TECHNICAL REPORTS FOR 2000-01
GEOLOGIC HAZARDS PROGRAM

compiled by
Greg N. McDonald

March 2002

REPORT OF INVESTIGATION 250
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

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GREG N. McDONALD

Cover photo: View of landslide in backyards in the Frontier Drive subdivision, Mountain Green. Photograph credit: Greg McDonald.

PREFACE

The Geologic Hazards (formerly Applied Geology) Program of the Utah Geological Survey (UGS) maps and defines geologic hazards and provides assistance to tax-supported entities (cities, towns, counties, and their engineers, planning commissions, or planning departments; associations of governments; state agencies; and school districts). We respond to emergencies such as earthquakes, landslides, and wildfires (where subsequent debris flows are a hazard) with a field investigation and a report of the geologic effects and potential hazards. We also conduct investigations to answer specific geologic questions from state and local government agencies, such as geologic investigations of slope stability, soil problems in developing areas, and hazards from debris flows, shallow ground water, rock falls, landslides, and earthquakes. We perform preliminary site evaluations of geologic-hazard potential for critical public facilities such as public-safety complexes, fire stations, waste-disposal facilities, water tanks, and schools. In addition to performing engineering-geologic studies, we review and comment on geologic reports by consultants for school sites, residential lots, subdivisions, and private waste-disposal facilities.

Dissemination of information is a major goal of the UGS. Studies of interest to the general public are published in several UGS formats. We present projects that address specific problems of interest to a limited audience in a technical-report format, which we distribute on an as-needed basis. We maintain copies of these reports and make them available for inspection upon request. This Report of Investigation presents, in a single document, the Geologic Hazards Program's 31 technical reports completed in 2000-01 (figure 1). The reports are grouped by topic, and each report identifies the author(s) and requesting agency. Minor editing has been performed for clarity and conformity, but I have made no attempt to upgrade the original graphics.

Greg N. McDonald
February 18, 2002

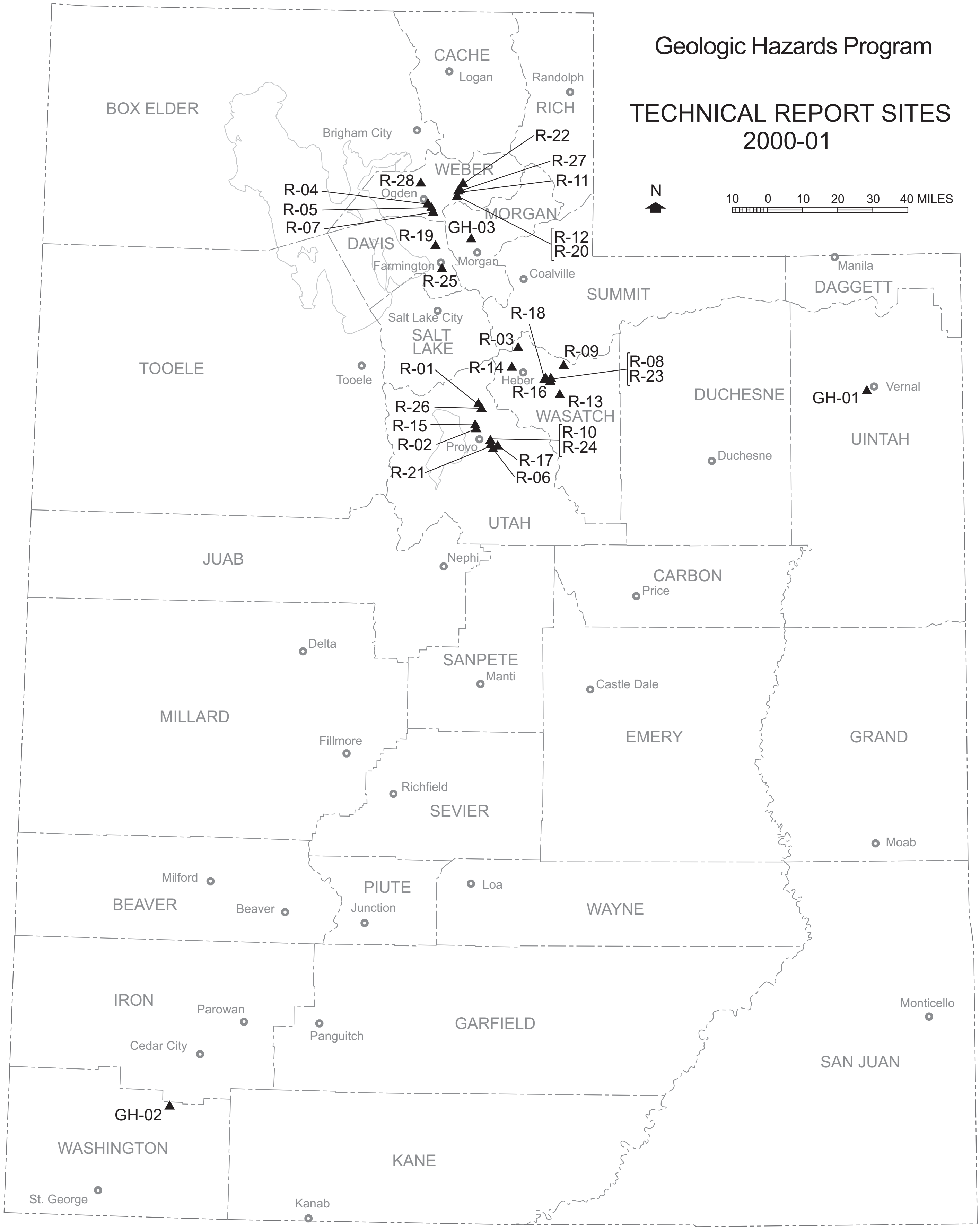

Figure 1. Locations of 2000-01 Technical Report Sites

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Illustration

GEOLOGIC HAZARDS

Utah Geological Survey

Project: Investigation of ground subsidence in a residential neighborhood in Vernal, Uintah County, Utah.			Requesting Agency: Vernal City
By: Greg N. McDonald Gary E. Christenson	Date: 6-12-00	County: Uintah	Job No: 00-07 (GH-01)
USGS Quadrangle: Vernal NE (1112)		Number of attachments: 3	

INTRODUCTION

At the request of Ken Bassett, Vernal City Manager, the Utah Geological Survey (UGS) investigated an area of ground subsidence affecting a roadway and at least two residential properties in Vernal, Uintah County, Utah. The site is in the NE1/4 NW1/4 section 28, T. 4 S., R. 21 E., Salt Lake Base Line and Meridian, in the southwest part of Vernal City on 2100 West at approximately 600 South (attachment 1). The purpose of the investigation is to assess what, if any, geologic factors may be involved in the subsidence and to make recommendations regarding the need for detailed studies to characterize the problem, determine the cause, and recommend mitigation measures. The scope of our study included a review of geologic and soil-survey maps, aerial photos, and available site-specific geotechnical studies for the area, and a site inspection on June 1, 2000. We performed no subsurface investigations.

SITE DESCRIPTION

Ground subsidence at the site has recently affected a roadway and at least two residential properties: one west (592 South) and one east (595 South) of 2100 West (attachment 1). We did not investigate adjacent properties in detail or survey the neighborhood for other damaged houses, although the neighboring property south of 595 South may also be distressed. The affected subdivision was developed and incorporated into Vernal City in the early 1980s. Underground utilities including water and sewer lines were installed along 2100 West at that time and the road was paved in the early 1990s. Aerial photos (1963) indicate that prior to development the area consisted primarily of irrigated farmland with a few roads and houses with yards. A gravel road was present along what is now 2100 West. Undeveloped parcels of land remain in the area including several acres approximately a block west of the affected site owned by the local school district.

We are not certain exactly when subsidence began to occur or when property damage was first observed. Recently (within the past few months), an underground water line connecting the main line to the house at 592 South was found to have a leak and was repaired. This line is about

5 feet deep. The timing of this leak reportedly coincided with accelerated movement of pre-existing cracks and gaps, and subsidence/cracking of the roadway, adjacent curbing, and sidewalks, as well as interior damage to the house at 595 South.

The most prominent subsidence feature is a section of 2100 West roughly 25-35 feet across that has dropped as much as a few inches from original grade in a relatively uniform manner (attachment 2). This area of collapse and associated cracks in the asphalt is relatively concentric around the asphalt patch in the road where the water line was repaired. Adjacent curbing/gutters along both sides of the street have also subsided and are low spots containing ponded water at the time of the investigation.

The two affected residential properties, 592 South and 595 South, directly west and east of the water-line repair, respectively, were briefly inspected for subsidence-related damage. The neighboring property south of 595 South and southeast of the repair, although not closely inspected, we observed as having settlement in a concrete driveway slab and a large gap beneath the garage door.

Subsidence-related damage at 592 South included cracks/gaps within a concrete driveway slab and along the front porch where it meets the house (attachment 3). The sidewalk in front of the house in the vicinity of the water-line repair, as well as a walkway leading from the driveway to the front porch, are down-dropped and tilted eastward toward the street. Sections of this sidewalk and walkway have recently been repaired (uplifted). Some cracks had been previously caulked, and this recent subsidence has separated the caulking indicating recurrent subsidence. Most gaps are about an inch or less in width while downward displacement may be as much as a few inches in places. The inside of the house was not inspected during our site visit, but no interior damage has been reported to the city.

The property at 595 South showed similar signs of exterior damage. The front porch and walkway and the back patio have all dropped a few inches and separated from the house foundation. A small crack was present in the foundation at the front of the house. Vinyl siding on the front of the house is bulging outward in two places between window frames, likely due to compression. An unusual depression is in the backyard lawn of the east property. The interior of this house showed signs of stress on the second level including a small ceiling crack, en echelon crinkles in linoleum flooring along a wall, and a skewed sliding-door frame. The house's lower level is finished/carpeted and therefore the foundation could not be inspected for cracking but, according to the homeowner, no unusual damage has been observed.

SITE GEOLOGY AND SOILS

The site is on unconsolidated deposits that gently slope about 2 degrees to the east toward the Ashley Valley. To the west approximately 2 miles are the predominantly sandstone cliffs forming Asphalt Ridge. Carrara (1980) and Rowley and others (1985) mapped deposits at the site as sand and gravel on older pediment surfaces whereas Doelling and Graham (1972) mapped them as simply alluvium. We consider them to be alluvial-fan deposits of probable Holocene tolate Pleistocene age derived from sedimentary rocks to the west, including shale, mudstone, siltstone, sandstone, and conglomerate. Water wells in the area indicate an approximate depth to rock, probably Mancos Shale, of about 80 feet (Wood, 1977).

Unpublished maps by the USDA Soil Conservation Service (1983) show two soil types near the area of subsidence. Both soils are described as loams or clay loams to depths of 60 inches or more. In 1983, the UGS (Lund, 1983) investigated an undeveloped property west of the site for the local school district (attachment 1). Two test pits were excavated and lithologically logged to about 10 feet below grade. The easternmost excavation closest to the area of subsidence revealed alluvial-fan deposits consisting of silty clay from the surface to a depth of about 1 foot, followed by a caliche horizon from about 1 to 2.5 feet, underlain by clayey sand and sandy silt-silty sand with tubular pores to the bottom of the test pit at 10.6 feet (Lund, 1983). Soils at the study site are expected to be similar in composition. None of these studies indicate highly expansive soils or soluble material such as gypsum. The depth to ground water at the site is not known, although a log for a water well about 500 feet to the west indicates a depth measurement of about 20 feet in 1993.

POSSIBLE CAUSES OF SUBSIDENCE

Based on our observations and knowledge of the area, the subsidence is most likely due to hydrocompaction of collapsible soils. Collapsible soils are low-density, relatively dry, generally fine-grained sediments with considerable dry strength that subside when they become wet for the first time since deposition (Owens and Rollins, 1990). Collapsible soils are commonly found in semiarid and arid environments where the depth of wetting is shallow and the water table is below the depth of wetting.

Geotechnical tests performed by Dames and Moore (1981) on soil samples at the Painted Hills subdivision, about 4 miles to the northwest, indicated soils with collapse potentials ranging from less than 1 to about 13 percent by volume. In addition, the 1983 UGS study of the vacant school property east of the site revealed sandy silts/silty sands containing voids (described as root holes and tubular pores) in the easternmost test pit from about 2.5 feet to the total depth of the test pit (10.6 feet). Visible voids within a soil's structure commonly indicate collapsible soils.

Subsidence due to other geologic causes, such as drying and shrinkage of clay-rich soils or dissolution of gypsum or other soluble minerals, are also possibilities, although less likely given the soil types indicated by previous studies. Similarly, subsidence caused by non-geologic causes, such as poor road construction or the use of unsuitable fill, are also possible but unlikely. Subsidence from poor road construction would not be affecting adjacent houses and would likely be less localized and extend along the road for a greater length.

Assuming the subsidence is due to hydrocompaction of collapsible soils, we must consider:

(1) What factors (lawn irrigation, underground utilities including water and sewer lines, septic-tank drain fields) have been contributing water to the subsurface in the area?

(2) What is the role of the water-line leak; that is, did the leak cause subsidence, did subsidence cause the water line to break, or both?

(3) To what depth are collapsible soils present at the site?

(4) What is the possible aerial extent of the problem?

Settlement has occurred previously as indicated by cracked caulking and earlier repairs in some of the cracks and gaps. Water leaking from the broken water line may have promoted the most recent subsidence and damage to the road given the concentric nature of the road damage around the repair, but again, the original cause of the water-line break is unknown. Some houses east of 2100 West are reportedly not connected to the sewer main due to grade restrictions which would require a pumping system. This includes the property at 595 South which uses a septic tank and drain field located behind the house, which may be contributing to settlement in that area.

RECOMMENDATIONS

Based on our limited investigation, we believe ground subsidence is most likely related to hydrocompaction of collapsible soils. Geotechnical drilling, sampling, and laboratory testing of soils in the area will be required to confirm the presence of collapsible soils. At a minimum, boreholes located within and just outside the area of subsidence should be continuously sampled and lithologically logged to depths of at least 15-20 feet below grade or to the ground-water table, whichever is encountered first. Soils collected from boreholes should be inspected by a geologist or geotechnical engineer and appropriate intervals tested for density, collapse potential, shrink-swell potential if clays are encountered, and gypsum or other soluble minerals using methods complying with ASTM standards. Once the problem soils are identified, additional work to delineate their extent will be required to define the area potentially affected by future subsidence.

Mitigation and repair efforts will depend on conclusions of the investigations above regarding the type of problem soil. In the meantime, if collapsible soils are the problem as we suspect, interim mitigation measures should be taken to minimize the amount of water infiltration to soils, especially near house foundations where substantial settlement could cause structural damage. These efforts can include landscaping requiring less watering and diversion of roof runoff and rainwater away from foundations and structures susceptible to damage from subsidence. Particular attention should be paid to water and sewer lines to detect and prevent leakage. Also, the presence of problem soils, whether they are collapsible or not, indicates that Vernal City should require geotechnical studies for future developments in the area to identify problem soils and consider them in site and building design.

REFERENCES

Carrara, P.E., 1980, Surficial geologic map of the Vernal 1 x 2 degree quadrangle, Colorado, Utah, and Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-1204, scale 1:250,000.

Dames & Moore, 1981, Report - soils, foundation, and roadway investigation, proposed Painted Hills subdivision, located near Maeser, Utah, 24 p.

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Lund, W.R., 1983, Evaluation of seven proposed school sites for the Uintah School District: Salt Lake City, Utah, unpublished Utah Geological Survey letter report, 3 p.

Owens, R.L., and Rollins, K.M., 1990, Collapsible soil hazard map for the southern Wasatch Front, Utah: Utah Geological and Mineral Survey Miscellaneous Publication 90-1, 38 p., 3 pl., scale 1:48,000.

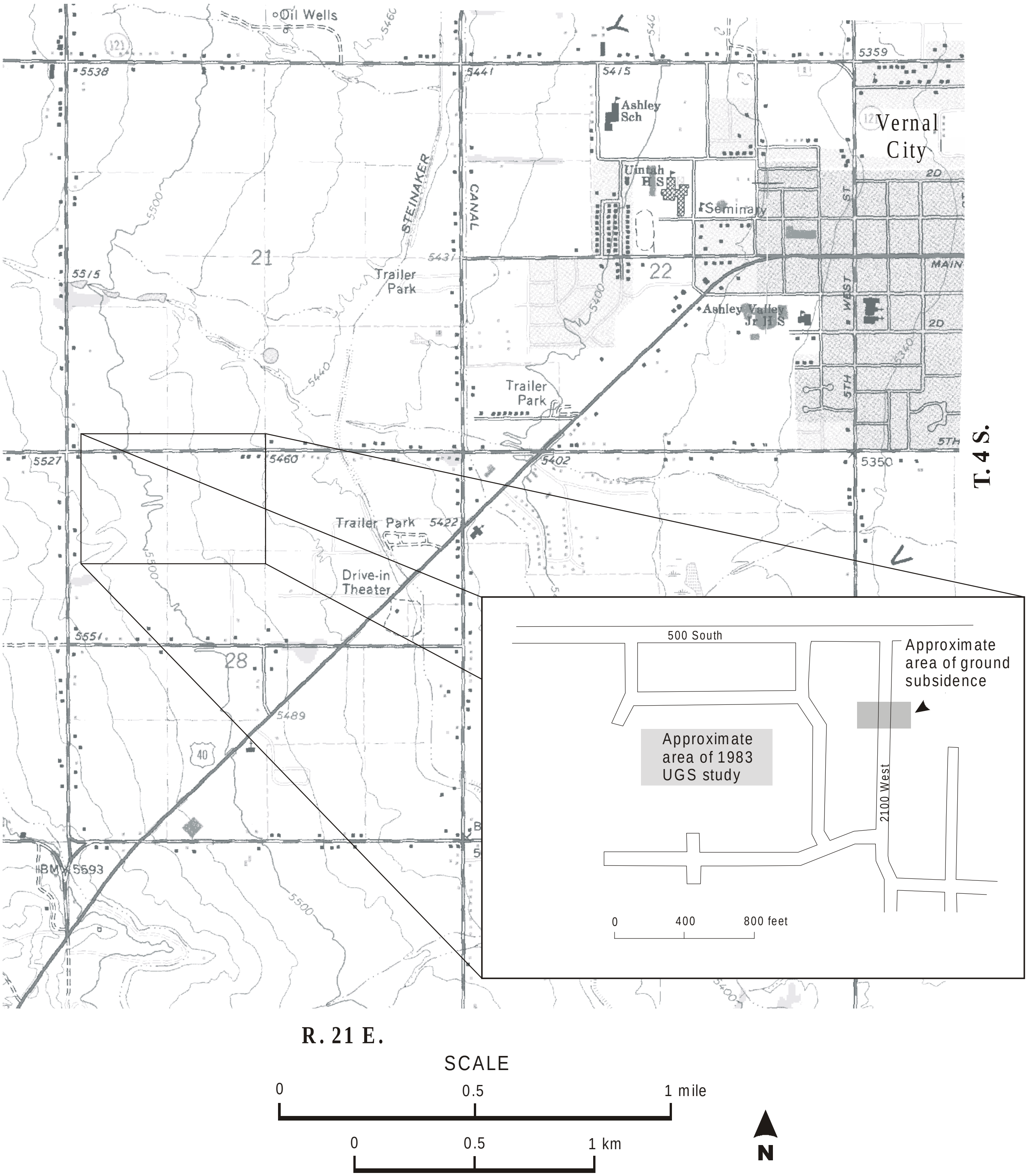
Rowley, P.D., Hansen, W.R., Tweto, Ogden, and Carrara, P.E., 1985, Geologic map of the Vernal 1 x 2 degree quadrangle, Colorado, Utah, and Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-1163, scale 1:250,000.

USDA Soil Conservation Service, 1983, Soils mapping and descriptions from selected areas in Ashley Valley: Vernal, Utah, unpublished data.

Wood, J.H., 1977, Hydrologic evaluation of Ashley Valley, northern Uintah Basin area, Utah: Utah Department of Natural Resources Technical Publication No. 54, 25 p.

Attachment 1
Job number 00-07

Base map from Vernal NE 7.5'
USGS topographic quadrangle



Attachment 1. Location and site map.

Attachment 2
Job number 00-07

Attachment 2. Subsidence-related crack along 2100 West.

Attachment 3
Job number 00-07

Attachment 3. Porch (top) and driveway (bottom) at 592 South showing cracks and eastward tilting of concrete.

Project: Possible collapsible-soil damage to a house at 55 South 3900 East, New Harmony, Washington County, Utah			Requesting Agency: Emergency Response
By: William R. Lund	Date: 08-17-01	County: Washington	Job No: 01-05 (GH-02)
USGS Quadrangle: Kolob Arch (157)		Section/Township/Range: Sec. 20, T. 38 S., R.12 W.	

INTRODUCTION AND PURPOSE

I inspected damage to a private residence at 55 South 3900 East in New Harmony, Utah on July 30, 2001. Damage included sidewalks that are cracked and pulling apart, a cracked patio, tilting of both interior and exterior concrete surfaces, some interior wall cracking, and significant subsidence and ground cracking in the back yard. The purpose of the inspection was to determine if the damage is related to geologic conditions at the site and provide recommendations.

CONCLUSIONS AND RECOMMENDATIONS

Based on the nature of the damage to the house, other evidence from the site, and the geologic setting, I conclude that the damage results from collapse-prone (hydrocompactable) soils. The site soils are derived from erosion of the Moenkopi Formation, which typically yields collapse-prone soils in southwestern Utah. Collapsible soils also derived from the Moenkopi Formation have similarly caused extensive damage to structures and infrastructure in Cedar City, approximately 15 miles to the north. Soil collapse occurs following wetting, and the source of water causing the collapse at the residence appears to be the septic tank system, which may be malfunctioning. For confirmation of the presence of collapsible soils, I recommend subsurface exploration and soil testing. If collapsible soils are present, I recommend that the septic tank be investigated as the possible source of the water causing the soil collapse.

SITE GEOLOGY

The residence is at the base of the Hurricane Cliffs just east of Exit 42 on Interstate 15 in Washington County, Utah (figure 1; NE1/4NE1/4 section 20, T. 38 S., R. 12 W., Salt Lake Base Line and Meridian). The Hurricane fault trends along the lower part of the cliffs immediately east of the house and has downdropped the red Mesozoic Moenkopi Formation such that it crops out along the lower portion of the cliffs in the area. The Moenkopi Formation consists of alternating, relatively soft beds of sand, silt, and clay that are easily eroded by wind and water. Slope wash and small debris floods and flows from minor drainages along the cliff face have carried the eroded Moenkopi material to the site. Deposited and drained quickly, the soils maintain a loose openwork structure, usually held in place by clay bonds between sand grains, until the soils are sufficiently wetted to dissolve the bonds, allowing the soil to collapse and subside. Because of southwestern Utah's arid climate and the slope on which such soils are typically deposited, collapse-prone soils can exist in nature for long periods of time (many thousands of years or longer) without collapsing. Collapse occurs only when the soils are thoroughly wetted, often as the result of human activity.

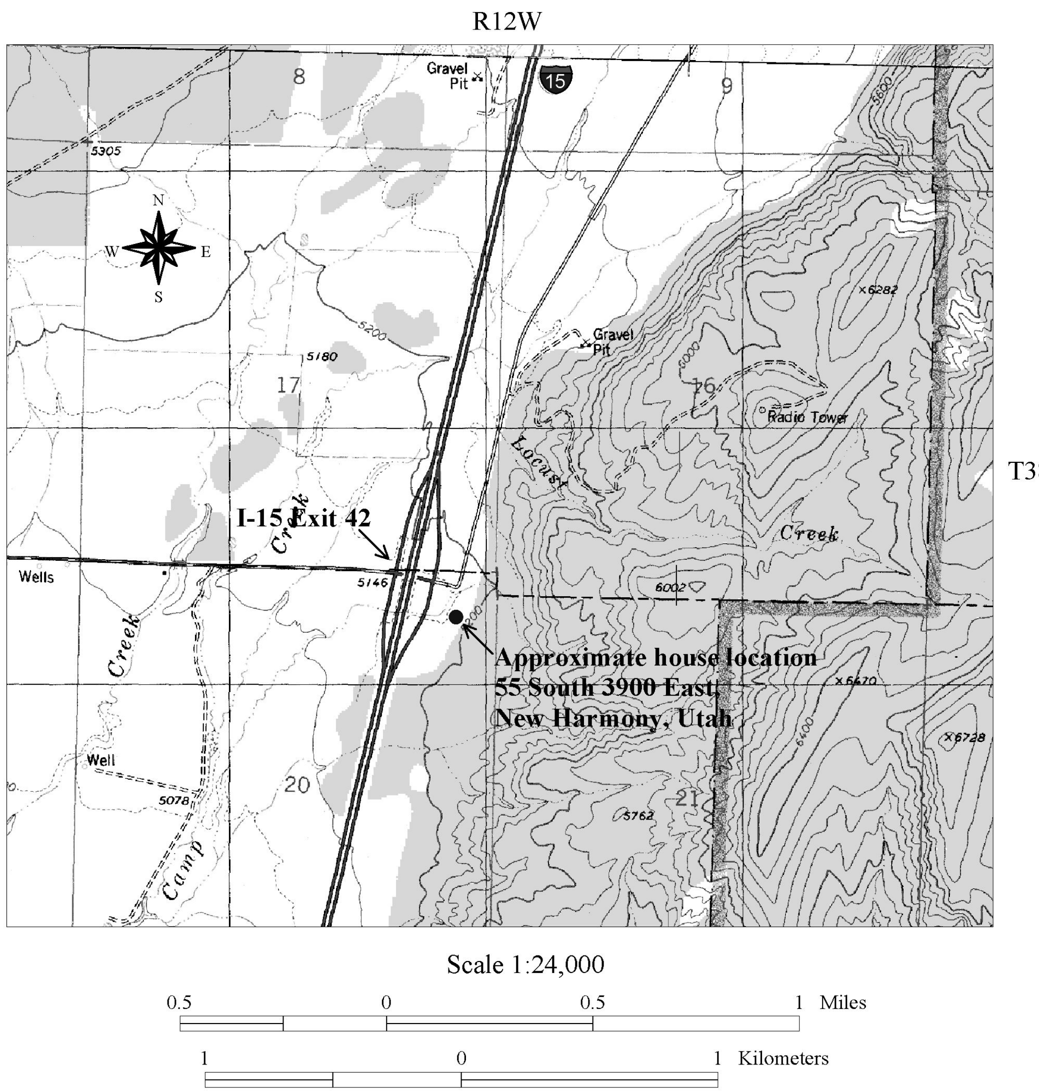


Figure 1. Approximate location of house a 55 South 3900 East, New Harmony, Utah damaged by collapsible soil (modified from U.S. Geological Survey Kolob Arch, Utah 7.5-minute quadrangle).

DAMAGE

My inspection of the house showed damage typical of that caused by collapsible soil. Exterior sidewalks and a concrete patio pad are cracked and appear to be pulling apart with the direction of movement toward the east (back of the house) (figure 2). The garage floor is cracked and also tilted to the east. According to the owner, who accompanied me on my inspection, the previous homeowner had seven concrete piers installed along the east side of the garage to remediate tilting in that area. I observed the top of one of the piers in the garage floor. The current owner stated that the company that installed the piers told her they poured five cubic yards of concrete into one of the holes drilled for a pier.

Figure 2. Pull apart between sidewalk as the slab on the left moves to east.

Inside the house, the floor of a bedroom on the east side adjacent to the garage is noticeably tilted to the east, and in a closet on the west side of the bedroom, the carpet is pulling away from the adjacent wall (figure 3), again indicating movement to the east.

Cracks in interior walls are minimal, but I observed two cracks at wall corners. Outside, on the east side of the house, I observed a large arcuate crack in the yard (figures 4 and 5) that appears to delineate an area of subsidence. At the time of my inspection, the crack was approximately 30-40 feet long, up to three inches wide, and at it's farthest point, about 30 feet from the house. The ends of the crack terminate at or near the house. Wastewater is disposed in a septic tank and drain field on the east side of the house near the center of the area of subsidence as indicated by the arcuate crack. The homeowner reported that the drain field is east of the septic tank, very near or beneath the crack. The topographic slope on the east side of the house is

Figure 3. Carpet pulling away from an interior closet wall as the concrete floor slab tilts to the east (right).

uphill to the east, placing the septic tank at a lower elevation than the drain field, unless the trenches excavated for the drain field distribution lines were sufficiently deep to allow the gradient to be reversed.

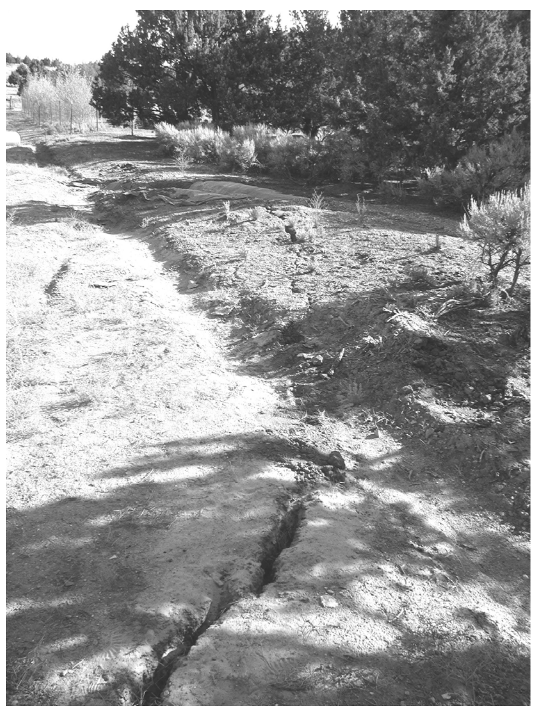


Figure 4. Crack on east side of the house, near or above the septic-tank drain field. View to the north.

