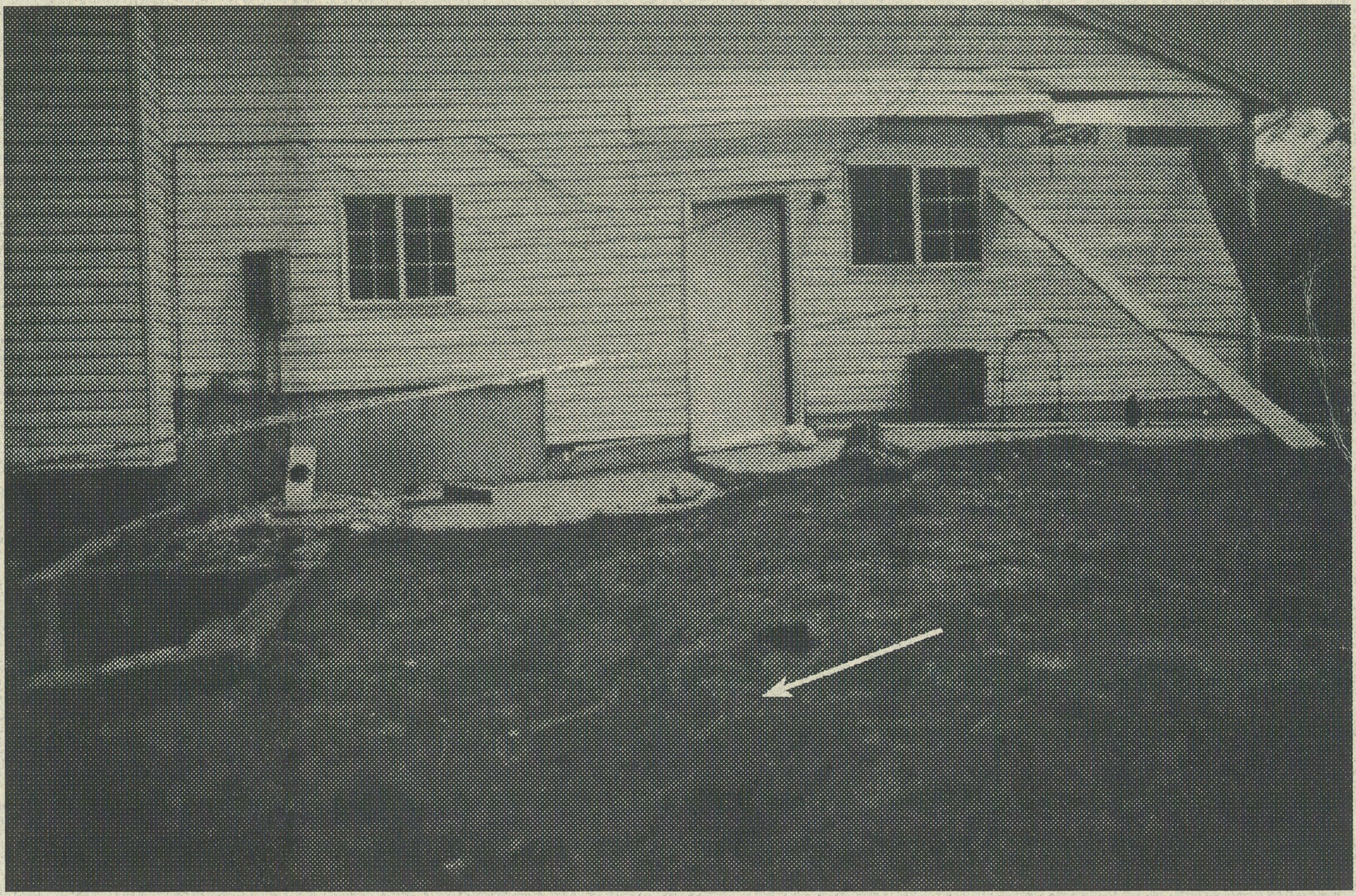
TECHNICAL REPORTS FOR 1998
APPLIED GEOLOGY PROGRAM

compiled by
Greg N. McDonald



Report of Investigation 242 March 1999
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

UTAH GEOLOGICAL SURVEY

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The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information on UGS publications, contact the Natural Resources Map/Bookstore, 1594 W. North Temple, Salt Lake City, Utah 84116, (801) 537-3320 or 1-888-UTAH MAP. E-mail: nrugs.geostore@state.ut.us and visit our web site at http://www.ugs.state.ut.us.

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GREG N. McDONALD

Cover photo: Landslide damage to house at 1851 East Sunset Drive, Layton, Utah. Arrow points to scarp position in lawn. View is to the east. Photo taken on April 27, 1998, by Richard Giraud.

PREFACE

The 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 perform 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, we respond to emergencies such as earthquakes, landslides, and wild fires (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. In addition to performing engineering-geologic studies, we review and comment on geologic reports submitted by consultants to state and local government agencies, such as those dealing with sites for 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 Applied Geology Program's 46 technical reports completed in 1998 (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, some of which were produced on a copy machine. This is the twelfth year the Applied Program's technical reports have been compiled.

Greg N. McDonald
February 25, 1999

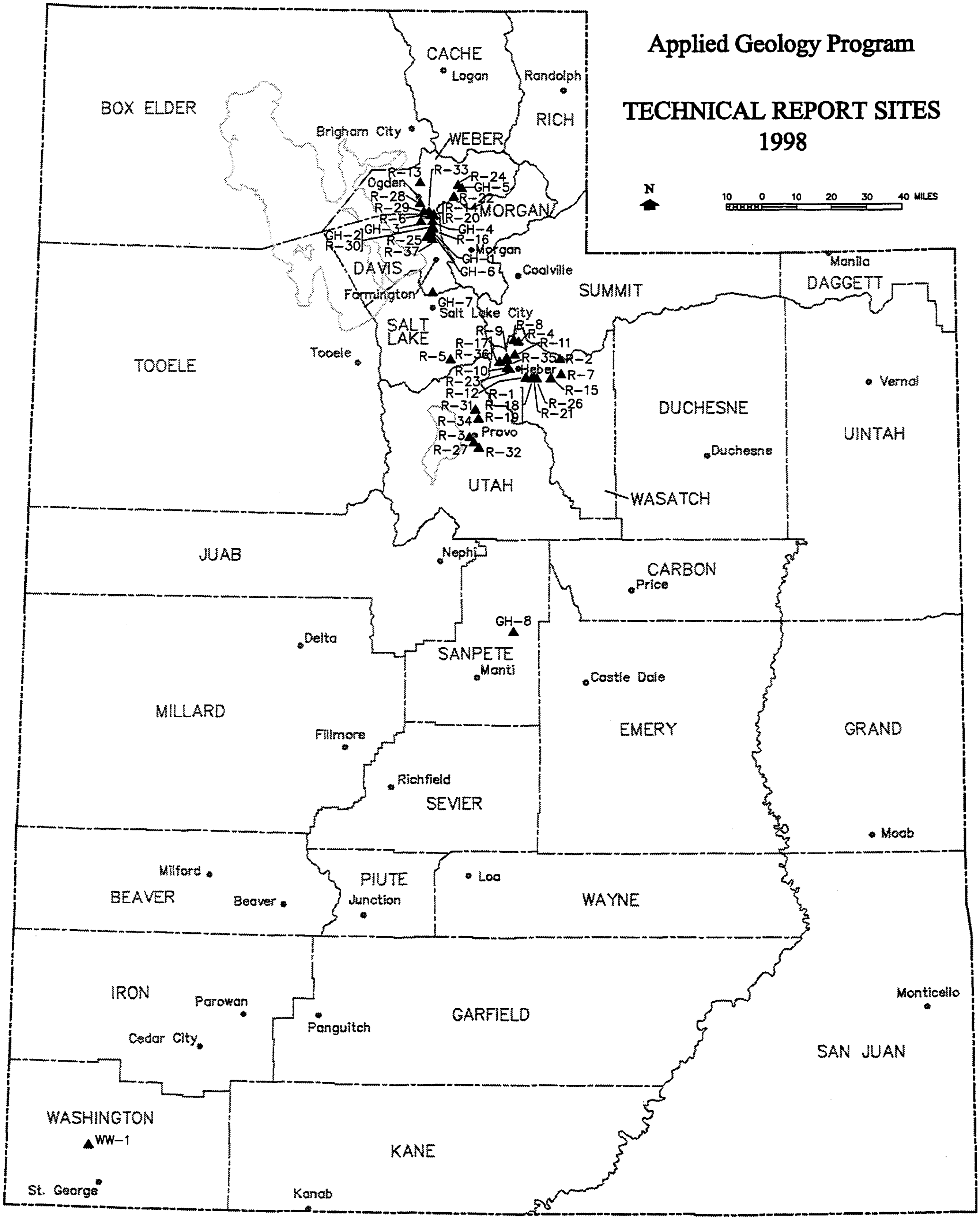

Figure 1. Locations of 1998 Technical Report Sites

CONTENTS

Illustration

WASTEWATER DISPOSAL

Project: Evaluation of geologic conditions regarding suitability for individual wastewater-disposal systems at Winchester Hills Phase 8, Washington County, Utah.			Requesting Agency: Southwest Utah Public Health Department
By: William R. Lund	Date: 02-11-98	County: Washington	Job No: 98-03 (WW-1)
USGS Quadrangle: Washington (1978)		Number of attachments: 8	

INTRODUCTION

This report presents the results of a study by the Utah Geological Survey (UGS) of Winchester Hills Phase 8, a subdivision in Washington County, Utah. The Southwestern Utah Public Health Department (SWUPHD) requested that the UGS evaluate the suitability of geologic conditions at the subdivision for individual septic-tank and soil-absorption-field wastewater-disposal systems. The study included a review of available geologic, soils, and ground-water information for the subdivision and vicinity, including two previous UGS reports on wastewater-disposal-system suitability for Winchester Hills Phases 1 (Lund, 1980) and 2 (Lund, 1985); review of the Phase 8 feasibility report by the developer's consultant (New, 1997); and a field reconnaissance of the subdivision on November 24, 1997, with representatives of SWUPHD, the Utah Department of Environmental Quality (DEQ), and the developer's consultant.

Shallow depth to bedrock (less than 5 feet) makes portions of Winchester Hills Phase 8 unsuitable for conventional septic-tank and soil-absorption-field systems. Additionally, site soils consist of highly permeable, fine-grained, poorly graded, eolian (wind blown), quartz sand. However, because of the very small pore spaces, these sands tend to plug, causing soil-absorption fields to fail. Because depth to bedrock changes rapidly across the subdivision, approval of wastewater-disposal systems should be made on a lot-by-lot basis to ensure compliance with DEQ regulations. However, geologic and ground-water conditions at Winchester Hills, which is in the primary recharge zone of the Navajo aquifer, create a high potential for conventional wastewater-disposal systems to contaminate the aquifer, the principal source of water for human consumption in Washington County. Therefore, the UGS recommends that Washington County require developers proposing subdivisions within the primary recharge zone of the Navajo aquifer to submit site-specific ground-water studies that establish a minimum septic-tank and soil-absorption-field system density (lot size) for the subdivision that will ensure ground-water quality beneath the subdivision is not degraded beyond county-established limits. The UGS further recommends that where subdivisions utilizing septic-tank and soil-absorption systems already exist within the primary recharge zone of the Navajo aquifer (such as the Winchester Hills development), the county require similar site-specific ground-water studies to determine if the subdivisions will degrade ground-water quality beyond acceptable limits. Where such degradation will occur, septic-tank and soil-absorption-field disposal systems should be replaced by a wastewater-disposal method that will prevent excessive ground-water contamination.

SETTING

The Winchester Hills Phase 8 subdivision is located on Big Sand flat about 6 miles north of St. George immediately east of Utah Highway 18 (attachment 1). Big Sand flat is a sand-covered bedrock bench lying between deeply incised Snow Canyon on the west and steep-sided Lava Ridge on the east. Surface drainage is generally to the south, although semiactive sand dunes mask most drainage across Phase 8. Vegetation is sparse, consisting of sage brush, creosotebush, blackbrush, cactus, and a few junipers. Average annual precipitation is less than 10 inches per year. Phase 8 is the latest expansion of the larger Winchester Hills development, and contains 41 lots on 48.5 acres in section 23, T. 41 S., R. 16 W., SLB&M. The largest lot in Phase 8 is slightly larger than 1.5 acres, but most lots are about an acre in size (range 0.929 to 1.519 acres). Including Phase 8, the Winchester Hills development has 381 lots; most are smaller than 2 acres and none are larger than about 4 acres (attachment 2).

PREVIOUS WORK

The UGS evaluated Phase 1 of the Winchester Hills development for wastewater-disposal-system suitability in 1980 at the request of the Bureau of Sanitation, Utah Environmental Health Services (Lund, 1980). In 1985, the UGS made a similar study for Phase 2 at the request of the Southwestern Utah District Health Department (Lund, 1985). The UGS was not asked to evaluate Phases 3 through 7, which now, along with Phases 1 and 2, are being developed. In 1995, the UGS published Open-File Report 324, *Interim Geologic Map of the Washington Quadrangle, Washington County, Utah* (Willis and Higgins, 1995). The Winchester Hills development is in the Washington quadrangle and this new 1:24,000-scale mapping provides detailed information about geologic conditions in and around the subdivision. A cooperative study between the U.S. Geological Survey, the Utah Division of Water Rights, and the UGS to characterize and model the Navajo Sandstone aquifer is currently underway. As part of that study, the UGS has prepared a report on the geology of the area titled *The Geology of the Central Virgin River Basin, Southwestern Utah, and its Relation to Ground-Water Conditions* (Hurlow, in press). Hansen, Allen, and Luce, Inc., a consulting engineering firm, is conducting a study funded by the Washington County Water Conservancy District and several cooperating agencies, to determine recommended septic-system densities for ground-water quality protection in Washington County. Their report titled *Determination of Recommended Septic System Densities for Groundwater Quality Protection* (Hansen, Allen, and Luce, Inc., in preparation) is in final draft form and has been distributed for review and comment as of this writing.

GEOLOGIC CONDITIONS

Geology

Big Sand flat is underlain by the Jurassic Navajo Sandstone, a grayish-yellow, pale-reddish-gray, and pale-brownish-orange, fine- to medium-grained sandstone. Sand grains consist chiefly of well-rounded, frosted quartz. Cementation is generally poor to moderate and varies from calcareous to silicious (Willis and Higgins, 1995); limonite cementation occurs locally. The Navajo Sandstone is about 2,000 feet thick in this part of Washington County (Willis and Higgins, 1995), and crops out spectacularly in the walls of Snow Canyon and on Lava Ridge. Due to sand cover, Navajo outcrops are of limited extent within the Winchester Hills development. On Phase 8, there are a few small, weathered outcrops and one exposure in an old construction cut (attachment 3). The Navajo dips at a low angle (about 5 degrees) to the north-northwest beneath the site.

The new mapping by Willis and Higgins (1995) shows no faults or folds in the vicinity of the Winchester Hills development. However, nearby in Snow Canyon and along Lava Ridge, the Navajo Sandstone is extensively fractured by long, vertically and horizontally continuous joints and joint zones (clusters of closely spaced parallel joints) (attachments 4 and 5). Willis and Higgins (1995) recognize three principal fracture types in the Navajo Sandstone in the Washington quadrangle. The first type consists of generally evenly spaced, north-trending, parallel, high-angle, open joints. They are not healed or recemented, and in many places weather to form a pattern of straight cracks in the rock a few inches to several feet wide that locally are visibly open to depths of 50 feet. The second type of fracture consists of a less prominent but still common set of widely spaced, high-angle, parallel, northwest-trending joints. These joints are distinguished by strong siliceous and calcareous recementation that is commonly more resistant than the surrounding rock. The third type is similar to the second except the fractures are longer. They form large, straight gashes in the rock and several are more than a mile long (Willis and Higgins, 1995, figure 9). Both brecciation and recementation are common along these fractures, and many have crushed zones 5 to 10 feet wide that are typically nonresistant and erode to form washes. Willis and Higgins (1995) measured many north- and northwest-trending joints of all three types in the Navajo Sandstone where it crops out immediately north and south of the Winchester Hills development. Similar joints are present in the Navajo outcrops on Phase 8 (attachment 6) and elsewhere within the Winchester Hills development (Hugh Hurlow, Utah Geological Survey, verbal communication, 1998).

Soil

Big Sand flat is mantled by a layer of reddish-brown, fine- to medium-grained, well-rounded, wind-blown, quartz sand derived from the Navajo Sandstone. Thickness of the sand layer varies, and depends on factors such as erosion along ephemeral streams, irregularities in the underlying bedrock surface, and the presence of sand dunes. On Phase 8, thickness of the sand layer ranges from zero where the Navajo Sandstone crops out at the ground surface to more than 15 feet where large dunes have formed. As part of the Phase 8 feasibility study, the developer's consultant excavated 19 soil test pits. Ten pits exposed reddish-brown quartz sand for their entire depth (10 feet). In the other nine pits, the backhoe encountered similar sandy soil before reaching resistant bedrock at depths ranging from 5.5 to 10 feet (New, 1997). Mortenson and others (1977) identify the soil on Phase 8 as belonging to the Pintura series, which consists mostly of wind-blown sand with depth to bedrock sometimes less than 5 feet. They further report that 75 to 95 percent of a typical Pintura series soil will pass the No. 40 sieve (fine sand fraction) and that an additional 5 to 10 percent will pass the No. 200 sieve (silt and clay fraction). Using the Unified Soil Classification System, Mortenson and others (1977) classify Pintura series soils as poorly graded sand (SP) and silty sand (SM). The consultant's feasibility report (New, 1977) and the field reconnaissance performed for this study support their observations.

Three test pits encountered irregularly shaped accumulations of secondary calcium carbonate. The accumulations are small, only a few feet in maximum dimension and approach Stage III+ development locally. There was no evidence that the calcium carbonate extends continuously between test pits. Considering their limited size and irregular shape, the accumulations are probably not pedogenic. They more likely represent relict ground-water deposits that accumulated when the area had a moister climate. Distribution of the deposits may reflect the position of bedrock lows beneath the sand that served to pond and channel ground water.

The developer's consultant performed 46 soil percolation tests on Phase 8 as part of the feasibility study. Results ranged from 3.3 to 16 minutes per inch (New, 1997), demonstrating the highly permeable nature of the soils. The 16 minute-per-inch rates came from areas where the soil profile is partially plugged with secondary calcium carbonate.

Ground Water

Ground water from the Navajo aquifer is the main source of high quality water for human consumption in Washington County (Freethey, 1993). Wells in the Navajo provide much of the St. George area with drinking water and at least two deep wells in the Navajo aquifer at Winchester Hills supply water to that development. The Navajo Sandstone is an excellent aquifer because it has a high degree of primary porosity and permeability, and because it is extensively fractured by large, throughgoing joints and joint zones. Hurlow (in press) found that joints and joint zones in the Navajo Sandstone are 5 to 35 times more permeable than the surrounding rock mass and provide conduits for conveying recharge directly to the ground-water system. Cordova (1978) states when discussing recharge to the Navajo aquifer "* * * * most of the infiltration occurs where the sandstone is bare and jointed or where only thin sandy deposits cover jointed rock." Cordova (1978) further states "Joints are the main conduits for water moving from the surface to the saturated zone." Typically, both a principal and a secondary joint set(s) are present in the Navajo Sandstone. Secondary joints tend to link individual members of the principal set throughout the rock mass so that the principal joints are often physically connected over length scales of several hundreds of feet to miles (Hurlow, in press).

The primary recharge areas for the Navajo aquifer in western Washington County (west of the Hurricane fault) are an outcrop belt along the south and southeast sides of the Pine Valley Mountains and a narrow strip immediately west of the Hurricane fault (Cordova, 1978; Freethey, 1993). These are areas where the Navajo Sandstone either crops out or is buried by thin, permeable deposits. The Winchester Hills development lies within the primary Navajo recharge area on the south side of the Pine Valley Mountains. Depth to ground water in the Navajo aquifer beneath

Winchester Hills is about 750 feet (Hansen, Allen, and Luce, Inc., in preparation) and the direction of flow is to the south toward the Virgin River (Cordova, 1978; Freethey, 1993; Willis and Higgins, 1995). The success of the two wells drilled at Winchester Hills and the numerous springs that discharge from the base of the Navajo near the mouth of Snow Canyon attest to the excellent water-bearing nature of the formation beneath the subdivision. Because the Navajo Sandstone consists mostly of clean, weakly to moderately cemented sand though its entire thickness, ground water in the formation is normally under unconfined conditions, meaning there are no impermeable horizons above the water table to impede or stop the vertical flow of recharge to the aquifer. Ground-water quality at Winchester Hills is excellent and meets State of Utah Primary Drinking Water Standards (Utah Division of Drinking Water, unpublished data).

No evidence exists for modern perched ground water on Phase 8 of the Winchester Hills development. There is no phreatophytic vegetation, all test pits were dry, and soils exposed in the test pits showed no indication of a seasonally fluctuating water table. The absence of perched ground water is not surprising considering the highly permeable nature of the sandy soils on site and the presence of porous, fractured bedrock beneath the subdivision. Any precipitation or runoff reaching Phase 8 would quickly infiltrate and move rapidly downward to the water table.

SUITABILITY FOR INDIVIDUAL WASTEWATER-DISPOSAL SYSTEMS

Geologic conditions at Winchester Hills Phase 8 are locally unsuitable for installation of septic-tank and soil-absorption-field wastewater-disposal systems under current DEQ regulations. There must be sufficient depth of suitable soil to provide 4 feet of separation between the bottom of the drain field and bedrock. Therefore, a minimum of 5 feet of soil is required to accommodate a shallow trench drain-field installation; one foot in which to install the system and 4 feet between the bottom of the trench and bedrock. Soils in Phase 8 consist of poorly graded sands and silty sands with percolation rates ranging from about 3 to 8 minutes per inch (New, 1997). A few areas where secondary calcium carbonate has accumulated in the soil have percolation rates as low as 16 minutes per inch, but these areas are too small and isolated to accommodate a drain field. Depth to bedrock across Phase 8 ranges from zero to more than 15 feet. Lots in the subdivision where the soil is too thin to meet DEQ regulations should be excluded from development. Additionally, although the fine-grained eolian (wind blown) sand, such as that found on Phase 8, is highly permeable, it has a tendency to plug as solid particles too large to pass through its small pore spaces are filtered from the wastewater. Soil-absorption-field failures of this kind have occurred in sandy soils similar to those on Phase 8 elsewhere in southwestern Utah.

A larger issue regarding suitability of septic-tank and soil-absorption-field systems for wastewater disposal involves not only Phase 8, but the entire Winchester Hills development. Winchester Hills lies within the primary recharge area for the Navajo aquifer, the main source of drinking water in southwestern Utah. Soils at Winchester Hills are generally thin and consist almost entirely of quartz sand. They are highly permeable and provide an excellent filter for removing solid particles from wastewater, but lack the fines and organic content necessary to facilitate the chemical reactions necessary for the removal of most chemical contaminants and viruses found in domestic wastewater. The underlying Navajo Sandstone has high primary permeability, and a high secondary permeability because it is cut by numerous, throughgoing joints and joint sets. DEQ estimates a typical three-bedroom home occupied on a year-round basis produces 400 gallons of wastewater per day or 146,000 gallons of wastewater per year. With the addition of Phase 8, the Winchester Hills development will contain 381 lots (attachment 2), most about one acre in size. When all 381 lots are developed, the average volume of water discharged in soil-absorption fields at Winchester Hills will be approximately 152,000 gallons per day or nearly 55,500,000 gallons per year. Because site soils mainly provide filtering of solids, and because they transmit water readily, as does the underlying bedrock, it is likely that most if not all of the more than 55 million gallons of partially treated wastewater produced annually at Winchester Hills will reach the underlying Navajo aquifer. Therefore, even though geologic conditions over much of Phase 8 meet minimum DEQ regulations for septic-tank and soil-absorption-field installation, the UGS believes that the use of septic-tank and soil-absorption-field systems at Winchester Hills will eventually result in contamination of the Navajo aquifer. This observation also applies to other areas in Washington County within the primary recharge zone of the Navajo aquifer where subdivisions utilizing septic tanks and soil-absorption fields for wastewater disposal either exist or may be developed in the future. Hansen, Allen, and Luce, Inc. (in preparation) recommend a maximum density of one septic-tank and soil-absorption-field system per 10 acres at Winchester Hills. Existing lots at Winchester Hills average about 1 acre in size. Under current conditions (350 lots), Hansen, Allen, and Luce, Inc. (in preparation, table C-1) estimate that nitrate contamination in ground water beneath Winchester Hills will eventually reach 17.7 mg/L, 1.7 times the Utah Primary Drinking Water Standard. Nitrate is considered a good indicator of human activity because the major sources of nitrate in ground water are wastewater disposal and fertilizer, and nitrate seldom attenuates once it enters ground water except by dilution. In excessive concentrations (> 10 mg/L) nitrate is also a well-documented health hazard. If development at Winchester Hills continues with an average one-acre lot size until a limit is reached based on either (a) available water supply (600 lots), or (b) all available privately owned land is developed (2,510 lots - this scenario requires an additional source of drinking water), Hansen, Allen, and Luce, Inc. (in preparation, table C-1) estimate nitrate concentrations in ground water beneath Winchester Hills could reach 22.9 and 33.9 mg/L, respectively.

