youngest to oldest in age as:

***Cbl, Cbm, Cbh* – Blacksmith Dolomite.** *Medium-gray, very thick- to thick-bedded, coarsely crystalline cliff- and ridge-forming dolomite that weathers to a lighter gray.*

***Cu* – Ute Formation.** *Gray, thick-bedded limestone and minor medium-bedded, gray to light-gray dolomite above and below interbedded, thin-bedded, gray to dark-gray limestone with tan-, yellow-, and red-weathering, wavy silt layers and olive-gray to tan-gray, thin-bedded, micaceous shale and argillite.*

***Cg, Cgc* – Geertsen Canyon Quartzite.** *Mostly buff quartzite, but some brown-weathering argillite mapped locally and common at top.*

***Zm* – Mutual Formation.** *Purple, thick- to very thick-bedded quartzite with conglomerate lenses, locally arkosic.*

6.0 GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the site for development. A discussion and analysis of geologic hazards follows.

6.1 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. Mapped active faults within this distance include: the East and West Cache fault zones; the Eastern Bear Lake fault; the Brigham City, Weber, and Salt Lake segments of the Wasatch fault zone; the East Great Salt Lake fault zone; the Morgan Fault; the West Valley fault zone; and the Bear River fault zone (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 accelerations (% of gravity) at the site for 10% and 2% probabilities of exceedance in 50 years are estimated at 20 to 25 %g, and 40 to 50 %g respectively for NEHRP B-C boundary (firm rock) sites (Frankel and others, 1996). Horizontal accelerations on the 10 percent in 50-year map were typically used in building design prior to 2003.

Given this information, earthquake ground shaking is a 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.

6.2 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.

Coogan and King (2001) map several thrust faults at the site (figure 2; shown by heavy toothed lines), and one down-to-the-west northeast-trending normal fault (figure 2; shown by heavy line with bar and ball, dotted where concealed). These faults are bedrock faults that show no evidence of activity in recent geologic time, and no scarps suggestive of surface faulting were observed on air photos. Based on this information, the hazard from surface fault rupture is very low.

6.3 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, ground water conditions, and presence of susceptible soils.

The site is mapped in quartzite bedrock, likely with a thin veneer of surficial sediment. Based on the lack of sandy cohesionless soils at the site and likely shallow depth to bedrock, the hazard from liquefaction and lateral spreads is very low.

6.4 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). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of a normal fault. No faults are mapped at the site. Based on this, the risk from tectonic subsidence is very low.

6.5 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. Given the elevation of the subject property and distance from large bodies of water, the risk to the subject property from seismic seiches is rated as very low.

6.6 Stream Flooding

Stream floods 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. Stream flooding is likely only a localized seasonal concern in the shallow swale on the western edge of the site. Site drainage and hydrology should be addressed in a site-specific drainage report for the development.

6.7 Shallow Groundwater

No springs are shown on the topographic map for the James Peak quadrangle at the site. The site is likely in a recharge zone for the South Fork Ogden River, and ground water is likely deep. Depth to groundwater can fluctuate based on seasonal and climatic variations in up-gradient runoff infiltration, and depths may decrease as water is added from sources such as landscape irrigation. However, shallow groundwater should not pose a significant constraint for the proposed development.

6.8 Landslide 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 ground-water 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.

Figure 2 shows no mass movement deposits at the site, or in slopes above or below the site. This evidence suggests slopes at the site are stable and the risk from slope failures is low. However, to ensure slopes at the site are not destabilized, recommendations regarding slope stability, grading, and site drainage should be addressed in a geotechnical engineering evaluation during the subdivision approval process.

6.9 Debris Flows

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. The site is mapped as being underlain by bedrock and no alluvial fans are shown in the vicinity. Based on this, the risk from debris flows is low.

6.10 Rock Fall

No rock accumulations were evident at the site, and no large bedrock outcrops are in slopes above the site that could present a source area for rock fall clasts. Based on this, the risk from rock falls is likely low.

6.11 Snow Avalanche

A hazard from snow avalanches may exist due to proximity of the site to mountainous areas with south-, west- and north-facing slope aspects. Based on the elevation of the site and potential mountainous source areas, the hazard from snow avalanche is moderate to high. However, proximity of the development to Powder Mountain Ski Area, which regularly performs avalanche control during operation, reduces the hazard.

6.12 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 site is located in a "Moderate" radon-hazard potential area (Black, 1993). A moderate rating 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.

6.13 Swelling and Collapsible Soils

Surficial soils that contain certain clays can swell or collapse when wet. Based on the lack of soil development at the site, the risk from swelling and collapsible soils is likely low. However, a geotechnical engineering evaluation should be performed during the subdivision approval process to address soil conditions and provide specific recommendations for site grading, subgrade preparation, and footing and foundation design

6.14 Volcanic Eruption

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

7.0 CONCLUSIONS AND RECOMMENDATIONS

Potential hazards from earthquake ground shaking and snow avalanche exist at the site. The earthquake ground-shaking hazard can be adequately mitigated by designing and constructing the proposed structures to proper seismic standards. The potential snow avalanche hazard is likely already reduced by avalanche control for Powder Mountain Ski Area, as long as the ski area remains in operation, however it is recommended that the risk from snow avalanche be disclosed to future buyers.