Figure 5. Crack on east side of the house near septic tank. View to the northeast.

A small concrete pad next to the house and just west of the septic tank is tilted to the east toward the septic tank. The pad provides support for an air conditioning unit, and the tilting has necessitated propping up the east end (septic tank side) of the unit to prevent it from being suspended in the air by the piping that leads into the house. Immediately south of the septic tank, a concrete patio attached to the east side of the house has become suspended in the air as soil has collapsed from beneath it. My inspection showed 4 to 6 inches of free space beneath the south, east, and north sides of the patio (figures 6 and 7).

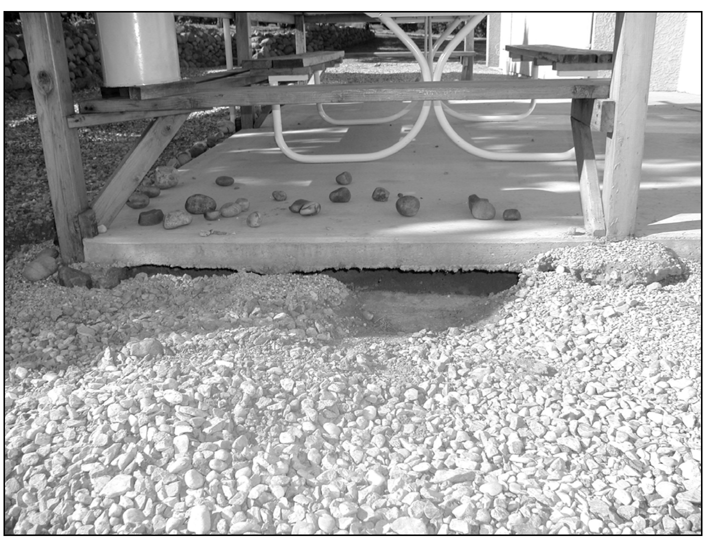


Figure 6. Void space beneath concrete patio slab due to soil collapse. View to the south.

Figure 7. Void space beneath concrete patio slab due to soil collapse. View to the west.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Based upon my inspection, I believe the damage to the house is the result of soil collapse. The collapse seems to be centered on the septic tank immediately east of the house. Collapse does not appear to be related to the drain field, and soil collapse in the vicinity of the septic tank may have reversed the gradient between the septic tank and the drain field, raising the possibility that the drain field is no longer operational. If that is the case, effluent entering the tank is likely overflowing from the tank in the subsurface, causing the soils adjacent to the house to become thoroughly wetted and collapse. I understand that culinary water lines are also on the east side of the house. If they run through the collapse area, they also may be leaking, further compounding the problem.

Because my inspection did not include subsurface exploration or soil testing, I recommend that a qualified geotechnical consulting firm test the site soils for collapse potential to confirm the source of the problem, or identify an alternative cause. If collapse-prone soils are present, I further recommend that the septic tank be investigated to determine if the gradient between the tank and the drain field has reversed causing the septic tank to leak adjacent to the house.

Project: Preliminary hazard assessment of the Frontier Drive landslide, Mountain Green, Morgan County, Utah			Requesting Agency: Emergency Response
By: Francis X. Ashland	Date: 9-4-01	County: Morgan	Job No: 01-07 (GH-03)
USGS Quadrangle: Snow Basin (1088)		Section/Township/Range: Section 23, T.5N., R.1E.	

INTRODUCTION AND PURPOSE

In late February 2001, landslide movement initiated on the west-facing slope west of Frontier Drive in Mountain Green, Utah. The landslide affected seven residential lots and abutting common-area open space and caused the most severe damage to the two lots on the south end of Frontier Drive. Utah Geological Survey (UGS) geologists conducted an initial reconnaissance of the landslide on May 8, 2001, and monitored landslide movement and ground-water levels on subsequent visits to the site. This report summarizes the conclusions of the UGS regarding the landslide hazard. In addition, the report documents site conditions, landslide features, and landslide damage.

CONCLUSIONS

Based on observations, measurements, and stability analysis of the Frontier Drive landslide, the UGS concludes the following.

- The landslide will continue to pose a threat to the residential properties along the west side of Frontier Drive south of Woodland Drive until the slide is stabilized.
- With the exception of the houses on lots 48 and 49 (6827 N. and 6815 N.), the houses on the west side of Frontier Drive appear to be adequately set back from the active main scarp zone of the landslide such that the immediate threat to the houses is low.
- If the landslide is not stabilized, additional damage to the house at lot 49 (6815 N. Frontier Drive) will likely occur and enlargement of the landslide in an upslope direction is possible, potentially endangering the houses to the north.
- Movement of the Frontier Drive landslide triggered in late February and continued through May and June.
- Movement in 2001 was a partial reactivation of a pre-existing landslide that was modified during development of the Trapper's Pointe subdivision.

- Landsliding was triggered despite near-normal precipitation prior to and during the period of movement and suggests the pre-existing landslide was marginally stable prior to hillside modifications.
- Reactivation of the remainder of the pre-existing landslide north and south of the Frontier Drive landslide is possible, particularly if hillside modifications are made.

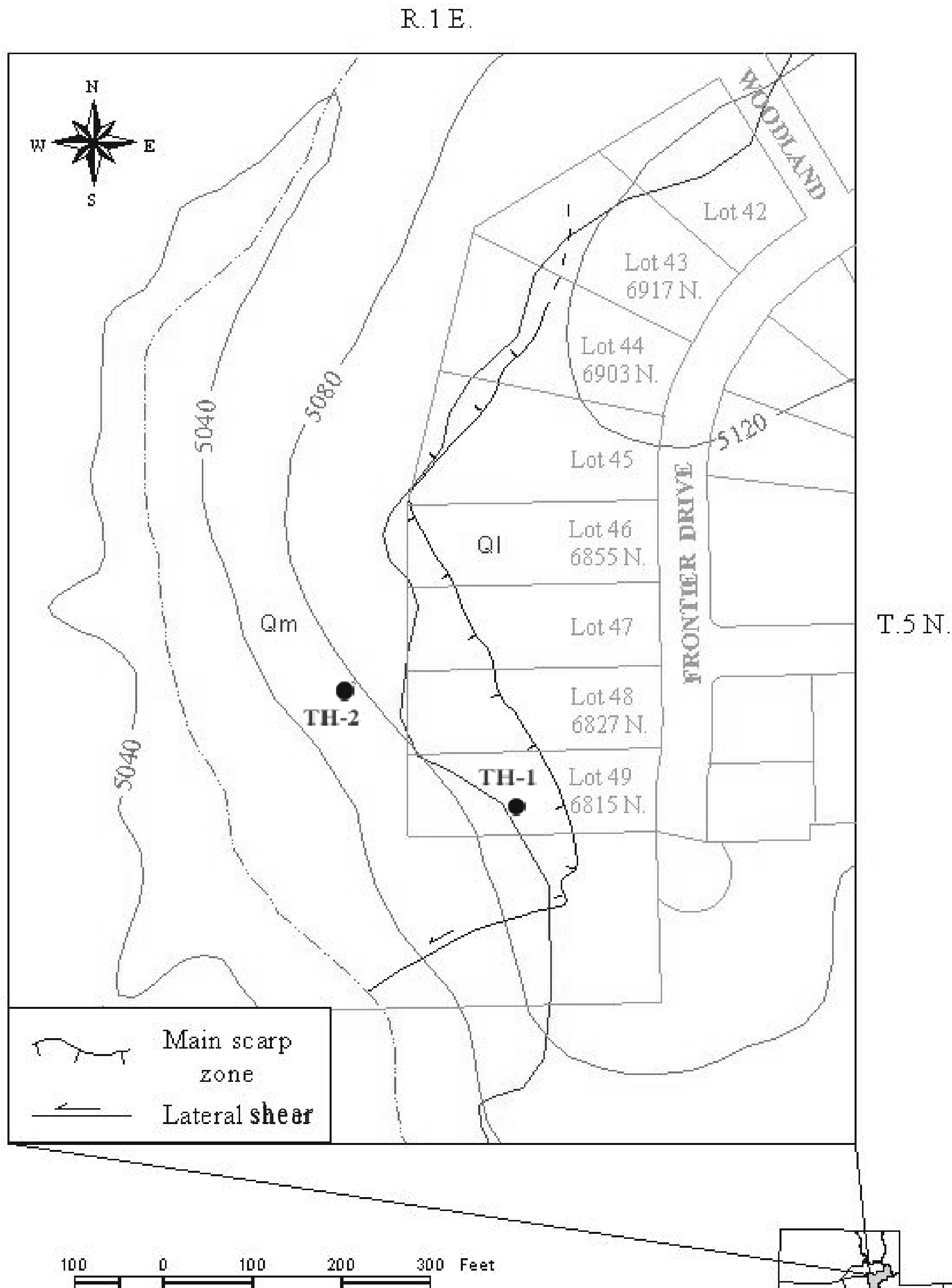
STUDY RESULTS

Landslide Description

The Frontier Drive landslide is on a generally west-facing slope between an unnamed creek on the west and the approximate crest of the natural slope on the east (figure 1). The landslide is along the western edge of the Trapper's Pointe subdivision (Landmark Surveying and Engineering, Inc., [LSE], 2001) in Mountain Green, Morgan County, and is approximately between elevations 5,020 and 5,100 feet. The main scarp of the landslide (figure 2) generally coincides with the inferred position of the natural crest of the slope prior to hillside modifications during development of the site. Locally, an individual main scarp is difficult to recognize and instead a zone of scarps and transverse ground cracks or crown cracks exists (figure 2b). The main scarp steps to the west and transitions into a ground crack with no vertical offset at the north end of the landslide (figure 2c). The ground crack does not extend downslope to the creek. Thus, the exact position of the northern boundary of the landslide is uncertain. The toe of the landslide is along the east edge of the creek at the base of the slope in the southern part of the landslide. The toe locally consists of zones of overriding thrusts that form a stair-stepped geometry in the lower slope (figure 3). The location of the toe in the northern part of the landslide is less certain. I observed probable toe-like features in the lower third of the slope in the northern part of the landslide. The southern edge of the landslide is bound by a discrete left-lateral shear.

The Frontier Drive landslide is about 800 to 1,000 feet wide (north-south) and, on average, about 300 feet long (east-west). Table 1 summarizes the landslide width measurement data. Based on these dimensions, I estimate the landslide area to be about 27,000 to 33,000 square yards. Rock was encountered beneath the landslide deposits at depths of 68 and 28 feet in two boreholes (Earthtec Testing and Engineering, P.C. [Earthtec], 2001). Assuming an average depth of about 50 feet for the landslide deposits, I estimate the landslide volume to be between approximately 440,000 and 560,000 cubic yards.

The average slope of the landslide, from the toe to the crown, ranges from about 20 to 30 percent. I determined the average slope angle in two locations south of lot 45 using the topography on the LSE (2001) plan. Table 2 summarizes average slope information for the landslide south of lot 45. I observed the slope north of lot 45 and estimated that the average slope of the landslide in that area is flatter than 23 percent.



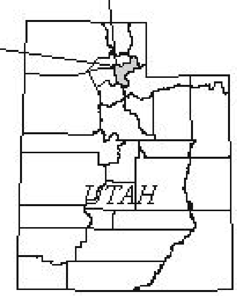


Figure 1. Location and sketch map of the Frontier Drive landslide in Mountain Green, Morgan County, Utah. The landslide is bounded on the east by a main scarp zone and on the west by an unnamed creek. The main scarp zone transitions to the north into a zone of ground cracking (dashed line). The main scarp zone roughly coincides with the contact between landslide deposits (Qm) and lacustrine deposits (Ql) of King and others (in preparation). A lateral shear bounds the landslide on the south. Earthtec (2001) boreholes TH-1 and TH-2 shown.

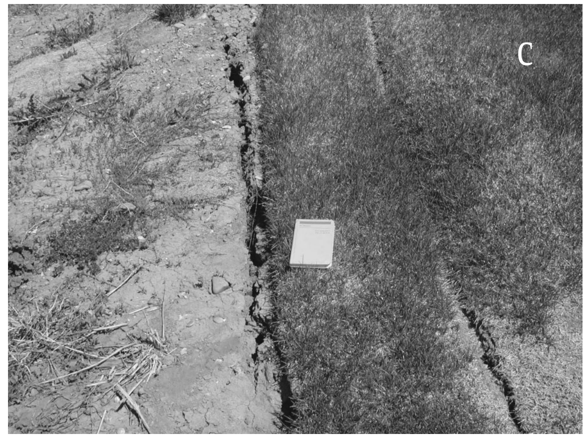


Figure 2. Main scarp zone of the Frontier Drive landslide. (a) View to the southeast of main scarp at lot 49 (6815 N.). (b) View to north of main scarp zone near lots 44 and 45. (c) View to the north of main scarp-ground cracks along west edge of lot 43.

Figure 3. Toe of the Frontier Drive landslide. Overriding thrusts form stair-stepped geometry in lower slope. View is to the northeast. Field book measures about 9 inches in height.

Table 1.
Summary of landslide width measurement data.

Source of Data	Width (feet)	Notes
UGS GPS[1] survey by G.N. McDonald	720	Minimum dimension. Main scarp zone extends north of northernmost survey point.
LSE (2001) topographic plan	625	Width of southern part of landslide south of lot 44.
Aerial photograph dated October 4, 1997	1,000	Maximum dimension. Limited features to define boundaries of 2001 landsliding.

[1]GPS = Global Positioning System.

Table 2.
Summary of average slope information.

Location	Slope (percent)	Gradient (Horizontal:Vertical)	Local Relief (feet)
Southwest of the house at lot 49	30	3.3H:1V	81
West of lot 46	23	4.3H:1V	74

The Frontier Drive landslide is a partial reactivation of a pre-existing landslide. King and others (in preparation) mapped the area west of the natural crest of the slope as landslide deposits. The eastern boundary of their landslide is similar to the trace of the main scarp zone of the Frontier Drive landslide particularly north of lot 46 (figure 1). Based on field observations and review of the September 17, 1980, aerial photograph, I believe that the crest of the natural slope is the scarp of a pre-existing landslide. This crest-line scarp extends more than 300 feet south of the Frontier Drive landslide (figure 4). The pre-existing scarp is obscured by development and grading to the north. On the aerial photograph, two arcuate scarp-like features appear east of the crest-line main scarp of the pre-existing landslide. I believe these features are small scarps or ground cracks in the crown of the pre-existing landslide. The easternmost of these features appears to be east of the lots along the west side of Frontier Drive and is about 1,400 feet long. These features appear to coincide with a subtle break in slope in the areas south of the Frontier Drive landslide, but have been removed or buried by regrading and construction of Frontier Drive. On the 1980 aerial photograph, the slope below the crest-line main scarp of the pre-existing landslide appears deformed by localized small landslides and landslide deformation features. The latter are likely associated with movement of the entire pre-existing landslide.

King and others (in preparation) map the remainder of the subdivision east of the crest of the slope as lacustrine deposits. The slope failure which formed the pre-existing landslide likely initiated after the unnamed creek incised through the lacustrine deposits into the underlying Tertiary Norwood Tuff. The surficial lacustrine deposits which were temporarily exposed in cuts south of

Figure 4. Scarp of pre-existing landslide (vegetation-covered slope on right) south of the Frontier Drive landslide. View is to the north. House in background is on lot 49 (6815 N.).

Frontier Drive consist of reddish brown, laminated clay (figure 5). Atterberg limits tests of the clay soils by Earthtec (2001) indicate the soils consist of low (CL) and high plasticity (CH) clay. The arcuate scarp-like features that appear on the September 17, 1980, aerial photograph are in the area mapped by King and others (in preparation) as lacustrine deposits. Whereas the features may be caused by landsliding, their exact origin is uncertain.

Figure 5. Exposure of laminated lacustrine clay south of the Frontier Drive landslide. Field book shown for scale.

The landslide and lacustrine deposits are underlain by the Tertiary Norwood Tuff. Two boreholes (Earthtec, 2001) encountered highly to completely weathered claystone and sandstone beneath the soil deposits. Earthtec (2001) described the uppermost rock as friable and weak. Coogan and King (2001) described the Norwood Tuff as consisting of tuffaceous siltstone and sandstone, altered tuff/claystone, and conglomerate. The lacustrine deposits were likely mostly derived from the underlying Norwood Tuff.

Damage Caused By Landsliding

Landsliding has affected seven residential lots and common-area open space west of Frontier Drive. The most damage occurred to lots 48 (6825 N.) and 49 (6815 N.). Figures 6a through 6d show some of the damage. Table 3 summarizes the building and lot damage caused by the landslide.

Figure 6. Damage caused by the Frontier Drive landslide. (a) Severed and segmented storm drain pipe downslope of lot 49. (b) Stair-stepping crack in wall of house on lot 49 (6815 N.). (c) Cracking of brick veneer of porch column of house on lot 49 caused by downslope movement (d) Damage to concrete patio or pad on lot 46 (6855 N.).

Table 3.

Summary of damage caused by Frontier Drive landslide.

Lot Number, Address or Parcel Description	Description of Damage
Storm drain pipe easement - open space parcel - common area (south of lot 49)	Storm drain pipe severed (figure 6a) and released water which caused accelerated landsliding, erosion, and perhaps earth flow. Ground surface along easement severely disrupted.
Lot 49 - 6814 N.	Main scarp zone underlies western part of house. Cracking of exterior brick walls on west and north (figure 6b) and porch column brick veneer (figure 6c), and of concrete patio. Tilting of patio and porch. Horizontal displacement of porch column. Severe disruption to ground surface in entire rear lot. Perimeter foundation drain pipe currently exposed in main scarp zone. Minor cracking inside house near structural beam.
Lot 48 - 6827 N.	Severe disruption to ground surface in western part of rear lot.
Lot 47 - Vacant	Main scarp zone crosses western part of lot.
Lot 46 - 6855 N.	Cracking, settlement, and tilting of concrete pad or patio (figure 6d). Main scarp zone crosses westernmost edge of lot.
Lot 45 - House under construction	Main scarp zone crosses near western boundary of lot. Crown cracks and incipient scarps cross recently placed fill.
Lot 44 - 6903 N.	Main scarp zone crosses western landscaped part of rear lot. Landscaping slightly disrupted. Slight offsets and cracks in lawn.
Lot 43 - 6917 N.	Transverse ground cracking along western edge of landscaped lot.
Western open space parcel - common area (lower slope)	Ground surface disrupted. Severity of disruption increases to south.

Landslide Movement

Landslide movement continued throughout the period of this investigation (May 11, 2001 through June 25, 2001). Figure 7 shows cumulative displacement (movement) for this period at six survey stations in the main scarp zone. The survey stations measure stretching (extension) across the main scarp zone. The data show movement at the four northernmost stations (on or near [west of] lots 44 through 47). Field observations suggest movement possibly occurred at the other two southern stations (on lots 48 and 49), but the measurements indicate that the movement, if any, was less than the accuracy of the measurement technique. The maximum average rate of movement declined from a slow rate in early May to a very slow rate in late June. The absence of any significant movement in the main scarp zone in the southern part of the landslide may be due to the ability of the numerous minor scarps downslope of the main scarp zone (figure 8) to accommodate movement.

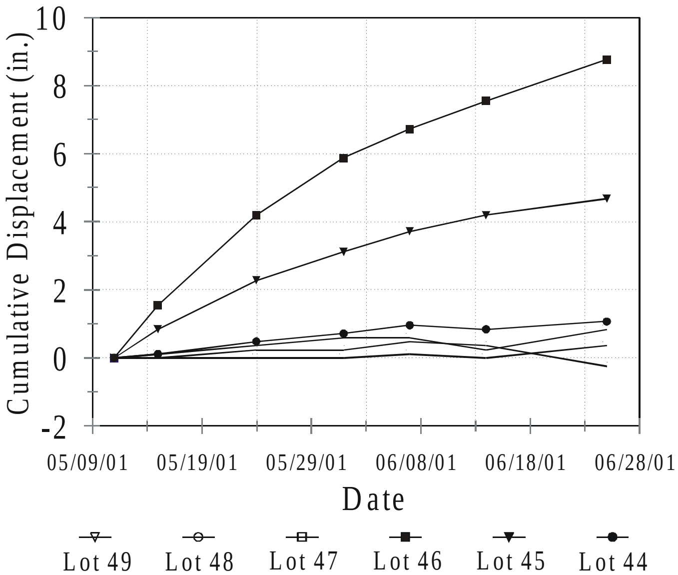


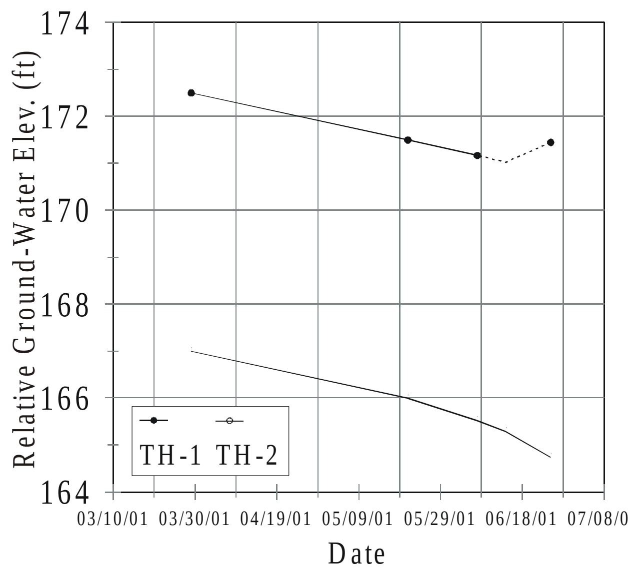
Figure 7. Cumulative displacement plot showing the amount of stretching across the main scarp zone between May 11 and June 25, 2001. Up to 8.8 inches of stretching occurred at lot 46 (6855 N.). Whereas movement continued through the period of measurement, the rate of movement decreased. Apparent movement amounts of less than a half inch are likely the result of measurement error or stake disturbance, and not landslide movement.

Figure 8. Minor scarps (in foreground below main scarp) in the upper part of the Frontier Drive landslide. View is to the east-northeast. House in background is on lot 48 (6827 N.).

Ground-Water Levels

Ground water in the slope is relatively shallow and ground-water levels declined slightly since the initial measurement by Earthtec (2001) in late March. During the measurement period (March 29 through June 25, 2001), ground water was about 18 to 19.5 feet deep in Earthtec's well TH-1 located near the main scarp zone. Ground water was less than 5 feet deep in Earthtec's well TH-2 located downslope of the main scarp and about 20 feet lower in elevation than well TH-1. Ground-water levels declined by about 1.3 to 1.5 feet between March 29 and June 25, 2001. Figure 9 shows that the rate of ground-water-level decline was relatively constant. Earthtec (2001) observed numerous seeps in the hillside in March that gradually dried up sometime after late April. Based on this observation, I infer that ground water was near or at the surface in the lower slope in March. The slight decline in ground-water levels in the lower slope was sufficient to dry up the seeps in this area. Comparison of figure 7 with figure 9 indicates that the rate of landslide movement decreased with declining ground-water levels.

Figure 9. Plot showing fluctuation in ground-water levels in two wells in the Frontier Drive landslide. Ground-water levels declined about 1.3 to 1.5 feet from March 29 to June 25, 2001. Well TH-1 is located in the main scarp zone on lot 49. Well TH-2 is located downslope of lot 48. Dashed line shows inferred level where data are lacking.



Cause of Landsliding

The Frontier Drive landslide was likely caused by hillside modifications associated with development of the Trapper's Pointe subdivision. Evidence supporting this includes the following.

- The recent movement occurred during a period of normal or slightly below-normal precipitation and was preceded by two calendar years (1999 and 2000) with below-normal precipitation.
- Although the landslide movement appears to have triggered in late February 2001 and coincides with the early part of the snowmelt, the amount of snow on the slope in February was likely significantly less than in previous wet years including 1998 (a year of numerous landslides in the Wasatch Front and adjacent canyon areas).
- Landsliding initiated only a few years after development began in the subdivision and within a year or so of hillside modifications on the west side of Frontier Drive.

In addition, the short amount of time between hillside modifications and landslide movement, including probable movement in 2000 which likely caused a break in the storm drain pipe south of ot 49 (6815 N.), suggests the pre-existing landslide was marginally stable prior to development. Based on my field observations and information provided by property owners of the affected lots, the significant hillside modifications included:

- regrading of the upper slope west of Frontier Drive and placement of fill on the head of the pre-existing landslide, which added a surcharge load,
- introduction of water-consumptive sod and vegetation and landscape irrigation, adding potential excess water to the hillside which likely contributed to a ground-water-level rise,
- construction of a perimeter drain around the house at lot 49 (6815 N.) that discharged onto the slope,
- construction of an unlined storm-water detention basin adjacent to the main scarp of the pre-existing landslide and south of the house at lot 49 (6815 N.), and
- construction of a storm drain pipe across the southern part of the landslide.

Based on the chronology of hillside modifications provided by Mr. George Sousa (2001, written communication), the property owner of lot 48 (6827 N.), and information inferred from the October 4, 1997, aerial photograph, I believe the surcharge load of the fill placed on the head of the landslide was likely the primary cause of the recent landsliding. The probable movement in the spring of 2000, an extremely dry year in northern Utah, also supports this inference. Infiltration from the detention basin and possible leakage from the storm drainpipe may have been a significant cause of the increased movement of the southern part of the landslide in 2001.

SCOPE AND METHODS

The scope of this investigation included an initial site reconnaissance on May 8, 2001, by Greg McDonald and Francis Ashland (UGS), and numerous other site visits in May and June by UGS geologists to measure landslide movement and ground-water levels. We used 2-inch square wood stakes with finish nails and a Keson fiberglass measuring tape to record movement. The estimated accuracy of the measurement technique was about 0.01 foot in May and about 0.03 foot in June. The increase in measurement error was, in part, due to minor survey stake loosening and disturbance. We measured ground-water levels using a Slope Indicator model 51543 water-level indicator. In addition, I reviewed the available published and unpublished literature for the site including geologic and landslide maps (King and others, in preparation; Harty, 1992), pre-development site investigation reports (Geo Company, 1998; CTC-Geotek, 1992), the stabilization design report (Earthtec, 2001), and other written documentation provided by Mr. George Sousa. I also reviewed aerial photographs dated September 17, 1980, and October 4, 1997. UGS review comments related to the stabilization design proposed by Earthtec (2001) are included in a letter dated June 11, 2001, to Kent Wilkerson, Morgan County.

SUMMARY OF CONCLUSIONS

The landslide will continue to pose a threat to the residential properties along the west side of Frontier Drive south of Woodland Drive until the slide is stabilized. With the exception of the houses on lots 48 and 49 (6827 N. and 6815 N.), the houses on the west side of Frontier Drive appear to be adequately set back from the active main scarp zone of the landslide such that the immediate threat to the houses is low. If the landslide is not stabilized, additional damage to the house at lot 49

(6815 N.) will likely occur and enlargement of the landslide in an upslope direction is possible, potentially endangering the houses to the north.

Movement of the Frontier Drive landslide triggered in late February 2001 and continued through the period of this investigation. Reactivation of the remainder of the pre-existing landslide north and south of the Frontier Drive landslide is possible, particularly if hillside modifications are made. Movement in 2001 was a partial reactivation of a pre-existing landslide that was modified during hillside development west of Frontier Drive. Landsliding was triggered despite near-normal precipitation prior to and during the period of movement and suggests the pre-existing landslide was marginally stable prior to hillside modifications.

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Landmark Surveying and Engineering, Inc., 2001, Topographic plan showing proposed location of land drains and fill buttress, Trapper's Pointe P.R.U.D. plat "B": Roy, Utah, scale 1:480.

REVIEWS

<table>
<tr><td colspan="3">Project:
Review of geotechnical, geologic, and preliminary design reports, Mahogany Ridge at Grove Creek, Pleasant Grove, Utah County, Utah</td><td>Requesting Agency:
Pleasant Grove City</td></tr>
<tr><td>By:
Richard E. Giraud</td><td>Date:
01-19-00</td><td>County:
Utah</td><td rowspan="2">Job No:
00-01
(R-01)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Orem (1088) and Timpanogos Cave (1129)</td><td>Number of attachments:
None</td></tr>
</table>

INTRODUCTION

At the request of Mark Sargent, Pleasant Grove City Planner, I reviewed the geologic-hazards portions of a geotechnical report by Earthtec Testing and Engineering, P.C. (Earthtec, 1999); a geologic reconnaissance report by American Geological Services, Inc. (AGS, 1999); and a preliminary design report and plans by Aqua Engineering, Inc. (Aqua, 1999a, b) for the Mahogany Ridge at Grove Creek development. The proposed development is located in the NE1/4 section 21 and NW1/4 section 22, T. 5 S., R. 2 E., Salt Lake Base Line and Meridian, Pleasant Grove, Utah. I received the reports on December 13, 1999. The purpose of this review is to evaluate if geologic hazards are adequately addressed. The scope of work for the review included a literature review and inspection of published geologic maps, Utah County geologic-hazard maps, and aerial photographs. I did not perform a site visit. Earthtec (1999) provides foundation and other geotechnical-engineering recommendations that should be reviewed by a qualified geotechnical engineer. Aqua (1999a, b) provides drainage and other civil-engineering recommendations that the Utah Geological Survey does not review.