The critical nature of the soil and bedrock conditions at Winchester Hills and their relation to the Navajo aquifer were recognized early in the subdivision's history. In the cover letter for the report by Lund (1980) on Winchester Hill Phase 1 (attachment 7), Bruce N. Kaliser, then Chief of the UGS Urban and Engineering Geology Section, questioned "* * * *the desirability of permitting subsurface disposal systems on Navajo Sandstone terrain." He went on to point out that the Navajo aquifer was becoming an increasingly important source of culinary water in southern Utah and that considering the geologic and ground-water conditions at Winchester Hills it was "* * * *entirely likely, therefore, that the fluid introduced to the subsurface environment could gain access to the subsurface ground-water reservoir with little, if any, filtration afforded during vertical migration."

SUMMARY AND RECOMMENDATIONS

Geologic conditions are locally unsuitable for the disposal of wastewater in septic-tank and soil-absorption-field systems at Winchester Hills Phase 8 under current DEQ regulations. Bedrock either crops out at the surface or is at depths too shallow to meet the installation requirements over part of the subdivision. Therefore, if septic-tank and soil-absorption-field systems are permitted on Phase 8, the UGS recommends that system approval be made on a lot-by-lot basis to ensure each installation meets DEQ requirements.

Winchester Hills is situated within the principal recharge zone of the Navajo aquifer, the main source of water for human consumption in Washington County. Soil and bedrock at Winchester Hills are highly porous and permeable and provide a direct route for recharge to the unconfined ground-water system in the underlying Navajo aquifer. The high density of septic-tank and soil-absorption-field systems at Winchester Hills produces a concentrated source of wastewater (millions of gallons per year) and creates the potential for large volumes of only partially treated domestic wastewater to reach the ground-water system. The UGS believes that using septic-tank and soil-absorption-field systems to dispose of wastewater in subdivisions anywhere within the primary recharge zone of the Navajo aquifer represents a potential threat to ground-water quality. The Navajo aquifer's abundant supply of high quality ground water is critical to Washington County's future growth and development. Therefore, the UGS recommends that the county adopt zoning and other ordinances or regulations as necessary to require developers proposing subdivisions within the primary recharge zone of the Navajo aquifer to submit site-specific ground-water studies that establish a minimum septic-tank and soil-absorption-field system density (lot size) for the subdivisions that will insure ground-water quality is not degraded beyond county-established limits. The UGS further recommends that where subdivisions utilizing septic-tank and soil-absorption-field systems already exist within the primary recharge zone of the Navajo aquifer (such as at Winchester Hills), the county require a similar site-specific ground-water study to determine the long-term potential for the subdivision to contaminate ground water beyond acceptable limits. Where a high potential for excessive levels of contamination is found, septic-tank and soil-absorption-field systems should be replaced by a wastewater-disposal system that provides adequate ground-water protection. Attachment 8 contains septic-tank density analysis guidelines for proposed and existing subdivisions in the primary recharge zone of the Navajo aquifer in Washington County.

REFERENCES

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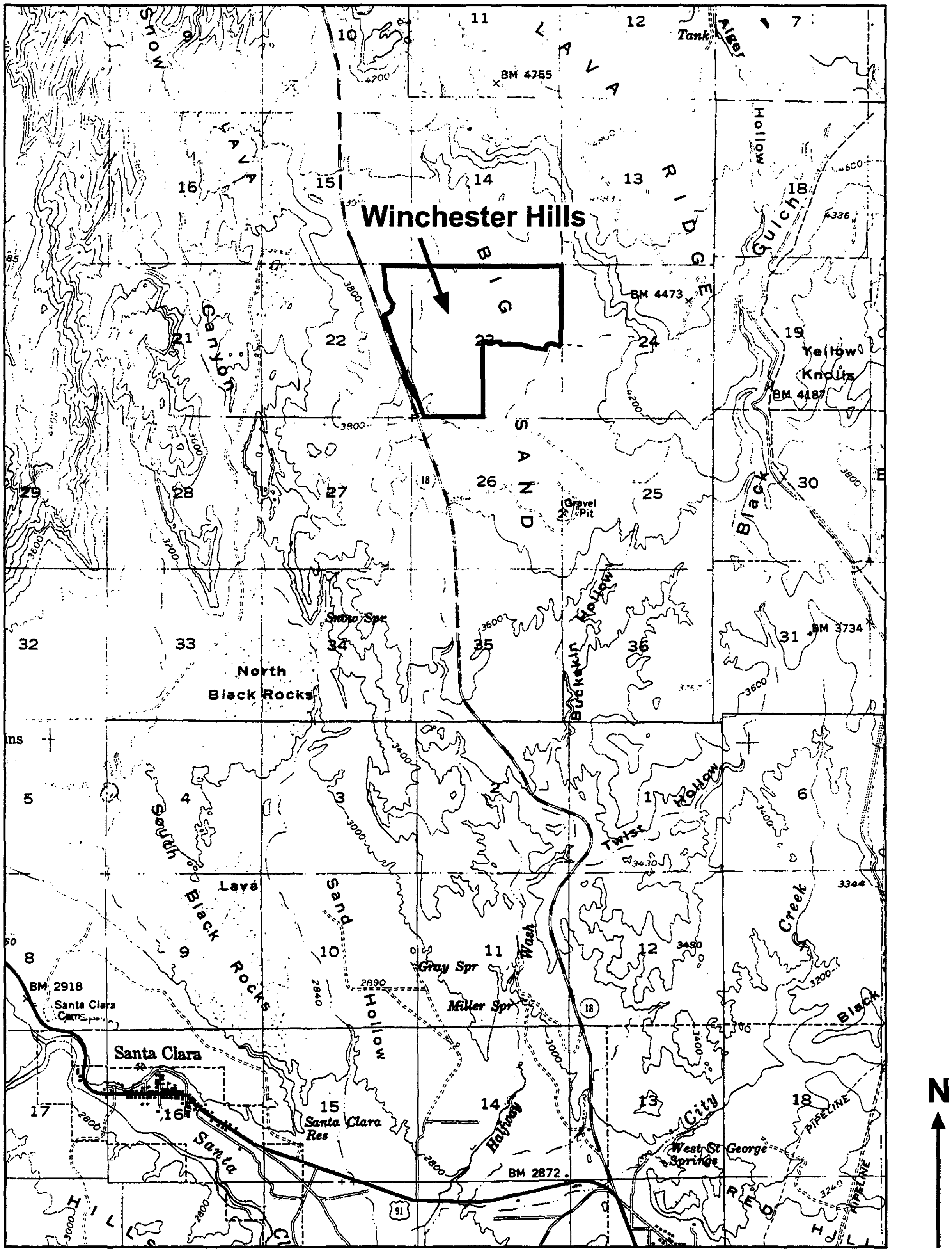

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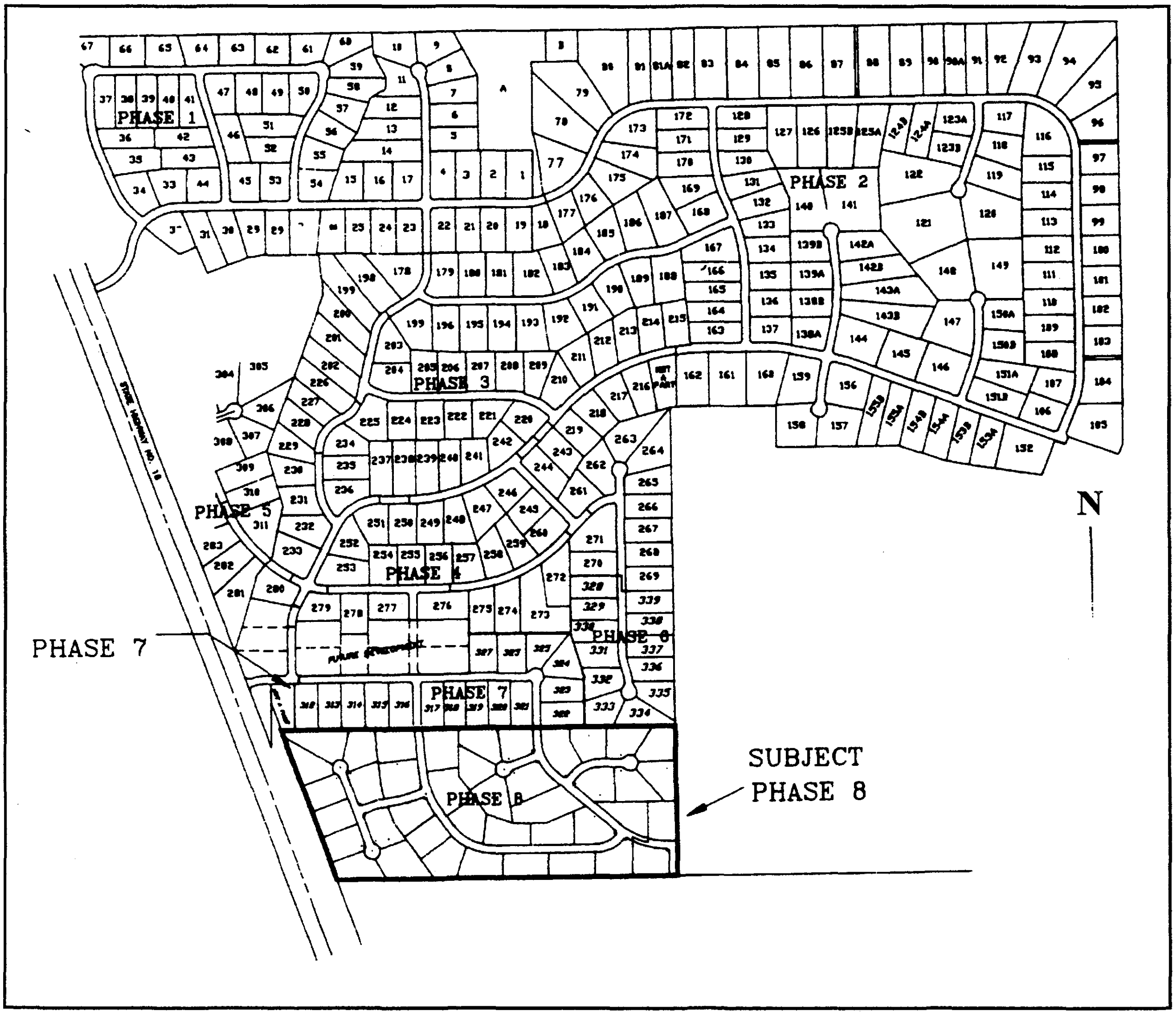
Attachment 1. Map showing location of Winchester Hills development along Utah Highway 18 north of St. George.

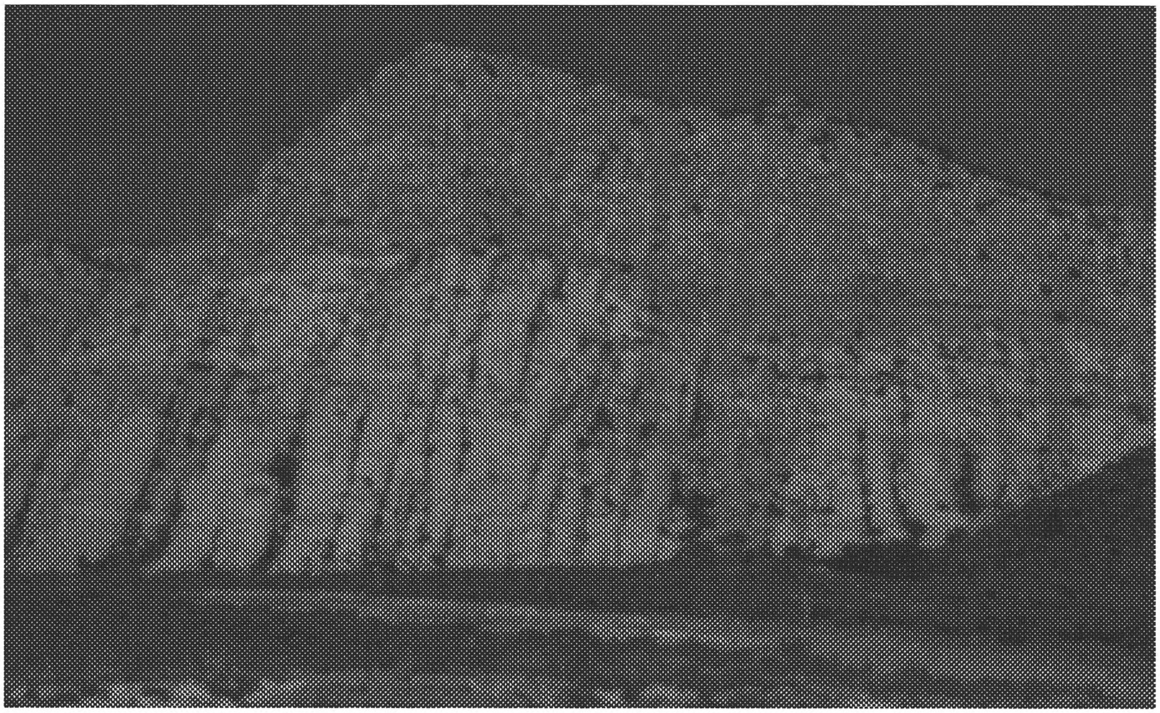
Attachment 2. Job No. 98-03



Attachment 2. Map of Winchester Hills development showing lot layout and location of proposed Phase 8 expansion. Approximate scale 1 inch = 1,100 feet (1:13,200)

Attachment 3. Outcrop of jointed Navajo Sandstone in an old construction cut on Winchester Hills Phase 8; note shallow depth of soil over bedrock at this location. View is to the south.

Attachment 4. Highly jointed Navajo Sandstone exposed along Lava Ridge north of the Winchester Hills development. The Navajo also crops out within and therefore underlies the subdivision.



Attachment 5. Joints in the Navajo Sandstone along Lava Ridge immediately north of the Winchester Hills development. View to the northeast.

Attachment 6. Close-up of jointed Navajo Sandstone exposed in construction cut on Winchester Hills Phase 8. View is to the southeast.

UTAH GEOLOGICAL AND MINERAL SURVEY

606 BLACK HAWK WAY
SALT LAKE CITY, UTAH 84103
(801) 581-6831

DONALD T. McMILLAN
Director

SCOTT M. MATHESON
Governor

GORDON E. HARMSTON
Executive Director
Department of Natural Resources

January 31, 1980

Mervin R. Reid, Director
Bureau of Sanitation
Environmental Health Services
150 W. N. Temple, Room 426
Salt Lake City, Utah 84103

Dear Mr. Reid:

At your request, Bill Lund of my staff investigated four properties in Southwestern Utah during the week of January 14th. His memo to me dated January 31st is herewith attached.

With respect to subdivision IV in his memo, a question arises as to the desirability of permitting subsurface disposal systems on Navajo Sandstone terrain. This formation is becoming increasingly more recognized as a major groundwater aquifer in southern Utah and it already serves as a large source of culinary water for the city of St. Geroge. Though the water table of the proposed site is relatively deep, approximately 700 feet, it appears to be under unconfined hydrogeologic conditions, meaning that there is no retarding stratum to the vertical migration of fluid from the surface. In addition, this formation is normally beset with a pattern of high angle or vertical fractures which increases its permeability to the point where it becomes attractive as a supplier of groundwater to municipal wells. It would appear to be entirely likely, therefore, that the fluid introduced in the subsurface environment could gain access to the subsurface groundwater reservoir with little, if any, filtration afforded during the vertical migration. Unless it can be determined through the acquisition of more detailed subsurface data and testing that facts differ from the above, it would be my recommendation that subsurface wastewater disposal systems not be employed on Navajo terrain.

Should you have any questions, please address them to me.

Sincerely yours,

Bruce N. Kaliser

Bruce N. Kaliser, Chief
Urban & Engineering Geology Section

BNK/co
Att.

The following is excerpted and modified from Valley-wide assessment of the potential impact of septic-tank-soil-absorption systems on water quality in the principal valley-fill aquifer and guidelines for site-specific septic-tank-density studies for proposed subdivisions in Tooele Valley, Tooele County, Utah (Wallace and Lowe, in preparation).

The purpose of these guidelines is to provide a procedure for assessing the impact of septic-tank-soil-absorption-field systems on ground-water quality for proposed subdivisions in the primary recharge zone of the Navajo aquifer in Washington County, Utah. The procedure outlined here uses a mass-balance approach similar to the analysis conducted by Hansen, Allen, and Luce, Inc. (1994) in Wasatch County, Utah. This approach was subsequently modified to include nitrogen added from fertilizer and precipitation for an analysis in the western part of Washington County (Hansen, Allen, and Luce, in preparation), but those modifications are not applied in these guidelines. In this mass-balance approach, the nitrogen mass from projected new septic tanks is added to the existing nitrogen mass and then diluted with the ground-water flow available for mixing plus the water added to the system by septic tanks. Hansen, Allen, and Luce (1994) estimates a discharge of 400 gallons of effluent/day for a domestic home, and determined a best-estimate nitrogen loading of 40 mg/L of effluent per domestic septic tank, with 80 mg/L and 30 mg/L per septic system as appropriate high and low values for nitrogen loadings.

There are several limitations to the mass-balance approach.

1. Computations are typically based on a short-term, hydrologic budget.
2. Background nitrate concentration is attributed to natural sources, agricultural practices, and septic-tank systems, but projected nitrate concentrations are for septic-tank systems only and do not include nitrate from other potential sources (such as lawn and garden fertilizer).
3. Calculations do not account for localized, high-concentration nitrate plumes associated with individual or clustered septic-tank systems.
4. The procedure assumes negligible denitrification.
5. The procedure assumes uniform, instantaneous ground-water mixing for the entire aquifer below the site.
6. Calculations do not account for pumping water wells.

Site-specific evaluation of the effect of septic-tank systems on ground-water quality requires accurate determination of local aquifer parameters. Steps in the evaluation process include: (1) compiling existing topographic and geologic maps and driller's logs, (2) determining the ground-water-flow-transect area (usually the subdivision area) and analyzing water-well driller's logs to determine the geologic characteristics, thickness, and extent of the aquifer, (3) determining the number of existing and proposed septic-tank systems in the area, (4) analyzing samples from selected wells to determine background nitrate concentrations, (5) measuring static water levels in existing wells to determine hydraulic gradient and ground-water-flow direction, (6) selecting observation and pumping wells and conducting 24- to 100-hour aquifer tests to determine aquifer transmissivity values, and (6) calculating the projected site-specific nitrate concentration by applying the Hansen, Allen, and Luce (1994) mass-balance approach using site-specific parameters obtained from steps 1 through 6 above to determine the existing nitrogen load and the amount of ground water available for mixing. Ground water available for mixing (not including water in effluent) can be calculated using the following equation:

$$Q=TLI$$

where:

Q = volume of water in aquifer below subdivision available for mixing,
T = transmissivity,
L = length of flow through aquifer parallel to hydraulic gradient, and
I = hydraulic gradient.

The report submitted for approval should contain: (1) detailed topographic and geologic maps showing the location of all relevant features, (2) water-well driller's logs used in the analysis, (3) laboratory data reporting nitrate concentrations, (4) static water-level measurements from wells, (5) tables reporting raw drawdown and recovery data from the aquifer test, (6) explanation of the methods/models used to interpret the aquifer-test data, and (7) all numbers (including conversion factors) and equations used to calculate results.

GEOLOGIC HAZARDS

Project: Preliminary geotechnical-engineering slope-stability assessment of a bluff and cut slopes at Hidden Oak subdivision, South Weber, Utah			Requesting Agency: South Weber City
By: F.X. Ashland	Date: 5-15-98	County: Davis	Job No: 98-11 (GH-1)
USGS Quadrangle: Kaysville (1320)		Number of attachments: 1	

INTRODUCTION

At the request of Mark Larsen, South Weber Building Inspector, I conducted a preliminary geotechnical-engineering slope-stability assessment of a bluff and cut slopes at the Hidden Oak subdivision in South Weber, Utah. The site is in the NE1/4NE1/4 section 2, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian (attachment 1). The proposed Hidden Oak subdivision is at the base of an approximately 160-foot-high bluff. In two areas, steep cut slopes that locally exceed 20 feet in height exist at the base of the slope. A residential subdivision is atop the bluff in Layton City. Two homes are near the crest of the bluff above the cut slopes. The purpose of this study was to assess the potential for slope instability above the cut slopes, address the potential hazard to existing homes atop the bluff and proposed homes at the base of the cut slopes, and to determine the need for an additional detailed slope-stability study. This report also briefly addresses potential flood and erosion hazards posed by the cut slopes. The scope of this study consisted of a review of published engineering-geologic reports, maps, and aerial photographs; a site reconnaissance; and a preliminary geotechnical-engineering slope-stability evaluation using the PC-STABL5M computer program.

SITE CONDITIONS

The Hidden Oak subdivision is at the base of a north-facing bluff that is approximately 160 feet high. The average slope of the bluff, as determined from contour lines on the Kaysville 7-1/2 minute topographic quadrangle map, is approximately 63 percent (32 degrees). However, I measured local slopes as steep as 100 percent (45 degrees). The southwestern part of the proposed subdivision is in a formerly excavated area at the base of the bluff. The excavated area is visible on aerial photographs dated April 10, 1985 and is possibly an abandoned borrow pit. On the south side of the excavated area cut slopes currently exist at the base of the bluff that locally exceed 20 feet in height. The western cut slope trends approximately east-west and cuts the mouth of a north-northwest trending drainage cut into the bluff (attachment 1). Thus, the main channel of the drainage is currently hanging atop an approximately 20-foot-high cut slope. The eastern cut slope is slightly curved and trends roughly northeast-southwest.

Two homes exist south of the cut slopes atop the bluff in the Meadowood subdivision in Layton, Utah. The homes are located near the crest of the bluff and each are separated from the slope by only a narrow strip of lawn. In addition, a narrow undeveloped lot is also atop the bluff and separates the two homesites.

BLUFF GEOLOGY

Surficial geologic mapping by Lowe (1989) and Nelson and Personius (1993) indicates the bluff and the majority of the Hidden Oak subdivision is underlain by prehistorical landslide deposits. Lowe (1989) inventoried this area as prehistorical slope failure LS 335. Nelson and Personius (1993) indicate that landslide deposits extend out about 500 (eastern part of the proposed subdivision) and 1,000 (western part of the proposed subdivision) feet beyond the base of the bluff. Lobate, hummocky terrain is visible on the 1985 aerial photographs to the north of the excavated area near the base of the bluff and suggests a landslide origin for the surficial materials. Nelson and Personius (1993) also mapped a landslide escarpment, or main scarp, near the crest of the bluff.

The landslide deposits on the bluff are likely derived from lacustrine soils deposited by glacial Lake Bonneville. Nelson and Personius (1993) mapped lacustrine sands atop the bluff. These soils consist of coarse to fine-grained sand interbedded with gravelly and silty sand. Mapping in the Hobbs Reservoir area to the south by Nelson and Personius (1993) suggests the lacustrine sands may be underlain by finer grained lacustrine soils. I observed soils in the cut slopes to consist mostly of interbedded clean, fine-grained sand; silty fine-grained sand; and oxidized, red silty clay.

I observed no direct evidence of seepage in the bluff, but soils in the lower part of the cut slopes were moist. However, I observed moss vegetation on the lower bluff between the two cut slopes and also about midslope on the bluff. The presence of moss suggests ground-water seepage is sufficient to support this plant type in these locations. I infer that the moss grows in places where perched ground water exists, possibly above thin clay layers, and intercepts the edge of the bluff.

PREVIOUS STUDIES

Three previous studies were conducted by Strata Consultants (Strata) (1992, 1996a, and 1996b) that address general slope stability, but were generally reconnaissance in nature. These studies were conducted at the request of Mr. Dennis Lower, the developer of the Hidden Oak subdivision. Strata (1992) identified prehistorical landsliding at the site and inferred that it was triggered by oversteepening caused by stream erosion as the Weber River incised into the lacustrine deposits and formed the bluff. Strata (1992) indicated that surficial soils at the site include landslide deposits and that an active landslide exists to the west of the site in the same north-facing bluff. Strata (1992) observed no evidence for historical landsliding at the site excluding surficial sloughing on the faces of the 10-foot-high cut slopes that were present at the base of the bluff at the time of its site investigation in 1992. The Strata (1992) report presented several recommendations including:

1. 25-foot setbacks for homes and buildings from the cut slopes,
2. no additional cuts in the base of the bluff without adequate engineering evaluation, and
3. general erosion and drainage measures.