Because of snow cover an on-site reconnaissance was not feasible during preparation of this report and it is therefore recommended that field conditions be verified prior to construction by a follow-up site visit when the site is accessible and not snow covered.

A geotechnical engineering study is recommended prior to construction to address soil conditions at the site for use in foundation design, site grading, and drainage; and provide recommendations regarding building design to reduce risk from seismic acceleration. Although slopes at the site show no evidence of instability, care should be taken in site grading and preparation to ensure slopes are not destabilized.

The site is considered suitable for the proposed development if the recommendations in this report are followed.

7.1 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 the excavations observed and not as a warranty of subsurface conditions throughout the site.

8.0 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 air photos and geologic literature. 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 subdivision boundaries, 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 evaluation.

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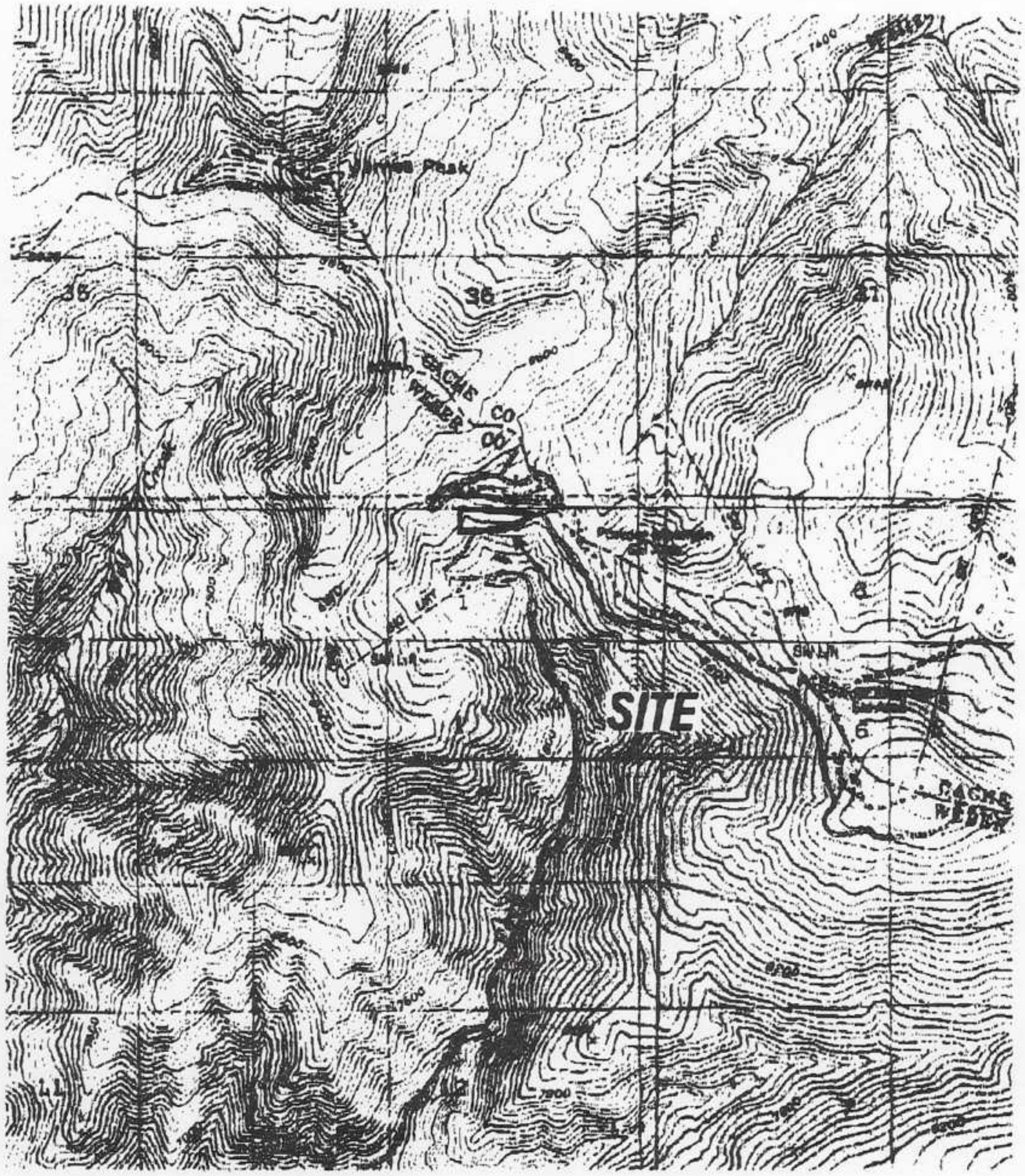


Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps - James Peak and Huntsville, UT 1953-54 (photorevised 1986, edited 1991).