DISCUSSION AND COMMENTS

Earthtec (1999), AGS (1999), and Aqua (1999a, 1999b) address possible hazards resulting from earthquake ground shaking, liquefaction, problem soils, shallow ground water, landslides, surface fault rupture, rock falls, debris flows, and flooding. I concur with their recommendations regarding possible hazards resulting from earthquake ground shaking, liquefaction, problem soils, and shallow ground water and provide comments regarding the other hazards below.

Regarding landslides, my main concern is with steeper slopes in the vicinity of the proposed water tank and landslide features noted by AGS (1999). Baker and Crittenden (1961) and Baker (1964) map slide-prone Manning Canyon Shale north and south of the site, and Great Blue Limestone, which also contains shale beds, east of the site. Machette (1992) maps younger landslide deposits (Holocene to upper Pleistocene) north and south of the site, which coincide with areas of Manning Canyon Shale. Woodward-Clyde (1980) also mapped younger landslides south of the site between Grove Creek and Battle Creek Dams. The presence of landslides in the area indicates that the potential for landslides within and adjacent to the site should be addressed. AGS (1999) describes, but does not map, landslide features east of the existing Grove Creek water tank. AGS (1999) and Earthtec (1999) provide no discussion of potential slope-stability problems related to the Manning Canyon Shale or other slide-prone units in the area. Clay was encountered in test pit 10 (Earthtec, 1999) at the proposed water tank at 5,320 feet elevation (Aqua, 1999b), which is above the elevation of Lake Bonneville clays. Earthtec (1999) does not discuss the origin of this clay (whether it may be related to a weathered slide-prone shale or a landslide feature described by AGS (1999)) in test pit 10. AGS (1999) recommends a slope-stability analysis of the lower mountain slopes, and Earthtec (1999) performed a preliminary slope-stability analysis in the area of the proposed water tank. Because AGS (1999) does not show the location or describe the geologic setting (slope, soil type and/or bedrock unit, ground-water conditions) of the landslide features and Earthtec (1999) does not document conditions used in their slope-stability analysis, I cannot determine whether static and dynamic (earthquake) slope stability are adequately evaluated. Therefore, I recommend that such supporting information, as outlined in Hylland (1996), be presented to demonstrate the adequacy of the evaluation. The evaluation must determine if shallow landslide-prone bedrock, or soil derived from it, underlies steep slopes at the proposed water tank site. If such material is present at shallow depths, appropriate material strengths must be used in the slope-stability analysis.

Earthtec (1999) provides recommendations for temporary cuts but not for permanent cuts and fills. On the grading plan, Aqua (1999b) shows cuts and fills along the water-tank access road steeper than 2H:1V (50 percent). The Uniform Building Code (UBC) (International Conference of Building Officials, 1997) does not allow permanent fill slopes steeper than 2H:1V (50 percent), and only allows steeper cut slopes if the soil engineer or engineering geologist indicates the slopes are stable. If road or any other permanent cuts are steeper than 2H:1V (50 percent), their stability must be addressed.

AGS (1999) states that the Salt Lake City Aqueduct is constructed on or parallel to the westernmost trace of the Wasatch fault, and the aqueduct right-of-way will provide an adequate setback from the fault. This may be true, but no supporting map showing the fault location in relation to the right-of-way and proposed building sites was provided to show setback distance and demonstrate that it is appropriate. The entire subdivision is within the Utah County fault-rupture overlay zone (Robison, 1990). Within this zone, site-specific studies are recommended to identify faults and determine appropriate setbacks from active faults. I recommend that this western fault be mapped in relation to the aqueduct to demonstrate the right-of-way is an adequate setback from the fault. On the northern portion of the site, where the fault is buried by the alluvial fan (Machette, 1992) and not expressed as a scarp, lots on the projected trace (lot 1, plat C and lot 4, plat B) will probably need to be trenched. Also, the proposed water tank is near the eastern fault trace (Machette, 1992) which AGS (1999) considers the main trace of the Wasatch fault. Because water tanks are critical facilities, a fault investigation (trenching) of the footprint and a reasonable distance beyond to account for setbacks from possible faults outside the footprint will need to be performed.

AGS (1999) identified a rock-fall hazard east of the site but did not recommend any risk-reduction measures. Earthtec (1999) recommends "cobbles and boulders be removed from the slope or be broken into small pieces" to prevent rocks from rolling downslope, but provides no discussion of how this is to be done or who is responsible. Such details must be defined in order for the recommendation to be effective. However, because AGS (1999) indicates the source area is within the Wasatch National Forest, the above recommendation may not be possible so other alternatives to reduce the rock-fall hazard, such as constructing an appropriately sized rock-fall catchment structure, may need to be considered.

AGS (1999) states that the debris-flow hazard is "low" but does not define a "low" hazard in terms of magnitude and frequency. I agree with AGS (1999) that the Grove Creek debris basin will mitigate the sedimentation hazard associated with Grove Creek. However, AGS (1999) does not discuss the sedimentation hazard from the small drainage east of the site which has deposited an alluvial fan (Machette, 1992) in the northern portion of the development. The proposed development is within the Utah County debris-flow hazard overlay zone (Robison, 1990), where studies are recommended to evaluate the sedimentation hazard. I recommend evaluation of the sedimentation hazard in the part of the development underlain by this alluvial fan, including determination of whether past sedimentation events were debris flows.

In addition to the sedimentation hazard from the small drainage basin east of the site, surface-water runoff associated with rapid snowmelt or intense rainfall may cause alluvial-fan flooding in the subdivision. Aqua (1999a) estimated the 100-year peak flood discharge for the Grove Creek drainage basin but only designs for a 10-year peak discharge for the basin east of the site. The 100-year alluvial-fan-flooding potential from the basin east of the site was not considered. Aqua (1999a) plans to route flood flows from the basin east of the site through the subdivision. Therefore, I recommend evaluating the alluvial-fan-flooding hazard using at least the 100-year peak discharge to determine subdivision areas that could be inundated by the 100-year flood. Both FEMA (1999) and the National Research Council (1996) provide guidance for evaluating alluvial-fan flooding. Regarding hazard-reduction measures, steps taken to reduce the sedimentation hazard can usually also reduce the alluvial-fan-flooding hazard to acceptable levels.

RECOMMENDATIONS

Regarding the Earthtec, AGS, and Aqua assessments of geologic hazards at the site, I recommend the following:

- Provide supporting geologic information, including computer slope-stability output plots, to demonstrate adequate evaluation of slope stability for the proposed water tank. If slide-prone bedrock, or soil derived from it, is present at shallow depths, appropriate material strengths must be used in the slope-stability analysis.

- Allow no permanent fill slopes steeper than 2H:1V (50 percent) and address the stability of any permanent cut slopes steeper than 2H:1V (50 percent) as required by the UBC.

- Provide supporting geologic information to demonstrate that the aqueduct right-of-way is an adequate setback for surface fault rupture for the proposed building sites, and provide geologic information to demonstrate evaluation of the surface-fault-rupture hazard at the proposed water tank.

- Determine if the rock-fall hazard-reduction recommendation is acceptable to the U.S. Forest Service, and if so, recommend a mechanism to carry it out. If not, consider other alternatives such as constructing an appropriately sized rock-fall catchment structure.

- Evaluate the sedimentation and alluvial-fan-flooding hazards in the north portion of the development on the small alluvial fan. The evaluation must define areas of active deposition (post-Bonneville alluvial fans) and flooding; estimate the type, frequency, and volume of flows; define travel paths and flow depths in relation to the proposed development; and recommend hazard-reduction measures, if necessary.

- Have foundation and other geotechnical-engineering recommendations reviewed by a qualified geotechnical engineer.

- Disclose the existence of the Earthtec, AGS, and Aqua reports, subsequent reports, and this review to future buyers.

Many of these recommendations result from the need to do a detailed site-specific geologic study, including large-scale geologic mapping of faults and landslides, and inspection and geologic logging of test pits, rather than a "Geologic Reconnaissance" as indicated in the title and by the scope of the AGS (1999) report. Also, studies by the three independent consultants must be coordinated such that all concerns and site-design issues are adequately addressed by the appropriate consultant(s). A lack of coordination is evidenced by AGS (1999) describing landslide features east of the Grove Creek water tank but Earthtec providing no discussion of these in their slope-stability analysis in that area. Another example is Aqua (1999) showing cuts and fills steeper than 2H:1V along the proposed water-tank access road but Earthtec (1999) addressing only the stability of temporary cuts and not these steeper permanent cuts and fills along the road.

Any setbacks, hazard areas, and protective structures determined from the above hazard evaluations must be shown on the site map to delineate buildable areas. Specific recommendations and restrictions pertaining to the site and buildings should be included in the report. All conclusions and recommendations must be supported by quantified data and presented in the report so a technical reviewer can evaluate their validity. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer. Also, Pleasant Grove City should provide a means to ensure that final recommendations are followed; one way to do this is to require the developer to submit written documentation from the consultants indicating that their recommendations have been followed.

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Project: Review of "Geologic and geotechnical investigation, Kaufer parcel, 1550 East 1950 North, Provo, Utah"			Requesting Agency: City of Provo
By: Richard E. Giraud	Date: 01-20-00	County: Utah	Job No: 00-02 (R-02)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

At the request of Dave Graves, Provo City Project Engineer, I reviewed a geologic and geotechnical investigation for the Kaufer parcel by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 1996). The site is located at 1550 East and 1950 North in Provo, Utah, in the E1/2NW1/4 section 32, T. 6 S., R. 3 E., Salt Lake Base Line and Meridian. I received the report on December 22, 1999. The purpose of this review is to evaluate if geologic hazards are adequately addressed. The scope of work for the review included a literature review, inspection of published geologic maps, Utah County geologic-hazard maps, Provo City geologic-hazard maps, and aerial photographs. I did not perform a site visit. AGEC (1996) provides foundation and other geotechnical-engineering recommendations that should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND COMMENTS

AGEC (1996) addressed possible hazards resulting from surface fault rupture, earthquake ground shaking, slope stability, rock fall, problem soils, and shallow ground water. I concur with their recommendations regarding earthquake ground shaking, slope stability, problem soils, and shallow ground water, and provide comments on surface fault rupture and rock fall. I also provide comments on sedimentation and alluvial-fan-flooding hazards that were not addressed.

AGEC (1996) states that mapping (presumably Machette, 1992) indicates a fault along the eastern property boundary is buried by Lake Bonneville deposits and is therefore inactive. Further, AGEC (1996) finds no evidence of surface fault rupture in test pits, but does not discuss the extent of their independent site investigations for the site. The proposed subdivision is within the Utah County fault-rupture overlay zone (Robison, 1990) and within this zone, site-specific studies are recommended to assess the impacts of faulting. Site-specific investigations include detailed field investigations to identify fault scarps, followed by trenching of fault scarps as necessary to locate faults and determine appropriate setbacks. In the AGEC study, the test pits are not located to evaluate faulting, so the lack of faulting in test pits is not conclusive. Machette's (1992) mapping is small-scale, and must be confirmed by site-specific study. Lund and Black (1998, figure 3) show faulted Lake Bonneville deposits on trend with the “buried” fault about 600 feet to the north. AGEC must clarify the extent of their investigations for surficial evidence for faulting, and if scarps are present they must be trenched to locate faults and determine appropriate setbacks.

AGEC (1996) identified a rock-fall hazard from slopes east of the site and states the computer modeling indicates that rock clasts could travel onto lot 1 and the northern half of the road east of the proposed development. Supporting information for the hazard analysis is not provided, so I cannot determine if the rock-fall hazard is adequately evaluated and if suggested risk-reduction measures are appropriate. Also, no supporting discussion was included of rock-fall deposits at the base of the slope, the size and distribution of rock-fall clasts, and if the computer model was calibrated with observed rock-fall runout patterns and distances. I recommend providing information supporting the conclusions and recommendations from the rock-fall-hazard evaluation.

Runoff from the steep drainages east of the subdivision, associated with rapid snowmelt or intense rainfall, may produce sedimentation (debris flows and debris floods) and alluvial-fan flooding events. AGEC (1996) did not address these hazards. The subdivision is within the Utah County debris-flow hazard overlay zone (Robison, 1990), where studies are recommended to evaluate the sedimentation hazard. Machette (1992) maps young fan alluvium (Holocene to uppermost Pleistocene) on the south portion of the site. Based on the Provo City geologic-hazard maps (International Engineering Company Inc., 1984) and my analysis of aerial photographs, I believe deposits of young alluvium are also present in the northern portion of the site. AGEC (1996) does not discuss the geologic origin of gravels at the site (for example, whether they are debris-flow/alluvial-fan deposits, hillslope colluvium, or Lake Bonneville deposits), but describes boulders up to approximately 4 feet in size that may be related to sedimentation events. Because these young alluvial deposits indicate a potential for flooding from drainages east of the site, I recommend evaluating the sedimentation and flooding hazard. The sedimentation and flooding hazard evaluation must define areas of active sediment deposition (post-Bonneville alluvial fans) and flooding; estimate the frequency, volume, and types of flows; define travel paths; estimate flow depths; and recommend mitigation measures. FEMA (1999) and the National Research Council (1996) provide guidance for evaluating erosion and flooding on alluvial fans. Mitigation measures, if necessary, can be incorporated into the subdivision drainage plan to ensure that sediment-laden water and flood flows are conveyed to designated collection areas.

RECOMMENDATIONS

Regarding the AGEC assessment of geologic hazards at the site, I recommend the following:

- Provide information indicating that an adequate investigation of surficial evidence for scarps or other fault-related features has been performed. If scarps are present they must be trenched to locate faults and determine setbacks.

- Provide information supporting the conclusions and recommendations of the rock-fall-hazard evaluation. The supporting information must define source areas, travel paths, deposit areas, runout distances, and bounce heights, and demonstrate that proposed risk-reduction measures are appropriate.

- Evaluate the sedimentation and alluvial-fan-flooding hazards from drainages east of the site. In relation to the proposed development, the evaluation must define areas of active sediment deposition (post-Bonneville alluvial fans) and flooding; estimate the type, frequency, and volume of flows; define travel paths; estimate flow depths; and give design specifications and locations for proposed mitigation measures.

- Have geotechnical-engineering recommendations reviewed by a qualified geotechnical engineer.

- Disclose the AGEC report, subsequent reports, and this review to future buyers.

Any setbacks, hazard areas, and protective structures determined from the above hazard evaluations must be shown on the site map to delineate buildable areas. Specific recommendations and restrictions pertaining to the site and buildings should be included in the report. All conclusions and recommendations must be supported by quantified data and presented in the report so a technical reviewer can evaluate their validity. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer. Also, Provo City should provide a means to ensure that final recommendations are followed; one way to do this is to require the developer to submit written documentation from the consultants indicating that their recommendations have been followed.

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Project: Review of "Letter report, slope stability analysis, proposed Deer Mountain Resort housing community, phase III, Township 2S, Range 5E, sections 5, 7, and 8, SLB&M, northeast of Jordanelle Reservoir, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 01-21-00	County: Wasatch	Job No: 00-03 (R-03)
USGS Quadrangle: Park City East (1209)		Number of attachments: None	

INTRODUCTION

In response to a request from Al Mickelsen, Wasatch County Planning Director, I reviewed the slope-stability analysis for the proposed Deer Mountain Resort housing community, phase III, by AGRA Earth and Environmental, Inc. (AGRA, 2000). I received the report on January 7, 2000. Deer Mountain phase III is in sections 5, 7, and 8, T. 2 S., R. 5 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether AGRA (2000) adequately addressed the potential for landslides on phase III. My scope of work included a review of published geologic and geologic-hazards mapping (Bromfield and Crittenden, 1971; Hylland and Lowe, 1995) but I did not inspect the property.

DISCUSSION

AGRA initially addressed the landslide hazard at the proposed Deer Mountain development in a preliminary geotechnical/engineering-geology study (AGRA, 1998). Anthony Kohler, Wasatch County Assistant Planner (verbal communication, November 15, 1999), requested that I review the portion of that report related to landslides and slope stability, and indicated that development was only being considered for the area referred to in figure 2 of AGRA (1998) as "the proposed 'lower terrace' development area." This area includes only the gentle slopes in the southwest part of the Deer Mountain development which range from about 15 percent to 20 percent. Hylland and Lowe (1995) map this area with a low relative landslide hazard based upon the absence of known landslides and the presence of gentle slopes. In my review (written communication to Al Mickelsen, November 17, 1999) I indicated that I agreed with AGRA (1998) that landslides did not pose a significant hazard for the area. However, I indicated that prior to development of steeper slopes, a further evaluation of the landslide hazard should be conducted.

Phase III generally coincides with the proposed 'lower terrace' development area, but includes lots to the east that are on steeper slopes which range from about 25 percent to 30 percent. Hylland and Lowe (1995) map these slopes with a moderate relative landslide hazard, and AGRA (1998, figure 5) maps three “possible ancient landslide scarps” upslope of the eastern edge of phase III. AGRA therefore conducted additional studies of the landslide hazard that are summarized in their most recent report (AGRA, 2000).

AGRA (2000, p. 9) concludes that no significant hazards related to instability of natural slopes exist at the proposed Deer Mountain development. This conclusion is based on their quantitative analysis of slope stability along three profiles (two on the gentle western slope and one on the steeper upslope area to the east). The slope-stability analysis uses data from three test pits and three boreholes in the vicinity of the profiles. I believe AGRA (2000) used reasonable estimates of soil parameters in their analysis and modeled slope stability under a wide range of conditions that may be expected to occur on the site. These conditions include both dry and saturated (to depths of from 5 to 10 feet) soil, shallow and deep bedrock, and static and earthquake loading. AGRA (2000) calculated minimum factors of safety ranging from 1.98 to 5.18 under static loading and from 1.0 to 2.43 under earthquake loading.

AGRA (2000) also investigated the three “hollows” on the eastern edge of the property, initially identified in AGRA (1998) as three “possible ancient landslide scarps,” and collected data on the orientation of bedrock discontinuities. AGRA (2000) found shallow bedrock throughout the area and postulates five different possible origins for the hollows, including the possibility of “extremely ancient” landsliding. AGRA (2000) found no consistent orientation of bedrock discontinuities, but noted that most discontinuities do not dip downslope.

CONCLUSIONS AND RECOMMENDATIONS

I believe that AGRA has adequately assessed the potential for landslides at Deer Mountain phase III, and agree with their conclusion that no significant landslide hazard exists. The slope-stability analyses in AGRA (2000) assume a wide range of slope conditions, all resulting in factors of safety that meet or exceed acceptable levels (1.5 under static loading and 1 under earthquake loading), indicating that site slopes are stable. These conditions include those that are consistent with AGRA’s field observations of soil type and thickness, ground-water depth, and nature of bedrock discontinuities, and reasonable variations that account for uncertainties. Although the possibility of ancient landsliding is not totally discounted in AGRA (2000), the variety and results of slope-stability analyses in the report suggest that the landslide-hazard potential is low on phase III slopes regardless of the scenario postulated by AGRA (2000) for the origin of the three hollows along the eastern edge of the development.

To ensure slope stability, I recommend that the developer:

- Provide an engineered design for retaining walls; the design must include a site map and slope profile showing cuts, fills, and retaining walls, consider static and earthquake ground-shaking conditions, and incorporate pertinent drainage recommendations; and

- Address cut-slope stability in accordance with the Uniform Building Code (International Conference of Building Officials, 1997, Appendix Chapter 33, section 3312) for any proposed permanent cuts with slopes steeper than 2H:1V (50 percent) that are not supported by retaining walls.

Wasatch County should have these designs reviewed by a qualified geotechnical engineer, as appropriate, and provide a means to ensure compliance with final recommendations. To accomplish this, the County should require the developer to submit written documentation from the consultant indicating that their recommendations were followed.

REFERENCES

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Project: Review of "Surface fault rupture hazard and engineering geology study, proposed Shadow Brook subdivision, west ½ of section 14, Ogden, Utah"			Requesting Agency: Ogden City
By: Richard E. Giraud	Date: 02-15-00	County: Weber	Job No: 00-04 (R-04)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

INTRODUCTION

At the request of John Mayer, Ogden City Planner, I reviewed a surface-fault-rupture and engineering geology study by AGRA Earth and Environmental, Inc. (AGRA, 1999) for the Shadow Brook subdivision in Ogden, Utah (W1/2 section 14, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian). I received the report on January 14, 2000. The purpose of this review is to evaluate if geologic hazards were adequately addressed. The scope of work for the review included a literature review and inspection of published geologic maps, Weber County geologic-hazard maps, and aerial photographs. I did not conduct a field inspection of the property.

DISCUSSION AND COMMENTS

AGRA (1999) addressed possible hazards resulting from earthquake ground shaking, surface fault rupture, slope instability, debris flows, and flooding. I concur with their recommendations regarding earthquake ground shaking and slope instability (assuming the recommendation in the last paragraph, page 7, has typographical errors, and all "1H:1V" are intended to be "2H:1V"). I provide comments on fault setbacks, debris-flow and related sedimentation hazards, and stream and alluvial-fan flooding.

AGRA (1999) provided recommendations for locating habitable structures away from active faults, and I concur with their recommendations except for those on lot 3. AGRA's trench T-2 does not extend far enough northeast to encounter the projected trace of the westernmost fault. Therefore the area between the trench and the projected fault location is unevaluated. AGRA's evaluation is adequate if the building footprint on lot 3 does not extend northeast of trench T-2; however, if the building footprint extends east of the trench, I recommend trenching to evaluate this unexplored area.

AGRA (1999) indicates a "low to very low" debris-flow/debris-flood hazard from Burch Creek based on an estimated recurrence interval and presumed sufficient sediment storage behind structures in and near the channel. AGRA (1999) estimates an average post-Lake Bonneville debris-flow/debris-flood recurrence interval of 2,000 years from deposits in trench T-3 at lot 5. This recurrence may apply only to larger volume flows that affect the upper lots (4 and 5) above the fault scarp; smaller volume and probably more frequent flows have formed a young alluvial fan on the lower lots (1, 2, and 3) below the fault scarp. Because individual sedimentation events rarely cover the entire alluvial-fan surface, a recurrence interval at one point on the fan does not accurately reflect the overall frequency of events on the fan, and hazard-evaluation decisions should not be based on such single-location recurrence-interval calculations. Similar issues were addressed at the Grey Stone (formerly Burch Creek Estates) subdivision to the south which is on the same young alluvial-fan deposits as the lower Shadow Brook lots. AGRA (1996) considered debris flows "unlikely" at Grey Stone, but the Utah Geological Survey (Ashland, 1997) recommended further evaluation of debris-flow and alluvial-fan-flooding hazards.

AGRA (1999) does not compare the sediment storage capacity of in- and near-channel structures (Ridgedale Drive road embankment and catchment basin) with the expected volume of future debris flows/debris floods to demonstrate adequate hazard reduction. Also, AGRA (1999) does not discuss if these structures are engineered to safely route, capture, and store sediment and water associated with a sedimentation event. A structure not engineered as a dam or retention structure may be eroded and contribute sediment to the flow. AGRA (1999) states that a proposed driveway crossing lot 3 will be sufficient to deflect debris flows/debris floods back into the channel but does not consider if the driveway will deflect flows onto lot 16 of the Grey Stone subdivision.

I recommend the debris-flow/debris-flood hazard be re-evaluated using quantified data. The evaluation must define areas of active sediment deposition; estimate the frequency, volume, and types of flows; define travel paths; estimate flow depths; and recommend mitigation measures where appropriate. Historical records of debris flows along the Wasatch Front show that debris flows and related sedimentation events are highly variable in terms of size, material properties, and behavior; therefore I recommend that conservative design volumes be used in hazard evaluation and that conservative design approaches be used where risk reduction is necessary.

Despite their assessment of a "low to very low" debris-flow/debris-flood hazard, AGRA (1999) provides hazard-reduction recommendations for the house on lot 1, but their recommendations are confusing. AGRA (1999) recommends that concrete basement walls extend 4 feet above the existing grade with no windows or doors on the north and west sides of the structure. However, I believe their intent is to provide structural and flood protection on the northeast and southeast sides of the house (the sides of the house facing the creek), since Burch Creek flows southwest and is southeast of lot 1 (figure 2, AGRA, 1999). Windows should probably be avoided in all basement walls for protection from flood and sedimentation events. For AGRA's design to be effective, flow depths must not exceed 4 feet and the basement walls must be able to withstand the impact pressure exerted by a debris flow/debris flood. Use of this design to reduce the hazard to the house still requires the clean up of sediment from the lot and city streets following a debris-flow/debris-flood event, and other lot structures and city infrastructure may be damaged. If this proposed mitigation measure for the house on lot 1 is acceptable to Ogden City, I recommend an evaluation of anticipated impact pressures and flow depths to ensure that the house on lot 1 is adequately designed.

The Federal Emergency Management Agency (FEMA) has mapped a 100-year flood inundation area (zone A2; FEMA, 1983) along Burch Creek one-half mile downstream of the site. The FEMA mapping does not extend east to the Shadow Brook subdivision. However, based on the FEMA mapping downstream, a 100-year flood inundation area likely exists upstream along Burch Creek which borders the southern edge of the subdivision, particularly lots 1 and 3. The subdivision may be subject to alluvial-fan flooding in addition to stream flooding where Burch Creek emerges from its incised channel. AGRA (1999) comments on flood inundation areas and flow behavior but their comments are not based on quantified hydrologic data. I recommend that the areas of stream and alluvial-fan flooding be determined based on quantified data to determine if the proposed subdivision is outside of the 100-year inundation areas or if flood risk-reduction measures are needed. FEMA (1999) and the National Research Council (1996) provide guidance for evaluating erosion and flooding on alluvial fans. In general, steps taken to reduce debris-flow and sedimentation hazards can also reduce the stream and alluvial-fan-flooding hazards to acceptable levels, so these hazards should be analyzed together.

RECOMMENDATIONS

Regarding the AGRA assessment of geologic hazards at the site, I recommend the following:

- If the house footprint on lot 3 extends northeast of trench T-2, the unexplored area must be trenched for faulting.
- Re-evaluate the debris-flow and sedimentation hazard using quantified data. The evaluation must define areas of active sediment deposition; estimate the frequency, volume, and types of flows; define travel paths; estimate flow depths; and recommend mitigation measures where appropriate. If existing and proposed structures are considered to reduce the debris-flow/debris-flood hazard by storing sediment or deflecting flows, their capacities and heights must be evaluated relative to a design volume and flow depth. Also, existing structures must be shown to be capable of safely routing, capturing, and storing sediment.
- If the design of the house on lot 1 to withstand debris flows/debris floods is acceptable to Ogden City, evaluate the anticipated debris-flow/debris-flood impact pressures and runup to ensure the house is adequately designed to withstand a design sedimentation event.
- Evaluate stream and alluvial-fan flooding using quantified data to determine 100-year inundation areas and the need for flood risk-reduction measures.
- Disclose the AGRA report, subsequent reports, and this review to future buyers.

Any setbacks, hazard areas, and protective structures determined from the above hazard evaluations must be shown on the site map to delineate buildable areas. Specific recommendations and restrictions pertaining to the site and buildings should be included in the report. All conclusions and recommendations must be supported by quantified data and presented in the report so a technical reviewer can evaluate their validity. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer, as appropriate. Also, Ogden City should provide a means to ensure that final recommendations are followed; one way to do this is to require the developer to submit written documentation from the consultants indicating that their recommendations have been followed.

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Utah Geological Survey

Project: Review of two geologic-hazard reports for two lots in the Spring Loop subdivision, Weber County, Utah			Requesting Agency: Weber County Planning Commission
By: Francis X. Ashland	Date: 04-12-00	County: Weber	Job No: 00-05 (R-05)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

INTRODUCTION

At the request of Jim Gentry,Weber County Planning Commission, I reviewed two geologic-hazard reports by LGS Geophysics Inc. (LGS) (2000a, b) for separate but adjacent proposed residential lots in the Spring Loop subdivision, Weber County, Utah. The two lots are in the NW1/4 section 25, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The lots are along Bybee Drive and west of the Weber Aqueduct. Lot 1 and the majority of lot 2 are within the limits of the former proposed Spring Creek Estates subdivision (Great Basin Engineering, Inc., 1982), for which Chen and Associates, Inc. (1980) addressed geologic hazards and made subdivision-scale hazard-reduction and design recommendations. The Chen and Associates, Inc. (1980) report was reviewed by the Utah Geological Survey (UGS) in 1982 (Gill, 1982). The purpose of the present review is to determine whether LGS provides adequate information on which to base decisions for final site approval, design, and residential development at the two lots. The scope of my evaluation consisted of a review of available engineering-geologic reports and maps (see references), but did not include a site reconnaissance. The UGS received the two reports on March 20, 2000. Supplemental site topography information was requested and received on March 29 and 31.