Strata (1992) indicated that human activity could induce "catastrophic" slope failure in the unlikely event that a water line broke atop the bluff and that earthquake-induced landsliding was also possible.

In two subsequent letter reports, Strata (1996a, 1996b) further addressed slope stability issues and either modified or made additional recommendations. Strata (1996a) recommended that cuts in the base of the bluff should not exceed 8 feet high, and added that cuts higher than this require detailed analysis. A final Strata report (1996b), dated November 18, 1996, indicated that in some areas, recently excavated cut slopes "...are higher than we anticipated." Strata commented that the "...excavation contractor got carried away... and exceeded these (Strata's) recommendations." Strata (1996b) stated "further excavation of slopes along this hillside...are not recommended."

SLOPE STABILITY

The geologic interpretation (Lowe, 1989; Nelson and Personius, 1993) that the bluff is underlain by landslide deposits indicates that the bluff has been susceptible to landsliding. Important issues to be considered given the existing development atop the bluff and proposed development at its base are whether human activities could trigger future landslides and also the potential for naturally caused landslides to impact property or present a life-safety concern.

At present, human activities that may trigger landsliding include excavation at the base of the bluff and landscape irrigation and alterations to natural drainage atop the bluff. Although only two homes exist directly above the slope, landscape irrigation and drainage alterations throughout the subdivision atop the bluff may contribute to perched water tables and slope instability. Excavation at the base of the bluff also contributes to slope instability. My preliminary geotechnical-engineering slope-stability assessment of the net effect of the excavation at the base of the bluff suggests a decrease in stability of about 5 to 10 percent relative to the natural state under dry conditions. In my analysis, I incorporated soil properties and soil-strength information from laboratory testing of similar soils at nearby sites. My analysis also suggests the most likely type of slope failure is shallow landslides that intercept the cut slopes.

Another potential hazard is from naturally caused landslides. Two types of landslides are possible. The first are shallow landslides that occur above the cut slopes but are not directly the result of instability induced by excavation at the base of the bluff. The second are larger, composite earth slide-flows. These landslides appear to be the type which have occurred in the past and have involved movement of the entire bluff. Nelson and Personius (1993) interpreted the drainage southwest of the site to be of landslide origin. They show landslide deposits as having moved downslope and north across the flat slope at the base of the bluff as far as 1,000 feet. The extreme distances the landslide deposits appear to have moved suggest the soils flowed like a viscous liquid. The exact causes of these larger prehistorical landslides are unknown, but may include earthquake ground shaking and liquefaction.

Human activities, such as those described above, contribute further to the likelihood of similar future slope failures. Excavations at the base of the bluff destablize the slope in a similar manner as the inferred process of prehistorical stream erosion (Strata, 1992) by removing lateral support at the base and oversteepening the slope. Irrigation and drainage alterations, particularly atop the bluff, have the potential to introduce more water into the bluff than under prior natural conditions. It is commonly assumed that many prehistorical landslides occurred during times when conditions were wetter than at present. In some situations, modern irrigation practices may reproduce these wetter conditions.

IMPLICATIONS

The potential for instability in the bluff has implications for both the existing homes atop the bluff and proposed homes at the base. Given the limited setbacks of the homes atop the bluff from the crest of the slope, a potential hazard exists from both shallow and larger, composite, slide-flow landslides. My preliminary analysis suggests that the excavation at the base of the bluff has removed lateral support and reduced slope stability, thus increasing the likelihood of shallow landsliding damaging homes atop the bluff. Some of the potential surfaces of rupture could form scarps far enough behind the crest of the slope to cause foundation damage to existing homes.

Natural landslides may also occur and should be considered in building setbacks both atop and at the base of the bluff. The head of the drainage (attachment 1) which Nelson and Personius (1993) interpret to be a prehistorical landslide area is farther south than existing homes atop the bluff. Thus, the existing homes are most likely not setback adequately in the event of a large composite earth slide-flow as has happened prehistorically. Nelson and Personius (1993) interpreted hummocky deposits north of the excavated area at the base of the bluff as prehistorical landslide deposits. Based on my review of 1985 aerial photographs, I concur with their interpretation. Thus, prehistorical landslide deposits appear to have moved hundreds of feet downslope and beyond the northern limit of the western part of the proposed Hidden Oak subdivision. Proposed building setbacks at the base of the bluff range between 25 and 15 feet depending on whether a retaining system will be used, and are inadequate to prevent property damage or protect occupants in the unlikely event of a large, catastrophic landslide.

FLOODING AND EROSION HAZARDS

The western cut slope truncates the drainage southwest of the subdivision and leaves the channel hanging atop the cut slope posing both flooding and erosion hazards. The drainage upslope of the cut slope drains an area about 7 acres in size. Thus, an intense rainstorm that drops an inch of rain in a short period of time delivers about 0.6 acre-feet of water to the area. A percentage of this likely flows across the ground surface to the channel and, given the current position of the hanging channel, would likely cause erosion in the upper cut slope and local flooding at the base of the bluff.

RECOMMENDATIONS

My preliminary assessment suggests that the potential for slope instability resulting from excavation at the base of the bluff and irrigation and drainage alterations atop the bluff cannot be ruled out given the uncertainties regarding actual site conditions. These uncertainties include actual soil strengths and ground-water conditions in the bluff. Because of these uncertainties and the apparent potential for damaging landslides in the bluff, I recommend that a detailed geotechnical-engineering slope-stability evaluation be performed. General guidelines for this study are found in

Utah Geological Survey (UGS) Circular 92 (Hylland, 1996). At a minimum, this study should include at least one deep borehole in the upper part of, or atop, the bluff; laboratory testing to determine actual soil strengths; and ground-water monitoring, particularly during the late winter and spring when ground-water levels may be highest. The study should be reviewed by the UGS to ensure that it adequately addresses the slope-stability issues.

In addition, I concur with Strata's (1996b) recommendation that cut slopes greater than 8 feet high at the base of the bluff should have engineered retaining-wall systems. At present, most of the cut slopes exceed this height. Because excavation at the base of the bluff could induce shallow damaging landslides, proposed retaining-wall systems should be designed to increase slope stability as well as impede erosion. The retaining-wall design should not only protect against cut-slope failures but should also consider the downslope movement of potential shallow landslides that toe in the cut slope and have thrust angles subparallel to the slope. Proper engineering of the retaining-wall systems may not be possible until after the detailed investigation described above, as determined by the design engineer. Because of the importance that the retaining walls perform adequately, measures should be taken to ensure the walls are constructed according to design specifications. One way to do this is to require the design engineer to send a letter to South Weber City confirming the walls were constructed according to design specifications.

Potential flooding and erosion hazards posed by the hanging drainage channel atop the western cut slope should also be addressed as either part of the detailed slope-stability evaluation, or in a separate study. The study should address the potential channel flow in the drainage and make appropriate recommendations to mitigate flooding and erosion. The results of this study should be incorporated into the retaining-wall design as necessary.

South Weber City should also consider disclosing the existence of this report, the Strata (1992, 1996a, 1996b) reports, and subsequent slope-stability reports to future lot owners. This would help ensure that future property owners are aware of potential landslide hazards, including naturally caused, potentially catastrophic landsliding induced by earthquakes or liquefaction.

REFERENCES

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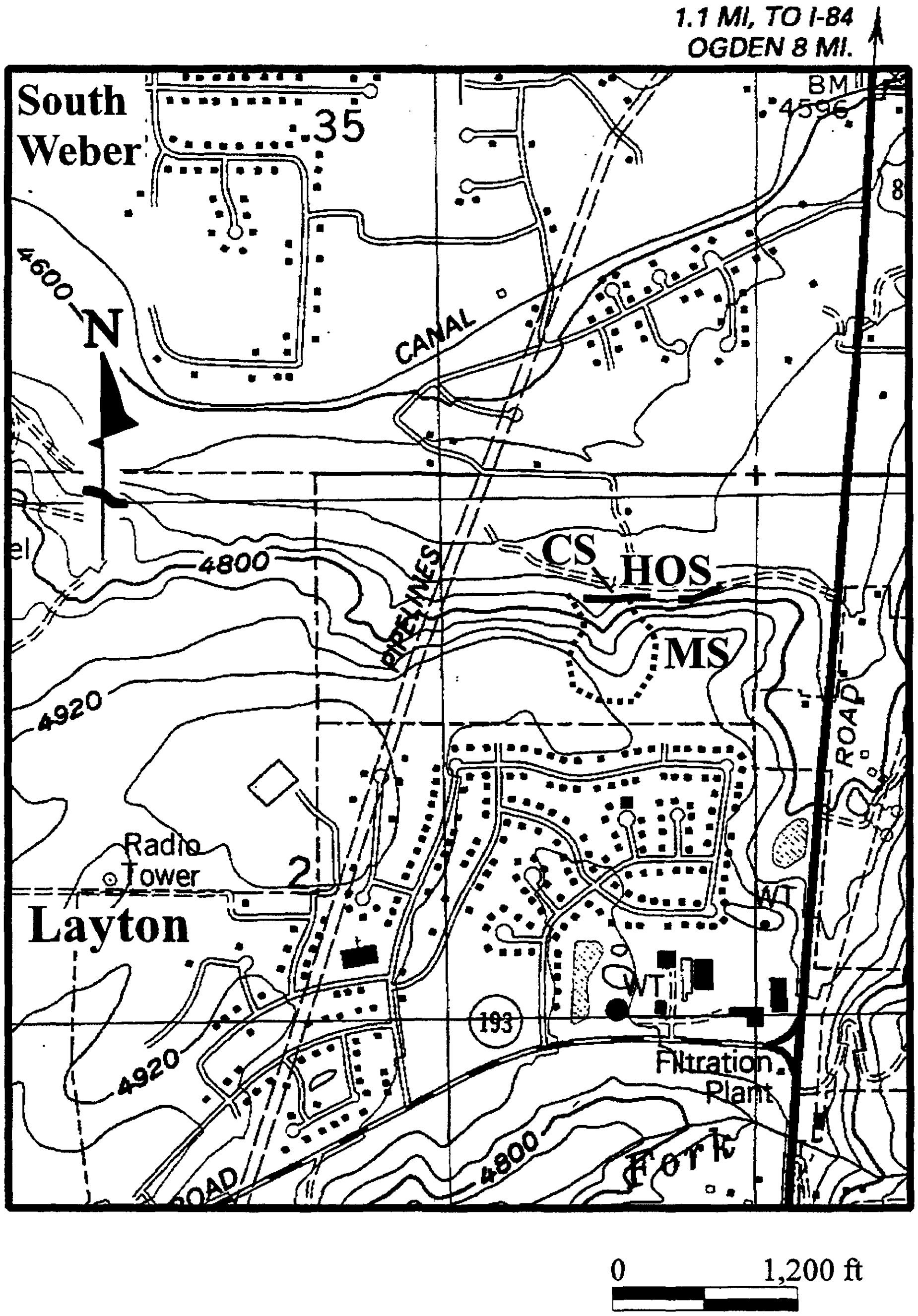

Attachment 1. Location map showing prominent features in the vicinity of the Hidden Oak subdivision (HOS). Two homes exist atop the north-facing bluff in the Meadowood subdivision (MS). Two cut slopes (CS) exist at the base of the bluff. The western cut slope severs the mouth of the unnamed drainage (approximate limits shown by dashed line) and leaves the channel hanging about 20 feet atop the cut slope.

Project:			Requesting Agency:
Reconnaissance of a landslide on East Sunset Drive, Layton, Davis County, Utah			Layton City Community Development Department
By: Richard E. Giraud	Date: 6-11-98	County: Davis	Job No: 98-12 (GH-2)
USGS Quadrangle: Kaysville (1320)		Number of attachments: 3	

INTRODUCTION

At the request of Scott Carter, Layton City Community Development Director, I performed a reconnaissance of a landslide at 1851 East Sunset Drive in Layton. The landslide is on the north side of Sunset Drive at the top of a slope above the North Fork of Kays Creek (attachment 1). The purpose of this investigation was to determine the hazard potential of the landslide and provide recommendations for subsequent investigations. The scope of work included review of published geologic reports and maps, unpublished consultant's reports, and aerial photographs (1985). Field visits were performed on April 17, 1998, with Fred May (Utah Division of Comprehensive Emergency Management); April 20, 1998, with Francis Ashland (Utah Geological Survey [UGS]); and April 27, 1998, with Gary Christenson (UGS) and Robert Rasely (Natural Resource Conservation Service).

The landslide damaged a house at 1851 East Sunset Drive on lot 105 in phase 2 of the Heather Glen subdivision (attachment 2). Upon discovery of the damage on April 13, 1998, Layton City condemned the house for human occupancy. Movement of the landslide and damage to the house began earlier in the spring, and five years prior, the house reportedly had experienced some structural distress (Scott Carter, verbal communication, April 17, 1998). Exterior house damage includes a cracked and displaced foundation, tilted and bowed walls, and sheared door frames. Other property damage includes cracked and displaced driveway slabs, and pull-apart gaps between the driveway and garage and between a house wall and free-standing brick wall. The house to the west on lot 104 has two vertical cracks in the east foundation wall and the attached exterior deck has dropped downward. The house to the east on lot 106 has ground cracks at its northwest foundation corner. These three houses are directly affected by the landslide; other lots show damage to landscaping.

PHYSICAL SETTING AND GEOLOGY

Phase 2 of the Heather Glen subdivision is on a gently west-sloping bluff at an elevation of 4,750 feet. The bluff top was dry-farmed before subdivision development. The landslide lies at the crest of a northwest-facing slope. Slope vegetation consists of grass, shrubs, and a few trees. The North Fork of Kays Creek flows southwest through a broad open valley 160 feet below the slope crest (attachments 1 and 2). The creek has been realigned along the south flood-plain margin for agricultural purposes. The slope steepness averages 30 percent. During development of the subdivision fill was placed along the top of the slope to create level ground for building pads and landscape areas. Some house footings at the slope crest may rest partially on fill and partially on native materials.

The North Fork of Kays Creek has incised into lake (lacustrine) sediments that were deposited in Lake Bonneville as part of the Weber River delta. Nelson and Personius (1993) map two different lacustrine units in the vicinity. Lacustrine clay, silt, and minor fine sand deposits, of latest Pleistocene age, are present in the valley slopes. Lacustrine sands of latest Pleistocene age, related to the regressive phase of Lake Bonneville, occur on the surface of the sloping bluff. Stream alluvium, along the North Fork of Kays Creek, is of Holocene to latest Pleistocene age. The alluvium consists of silty sand, sand, and gravel. Soil mapping by Erickson and others (1968) shows that native soils along the bluff are of eolian (wind blown) origin.

Borehole data from Heather Glen subdivision phases 3 and 4 indicate interbedded clay and silty sand with minor gravel (Chen and Associates, 1987). Phase 3 is east and phase 4 is southwest of phase 2. Phase 4 was subsequently developed as the Autumn Woods subdivision.

The slope crest around lots 104-108 has a scalloped shape that suggests previous landsliding (attachment 2). Fill placement and surface grading have modified the scalloped shape. Anderson and others (1982) and Lowe (1988) mapped the northwest-facing slope as prehistoric landslide deposits. Lowe (1990) and Robison and Lowe (1993) point out that landslides are common where streams have incised into the Weber River delta creating steep slopes exposing clay, silt, and sand deposited in Lake Bonneville.

LANDSLIDE FEATURES

The most prominent landslide feature is a roughly east-west scarp that crosses seven lots along the slope crest (attachment 2). The scarp results from downward displacement of the ground surface to the north. The scarp displaces fill material, a sidewalk, a driveway, a house foundation, and landscaped areas. The distressed house on lot 105 straddles the scarp (attachment 3). In lawn turf, the scarp forms a small fold. The maximum scarp height is 12 inches on the west side of the house. West of lot 105, the scarp extends to the eastern house foundation wall on lot 104, then north and west along the foundation walls. North of lot 104 the scarp arcs onto the valley slope below. I placed a movement-monitoring stake at the western scarp tip on April 27, 1998. East of lot 105 through lot 109, the scarp can be traced as a relatively linear small fold of lawn turf. Ground cracks, having a horizontal separation of ½ inch are present at the northwest foundation corner of the house on lot 106. Maximum scarp height east of lot 105 is 6 inches.

Another scarp is present on the lower valley slope below the subdivision houses at 4,665 feet elevation (attachment 2). The scarp trends northeast and has a maximum height of 6 inches. I placed movement-monitoring stakes at the lower scarp tips on April 27, 1998. The relationship of the lower scarp to the scarp at the slope crest is unknown. The two scarps may represent two distinct landslides or may be part of the same, larger landslide. Both scarps have a fresh, sharp morphology and represent movement in the spring of 1998. I observed no other landslide features other than the two scarps and ground cracks.

GROUND-WATER CONDITIONS

I identified two springs and one seep during my field reconnaissance. One spring is present in a clump of Hawthorne trees at 4,665 feet elevation (attachment 2) east of the lower scarp discussed above. The estimated flow rate was 1 gallon per minute on April 27, 1998. The water flows down an abandoned road and percolates into the ground before reaching the North Fork of Kays Creek. Another spring was identified northwest of lot 103 in a small road cut at 4,655 feet. A small seep is present north of lot 103 at 4,630 feet. Saturated soil and moss are present around the seep. Chen and Associates (1987) reported ground-water depths of 13 to 33 feet below the ground surface in Heather Glen subdivision phases 3 and 4. The interbedded lacustrine clay, silt, and sand may create multiple perched aquifers that discharge at different elevations on the valley slope. Landslide movement occurred during the spring when the ground-water table is expected to be highest.

HAZARD POTENTIAL

I believe continued and/or future landslide movement along the upper scarp is likely. The houses at greatest risk are those crossed by or adjacent to the scarp on lots 104, 105, and 106. The scarp traverses the back yards of lot 103 and lots 107 through 109 and future movement on the scarp could cause further damage to these lots and possibly affect houses. Additional movement may also cause the landslide to propagate to the south or the existing scarp to lengthen and affect additional lots.

Once a landslide has moved, it is more susceptible to future movement because subsurface conditions such as increased permeability, allowing greater water infiltration, and an established landslide slip surface, reduce stability. Sources of water infiltration include precipitation, runoff from roof downspouts, and landscape irrigation. The lateral migration of ground water from elsewhere in the subdivision may also add water to the landslide. Thus, even if landslide movement stops, the potential for reactivation is high because of the close spatial association of the scarp, the landslide slip surface, and water infiltration sources.

The general topographic setting, geologic materials, ground-water conditions, and historical slope instability indicate that slopes in the area are susceptible to landsliding. Landslides causing valley widening have been an on-going natural response to the downcutting of the North Fork of Kays Creek. As discussed above, the relationship between the lower scarp and the scarp at the slope crest is unknown. The two scarps may represent two distinct landslide areas or may be part of a large landslide. A large landslide may affect more lots than the seven currently affected (Robert Rasely, verbal communication, April 30, 1998).

Chen and Associates (1987) modeled the slope stability of Heather Glen subdivision phases 3 and 4. They concluded that the natural slopes were stable but that slope failure was probable under earthquake conditions. The static (non-earthquake) factors of safety ranged from 1.3 to 1.5 and earthquake factors of safety ranged from 0.7 to 1.0. The analyses also indicate that a relatively deep landslide is more probable than a shallow landslide under both static and earthquake conditions. The static factors of safety less than 1.5 and probable slope failure under earthquake conditions further indicate the susceptibility of slopes in the area to landsliding.

RECOMMENDATIONS

I recommend a detailed geotechnical-engineering slope-stability investigation, as outlined in Hylland (1996), of the landslide area. The purpose of the investigation would be to determine the landslide boundaries, ground-water depth, and soil-strength parameters to assess slope stability and possible hazard reduction. The investigation must determine the role of the fill in the failure, the likelihood of southward landslide propagation, and the possibility of a large landslide involving the entire slope. I also recommend movement monitoring to determine the rate, timing, and extent of landslide movement. Monitoring should be performed at the slope crest near the houses and on the valley slope to evaluate any movement above, between, and below the two scarps. I also recommend continued monitoring for new scarps, new ground cracks, displacement and lengthening of existing scarps, and spring flow.

Interim measures should be taken to reduce the landslide risk until the slope-stability analysis is completed and possible hazard reduction is implemented. Interim measures include preventing infiltration of water in the scarp and landslide areas by draining runoff from downspouts and driveways to the street and the storm-water system, ensuring that buried water and sewer lines are not leaking, and avoiding landscape irrigation. These interim measures should be carried out on both sides of Sunset Drive in the vicinity of the scarp at the slope crest.

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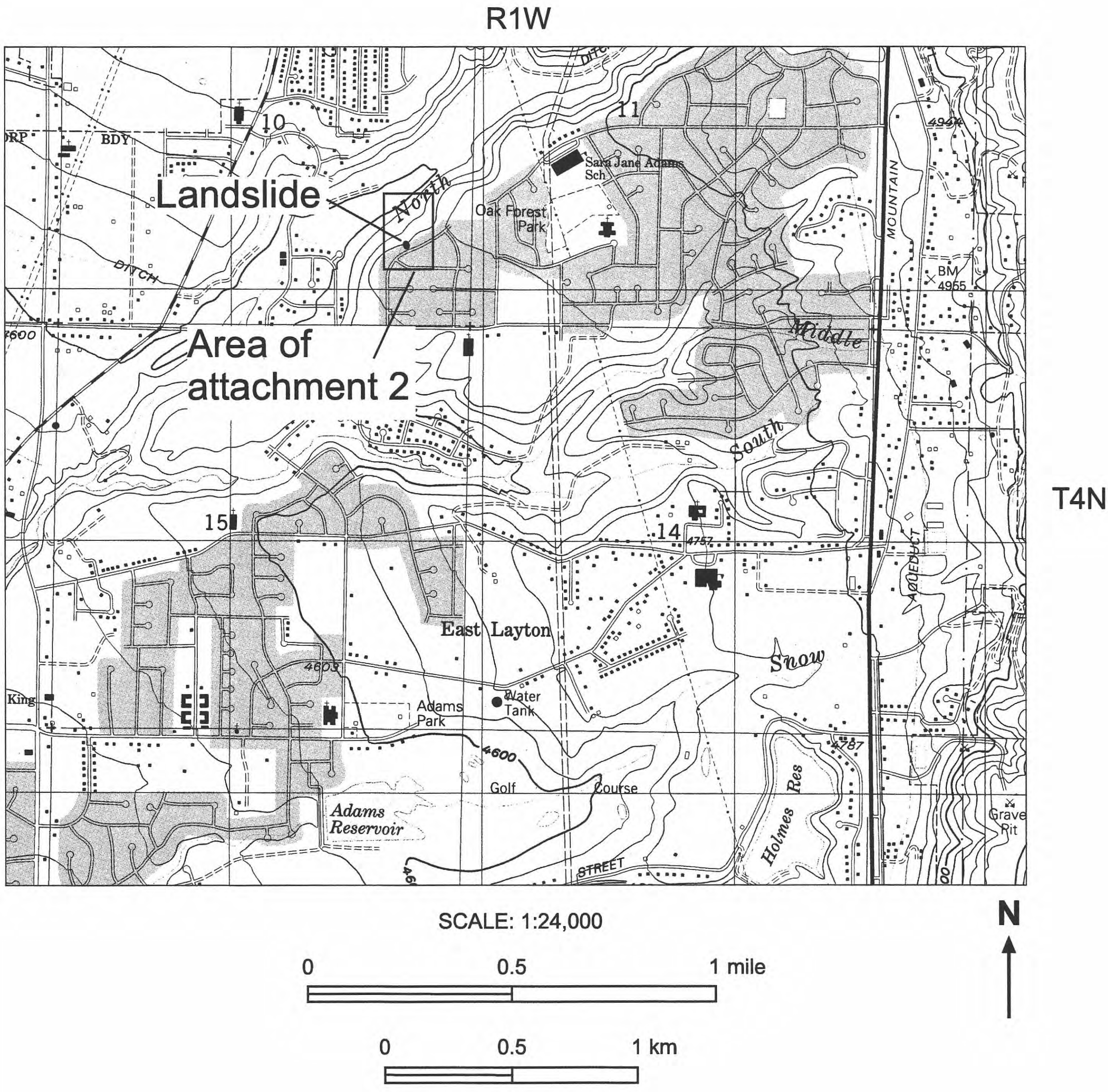
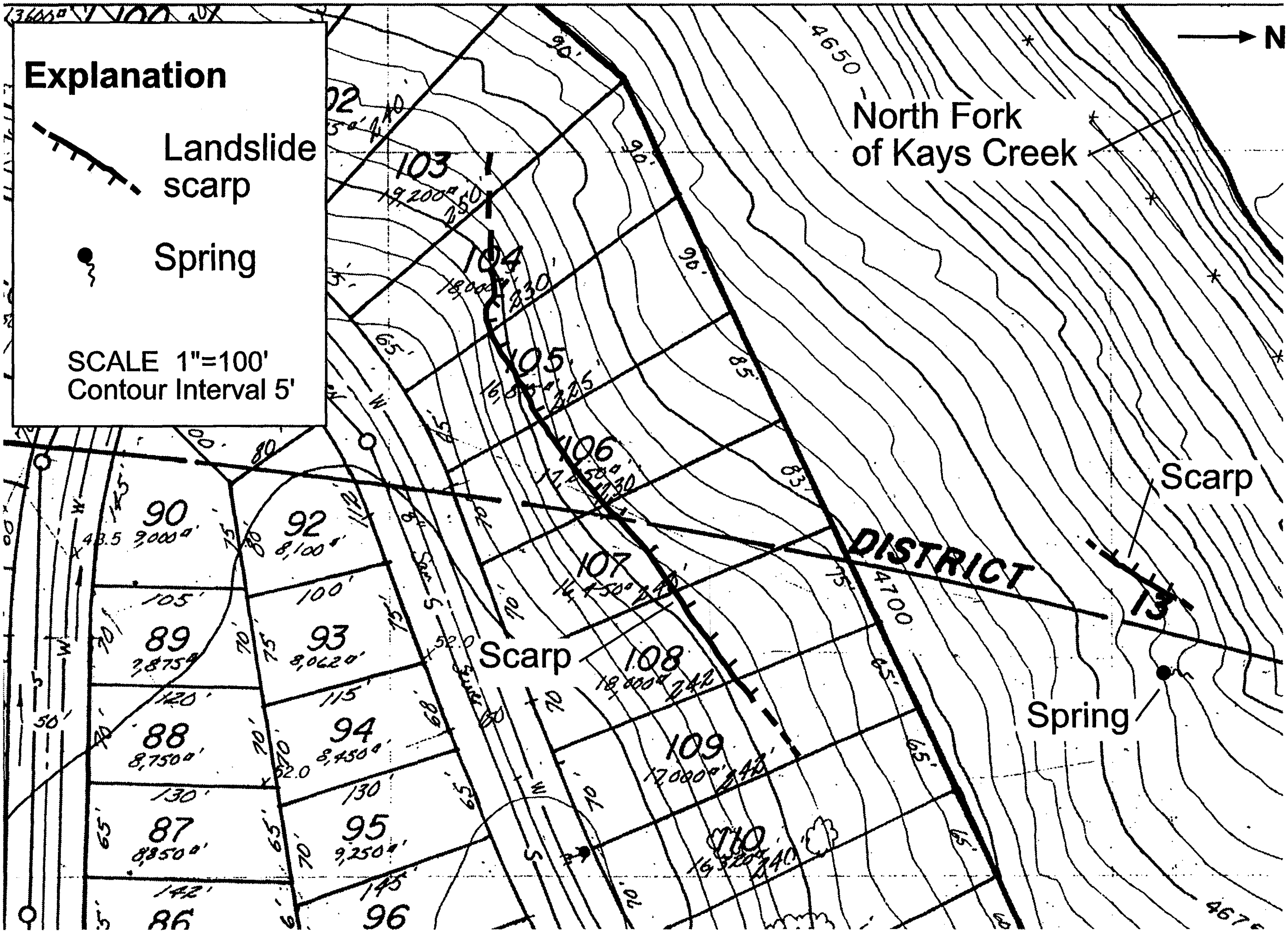


Attachment 1. Location of the Sunset Drive landslide; box area shown in attachment 2.