WESTERN GEOLOGIC

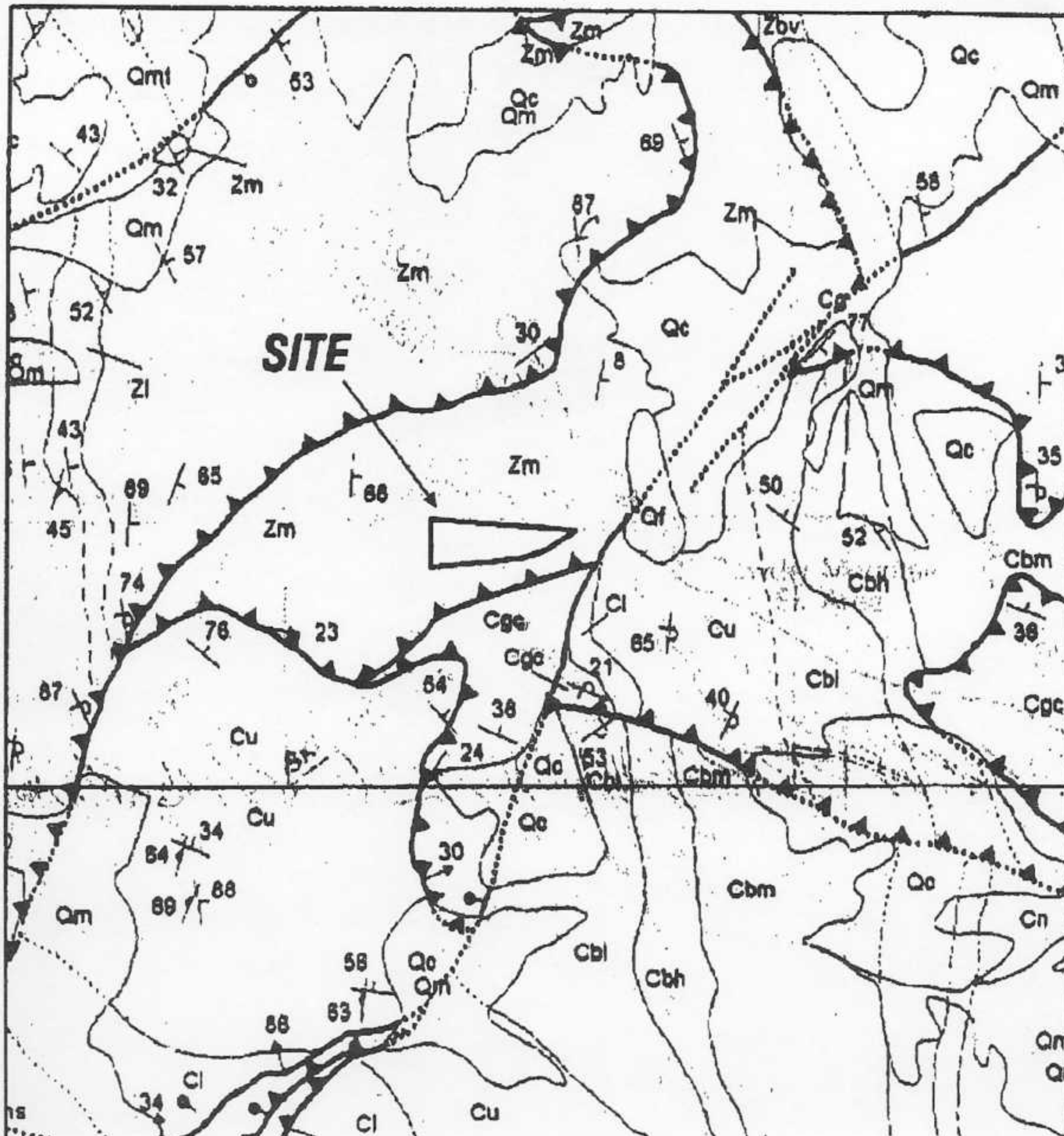
N W E S
Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed 14-lot Residential Subdivision
at Powder Mountain Ski Area,
Weber County, Utah

FIGURE 1



Source: Unpublished geologic mapping used in compilation of the Ogden 30' x 60' quadrangle (Coogan and King, 2001)

WESTERN GEOLOGIC

N W E S

Scale 1:12,000 (1 inch = 1000 feet)

GEOLOGIC MAP

GEOLOGIC HAZARDS RECONNAISSANCE

Proposed 14-lot Residential Subdivision at Powder Mountain Ski Area, Weber County, Utah

FIGURE 2

WESTERN GEOLOGIC, LLC

Bill D. Black, P.G.

Title Associate Engineering Geologist

Expertise Engineering Geology
Geologic Hazards
Groundwater Geology
Environmental Geology

Academic Background B.S., Geology, Weber State University, 1986, top department graduate

Registration Professional Geologist – Utah #5224898

Experience Mr. Black has over 13 years of experience conducting geologic investigations, mostly gained while working as a project geologist for the Utah Geological Survey. His expertise is in fault and seismic studies; geologic hazards mapping, analysis and mitigation; landslide, debris flows, and slope stability; and radon. He has completed numerous fault investigations under the U.S. Geological Survey's National Earthquake Hazard Reduction Program (NEHRP), and radon-hazard studies under the Environmental Protection Agency's State Indoor Radon Grant (SIRG) Program. Mr. Black served from 1998 to 2000 on the Utah Division of Comprehensive Emergency Management Interagency Technical Team.