DISCUSSION

The LGS (2000a, b) reports addressed the potential for surface fault rupture, earthquake ground shaking, flooding, soil erosion, landsliding, and debris flows as potential geologic hazards at the lots. The reports indicate no evidence for flooding, debris flows, or landsliding at the lots. The reports confirm the presence of two active fault traces (scarps) in the vicinity, but indicate that neither of these fault traces crosses or is within 50 feet of the lots. The reports make general recommendations related to reducing erosion during construction and damage resulting from earthquake ground shaking. Published geologic-hazard maps (Lowe, 1988a, b; Nelson and Personius, 1993) indicate the absence of Holocene alluvial fans or active fault traces of the Wasatch fault zone on the lots. The Chen and Associates (1980) report indicates a generally east-west-trending probable (secondary) fault (concealed or inferred) crosses the lots. Chen and

Associates (1980) mapped pre-Lake Bonneville, but no Holocene-age, debris-flow deposits in the vicinity and northern part of lot 2. Yonkee and Lowe (in preparation) mapped a prehistorical landslide in the vicinity of lot 2, although landslide deposits were not identified at the site in the LGS (2000b) report. The Yonkee and Lowe (in preparation) map indicates the landslide extends downslope to about elevation 4,800 feet, and thus, may underlie most of lot 2. The relation of this potential landslide to the site and its stability should be further investigated.

The LGS (2000b) report indicates that a potentially unstable 20-foot-high road cut exists near the northwest corner of lot 2. The report describes the slope of the road cut to be about ½ H:1 V and thus, it exceeds the cut-slope design recommendations (maximum slope 1.5 H:1 V) in the Chen and Associates, Inc. (1980) report. The height of the road cut is in the range for which the Chen and Associates, Inc. (1980) report recommends slope-specific investigation and design. The LGS (2000b) report indicates a seep at the base of the road cut which could potentially undercut soils and cause shallow landsliding. The report also concludes that such landsliding would only impact "a small, undevelopable portion of the lot," but does not define the dimensions or specific location of this area or the conditions that preclude development in this part of the lot. I recommend that development setbacks be established for this area based on the original slope recommendations in the Chen and Associates, Inc. (1980) report, until adequate permanent slope-stabilization measures are made.

The LGS (2000a) report describes "steep fill slopes" along Bybee Drive and the northeast edge of lot 1. Although the specific slope angle is not indicated, the slope description in the LGS (2000a) report suggests it does not conform to recommendations in Chen and Associates, Inc. (1980) (maximum fill slope 2 H:1 V). If such is the case, I recommend that the fill slope on or abutting the lot be regraded in conformance to the Chen and Associates, Inc. (1980) recommendations prior to site development. Alternatively, the potential impact of the fill slope on lot slope stability should be assessed by a qualified geotechnical engineer.

Site topography indicates that relatively steep slopes, locally exceeding 100 percent, exist at lot 2. Residential development at this site may require significant cut and fill slopes. In such a case, site-specific cut- and fill-slope plans should be reviewed by a qualified geotechnical engineer and conform to the recommendations in the Chen and Associates (1980) report or to site-specific design recommendations provided by the developer's engineer. I also recommend the city require a letter from the design engineer documenting slope-related construction conforms to design recommendations. The possible existence of a landslide, as suggested by recent mapping (Yonkee and Lowe, in preparation), in any proposed cut or fill areas should also be determined through subsurface investigations prior to final site design. If landslide deposits are identified in proposed cut or fill areas, their geotechnical characteristics and stability may need to be quantified for use in final design. Based on soil types, the stability of natural slopes greater than 30 percent should also be assessed.

The seep at the base of the road cut described in the LGS (2000b) report indicates the potential for shallow perched ground water at the lots. I recommend that a geotechnical engineer provide a perimeter drain design based on review of the LGS (2000b) report and the Chen and Associates, Inc. (1980) perimeter drain recommendation.

The possibility of significant ground deformation exists between active fault traces (Gill, 1982). Accordingly, Chen and Associates, Inc. (1980) showed a probable secondary fault trace crossing the two lots and recommended excavation inspections in the vicinity of such faults to identify small faults with potentially damaging offsets. I concur with this recommendation for these two lots and strongly suggest the foundation excavations be inspected by a qualified engineering geologist prior to construction or the issuance of a building permit, in accordance with county regulations. I recommend that the engineering geologist submit a letter report indicating the presence or absence of faults along with any recommendations, as necessary, prior to construction at the lots. The developer and contractor must understand that these inspections may necessitate relocation of a building site or abandonment of a lot, so they should allow for this possibility in the construction scheduling, and may wish to dig a trench beforehand to eliminate this uncertainty.

RECOMMENDATIONS

Regarding the Spring Loop subdivision and my review of the AGS (2000a,b), Chen & Associates (1980), and other available information, I make the following recommendations.

- The existing road cut on lot 2 should be modified so that it conforms to Chen and Associates, Inc. (1980) permanent cut-slope recommendations.

- The fill slope along lot 1 should be modified so that it conforms to Chen and Associates, Inc. (1980) fill-slope recommendations.

- A qualified geotechnical engineer should assess subsurface conditions and provide cut- and fill-slope and perimeter-drain recommendations for lot 2. The engineer should provide documentation to the city that construction was in accordance with design.

- Subsurface investigations should determine the presence or absence of landslide deposits on lot 2, and be used to assess the stability of natural slopes greater than 30 percent.

- Building excavations should be inspected by a qualified engineering geologist to determine whether faults with significant offsets are present. The geologist should submit a report documenting the excavation inspection and, as necessary, summarizing recommendations.

Finally, I recommend disclosure of the LGS (2000) and Chen & Associates (1980) reports, this review, and any subsequent geologic-hazard reports to future lot and/or home buyers.

REFERENCES

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Utah Geological Survey

Project: Review of "Geotechnical study, lots 1 through 33, plat J, East Mountain development, Provo, Utah"			Requesting Agency: Provo City Engineering Department
By: Francis X. Ashland	Date: 04-20-00	County: Utah	Job No: 00-06 (R-06)
USGS Quadrangle: Springville (1046)		Number of attachments: None	

INTRODUCTION

At the request of David J. Graves, Provo City Development and Project Engineer, I reviewed geologic-hazard aspects of a report by Earthtec Testing & Engineering, P.C., (Earthtec) entitled "Geotechnical study, lots 1 through 33, plat J, East Mountain development, Provo, Utah,"and dated March 21, 2000. Two supplemental reports were included as appendices to the Earthtec (2000) report: an American Geological Services, Inc. (AGS) (2000) report addressing site geology and geologic hazards including surface fault rupture, and an LGS Geophysics Inc. (LGS) (2000) report describing the results of geophysical surveys at the site. The proposed residential development is in the NW1/4 section 21, T. 7 S., R. 3 E., Salt Lake Base Line and Meridian in the southeast part of Provo City near Ironton and the intersection of Mountain View Drive and Alaska Avenue. The purpose of this review is to assess whether adequate information is provided on which to base decisions for final site approval, design, and residential development. The Utah Geological Survey received the report on April 3, 2000. No site inspection was performed for this review.

GEOLOGIC HAZARDS

The Earthtec (2000) and supplemental AGS (2000) reports identify surface fault rupture, earthquake ground shaking, landslides, rock falls, debris flows, collapsible soils, liquefaction, and flooding as potential geologic hazards at the proposed development. This appears to be a complete list of potential geologic hazards at the site and the reports provide a reasonable and complete assessment of the majority of these potential hazards. My review comments focus on the tension cracks described in the AGS (2000) report, particularly their potential relation to either earthquake- induced landsliding or collapsible soils, and debris-flow- and flood-hazard mitigation.

Significance of the Tension Crack Zone and Possible Collapsible Soils

The AGS (2000) report identifies at least nine tension cracks across an approximately 215-foot-wide zone in a trench excavated as part of the on-site investigations. Both the Earthtec (2000) and AGS (2000) reports conclude that these cracks resulted from "an adjustment...due to ground shaking during an earthquake." Whereas this is a plausible interpretation, the magnitude of the deformation justifies further consideration of these features.

My preliminary tabulation of the crack separation described in the AGS (2000) report indicates that between 31 and 60 inches (2.6 to 5 feet) of extension occurred across the zone. Thus, I estimate the total stretch (the ratio of the final zone length to the original zone length [l_f/l_o]) to be between 1.01 and 1.02. The impact of this extension on a building foundation can be estimated by multiplying the stretch by a typical foundation width. For a 40-foot-wide house, extension exceeding 9 inches could occur if the deformation that formed the tension crack zone was repeated.

The potential for damaging ground deformation indicates the need for either further geologic investigation and/or assessment of the need for engineered, reinforced building foundations. I believe further geologic studies are necessary because:

- the conclusion of Earthtec's slope-stability analysis that the hillslope is stable during earthquake ground shaking is apparently inconsistent with the implied "movement" within the clay or silt layers during the "adjustment" of the alluvial-fan deposits (AGS, 2000),

- the extent of the tension crack zone is unknown, and

- the association of "pinhole" soil texture described in boreholes TH-2 and TH-4 and test pit TP-4, which suggests possible collapsible soils, and the tension cracks has not been explored.

Further geological investigation may be inconclusive because of the difficulty in determining the cause of the tension cracks. Such investigations would, however, delineate the extent of the ground cracking which would be useful in determining which lots might be affected. Determination that the cracks extend from alluvial-fan deposits into on-site lacustrine soils would, in my opinion, favor an earthquake-induced cause for the tension cracks. The proximity of the tension cracks with areas of "pinhole" soil texture would suggest an association with collapsible soils. Although the Earthtec (2000) and AGS (2000) reports state that no collapsible soils were encountered in their investigations, such soils are not always apparent from field observations alone and require laboratory soil testing to identify. Laboratory consolidation testing of soils with "pinhole" texture would confirm the presence or absence of collapsible soils at the site, and, if present, help quantify the amount of settlement (collapse) to be expected, regardless of whether it is caused by wetting or ground shaking. However, the exact cause of the tension cracks may be elusive even if an association with collapsible soils is found because the tension cracks could still be the result of earthquake-induced collapse.

Debris-Flow-Hazard Mitigation

The Earthtec (2000) report recognizes two separate debris-flow deposits on the site and concludes that the potential for impact to the site from flooding and/or debris flows is moderate to high, and I concur. Earthtec recommends a hydrologic analysis to determine flood volumes and the construction of detention, retention, or control structures to protect proposed buildings. In general I concur with these recommendations, but I believe they are not specific enough, nor does the Earthtec (2000) report explain the potential impacts of these recommendations to the proposed development. The Earthtec (2000) report suggests the possibility of diverting floods or debris flows. Whereas it may be possible to divert these to an on-site location, the Earthtec (2000) report indicates that private property abuts the proposed development. Thus, diversion to offsite locations may not be feasible.

RECOMMENDATIONS

In my opinion, the magnitude of extension across the tension crack zone is a concern, and I recommend further geologic investigation to, at a minimum, determine the extent of the zone on the site, and if possible obtain more information on its cause. In addition, I recommend that a structural engineer review the available data to determine if reinforced foundation designs could reduce potential damage from future ground deformation. I believe that Earthtec's conclusion that the ground cracking was caused by earthquake ground shaking is reasonable, but it is not the only possibility. If the ground cracking and extension is earthquake induced, I believe it is reasonable to assume an occurrence at least as frequent as surface fault rupture on the nearby Provo segment of the Wasatch fault zone, for which the city requires hazard-reduction measures. Thus, the hazard from ground cracking and extension should be reduced also.

I believe that the Earthtec (2000) and AGS (2000) studies overlooked the possible association of the "pinhole" texture in subsurface soils and alluvial-fan setting in part of the site with collapsible soils. I recommend laboratory testing of the soils described as having "pinhole" texture to determine whether they are collapsible. The absence of collapsible soils at the site would eliminate this as a possible cause for the tension cracks. If collapsible soils are found, design recommendations to prevent or withstand collapse must be given.

Finally, detailed drawings showing locations and designs of proposed debris-flow and flood-hazard mitigation measures should be completed. The designs should incorporate information from both the recommended hydrological investigation and debris-flow volumes based on further investigations. I recommend that debris-flow-hazard mitigation measures consider not only the volumes of mapped debris flows but also the potential volumes based on drainage area, slope, and existing upstream sediment load.

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Earthtec Testing and Engineering, P.C., 2000, Geotechnical study, lots 1 through 33, plat J, Eastern Mountain Development, Provo, Utah: Orem, Utah, unpublished consultant's report, 25 p.

LGS Geophysics Inc., 2000, Results of geophysical investigations at the East Mountain Development site, Provo Utah: Salt Lake City, Utah, unpublished consultant's report, 2 p.

Project: Review of geotechnical and surface-fault-rupture-hazard reports for the proposed Uintah water tank (reservoir), Weber County, Utah			Requesting Agency: Weber County Planning Commision
By: Francis X. Ashland	Date: 06-19-00	County: Weber	Job No: 00-08 (R-07)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

INTRODUCTION

At the request of Kevin Hamilton, Weber County Planning Commission, I reviewed geologic-hazard aspects of a geotechnical report (Earthtec Testing & Engineering [Earthtec], 1999) and a surface-fault-rupture-hazard report (Terracon, 2000) for a proposed municipal water tank (reservoir) for the town of Uintah in Weber County, Utah. The proposed water tank site is north of Bybee Drive in the SW1/4 section 24, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The site is partly occupied by an existing water tank that has insufficient capacity for current municipal needs. The purpose of the review is to determine whether geologic hazards that could affect the proposed water tank are adequately identified and addressed. The scope of my evaluation consisted of a review of aerial photographs and available engineering-geologic reports and maps (see references); a site reconnaissance on May 4, 2000; and a subsequent inspection of the Terracon trenches on May 24, 2000. This technical report was reviewed by Gary E. Christenson and Michael D. Hylland of the Utah Geological Survey. I received the Earthtec (1999) report on May 2, 2000, and the Terracon (2000) report on June 9, 2000.

GEOLOGIC HAZARDS

The Earthtec (1999) report identified potential earthquake and landslide hazards at the site. Potential earthquake hazards include ground shaking, liquefaction, and surface fault rupture. Other potential hazards at or near the site include lateral spreading (Lowe, 1988b) and problem (moisture-sensitive) soils (Chen and Associates, Inc., 1980).

Earthquake Ground Shaking

The Earthtec (1999) report correctly indicated that the site is in seismic zone 3 of the 1997 Uniform Building Code (UBC) (International Conference of Building Officials, 1997). I recommend consideration of possible topographic effects on ground motion (Bouchon, 1973; Frankel and others, 1999) because the tank is a critical facility located on a narrow ridge that may be subject to more intense ground shaking during a large earthquake than if located on a flatter site. One way to reduce this risk is to upgrade the design of the water tank to meet UBC seismic zone 4 criteria. Earthtec also conservatively characterized the UBC soil profile type as S_E, based on the average soil penetration resistance (*N*) of the upper 21.5 feet of the soil column at the site. The use of the average *N* from shallow boreholes (less than 100 feet deep) is generally considered a conservative method of characterizing seismic site response (the influence of near-surface soils on earthquake ground shaking) (Ashland and Rollins, 1999).

Liquefaction

The Earthtec (1999) report indicated that liquefaction of shallow soils is unlikely because the soils to a depth of 21.5 feet were unsaturated at the time of the subsurface investigation. The borehole, however, was drilled in August 1999, a period of below-normal precipitation and seasonally declining ground-water levels in undeveloped areas. The absence of shallow ground water in August does not preclude its presence at other times of the year or during wet years. The presence of phreatophytes, specifically Russian olive trees, indicate, at a minimum, seasonally perched ground water. The depth of the Earthtec borehole is inadequate to assess deeper liquefaction which could contribute to future landsliding at the site. The Terracon (2000) report indicated no evidence of liquefaction features in the trenches excavated at the site.

Surface Fault Rupture

Earthtec (1999) identified the proposed tank site within and near the western border of the Weber County surface-fault-rupture sensitive-area overlay zone (Lowe, 1988a). Nelson and Personius (1993) mapped a north-trending antithetic fault trace of the Wasatch fault zone south-southeast of the site. My review of aerial photographs suggested the trace may continue farther north than as mapped by Nelson and Personius (1993). Thus, the steep slope directly east of the site may be the scarp of the antithetic fault. Based on the presence of the site in the Weber County surface-fault-rupture sensitive-area overlay zone, I recommended to Mr. Greg Seegmiller, acting Uintah Engineer, that a surface-fault-rupture investigation be conducted at the site. The subsequent investigation by Terracon (2000) addressed this potential hazard.

The Terracon (2000, figure 4) report identified three separate secondary faults or fault zones at the site. In addition, I identified a fourth fault in a temporary excavation east of the existing tank during my site reconnaissance on May 4, 2000. This excavation was filled with spoils from the trenches during the Terracon investigation on May 24, 2000. The three main faults identified by Terracon underlie the proposed water tank and have individual vertical offsets of about 9 to 10 inches. A total vertical offset of about 12 inches occurs across a zone of faulting about 5 feet wide associated with the fault in the southwestern part of the proposed tank. Terracon (2000) estimated the total vertical offset in the southern part of the proposed tank to be about 22 inches. Based on the consistent down-to-the-east-northeast offsets of the three faults, Terracon believed that they are related to antithetic faulting and infers the antithetic fault exists beneath the slope directly east of the site, and I concur. The fourth fault that I identified in the temporary excavation east of the existing tank had a down-to-the-west offset of slightly more than one inch.

Landsliding/Lateral Spreading

The Earthtec (1999) report indicated that no visible evidence of landsliding exists in the vicinity of the tank site based on a visual inspection of the site. Earthtec indicated that the Weber County slope-failure inventory map (Lowe, 1988b) shows that a potential prehistorical lateral spread underlies the site; however, Earthtec performed no subsurface investigations to confirm whether lateral spreading had occurred at the site. More recent mapping of the area (Yonkee and Lowe, in preparation) shows the site to be underlain by in-place lacustrine soils and does not indicate prehistorical lateral spreading at the site. Other recent mapping by the U.S. Geological Survey (Nelson and Personius, 1993) indicated the site may possibly be underlain or bounded on the west by landslide deposits. Terracon (2000) did not interpret displacements in the trenches as evidence of landsliding or lateral spreading at the site, and I concur.

The stability of existing slopes, including a cut slope above the proposed and existing water tank, is also addressed in the Earthtec (1999) report. Earthtec's analysis indicated that the existing slopes have a low factor of safety with respect to landsliding under static conditions and may fail during an earthquake. Earthtec's slope-stability analysis used reasonable soil shear-strength parameters and seismic coefficient, but assumed dry conditions which may not exist at all times at the site. On the basis of its analysis, Earthtec recommended a building setback of 20 feet from the crest of the lower slope below the proposed tank and flattening of the existing cut slope above the tank. Earthtec's slope-stability analysis indicated suitable factors of safety under static and pseudostatic (earthquake) conditions if these site improvements are made. Mr. Gregory Seegmiller, project engineer for Jones & Associates, indicated that it may not be feasible to flatten the cut slope as recommended by Earthtec. Mr. Seegmiller indicated to me in a verbal communication (May 1, 2000) that physical-mitigation measures have subsequently been proposed by Earthtec as an alternative method to stabilize the cut slope. I requested written documentation of these mitigation measures from Mr. Seegmiller, but I did not receive any information in time for this review.

Earthtec's (1999) assessment of landsliding primarily focused on the stability of the south-facing cut slopes. The distinct narrow ridge on which the tank is proposed has moderate to steep slopes on both the east and west as well. The western slope has been mapped as a landslide scarp (Nelson and Personius, 1993) and surficial soils west of the site as landslide deposits. I observed active soil creep in an existing cut slope along Bybee Drive at the residential lot directly west of the site. Whereas the Terracon (2000) investigation revealed no obvious landslide deformation features in the trenches, as stated in its report, the trenches did not extend beyond the property boundary into the landslide scarp area. Additionally, landslide hazards may exist in the eastern slope which may have formed partly as the result of antithetic faulting (Terracon, 2000) and along which Spring Creek flows at its base. I observed a small shallow landslide in a cut in this slope above a private access road beneath the proposed tank site. In Earthtec's assessment of the stability of the south-facing slopes it considered earthquake-induced acceleration of the soil mass. In addition, if an antithetic fault underlies the eastern slope, the slope geometry may be modified during surface fault rupture by the formation of a small steep scarp in the lower part of the slope. The potential and extent of landsliding on the east slope from a combination of likely earthquake-induced conditions should also be considered.

Problem Soils

Geologic mapping (Lowe, 1988c; Nelson and Personius, 1993; Yonkee and Lowe, in preparation) indicates alluvial-fan deposits in the vicinity of the site. Alluvial-fan and other valley-margin deposits may contain moisture-sensitive soils. A Chen & Associates, Inc. (1980) report identified both expansive and collapsible soils on the property abutting the tank site on the east, although I do not know which deposits contain the problem soils. The Terracon (2000) investigation revealed the proposed tank foundation is underlain by deltaic deposits which are unlikely to exhibit significant moisture-sensitive properties.

CONCLUSIONS AND RECOMMENDATIONS

In my opinion, the surface-fault-rupture hazard has been adequately characterized at the site, but landsliding and problem-soils require further assessment. Based on my review of these reports, I recommend the following.

- The design structural engineer should review the Terracon (2000) report to determine the feasibility of accommodating the documented fault displacements in the foundation design, and provide the county with a letter report either presenting the engineer's conclusions regarding the proposed reinforced foundation design or recommending an alternate site.
- A qualified engineering geologist should inspect the tank excavation to determine if additional faulting is present that may require a change in design.
- Final site and slope design data and drawings should be submitted to the county and evaluated with respect to Earthtec's 20-foot lower-slope setback and upper-slope physical-mitigation recommendations.
- The stability of slopes east and west of the tank should be evaluated, including possible steepening of the slopes by faulting (east slope) or landsliding (west slope), and the effects of ground shaking and liquefaction in lower slopes or at depths greater than 21.5 feet below the pad.
- Earthtec should review available site and nearby soil information, including the Chen & Associates (1980) report showing the presence of moisture-sensitive soils in the vicinity, to evaluate the potential for moisture-sensitive, and particularly collapsible, soils in the tank foundation.

Finally, I encourage the design engineers who will evaluate and make a final conclusion regarding the suitability of this site for the proposed water tank to recognize the uncertainties inherent in characterizing geologic conditions. In my opinion, the available information is still incomplete, primarily because access to adjacent private property was not possible as part of the site investigations. Conditions immediately adjacent to the site, such as the potential for landslide scarps and faults, may in the future impact the performance of the proposed tank. The County may wish to require a risk assessment for potential impacts on abutting and downstream properties in the event of a tank failure. The assessment should also consider potential impacts to water users in the town of Uintah, including the lack of fire suppression capabilities in the event of a more regional disaster such as a large earthquake along the Weber segment of the Wasatch fault zone.

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-----1988b, Slope-failure inventory map, Ogden quadrangle: Weber County Planning Commission unpublished map, scale 1:24,000.

-----1988c, Debris-flow hazard special study zone map, Ogden quadrangle: Weber County Planning Commission unpublished map, scale 1:24,000.

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Yonkee, W.A., and Lowe, Mike, in preparation, Geologic map of the Ogden quadrangle, Utah: Utah Geological Survey Map, scale 1:24,000.

Project: Review of "Follow-up geotechnical examination of lots 1321 & 1412 and environs, Timber Lakes Estates, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 07-20-00	County: Wasatch	Job No: 00-09 (R-08)
USGS Quadrangle: Center Creek (1126)		Number of attachments: None	

INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report for Timber Lakes Estates lots 1321 and 1412 by D.A. Hedderly-Smith (2000b). I received the report on July 13, 2000. The geotechnical report includes an appendix by Intermountain GeoEnvironmental Services, Inc. (IGE), describing the results of a slope-stability analysis of the lots. The lots are in the N1/2 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Hedderly-Smith (2000b) adequately addressed the potential for landslides on the lots, for which a certificate of zoning compliance is sought. My scope of work included a review of published geologic-hazards literature and aerial photographs (1987, 1:40,000 and 1999, 1:8,220) but I did not inspect the property.

DISCUSSION

The lots lie partially within the buffer zone surrounding a landslide special-study area designated by Wasatch County, and a small part of lot 1321 lies within the special-study area itself. This special-study area was established to ensure that slope stability is evaluated prior to development on lots within a landslide mapped by consultant William Klauber (1995). The buffer zone accounts for the uncertainty of the landslide boundary with respect to lot boundaries due to map scale and landslide-mapping accuracy. Thus, an important element of lot-specific geologic studies required in special-study areas and buffer zones is to accurately map the landslide boundary to determine its relationship to the lots.

An earlier reconnaissance geological examination of the lots (Hedderly-Smith, 2000a) did not map the landslide boundary. In my review of the earlier study (Solomon, 2000), I recommended mapping of the landslide boundary, and this subsequent study (Hedderly-Smith, 2000b) fulfills this recommendation. Hedderly-Smith (2000b) demonstrates that the landslide does not extend onto either lot 1321 or 1412, and the stability of the landslide is not relevant to the stability of slopes on the two lots.

Solomon (2000) also recommended that the stability of steep on-site slopes be evaluated even if the lots are not on the landslide. Hedderly-Smith (2000b) includes slope-stability analyses conducted by IGE using PCSTABL5 that demonstrate the relative stability of on-site slopes under a variety of conditions. Analyses were conducted along two profiles, one across each lot. The slope-stability analyses conducted by IGE were performed along each profile assuming an upper layer of coarse-grained colluvium overlies volcanic bedrock (Tertiary Keetley Volcanics). Slopes along the profiles range from 23.3 percent to 43.9 percent, mostly exceeding the critical slope angle of 25 percent determined by Hylland and Lowe (1997) as the angle above which late Holocene landsliding has typically occurred in the Keetley Volcanics. IGE modeled the slopes using soil properties taken from an earlier analysis of nearby slopes on lot 1325 (Payton, 1999). Black (1999), in his review of Payton (1999), considered the soil properties to be reasonable and I believe that they are appropriate to use in slope-stability analyses for the similar conditions on lots 1321 and 1412.

To account for the uncertainty of bedrock depth in three test pits excavated earlier to conduct percolation tests and observe soil conditions relevant to the siting of septic tanks, IGE carried out successive static analyses assuming bedrock depths of 10, 15, and 25 feet. To determine the sensitivity of the analyses to differing values of soil cohesion, one static analysis was conducted with a cohesion of 50 pounds per square foot (psf) and a soil thickness of 25 feet. All other analyses were conducted with a soil cohesion of 200 psf. IGE also conducted one pseudo-static analysis for each profile assuming an earthquake acceleration of 0.2g. Under these conditions, critical static factors of safety ranged from 1.61 (25 feet of soil, 50 psf cohesion) to 2.57 (10 feet of soil, 200 psf) and critical pseudo-static factors of safety ranged from 1.13 to 1.17. I believe that this range of conditions, except for assumed ground-water level, conservatively models conditions that may be expected to occur at lots 1321 and 1412, and demonstrates the stability of site slopes under the modeled conditions.

IGE assumes dry slopes for their analyses. This is based on the observation by Hedderly-Smith (2000b) of no moisture in the test pits, no springs on site slopes (although plate 1 of Hedderly-Smith [2000b] shows a flowing stream, presumably from a spring, heading on lot 1214 just below lot 1321), and sparse vegetation reflecting deep ground water. Although I concur with the conclusion of Hedderly-Smith (2000b) regarding the depth of ground water on lots 1321 and 1412 under natural conditions, this is not a conservative estimate of ground-water depth that may occur once the lots are developed. Slopes may become saturated by infiltration from a septic-tank soil-absorption (STSA) system. Because a certificate of zoning compliance, rather than a building permit, is being sought at this time, locations of home sites or STSA systems are unknown. As Hedderly-Smith (2000b) correctly notes, we agreed in a meeting on June 9 that issues regarding STSA systems need not be addressed now but should be considered at the time a building permit is sought.

CONCLUSIONS AND RECOMMENDATIONS

My review (Solomon, 2000) of the earlier reconnaissance geological examination of Timber Lakes Estates lots 1321 and 1412 (Hedderly-Smith, 2000a) concluded that the report did not provide sufficient detail to assess landslide hazards. The subsequent geotechnical report (Hedderly-Smith, 2000b) provides sufficient detail and, with minor exceptions noted above, represents a good example of the type of study needed to address hazards on individual lots within landslide-prone areas. The geotechnical report accurately maps the location of the Klauber (1995) landslide boundary and demonstrates that lots 1321 and 1412 do not lie on the landslide. The report does not find any evidence of past slope instability on the lots, and presents analyses to show that steep on-site slopes are stable under natural conditions. Although the analyses do not model the slopes with modifications or under saturated conditions that might occur once STSA systems are installed, this is not necessary for the issuance of certificates of zoning compliance. The saturation of site slopes will depend on the ultimate location of houses and STSA systems, and prudent location may result in conditions similar to those modeled by IGE. I therefore recommend:

- Lots 1321 and 1412 can be removed from the landslide special-study area and associated buffer zone designated by Wasatch County.
- Wasatch County issue a certificate of zoning compliance for the lots.
- Prior to issuing a building permit for either lot, the location of a building site, any proposed site grading, and an STSA system should be considered in the stability of on-site slopes.
- This report and all prior reports and reviews should be provided to any potential buyer of the lots.