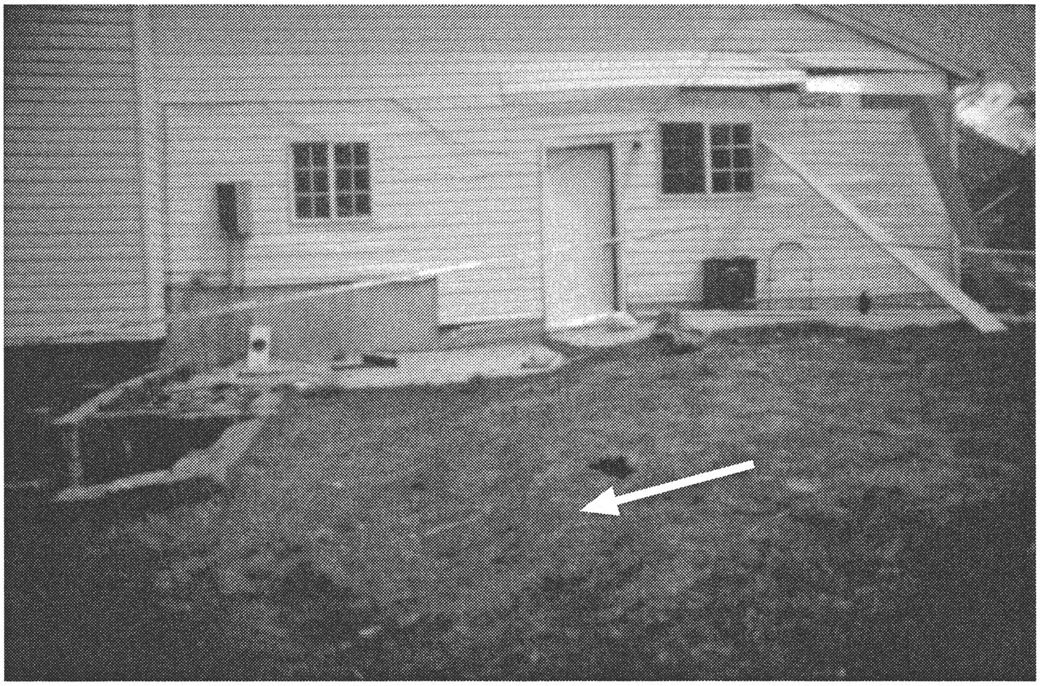
Attachment 2. Job No. 98-12

Base map from Layton City Community Development Department



SCALE 1:1,200

Attachment 2. Location map showing residential lots, topography, and approximate scarp locations



Attachment 3. Landslide damage on April 27, 1998, to house on lot 105. Arrow points to scarp position in lawn. View is to the east.

Project:			Requesting Agency:
Reconnaissance of a landslide along the Davis-Weber canal near 1250 East South Weber Drive, South Weber, Davis County, Utah.			South Weber City
By: Bill D. Black	Date: 05-21-98	County: Davis	Job No: 98-13 (GH-3)
USGS Quadrangle: Ogden (1345)		Number of attachments: 3	

INTRODUCTION

On April 29, 1998, I conducted a reconnaissance of recent landsliding along the Davis-Weber canal in South Weber, Utah, in the SE1/4NE1/4 section 33, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian (attachment 1). The landslide was initially investigated by Utah Geological Survey (UGS) geologist Barry J. Solomon on April 25, at the request of South Weber City through Fred May of the Utah Division of Comprehensive Emergency Management. Barry J. Solomon (UGS), Francis Ashland (UGS), Kevin Bourne (Operable Unit 1 Project Manager, Environmental Management Directorate for Hill Air Force Base), and Ivan Ray (President) and Floyd Baham (Manager) of the Davis and Weber Counties Canal Company were present during my reconnaissance. The purpose of this investigation was to determine physical characteristics of the landslide and evaluate its potential to damage or possibly block the Davis-Weber canal and cause flooding of homes and a school below it. The scope of work included a literature review, interpretation of air photos, and additional visits to the site on May 1 and May 11.

DESCRIPTION

The 1998 landslide is in a steep north-facing bluff along the Weber River flood plain near the eastern edge of the South Weber landslide complex, a zone of prehistorical and historical landsliding that consists of a series of interconnected rotational earth slumps and slides (Pashley and Wiggins, 1971). Montgomery-Watson (1995) indicates several existing landslides are in slopes at the site, including a large historical slide involving the entire slope and several recent, localized slides along the Davis-Weber canal. The large historical landslide occurred in the spring of 1984, and extended from the Hill Air Force Base perimeter fence to the canal and for about 300 to 400 yards (275-365 m) along the bluff (Lund, 1984). This landslide shattered the concrete wall of the south canal bank and partially filled the canal with debris (Ogden Standard Examiner, April 25, 1984).

The 1998 landslide is a zone of earth slumps and slides about 250 feet (76 m) long and 1,200 feet (366 m) wide along the south bank of the Davis-Weber canal (attachment 2). The 1998 landslide is on the eastern edge of the 1984 landslide. Slumping in the upper portion of the landslide formed a near-vertical main scarp up to about 6 feet (2 m) high in places, as well as numerous smaller subsidiary scarps and fissures between jumbled blocks of intact soil (attachment 3). Shallow earth slides occurred at the oversteepened slide toe just above the canal (attachment 3). All slip surfaces appear to be shallow and show no evidence of extending under the canal.

Failure of the slope accelerated in early to mid-April (Floyd Baham, verbal communication, April 1998), causing the landslide to encroach on the canal and deposit debris in it. Mr. Baham (verbal communication, April 1998) also reported the slope at this location has been slumping into the canal for more than a decade, and the Davis and Weber Counties Canal Company has periodically stationed construction equipment to remove debris. This section of the canal was replaced and reinforced in 1996 (Floyd Baham, verbal communication, April 1998; attachment 2) and shows no evidence of damage.

Cause(s) of the 1998 landslide are unclear, but are probably a combination of marginal slope stability and elevated ground-water levels. Sediments at the site are deltaic deposits of the Weber River as it flowed into Lake Bonneville, and consist of low plasticity silty clay having sand interbeds and laminations (Montgomery-Watson, 1995). Montgomery-Watson (1995) concluded that landslides in these sediments are likely to occur when they are saturated, and I observed water issuing from the slide and from a gravel drain/PVC pipe that passes beneath the canal. The drain was emplaced to maintain drainage of the slope during the 1996 canal repair. Timing of the 1984 and 1998 landslides is similar, and suggests that seasonally high water levels may be a significant contributor to slope instability. High soil moisture and above-average precipitation this spring appear to be the primary source of water in the slope. The Palmer Drought Index, which is a measure of soil moisture, indicates soils in region 3 of Utah (which includes South Weber) are currently very to extremely moist (unpublished National Oceanic and Atmospheric Administration [NOAA] Climate Prediction Center data). Precipitation in January and February 1998 in the South Weber area was also about 200% of normal (unpublished NOAA National Weather Service data).

RISKS AND RECOMMENDATIONS

A risk exists for the landslide to cause flooding to several homes and a school (South Weber Elementary) north of the canal and along the canal east of the landslide. Flow in the Davis-Weber canal was about 60 cubic feet per second (1.7 m^3/sec) on April 29, though the maximum capacity is about five times that amount. A sufficiently large failure could block the canal, causing water to back up and overtop the canal bank, or possibly damage the canal. Sediment from a large failure and/or spillage erosion (gullying) may also combine with the floodwater to produce a shallow debris flood. If the canal overtopped at the site, Merkley (1994) concluded that under worse-case conditions (full canal flow, complete blockage, and a floodwater flow width of 50 feet [15 m]), floodwaters would take about 30 minutes to reach the school and would be less than 1.2 feet (0.4 m) deep. Based on a flow width of about 500 feet (152 m) (likely a more realistic estimate), flooding at the school would be fewer than 3 inches (8 cm) deep and probably would not pose a life-safety threat (Merkley, 1994). However, because the canal gradient is low (3 feet/mile [0.6 m/km]), water may back up for a long (unknown) distance and possibly cause flooding farther east. South of the school, homes are closer to the canal (attachment 1). In such a case, flooding could pose a life-safety threat. In either case, floodwaters will likely cause considerable property damage. In the event of a large, rapid slope failure, construction equipment may not be able to remove material fast enough to prevent spillage, particularly if the access road is blocked or damaged. The equipment and its operator would also be at risk.

Because of the risk of flooding from blockage or damage to the canal, I suggest the Davis and Weber Counties Canal Company and South Weber city officials regularly inspect the landslide for evidence of additional movement and impending failure, particularly in wet seasons and after periods of increased precipitation. The canal company should also have an emergency plan to quickly turn out water from the canal in the event of blockage and control any remaining flow. South Weber City has provided sandbags for residents north of the canal that may be flooded and instructed the residents to fill and place them (Henry Dickamore, Mayor, verbal communication, May 1998), but they may also want to consider sandbagging of the canal berm to the east of the site to control possible unpredictable flooding if canal waters back up. Residents east of the landslide which live closer to the canal should also be warned of the flood risk. Debris which enters the canal can be removed, although care should be taken in removing material from the slide toe so as not to cause additional instability. In addition to flood hazards, blockage or damage to the canal may cause economic hardship for water users. Therefore, the canal company may wish to consider long-term mitigation measures for reducing the risk from landsliding at the site (such as means to dewater the slope). Montgomery-Watson (1995) contains detailed data that could be used to provide recommendations for effective measures, although they did not provide any recommendations. These data could be used by a qualified geotechnical engineer to recommend effective mitigation designs. The UGS can review the geotechnical recommendations if requested.

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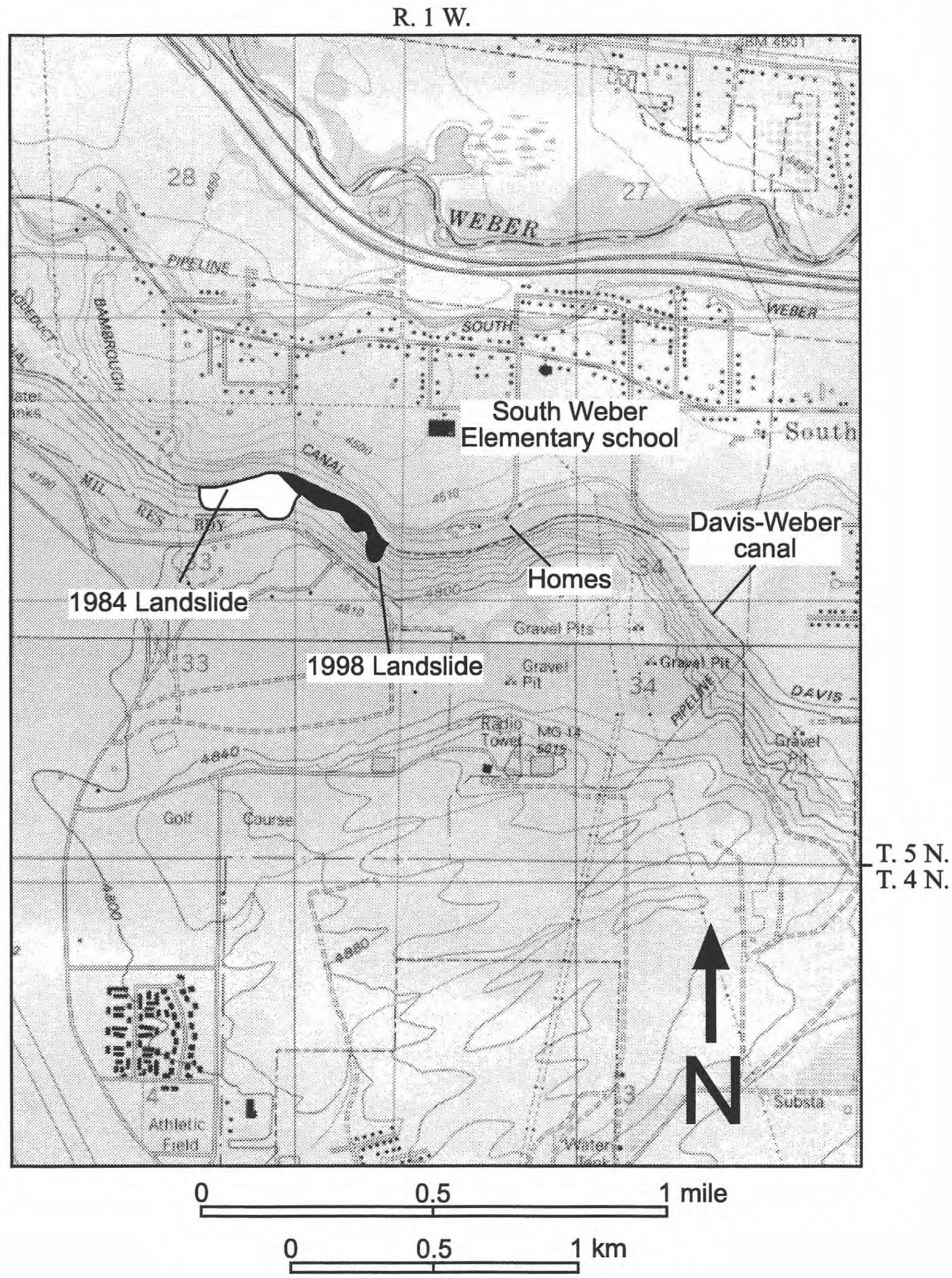
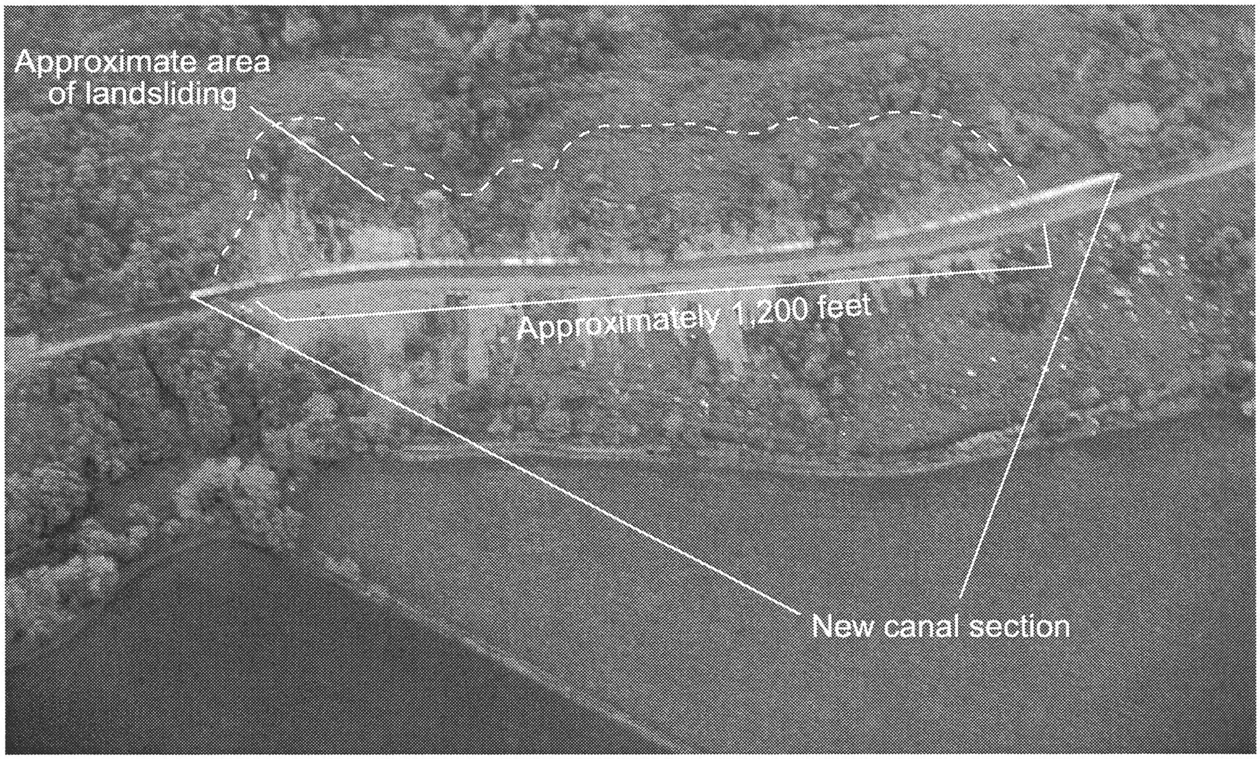
Attachment 1.
Job No. 98-13

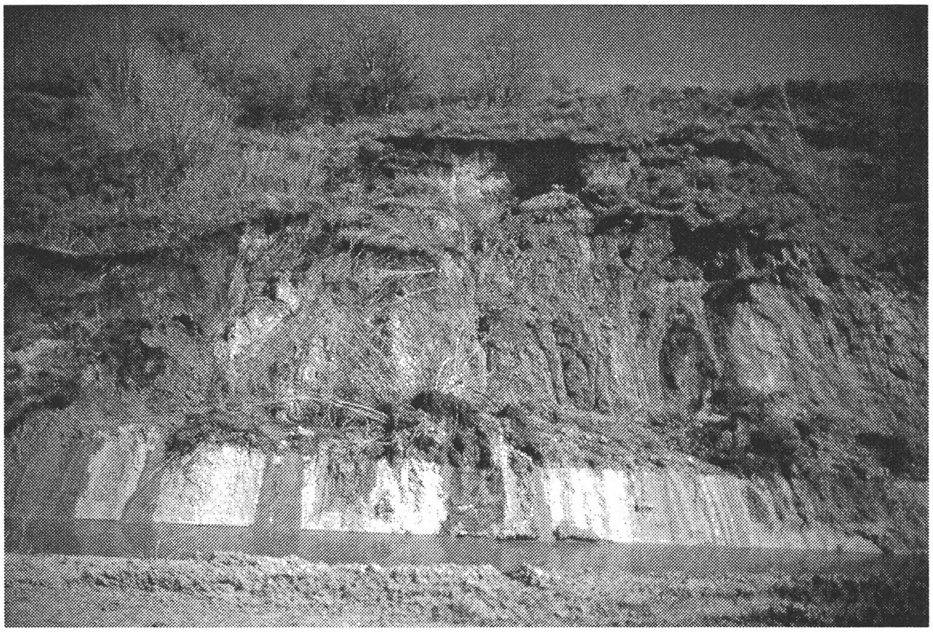
Base map from OGDEN and KAYSVILLE,
U.S.G.S. 7-1/2' topographic quadrangles.



Attachment 1. Location map. Location of the 1984 landslide is from Lund (1984).



Attachment 2. Oblique aerial view of the 1998 landslide along the Davis-Weber canal in South Weber. A section of the canal was replaced in 1996, and nearly corresponds to the area of landsliding. Numerous scarps and ground cracks are evident on the slope in this area. Shallow earth sliding is occurring off the toe of the landslide.



Attachment 3. South views of shallow earth sliding on the right (eastern) flank of the 1998 landslide in South Weber on May 1 (top) and May 11 (bottom). The Davis-Weber canal is in the foreground.

Project:			Requesting Agency:
Reconnaissance of a landslide near the Cedar Bench subdivision, South Weber, Utah			South Weber City
By: Barry J. Solomon	Date: 5-21-98	County: Davis	Job No: 98-14 (GH-4)
USGS Quadrangle: Kaysville (1320)		Number of attachments: 3	

INTRODUCTION

At the request of South Weber City, through Fred May, Utah Division of Comprehensive Emergency Management (CEM), I conducted a reconnaissance on April 24, 1998, of an active landslide near the Cedar Bench subdivision, South Weber, Davis County, Utah. The landslide is located in the SW1/4SW1/4 section 35, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian (attachment 1). I was accompanied by Fred May, Steve Anderson (Hansen, Allen, & Luce, Inc., consulting for South Weber), Bob Fowler (CEM liason officer to Davis County), Mark Larsen (South Weber building inspector), Brian Law (Davis County Emergency Coordinator), and Bob Rasely (U.S. Natural Resources Conservation Service). According to Mr. Larsen, the landslide moved the week of April 12, likely triggered by heavy precipitation, but the movement was only the latest episode of recent activity. The purpose of my investigation was to determine the physical characteristics of the slide and evaluate its hazard potential. As part of this investigation, I revisited the site on April 29 with Utah Geological Survey (UGS) geologists Francis Ashland and Bill Black, Mr. Larsen, Mr. Law, and Barry Burton, Assistant Director of the Davis County Department of Community and Economic Development.

PHYSIOGRAPHY AND GEOLOGIC SETTING

The landslide occurred on the lower part of a northeast-facing slope on the edge of a bluff forming the south side of the Weber River valley (attachment 2). The lower and upper parts of the slope are separated by a bench about 400 feet wide. The lower part of the slope is about 110 feet high and the upper part is about 80 feet high. Both parts of the slope have an average gradient of about 35 percent. The Cedar Bench subdivision lies at the toe of the lower slope, a retention pond maintained by the South Weber Water Improvement District lies on the bench, and the North Davis Refuse District disposal site operated by Wasatch Energy Systems lies on the gently sloping upper surface of the bluff above the upper slope. A shallow canal, mostly lined with wood shavings in a wire mesh but unlined near the northeast corner of the retention pond, is present around the edge of the pond. The canal empties into a series of small berms and flood-control basins in a drainage east of the pond which carries the flow in the canal, if of sufficient volume, from the bench to the base of the bluff. An abandoned road traverses the middle portion of the lower slope. The road is unpaved and has a cut-slope height of about 10 feet. According to city officials, a 4-inch diameter PVC pipe is buried near the road cut to carry runoff to the northwest and discharge it below the slope. A cut slope excavated into the toe of the lower slope, with a maximum cut height of about

20 feet, is covered with a rock wall of boulders up to 3 feet in diameter. An additional cut was excavated below the wall in one back yard, adding another 10 to 15 feet to the cut-slope height.