Mr. Black also has experience in field reconnaissance and sampling of stream sediment for economic mineral evaluation, including trace mineral suites characteristic of Kimberlite deposits in northern Wyoming. Mr. Black has been involved in hydrogeologic investigations measuring spring flow and water quality, environmental investigations determining suitability for landfills and wastewater soil-absorption systems, and conducted numerous geotechnical report reviews for local governments.

Hydrogeology Projects

- Conducted a depth to bedrock seismic refraction study for Spring City, Utah municipal water well location in cooperation with the Utah Division of Water Resources.
- Conducted water quality and flow measurements for potential water sources, Antelope Island State Park, Utah.
- Conducted percolation tests and assisted in field bedrock characterization for a waste-water soil-absorption system suitability study for Duchesne County, Utah.
- Mapped areas of shallow ground water in Tooele Valley and the West Desert Hazardous Industry Area, Utah.
- Conducted shallow drilling studies to determine depth to the unconfined aquifer, Ogden Valley, Utah, for a water quality assessment.

Environmental Geology

- Authored and co-authored studies mapping and evaluating the radon-hazard potential of the lower Weber River area, Weber and Davis Counties, Utah; Tooele Valley, Tooele County, Utah; western Salt Lake Valley, Salt Lake County, Utah; and Sandy and Provo Cities, Salt Lake and Utah Counties, Utah.
- Compiled, mapped, and published the statewide radon-hazard potential map for Utah.
- Assisted in field reconnaissance for four proposed landfill sites in Wasatch County, Utah.

Geologic Hazards

- Authored and co-authored six NEHRP fault and trenching studies at sites along the Wasatch fault zone, Oquirrh fault zone, Mercur fault, and West Cache fault zone in Tooele, Cache, Salt Lake, and Utah Counties, Utah.
- Principal investigator, Cache Landmark Engineering, Canyon Ridge Estates fault trenching project, East Cache fault zone, North Logan, Cache County, Utah.
- Assisted with the Mapleton Megatrench project, Provo segment of the Wasatch fault zone, Utah County, Utah in cooperation with URS Corp. (Oakland, CA) and the Utah Geological Survey.
- Conducted numerous geologic hazard assessments for water tanks, schools, fire stations, and School Trust Lands in Utah.
- Evaluated and documented geologic effects associated with the 1992 St. George earthquake and Springdale landslide; evaluated causes and effects of the 1999 Weber-Davis Canal breach in Riverdale, Weber County, Utah; and responded to numerous other geologic hazard events in Utah resulting from landslides, rock falls, canal failures, and earthquakes.
- Mapped geology and geologic hazards of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah; co-author for Geologic hazards of the Ogden area and Geology of Salt Lake City.
- Co-authored the digital Quaternary fault and fold database and map of Utah.
- Conducted numerous geologic hazard and site suitability assessments for water tanks, schools, fire stations, subdivisions, and State Trust land sales.

Economic Mineral Evaluation

- Conducted stream sediment sampling for trace minerals characteristic of Kimberlite deposits, Big Horn Mountains, Wyoming.

Geologic Hazards - Land Use Planning

- Prepared the geologic hazards analysis and maps for Tooele County Planning Division for Tooele Valley. Geologic hazards of prime consideration included: surface fault rupture, earthquake ground shaking, landslides, rock fall, debris flow, problem soils, stream flooding, liquefaction, shallow ground water, and radon.
- Prepared the geologic hazards analysis and maps for Tooele County Planning Division for the West Desert Hazardous Industry Area. Geologic hazards of prime consideration in included: earthquake ground shaking, landslides, rock fall, pond and sheet flooding, problem soils, liquefaction, shallow ground water, and radon.
- Conducted numerous geologic and geotechnical consultant report reviews for developments in Cache, Weber, Davis, Morgan, Salt Lake, and Utah Counties, Utah.

Professional History

Associate Engineering Geologist, Western GeoLogic, Salt Lake City, UT (2003-present)
Project Geologist, Utah Geological Survey, Applied Geology Section, Salt Lake City, Utah (1995-1999).
Geologist, Utah Geological Survey, Applied Geology Section, Salt Lake City, Utah (1990-1995).
Geotechnician, Utah Geological Survey, Applied Geology Section, Salt Lake City, Utah (1986-1990).
Field Geotechnician, North American Exploration, Kaysville, Utah (1986).

Professional Awards

Co-recipient, Geological Society of America John C. Frye award for 1995.
Received numerous Utah Geological Survey awards for excellence.
Received Utah Division of Radiation Control award for achievements in radon hazards.

Citizenship

United States

Countries Worked In United States

Language Proficiency English

Partial List of Publications

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WESTERN GEOLOGIC, LLC

CRAIG V. NELSON, C.E.G., R.G.