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Utah Geological Survey

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<tr><td colspan="3">Project:
Review of “Geotechnical study, lot 17, Diamond Bar-X subdivision, Woodland, Utah”</td><td>Requesting Agency:
Wasatch County Planning</td></tr>
<tr><td>By:
Barry J. Solomon</td><td>Date:
07-20-00</td><td>County:
Wasatch</td><td rowspan="2">Job No:
00-10
(R-09)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Woodland (1166)</td><td>Number of attachments:
None</td></tr>
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INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report for Diamond Bar-X subdivision lot 17 by Earthtec Testing & Engineering, P.C. (Earthtec, 2000). I received the report on July 14, 2000. The lot is in the NE1/4 section 21, T. 3 S., R. 7 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Earthtec (2000) adequately addressed the potential for geologic hazards on the lots. My scope of work included a review of published geologic literature (Bryant, 1992; Harty, 1992; Hecker, 1993), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in Earthtec (2000) should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND RECOMMENDATIONS

Earthtec (2000) lists landslides, faulting, earthquake ground shaking, rock falls, debris flows, and flooding as potential geologic hazards on the property. I believe the report adequately addresses these geologic hazards on Diamond Bar-X lot 17 and I agree with the report’s conclusions regarding hazard potential and recommendations for hazard reduction.

Earthtec (2000) indicates that the greatest potential for slope instability is associated with cutting into the steep slope on the south portion of the site. The report recommends design and construction of retaining walls to reinforce cut slopes in this area should excavation be necessary, and I concur. To ensure slope stability, I recommend that the developer:

- Provide an engineered design for retaining walls and have the design reviewed by a qualified engineer; the design must include a site map and slope profile showing cuts, fills, and retaining walls; the retaining-wall design must consider static and earthquake ground-shaking conditions and incorporate pertinent drainage recommendations.

- Address cut-slope stability in accordance with the Uniform Building Code (International Conference of Building Officials, 1997, Appendix Chapter 33, section 3312) for any proposed permanent cuts with slopes steeper than 2H:1V (50 percent) that are not supported by retaining walls.

Wasatch County should provide a means to ensure that final recommendations are followed; one way to do this is to require the developer to submit written documentation from the consultant indicating that their recommendations were followed.

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Utah Geological Survey

Project: Review of geotechnical and geologic-hazard reports for a proposed residential subdivision on the Liechty property, Provo, Utah			Requesting Agency: Provo Engineering Department
By: Francis X. Ashland	Date: 07-31-00	County: Utah	Job No: 00-11 (R-10)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

At the request of David J. Graves, Provo Engineering Department, I reviewed geologic-hazard aspects of a geotechnical report (Earthtec Testing & Engineering [Earthtec], 2000) and a geologic-hazard report (American Geological Services, Inc. [AGS], 2000) included as an appendix in the Earthtec (2000) report. The reports present the results of investigations for a proposed five-lot residential subdivision in Provo City south of the mouth of Rock Canyon at approximately 2100 North 1450 East in the SW1/4 section 29, T. 6 S., R. 3 E., Salt Lake Base Line and Meridian. The purpose of the review is to determine whether geologic hazards that could affect the proposed subdivision are adequately identified and addressed. The scope of my evaluation consisted of a review of aerial photographs and available engineering-geologic reports and maps (see references). I received the Earthtec (2000) report on July 7, 2000.

GEOLOGIC HAZARDS

The Earthtec (2000) report identified potential earthquake and rock-fall hazards, and problem (collapsible) soils at the site. The report also indicated the absence of landslide, debris-flow, and flood hazards, but identified a small landslide in a cut slope directly east of the site. The AGS (2000) report indicated the absence or low probability of subsidence, shallow ground water, and liquefaction. Potential earthquake hazards include ground shaking and surface fault rupture. The Earthtec (2000) report adequately characterized the earthquake ground shaking and collapsible-soils hazards at the site and made reasonable recommendations, where necessary, to reduce the effects of these hazards on the proposed houses. I concur with the hazards assessments except for those regarding surface fault rupture and rock fall, which are discussed below.

Surface Fault Rupture

The AGS (2000) report identified three faults in a trench on the east-central part of the site. The Earthtec (2000) report indicated that the faults have offsets exceeding 1 foot (range 1-4 feet) and recommended a minimum 15-foot building setback from the faults. This setback is the minimum recommended (Batatian and Nelson, 1999), and is generally used only when faults are accurately located. Based on fault spacing and cumulative setback distance, Earthtec (2000) defined a 95-foot-wide zone in which it recommended no building. The AGS (2000) report indicated that a previous surface-faulting investigation on a property north of the site revealed no surface faulting but did not provide trench logs, maps, or other data from that investigation to review. The Earthtec (2000) report used the strike of the faults measured in the AGS (2000) investigation to estimate the fault locations between the trench and the northern and southern property boundaries. However, the AGS (2000) report predicted the faults might change direction within the limits of the property as shown in figure 2 of its report. Thus, estimation of the fault locations based on the measured fault strikes in a single trench and use of minimum (15-foot) setbacks along the estimated locations is inappropriate. Further investigation is needed to determine the precise locations of the faults on the site to the north and south, and to confirm the absence of surface faulting in the western part of the site. The Earthtec (2000) report also does not specifically address the implications of its proposed fault-zone building setbacks, which appear to have a significant impact on buildable area in some of the proposed lots and may necessitate redesign.

The AGS (2000) report indicated that the three faults lack any significant surface expression. On this basis, the reason the western part of the property was not trenched to search for other possible faults is unclear. The presence of three faults in the eastern part of the property, the westernmost more than 70 feet from the nearest mapped fault trace, suggests that secondary faulting is possible elsewhere on the property. The entire site is in a fault zone on a backtilted block between two major fault traces (Lund and Black, 1998; International Engineering Company, Inc., 1984). The Earthtec (2000) report indicated that five houses are proposed, each on approximately one-half acre lots. Before the subdivision plans are finalized, either the exact locations of all possible faults should be determined or the proposed building footprints for each house trenched. The AGS (2000) report acknowledges this concern in its recommendation for inspection of foundation excavations for possible faults. However, if unexpected faults are encountered during foundation excavation, the proposed subdivision design may not allow for the relocation of houses because of the restrictive lot size and prior construction of subdivision infrastructure (roads and utilities).

Rock Fall

The AGS (2000) and Earthtec (2000) reports identified a potential rock-fall hazard at the site. The Earthtec (2000) report indicated a moderate potential for a rock fall to impact the site and recommended that the eastern boundary of the property be regraded to act as a rock-fall-catchment area. The recommendation included reversing the natural slope of this area from westward to eastward to form a rock-fall-catchment area and constructing of an earth berm along its west edge. The recommendation, however, did not appear to consider concerns expressed in the AGS (2000) report regarding the potential for shallow landsliding on the slopes near the eastern boundary of the site. Specifically, cut-slope angles are not specified or supported with a slope-stability assessment despite the recommendation in the AGS (2000) report not to make cuts in the slope in the eastern part of the site. The Earthtec (2000) report also recommended removal or stabilization of precarious rocks in the rock-fall source area east of the site. The Earthtec (2000) report does not indicate ownership of the rock-fall-source-area property or specifically discuss the practicality or methods associated with this work or limitations, if any, associated with the ownership issue. My review of the 7-1/2' topographic map of the Orem quadrangle indicates that a Uintah National Forest boundary is approximately 700 feet east of the power-line easement centerline, which is near the eastern property boundary. Thus, Earthtec's recommendation to remove or stabilize loose rocks in the source area may require permission from the U.S. Forest Service, utility companies, and other property owners. This, along with likely costs, access problems, and liability issues, such as if loose rocks tumbled downslope unexpectedly during this work, suggest this recommendation is impractical.

CONCLUSIONS AND RECOMMENDATIONS

In my opinion, the Earthtec (2000) and AGS (2000) reports adequately address possible earthquake ground shaking, collapsible soils, and other hazards at the site. However, the surface-fault-rupture hazard has not been adequately characterized and the rock-fall hazard mitigation recommendations need to be clarified and designs provided. On the basis of my review of these reports and other available site information, I recommend the following:

- Additional investigations should be conducted to determine the exact locations of the three faults identified in the eastern part of the site and whether other faults exist in the western part of the site. All faults should be mapped at an appropriate scale on subdivision plans showing any impacts to proposed lot layout or on buildable areas in each affected lot. Alternatively, footprints of proposed buildings could be trenched and proposed building locations moved, as necessary, to avoid faults.

- Earthtec should provide design drawings of its proposed rock-fall catchment and earth berm showing proposed berm-slope and other cut-slope angles. It should also assess cut-slope stability, as necessary, based on the potential susceptibility of landsliding of cut slopes east of the property as described in the AGS (2000) report.

- Earthtec should document the feasibility of its rock-fall-source-area removal/stabilization recommendations and discuss the methods of how loose rocks will be identified and removed/stabilized. The developer should also obtain written verification from the appropriate property owners that such work would be possible on their land.

- Disclosure of the existence of the Earthtec (2000) and AGS (2000) reports, subsequent reports, and this review to future buyers.

REFERENCES

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<table>
<tr><td colspan="3">Project:
Review of “Geotechnical investigation - Pineview Ridge & Hawkes Landing development, Ski Lake, Huntsville, Utah”</td><td>Requesting Agency:
Weber County Planning</td></tr>
<tr><td>By:
Greg N. McDonald
Gary E. Christenson</td><td>Date:
08-31-00</td><td>County:
Weber</td><td rowspan="2">Job No:
00-12
(R-11)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Snow Basin (1344)</td><td>Number of attachments:
None</td></tr>
</table>

INTRODUCTION

This report is a review of a geotechnical investigation by KPS and Associates, Inc. (KPS, 2000) for the Pineview Ridge and Hawkes Landing development southwest of the junction of State Highway 39 and Snow Basin Road, Weber County, Utah. The development consists of approximately 92 acres in the NE¼ section 23 and the NW¼ NW¼ section 24, T. 6 N., R. 1 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission, requested the review. We received the report on August 10, 2000. The purpose of our review is to assess whether geologic hazards affecting the property are adequately addressed. The scope of work for our review consisted of a literature review and examination of 1:24,000-scale aerial photos (1952). No site visit was made. The KPS report contains sections on earthwork and foundations that should be reviewed by a qualified engineer.

DISCUSSION

KPS (2000) addresses possible hazards resulting from surface fault rupture and earthquake ground shaking, and we concur with their recommendations. However, we have concerns with their conclusions regarding shallow ground water, flooding, liquefaction, problem soils, and slope stability, and discuss these issues below.

Shallow Ground Water

KPS encountered wet soils or water in boreholes near a “storm drain” or local drainage along the southern portion of the property. KPS believes the wetness is not ground water but rather due to a “saturated zone formed by continuous seepage from the storm ditch,” which seemingly describes a localized or perched zone of ground water. It therefore appears to us from the borehole data that a localized zone of shallow ground water is present in the alluvium along the southern portion of the site. KPS also indicates that seven boreholes elsewhere at the site and deeper boreholes drilled at a wastewater facility across Snow Basin Road to the east, presumably in Norwood Tuff, did not encounter ground water. KPS believes shallow ground water is not presently a concern in the remainder of the site, and we concur. However, given the nature of the Norwood Tuff and clayey soils, perched shallow ground water induced by landscape irrigation and surface-water infiltration could occur anywhere in the subdivision.

Flooding

The KPS report does not address flooding hazards for the proposed development. A flooding hazard may exist in and along drainages at the southern end of the site. An evaluation should be done to define areas affected by a 100-year flood as required by the Federal Emergency Management Agency (FEMA) under the National Flood Insurance Program (NFIP), and flood-hazard reduction measures should be incorporated into the subdivision drainage design as necessary.

Liquefaction and Soil-Profile Type

KPS states an earthquake in the region could cause damage at the site by liquefaction, but does not specify where liquefaction may occur or recommend hazard-reduction measures. However, elsewhere in the report, KPS indicates shallow ground water is likely not present at the site, which would preclude a liquefaction hazard. Although shallow ground water may be present in the southern part of the subdivision as discussed above, soils in this area are clayey and probably not highly susceptible to liquefaction. Further consideration of the hazard is necessary and, if present, zones of potential liquefaction hazard should be delineated and addressed.

KPS concludes, based on their assessment of the boreholes, a soil-profile type S_D could be used for design specifications at the site. A soil profile of S_D is probably conservative for the site in general except for the alluvium at the south end of the site. Standard penetration test (SPT) blowcounts from boreholes #1, #3, and #4 were low (less than 15) and are more representative of soils in the S_E range.

Problem Soils

Soils derived from the Norwood Tuff, which appears to underlie the entire site, are known to be expansive and possibly collapsible. KPS believes laboratory testing of soils for swelling characteristics is not necessary at this stage of development. They state clayey soils at the site have a reasonable silt fraction and low to medium plasticity, but in some cases high swell potentials are possible. KPS further states that lots in certain areas, namely the storm-water flooded area to the south, may require special attention.

We believe moisture-sensitive soils will need to be identified and addressed for road and building design. Expansive-clay soils weathered from Norwood Tuff have been found nearby and tested, and some soil-test results exceeded 1 percent swell (Resource Engineering, 1986; Earthtec, 1996). In addition, a soil sample collected from a site about 1 mile to the southwest was consolidation tested and collapsed 0.3 percent (Earthtec, 1998). We therefore recommend that potential expansive and collapsible soils be identified in a soil-foundation investigation, and recommendations be given for foundation and road design.

Slope Stability

The KPS report does not adequately address slope stability at the site. KPS notes that slopes are steep, but states that ". . . slope stability is not likely to be a concern for the overall development . . ." KPS reaches this conclusion based on existing slopes in the region which "seem to be stable," the lack of "obvious signs of erosion," the generally high SPT blow counts observed, and an estimated angle of internal friction of 20 to 30 degrees.

The entire subdivision is underlain by the Norwood Tuff, one of Utah's most landslide-prone geologic units. Numerous landslides in this unit are evident on aerial photos and documented on maps by Coogan and King (1999) and Lowe (unpublished UGS map of Ogden Valley). In addition, Black (1996) indicates landsliding in the Norwood Tuff near Olympeak Estates about 1 mile to the southwest on slopes as gentle as 15 percent (6.7H:1V). We believe certain areas of the site, including lots 51, 52, and 53 in the southwest corner and lots 43-46 and 49 south of Hummingbird Point, may be on old landslides and therefore are particularly susceptible to renewed landsliding.

KPS does not discuss the bedding attitudes or stratigraphy (presence of slide-prone tuffaceous layers) of the Norwood Tuff, or the possible landslides south of Hummingbird Point. At a minimum, a geologic evaluation (Hylland, 1996) of the presence and stability of existing landslides and steep slopes, particularly dip slopes where bedding daylights, is needed. Subsequent geotechnical-engineering analyses may be needed, depending on the results of geologic studies. Studies must consider the effects of grading and landscape irrigation on slope stability, and should include recommendations for cuts and fills.

SUMMARY AND RECOMMENDATIONS

Hazards from shallow ground water, flooding, liquefaction, problem soils, and landsliding may be present at the property and are not adequately addressed in the KPS report. Therefore, we recommend the following:

- A site geologic map should be prepared showing alluvium, landslides, bedding dips, and areas of expansive-clay layers in the Norwood Tuff for use in addressing hazards issues listed below.
- The depth and extent of shallow ground water in the alluvium along the southern portion of the site should be delineated in the soil-foundation study (see below).
- Areas of flooding should be defined to comply with FEMA NFIP regulations.
- If present, areas of potential liquefaction and S_E soil-profile types be delineated and addressed.

- A soil-foundation investigation should be conducted to identify areas of expansive and collapsible soils and as necessary, revise site-grading and foundation-design recommendations.
- At a minimum, a geologic slope-stability evaluation should be conducted using site-specific data with special consideration given to areas where landslide deposits have been mapped (lots 51-53) or are suspected (lots 43-46, 49).
- Weber County should provide a means to ensure that final recommendations are followed, such as requiring the developer to submit written documentation from the consultant confirming that their recommendations have been followed.
- The existence of the KPS (1996) report, this review, and any subsequent reports and reviews should be disclosed to future buyers.

REFERENCES

Black, B.D., 1996, Review of a geologic evaluation for Olympeak Estates along Snow Basin Road, Weber County, Utah, *in* Mayes, B.H., compiler, Technical reports for 1996, Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 92-94.

Coogan, J.C. and King, J.K., 1999, Progress report - Geologic map of the Ogden 30' x 60' quadrangle, Utah and Wyoming, year 2 of 3: Utah Geological Survey Open-File Report 247, scale 1:100,000.

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Utah Geological Survey

Project: Review of "Geotechnical study, Eric Younger lot, 6100 Snow Basin Road, Huntsville, Utah"			Requesting Agency: Weber County Planning
By: Greg N. McDonald Gary E. Christenson	Date: 8-6-00	County: Weber	Job No: 00-13 (R-12)
USGS Quadrangle: Snow Basin (1344)		Number of attachments: None	

INTRODUCTION

This report is a review of geologic-hazards aspects of a geotechnical study by Earthtec Testing & Engineering, P.C. (Earthtec, 2000) for the Eric Younger lot in the Nichols subdivision at 6100 Snow Basin Road, Weber County, Utah. The property is in the SW¼NE¼SW¼ section 23, T. 6 N., R. 1 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission, requested the review. We received the report on August 18, 2000. The purpose of our review is to assess whether geologic hazards possibly impacting the property are adequately addressed. The scope of work for our review consisted of a literature review and examination of 1:24,000-scale aerial photos (1952). No site visit was made.

DISCUSSION

Earthtec (2000) addresses possible hazards resulting from perched shallow ground water, problem soils, surface fault rupture, ground shaking, and liquefaction, and we concur with their recommendations. However, slope stability at the site was not addressed. Also, the suitability of the lot for a septic-tank soil-absorption (STSA) system is not addressed in this report. This may not have been in the scope of work, but nevertheless, the impact of an STSA system needs to be addressed as part of the geotechnical study because infiltration may directly affect ground-water levels and resulting hazards at the site. These issues are discussed below.

Slope Stability

The Earthtec (2000) report does not address slope stability at the site. Figure 1 of the report shows a slope-failure-inventory map, but the Younger lot is outside the study-area boundary. Aerial photos and maps by Coogan and King (1999) and Lowe (unpublished UGS map of Ogden Valley) show the proposed house is on an isolated ridge of weathered Norwood Tuff (one of Utah's most landslide-prone geologic units) bounded by large (likely prehistoric) landslides. This ridge may itself be a block within a larger landslide. Smaller slides, which are not apparent at the scale of our aerial photos, may also be present on some of the steeper slopes along the drainage at the northwest part of the property. Such slides have been observed in the same drainage a few hundred feet downstream (Black, 1996).

Given the evidence for landsliding in the area, we recommend at least a geologic evaluation (Hylland, 1996) of the presence and stability of existing landslides and steep slopes affecting the site. Such a study should map landslides, describe material types in the Norwood Tuff, identify slide-prone units, and determine the bedding dip and its relation to slopes and the regional dip of known in-place Norwood Tuff. Results of the geologic evaluation can be used to determine if a subsequent geotechnical-engineering slope-stability study is necessary to determine both static and seismic stability of slopes based on site-specific soil, rock, and natural and development-induced ground-water conditions. Slope-stability issues may affect layout for the property and therefore must be considered prior to development.

Earthtec recommends that permanent cut and fill slopes on the property should not exceed 2H:1V (50 percent), which we believe may be too steep given the nature of the Norwood Tuff and documented landslides in the area. Slides in the area have occurred on slopes as shallow as 6.7H:1V (15 percent) (Black, 1996).

STSA-System Suitability

STSA-system suitability of the lot may not have been within the scope of work for the geotechnical study, but must be addressed. The location and size of an STSA system needs to be considered as part of the geotechnical evaluation because associated infiltration may directly affect geologic hazards at the site including shallow ground water, problem soils, and slope stability. In addition, expansive or low-permeability soils can be unsuitable for STSA systems and preclude health-department approval.

SUMMARY AND RECOMMENDATIONS

Potential hazards from shallow ground water, expansive soils, earthquake ground shaking, and landsliding may be present at the site. The Earthtec report adequately addresses all of these hazards except landsliding. Earthtec also does not address STSA-system suitability and possible effects on hazards. Therefore, we recommend the following:

- At least a geologic slope-stability analysis should be conducted using site-specific data, with special consideration given to areas where landslide deposits have been mapped (along the northwest portion of the property) or are suspected, and where the STSA system will cause an increase in ground-water levels.
- Re-evaluate 2H:1V cut-slope recommendations based on results of slope-stability analyses.
- An STSA-system suitability study must be performed to determine if soils are sufficiently permeable for proper STSA-system operation.

- Foundation design and site grading recommendations for reducing problem-soil and ground-shaking hazards should be reviewed by a qualified geotechnical engineer.
- Weber County should provide a means to ensure that final recommendations are followed, such as requiring the developer to submit written documentation from the consultant confirming that their recommendations have been followed.
- The existence of the Earthtec (2000) report, this review, and any subsequent reports and reviews should be disclosed to future buyers.

REFERENCES

Black, B.D., 1996, Review of a geologic evaluation for Olympeak Estates along Snow Basin Road, Weber County, Utah, *in* Mayes, B.H., compiler, Technical reports for 1996, Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 92-94.

Coogan, J.C., and King, J.K., 1999, Progress report - Geologic map of the Ogden 30' x 60' quadrangle, Utah and Wyoming, year 2 of 3: Utah Geological Survey Open-File Report 247, scale 1:100,000.

Earthtec Testing and Engineering, P.C., 2000, Geotechnical study, Eric Younger lot, 6100 Snow Basin Road, Huntsville, Utah: Ogden, Utah, unpublished consultant's report, 12 p.

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Project: Review of "Geotechnical/geological study, lot 642 Timber Lakes Estates, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 09-06-00	County: Wasatch	Job No: 00-14 (R-13)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: None	

INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report and supplemental slope-stability analysis for Timber Lakes Estates lot 642 by Delta Geotechnical Consultants, Inc. (Delta, 2000a, 2000b). I received the report on August 15, 2000, and the supplemental analysis on August 21, 2000. The lot is in the NW1/4 section 14, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Delta (2000a, 2000b) adequately addressed the potential for landslides on the lot in support of a building permit. My scope of work included a review of published geologic-hazards literature and aerial photographs (1987, 1:40,000 and 1999, 1:8,220) and an inspection of the property on August 18, 2000.

DISCUSSION

Lot 642 lies mostly within the buffer zone surrounding a landslide special-study area designated by Wasatch County. This special-study area was established to ensure that slope stability is evaluated prior to development on lots within a landslide mapped by Hylland and Lowe (1995). The buffer zone accounts for the uncertainty of the landslide boundary with respect to lot boundaries due to map scale and landslide-mapping accuracy. Thus, an important element of lot-specific geologic studies required in special-study areas and buffer zones is to accurately map the landslide boundary to determine its relationship to the lots.

Although Delta (2000a) does not include a map of the landslide boundary, the report (p. 4) states that there is no evidence of landslides on or immediately adjacent to lot 642. The report describes a topographically concave feature east of the lot that Delta (2000a) suggests may be evidence for the nearby landslide mapped by Hylland and Lowe (1995). Based on my review of aerial photographs and my field inspection, I agree with Delta (2000a) that the landslide is not on lot 642 and believe that the report adequately documents the relationship of the landslide to the lot. However, Delta (2000a) does not consider the potential for future movement of the landslide and migration of slope failure onto the lot. I believe evaluating stability of the landslide is beyond the scope of work for this single lot, and future landslide movement would be unlikely to affect the lot, but the possibility of slope instability on lot 642 due to movement on the nearby landslide cannot be ruled out.

Delta (2000a) uses PCSTABL6 to demonstrate the relative stability of on-site slopes using a representative slope profile and assuming conservative soil characteristics. Delta (2000a) calculates minimum factors of safety of 2.11 for unsaturated static conditions, 1.01 for unsaturated pseudostatic conditions, and 2.00 for saturated static conditions. These minimum factors of safety all exceed the minimum criteria recommended by Hylland (1996) (static factor of safety ≥ 1.5; dynamic factor of safety ≥ 1) and indicate slopes are stable. However, Delta (2000a) calculates a minimum factor of safety of only 0.77 for saturated pseudostatic (dynamic) conditions. This value is apparently the result of the value of the peak ground acceleration (PGA) chosen by Delta (2000a) for use in the analysis, which is approximately equivalent to the value cited by Delta for a PGA with a 5 percent probability of exceedance in 50 years. In a phone conversation on August 17 with Anthony Pawloski, Senior Geotechnical Engineer for Delta, I indicated that this may be an overly conservative estimate for a single-family residence and suggested he may wish to re-evaluate the coefficient. Using a coefficient of 0.08 *g* (about one-half of the PGA with a 10 percent probability of exceedance in 50 years), Delta (2000b) recalculated minimum pseudostatic factors of safety to 1.49 (saturated) and 1.68 (unsaturated). I believe that the slope-stability analysis in Delta (2000a), with modifications in Delta (2000b), conservatively models conditions that may be expected to occur at lot 642 and demonstrates the stability of site slopes under the modeled conditions.

CONCLUSIONS AND RECOMMENDATIONS

I believe Delta (2000a), as modified by Delta (2000b), adequately addresses the potential for landslides on Timber Lakes Estates lot 642 for purposes of issuing a building permit. Delta demonstrates that the lot does not lie on a landslide, does not find any evidence of past slope instability on the lot, and shows that on-site slopes are stable under modeled conditions. The potential for landslides may be further reduced by implementing site-design features suggested in Delta (2000a). I therefore recommend the following:

- Wasatch County can remove Lot 642 from their landslide buffer zone.

- Because slope instability, although unlikely, is still possible on lot 642 due to movement on the nearby landslide, the lot owner should disclose to potential buyers of the lot the existence of the landslide, the Delta (2000a, 2000b) reports, this review, and subsequent reports and reviews.

- Recommendations pertaining to foundation design and site grading in Delta (2000a) and any subsequent studies should be reviewed by a qualified geotechnical engineer.

I further recommend the following to the developer:

- If retaining walls are planned, provide an engineered design for the walls and have the design reviewed by a qualified engineer; the design must include a site map and slope profile showing cuts, fills, and retaining walls; the retaining-wall design must consider static and earthquake ground-shaking conditions and incorporate pertinent drainage recommendations.

- If permanent cuts have slopes steeper than 2H:1V (50 percent) and are not supported by retaining walls, cut-slope stability must be addressed in accordance with the Uniform Building Code (International Conference of Building Officials, 1997, Appendix Chapter 33, section 3312).

Wasatch County should provide a means to ensure that final recommendations are followed. One way to do this is to require the developer to submit written documentation from the consultant indicating that their recommendations were followed.

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Delta Geotechnical Consultants, Inc., 2000a, Geotechnical/geological study, lot 642 Timber Lakes Estates, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 11 p.

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Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, *in* Hylland, M.D., Lowe, Mike, and Bishop, C.E., Engineering-geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plate 1D, scale 1:24,000.

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International Conference of Building Officials, 1997, Uniform Building Code: Whittier, California, International Conference of Building Officials, Volume 1, Appendix Chapter 33, p. 407-411.

Utah Geological Survey

Project:			Requesting Agency:
Review of "Geotechnical study, proposed Leander Kellog residence, 391 Bern Way, lot #150, Midway, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 09-06-00	County: Wasatch	Job No: 00-15 (R-14)
USGS Quadrangle: Heber City (1168)		Number of attachments: None	

INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report and supplemental slope-stability analysis for Interlaken Estates lot 150 by Delta Geotechnical Consultants, Inc. (Delta, 2000). I received the report on August 7, 2000. The lot is in the SE1/4 section 22, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of this review is to assess whether Delta (2000) adequately identifies and addresses geologic hazards that could potentially affect the lot. My scope of work included a review of published geologic-hazards literature and examination of 1:48,000-scale aerial photographs (1987). I did not inspect the property.

DISCUSSION

Delta (2000) lists earthquake ground shaking and liquefaction as potential geologic hazards on the property. I believe Delta (2000) adequately addresses these geologic hazards and concur with the report's recommendations. However, I believe landsliding is also a potential geologic hazard that may impact lot 150 but is not addressed by Delta (2000).

Hylland (1996) outlines a three-step process to address landslide hazards, beginning with a geologic evaluation. The primary purpose of a geologic evaluation is to determine the hazard potential relative to proposed development and the need for geotechnical-engineering studies (Hylland, 1996). A geologic evaluation should address site geologic conditions that relate to potential hazards. Landsliding has historically been one of the most damaging geologic hazards in western Wasatch County (Hylland and Lowe, 1997) and, therefore, the landslide potential should be considered in geologic evaluations for proposed hillside development in the region.