The geology in the vicinity of the landslide is mapped in detail by Nelson and Personius (1993). They map the bench, upper slope, and upper surface of the bluff as lacustrine sands related to the transgressive phase of Lake Bonneville. These fine- to coarse-grained sands, commonly interbedded with gravelly and silty sands, were deposited in the latest Pleistocene as the lake rose to its highest level. Nelson and Personius (1993) map the lower bluff slope as landslide deposits, which are probably also underlain by Lake Bonneville sands. As the lake receded, the Weber River cut down and eroded through the lake deposits, leaving the steep bluff face adjacent to the river flood plain. As the river cut progressively deeper, the height and steepness of the bluffs exceeded their threshold of stability, causing latest Pleistocene through Holocene landslides along the edge of the bluff. The landslide deposits near the Cedar Bench subdivision are an apparent eastward extension of similar deposits first mapped by Pashley and Wiggins (1972) as the South Weber landslide complex, from 2 to 5 miles to the northwest. Nelson and Personius (1993) also map a late Holocene alluvial fan from the drainage east of the retention pond. The fan deposits underlie part of the subdivision, but natural runoff is now controlled by the flood-control structures noted earlier.

LANDSLIDE DESCRIPTION

The 1998 landslide (attachment 3) is likely a composite slide consisting of ancient, deep-seated rotational slides or slumps (possibly reactivated) overlain by active, shallow translational earth slides and flows. Possible reactivation of the deep-seated ancient landslide deposits is suggested by subtle convex bulges in the lower part of the slope, and by a slight bend in the upper metal rail of the chain-link fence at the toe of the slope. However, without knowledge of pre-existing conditions, I cannot conclusively determine if deep-seated landslide movement occurred recently. I did not observe any ground cracks on the bench above the lower slope to indicate the presence of a deeper surface of rupture.

The complex of shallow slides is about 400 feet wide, and is mostly restricted to the area above the road cut in the lower slope. The maximum scarp height is about 8 feet at the head of slides along the road cut, but deformed ground and open ground cracks up to 4 inches wide extend upslope from the road cut for about 50 feet. The complex of shallow slides is thus about 2,000 square yards in area and, if the slip surface is about 8 feet deep on average, the estimated volume of the shallow slides is about 6,000 cubic yards. A small amount of slumping occurred along the lower edge of the road cut, and saturated silty sands flowed downslope from the road cut in two locations, but I estimate their volume to be small compared to the total volume upslope of the road cut. I did not observe any springs along the slope, but some soil in the road cut was damp. The only ponded water above the slope was in the unlined portion of the drainage ditch at the northeast corner of the complex of shallow slides. Delicate striations were preserved in two locations on slide planes in silty sand, indicating very recent movement prior to my April 24 visit. I did not notice any evidence of additional significant movement on April 29, but subtle movement may have occurred that I could not detect without quantitative measurements.

PROBABLE CAUSES OF RECENT MOVEMENT

The proximity of the shallow slides to the road cut in the lower slope, and the pattern of recent precipitation and snowmelt, suggest that the slides were caused by increased pore pressure and inadequate support for material above the road cut. Precipitation in April measured by the National Weather Service in the Ogden-South Weber-Layton areas was 3.01 inches, or 117 percent of average for the month, and rainfall was reported at the site in the week prior to the slope failure. Precipitation for the calendar year (January through April, 1998) was 147 percent of average. Some additional water was introduced into the northeast corner of the slope as water ponded in the unlined portion of the canal around the retention pond, but I do not believe this contributed significantly to the movement because the most severe landsliding was closer to the northwest corner of the pond. The lack of springs and saturated soils on the lower slope suggests to me that there is no significant leakage from the retention pond on the bench above the slides. This lack of pond leakage, and the fact that the impounded water weighs less than the native soil excavated to create the pond, indicates that the retention pond was not the cause of the slides.

HAZARD POTENTIAL

Three hazards are posed to the Cedar Bench subdivision by the nearby landsliding. These hazards include continuing movement of active shallow earth slides and flows, reactivation of deep-seated landslide deposits, and a flood hazard from disruption of the flood-control structures near the east side of the retention pond.

Shallow earth slides and flows may continue to occur on the lower slope, particularly above the road cut. Shallow earth slides may also be initiated downslope by removal of material at the toe of the slope. A preliminary slope-stability analysis by UGS geologist Francis Ashland shows that the factor of safety is reduced to a cautionary level by the recent back-yard excavation below the rock wall at the base of the slope. Moreover, I believe the rock wall provides a mostly decorative function, with minimal slope reinforcement. Debris from shallow slope failures, particularly from the more fluid earth flows capable of traveling farther downslope, can be hazardous to persons near the slope at the time of slope failure and may inundate basements of nearby homes. Most nearby homes are set back from the toe of the slope by about 50 to 60 feet, but two homes on Juniper Court are set back from 15 to 30 feet. This may be too close to the slope to afford adequate safety. A small garage or storage building on one lot on Cedar Court is also at risk because of a small setback, although the building does not appear to be designed for human occupancy.

Reactivation of deep-seated landsliding, although a lower probability, may pose a greater risk than shallow slides and flows. A much larger volume of material would be involved in deep-seated landsliding, probably capable of moving farther from the toe of the slope. If the main scarp of the landslide regressed far enough southward, the potential exists for failure of the retention-pond lining, resultant flooding, and saturation of landslide debris. This would contribute to additional landsliding and possibly create a fluid mass of debris capable of traveling a considerable distance downslope into the subdivision.

Flooding from disruption of the flood-control structures in the drainage on the east side of the retention pond may result from landsliding or, during periods of intense rainfall, failure of the berms that border the flood-control basins. On my site visits, I observed piping in the berms which may contribute to their failure. The presence of alluvial-fan deposits at the mouth of the drainage indicates that significant floods and debris flows have occurred there in the past. Homes near the outlet of this drainage may be at risk even with the flood-control structures in place as currently designed.

The landslide potential at the site was considered by UGS geologist Mike Lowe (1994) in his review of a geotechnical report for the Cedar Bench subdivision (Huntingdon Chen-Northern, Inc., 1993). The geotechnical report states that the factor of safety for the slope under static (non-earthquake) conditions, calculated using a quantitative slope-stability analysis, was 1.34 prior to subdivision construction. Lowe (1994) reports that it is standard practice to take precautions with development when the calculated factor of safety is less than 1.5 under static conditions. Also, he notes that the factor of safety in the geotechnical report assumed a depth to ground water of 100 feet, but that Gill (1985) determined a depth to ground water of between 13 and 20 feet about 1.3 miles southwest of the Cedar Bench subdivision. Lowe (1994) states that if the depth to ground water at the top of the lower slope is less than 100 feet, the calculated factor of safety would be lower than reported in Huntingdon Chen-Northern, Inc. (1993). Thus, the slope is potentially unstable under static conditions, and snowmelt and heavy precipitation increase instability. Under pseudo-static (earthquake) conditions, the slope is also potentially unstable. Huntingdon Chen-Northern, Inc. (1993) reported a pseudo-static factor of safety of 1.02 which, if ground water is shallower than assumed in the geotechnical report, would be even lower. Lowe (1994) reports that it is standard practice to take precautions with development when the calculated factor of safety is less than 1.1 under pseudo-static conditions. As a result, Lowe (1994) recommended that measures should have been taken prior to development to increase the stability of the slope to acceptable levels and/or delineate setbacks from the base of the slope to protect the development from potential slope failures.

RECOMMENDATIONS

The possibility of continued landsliding warrants remedial measures. The first remedial measure to stabilize the slope should be the immediate cessation of excavation into the toe of the slope. This should be followed by a detailed geotechnical-engineering slope-stability investigation, as outlined in Hylland (1996), to design an engineered solution which may include graded slopes, retaining walls, and drain systems. Proposed remediation should address the effect on slope stability of the abandoned road cut in the lower slope and infiltration of ponded water on the road into downslope material. The buried PVC pipe along the road cut may need to be relocated to remove any potential for introduction of water into the slope from leaks in the pipe, perhaps caused by the existing slope failure. Engineered remedial measures should also consider means to minimize water infiltration at the head of the slope, including the prevention of ponding in the drainage canal near the retention pond, and at the toe of the slope through diversion of drainage from flood-control structures on the slope into the municipal storm-drainage system rather than into the toe. Also, the flood-control structures should be inspected and, if necessary, repaired to prevent their failure from piping or other potential causes. Periodic inspection of the retention pond for leaks, and repairs as necessary, is also prudent.

Landslide activity should be monitored on a regular basis to provide an early indication of the hazard potential. This monitoring could include repeated surveying of permanent monuments on the landslide or measuring of separation distances between stakes spanning cracks and scarps. Monitoring should be conducted at least weekly throughout the spring and early summer to determine whether the slide continues to move. Even if no evidence of movement is found during this period, I also recommend that monitoring be conducted later in the year after intense rainstorms. If no movement is indicated over the next year the slide can be considered dormant, although the conditions for renewed movement will remain until remedial action is taken (Cruden and Varnes, 1996) and monitoring will be prudent each spring. The classification of the landslide as dormant does not preclude the potential for future movement.

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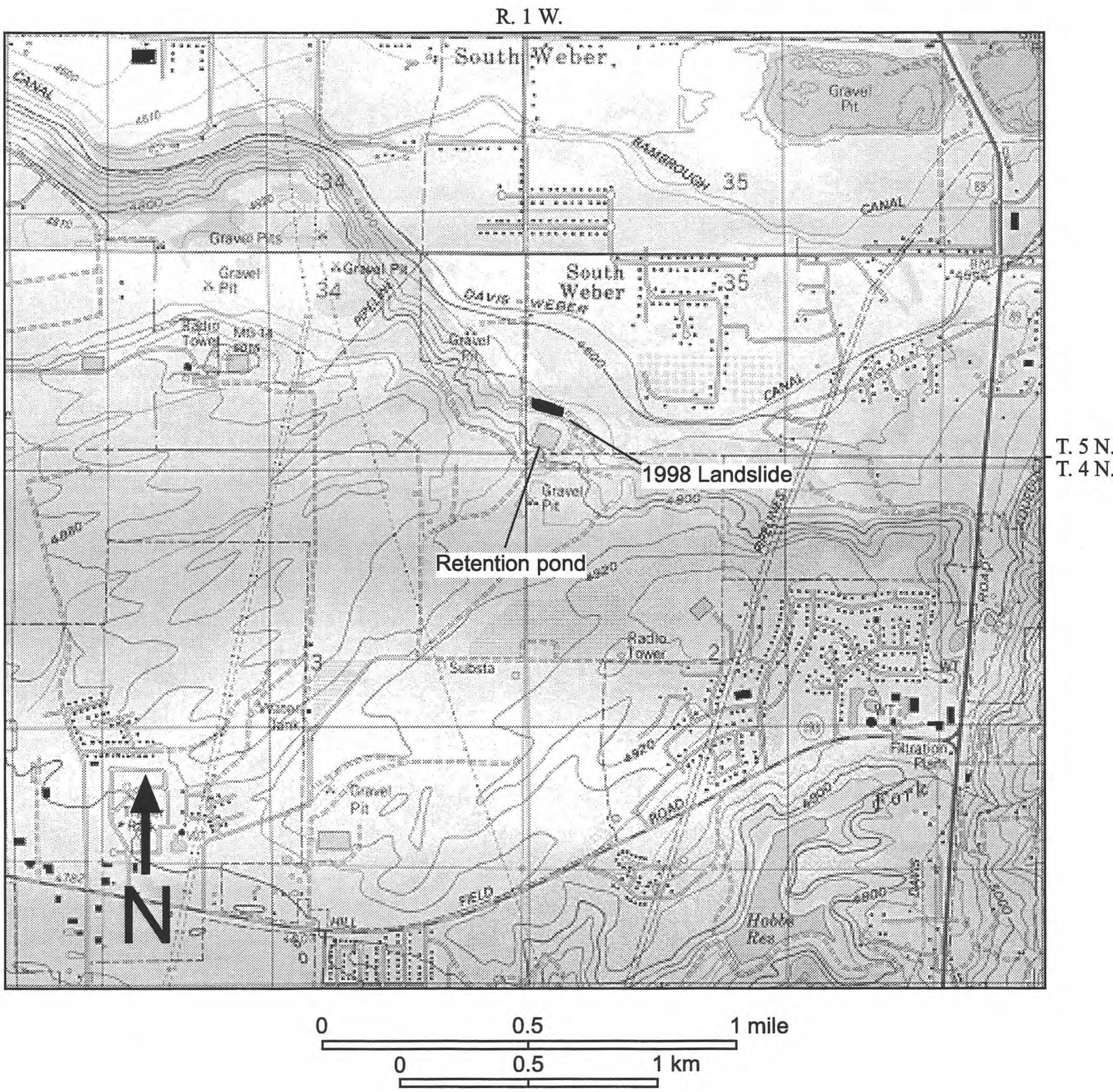
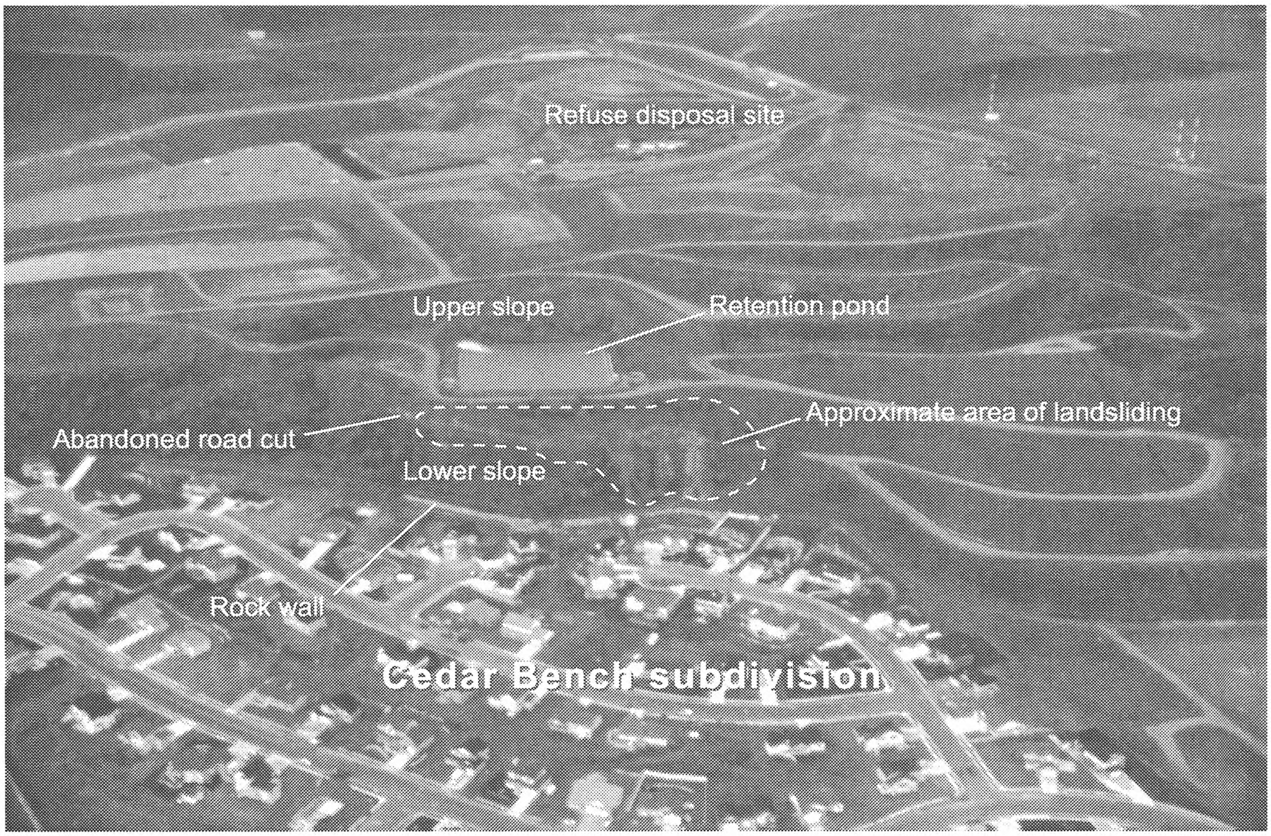
Attachment 1.
Job No. 98-14

Base map from OGDEN and KAYSVILLE,
U.S.G.S. 7-1/2' topographic quadrangles.



Attachment 1. Location map.



Attachment 2. Oblique aerial view looking south at the 1998 landslide near the Cedar Bench subdivision. Shallow earth slides are present on the lower slope below the retention pond and above the abandoned road cut. Earth slides and flows are present below the road cut to the toe of the slope.

Attachment 3. South view of lower slope behind the Cedar Bench subdivision. Shallow earth slides are above and below the abandoned road cut.

Project:			Requesting Agency:
Investigation of a recent cut-slope failure and implications for geotechnical slope-stability recommendations at Green Hill Country Estates Phase VI, Ogden Valley, Weber County, Utah.			Weber County Planning Department
By: Bill D. Black	Date: 06-22-98	County: Weber	Job No: 98-18 (GH-5)
USGS Quadrangle: Browns Hole (1368)		Number of attachments: 0	

INTRODUCTION

At the request of Craig Barker, Weber County Planning Department, I conducted a reconnaissance of a recent cut-slope failure in an undeveloped portion of Green Hill Country Estates Phase VI east of Huntsville, Utah, in the NW1/4NE1/4 section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. Applied Geotechnical Engineering Consultants (AGEC) previously conducted a geotechnical and landslide study for the development (AGEC, 1996), which was reviewed by Francis Ashland (Utah Geological Survey) at the request of the Weber County Planning Department and found to be thorough and adequate (Ashland, 1996). The purpose of my reconnaissance was to evaluate whether the slope of the failed cut met AGEC's (1996) recommendations and, if so, whether future slope-stability problems may be anticipated in spite of their recommendations being followed. The scope of work included a literature review and a site visit on May 29, 1998. Rob Edgar (AGEC) and Curtis Christensen (Weber County Engineer) were present during the site visit to conduct a follow-up investigation for possible expansive soils. I inspected only one area undergoing cut-slope failure; other cuts in the development may also be failing.

DISCUSSION

The 1998 slope failure is in a west-facing 4:1 (horizontal:vertical) road-cut slope about 15 feet (4.6 m) high on the east side of Maple Canyon in the eastern part of the Green Hill Country Estates development. The surface of rupture appears to be shallow (about 3 feet [0.9 m] deep) and is between an upper high-plasticity clay layer and an underlying clayey gravel deposit. I observed water seeping from the toe of the failure during my reconnaissance, which suggests the slope is saturated. AGEC (1996) previously noted four similar landslides that occurred during spring 1995 in 3.5:1 cut slopes in the development. The 1998 failure is not in an area of pre-existing landslides (AGEC, 1996). AGEC (1996) speculated the 1995 failures were triggered by a reduction in strength when clay soils became wet during infiltration of spring runoff. No failures were found in areas where the upper soil consists of clayey gravel (AGEC, 1996).

To maintain stability of road cuts and other cut slopes at the site, AGEC (1996) recommended no cuts steeper than 4:1 in natural clay soils. Although AGEC (1996) observed no evidence of shallow ground water during their subsurface investigation, they indicate the risk from slope instability is higher if shallow water is present. The 1998 failure is in a 4:1 cut slope saturated by spring runoff, and the slope of the cut is slightly steeper than the natural slope. This suggests disturbance of the natural slope may cause even shallow cuts in the clay soils to fail when wet.

RECOMMENDATIONS

Cut slopes in the clay soils at the site conform to AGEC's (1996) recommendations but are still failing. Thus, I recommend that:

- AGEC review and revise their recommendations as needed for maintaining cut-slope stability,
- Weber County devise a means to ensure that AGEC's recommendations are followed and that no unplanned cuts are made (such as for landscaping),
- AGEC's (1996) recommendation to maintain good surface drainage upslope of the cut slopes and to direct water away from the cut faces be followed, and
- as a precaution, landowners minimize landscape irrigation. Although spring runoff is the principal cause of both the 1995 and 1998 failures, landscape irrigation may cause further slope instability.

REFERENCES

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Ashland, Francis, 1996, Review of a geotechnical and landslide-hazard report for the proposed Green Hill Country Estates Phase VI, Weber County, Utah, *in* Mayes, B.H., compiler, Technical reports for 1996 Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 109-111.

Project:			Requesting Agency:
Reconnaissance of a landslide on South Fork Kays Creek, Layton, Davis County, Utah			Layton City Community Development Department
By: Richard E. Giraud	Date: 6-30-98	County: Davis	Job No: 98-21 (GH-6)
USGS Quadrangle: Kaysville (1320)		Number of attachments: 4	

INTRODUCTION

At the request of Scott Carter, Layton City Community Development Director, I performed a reconnaissance of a landslide at 1543 North 1050 East in Layton. The landslide is on a steep north-facing slope above South Fork Kays Creek in the SW1/4NW1/4 section 15, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian (attachment 1). The purpose of this investigation is to determine the hazard potential of the landslide and provide recommendations for subsequent investigations. The scope of work included review of published geologic reports and maps, and aerial photographs (1985, scale 1:24,000). Field visits were performed on April 29, 1998, with Scott Carter and Gary Christenson (Utah Geological Survey); May 1, 1998; and May 22, 1998, with Scott Carter. The 1998 landslide movement was noticed and mentioned to Scott Carter by Nancy Kotlewski, a homeowner at 1523 North 1050 East.

The landslide main scarp traverses the north ends of three residential lots at the following addresses: 1523 North 1050 East, 1543 North 1050 East, and 1550 North 1077 East. Movement on the main scarp has displaced lawn turf, concrete curbing, a landscaped rock wall, and a chain-link fence.

PHYSICAL SETTING AND GEOLOGY

The three lots are near the edge of a bluff at an elevation of 4,550 feet. The landslide is on a steep north-facing slope between the bluff crest and South Fork Kays Creek (attachment 1). South Fork Kays Creek flows west through a valley 80 feet below the top of the bluff. The landslide head and main scarp cross the northern edge of the three lots. A chain-link fence marks the northern property boundary of the lots. Slope vegetation consists of a thicket of hawthorne, maple, and oak trees with grass and shrubs. Moss is present locally on the upper slope below the chain-link fence. The slope gradient between the creek and bluff top averages 50 percent. A previous landslide main scarp in the bluff crest, evident on 1985 aerial photographs, was regraded into a smooth slope profile. The regrading placed fill on the landslide head and the northern edge of the lots. The back yard of the lot at 1543 North 1050 East has two landscaped terraces that step down to the north. The 1998 landslide main scarp displaces the lower terrace.

At the site, South Fork Kays Creek has incised into lacustrine (lake) sediments that were deposited in ancient Lake Bonneville as part of the Weber River delta. Nelson and Personius (1993) map two different geologic units in the vicinity. Lacustrine clay, silt, and minor fine sand deposits, of latest Pleistocene age, are present in valley slopes and are confirmed by subdivision boreholes (Maughan, 1992). Stream alluvium, along South Fork Kays Creek, is of Holocene to latest Pleistocene age. The alluvium consists of silty sand, sand, and gravel. The main scarp face exposes a massive, light brown, well-sorted, medium- to fine-grained sand.

Anderson and others (1982) and Lowe (1988) map the north-facing slope as prehistoric landslide deposits. Lowe (1990) and Robison and Lowe (1993) point out that landslides are common where streams have incised into the Weber River delta creating steep slopes exposing clay, silt, and sand deposited in Lake Bonneville. The main scarp of a landslide evident on 1985 aerial photographs has a scarp shape, length, and position similar to the 1998 scarp. The 1985 aerial photographs predate subdivision development. Maughan (1992) implies the presence of a landslide on the steep north-facing slope that is presently stable and recognizes an erosional slough caused by Kays Creek undercutting the bank.

LANDSLIDE FEATURES

The main scarp is the most prominent landslide feature (attachments 2, 3, and 4). The scarp is oriented roughly east-west and is 350 feet long. The scarp results from downward displacement of the ground surface and soil mass to the north. The scarp displaces the landscaped areas of back yards near the slope crest. The scarp height is a maximum of 3 feet (attachment 2) at the northwest lot corner of 1550 North 1077 East. The scarp height is 1 to 2 feet (attachments 3 and 4) in the back yard of 1543 North 1050 East. The porch support posts of this house are approximately 15 feet south of the main scarp (attachment 4). Scarp displacement decreases to the west and the scarp ends near the northwest lot corner of 1523 North 1050 East. Several transverse ground cracks in the landslide head are present below the main scarp at 1543 North 1050 East. The ground cracks have horizontal separations of 1 to 2 inches. Also on the landslide head, immediately north of the chain-link fence, several shallow, small slumps displace native grass turf.