Title Principal Engineering Geologist

Expertise
Engineering Geology
Groundwater Geology
Environmental Due Diligence
Environmental Geology
Geologic Hazards
Litigation Support

Academic Background
M.B.A., Eccles School of Business, University of Utah, 1991
M.S., Geology, Utah State University, 1986
B.S., Geology, Utah State University, 1982

Registration
Registered Geologist - California and Arizona
Certified Engineering Geologist - California

Experience

Mr. Nelson has over 20 years of experience managing a wide variety of projects in engineering and environmental geology. His expertise in geologic hazards mapping, analysis and mitigation stem from successful completion of numerous geologic hazard studies, fault and seismic investigations, rockfall probability assessments, landslide and debris flow studies, and slope stability projects. He has completed geologic studies and risk analysis for engineered structures, public facilities, subdivisions, dams, highways, and corridors throughout the western U.S. and Canada.

His environmental and hydrogeology work has included subsurface site characterizations, Phase I Environmental Site Assessments, and soil and groundwater remediation projects involving a variety of contaminants and remediation technologies. He has provided expert witness and third-party review services in a number of geology and ground water related cases.

Dam Projects

- Provided engineering geology analysis for the seismic stability evaluation of Twin Lakes (concrete arch) and Lake Mary (concrete gravity) dams. Project included detailed bedrock mapping of abutments, seismic refraction survey, and slope stability analysis.
- Performed the geologic site reconnaissance and seismic design criteria for the reconstruction and enlargement of an earthfill dam in Payson Canyon, Utah.
- Project manager for the engineering compliance evaluation of Red Pine Dam for Salt Lake City Public Utilities. Conducted the engineering geologic analysis for the project and geophysical evaluation across the dam foundation.

Expert Witness and Litigation Support

- Provided expert witness testimony and third-party review on a variety of geology and hydrogeology cases.

Geologic Hazards - Land Use Planning

- Prepared the geologic hazards analysis and land use overlays for Salt Lake County Planning Division's Foothill Area Master Plan. Geologic hazards of prime consideration in this land use plan include: surface fault rupture, earthquake ground shaking, landslides, rockfall, debris flow, mine and tunnel collapse, and avalanche.

- Prepared the geologic hazards analysis and land use overlays for Salt Lake County Planning Division's Holaday/Cottonwood Master Plan. Geologic hazards of prime consideration in this land use plan include: surface fault rupture, earthquake ground shaking, unstable slopes, and liquefaction.
- Prepared the geologic hazards analysis and land use overlays for Salt Lake County Planning Division's Magna Area Master Plan. Geologic hazards of prime consideration in this land use plan include: surface fault rupture, earthquake ground shaking, unstable slopes, and liquefaction.
- Prepared the geologic hazards analysis and land use overlays for Salt Lake County Planning Division's Taylorsville-Bennion Master Plan. Geologic hazards of prime consideration in this land use plan include: surface fault rupture, earthquake ground shaking, and liquefaction.
- Prepared the geologic hazards analysis and land use overlays for Salt Lake County Planning Division's Herriman Area Master Plan. Geologic hazards of prime consideration in this land use plan include: earthquake ground shaking, landslides, rockfall, debris flow, and liquefaction.

Corridor and Transportation Projects

- Project geologist conducting the geologic hazards analysis for the Independent Review of the Yellowstone Pipeline on Lolo National Forest in Montana and Idaho. Prepared a reconnaissance-level geologic hazards characterization of the pipeline corridor for hazards including: surface fault rupture, liquefaction, seismic ground acceleration, landslide, debris flow, rock fall, avalanche, and other hazards such as acid ground water corrosion.
- Project manager for the geotechnical exploration, testing, analysis and preliminary design recommendations for roadway embankment settlement, bridge abutments, pile design, and retaining walls for the redesign of the complex I-15/I-80 Junction at 2400 South in Salt Lake County. This major reconstruction project involved exploration of over 200 borings and CPT soundings, many in areas of soil and groundwater contamination from heavy metals, hydrocarbons, PCBs, solvents, and low-level radioactive fill material.
- Project manager for exploration and analysis to provide pavement design parameters to UDOT at over 80 sites along existing and planned surface roads adjacent to the I-15 corridor.
- Project manager for geologic and geotechnical exploration of the realignment of U.S. 189 in upper Provo Canyon, Utah. This section included routing through the infamous Hoover landslide complex as well as rock cuts ranging to 75m in height. Coordinated drilling, inclinometer installation and monitoring, downhole geophysics, and soil and rock mechanics testing. Provided detailed geologic maps, cross sections, and geologic hazards analysis including discontinuity and seismic parameters for the transportation design engineers.
- Project manager for the seismic hazard analysis of the I-15 corridor through Salt Lake County. This project involved exploration of 200 and 300 foot borings for downhole shear wave velocity and gamma and EM logging; seismic source characterization; ground-motion analysis; probabilistic and deterministic seismic hazards analyses; site response analyses; and seismic design spectra for more than 50 bridge sites along the corridor.
- Project manager for the geotechnical exploration, testing, analysis and preliminary design recommendations for the redesign of the I-15 "collector" system between 800 south and 1700 south in Salt Lake City. This major reconstruction project involved embankment widening with retaining walls and bridge replacement and widening.
- Project manager for the geotechnical exploration, testing, analysis and preliminary design recommendations for the I-15 600 South off-ramp in Salt Lake City.