The Delta (2000) report lacks sufficient documentation to determine the landslide hazard on lot 150. Specifically, the report does not contain a topographic and/or slope map at a scale suitable for planning, or a description of site geologic conditions sufficient to determine if slope instability has occurred or may occur. The report contains a site map showing a test-hole location, but the map does not include topographic or slope data, nor does it include a map scale.

Geotechnical studies of three nearby lots, and subsequent reviews by the Utah Geological Survey, evaluate the landslide hazard in this part of the Interlaken subdivision. Lots 116 (Dames & Moore, 1998; Solomon, 1999) and 120 (American Geological Services, 1999; Earthtec, 1999; Giraud, 2000) lie about 0.4 miles northeast of lot 150; lot 146 (Dames & Moore, 1997; Black and Ashland, 1998) lies about 0.1 miles south of lot 150. All three lots, as well as lot 150, are on colluvium-covered slopes underlain by the Weber Sandstone of Permian and Pennsylvanian age; Bromfield and others (1970) show that the Weber Sandstone generally dips downslope, but at steeper angles than the ground surface.

Geotechnical studies and reviews for these nearby lots consider three slope-failure mechanisms: circular failures in rock, slab or wedge failures in rock, and shallow debris sliding of soils and weathered rock along the rock interface. These studies and reviews may be referenced in lieu of performing similar studies at lot 150 if geologic conditions are shown to be similar. Dames & Moore (1998) reports results of quantitative slope-stability analyses which assess the likelihood of circular failures in rock and concludes that this type of failure seems unlikely on lot 116. Solomon (1999) concurs, but indicates that the analyses do not consider slab or wedge failures, which are more likely to occur along planar bedrock discontinuities. Although slab or wedge failures may not be significant on natural slopes of lot 116 because of the steep dip of sandstone beds and the lack of documented consistent fracture orientations, the potential for such bedrock slope failures may be particularly important in cuts exposing bedrock if cut-slope heights greater than 5 feet are planned. Black and Ashland (1998) state that the most likely failure mode on lot 146 is shallow debris sliding, and this is supported by a slide of this type in the slope roughly 300 feet south of lot 146 (Hylland and Lowe, 1995). Because failure surfaces associated with such debris slides are shallow and not circular, Black and Ashland (1998) use an infinite-slope analysis to estimate a static factor of safety of 1.1 for shallow slides on local steep slopes (about 30 percent grade, probably equivalent to the abrupt slope on the east side of lot 150 noted by Delta [2000]) under dry conditions. With seasonal infiltration from snowmelt or rainstorms, infiltration from drainage or irrigation, and undercutting by road and building-pad cuts, stability could be reduced even further. Dames & Moore (1998) analyzes similar slopes on lot 116 for sliding-block failures along the rock interface and calculates static factors of safety of 1.6 when slopes are dry and 1.4 when saturated. The UGS (Hylland, 1996) recommends a static factor of safety (FS) $\geq$ 1.5.

Although Delta (2000) reports only a thin (2-foot-thick) veneer of soil over bedrock measured in a test hole on the west side of lot 150, soil may be thicker on the eastern slope. A shallow failure in thin soil may not impact a house built on the property because the house would be near the top of the slope with a foundation in bedrock, but a failure of thicker soils on the eastern side of lot 150 could impact structures and roads directly downslope.

CONCLUSIONS AND RECOMMENDATIONS

I believe Delta (2000) does not adequately evaluate landslide potential for lot 150. My review of geotechnical reports for nearby lots suggests three possible slope-failure mechanisms: circular failures in rock, slab or wedge failures in rock, and shallow debris sliding of soils and weathered rock along the rock interface. Slope-stability analyses on nearby lots, and the presence of a slope failure about 300 feet south of lot 146, indicate that shallow debris sliding along the steeper, eastern slope of lot 150 is most likely. However, as shown in the slope-stability analysis for lot 146 (Black and Ashland, 1998), a shallow failure on lot 150 probably would not impact a structure on the lot but could impact downslope structures and roads. I therefore recommend the following:

- The developer's geotechnical consultant should submit a map of topography or slope at a scale suitable for planning.

- In a report on the landslide hazard, the developer's geotechnical consultant should document the presence or absence of existing landslides and, if landslides are present, identify their geologic characteristics. The report should also describe site conditions with emphasis on existing slope stability, based on observation and measurement of geologic criteria such as slope inclination, rock type and condition, the nature of planar features within soil or rock, ground-water conditions, and thickness and description of soil and colluvium overlying rock.

- The developer's geotechnical consultant should assess the need for additional slope-stability studies on lot 150 by evaluating relevant on-site conditions, comparing these conditions with those of nearby lots, and determining the applicability of landslide-hazard assessments from nearby lots to lot 150; the consultant should conduct additional studies if necessary.

- During and after construction, drainage at the homesite on lot 150 should be carefully controlled so that the slope below the home is not artificially wetted. Drainage control should include, but not be limited to, minimizing landscape irrigation and monitoring water and sewer lines for leakage to prevent infiltration into the slope.

- When evaluating development either on the lower part of lot 150 or downslope from the lot, Wasatch County should consider the slope-failure hazard.

- Recommendations pertaining to foundation design and site grading in Delta (2000) and any subsequent studies should be reviewed by a qualified geotechnical engineer.

- The existence of the Delta (2000) report, this review, and subsequent reports and reviews should be disclosed to potential buyers of lot 150.

I further recommend the following to the developer:

- If retaining walls are planned, provide an engineered design for the walls and have the design reviewed by a qualified engineer; the design must include a site map and slope profile showing cuts, fills, and retaining walls; the retaining-wall design must consider static and earthquake ground-shaking conditions and incorporate pertinent drainage recommendations.

- If permanent cuts have slopes steeper than 2H:1V (50 percent) and are not supported by retaining walls, cut-slope stability must be addressed in accordance with the Uniform Building Code (International Conference of Building Officials, 1997, Appendix Chapter 33, section 3312).

Wasatch County should provide a means to ensure that final recommendations are followed. One way to do this is to require the developer to submit written documentation from the consultant indicating that their recommendations were followed.

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Project: Review of geotechnical and geologic-hazard reports for the proposed Granite Heights subdivision, Pleasant Grove, Utah			Requesting Agency: Pleasant Grove City Engineer
By: Francis X. Ashland	Date: 9-8-00	County: Utah	Job No: 00-16 (R-15)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

At the request of John E. Schiess, acting Pleasant Grove City engineer, I reviewed geologic-hazard aspects of a geotechnical report (Earthtec Testing & Engineering, P.C. [Earthtec], 1998), a geologic-hazard report (Earthtec, 2000a), and a design report (Earthtec, 2000b) that addressed cut and fill slopes. Geotechnical and foundation-design portions of these reports were not reviewed. The reports present the results of investigations for a proposed eight-lot residential subdivision in Pleasant Grove City east of the Salt Lake aqueduct at approximately 200 North 1400 East in the SE1/4 section 22, T. 5 S., R. 2 E., Salt Lake Base Line and Meridian. The purpose of the review is to determine whether geologic hazards that could affect the proposed subdivision are adequately identified and addressed. The scope of my evaluation consisted of a review of aerial photographs and available engineering-geologic reports and maps (see references). The Utah Geological Survey (UGS) received the Earthtec reports on August 25, 2000.

GEOLOGIC HAZARDS

The Earthtec (2000a) report identifies potential earthquake, landslide, rock-fall, alluvial-fan-flooding, debris-flow, shallow ground-water, and problem-soils hazards at the site. Potential earthquake hazards include ground shaking, surface fault rupture, and liquefaction. A potential landslide hazard is associated with the possible presence of the Manning Canyon Shale in the subsurface (Baker, 1964; Earthtec, 2000a).

Earthquake Hazards

The Earthtec (2000a) report indicates the potential for significant earthquake ground shaking and makes building design recommendations consistent with seismic zone 3 criteria of the Uniform Building Code (UBC) (International Conference of Building Officials, 1997). The Earthtec (2000a) report appropriately identifies the UBC soil-profile type as S_D, and differs from the previous Earthtec (1998) report in which the UBC soil-profile type was identified as S_C. A design plan (Hubble Engineering, Inc., 2000) for the proposed subdivision also lists the UBC soil-profile type as S_C and is inconsistent with the most recent Earthtec (2000a) report. UBC recommends soil-profile type S_D as the default category in the absence of geotechnical data, such as standard penetration resistance (N) or shear-wave velocity (Vs), that indicate other soil-profile types. Although soil-profile type S_C may be an appropriate characterization of the gravel soils east of the aqueduct, it should be supported by on-site geotechnical data.

The Earthtec (2000a) report indicates no evidence of surface fault rupture on the site and identifies the active trace of the Wasatch fault zone approximately 200 feet east of the site boundary. Earthtec's conclusion is consistent with mapping by Machette (1992) that shows the main fault east of the site and several western traces southeast of the Battle Creek debris basin which trend toward but don't appear to reach the site. The Earthtec (2000a) report indicates the presence of several scarps on the site, but concludes these scarps are possible shoreline features associated with the former Lake Bonneville which occupied most of Utah Valley. Machette (1992) mapped the uppermost Bonneville level shoreline at approximately elevation 5,130 feet in the area, mostly below the subdivision. Thus, any scarps above this elevation are unlikely to be associated with Lake Bonneville.

The Earthtec (2000a) report concludes the potential for liquefaction is low at the site based on the subsurface information in the Earthtec (1998) report. The Earthtec (1998) report indicates the absence of ground water (in July) and the presence of gravel soils in the upper 10 feet across most of the site. Although the limited data support the low probability of liquefaction of the shallowest soils, the data are inadequate to fully assess the liquefaction potential at the site. However**,** Earthtec's assessment is consistent with that of Anderson and others (1994) who rate the liquefaction potential as very low in the area and do not recommend additional site-specific study.

Landslides

The Earthtec (2000a) report indicates the absence of recent landsliding at the site, but identifies a moderate potential for landsliding both locally at the site and in the steep slopes east of the site. The Earthtec (2000a) report indicates a concern regarding the susceptibility of the underlying Manning Canyon Shale to landsliding. Earthtec (1998, 2000a) identifies clay soils in the western part of the site and classifies them as lacustrine soils. However, the close proximity of these soils to the Bonneville shoreline suggests a lacustrine origin is unlikely and the possibility that these soils are derived from the Manning Canyon Shale should be considered.

The Earthtec (1998, 2000a) reports recommend that surface drainage be controlled to prevent surficial soils from becoming saturated. However, neither report addresses the potential impacts on stability from landscape irrigation water. Ground-water-level data and other observations from several 1998 Wasatch Front landslides suggest a long-term cumulative rise in ground-water levels is caused by landscape irrigation in residential subdivisions. In addition, exactly how drainage recommendations on page 7 of the Earthtec (1998) report would prevent soils from becoming saturated is unclear. These recommendations address how to prevent soils around building foundations from becoming wet but imply that runoff would eventually be allowed to infiltrate into on-site soils rather than being directed to storm sewers. The Earthtec (1998, 2000a) reports do not adequately address the potential impacts of proposed hillside modifications, including long-term changes in ground-water levels, on slope stability.

The Earthtec (2000a) report also does not address the implications of nearby landslides on the susceptibility for landsliding at the site. Machette (1992) mapped landslides to the north and south of the site. A prehistoric (post-Bonneville) landslide about 2,200 feet north-northwest of the site occurred in the same geologic unit that underlies the proposed subdivision. Machette (1992) also mapped older landslides to the south-southeast which are also likely underlain by geology similar to that at the site. These landslides demonstrate the susceptibility of the foothills near Pleasant Grove to instability under natural conditions including extended successive periods of above-normal precipitation and during earthquakes.

Other Geologic Hazards

The Earthtec (2000a) report indicates the presence of possible rock-fall boulders at the site and concludes that a moderate rock-fall hazard exists. The report generally describes possible rock-fall-hazard mitigation techniques but does not provide specific recommendations for this site.

The Earthtec (2000a) report identifies a low to moderate potential for alluvial-fan flooding (flash flood) and debris flows which could affect the entire development. The report indicates that the hazard could be reduced by careful site drainage and building location but does not provide specific recommendations on how to accomplish this.

The Earthtec (1998, 2000a) reports also attempt to address the potential for problem (collapsible or expansive) soils at the site. Earthtec (2000a) rates the gravels as having a low potential for collapsible or expansive behavior. The results of a one-dimensional consolidation test of one clay-soil sample are shown in the Earthtec (1998) report, but whether the sample was wetted during the testing to evaluate problem-soil characteristics is unclear. The soft clay soil that was tested from the western part of the site exhibited pinhole structure that is commonly characteristic of collapsible soils. Earthtec (2000a) mapped the surficial soils in this part of the site as lacustrine (lake) silt and clay. Collapsible soils, although sometimes associated with lacustrine deposits, are generally associated with young alluvial-fan and related valley-margin deposits such as those mapped by Earthtec (2000a) in the majority of the site east of the Salt Lake aqueduct. The alluvial-fan gravels identified by Earthtec (1998) are more likely to exhibit collapsible-soil characteristics than lacustrine clays. The gravels also share some similar characteristics to collapsible soils described by Rollins and others (1993) at foothill sites elsewhere including a site as close as Provo, Utah. These characteristics include:

- the alluvial-fan setting,
- the gravel soil-type classification (GM),
- the inferred low moisture content of the gravel soils, and

- the range in the percent fines (12-30%, of which three of the Earthtec [1998] soil samples fall within).

Owens and Rollins (1990) indicated that surficial soils in the area have a moderate to high collapse potential. One soil sample collected nearby and downslope of the site exhibited a collapse potential of 1.3 percent which falls within the “moderate trouble” severity designation of Jennings and Knight (1975).

CONCLUSIONS AND RECOMMENDATIONS

In general, the Earthtec (1998, 2000a) reports adequately identify potential geologic hazards and characterize near-surface conditions at the proposed subdivision. However, Earthtec does not adequately address how to avoid or reduce the impacts of geologic hazards because either its assessment is incomplete or subdivision-specific recommendations are lacking.

Landsliding is potentially the most significant hazard at the site. Based on Earthtec’s (2000a) concerns for potential future landsliding, I recommend additional slope-stability investigations. These investigations should attempt to further characterize subsurface conditions including determination of:

- the depth to the top of the Manning Canyon Shale, if present,
- the geotechnical characteristics of the shale and/or overlying soils derived from it, and
- the depth to and type (confined, unconfined, perched) of ground water.

This information should be used to assess the natural slope stability and its sensitivity to anticipated hillside modifications, including higher ground-water levels resulting from landscape irrigation and redirected and concentrated runoff. As part of this investigation, Earthtec may wish to consider conditions in similar geologic settings including in the vicinity of the landslide mapped by Machette (1992) north of the site, as well as previously developed hillside areas now experiencing landslide damage such as the Sherwood Hills subdivision in nearby Provo.

With respect to other potential geologic hazards, Earthtec should:

- clarify its recommended UBC soil-profile type,
- re-evaluate the origin and hazard implications of any scarps with a base elevation above 5,130 feet,
- provide subdivision-specific risk-reduction measures for potential rock-fall, alluvial-fan-flooding, and debris-flow hazards, and
- complete its assessment of possible collapsible soils in the alluvial-fan gravels that underlie the majority of the site.

Demonstration of the appropriateness of any proposed risk-reduction measures may require further assessment of potential rock-fall, alluvial-fan-flooding, and debris-flow hazards. The design basis of rock-fall risk-reduction measures should include characterization of source areas, bounce heights, and size and distribution of on-site rock-fall clasts. The design basis of risk-reduction measures for alluvial-fan flooding and debris-flows should include definition of active sedimentation and flood areas; and estimation of flow type, frequency, volume, and depth.

The conclusions and subdivision-specific recommendations from the additional investigations should be supported by quantified data and presented in a suitable format in a report so that a technical reviewer can evaluate their validity. Specific design recommendations should be shown on a site map such as the plat map of Hubble Engineering, Inc. (2000) and design drawings provided as necessary. The hazard evaluations supporting specific recommendations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer, as appropriate. Geotechnical designs should be reviewed by the city engineer or, if possible, a qualified third-party geotechnical engineer. Upon approval of any final subdivision (risk-reduction) designs or recommendations, Pleasant Grove City should provide a means to ensure these are followed. A possible way to ensure this is to require the developer to submit written verification from the design consultants that their recommendations were followed during construction. City building inspectors or ordinance officials should also be notified of any land-use restrictions and make periodic inspections of the subdivision. As a final recommendation, the Earthtec reports, subsequent reports, and this review should be disclosed to future buyers.

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Utah Geological Survey

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<tr><td colspan="3">Project:
Review of “Geological reconnaissance, lot 907 Spurwood Dr., Timber Lakes development, east of Heber City, Utah”</td><td>Requesting Agency:
Wasatch County Planning</td></tr>
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00-17
(R-16)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
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INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geological report for Timber Lakes subdivision lot 907 by Earthtec Testing & Engineering, P.C. (Earthtec, 2000). I received the report on October 3, 2000. The lot is in the NW1/4 section 10, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Earthtec (2000) adequately addressed the potential for landslides on the lot. My scope of work included a review of published geologic-hazards literature and aerial photographs (1987, 1:40,000) but I did not inspect the property.

DISCUSSION AND RECOMMENDATIONS

Earthtec (2000) maps what appears to be a previously unmapped local landslide along the northwestern border of lot 907 but finds no indication of recent slope movement. The report recommends that construction on the lot await the completion of landslide studies by the University of Utah for Wasatch County and Timber Lakes homeowners to determine landslide boundaries within the Timber Lakes subdivision and evaluate landslide stability. I believe this to be a prudent recommendation, although I base this finding on evidence that is not discussed by Earthtec.

Lot 907 lies partially within the buffer zone surrounding a landslide special-study area designated by Wasatch County. Special-study areas were established to ensure that slope stability is evaluated prior to development on lots within landslides mapped by the UGS (Hylland and Lowe, 1995) and local consultants in their site-specific studies. The buffer zone accounts for the uncertainty of landslide boundaries due to map scale. The zone on lot 907 is associated with a large, deep-seated landslide northeast of the lot rather than the small, local landslide identified by Earthtec in the drainage on the northwestern border of the lot. The precise extent and stability of the large landslide, referred to as the Witts Lake landslide, is unknown. The stability of another large landslide northwest of the site, referred to as the Pine Ridge landslide, was studied by the UGS (Ashland and Hylland, 1997), which determined that the southern part of the landslide nearest lot 907 is relatively stable. Because of this relative stability, no special-study area or buffer zone is associated with the southern part of the Pine Ridge landslide. However, because lot 907 lies near the Witts Lake landslide, lot suitability is initially based on the location and stability of that landslide. Should the University of Utah determine that lot 907 will not be affected by the Witts Lake landslide, the suitability of lot 907 will then depend upon the characteristics of steeper slopes on the lot and possible impacts of the small landslide.

I therefore recommend the following:

- As indicated by Earthtec (2000), development on lot 907 should be postponed until the University of Utah study of the Witts Lake and other large, deep-seated landslides is complete.

- If the study shows that the Witts Lake landslide may be susceptible to additional movement, and either extends onto lot 907 or may affect it, development should not proceed unless adequate factors of safety are determined for the landslide by a detailed geotechnical-engineering slope-stability analysis using guidelines recommended by Hylland (1996), or unless measures are taken to ensure stability.

- If the study shows that the Witts Lake landslide does not extend onto lot 907, or extends onto the lot but is stable, a site-specific geotechnical study as recommended by Earthtec (2000) should be conducted to evaluate (1) the stability of the steep slope on the northwestern and eastern edges of the lot, (2) possible impacts of the landslide on the northwestern edge, (3) the potential for flooding along lower slopes, and (4) the potential for shallow ground water associated with vegetation noted by Earthtec on property southwest of lot 907.

- The site-specific study should map geology, appropriate setbacks, the location of the septic-tank soil-absorption system, and buildable areas on a detailed topographic base map.

REFERENCES

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Review of “Surface fault rupture hazard study phase I, McCoard subdivision, Provo, Utah”</td><td>Requesting Agency:
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(R-17)</td></tr>
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INTRODUCTION

At the request of Dave Graves, Provo City Project Engineer, I reviewed a geologic and geotechnical report for the McCoard subdivision by RB&G Engineering Inc. (RB&G) (RB&G, 2000). The subdivision is southwest of the intersection of Nevada Avenue and Slate Canyon Drive at approximately 1250 South in Provo in the NE1/4 NW1/4 section 17, T. 7 S., R. 3 E., Salt Lake Base Line and Meridian. I received the report on October 2, 2000. The purpose of this review is to evaluate if geologic hazards are adequately addressed. The scope of work for the review included a literature review and inspection of published geologic maps, Utah County geologic-hazard maps, and Provo City geologic-hazard maps. I did not visit the site.

DISCUSSION AND RECOMMENDATIONS

RB&G (2000) addressed possible hazards resulting from surface fault rupture, earthquake ground shaking, liquefaction, rock fall, debris flows, and landslides. I generally concur with their recommendations and provide additional comments on liquefaction and lateral-spread hazards. RB&G (2000) identified areas of active faulting and provided setbacks from faults A and B and I concur with their setback recommendations. I also agree with the RB&G recommendation that if houses are planned within 25 feet of the fault mapped along the north property boundary, trenching should be performed. RB&G (2000) states the small-displacement faults C, D, and E, between fault B and the southeast property boundary (plate 1), are liquefaction- and lateral-spread-related displacements rather than tectonic. No matter what the origin (liquefaction or tectonic), RB&G recommends not building in this area. I agree, and believe this area should be shown as a no-build zone on site plans.

RB&G states that liquefaction-related deformation is unlikely now because they presume the water table is lower than when liquefaction occurred, but they do not state a depth to ground water. Robison (1990) indicates the site likely has ground water within 11 to 50 feet below the surface. Seepage from the irrigation canals along the northeast and southwest property boundaries may recharge a shallow aquifer underlying the site. Mapping by Anderson and others (1994) indicates the proposed subdivision is on a boundary between areas of high and very low liquefaction potential. Because of evidence for previous liquefaction and the potential for shallow ground water at this proposed subdivision, I recommend liquefaction and lateral-spread hazards be evaluated in the geotechnical soils report for the subdivision.

I also recommend disclosure of the RB&G report, any subsequent reports, and this review to future buyers, and that Provo City provide a means to ensure that final recommendations are followed. One way to do this is to require the developer to submit written documentation from the consultants indicating that their recommendations have been followed.

REFERENCES

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Utah Geological Survey

Project: Review of geotechnical investigation reports for an approximately 8,000 acre proposed recreational property, Heber, Wasatch County, Utah			Requesting Agency: Wasatch County Planning
By: Greg N. McDonald Gary E. Christenson	Date: 11-3-00	County: Wasatch	Job No: 00-19 (R-18)
USGS Quadrangle: Center Creek (1126), Heber Mountain (1125)		Number of attachments: None	

INTRODUCTION

This report is a review of two geotechnical investigations by Intermountain GeoEnvironmental Services, Inc. (IGES) for over 8,000 acres of recreational property southeast of Heber City, Wasatch County, Utah. One report (IGES, 1998) covers about 6,000 acres in all or parts of sections 13 and 24, T. 4 S., R. 5 E., and sections 7, 9, 15, 16, 17, 18, 19, 21, 22, 23, and 30, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian (SLBM). The other report (IGES, 1999) covers more than 2,000 additional acres in all or parts of sections 25, 26, 35, and 36, T. 4 S., R. 6 E., SLBM. Sharon Mayes-Atkinson, Wasatch County Assistant Director of Planning and Zoning, requested the review. We understand that lodges, cabins, and other permanent facilities for year-round human occupancy are planned, as well as critical facilities such as water tanks. Our scope of work consisted of a literature review. No site visit was made. We received the reports on September 20, 2000, and accompanying maps on October 6, 2000. Recommendations pertaining to foundation design and site grading should be reviewed by a qualified geotechnical engineer.

DISCUSSION

Both IGES reports adequately address possible hazards resulting from rock falls, stream flooding, expansive soils, shallow ground water, earthquake ground shaking, surface fault rupture, and shallow bedrock and we concur with their recommendations. We also concur with their assessment that conditions are generally unsuitable for septic-tank soil-absorption (STSA) systems. However, we believe the landslide hazard was not adequately addressed. In addition, possible hazards from alluvial-fan flooding/debris flows and snow avalanches were not addressed in the reports.

We concur with the general IGES statements, “older landslides exist in many areas of the project site” and “we recommend additional geotechnical studies be completed as the facility locations become finalized to aid in minimizing the development impacts on the landslide-prone areas.” We also concur with the IGES conclusion that more detailed geotechnical data are necessary to completely assess the possibility of earthquakes destabilizing the old landslides within the project area. However, in addition to considering development and earthquake impacts on landslide stability, we believe the present static stability of steep slopes and landslides must also be evaluated in areas where critical facilities or facilities for human occupancy are planned. The fact that an old landslide is not presently moving does not ensure adequate stability for development. Many historical slope movements in Utah are natural reactivations of older landslides with or without impacts from development or earthquakes.

Both IGES reports identify specific areas of landslide hazard (all within T. 4 S., R. 6 E), although IGES (1998) does not show landslides or landslide-hazard areas on a map, and the map in IGES (1999) does not include all landslides that have been identified by Hylland and others (1995). IGES (1998) discusses potential landslide deposits in the southern portion of section 16 and northern portion of section 21 and interprets the area to be presently stable, but does not present evidence to support this conclusion. Biek and others (2000) mapped possible sackung features in the area. Sackungen are scarps along ridge crests formed by gravitational spreading of bedrock. We believe further study is warranted if structures are planned here. IGES identifies additional areas of landslide hazard including a north-facing slope in section 17 and the southwest portion of section 35. IGES recommends further investigation in these areas if construction is planned, and we concur.

IGES (1998) acknowledges the presence of old landslide deposits in a cirque area (section 22) based on their observations of disturbed bedding in soils and hummocky terrain. IGES indicates shallow ground water is likely in this area and that soft and saturated soils were noted by construction workers excavating in the area. However, IGES concludes the area is stable because no evidence of landslide activity was observed during their field reconnaissance. IGES also believes that proposed development of local spring water will lower the ground-water table and further stabilize the area. We believe this is an inadequate geological landslide evaluation for this area and recommend a more comprehensive geologic evaluation following the guidelines of Hylland (1996) if critical facilities or facilities for human occupancy are planned here.

Features identified by IGES in section 36 as potential sackung scarps may also be older landslide scarps. The scarps as shown by IGES (1999) are in an area of mapped older landslide deposits (unpublished UGS mapping, Coogan and Constenius, 2000). In either case, we believe site-specific evaluation of this area is needed if facilities will be located here.

In general, the landslide hazard warrants site-specific studies for proposed facilities located in areas identified by Hylland and others (1995) as having a moderate to high landslide hazard, particularly in areas of mapped landslides (Hylland and others, 1995; Biek and others, 2000). Site-specific studies should follow guidelines as outlined in Hylland (1996).

The two IGES reports conflict regarding recommended cut slopes in volcanic bedrock at the site. One report recommends cut slopes no greater than 2H:1V whereas the other recommends 3H:1V. Neither report presents supporting information regarding the recommended cut slopes. Cut slopes in weathered tuffaceous bedrock may need to be evaluated on a site-specific basis given the variable lithologies of the Keetley Volcanics. In addition, local bedding attitudes and fracture orientations may also affect cut-slope stability.

A few small alluvial fans along the western property boundary and one in the northwestern portion of the property (Hylland and others, 1995) indicate possible flooding, debris-flow, and collapsible-soil hazards in these areas. These fans comprise a very small portion of the development, but they should be evaluated if structures and/or roadways are to be built on them.

An avalanche hazard may be present at the site, especially in the higher elevation areas in the southeastern part of the property. Avalanche slide paths, if present, may affect the placement and design of facilities and should be addressed, particularly if the area is to be used during winter months.

CONCLUSIONS

In summary, the IGES reports identify rock fall, stream flooding, expansive soil, shallow ground water, earthquake ground shaking, surface fault rupture, and shallow bedrock hazards at a sufficient level of detail for a reconnaissance study. However, landslide, sackung, alluvial-fan flooding, debris-flow, and avalanche hazards are not adequately addressed. Therefore, we recommend the following:

- IGES recommendations regarding problem soils, STSA systems, and more detailed site-specific studies should be followed.

- At a minimum, geologic landslide evaluations should be conducted for sites for critical facilities (water tanks) or permanent structures for human occupancy in areas depicted by Hylland and others (1995) as having moderate to high landslide potential, particularly in areas of mapped landslides, and in areas of suspected sackungen (IGES, 1999) to consider possible landslide origins.

- An avalanche-hazard study should be performed, particularly for facilities that are to be used during winter months.

- Alluvial-fan flooding, debris-flow, and collapsible-soil hazards should be addressed if facilities are planned on alluvial fans.

- Subsequent reports regarding geologic conditions and site design/grading recommendations should be reviewed by appropriate agencies.

REFERENCES

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Hylland, M.D., Lowe, Mike, and Bishop, C.E., 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, 12 plates, scale 1:24,000.

Intermountain GeoEnvironmental Services, Inc., 1998, Report, geotechnical investigation, Heber 6,000 acre recreational property, Heber, Utah: Salt Lake City, Utah, unpublished consultant's report, 29 p.