Scott Carter and I placed four rows of movement-monitoring stakes across the main scarp on May 22, 1998. The purpose of the monitoring stakes is to determine the rate and amount of movement. The movement stakes straddle the main scarp and the adjacent area to the south. Future monitoring will allow detection of additional movement and possible landslide propagation southward toward the houses.

Landslide movement is also evident as a right-lateral shear along the right flank. The left flank has no distinguishable shear zones. The landslide toe is apparently at the level of South Fork Kays Creek, resulting in a landslide height of 80 feet. The only evidence for movement in the landslide foot area was a slump, approximately 50 feet wide and 25 feet high, on the outside of a creek meander. Ground water was seeping from the main scarp of the slump, confirming the presence of free water in the main landslide mass. The slump in the foot area resulted from undercutting and removal of support by the creek. Another similar but older slump was observed a short distance downstream. Both slumps probably result from stream erosion which has removed support in the toe area of the main landslide. I observed no other scarps, ground cracks, or landslide deformation features on the landslide. In addition to the seeps in the landslide foot area, one of three boreholes drilled near the bluff crest in 1992 (Maughan, 1992) indicated the presence of shallow ground water 25 feet below the surface.

Based on the existence of a fresh, unweathered main scarp evident in the 1985 aerial photographs, landslide movement observed in 1997 (Nancy Kotlewski, homeowner, verbal communication, April 17, 1998), and the movement observed in spring 1998, the landslide has had repeated historical movement. The style of movement in spring 1998 produced a main scarp similar to the scarp visible in 1985 aerial photographs. These similar scarp styles may result from grading and landscaping of a preexisting main scarp and subsequent renewed landslide movement producing a similar scarp. The difference in height along the scarp indicates more movement in the eastern portion of the landslide. A topographic setting where a landslide toe is actively being eroded by a stream generally results in ongoing landslide movement because the stream continually removes the lateral support at the toe, decreasing landslide stability.

HAZARD POTENTIAL

I believe continued and/or future landslide movement is likely. The house at greatest risk is at 1543 North 1050 East, which is nearest the scarp. Additional movement may also cause the landslide to propagate farther to the south, potentially affecting the foundations of the three houses.

Once a landslide has moved, it is more susceptible to future movement because subsurface conditions such as increased permeability (allowing greater water infiltration) and an established landslide slip surface reduce stability. Sources of water infiltration include precipitation, runoff from roof downspouts, and landscape irrigation. The lateral migration of ground water from elsewhere in the subdivision may also add water to the landslide. Thus, even if landslide movement stops, the potential for reactivation is high because of the close spatial association of the main scarp, the landslide slip surface, and water infiltration sources, and erosion of the landslide toe by South Fork Kays Creek.

Landslide movement has been an ongoing natural response to the downcutting and lateral migration of South Fork Kays Creek into the steep slope north of the houses. The combined factors of weak geologic materials, steep slopes, stream erosion of the landslide toe, and historical landslide movement suggest that future landslide movement is likely.

RECOMMENDATIONS

I recommend performing a detailed geotechnical-engineering slope-stability investigation of the landslide, as outlined in Hylland (1996). The purpose of the investigation would be to determine the landslide boundaries, ground-water depths and sources, and soil-strength parameters to assess slope stability and possible hazard reduction. The investigation must determine the role of landscape irrigation, ground water, and stream erosion in the slope failure, and the likelihood of southward landslide propagation. I also recommend movement monitoring (in addition to the scarp monitoring stakes) to determine the rate, timing, and extent of landslide movement. Monitoring should be performed at the slope crest near the houses, on the valley slope, and along the creek to document any movement. I also recommend continued monitoring for new scarps, new ground cracks, and displacement and lengthening of the main scarp.

Interim measures should be taken to reduce the landslide risk until the slope-stability analysis is completed and possible hazard reduction is implemented. Interim measures include preventing infiltration of water in the scarp and landslide areas by draining runoff from downspouts and driveways to the street and the storm-water system, ensuring that buried water and sewer lines are not leaking, and avoiding landscape irrigation. These interim measures should be carried out at all lots in the vicinity of the landslide. Another possible interim measure is to prevent erosion of the landslide foot area.

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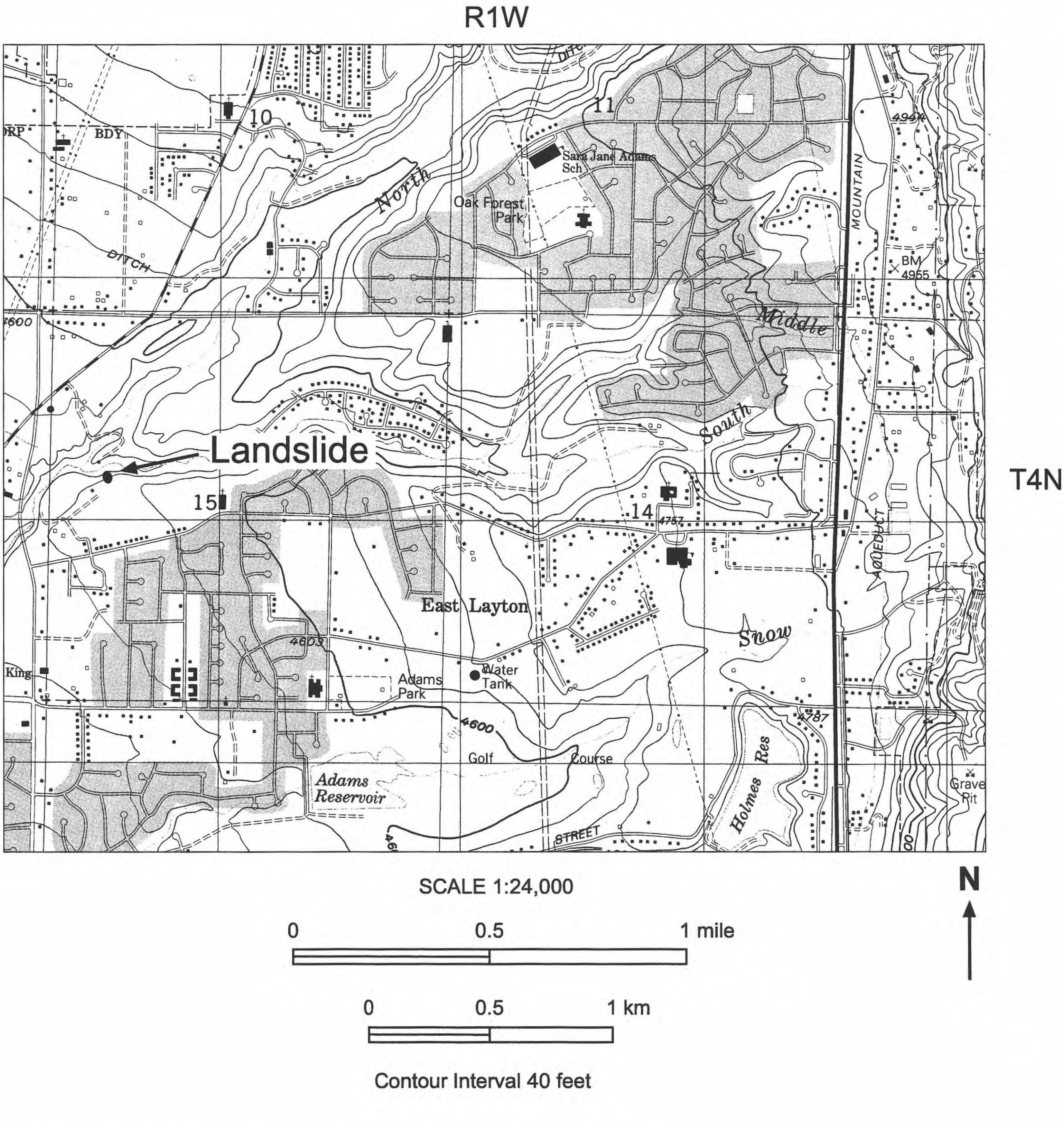
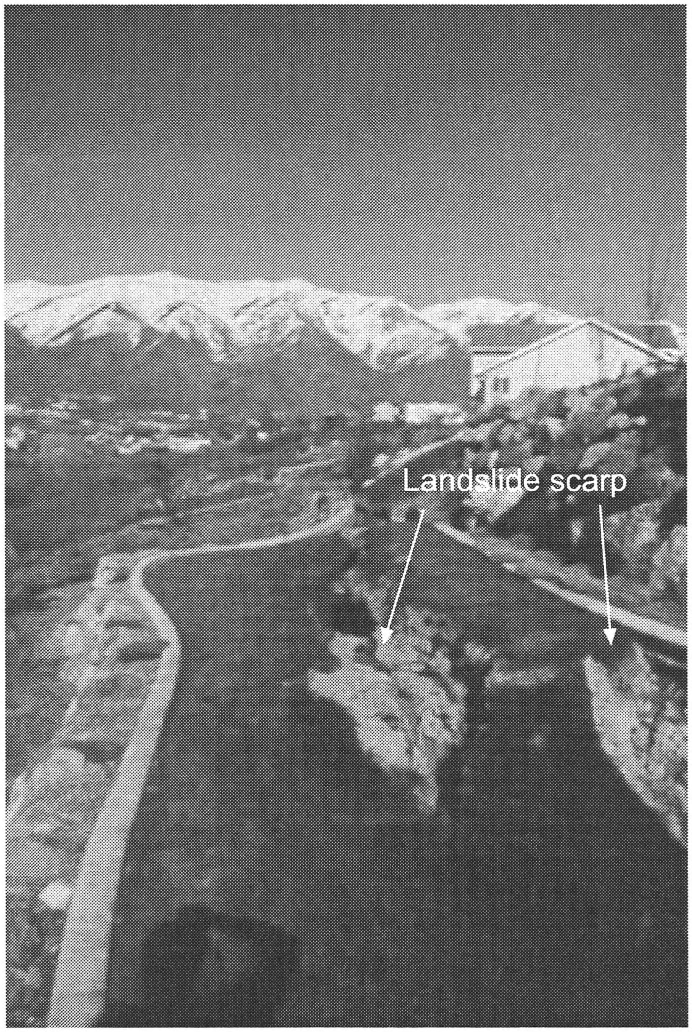
Robison, R.M., and Lowe, Mike, 1993, Landslide hazards - a guide for land-use planning, Davis County, Utah, *in* Gori, P.L., editor, Applications of research from the U.S. Geological Survey program, Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah: U.S. Geological Survey Professional Paper 1519, p. 129-137.

Attachment 1. Job No. 98-21 Base Map from KAYSVILLE U.S.G.S. 7-1/2' topographic quadrangle

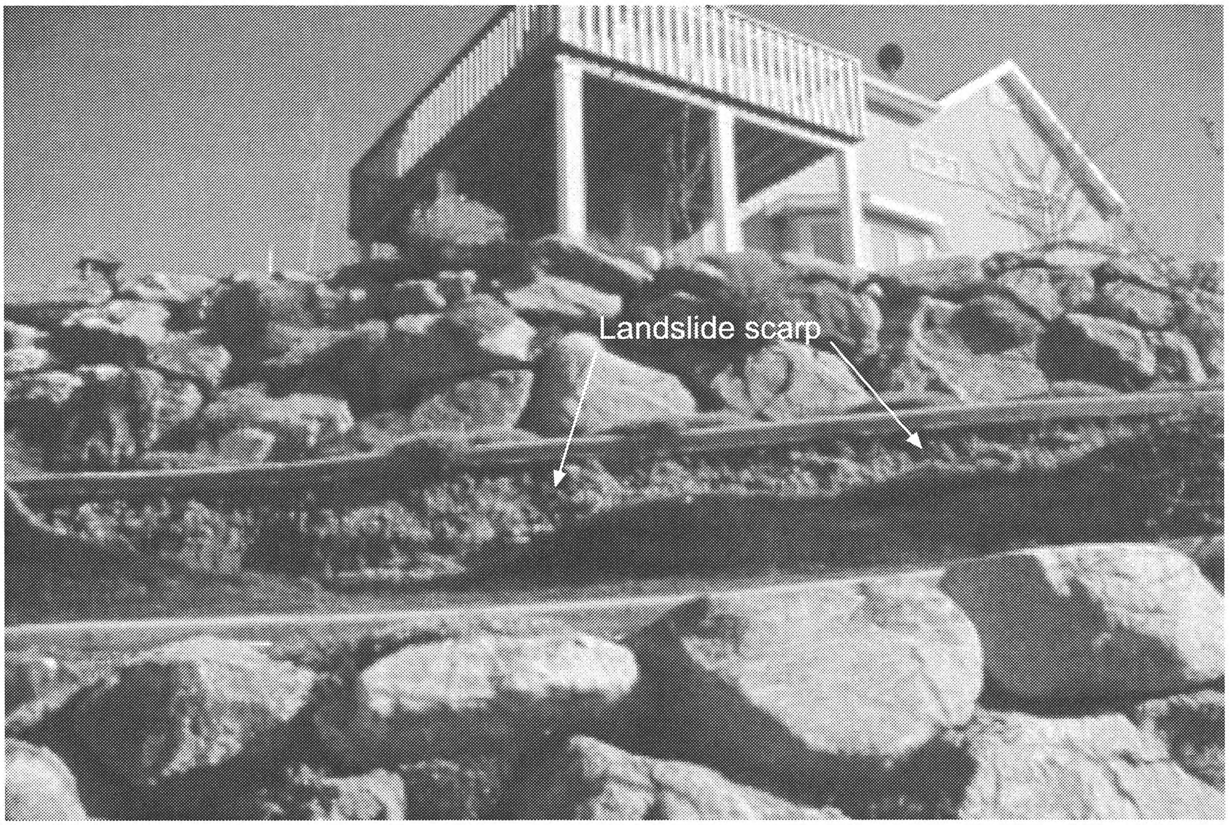


Attachment 1. Location of the South Fork Kays Creek landslide.

Attachment 2. South Fork Kays Creek landslide main scarp, showing damage to chain-link fence and lawn. Arrow points to scarp. The area left of the scarp has dropped down and moved to the left. View is to the east on April 29, 1998.



Attachment 3. South Fork Kays Creek landslide main scarp, showing damage to lawn. Arrows point to main scarp. The area left of the scarp has dropped down and moved to the left. View is to the east on April 29, 1998.



Attachment 4. South Fork Kays Creek landslide main scarp, showing damage to landscaping. Arrows point to main scarp. The area in front of the scarp (foreground) has dropped down relative to the area behind the scarp (background). View is to the east on April 29, 1998. The house at 1543 North 1050 East is in the background.

Project:			Requesting Agency:
Reconnaissance of building distress and ground movement in the Springhill Circle area, North Salt Lake, Davis County, Utah			City of North Salt Lake
By: Richard E. Giraud	Date: 8-31-98	County: Davis	Job No: 98-29 (GH-7)
USGS Quadrangle: Salt Lake City North (1254)		Number of attachments: 7	

INTRODUCTION

At the request of Mayor James Dixon, North Salt Lake, I performed a reconnaissance investigation of residential building distress and ground movement in the Springhill Circle, Springhill Drive, 350 East, and Barry Circle areas of North Salt Lake (SE1/4NW1/4 section 12, T. 1 N., R. 1 W., Salt Lake Base Line and Meridian; attachments 1 and 2). The purpose of this investigation is to observe the area for building distress and ground movement, determine the hazard potential, and provide recommendations for subsequent investigations. The scope of work included review of reports, maps, and aerial photographs (1937, scale 1:20,000; 1985, scale 1:24,000). I performed field visits on July 1, 6, 9, and 28, 1998. Francis Ashland (Utah Geological Survey) accompanied me on July 6. Gary Christenson (Utah Geological Survey) visited the area on July 21 and accompanied me on July 28.

The building distress was brought to my attention by Steve Mott, the property owner at 410 Springhill Circle. Mr. Mott and his neighbors were concerned about new cracks in foundation walls and concrete slabs. Several houses in the area have significant building distress. The house at 160 South Springhill Drive, which is substantially damaged, was condemned by North Salt Lake on July 9, 1998 (attachment 3). For the purposes of this report, the Springhill Circle, Springhill Drive (150 through 200 South), 350 East (133 through 201 South), and Barry Circle areas will be referred to as the Springhill area or Springhill subdivision (attachment 2).

PHYSICAL SETTING AND GEOLOGY

The Springhill subdivision was constructed in a former gravel-mining area. Residential subdivisions are present north and west of the Springhill area. Slopes of the former mining area and unaltered natural slopes are present east of the Springhill area. Currently the Concrete Products Company (CPC) operates a gravel pit bordering the subdivision on the south. Part of the CPC gravel pit is present east and upslope of the Springhill area.

The Springhill area lies near the base of the Wasatch Range. The land surface slopes westward from an elevation of 4,600 feet on the east at Springhill Circle to 4,500 feet on the west at 350 East. Slopes east of Springhill Circle define the upslope extent of the former gravel-mining area and have a gradient of 34 percent. The slope gradient along Springhill Circle is 12 percent. A steep slope is present in the back yards of lots on the west side of Springhill Drive and the east side of 350 East and Barry Circle. The slope has a gradient of 40 percent and is approximately 30 feet high. The steep slope is a remnant of the Warm Springs (Wasatch) fault scarp altered by gravel-mining operations (attachment 2). The original fault scarp was already partially removed by gravel mining as seen in the 1937 aerial photographs. The slope at 350 East has a 2 percent gradient to the west.

The ground surface is entirely covered with houses, landscaping, and streets. Landscaping consists of lawns, shrubs, and trees. Cottonwood trees and willows grow naturally outside irrigated areas. Several springs and seeps are present in the area.

Two Tertiary bedrock units are mapped by Van Horn (1981) in the area east of the Warm Springs fault. One unit, comprising tuffaceous siltstone, mudstone, sandstone, and limestone, is present in and south of the Springhill Circle area. The tuffaceous rocks strike northwest and dip 35 degrees northeast. Outcrops of tuffaceous siltstone and sandstone are present on the slope southeast of Springhill Circle and in the gravel pit to the south. Tuffaceous siltstone and sandstone were also encountered at 410 Springhill Circle in drillholes for three monitoring wells drilled to 20-foot depths by the property owner. The subsurface samples display different degrees of weathering and some samples are very soft where the ash is altered to clay.

The tuffaceous rocks are overlain by a volcanic breccia of andesite composition. A large breccia outcrop is present behind 171 South Springhill Drive and 411 Springhill Circle. The outcrop is not present on the 1937 aerial photographs and was apparently exposed by gravel mining. Breccia outcrops are present on the hillside northeast of Springhill Circle and in the front yard of 161 South Springhill Drive. The contact between the tuffaceous rocks and the volcanic breccia likely trends northwest through the subdivision. The outcrop and drillhole data suggest that at least the Springhill Circle area of the subdivision, and perhaps the entire area east of the Warms Springs fault (attachment 2), may be underlain by shallow bedrock.

The mapped surficial-geologic deposits are mostly gravels. Nelson and Personius (1993) map two different surficial-geologic units in the Springhill area. Undivided lacustrine (lake) sand and gravel of latest Pleistocene age, deposited during the Bonneville lake cycle, is present east of the Warm Springs fault. Undivided fan alluvium of Holocene to latest Pleistocene age, that postdates the recession of Lake Bonneville, is present west of the fault. The original unconsolidated surficial deposits have been removed by mining. A small conglomerate outcrop of calcium-carbonate-cemented beach gravel deposited during the Bonneville lake cycle is present in the back yard of 367 Barry Circle. Shallow bedrock is likely not present west of the fault scarp on the down-dropped side.

Because the area is a site of previous gravel mining and was regraded prior to development, varying thicknesses of fill may be present. Drillholes at 410 Springhill Circle indicate all original unconsolidated material was removed down to bedrock, and this is likely the case throughout the eastern part of the subdivision. Elsewhere, significant thicknesses of fill may be present and unconsolidated surficial deposits described above may be locally present.

BUILDING-DISTRESS AND GROUND-MOVEMENT FEATURES

I performed a reconnaissance of the Springhill subdivision on July 6, 1998, to observe building distress and evidence of ground movement. Property owners were interviewed to obtain information on the location and history of building distress. The reconnaissance involved inspecting house exteriors for building distress and inspecting lots for evidence of ground movement. The following lots were inspected: all lots on Springhill Circle, 150 South through 200 South Springhill Drive, 141 South through 202 South on 350 East, and all lots on Barry Circle (attachment 2). Lot owners at 149 South 350 East, 157 South 350 East, and 160 South Springhill Drive stated some building distress occurred in spring 1997 but stopped during August 1997. Most lot owners stated that the 1998 building cracks began or continued to develop in May or June. My reconnaissance observations are included in attachment 4.

Buildings with significant distress are present at: 402 and 410 Springhill Circle; 150 and 160 South Springhill Drive; and 141, 149, and 157 South 350 East. The most common types of building distress are fresh vertical and diagonal cracks in concrete foundation walls (attachment 5). Other signs of building distress include deformed interior and exterior walls and cracked and displaced concrete slabs.

Strike-slip, contractional, and extensional ground-movement features are present in the Springhill area (attachment 2). A northwest-trending strike-slip shear crosses Springhill Drive between 160 and 171 South. En echelon tension cracks in asphalt indicate a right-lateral sense of shearing. The right-lateral shear is also indicated by sidewalk deformation at 160 South Springhill Drive. The asphalt has subsided over the shear area to form a slight dip in the street.

I observed camera logging by the South Davis Sewer District of the underground sanitary sewer pipe under Springhill Drive. The sewer line consists of 4-foot sections of 8-inch diameter concrete pipe buried approximately 8 feet deep. The camera log showed that the pipe was extensively cracked and slightly offset in the shear area between 160 and 171 South Springhill Drive.

Another strike-slip feature is present on the west side of 402 Springhill Circle. Two sidewalk sections have a left-lateral displacement of approximately 4 inches. Left-lateral displacement is also apparent in a chain-link fence next to the sidewalk.

A contractional ground-movement feature or thrust is present within the turf along a landscaped terrace in the back yard of 367 Barry Circle. The thrust is approximately 70 feet long and 10 inches high. Railroad ties and other landscape edging materials bounding the terrace have been tilted downslope.

Another contractional ground-movement feature was present in the sidewalk south of 191 Springhill Drive where two sections of sidewalk have been pushed together, buckling the sidewalk upward (attachment 6). The sidewalk has subsequently been replaced.

Extensional ground-movement features are present as pull-apart gaps between concrete curbs and lawn turf and between soil and house foundations. Pull-apart gaps are present between lawn turf and concrete curbing in parking strips at 410 Springhill Circle, 191 South Springhill Drive, 141 South 350 East, and 149 South 350 East. The separation between the curb and the lawn turf generally ranges from 1/4 to 3/4 inch. Pull-apart gaps between soil and the west foundation walls are present at 150 and 160 South Springhill Drive. Pull-apart gaps between street asphalt and concrete gutters are present at 160 and 171 South Springhill Drive and are apparently related to the right-lateral shear movement discussed above. Extensional cracks are also present in many concrete slabs but it is difficult to differentiate whether the movement is related to normal slab settlement or ground movement. Extensional cracks are present at 402 and 410 Springhill Circle, 160 South Springhill Drive, and 141 South 350 East, and have up to 1/4-inch horizontal separation and minor vertical displacement and appear to be related to ground movement.

Ground movement has also caused damage to retaining walls in the Springhill subdivision (attachment 7). Retaining walls constructed of cinder block, concrete, and railroad ties indicate downslope ground movement at 402 Springhill Circle, 200 South Springhill Drive, and 367 Barry Circle.

GROUND-WATER CONDITIONS

Shallow ground water is present throughout the Springhill area, as are several springs and seeps (attachment 2). A spring with a trickle flow is present at the curb in the parking strip at 418 Springhill Circle, and a seep with standing water is present in the back yard at the base of a steep slope. Spring water-collection systems are present in the back yards of 141 South 350 East and 359 Barry Circle. The springs discharge near the top of the steep slope believed to be the altered remnant fault scarp. Spring discharge at the slope crest suggests that relatively less permeable material, perhaps bedrock, is present at a shallow depth. Homeowners at 160 and 191 South Springhill Drive mentioned previous ground-water seepage into basements. A vertical standpipe at the east foundation wall at 160 South Springhill Drive has a depth to ground water of approximately 5 feet below ground surface. A sump pump in the standpipe periodically discharges water. A clean-out box for a ground-water drain is present in the west parking strip of 402 Springhill Circle. Apparently a ground-water drain system underlies the lot. Ground water was flowing from the drain. The presence of naturally established willow and cottonwood trees in the Springhill area also suggests shallow ground water in the area.