- Project manager for the I-15 Stage I geotechnical corridor investigation from 10800 South to 500 North in Salt Lake County, Utah. This project involves providing preliminary geotechnical recommendations for the roadway widening and reconstruction of structures along a 17.6-mile segment of I-15. This project provided preliminary settlement calculations for over 50 bridge sites and wick-drain analysis for embankment settlement.
- Project manager for the UDOT Stage I geotechnical investigation of the 17.6-mile segment of I-15 through the urban Salt Lake Corridor. This project involved CPT soundings and deep SPT borings, preliminary settlement analysis for bridge foundations and highway embankments, wick-drain analysis, and seismic microzonation of the corridor. Dames & Moore also prepared guideline manuals for subsurface, exploration, geotechnical analysis and design, and soil classification.
- Engineering geology analysis for proposed 945m long funicular railway system for ski resort access near Provo, Utah.

Geologic Hazards - Surface Fault Rupture

- Conducted a surface fault rupture hazard study fault study for a proposed multi-lot subdivision/apartment complex adjacent to the active East Bench portion of the Wasatch Fault. Included aerial photography analysis and fault mapping. Excavated and logged 4 trenches (total 120m in length) to locate the fault and determine rupture history (min. of 2.1m displacement observed). Provided recommendations for building set-backs, grading and footing placement in areas of rubble fill.
- Project manager for a combination fault and geotechnical investigation involving trenching a 59m long, 3.2m deep exploratory trench through Holocene alluvium and debris flow deposits into Pleistocene Lake Bonneville sediments. No active faults were delineated. The trench was logged using standard level-line techniques and a video log was also made to document the stratigraphy. Five test pits were also excavated, logged, and sampled for geotechnical testing.
- Conducted a fault investigation for a proposed residential development in a very structurally complex area within the active Wasatch Fault Zone. This project consisted of aerial photography analysis, fault and surficial geologic mapping, and excavating and logging a 77m long, 3m deep exploratory trench to delineate faulting and determine rupture history (nine active faults splays were documented). Provided recommendations for buildable areas to avoid future rupture hazard. Presented seismic techniques and risks to the Planning commission.
- Logs from geotechnical boreholes across this site indicated significant change in stratigraphy from east to west across the site. Analysis of aerial photographs proved inconclusive because of surficial disturbance from development in the earliest available photos (1938). Because the active East Bench portion of the Wasatch Fault has been mapped about 90m east of the site, an exploratory trench was excavated across the building pad to determine if the discontinuous stratigraphy was the result of past surface fault rupture. The 40m long trench was excavated 12m deep into Pleistocene Lake Bonneville sediments and revealed a silty clay lens interfingering with silty clay and gravel deposits. No evidence of faulting or liquefaction was observed, the contacts appeared to be depositional. No surface fault rupture-related constraints were recommended.
- Conducted surface fault rupture hazards evaluation for a proposed Salt Lake County Fire Station near the mouth of Little Cottonwood Canyon. Determined the location of the active Wasatch Fault in the vicinity of the site and provided recommendations to the structural engineer and architect for seismic design values for this critical structure. An exploratory trench 71.5m in length was excavated across the site to investigate the presence of recent fault activity. Recommendations were provided for earthquake ground shaking acceleration, ground tilting and deformation, surface fault rupture, and other geologic hazards. An earthquake probability analysis was prepared and recommendations for a risk assessment of the structure were provided.

- Project manager for a fault study conducted on a steep hillside lot (suspected fault scarp) in a subdivision approved in the mid 1970's before the Natural Hazards Ordinance prohibited placing structures over active faults. A 14.6m long, 5.2m deep trench was excavated into Pleistocene Lake Bonneville deposits. Three faults displacing sediment layers dated at 15,000-16,000 years old were logged. Recommendations were provided for siting the structure to avoid future surface fault rupture.
- Served as project manager and principal geologist for a fault hazard analysis for a proposed development located on 40 acres straddling a wide graben located within the active Wasatch Fault Zone. Project goals project were to determine the potential buildable areas in this geologically complex parcel. Prepared a detailed aerial photo-based fault and surficial geology map. Three parallel exploratory trenches were excavated across the site perpendicular to the trend of the faults for a total distance of 733m. A detailed fault map was created based on the fault locations observed in the trenches and air photos. Other geologic hazards were also addressed including: rockfall, debris flow and set-back from steep slopes.
- Conducted a fault investigation for a subdivision approved in the mid-1970's based on work performed by another consultant. The County Geologist questioned the previous work because no subsurface exploration was performed to accurately locate the faults. A 22m long exploratory trench was excavated through about 2.5m of Holocene fill and alluvium into Pleistocene sediments. No evidence of faulting was observed, however deformation at the east end of the trench (at the base of the suspected 15m high fault scarp) displayed evidence of drag deformation. A slope stability analysis was performed to determine an appropriate building set-back distance from the base of the slope, should the slope fail during a rupture event.
- This fault study was prepared for a large addition to an industrial building located about 100m northeast of the Granger Fault in the West Valley Fault Zone. Because of the shallow groundwater (about 1.5m) and the amount of fill on the site it was doubtful that any meaningful information would be gained from exploratory trenching. Given these factors and the distance from the proposed structure to the surficial expression of the scarp in the air photo mapping, I was successful in lobbying for development of the site without subsurface exploration.