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Utah Geological Survey

Project: Review of geologic hazard and geotechnical reports for the proposed Raz-De-Mare'e residential development, Layton, Davis County, Utah			Requesting Agency: Layton City Community Development Department
By: Richard E. Giraud	Date: 10-20-00	County: Davis	Job No: 00-20 (R-19)
USGS Quadrangle: Kaysville (1320)		Number of attachments: None	

INTRODUCTION

At the request of Doug Smith, Layton City Planner, I reviewed a preliminary engineering-geology investigation report by Dames and Moore (1979); a supplemental engineering-geology, geotechnical, and geoseismic study by SHB AGRA, Inc. (SHB, 1994); and a surface-fault-rupture-hazard and supplemental geotechnical report by AMEC Earth and Environmental (AMEC, 2000) for the proposed Raz-De-Mare'e (Seldon Young property) residential development in Layton. The site is located east of Highway 89 at Hill Field Road in Layton, Utah (NW1/4SW1/4 section 1, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian). The purpose of this review is to evaluate if geologic hazards were adequately addressed. The scope of work for the review included a literature review, including a geotechnical report for a proposed Layton City water tank in the proposed development by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 2000); inspection of published geologic and Davis County geologic-hazard maps; and a site visit on June 26, 2000. I received the Dames and Moore and SHB reports on June 19, 2000; the AMEC report on September 27, 2000; and the AGEC report on October 10, 2000. All reports have geotechnical-engineering recommendations that should be reviewed by a qualified geotechnical engineer, including the rock-wall design.

DISCUSSION AND COMMENTS

Dames and Moore (1979), SHB (1994), and AMEC (2000) addressed possible hazards resulting from surface fault rupture, earthquake ground shaking, liquefaction, landsliding, rock fall, problem soils, shallow ground water, flooding, and debris flows. The AMEC (2000) report discusses hazards relative to the current subdivision design and I generally concur with their hazard recommendations and provide additional comments on surface fault rupture, landslides, and cut and fill slopes below.

AMEC (2000) identified a fault in trench FT-3 and recommends at least a 25-foot setback for structures on lots 18 and 19. AMEC (2000) does not show the fault or setback area on the site drawings (figures 2A and 2B). Because this setback excludes at least a 50-foot-wide zone along the fault across lots 18 and 19, I recommend the fault and setback be shown on site drawings to show the actual buildable area. AMEC (2000) and AGEC (2000) did not discover any other faults within the proposed development.

AMEC (2000) states that the landslides identified in the SHB (1994) report are presently stable and recommends a 50-foot setback from the crest of steep slopes in this area. AMEC does not show the setbacks on site drawings (figures 2A and 2B), or state how they determined the setback distance or if the setback considers static and seismic stability and the effects of subdivision drainage, development-induced (landscape irrigation) ground-water conditions, and fill placement. A potential exists for these landslides to reactivate and/or for landslide main scarps and adjacent steep slopes to fail due to changed conditions associated with development. Without subsurface information and geotechnical characterization of the landslides, I have no way to evaluate the adequacy of the 50-foot setback. Therefore, I recommend performing a detailed geotechnical-engineering landslide- and slope-stability evaluation, as outlined in Hylland (1996), to characterize the landslides; address the stability conditions mentioned above, including determining the possible impacts of development in reactivating existing landslides or promoting landsliding on adjacent steep slopes; and demonstrate the adequacy of the 50-foot setback.

The SHB (1994) report recommends that final permanent cut and fill slopes be no steeper than 2H:1V. The SHB (1994) recommendation conforms to the Uniform Building Code (UBC) (International Conference of Building Officials, 1997) which does not allow permanent cut and fill slopes steeper than 2H:1V (50 percent) unless the soil engineer or engineering geologist indicates the slopes are stable. AMEC (2000) does not provide additional final cut and fill slope recommendations, so presumably AMEC concurs with the SHB (1994) recommendations. However, AMEC (2000) states that stacked rock walls will be placed over “stable” cut and fill slopes (presumably 2H:1V slopes) and provides an overall slope recommendation of 1.5H:1V for individual rock walls up to a maximum 10 feet high to ensure both static and dynamic stability.

Based on the lot layout and flat area needed for building footprints, the lots east of Tsunami Court and Tsunami Lane may require cuts steeper than 2H:1V into the toe of the steep (32 to 34 degrees) mountain slope. Shallow bedrock may be encountered in some cuts. SHB (1994) provides bedrock cut recommendations, including for the water-tank access road on this mountain slope, and states that retaining structures will be required to support road cuts in colluvium. AMEC (2000) does not address the stability of cuts into the toe of the steep mountain slope. Because of the high, steep cuts and variability in thickness of colluvium, I recommend a grading plan be developed showing proposed cuts, thickness of colluvium, and slope design to ensure both cut-slope and natural-slope stability for cuts on the east side of the subdivision and the water-tank access road. Slope performance must be evaluated under appropriate earthquake ground-shaking and estimated development-related irrigation conditions.

AMEC provides recommendations for surface-water drainage-ditch construction at the top of stacked rock walls. UBC Chapter 33 (International Conference of Building Officials, 1997) lists additional depth, gradient, concrete type, and concrete depth criteria for drainage ditches above cuts that I recommend be followed. A designated receiving location must also be specified for water discharged from these ditches.

RECOMMENDATIONS

Regarding the Dames and Moore, SHB, and AMEC assessments of geologic hazards at the site, I recommend the following:

- Show the fault and setbacks on site plans to indicate the buildable areas of lots 18 and 19.

- Perform a detailed geotechnical-engineering slope-stability evaluation, as outlined in Hylland (1996), of landslides and adjacent steep slopes to show that the 50-foot setback is adequate. The landslide and slope-stability evaluation must characterize subsurface conditions at the site and consider static and seismic conditions; effects of subdivision grading, drainage, and fill placement; and estimated development-induced (landscape irrigation) ground-water conditions. Final recommended setbacks must be shown on site plans.

- Prepare a grading plan showing slope design for cuts into the mountain slope east of the subdivision to ensure both cut and natural slope stability under appropriate earthquake ground-shaking and estimated irrigation conditions.

- Follow the UBC provisions for surface-water collection ditches at the top of stacked rock walls in addition to the recommendations provided by AMEC.

- Disclose the Dames and Moore, SHB, AMEC, and AGEC reports, subsequent reports, and this review to future buyers.

Any setbacks, hazard areas, and protective structures determined from the above hazard evaluations must be shown on the site map to delineate buildable areas. Specific recommendations and restrictions pertaining to the site and buildings should be included in the report. All conclusions and recommendations must be supported by quantified data and presented in the report so a technical reviewer can evaluate their validity. Also, Layton City should provide a means to ensure that final recommendations are followed; one way to do this is to require the developer to submit written documentation from the consultants indicating that their recommendations have been followed.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 2000, Geotechnical investigation, proposed 2 million gallon water reservoir, east of Highway 89 and State Road 193, Layton, Utah: Midvale, Utah, unpublished consultant's report for Layton City, 14 p.

AMEC Earth and Environmental, Inc., 2000, Surface-fault-rupture hazard and supplemental geotechnical study, Raz-De-Mare'e Development, east of Highway 89 at Hill Field Road, Davis County, Utah: Salt Lake City, Utah, unpublished consultant's report for the Jack Johnson Company, 9 p.

Dames and Moore, 1979, Preliminary engineering geology investigation, East Layton property, Highway 89 and Hill Field Road, South Weber, Utah: Salt Lake City, Utah, unpublished consultant's report for Reeve and Reeve, Inc., 20 p.

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International Conference of Building Officials, 1997, Uniform Building Code: Whittier, California, International Conference of Building Officials, variously paginated.

SHB AGRA, Inc., 1994, Supplemental engineering geology, geotechnical, geoseismic study, proposed Ras-De-Mare'e residential development, east of Highway 89 at Hill Field Road, Davis County, Utah: Salt Lake City, Utah, unpublished consultant's report for Seldon Young, 18 p.

Utah Geological Survey

Project: Review of "Geological evaluation of landslide susceptibility, Eric Younger lot, 5824 Snow Basin Road, Lot 1, SW¼ of Section 23, T6N, R1E, Huntsville, Utah"			Requesting Agency: Weber County Planning
By: Greg N. McDonald Gary E. Christenson	Date: 11-8-00	County: Weber	Job No: 00-21 (R-20)
USGS Quadrangle: Snow Basin (1344)		Number of attachments: None	

INTRODUCTION

This report is a review of a geologic evaluation of landslide susceptibility by Simon-Bymaster, Inc. (SBI, 2000) for the Eric Younger lot at 5824 Snow Basin Road, Weber County, Utah. Jim Gentry, Weber County Planning Commission, requested the review. We received the report on October 30, 2000. The property is in the SW¼ section 23, T. 6 N., R. 1 E., Salt Lake Base Line and Meridian. The SBI study is a follow-up to an Earthtec (2000) geotechnical study reviewed by the Utah Geological Survey (McDonald and Christenson, 2000). The scope of work for our review consisted of a literature review and examination of 1:24,000-scale aerial photos (1952). In addition, we visited the site on October 5, 2000.

DISCUSSION AND CONCLUSIONS

The general conclusion of SBI's geologic evaluation of slope stability is that the Younger lot is suitable for the proposed single-lot development given proper design recommendations and practices are followed, and we concur. SBI's geologic evaluation determined the north-trending spur ridge on which the house is to be built consists of older landslide deposits. SBI characterizes the deposits as hard, well-indurated, slightly moist silty clay (CL). Under these existing conditions the deposits have relatively high strengths. SBI found no signs of deep-seated instability or recent large-scale movement such as ground cracks or tilted trees. SBI documents some small, shallow slumps in steeper areas of the property, but determined they will not adversely affect the house at its proposed location. We concur and emphasize development or site grading modifications in these areas of shallow slumps should be avoided.

SBI determined from soil profiles and geomorphic features that the landslide is relatively old. SBI concludes from these data that the deposit is at least 75,000 years old and presently stable under current conditions. We concur with the assessment that the deposit is old and appears to have been stable under climatic conditions during the Holocene (past 10,000 years) and perhaps longer.

SBI stresses the need for proper site design and practices to minimize water infiltration and makes recommendations to that effect. We agree with the assessment that proper site drainage and grading is critical for the development. Additionally, ruptured or leaking septic and water lines can induce or promote instability. We therefore recommend site drainage and design recommendations presented by SBI be implemented. In addition, Weber County will need to ensure future development upslope of the property does not alter drainage, introduce water into the subsurface, or otherwise adversely impact the stability of the old landslide at the Younger lot.

Although we concur that available evidence indicates the old landslide deposit is sufficiently stable for a single lot development, inherent uncertainties exist when building on older landslide deposits that do not exist elsewhere. Therefore, we recommend disclosure of the SBI report and this review to future home buyers, and strict adherence to SBI's recommended hazard-reduction recommendations.

REFERENCES

Earthtec Testing and Engineering, P.C., 2000, Geotechnical study, Eric Younger lot, 6100 Snow Basin Road, Huntsville, Utah: Ogden, Utah, unpublished consultant's report, 12 p.

McDonald, G.N., and Christenson, G.E., 2000, Review of "Geotechnical study, Eric Younger lot, 6100 Snow Basin Road, Huntsville, Utah": Utah Geological Survey Technical Report 00-13, 3 p.

Simon-Bymaster, Inc., 2000, Geological evaluation of landslide susceptibility, Eric Younger lot, 5824 Snow Basin Road, Lot 1, SW¼ of section 23, T6N, R1E, Huntsville, Utah: Bountiful, Utah, unpublished consultant's report, 10 p.

Project: Review of "Phase I, Geologic hazards study, Sunridge Hills, 16-acre property, Provo, Utah"			Requesting Agency: City of Provo
By: Richard E. Giraud	Date: 12-04-00	County: Utah	Job No: 00-22 (R-21)
USGS Quadrangle: Provo (1047)		Number of attachments: None	

INTRODUCTION

At the request of Dave Graves, Provo City Project Engineer, I reviewed the phase I geologic-hazards study for the Sunridge Hills 16-acre residential development (RB&G Engineering Inc. [RB&G], 2000). The property is part of a former gravel pit east of the intersection of 1080 South Street and Slate Canyon Road in Provo, Utah (SE1/4 SW1/4 and SW1/4SE1/4 section, T. 7 S., R. 3 E., Salt Lake Base Line and Meridian). I received the report on November 3, 2000. The purpose of this review is to evaluate if geologic hazards are adequately addressed. The scope of work for the review included a literature review and inspection of published geologic maps, aerial photos, Utah County geologic-hazard maps, and Provo City geologic-hazard maps. I did not visit the site. RB&G (2000) provides a hydrologic analysis for flooding from drainage basins east of the site that should be reviewed by a qualified hydrologist or engineer.

DISCUSSION AND RECOMMENDATIONS

RB&G (2000) addresses possible hazards resulting from surface fault rupture, earthquake ground shaking, rock falls, slope instability, flooding, and debris flows. I generally concur with their recommendations and provide additional comments on surface fault rupture, slope stability, and debris flows.

RB&G (2000) recommends that an engineering geologist inspect construction cuts for evidence of active faults and I agree. Because the site is disturbed by gravel mining, RB&G relied on pre-gravel-pit aerial photographs and previous mapping to identify possible faults. At the Alpine Brook development directly south of this site, RB&G (1999) identified active faults in cuts that were not evident on aerial photographs and lacked any ground-surface expression. Because faults in this area may lack surface expression, RB&G's recommendation to inspect cuts for evidence of faulting is critical. I also concur with RB&G's suggestion that further pre-development trenching be performed to evaluate the presence of faulting rather than risk discovering faults in cuts during development. Trenching unexplored areas prior to development is generally a more cost- and time-efficient mechanism to identify possible faults rather than to wait and inspect cuts, trenches, and foundation excavations and risk late-stage redesign or loss of lots due to previously unrecognized faults.

RB&G (2000) states that hydrologic or other changes associated with future development on or above the 50 to 70 percent slopes along the north and east boundaries could create a slope-stability problem, and such development must be done without negative impact to the site. The Uniform Building Code (UBC) (International Conference of Building Officials, 1997) does not allow permanent cut and fill slopes steeper than 50 percent unless the soils engineer or engineering geologist indicates the slopes are stable. Therefore, I recommend the stability of any permanent cut or fill slopes greater than 50 percent be addressed prior to development. Because portions of the 50 to 70 percent slopes lie outside of property lines shown on plate1 (RB&G, 2000), Provo City must be aware that future modification of these slopes could impact the Sunridge site. RB&G (2000) also recommends slope-stability analyses for final slopes greater than 30 percent along the south and west boundaries adjacent to developed properties and that the slope stability within the site be evaluated after a final grading plan is prepared. I agree with both recommendations. The performance of all slopes must be evaluated under appropriate earthquake ground-shaking and estimated development-induced (landscape irrigation) ground-water conditions.

Based on the distance from canyon mouths and the assumption that sediment will be deposited in a gravel pit east of the site, RB&G (2000) determined the debris-flow hazard is minimal at the present time. A current topographic map showing this gravel pit and the sediment storage area is not provided so I cannot determine whether RB&G's assessment is accurate. RB&G (2000) recommends that future development or mining in the gravel pit east of the site should be monitored to ensure no negative impact on this development, which I believe is critical because mining, reclamation, or development of the gravel pit may change the flow, deposition, and runout patterns of debris flows. RB&G does not state who owns the gravel pit to the east and if this owner is willing to follow their recommendations. Provo City will need to assess if and how this recommendation can be implemented. Also, provided RB&G can demonstrate that sufficient sediment-storage capacity exists in the gravel pit, Provo City will need to assess whether the presumably non-engineered gravel pit is suitable for use as a permanent debris basin.

Any setbacks, hazard areas, and protective structures determined from the above hazard evaluations must be shown on a site map to delineate buildable areas. Specific recommendations and restrictions pertaining to the site and buildings should be included in the report. All conclusions and recommendations must be supported by quantified data and presented in the report so a technical reviewer can evaluate their validity. I also recommend disclosure of the RB&G report, subsequent reports, and this review to future buyers. Also, Provo City should provide a means to ensure that final recommendations are followed. One way to do this is to require the developer to submit written documentation from the consultants indicating their recommendations have been followed.

REFERENCES

International Conference of Building Officials, 1997, Uniform Building Code: Whittier, California, International Conference of Building Officials, variously paginated.

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---2000, Phase I geologic hazards study, Sunridge Hills 16-acre property, Provo, Utah: Provo, Utah, unpublished consultant's report for Steve Stewart, Sunridge Development, 10 p.

Project: Review of "Geotechnical study, Lot 79, Green Hills Country Estates Phase 5, Ogden Valley, Utah"			Requesting Agency: Weber County Planning
By: Greg N. McDonald Gary E. Christenson	Date: 1-4-01	County: Weber	Job No: 00-23 (R-22)
USGS Quadrangle: Browns Hole		Number of attachments: None	

INTRODUCTION

This report is a review of a geotechnical study by Earthtec Testing & Engineering, P.C. (Earthtec, 2000) for lot 79 in Green Hills Country Estates on the east side of Ogden Valley, Utah. The property is in the NE¼SW¼NW¼ section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission, requested the review. We received the report on December 8, 2000. The purpose of our review is to assess whether geologic hazards possibly impacting the property are adequately addressed. The scope of work for our review consisted of a literature review and examination of 1:24,000-scale aerial photos (1952). No site visit was made.

DISCUSSION

Earthtec performed a geotechnical study for the lot in 1992 which was reviewed by the Utah Geological Survey (UGS) (Harty, 1992). Harty (1992) concluded Earthtec had adequately addressed geologic hazards at the site regarding expansive soils and seismic concerns but not slope stability. Because Earthtec (1992) determined the site to be on landslide deposits, Harty recommended the type, thickness, age, and geology of the landslide be better characterized and that additional field work by a qualified engineering geologist was needed to adequately assess its stability and potential impact on the property.

Earthtec (2000) reiterates its geologic-hazards recommendations from the earlier report with respect to seismic ground shaking, fault rupture, and expansive soils. Earthtec further addressed slope stability for this study by performing additional site reconnaissance and a slope-stability analysis (including pseudostatic) with XSTABLE (modified Bishop's method). Earthtec did not perform any additional subsurface investigation or sampling.

Earthtec (2000) describes the property as being on the toe of a landslide and reports no indication of active landsliding on the property. Material encountered in the 1992 trenches is described as 6 to 7 feet of slide debris underlain by "native" soils consisting of sandy clay with scattered cobbles. Earthtec does not present evidence substantiating the underlying "native" clayey material is in-place soil rather than old landslide debris. Earthtec (2000) states "The lot is situated at the toe of a prehistoric landslide which appears to have had at least two events. The later event is located at the northern side of the property while the primary event toe is located to the south of the property" and ". . . the (primary) slide scarp is approximately 1,500 feet north of the property." A landslide of this size, particularly one with a circular rupture surface, would likely be thicker than the 6 to 7 feet indicated. Given that the house is to be founded within the older landslide at the toe of the younger landslide, the UGS believes additional geologic characterization of both the older and younger landslides with respect to failed units, failure mechanism and landslide type, and age, per Harty's (1992) recommendations, is still needed.

As Harty (1992) indicated, characterizing the landslides may be more practical on a subdivision-wide, rather than single-lot, scale given their size, extent well beyond the site boundaries, and implications for other lots. Such a characterization must include mapping of both landslides beyond just lot 79, and preparation of at least one scaled geologic cross section trending northeast-southwest (parallel to the direction of movement and slope) showing the subsurface geology and depth of inferred rupture surfaces. The low surface gradient, large size of the older landslide as indicated by Earthtec (2000) and mapped by Harty and Lowe (1991) and Coogan and King (1999), and possible shallow rupture surface as indicated by Earthtec (2000), make this a unique landslide area that must be better understood to assess future stability and ensure safe development.

For another part of Green Hills Country Estates in soils similar to those described at this site, AGEC (1996) performed extensive soil testing which indicated a range of strengths and significant reductions in strength upon wetting with residual cohesion values of 162-165 psf and residual friction angles of 4-12.2 degrees for wet clay soils (AGEC, 1996, p. 7). The UGS recommends performing slope-stability sensitivity analyses for the older and younger landslides and final site grade using a range of applicable soil-strength values (including values obtained by AGEC [1996]) and shallow, post-snowmelt ground-water conditions. These analyses will yield a range of factors-of-safety for various assumed soil strengths for the older and younger landslides and final site grade which can then be the basis for judgements regarding future slope stability and levels of risk.

Earthtec recommends that permanent cut slopes in "native clay"on the property should not exceed 2 horizontal to 1 vertical (2H:1V; 50 percent). AGEC (1996) recommended maximum 4H:1V slopes in clayey soils based on extensive soil testing. Several small, shallow slides have been documented along road cuts and within a residential backyard east-southeast of the site (Harty and Lowe, 1991). Many of these slumps are in slopes shallower than 2H:1V with one at 4H:1V (Black, 1998). Therefore, the UGS believes Earthtec's recommended 2H:1V cut slopes may be too steep given the nature of soils in the area and observed slumps nearby, and that these cut-slope recommendations should be re-evaluated as part of the slope-stability analysis.

Also, if a septic-tank soil-absorption (STSA) system is planned, site suitability should be addressed. The location and size of an STSA system needs to be considered as part of the geotechnical evaluation because associated infiltration may directly affect geologic hazards at the site including shallow ground water, problem soils, and slope stability. In addition, expansive or low-permeability soils can be unsuitable for STSA systems and preclude health-department approval.

Although the location map in the Earthtec (2000) report does not show sufficient detail to determine the location of the lot with respect to the active drainage crossing the landslide from the mountain front, the lot appears to be near the drainage. If so, an assessment of the alluvial-fan flooding and debris-flow hazard from the drainage is necessary.

CONCLUSIONS AND RECOMMENDATIONS

Earthtec identifies potential hazards from shallow ground water, expansive soils, earthquake ground shaking, and landsliding at the site. The Earthtec report adequately addresses all of these hazards except landsliding. Earthtec also does not address STSA-system suitability and possible effects on hazards, or the potential for alluvial-fan flooding or debris flows. Therefore, the UGS recommends the following:

- The geology of the older and younger landslides should be further characterized, including determination of failed units (colluvium, alluvial-fan and debris-flow deposits, bedrock?), failure mechanism (earth flow, shallow translational slide, slump?), and age (pre- or post-Bonneville, late Holocene?).
- Because the site is on landslide deposits and in an area where numerous recent, shallow slope failures and low-strength soils have been documented, a slope-stability sensitivity analysis (including pseudostatic) should be conducted for the older and younger landslides and final site grade using a range of applicable soil strength values and assuming shallow ground-water conditions. Characterizing and analyzing the landslides may be more practical on a subdivision-wide scale given the fact that the landslides extend beyond the site boundaries and will impact other lots in the subdivision.
- The 2H:1V cut-slope recommendation should be re-evaluated based on results of the revised slope-stability analyses.
- Foundation design recommendations for reducing problem-soil and ground-shaking hazards should be reviewed by a qualified geotechnical engineer.
- If an STSA-system is planned, a site suitability study must be performed to determine if soils are sufficiently permeable for proper STSA-system operation.
- Alluvial-fan-flooding and debris-flow hazards from the active drainage should be assessed.
- Weber County should provide a means to ensure that final recommendations are followed, such as requiring the developer to submit written documentation from the consultant confirming that their recommendations were followed.
- The existence of the Earthtec (2000) report, this review, and any subsequent reports and reviews should be disclosed to future buyers.

REFERENCES

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Project: Review of “Geotechnical examination of lot 1268, Timber Lakes Estates, Wasatch County, Utah”			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 2-8-01	County: Wasatch	Job No: 01-01 (R-23)
USGS Quadrangle: Center Creek (1126)		Number of attachments: None	

INTRODUCTION

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report for Timber Lakes subdivision lot 1268 by D.A. Hedderly-Smith & Associates (Hedderly-Smith, 2001). I received the report on January 17, 2001. The lot is in the NW1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Hedderly-Smith (2001) adequately addressed the potential for landslides on the lot. My scope of work included a review of published geologic-hazards literature and aerial photographs (1999; 1:7,920), but I did not inspect the property.

DISCUSSION

Hylland and others (1995) map landslide hazards in western Wasatch County depending on the presence or absence of existing landslides, slope inclination, and types of geologic material. Although Hylland and others (1995) do not map a landslide on or near lot 1268, the lot lies within a landslide special-study area designated by Wasatch County based on additional UGS aerial-photo mapping of a possible landslide (1:20,000 scale, 1962; 1:40,000 scale, 1987) done after the publication of Hylland and others (1995). Detailed site investigations must be conducted for lots within Wasatch County’s special-study areas to assess the presence of landslides on or near the lots and, if present, their implications for lot stability.

Hedderly-Smith (2001) found no evidence of slope movement on lot 1268 and describes outcrops of the Jurassic Nugget Sandstone on lower slopes. These observations are consistent with recent geologic mapping. Biek and others (2000) map Jurassic Nugget Sandstone underlying the lower slope and Tertiary Keetley Volcanics underlying the upper slope. Ongoing landslide studies for the Timber Lakes subdivision (D. Neuffer and R. Bruhn, unpublished mapping) map the contact between the Nugget Sandstone and Keetley Volcanics across the upper part of the lot. Neither of the recent studies map landslides on the lot. I concur with the finding of no landslides on lot 1268.

Although evidence for a landslide is lacking on lot 1268, Hylland and others (1995) map a moderate landslide hazard on most of the lot because regional-scale slope maps indicate slope inclinations greater than a critical slope inclination, above which late Holocene landsliding has typically occurred. However, a detailed slope profile measured by Hedderly-Smith (2001) shows the slope inclination is about 32 percent in the lower part of the lot (underlain by the Nugget Sandstone) and about 21 percent in the upper part (underlain by the Keetley Volcanics). Because the Nugget Sandstone is not susceptible to landsliding, even at slopes exceeding 32 percent, and the slope inclination of the upper part of the lot underlain by the Keetley Volcanics is less than the critical slope inclination of 25 percent (Hylland and Lowe, 1997), I believe that further evaluation of on-site slopes is not necessary. I therefore agree with the conclusion of Hedderly-Smith (2001) that "No slope stability analysis is needed or recommended for this lot because the area of Keetley Volcanics on the upper portion of the lot (1) is relatively flat and (2) sits on a solid foundation of Jurassic Nugget Sandstone outcrops which occupy the lower portion of the lot."

CONCLUSIONS AND RECOMMENDATIONS

I believe Hedderly-Smith (2001) adequately addresses the potential for landslides on Timber Lakes Estates lot 1268 for purposes of issuing a building permit. Hedderly-Smith (2001) demonstrates that the lot does not lie on a landslide, does not find any evidence of past slope movement on the lot, and provides evidence that on-site slopes do not pose a significant landslide hazard and need not be further evaluated. I therefore recommend that Wasatch County remove lot 1268 from their landslide special-study area. I further recommend the following to the developer:

- If retaining walls are planned, provide an engineered design for the walls and have the design reviewed by a qualified engineer; the design must include a site map showing cuts, fills, and retaining walls; the retaining-wall design must consider static and earthquake ground-shaking conditions and incorporate pertinent drainage recommendations.

- If permanent cuts have slopes steeper than 2H:1V (50 percent) and are not supported by retaining walls, cut-slope stability must be addressed in accordance with the Uniform Building Code (International Conference of Building Officials, 1997, Appendix Chapter 33, section 3312).

Wasatch County should provide a means to ensure that final recommendations are followed. One way to do this is to require the developer to submit written documentation from the consultant indicating that their recommendations were followed.

REFERENCES

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Utah Geological Survey

Project: Review of geologic-hazard reports for the proposed Les Liechty Plat B subdivision, Provo, Utah			Requesting Agency: Provo City
By: Francis X. Ashland	Date: 2-9-01	County: Utah	Job No: 01-02 (R-24)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

At the request of David Graves, Provo City, I reviewed two geologic-hazard reports (Simon-Bymaster Inc. [SBI], 2000, 2001) for the proposed Les Liechty Plat B subdivision in Provo, Utah. The reports address surface-fault-rupture and rock-fall hazards, respectively, for a proposed four-lot residential subdivision east of 1450 East Street and north of 2050 North Street in the SW1/4 section 29, T. 6 S., R. 3 E., Salt Lake Base Line and Meridian. The site is located between active traces of the Wasatch fault zone and at the base of a moderate west-facing mountain slope. The reports were submitted in response to comments and recommendations made in a previous review by the Utah Geological Survey (UGS) (Ashland, 2000) of two earlier site-investigation reports (American Geological Services, Inc., 2000; Earthtec Testing & Engineering, P.C., 2000). The purpose of this current review is to determine whether the two reports adequately address the hazard-related issues raised by the UGS in its previous review, in order to support proposed development plans. The scope of my evaluation consisted of review of the referenced reports and a brief site visit on October 26, 2000. The UGS received the SBI (2000) report on December 8, 2000, and the SBI (2001) report on January 30, 2001.