A small wetland is present south of 402 Springhill Circle. Water flows into the wetland from a spring in a drainage southeast of the Springhill area. Most of the water drains into a culvert and into the CPC gravel pit. However, some water flows westward along a cinder block wall at the south boundary of 402 Springhill Drive. The small flow of water percolates into the ground near the south end of Springhill Drive. Cottonwood and salt cedar trees are present along the south subdivision boundary and suggest shallow ground water in this area.

The monitoring wells installed by the property owner at 410 Springhill Circle also show shallow depths to ground water. Measured depths to ground water below ground surface ranged from 0.9 to 9.8 feet in the three wells. Seepage of ground water was also observed at the base of a retaining wall on the west side of the lot.

CAUSES OF BUILDING DISTRESS

The most likely causes of building distress are slope movement (landsliding), expansive soils, or both. Slope movement could be occurring in several separate landslides or a single complex landslide having different rates and types of movement in different areas. Because my geologic inspections and examination of the drillhole samples at 410 Springhill Circle suggest that the Springhill Circle area is underlain by weathered tuffaceous bedrock with little overlying unconsolidated material, the slip surface of a landslide in this area would be within this bedrock. Elsewhere, where fill material from the previous gravel-mining operations or in-place unconsolidated deposits may be present, slip surfaces may be within these materials, at their basal contact, or in underlying bedrock. My preliminary interpretation is that building-distress and ground-movement features are caused at least in part by slope movement. If slope movement is occurring, it is in the initial phase because few landslide-related geomorphic features have developed.

The weathered tuffaceous sedimentary rock may be expansive. Organic, clayey soils exposed in the back yard at 141 South 350 East at the base of the steep slope may also be expansive. Expansive rock and soil are typically weak and prone to landsliding. The shrinking and swelling of expansive materials may be playing a role locally by directly causing building distress.

Both landslides and expansive soils are sensitive to ground-water levels. The occurrence of movement during springtime, when ground-water levels are typically high, in the last two wetter-than-average years suggests that ground water is an important factor relating to the onset and continuation of building distress. Unfortunately, few records exist to document the locations of drains, changes in spring locations, and the history of water-table fluctuations in the area. Similarly, ground-water flow paths, perched water, possible artesian aquifers, and general ground-water conditions are also not well understood. Such information will be needed to adequately assess the role of ground water in the mechanism(s) causing building distress.

Many homeowners expressed their belief that activities related to gravel mining and subdivision development east and south of the Springhill area may be the cause of the building distress, either from ground vibrations from blasting and operation of heavy equipment, or from alterations to the ground-water system. Assessment of the likely contribution from these sources must await determination of the mechanism causing building distress. However, even when the mechanism is known, it will be difficult to evaluate the relationship between gravel mining and subdivision development on ground-water levels without historical data before, during, and following active building distress. Also, I am not aware of any instrumental measurements of ground vibrations in the subdivision, which would be needed to assess their possible effects.

HAZARD POTENTIAL

I believe continued and/or future building distress and ground movement in the area is likely. Additional ground movement may better define boundaries of a landslide or discrete areas of slope movement. Once ground movement has occurred, future movement is more likely because subsurface conditions such as increased permeability, established slip surfaces, and weakened soil or rock are present and reduce stability. Ground movement may stop, but the potential for reactivation is high each spring, particularly in wet years, because of the shallow ground-water conditions. In addition to ground-water inflow from the east, surface sources of water infiltration include discharge from springs and seeps, precipitation, runoff from roof downspouts, and landscape irrigation. The infiltration of surface water into the ground will likely raise the shallow water table and increase the likelihood of both ground movement and ground-water seepage into basements.

RECOMMENDATIONS

I recommend performing a detailed engineering-geologic and geotechnical-engineering investigation to determine the cause(s) of building distress and ground movement. The investigation should define the subsurface geology; delineate ground-movement areas; define slip surfaces; determine and monitor ground-water depths, sources, and aquifer characteristics; determine material-strength and expansive parameters to assess the cause(s) of building distresses; and recommend hazard-reduction measures. This investigation should involve drilling and sampling and installation of piezometers and slope inclinometers to gather data for a detailed geotechnical-engineering slope stability analysis (Hylland, 1996). The investigation must determine the role of ground water and subsurface geology in relation to building distress and ground movement. I also recommend installing building crack monitors throughout the subdivision to document continued and/or future movement, as well as the timing, rate, and extent of movement, particularly in areas without slope inclinometers. Accurate land surveying to monitor surface locations for ground movement would also provide useful information, as would continued visual monitoring for new building distress and new ground-movement features.

Interim measures should be taken to reduce building distress and continued ground movement until the investigation is completed and hazard-reduction measures are implemented. Interim measures include preventing infiltration of water by draining runoff from downspouts and driveways to the street and into the storm-water system, ensuring that buried water and sewer lines are not leaking, and reducing landscape irrigation as much as possible. These interim measures should be carried out at all lots along Springhill Circle, both sides of Springhill Drive (from 150 through 200 South), the east side of 350 East (133 through 201 South), and Barry Circle.

Existing drains should also be inspected to verify operation. The placement of new drains can be considered while the investigation is being conducted, although the effectiveness of any new drains cannot be fully assessed until more is known about the subsurface geology and water-yielding characteristics.

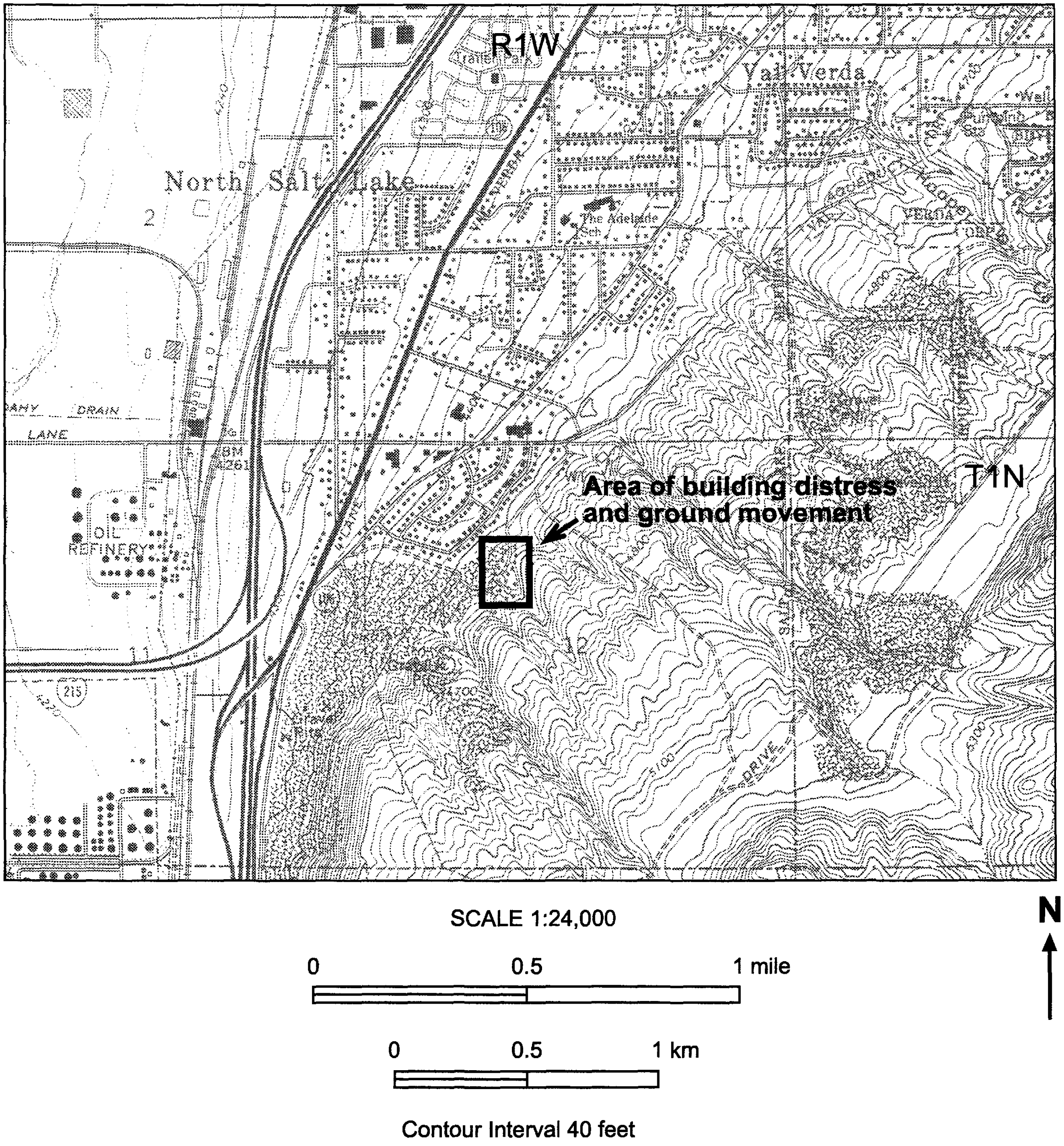
REFERENCES

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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 Miscellaneous Investigations Series Map I-2199, 22 p. pamphlet, scale 1:50,000.

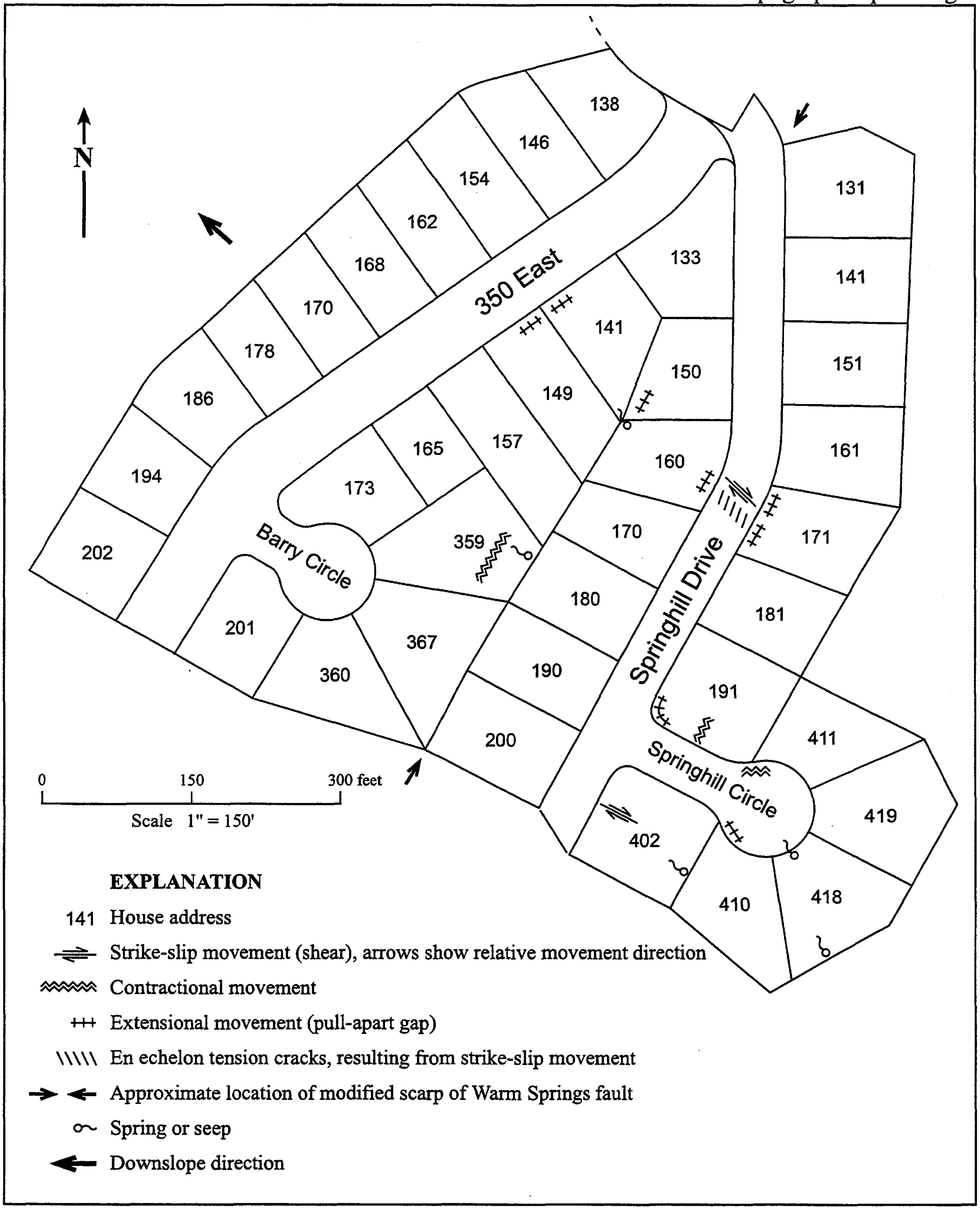
Van Horn, Richard, 1981, Geologic map of pre-Quaternary rocks of the Salt Lake City North quadrangle, Davis and Salt Lake Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1330, scale 1:24,000.

Attachment 1. Job No. 98-29 Base map from North Salt Lake City
U.S.G.S. 7-1/2' topographic quadrangle

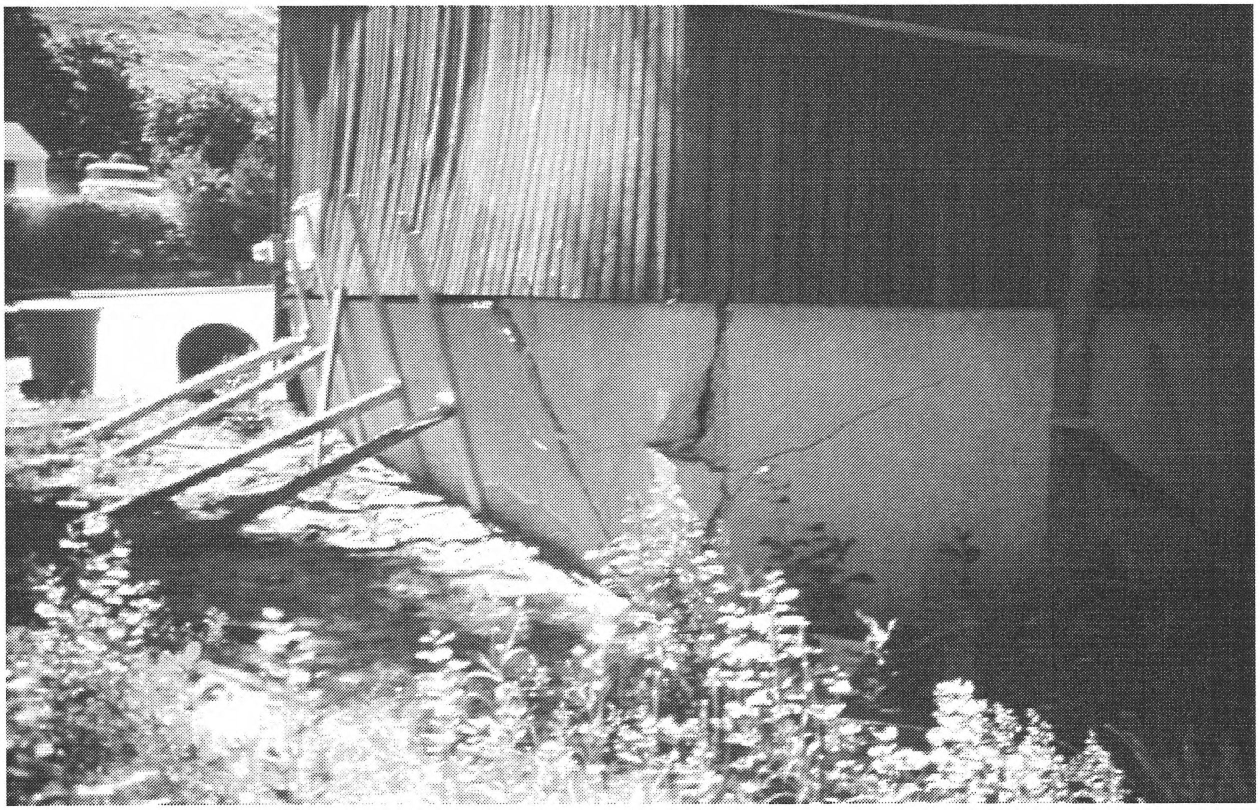


Attachment 1. Location of the Springhill building-distress and ground-movement area.

Attachment 2. Job No. 98-29 Base map from North Salt Lake City U.S.G.S. 7.5' topographic quadrangle



Attachment 2. Location map of the Springhill area showing streets, lots, slope movement features, and springs.



Attachment 3. Building distress in the north foundation wall of the house at 160 South Springhill Drive. View is to the southeast on July 6, 1998.

Attachment 4. Reconnaissance observations and reports of damage to Springhill area properties.

350 East - East Side

133 - Front steps: separation and pop-up
Large retaining wall - wood portions are tilted
Damage to cement veneer on foundation wall: south wall

141 - No problems noted in 1997
Approximately 2-yr-old garage: undamaged
Cracks in approximately 1-1/2-yr-old concrete driveway
Cracked garage slab: occurred recently - owner heard it pop
Separation between curb and lawn

149 - Interior cracking began in 1997 - owners marked crack tips on 7-9-97
Severe interior problems with cracking of sheet rock, doors ajar or jammed, tilting

157 - East-side-down offset of wallpaper in northeast corner room
Bow in downstairs east wall of family room
Severe foundation wall cracking in northwest corner room

165 - Leaking interior pipes
Chimney separated from house/foundation wall
Fence between backyard and lot 157 kinked

173 - Minor foundation wall cracking
Cracking near front steps
Garage door not at right angle

201 - Crack on upslope foundation wall projects to crack at lot 360 Barry Circle

Barry Circle

359 - Tilted front steps
Separation at garage door
Separation and cracking along west-side windows
Thrust at base of steep slope displaces grass turf
Spring discharge into black flex pipe near the crest of steep slope

367 - Damaged deck
Bulge in north end of wooden retaining wall
Northwest corner foundation wall: stepped crack
Northeast corner foundation wall: severe cracking
South foundation wall: cracking

360 - Tilted front retaining wall along driveway
West foundation wall has a crack that crosses driveway and projects to a cracked foundation wall at 201 S 350 E
Displaced retaining wall near southwest corner of house
East side retaining wall tilted
Stepping cracks in brick mortar on west wall

350 East - West Side

202 - Sagging/settlement of garage?

194, 186, 178 - No obvious damage to street side of houses

170 - Report of severed water line

162 - Large crack near front steps - reported not to be from 1998

154, 146 - No obvious damage to street side of houses but report of severed water lines

Springhill Drive - West Side

150 - Severe foundation damage to southwest corner

160 - Severe damage to entire north side of house, foundation wall breaking into pieces

170, 180 - No obvious damage to houses

190 - Foundation crack on northwest corner reported to be greater than 12 years old
Recent separation and damage to foundation wall near front steps

200 - Seepage of water into basement
Bulging cracked concrete retaining wall in back yard
Crack in north foundation wall that steps up into brick mortar

Springhill Drive - East Side

191 - Horizontal foundation crack in northeast corner - water seepage into house
Contractional movement has ramped the south sidewalk upward
Contractional movement has pushed asphalt over south concrete street gutter

181 - Stepped crack above garage door - reportedly old
New crack in painted garage floor on south end
New porch separated from house - apparent upslope movement

171 - Cracked concrete curb
Separation between curb-lawn-sidewalk
. Right-lateral shear with en echelon tension cracks crosses road to northwest and lot 160

Springhill Circle

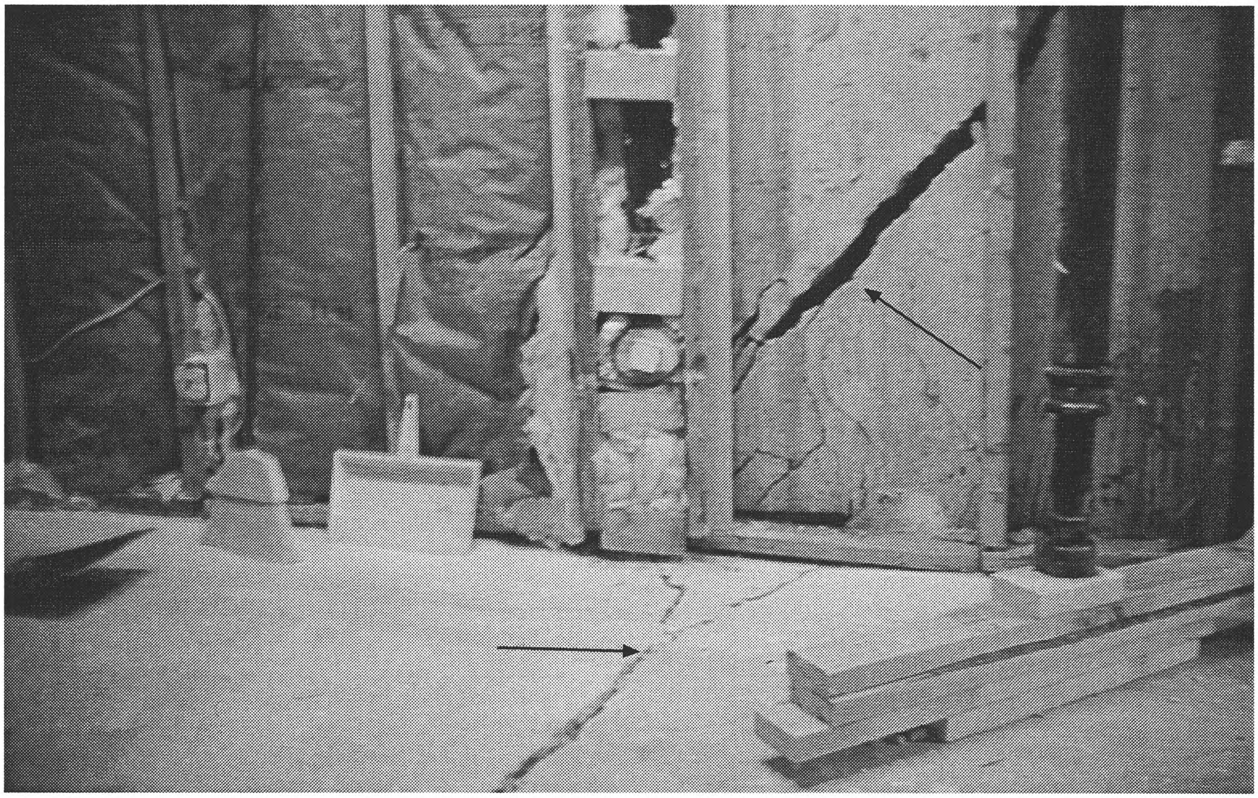
411- No obvious damage to street side of house

419 - Cracks in south foundation wall
Separation in rear steps and back patio

418 - Front porch posts tilted
Cracks in south foundation wall
Separation in front steps

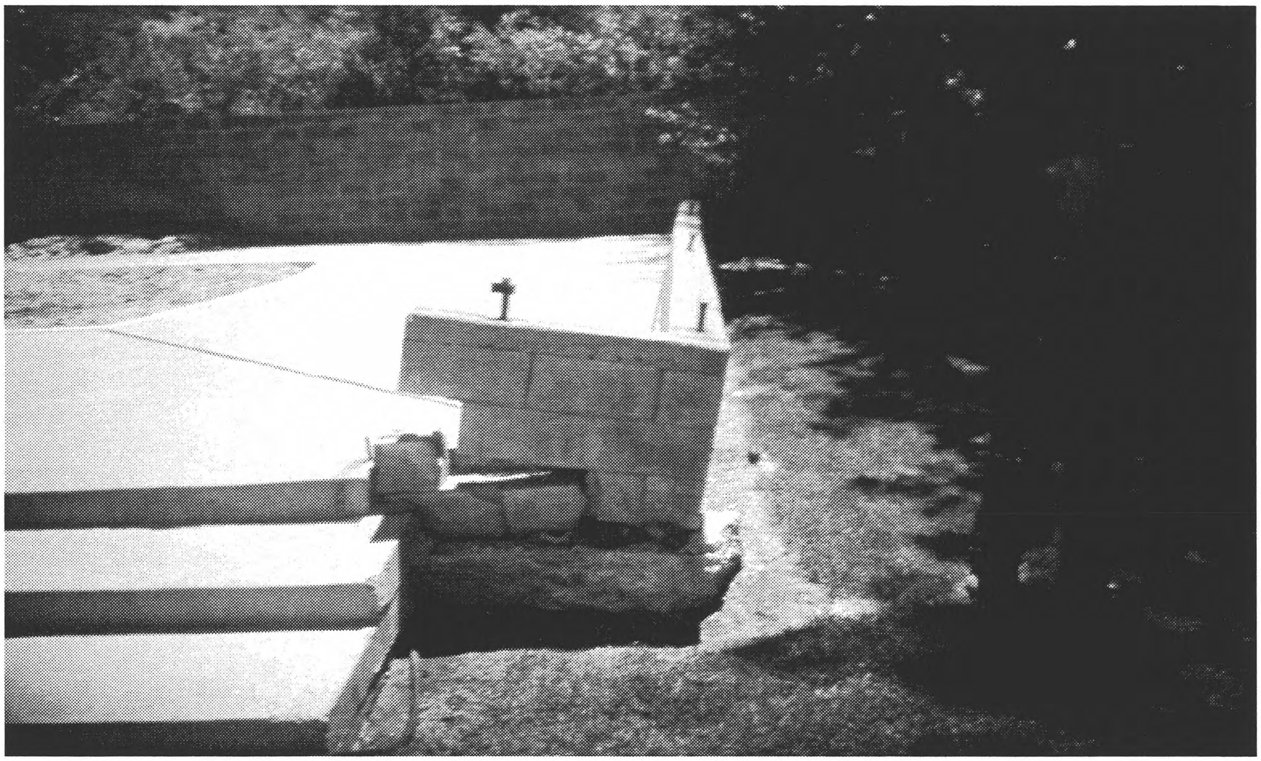
410 - Severe cracking of south foundation wall near southeast corner
Cracking of mortar in rock landscape wall and east garage foundation wall that may connect to cracks at 418 in south foundation wall
Large crack in garage floor

402 - Severe cracking of concrete slabs
South cinder-block wall has down-stepping crack along mortar
Cinder-block retaining wall rotated to the west
Large crack in garage floor



Attachment 5. Building distress in the south interior concrete foundation wall and floor at 410 Springhill Circle. Arrows point to cracks in the foundation wall and floor. View is to the south on July 1, 1998.