Geologic Hazards - Comprehensive

- Conducted numerous surface fault rupture hazard investigations for a variety of public and private structures and subdivisions.
- Conducted geologic hazard assessments and geoseismic evaluations for a many public facilities, residential subdivisions, dams, highways, and industrial facilities.
- Co-author of Salt Lake County's Natural Hazards Ordinance, which required developers to conduct special studies to address soil liquefaction and surface fault rupture in potential hazard areas.

Mining

- Project geologist on over twenty mining engineering projects including: highwall slope stability analysis; subsidence evaluation; pilot shaft evaluation; portal and main entry stability analyses; ground control assessment; and geotechnical logging/testing studies.

Environmental Site Assessments

- Directed, reviewed or conducted numerous Phase I Environmental Site Assessments for a variety of commercial and industrial facilities throughout the U.S., Ireland, Scotland, Great Britain, and Singapore.

Geologic Hazards - Debris Flow/Sediment Yield

- Evaluation of debris flow potential and recommendations for emergency watershed protection following the September 1988 Affleck Park wild fire which burned over 5600 acres (22.7 km^2) across several drainages in "suburbanized" Emigration Canyon, Utah. Analysis of the burned drainage indicated a 700 percent increase in potential sediment yield over the pre-fire conditions. Based on the recommendations of this study an emergency watershed restoration project was initiated to help mitigate erosion hazards. Erosion control structures consisting of 24 gabion baskets and 84 wire silt fences were installed across the upland slopes and a debris basin was constructed at the base of one major intermittent channel. The following spring a localized, intense rain storm (estimated to be in excess of the 100 year event) triggered a large mobilization of sediment across a portion of the not-yet-revegetated burn area. Silt fences and gabions helped collect sediment and reduce peak debris flow volumes (although the force of the flows toppled several of the gabion structures). Two homes near the base of one drainage suffered some mud-related basement damage. The debris-basin protected drainage was not impacted by the localized storm. Estimates of the debris generated closely matched the predicted sediment yield for a post-fire event.
- A 6-lot Planned Unit Development (PUD) located within a steep drainage on the northern slope of Mt. Olympus, near Salt Lake City, Utah may be subject to periodic storm flooding and debris flow deposition. The purpose of this study was to determine the risk to the proposed homes from these hazards and to quantify the flow rates for three scenarios: 1) runoff confined to pre-existing drainage channels, 2) runoff as pure sheet flow, and 3) a combination of sheetflow and channel flow. Runoff rates were calculated using the SCS runoff model for 24 hour duration storms with return periods of 2, 10, and 24 years and precipitation of 45, 65, and 94mm respectively. Recommendations were provided for locating the building pads and grading to minimize the risks from storm water and debris.
- An engineering geology report was required the Pleasant View (Utah) City Engineer prior to development of an approximately 200-acre hillside north of Ogden, Utah. The site was located near the apex of an active alluvial fan at the mouth of an intermittent stream drainage. City ordinance required that the runoff from the 10-year storm be addressed. An analysis was performed on the drainage basin to determine the channel size requirements for both the 10 and 100-year storm and associated debris flow events. A probability risk assessment was also provided to help characterize the large-scale debris flow return interval and relative risk to the site.
- Conducted a debris flow hazard assessment for a proposed residential subdivision and golf course in Carbondale, Colorado. Developed a debris flow model based on evidence from prehistoric debris flows observed in alluvial fan test pits and evidence from a large historic debris flood/flow. Provided recommendations for hazard avoidance and reduction.

Groundwater Studies & Site Characterizations

- Served as project manager for an environmental site assessment of property down gradient from chemical leach ponds at a Salt Lake City chemical company.
- Managed and directed numerous environmental site characterizations to determine extent and degree of soil and ground water contamination.
- Supervised UST removal sampling and preparation of closure plans.
- Provided senior technical review and client liaison for soil vapor extraction system in urban location. Site reached target cleanup levels in 3 months.