SURFACE FAULT RUPTURE

In a previous review (Ashland, 2000), the UGS recommended that (1) the location of three faults identified in a single trench (American Geological Services, Inc., 2000) be defined in the northern and southern part of the property and (2) the potential for additional faults in the western part of the site be evaluated. The SBI (2000) report adequately defines the location of the westernmost of three faults across the eastern part of the site and provides adequate building setback recommendations to avoid siting houses within the zone of deformation associated with these faults. In addition, SBI trenched the western part of the site and demonstrated the absence of faulting. SBI indicates that based on the location of the faults, the northernmost lot 3 will not be developed, but rather the lot will be annexed by an abutting residential property owner.

TECTONIC DEFORMATION

SBI's log of the westernmost trench T-1 (drawing no.1 of SBI, 2000) shows that the upper contact of the Lake Bonneville gravels is tilted east, rather than west as in the eastern three trenches. SBI infers that the eastward tilt of the contact is associated with tectonic deformation (tilting), and I concur. SBI estimates about 2.3 degrees of tilting per single earthquake event in which surface fault rupture occurs. SBI's estimated single-event tilt amount is probably a maximum rather than a minimum value because SBI considered only the three late Holocene earthquake events documented in the geologic record, and more (older) events are possible. SBI indicates that while tectonic tilting during a future large earthquake might cause some structural damage, it would not pose a life-safety issue for a typical wood-framed residential structure.

ROCK FALL

SBI (2001) addressed the potential for rock falls impacting the proposed residential lots. In a previous study, Earthtec (2000) indicated a moderate rock-fall hazard and recommended a rock-fall catchment and berm on the east side of the lots. However, Earthtec's (2000) assessment was not supported by adequate geological characterization of previous rock fall at the site or rock-fall modeling. SBI (2001) indicates the absence of any significant rock-fall sources or fragments on the moderate slope above a gas pipeline easement east of the site. Based on my reconnaissance of the site on October 26, 2000, I concur with these observations. The SBI (2001) report also provides photographic evidence of a drill hole in one of the rock fragments in the vicinity of the gas pipeline easement, suggesting these fragments may be the result of blasting and excavation of shallow rock for the pipeline rather that the result of recent rock fall onto the modern surface. SBI used the CRSP rock-fall simulation program (Jones and others, 2000) to demonstrate that rock falls would not likely impact the proposed residential lots. SBI's results indicate that falling rocks that initiate about midway up the slope above the easement would likely reach the easement, but would not likely reach the proposed residential lots to the west and farther downslope. Thus, SBI (2001) concludes that the rock-fall susceptibility at the site (proposed lots) is low, and I concur.

OTHER GEOLOGIC HAZARDS

The SBI (2000) report indicates the potential for earthquake-induced liquefaction, differential compaction, and landsliding is low primarily on the basis of the site topography and the nature of the surficial deposits. Whereas this opinion is not adequately supported by subsurface information, the trench logs in the SBI (2000) report indicate no evidence of prehistoric liquefaction or landsliding. The SBI (2001) report also indicates no evidence of gross instability (landsliding) at the site, but notes that some raveling has occurred at the base of cut slopes along the east side of the pipeline easement.

CONCLUSIONS AND RECOMMENDATIONS

The SBI (2000, 2001) reports adequately address the surface-fault-rupture and rock-fall hazards, respectively, at the site. Information and building-setback recommendations in the SBI (2000) report should be adequate to finalize layout of the proposed four-lot residential development and to locate houses outside the zone of deformation associated with the active fault traces that cross the site. SBI (2001) also adequately characterizes the rock-fall susceptibility at the site and supports its conclusion with geologic observations and computer modeling of probable rock falls originating from the mountain slopes above the site.

The UGS concurs with SBI's (2000) recommendations related to project plan review and foundation excavation inspections. Accordingly, the UGS recommends:

- that at a minimum, the foundation excavation in the southernmost lot should be inspected for evidence of faulting or deformation by a qualified engineering geologist,
- disclosure of the potential tectonic tilting hazard, and
- disclosure of the SBI reports, previous reports, and UGS reviews to potential buyers.

REFERENCES

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Project: Review of "Geotechnical and geologic investigation, proposed Davis County subdivision, 1700 South 300 East, Farmington, Utah"			Requesting Agency: Farmington City Corp.
By: Greg N. McDonald Gary E. Christenson	Date: 03-27-01	County: Davis	Job No: 01-03 (R-25)
USGS Quadrangle: Farmington (1295)		Number of attachments: None	

INTRODUCTION

This is a review of a geotechnical/geologic hazards study by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 1998) for a proposed subdivision in Farmington east of Highway 89 at 1700 South and 300 East. The property includes parts of the NW¼ and SW¼ of the NE¼, section 31, T. 3 N., R. 1 E., Salt Lake Base Line and Meridian. David Petersen, Farmington City Planning and Zoning Administrator, requested the review. I received the report on March 6, 2001. The purpose of this review is to assess whether geologic hazards possibly impacting the property are adequately addressed. The scope of work for our review consisted of a literature review, examination of 1:24,000-scale aerial photos (1985), and a site visit on March 13, 2001, with Rich Giraud (Utah Geological Survey [UGS]). A qualified geotechnical engineer should review the design and grading recommendations.

DISCUSSION

AGEC (1998) assesses possible hazards relating to ground shaking and rock fall and the UGS concurs with their evaluations and recommendations. However, hazards associated with surface faulting, debris flows, landslides, and shallow ground water require further evaluation as discussed below.

Surface Faulting

AGEC adequately assessed surface-faulting hazards except along a trace of the Wasatch fault mapped by Nelson and Personius (1993) at or near the eastern property boundary. Trenches 1 and 2 do not extend to the eastern property boundary, so if houses are planned on any of the easternmost lots (lots 1-5, 23, and 24), east of the ends of these trenches, additional trenching will be required.

Debris flows

AGEC (1998) indicates no debris-flow hazard exists at the site based on an assessment of the Lone Pine Canyon drainage which flows south of the property. The UGS concurs with AGEC's assessment of the debris-flow hazard associated with Lone Pine Canyon, but AGEC has identified the upper 3 to 5 feet of material in trench 1, along the northern property boundary, as debris-flow deposits overlying alluvial and/or lacustrine sand and gravel. The age and origin of these debris-flow deposits and implications regarding present-day hazards should be addressed. Aerial photographs show numerous shallow debris-slide scars on the hillside directly above the northern part of the subdivision.

Landslides

AGEC indicates no landslide hazard at the site based on site reconnaissance, a review of aerial photos, and the type of soil and bedrock present. However, the site is within an area that has been mapped as a large, older landslide complex (Lowe, 1988). Therefore, AGEC should present the geologic evidence that led to their determination that no landslide hazard exists, and give their interpretations regarding the presence, age, and stability of the mapped landslide complex. Such geologic evidence may include inspecting bedrock exposures and Lake Bonneville shorelines and deposits both on-site and nearby for landslide-related deformation.

Shallow ground water

AGEC encountered no ground water in their trenches or test pits. However, AGEC performed their field work during the late fall when ground water levels are typically low. On March 13, 2001, we observed cottonwood trees at the base of a steep slope near the southeast corner of the site. In addition, marshy ground/seeps were observed in the northeast portion of the gravel pit south of the site along the base of the identified fault scarp. Seasonal springs and seeps are common in Wasatch Front foothill settings such as this, and we recommend AGEC consider the potential for localized seasonal shallow ground water.

SUMMARY AND RECOMMENDATIONS

Hazards relating to surface faulting, debris flows, landslides, and shallow ground water need further clarification and/or evaluation. Therefore, we recommend the following:

- Additional trenching to identify surface-faulting hazards should be performed if houses are planned on the easternmost lots east of the ends of trenches 1 and 2.

- The age and origin of debris-flow deposits logged in trench 1 should be evaluated to determine the present-day hazard, if any.

- AGEC should present geologic evidence supporting their landslide-hazard evaluation to help determine whether a more comprehensive evaluation is needed.

- The potential for localized seasonal springs and seeps, as indicated by seeps in the gravel pit immediately southeast of the site, should be considered in the shallow ground water evaluation.

- A qualified geotechnical engineer should review site design and grading recommendations.

- Farmington City should provide a means to ensure that final recommendations are followed, such as requiring the developer to submit written documentation from the consultant confirming that their recommendations have been followed.

REFERENCES

Applied Geotechnical Engineering Consultants, 1998, Geotechnical and geologic investigation, proposed Davis County subdivision, 1700 South 300 East, Farmington, Utah: Sandy, Utah, unpublished consultant's report, 25 p.

Lowe, Mike, 1988, Natural hazards overlay zone – slope failure inventory, Farmington quadrangle: Weber County Planning Department unpublished map, scale 1:24,000.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Map I-2199, 22 p. pamphlet, scale 1:50,000.

Project: Review of geologic-hazard reports for the proposed Granite Heights subdivision, Pleasant Grove, Utah			Requesting Agency: Pleasant Grove City
By: Francis X. Ashalnd	Date: 6-13-01	County: Utah	Job No: 01-04 (R-26)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

In response to a request by John Schiess, Acting Pleasant Grove Engineer, the Utah Geological Survey (UGS) has completed its review of four addendum and supplemental reports for the proposed Granite Heights subdivision in eastern Pleasant Grove, Utah. Three addendum reports (Earthtec Testing & Engineering [Earthtec], P.C., 2000b, 2001a, 2001b) address geologic hazards issues raised in an initial review by the UGS of two earlier Earthtec reports (1998, 2000a). A fourth supplemental report (Hubble Engineering, 2001) addresses stream flooding at the site. As part of the present review, I conducted a reconnaissance site visit on March 27, 2001; reviewed aerial photographs of the site; and conducted slope-stability analyses using PCSTABL5M and STED software. The purpose of the UGS review is to determine whether geologic hazards have been adequately addressed and adequate design recommendations provided to allow for safe hillside development. In our previous review, we recommended additional assessment of potential landslide and collapsible- soil hazards. In addition, we recommended that subdivision-specific risk-reduction measures be provided for the site related to potential rock-fall, alluvial-fan-flooding, and debris-flow hazards.

LANDSLIDE HAZARD

Landsliding is likely the most significant potential geologic hazard at the site. Earthtec (2000b) mapped a landslide in the southern part of the site that underlies parts of six proposed lots and attributes two scarp-like features as being associated with landsliding. Earthtec (2000b) believes that the lower feature is the toe of the landslide. The toe appears to have been modified during construction of the Salt Lake aqueduct. Earthtec believes the upper feature is related to localized landsliding within the landslide mass. My review of aerial photographs and site reconnaissance indicate that a potentially back-tilted surface which may be associated with landsliding also exists between the two scarp-like features. In addition, hummocky topography upslope of the landslide boundaries mapped by Earthtec also appears to be underlain by shallow landslide or debris-flow deposits. Thus, the extent of landslide deposits at the site may be greater than shown by Earthtec (2000b). Site plans indicate that a road and cul-de-sac would be located near the base of these deposits that would likely require cut slopes in the potential landslide deposits. My review of aerial photographs suggests the upper scarp-like feature may be a toe of a landslide deposit. Boreholes drilled by Earthtec indicate the site is underlain by the Manning Canyon Shale, a unit recognized to be susceptible to landsliding elsewhere in Utah County.

The Earthtec (2000b, 2001a) reports present the results of preliminary geotechnical slope-stability evaluations of the landslide mass. Earthtec concludes that the landslide is stable under static and pseudostatic (earthquake ground shaking) conditions. Earthtec estimated soil-strength parameters and design ground-water elevations in its analyses. Whereas some of the input parameters used by Earthtec, such as the friction angles, appear to be reasonable estimates of the actual soil-strength values, the UGS disagrees with some of the assumptions Earthtec made in its analyses. My slope-stability analysis indicates the stability of the landslide mass is sensitive to the presence or absence of cohesion (a parameter assumed by Earthtec) and fluctuations in ground-water levels. The UGS believes it is reasonable and not overly conservative to assume that cohesion is absent along pre-existing landslide rupture surfaces. Recent investigations of other Wasatch Front landslides, including trenching of another landslide in Pleasant Grove underlain by Manning Canyon Shale, have shown that polished, grooved (slickensided) surfaces persist along the surface of rupture in the landslides. The strength of these unhealed surfaces is likely controlled solely by residual friction angles.

The reliance on baseline ground-water levels from drilling performed in October and December 2000 is another significant limitation of the Earthtec analyses. Seasonal ground-water-level data from other Wasatch Front landslides indicate that in natural settings the low ground-water levels generally occur between September and January. In addition, precipitation in Pleasant Grove during the informal 1999-2000 landslide water year (September-August) preceding the drilling was only 85 percent of normal (unpublished data from National Weather Service, Salt Lake City). Thus, ground-water levels at the site may have been lower than in previous years of above-normal precipitation. The underlying Manning Canyon Shale also likely exhibits very low permeability and transmissivity. Thus, the rate that the shale can transmit sufficient water to accurately represent the ground-water level in a borehole open for only a few hours is a concern. Ground-water-level measurements from a monitoring well in a similar low-permeability unit in North Salt Lake indicated that up to 15 days were required before ground-water levels reached equilibrium (unpublished data, Utah Geological Survey). During that period ground-water levels rose about 11 feet. Thus, whereas deep ground-water levels may have existed in the fall and early winter of 2000, reflecting the climatic conditions discussed above, ground-water levels may have been inferred to be deeper than actual because temporary boreholes in low-permeability materials may not allow for accurate measurement. Ideally, water levels determined from monitoring wells in the spring (March-May) and calibrated for annual precipitation during the measurement year should be the basis for design ground-water levels. Earthtec estimated design ground-water levels of about 17 feet above the shale which it assumed could be caused by landscape irrigation and re-directed runoff in the proposed subdivision. However, assessment of whether this level is conservative is difficult without better baseline ground-water-level information.

To reduce the uncertainty in Earthtec's slope-stability assessments, more information on site geology and subsurface conditions is needed. In order to properly assess the stability, the landslide origin of the distinctive site topography needs to be further evaluated. This could be evaluated by trenching the landslide at the site. Shallow trenching should explore the origin of the scarp-like features. One objective of the trenching would be to determine whether the upper feature is actually a minor landslide scarp, landslide toe, and/or has been modified by human activity. Trenching would also reveal the presence or absence of other landslide deformation features and allow evaluation of the nature of the surficial deposits (landslide, debris-flow, combination, or other). If landslide features are encountered in the trenching, their locations should be incorporated into subsequent slope-stability analysis. Better information from properly designed monitoring wells is also needed to reduce the uncertainty in ground-water conditions.

COLLAPSIBLE-SOILS

Soils on the site consist mostly of interlayered gravel and clay. Earthtec (2000a) identified low collapse potential for shallow clay soils on the site based on laboratory testing showing up to 2 percent collapse and concluded that structural damage could be avoided by employing "strict moisture control measures" to prevent foundation soils from becoming wet. Given the hillside setting, the practicality of preventing human-caused moisture fluctuations below the foundations of the houses, particularly where landscape irrigation occurs on the upslope side of the lot, should be considered. Such recommendations affecting individual lot owners are extremely difficult to implement and enforce. Earthtec's site drainage recommendations (2000b, 2001b), even if implemented properly, do not appear to reduce the potential for damage from collapsible soils (if present) to roads, utilities, and pavement, particularly where fill loads are anticipated. Earthtec (2000b) also reviewed properties of gravel soils on the site and concludes they are unlikely to exhibit any collapse based on their gradation and clast-supported nature. However, the soil type, gradation, and matrix percent of seven on-site gravel soils fall within the range noted by Rollins and others (1993) for possible collapse (see Earthtec, 2000b) as indicated in table 1.

Table 1.
Summary of soil characteristics associated with possible collapse.

No. of gravel samples	No. with GM type soil	No. within range for fines (6-30 %)	No. within range for matrix (40-65 %)	No. within all ranges
7	7	3	4	1

In addition, the Earthtec (2000b) report understates the fact that most if not all of the geological environment and geomorphic features at the site are similar to those cited for collapsible gravels, including the relatively arid setting (about 17 inches of precipitation per year), the low moisture content of surficial soils, the presence of alluvial-fan (debris-flow) and/or slope-wash deposits, and the location near collapsible fine-grained soils (as indicated by Earthec's soil testing).

ROCK-FALL HAZARD

The Earthtec (2000b) report provides a further evaluation of the rock-fall hazard at the site from that provided in its previous report (Earthtec, 2000a). Earthtec used the Colorado Rock-Fall Simulation Program (CRSP) to determine the likelihood that falling rocks would reach the site. The CRSP results provide estimates of rock-clast velocities and bounce heights. The results indicate that rocks could roll (and bounce) onto the eastern part of the property. Earthtec further defines the limits of the moderate rock-fall-hazard area and concludes that the risk to houses and other structures could be reduced if construction was limited to the western third of the eastern three lots. However, Earthtec does not specifically state this as a recommendation.

DEBRIS FLOWS AND FLOODING

The Earthtec (2000b) report indicates that no debris-flow deposits were encountered on the site; however, this appears to be inconsistent with the mapping by Earthtec of the majority of the site outside the landslide as alluvial-fan deposits. Also, in a previous report, Earthtec (2000a) concluded a low to moderate alluvial-fan-flooding and debris-flow hazard existed which could affect the entire development. The GM-type soils identified by Earthtec in its test pits (1998) and boreholes (2000b, 2001a) as well as the soils exposed in the cut in the lower scarp-like slope are consistent with debris-flow deposits, but could also be landslide deposits. Hummocky deposits upslope of the proposed cul-de-sac could also be debris-flow deposits. Debris-flow deposits are also suggested by the general morphology visible on aerial photographs and by the hummocky nature of deposits at the mouth of the scoured drainage above the site. The scoured nature of the drainage (see figure 5 in Hubble Engineering Inc., 2001) suggests that a historical debris-flow event may have occurred at the site and explains why detention basins were constructed north of the site (which currently detain at least rainstorm and snowmelt runoff water). Further research on the event(s) which led to construction of the diversion ditches and basins above and north of the site may reveal information on possible historical debris flows or flooding and be useful for assessing the potential hazard at the site.

The Hubble Engineering Inc. (2001) report addresses stream and site flooding associated with 10- and 100-year storm events, but does not address the potential for debris flows or provide site-specific design measures related to this potential hazard. The Hubble Engineering Inc. (2001) report provides a general recommendation that “special [placement and grading] precautions” be taken to reduce the problems associated with flooding from a 100-year storm by the eastern small watershed above the site, but does not provide any more specific details. A review of the flooding engineering analysis by Hubble Engineering Inc. (2001) is outside the purview of a UGS review. However, flooding and debris-flow processes are different and the Hubble report does not address debris-flow hazards. Further investigation is needed to assess the potential for debris flows from the drainages above the site as well as to assess the influence of diversion structures, detention basins (located north of the mouth of the drainage), and other slope modifications on future debris-flow paths. Based on this debris-flow assessment, subdivision risk-reduction measures should be proposed, as needed.

CONCLUSIONS AND RECOMMENDATIONS

The UGS believes that the four new reports mostly provide further assessment of the potential geologic hazards at the site, but do not provide the specific risk-reduction design measures as requested in our previous review. The UGS recommends that:

- the "buildable area" defined by Earthtec's rock-fall analysis be shown on an appropriate-scale site plan,

- more specific details be provided on the special placement and grading precautions necessary to reduce the risk from flooding at the site, and

- subdivision-specific debris-flow risk-reduction measures be provided, as necessary, based on further assessment of the debris-flow hazard of the drainages above the site which considers the influence, if any, of existing drainage and grade modifications above the site.

In addition, based on the data provided, the UGS cannot fully concur with Earthtec's conclusions regarding the collapsible soil hazard at the site, nor with the effectiveness and practicality of the site-drainage recommendations proposed to reduce any potential damage. The UGS recommends that the collapsible-soil hazard information be reviewed by a geotechnical engineer with experience in this hazard, such as Dr. Kyle Rollins at Brigham Young University, or an equivalent regional expert. Pleasant Grove City must also evaluate whether Earthtec's risk-reduction recommendations regarding drainage can be implemented effectively.

Regarding the landslide hazard at the site, Earthtec (2000b) recently recognized a large landslide mass which underlies part of six lots in the southern part of the subdivision. Although Earthtec (2000b, 2001a) concludes the landslide mass is stable, considerable uncertainty exists regarding:

- the extent and characteristics of landslide deposits on the site,

- the nature of scarp-like features and an apparently back-tilted surface in the mapped landslide, and

- the depth to seasonally high ground-water levels and the magnitude of natural ground-water fluctuations.

Because of the uncertainty in these factors, the current and future stability of the landslide could vary significantly from the values Earthtec predicted. To reduce this uncertainty, the UGS recommends further investigations including the following:

- Trenching of the site and landslide upslope of the Salt Lake aqueduct to the eastern property boundary. The trenching should be performed by a qualified engineering geologist with several years of experience logging trench excavations and conducting landslide investigations. The objectives of the investigation should be to log in detail the surficial soils exposed in the trench, characterize the nature of scarp-like and other features on the site, identify surfaces of rupture (slip surfaces), and sample sheared soils, if present, for laboratory testing (direct shear and ring shear testing). The report of the results of this investigation should include detailed trench logs. The UGS should be informed in advance of the dates of the trenching so that our staff have an opportunity to evaluate the trench exposures.

- Installation of ground-water-level monitoring wells; measurement of ground-water levels after sufficient time for levels to equilibrate; and, if time constraints allow, determination of ground-water levels or conditions in the spring of 2002. Ideally, at least one well should be located where it will not be damaged by subsequent construction activities and could be used to monitor post-development ground-water-level fluctuations. The new ground-water-level information should be used to adjust design ground-water levels used in slope-stability analyses, as necessary.

Upon completion of these investigations, the new information should be incorporated into a detailed slope-stability analysis of the landslide mass which considers a reasonable design ground-water level that reflects natural short- and long-term fluctuations, and the potential increase in ground-water levels resulting from hillside modifications. In addition, grading-induced loading and removal of lateral support should also be considered. The UGS believes this work, if completed in a professional manner and in keeping with the national standard of practice for geotechnical landslide slope-stability investigations, should provide an adequate basis for rendering a conclusion regarding the stability of the hillside at the proposed Granite Heights subdivision.

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Utah Geological Survey

Project: Review of "Report, geotechnical engineering study, Lot 1 – Branch subdivision, 5856 Snow Basin Road, Huntsville, Utah"			Requested by: Jim Gentry, Weber County Planning
By: Greg N. McDonald Gary E. Christenson	Date: 9-24-01	County: Weber	Date report received at UGS: 8-27-01
USGS Quadrangle: Snow Basin (1344)	Section/Township/Range: NE¼ SW¼ section 23/6N/1E, SLBM		Job number: 01-08 (R-27)

This report is a review of the geologic-hazards aspects of a geotechnical engineering report by Simon-Bymaster, Inc. (SBI, 2001) for lot 1 of the Branch subdivision at 5856 Snow Basin Road, Weber County, Utah. For the review, we conducted a literature review and examined 1:24,000-scale aerial photos (1952), and McDonald visited the site on February 2 and July 19, 2001. SBI addresses geologic hazards associated with slope stability, earthquake ground shaking, and problem soils and concludes that the Branch lot is suitable for the proposed single-family residence provided that their recommendations are followed. Although we cannot review the engineering analysis, the geologic aspects are reasonable and we concur with SBI's conclusions. However, we suggest SBI reconsider their recommendation allowing permanent cut (and fill) slopes up to 2:1, given the weak, clayey soil at the site.

SBI trenching confirmed that most of the lot sits on older mass movement deposits as mapped by King and others (in preparation). To assess the landslide hazard at the site, SBI performed geotechnical-engineering slope-stability analyses using assumed values based on a literature review and on-site geologic conditions. Their analyses indicate the landslide is "grossly stable" under present conditions. SBI cites geologic evidence to support this conclusion including the lack of ground cracks or tilted trees and the apparent buttressing of the deposit against a ridge of in-place Norwood Tuff bedrock. However, while the bedrock ridge may have buttressed the landslide at some time, streams have incised down to the inferred rupture surface, as shown on SBI figure 6, and we do not believe the landslide is presently buttressed. However, in the slope-stability analysis, the buttress was not necessary for stability.

To ensure stability at the site, SBI stresses the need for proper site design to minimize water infiltration, and we agree with these recommendations. Additionally, ruptured or leaking septic and water lines can induce or promote instability, and SBI's site drainage recommendations should be implemented. To ensure this, Weber County should request documentation from the consultant that their recommendations were followed. Also, Weber County will need to ensure that development adjacent to the property, particularly upslope, does not adversely impact conditions at the Branch lot.

SBI's recommendation that permanent cut and fill slopes be no greater than 2:1 (27 degrees) implies slopes up to 2:1 are stable. If any 2:1 cuts of significant height are planned, this recommendation should be reconsidered given the typically low friction angles associated with clayey landslide deposits at the site.

In summary, from a geologic standpoint, SBI has adequately demonstrated that the landslide at the Branch lot is stable under present conditions, although local steep slopes may be susceptible to surficial instability. Additionally, inherent uncertainties exist when building on landslide deposits as outlined in the closure section (section 12.0, paragraph 3) of the SBI (2001) report. Therefore, we recommend disclosure of the SBI report and this review to future homebuyers, and strict adherence to SBI's hazard-reduction recommendations. In addition, we recommend a qualified geotechnical engineer evaluate engineering aspects of SBI's slope-stability analysis and grading and foundation recommendations.

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Utah Geological Survey

Project: Review of “Geologic evaluation of the Bench at Mountain Road, North Ogden, Utah”			Requested by: John Mayer, Ogden City Planning
By: Greg N. McDonald Gary E. Christenson	Date: 11-15-01	County: Weber	Date report received at UGS: 11-5-01
USGS Quadrangle: North Ogden	Section/Township/Range: NE¼ NE¼ section 9, T6N, R1E, SLBM		Job number: 01-09 (R-28)

We reviewed a geologic evaluation of the proposed Bench at Mountain Road subdivision in northeast Ogden by James L. Baer (Baer, 2001). For the review, we conducted a literature review, examined 1:24,000-scale (1952) and 1:12,000-scale (1970?) aerial photos, and McDonald visited the site on November 7, 2001. The purpose of the review is to determine whether geologic hazards at the site are adequately addressed in the report. We conclude that further study is needed and recommend the following:

- An adequate site map must be provided that shows the inferred fault trace(s), accurate trench locations, and proposed setbacks or other hazard-reduction measures on a base map showing detailed topography, lots, and site boundaries at a scale of 1 inch=200 feet or larger (Association of Engineering Geologists, Utah Section, 1987), preferably 1 inch =100 feet.
- Trench T1E should be extended to the west beyond the base of the main scarp at least onto flat ground surrounding the buildings to intersect a possible fault-related secondary scarp. The trench must be logged at a scale of 1 inch=5 feet or larger (Association of Engineering Geologists, Utah Section, 1987).
- If no faults are found in the additional trenching, fault setbacks should be taken from the eastern end of trench T1E, rather than from an assumed fault location east of the subdivision.
- The Colorado Rockfall Simulation Program (Jones and others, 2000) should be used to better assess rock-fall hazards, including bounce heights, in the northeast corner of the subdivision.
- Recommendations to control drainage from the slope to the east should be provided.

Because a detailed site map was not provided, we could not determine the relationship between trench locations, lot and site boundaries, and topographic features. Therefore, our conclusions are based on observations during the site visit and thus are considered preliminary pending submittal of an adequate site map.

The northeast corner of the property is on a steep slope mapped as a scarp of the Wasatch fault (Nelson and Personius, 1993). Trench T1E was excavated at the base of this slope, but did not extend westward to intersect a secondary scarp evident on aerial photos or eastward to the east property boundary, presumably due to the steep grade. The trench was 23 feet long. The secondary scarp west of the trench faces southwest and may be either an erosional scarp or a parallel secondary fault within the zone of deformation. Baer(2001) believes the main fault is at least 100 feet east of the east property boundary based on the occurrence of the nearest rock outcrop at this location. We do not agree that the location of the nearest outcrop east of the site constrains the western limit of faulting. Therefore, pending results from additional trenching to the west, we believe it prudent to conservatively assume the nearest fault could be at the eastern end of the trench, and proposed setbacks must be taken from a line parallel to the scarp through the eastern end of the trench. We believe Baer has adequately demonstrated a lack of faulting elsewhere at the site, although a discrepancy exists between the log for trench T1W showing beds dipping over 15 degrees and the written description that beds are "horizontal to very gently dipping to the west."

Baer(2001) indicates that rock fall and flood hazards are generally low at the site, and we concur except in the northeast corner where large clasts, likely of rock-fall origin, were encountered in colluvium in trench T1E. In a study for the adjacent property to the north, Applied Geotechnical Engineering Consultants, Inc. (1998) identified a rock-fall hazard from the eastern slope and recommended a berm or other barrier at the base of the slope. A similar study is needed at the Bench subdivision and, if similar results are found, such a berm may be needed here as well. Drainage should also be provided at the base of the slope to control sheet-flood runoff from local cloudburst storm events.

In conclusion, we concur with Baer's(2001) overall assessment that surface faulting, rock fall, slope failure, and flood hazards are generally low at the subdivision, but believe his evidence indicates faulting, rock fall, and sheet-flood hazards may exist at lots in the northeast corner. Further studies addressing these hazards must be performed and carefully documented with detailed trench logs (1 inch=5 feet or larger) and an adequate site map on an appropriate base map showing trench locations, setbacks, and other recommended hazard-reduction measures.

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APPENDIX

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