Professional History

Principal Engineering Geologist, Western GeoLogic, Salt Lake City, UT (2001-present)
Operations Manager, URS Corporation, Salt Lake City, UT (2000-2001)
Managing Principal-In-Charge, Dames & Moore, Salt Lake City, UT (1997-2000)
Sr. Engr. Geologist - Geoscience Manager, Dames & Moore Salt Lake City, UT (1995-97)
Sr. Engineering Geologist, Delta Geotechnical Consultants, Salt Lake City, UT (1992-95)
County Geologist, Salt Lake County Public Works, Salt Lake City, UT (1985-92)
Teaching and Research Assistant, Utah State University, Logan, UT (1983-85)
Staff Engineering Geologist, Seegmiller International, Salt Lake City, UT (1981-83)

Professional Awards

American Planning Association, *1991 Award of Merit* in recognition of achievement in information technology made to the state of Utah for the Earthquake Awareness and Hazard Mitigation Video.
American Planning Association: *1990 Award of Merit* for development of Salt Lake County's Natural Hazards Ordinance.
U.S. Geological Survey: *1989 Certificate of Appreciation* for implementation of measures to reduce losses due to earthquakes in Utah.

Professional Affiliations

Member, Rocky Mountain Association of Environmental Professionals
Member, Association of Engineering Geologists
Member, National Ground Water Association
Member, Geological Society of America
Member, Utah Geologic Association
Board Member, Utah Geological Survey Advisory Board, Board Chairman 2000-2001
Member, Salt Lake School District Seismic Committee, (1989-1992)
Member, Geological Review Committee, Nuclear Repository Waste Siting Study, Davis/Lavender Canyons, Utah (1982-1983)

Citizenship United States

Countries Worked In United States, Canada, Jamaica

Language Proficiency English

Partial List of Publications

Christenson, G.E., Batatian, L.D., and Nelson, C.V., 2003, Guidelines for evaluating surface-fault-rupture hazards in Utah: Utah Geological Survey Miscellaneous Publication 03-6, 16 p.

Nelson, C.V., Brink, J.D., Heppler, Leslie, Braceras, Carlos, Bishoff, Jon, and Brown Keith, 1997, Interpretation of late-Pleistocene and Holocene stratigraphy and depositional environments in the Salt Lake Valley, Utah using borehole logs and cone penetrometer soundings: Geological Society of America Abstracts with Programs, vol. 29, no. 6, p. 56.

Nelson, C.V., Sakai, S., and Gunalan, K.N., Evaluating soil strength gain due to embankment loading - A case study from the I-15 Corridor reconstruction project, Salt Lake County, Utah: Proceedings of the 32nd Symposium on Engineering Geology and Geotechnical Engineering - March 26-28, 1997, Boise, Idaho, in press.

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Nelson, C.V., 1995, Rockfall hazard probabilistic risk analysis, A case study, Ogden Canyon, Utah: Geological Society of America Abstracts With Programs, Vol. 27, No.4, p. 49.

Nelson, C.V., 1993, Rockfall hazards: A guide for land-use planning, Salt Lake County, Utah: U.S. Geological Survey Professional Paper 1519, p. 138-142.

Nelson, C.V., and Christenson, G.E., 1992, Establishing Guidelines for Surface Fault Rupture Hazard Investigations - Salt Lake County, Utah: Proceedings of the Association of Engineering Geologists 35th Annual Meeting, p. 242-249.

Lowe, Mike, Nelson, C.V., Robison, R.M., and Christenson, G.E., 1991, Reducing Earthquake and Other Hazards Through Land-Use Planning, Wasatch Front, Utah: Annual Earthquake Engineering Research Institute Meeting (poster session abstract), Salt Lake City, UT, February 14-16.

Lund, W.M., Christenson, G.E., Harty, K.M., Hecker, S., Atwood, G.A., Case, W.F., Gill, H.E., Gwynn, J.W., Klauk, R.H., Mabey, D.R., Mulvey, W.E., Sprinkel, D.A., Tripp, B.T., Black, B.D., and Nelson, C.V., 1990, Geology of Salt Lake City, Utah, United States of America: Association of Engineering Geologists Bulletin, Vol. 27, No. 4, p. 391-478.

Nelson, C.V., and Rasely, R.C., 1990, Estimating Sediment Yield and Implementing Erosion-Control Mitigation Measures Following A Wild Fire Event, The Affleck Park Fire Case: Utah Non-Point Source Water Quality Conference Abstracts, p. 3.

Madsen, G.E., Anderson L.R., and Nelson, C.V., 1990, The Uses of Opinion Surveys in Earthquake Risk Reduction Programs in Utah: Presented at the Earthquake Engineering Research Institute Meeting, Palm Springs, California.

Nelson, C.V., and Rasely, R.C., 1990, Debris Flow Potential and Sediment Yield Analysis Following Wild Fire Events in Mountainous Terrain: Proceedings of the American Society of Civil Engineers International Symposium on the Hydraulics/Hydrology of Arid Lands, p. 54-59.

Madsen, G.E., Anderson, L.R., Barnes, J.H., and Nelson, C.V., 1989, Earthquake Risk and Defensive Policies as perceived by Community Leaders and the Public: Report to the Utah Council on Intergovernmental Relations, Second Annual Summit Conference, August 25, 1989, Salt Lake City, UT, 15p.

Nelson, C.V., 1989, Rock Fall Hazards, A Guide to Land Use Planning: Salt Lake County, Utah: U.S. Geological Survey Open-File Report 90-225, p. II-1 - II-15.

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Investigations No. 218, p. 129-131.

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