Attachment 6. Uplift of sidewalk caused by apparent contractional ground movement at 191 South Springhill Drive. View is to the south on July 1, 1998.



Attachment 7. Deformed cinder block retaining wall in the back yard of 402 Springhill Circle. View is to the south on July 6, 1998.

Project: Investigation of debris floods from Canal and Oak Creeks near Spring City, Sanpete County, Utah			Requesting Agency: Utah Division of Comprehensive Emergency Management
By: Barry J. Solomon	Date: 9-21-98	County: Sanpete	Job No: 98-34 (GH-8)
USGS Quadrangle: Spring City (799)		Number of attachments: 12	

INTRODUCTION

At the request of Fred May, Utah Division of Comprehensive Emergency Management (CEM), I visited the Spring City area of east-central Sanpete County to investigate a series of debris floods generated by intense summer rainstorms in the watersheds of Canal and Oak Creeks (attachment 1). The debris blocked creeks, culverts, and irrigation-diversion structures, resulting in flood damage as muddy water overflowed channels and flowed overland. Damage was predominantly agricultural, but the yards of eight houses and the grounds of one school were inundated by mud, four bridges and several roads were washed out, and one car was destroyed (attachment 2). Minor damage was sustained by the public water and power systems.

The purpose of my investigation was to provide information on geologic factors related to the flooding and help determine if future landslide damming and breakout flooding posed additional hazards to downstream residents. I first visited the area on Thursday, July 23. This visit included a ground inspection of flood damage, followed by an overflight of Spring City and the Canal Creek watershed in a fixed-wing aircraft. I returned to Spring City on Tuesday, July 28, after renewed flooding. My second visit included additional ground inspection on July 28 and 29, including examination of the lower reaches of the Canal and Oak Creek watersheds, and a helicopter overflight of Spring City and the watersheds on July 29.

Local residents first reported flooding in Spring City at about 5:00 p.m. on Wednesday, July 22, resulting from rain that was much more intense in the Canal Canyon watershed than in the city itself. Floodwaters overflowed the banks of Canal Creek, the perennial stream from the canyon, and several irrigation ditches and ephemeral distributary channels flowing from the creek (attachment 3). Flooding ended at about 9:00 p.m., but local officials requested assistance from state and federal officials to determine the potential for additional flooding. An interdisciplinary group, the Interagency Technical Team (IAT), responded and arrived on site on Thurday morning, July 23. Ground and aerial reconnaissance of the area revealed that stream flow had returned to channels, although considerable channel scour and redeposition of scoured material and debris in downstream channels and flood plains had occurred. No stream blockages were found, and no significant areas of potential landslides were observed to indicate that future ponding and resultant breakout floods posed a threat.

After the IAT departed, heavy rains fell again in the same general area on the afternoon of Friday, July 24. Local officials again requested IAT assistance but, before the IAT arrived in Spring City, the flood threat abated and the IAT returned home. However, intense storms recurred on Monday, July 27, resulting not only in renewed flooding from Canal Creek and associated drainages, but also flooding from Oak Creek, 1 to 3 miles (2-5 km) to the north. After the latest storm, local officials inspected the canyons from which Canal and Oak Creeks flow and reported an active landslide in Canal Canyon. The officials were concerned about the potential for stream blockage, ponding, and breakout flooding, and again requested the assistance of the IAT. I returned as part of the IAT on Tuesday, July 28, inspected the landslide, and also conducted a ground and aerial reconnaissance of the area. Recommendations in this report were presented to Spring City officials during the investigations and at a meeting on July 29, 1998.

SETTING AND GEOLOGY

Spring City lies on the eastern edge of Sanpete Valley, near the base of the Wasatch Plateau. The plateau is a zone of structural transition between the Colorado Plateau and Basin-and-Range physiographic provinces (Stokes, 1986). Canal Creek, crossing the southwest corner of Spring City, and Oak Creek, crossing the northeast corner, drain the western slope of the Wasatch Plateau. This slope is formed by the Wasatch monocline. The monocline consists of folded layers of sedimentary rock, with gently west-dipping rocks (dips of less than 5 degrees) within the drainage basins of the creeks abruptly descending (dips between 25 and 33 degrees) beneath the valley along the western edge of the plateau (Pashley, 1956). As the creeks exit the steep range front, they flow upon gently sloping alluvial fans in Spring City and the vicinity. The alluvial fans along the Wasatch Plateau skew the axis of the valley westward, forcing the San Pitch River to flow near the west valley margin. Canal Creek joins Oak Creek two miles west of Spring City, and Oak Creek flows westward into the San Pitch River.

The oldest rocks in the area, exposed only near the head of Oak Creek, are sandstone and conglomerate of the Upper Cretaceous Castlegate Sandstone and Price River Formation (Witkind and others, 1987). Overlying these rocks are mudstone, sandstone, and conglomerate of the Upper Cretaceous to Paleocene North Horn Formation. The North Horn Formation underlies most of both the Canal and Oak Creek drainage basins along the gently dipping limb of the Wasatch monocline, and is less commonly found along the steeply dipping range front. The steep spurs between the canyons along the range front are typically capped by the resistant Paleocene to Eocene Flagstaff Limestone, which overlies the North Horn Formation.

Rocks of the North Horn Formation are particularly prone to slope failure where factors such as slope angle, precipitation, aspect, and geologic structure are favorable (Godfrey, 1978; Harty, 1991). Shroder (1971) indicates that 75 percent of the landslides he studied on the Wasatch Plateau were associated with the North Horn Formation, and Godfrey (1985) states that 86 percent of the total acreage involved in slope movements in 1983, during a period of rapid snowmelt and above-average precipitation, occurred in areas underlain by these rocks. The costliest and most damaging of Utah's landslides involved failure of material from the North Horn Formation when the Thistle landslide (about 35 miles [56 km] north of Spring City) caused estimated losses of about $337 million in 1983 (Witkind and Page, 1983; Kaliser and Slosson, 1988). During the same period, numerous landslides occurred in the North Horn Formation on the west side of the Wasatch Plateau in Sanpete County, including one on the north side of Oak Creek that disrupted a downstream irrigation system (Kaliser, 1989). More recently, the Shurtz Lake landslide near Thistle moved in 1997, the result of partial reactivation of prehistoric landslides in the North Horn Formation (Ashland, 1997).

Debris from landslides in the North Horn Formation, and from debris slides on colluvium-covered canyon walls, has repeatedly been transported downstream and redeposited on the alluvial fan on which Spring City is built. Such landslides, and accompanying debris flows or floods, typically occur during periods of intense rainstorms or rapid snowmelt. From the settlement of Spring City in 1859 to the last date of published compilations in 1969, cloudburst floods affecting Spring City were reported in local newspapers in 1934, 1957, and 1965 (Woolley, 1946; Butler and Marsell, 1972). Local residents describe snowmelt floods in 1952 and 1983, and a flash flood in 1996 that destroyed a county bridge on Canal Creek.

CANAL CREEK DRAINAGE BASIN

Canal Creek is a perennial stream incised in a steep canyon (Canal Canyon) on the west flank of the Wasatch Plateau. The Canal Creek drainage basin encompasses 15.8 square miles (40.9 km^2) (Robinson, 1971). In the plateau, the stream flows within a flood plain incised into a gently sloping canyon floor bounded by steep canyon walls. The flood plain is generally less than 50 feet (15 m) wide, cut banks on the edge of the flood plain are up to 40 feet (12 m) high, the canyon floor is up to 800 feet (240 m) wide, and canyon walls rise as much as 1,300 feet (400 m) above the creek. The head of Canal Canyon is a large arcuate ridge at the crest of the plateau, locally referred to as Horseshoe Mountain (attachment 4). With the exception of the bedrock-floored troughs at the canyon head, bedrock outcrops are scarce (attachment 5). The Canal Canyon walls are mostly covered by colluvium, and the canyon floors are covered by colluvium and alluvium. The clast-supported alluvium in the flood plain contains subrounded boulders up to 4 feet (1 m) in diameter. Gravel, cobbles, and boulders are also common in stream and alluvial-fan deposits beyond the canyon mouth (attachment 6). Canal Creek tributaries have an average gradient of about 20 percent, but the gradient of the creek is only about 10 percent in the canyon, and decreases to less than 5 percent on the alluvial fan at Spring City. Once the creek exits the canyon, the creek branches off into a number of ephemeral channels and ditches, presumably for irrigation on the fan surface. The creek flows for about 3 miles (5 km) on the fan before it crosses the southwest corner of Spring City.

Debris Flooding

Flow from Canal Creek first flooded the Spring City area on July 22, and floods returned on July 27. The following description of the flooding is summarized, in part, from a memorandum by Fred May (written communication, 1998).

On July 22, residents reported viscous, muddy surges that filled the channel of Canal Creek to a depth of 4 feet (1 m) on the upper part of the alluvial fan. The mud carried with it a debris front of logs and boulders. The flood spread laterally across fields toward the city as the channel became clogged and overflowed. I observed large accumulations of debris that temporarily blocked the channel near the head of Canal Canyon at Temple Fork and near the canyon mouth, but the principal channel blockage occurred where logs and other debris clogged the channel beneath a bridge that crosses Canal Creek in the NE1/4 section 9, T. 16 S., R. 4 E., Salt Lake Base Line and Meridian (SLBM), about 3 miles (5 km) south of Spring City (attachments 1 and 7). Downstream from this blockage, a significant amount of sheet flooding occurred. As the flood flowed over and around the blockage, gravel and boulders from the channel and alluvial fan were eroded by turbulence. This process of channel blockage, overflow, erosion, and redeposition of boulders was repeated downstream as the debris flood encountered additional bridges, flood-control structures, and irrigation headgates, resulting in local accumulations of gravel and boulders along the flood flowpath.

As the debris flood flowed overland, it deposited debris to depths of up to 5 feet (2 m). Mud depths of 10 to 12 feet (3-4 m) were reported as the flood moved downslope, spreading to a width of up to 1,000 feet (300 m). The discharge of flood surges, calculated from high water marks and stream gradients, is estimated to be about 2,500 cubic feet per second (70 m^3/s) on Canal Creek on the south side of Spring City. Surges were apparently caused by temporary channel blockage and subsequent breakout flooding. Normal discharge from the creek is unknown, but is estimated at less than 100 cubic feet per second (3 m^3/s) during its peak springtime flow. Between July 22 and July 27, local emergency-response teams attempted to remove debris from within the channel, but flooding resumed on July 27 before removal was complete. Flooding on July 27 from Canal Creek was described in similar terms to that of the July 22 event.

Hazards

Renewed torrential rainfall or rapid spring snowmelt may cause additional debris flooding. The extent of the hazard will depend on the amount of rainfall or snowmelt, amount of debris and sediment, and the potential for breakout floods caused by blockage of stream flow in Canal Canyon. The amount of rainfall or snowmelt cannot be controlled, but the hazard posed by the other factors can be assessed.

A large supply of debris remains in the canyon in the form of timber and soil on canyon slopes, and boulders in colluvium and stream deposits. Such debris may enter the stream through landslides on colluvium-covered canyon walls. During my aerial reconnaissance of Canal Canyon, I observed several debris slides along Canal Creek and its tributaries. Most were apparently inactive during the recent flooding, but some were active (attachment 8). Older debris slides include five landslides mapped by Brabb and others (1989) in lower Canal Canyon that occurred during a period of rapid snowmelt in 1983, and several historical shallow landslides mapped by Harty (1991) at the head of Canal Creek and along Accord and Burnout Forks. The active debris slides did not block the channel at the time of my reconnaissance, but downstream from several debris slides along the slopes of Temple Fork in sections 29 and 30, T. 16 S., R. 5 E., SLBM (attachment 1) the channel was clogged by a large log jam, presumably resulting from accumulation of timber destroyed by the debris slides and washed down the channel by flood waters. Temporary ponding and breakout floods may have occurred at some of the active debris slides along Canal Creek, resulting in flood surges, but I do not believe that a significant amount of ponding could occur from additional sliding that would pose a breakout-flood threat to Spring City, 5 miles (8 km) away. The Temple Fork debris slides and log jam are near the head of the drainage where the upstream watershed is small, and the volume of each debris slide in Canal Canyon appears insufficient to create a large landslide dam. However, the material from the log jam and landslides will ultimately contribute to the amount of debris transported down the canyon in future floods.

Should a large landslide block the lower part of the canyon, where the contribution of precipitation from the upstream watershed is large and distance downstream to Spring City is less, then breakout flooding from local ponding may pose a greater hazard. During my reconnaissance, I observed only one active landslide in lower Canal Canyon that could potentially cause ponding and breakout flooding. I inspected the landslide, in the NE1/4 section 23, T. 16 S., R. 4 E., SLBM, in my ground reconnaissance of July 27 (attachment 1). The landslide was reported by local residents, who were aware of its existence prior to the first flooding event but noticed evidence of new movement when they visited the site between the first and second flooding events.

The landslide is likely a rotational slide, or slump. The slide is about 75 feet (23 m) long and 150 feet (46 m) wide on the northeast-facing slope on the southeast side of Canal Creek, and is thus about 1,300 square yards (1,100 m^2) in area. I estimate the slope gradient prior to failure to have been about 35 degrees. The main scarp is a maximum of about 20 feet (6 m) high, and I estimate that the slip surface is about 30 feet (9 m) deep on average, resulting in an estimated slide volume of about 13,000 cubic yards (9,900 m^3) (attachment 9). The main scarp is arcuate, with its apex about 50 feet (15 m) upslope of an unimproved dirt road that parallels the creek. The flanks of the main scarp cross the dirt road and intersect the cut bank, about 25 feet (8 m) high, along the flood plain. A secondary scarp, with a maximum scarp height of about 3 feet (1 m), is subparallel to the left flank and head of the landslide and runs along the dirt road for much of its length, but dies out in a series of en-echelon tension cracks near the right flank (attachment 10).

Grass, weeds, and small shrubs are growing on the main scarp, and an undisplaced colluvial wedge is present at its base, indicating a lack of significant recent movement, but the secondary scarp appears fresh and recent. A small earth flow is present at the base of the cut bank on the edge of the flood plain, apparently derived from the failure surface. The surface of the slide, consisting of a highly plastic clay, is saturated by springs. The clay is apparently derived from the underlying North Horn Formation, but the failure surface is likely along the colluvium-bedrock interface rather than along bedrock bedding planes. Outcrops of the North Horn Formation, visible in nearby slopes, dip less than 5 degrees to the northwest, oblique to the northeast-facing failure surface.

The canyon at this location consists of a channel and associated flood plain incised into a relatively broad, gently sloping canyon floor beneath steeper canyon walls. The flood plain is about 30 feet (9 m) wide, the cut slope on the edge of the flood plain is about 25 feet (8 m) high, the canyon floor is about 400 feet (120 m) wide, and the canyon walls have a maximum slope gradient of about 50 percent on the northeast side. The canyon width increases upslope. The cross-sectional area of the incised flood plain at this location is about 85 square yards (71 m^2). A 150-foot (46-m) length of the flood plain, equivalent to the width of the landslide, has a volume of about 4,200 cubic yards (3,200 m^3). Thus, if the entire slide were to fail and slide into the flood plain, one third of its volume could be accommodated within the flood plain itself, to the height of the cut banks. A 150-foot (46-m) length of the gently sloping canyon floor above the flood plain has sufficient volume, in a height of about 4 feet (1 m), to accommodate the remainder of the slide. However, the slide would probably not spread evenly over the floor but would accumulate to a greater depth in a relatively small area.

If the entire flood plain were blocked by slide debris, ponded water would accumulate to the depth of the flood plain beneath the rest of the canyon floor and, once this depth were reached, additional water would simply flow around the slide. With a maximum water depth of 25 feet (8 m) near the landslide dam, and a stream gradient of 10 percent, water would accumulate within 250 feet (76 m) upstream of the dam. The maximum volume of ponded water in the flood plain would be about 2.15 acre-feet (2,650 m^3). Using the Simplified Dambreak computer model (Fread and others, 1987), complete instantaneous failure of the dam would result in a discharge of about 1,020 cubic feet per second (29 m^3/s) at the mountain front and about 690 cubic feet per second (20 m^3/s) at Spring City. I do not believe that this volume of water would pose a significant threat to Spring City, almost 5 miles (8 km) downstream from the landslide, where the discharge of flood surges during the recent flooding is estimated to be about 2,500 cubic feet per second (70 m^3/s). A more likely scenario is that the slide would not entirely block stream flow to this depth, further reducing the hazard potential.

Areas in which trees have died, either by fire or disease, are particularly susceptible to landslides because of the destruction of a healthy root system which helps stabilize soil, a decrease in evapotranspiration leading to increased soil moisture, and resultant erosion and slope instability. During my aerial reconnaissance, I observed a burned area, encompassing several hundred acres, on the south side of Canal Creek in the SW1/4 section 24 and NW1/4 section 25, T. 16 S., R. 4 E., SLBM (attachments 1 and 11). According to local residents, this is an area of a controlled burn conducted in 1996 or 1997. There does not appear to be any significant contribution of debris from this area to the recent flooding, but future contributions cannot be discounted until the area is stabilized by complete revegetation.

OAK CREEK DRAINAGE BASIN

Oak Creek is a perennial stream incised in a steep canyon about 2 miles (3 km) north of Canal Canyon. The Oak Creek drainage basin encompasses 9.5 square miles (25 km^2) (Robinson, 1971), with a watershed less than two-thirds that of Canal Creek. Oak Creek lies between steep canyon walls, but its canyon lacks the broad, gently sloping floor of Canal Canyon. The head of Oak Creek lies between Knob Mountain to the north and Haystack Mountain to the south, and is fed by Meadow, South, and Sawmill Forks. As with Canal Canyon, bedrock along Oak Creek is commonly covered by colluvium on slopes except at the head of the canyon. Coarse-grained alluvium is common along the creek and in alluvial-fan deposits beyond the canyon mouth. The gradient of Oak Creek decreases from about 20 percent in tributaries at the head of the canyon to about 10 percent near the canyon mouth, and decreases further to less than 5 percent on the alluvial fan in the Spring City area. Unlike Canal Creek, ephemeral channels and ditches from Oak Creek beyond the canyon mouth are rare. Oak Creek flows for about 3 miles (5 km) on the fan before it crosses the northeast corner of Spring City.

Debris Flooding

Flow from Oak Creek flooded the Spring City area on July 27. Flooding was described by residents as similar to the Canal Creek flooding, although I did not observe large accumulations of debris beyond the canyon mouth in Oak Creek that may have blocked the channel as at Canal Creek. The discharge of flood surges, calculated from high water marks and stream gradients, is estimated to be about 2,400 to 4,000 cubic feet per second (68-110 m^3/s) (F. May, written communication, 1998). Information from a stream gage at the mouth of the Oak Creek canyon suggests that a 100-year flood should produce a flow of about 400 cubic feet per second (11 m^3/s), which may be approximately equivalent to the sustained flow during the recent flooding (F. May, written communication, 1998). Mean monthly discharge at the canyon mouth from 1964 to 1974 was greatest during June, when flow averaged about 45 cubic feet per second (1.3 m^3/s), and decreased to about 15 cubic feet per second (0.4 m^3/s) in July (Price, 1984).

Hazards

During my aerial reconnaissance of the Oak Creek canyon, I observed several landslides. Most are inactive debris slides, and include nine landslides mapped by Brabb and others (1989) that occurred during a period of rapid snowmelt in 1983, and several shallow and deep-seated landslides mapped by Harty (1991). The largest of these inactive landslides, about 4,000 feet (1,200 m) long and up to 1,000 feet (300 m) wide, is a 1983 debris flow on the west flank of Knob Mountain in sections 7 and 8, T. 16 S., R. 5 E., SLBM (attachments 1 and 12). I observed only one landslide that appeared to have moved during the recent floods, a small debris slide near the center of section 7, T. 16 S., R. 5 E., SLBM, that may have temporarily blocked the channel of Oak Creek, leaving a large accumulation of fallen timber behind. Future slope failure and channel blockage at this location may occur, and resultant breakout floods would contribute to flood surges farther downstream. Such blockages would be smaller than the potential slump blockage in Canal Canyon, so surges would pose little threat to Spring City, more than 4 miles (6 km) away.

Because of the presence of the slide-prone North Horn Formation and colluvium-covered canyon walls, the canyon is susceptible to landslides during intense rainstorms and periods of rapid snowmelt. However, I did not find any evidence that slope failure occurred to any significant extent during the recent flooding, and I do not believe that large slope failures are imminent along Oak Creek that would pose a threat to Spring City from channel blockage and subsequent breakout flooding.

SUMMARY AND RECOMMENDATIONS

The drainage basins of Canal and Oak Creeks exhibit a history of flooding and landslides that will continue. During periods of intense rainfall and rapid snowmelt, the potential for these hazards increases as debris from landslides combines with floodwaters to form fluid masses capable of traveling several miles down stream channels. As periods of intense rainfall decrease seasonally, the hazard potential will also decrease. However, hazards will recur each spring with snowmelt and additional rainfall.

The prinicipal hazard to Spring City arises from flood surges. As debris blocks natural or engineered channel constrictions, water ponds behind the dam that is formed. Either the dam breaks, sending a surge of debris-laden floodwaters downstream, or floodwaters flow around the dam outside of natural channels. A principal cause of natural stream damming in canyons is landsliding from steep canyon walls underlain by the North Horn Formation. Although I found evidence of landslide dams in the canyons of both Canal and Oak Creeks, I do not believe that these landslide dams, and resultant breakout flooding, directly caused significant flooding in Spring City. However, debris introduced into the creeks by the landslides, and accumulated debris from past landslides, flowed downstream, collected in engineered channel constrictions, and blocked stream flow. The most significant of these blockages occurred along Canal Creek, about 3 miles (5 km) south of Spring City, where debris collected beneath a small bridge. With the exception of significant debris flooding at the mouth of Canal Canyon where the stream gradient decreased and much debris was deposited, most flooding occurred downstream of the bridge. Flood surges and debris fronts reported by residents of Spring City were likely the result of repeated damming and breakout flooding from this and similar blockages on the alluvial fan.

The active landslide in Canal Canyon has a potential to advance into Canal Creek. However, the volume of landslide material is too small to form a significant landslide dam, and resultant breakout flooding poses little hazard to Spring City because of the relatively small volume of ponded water that might accumulate and because of the considerable distance between the landslide and the town. Landslide damming will depend upon the rapidity of slope failure and the volume of stream flow. Most similar historical landslides along both Canal and Oak Creeks do not appear to have displaced the creeks, indicating that creek channels commonly realign and accommodate landslide advance without damming.

The flood hazard beyond canyon mouths may be reduced with engineering techniques. Such techniques include the construction of erosion-control structures in creek beds to trap sediment and debris, reduce flood velocity, and minimize erosion; construction of debris basins at canyon mouths to prevent debris and flood water from flowing downstream; construction of containment/deflection berms along key portions of creek channels on alluvial fans to hold increased stream flow within channels and divert debris from adjacent land and structures; and proper land-use planning to minimize construction in flood-prone areas. Once culverts, bridges, and irrigation-diversion structures are cleared of debris, many should be redesigned to accommodate increased flow, remain clear of debris, and withstand debris impact. Engineered structures should be designed by a qualified engineer.

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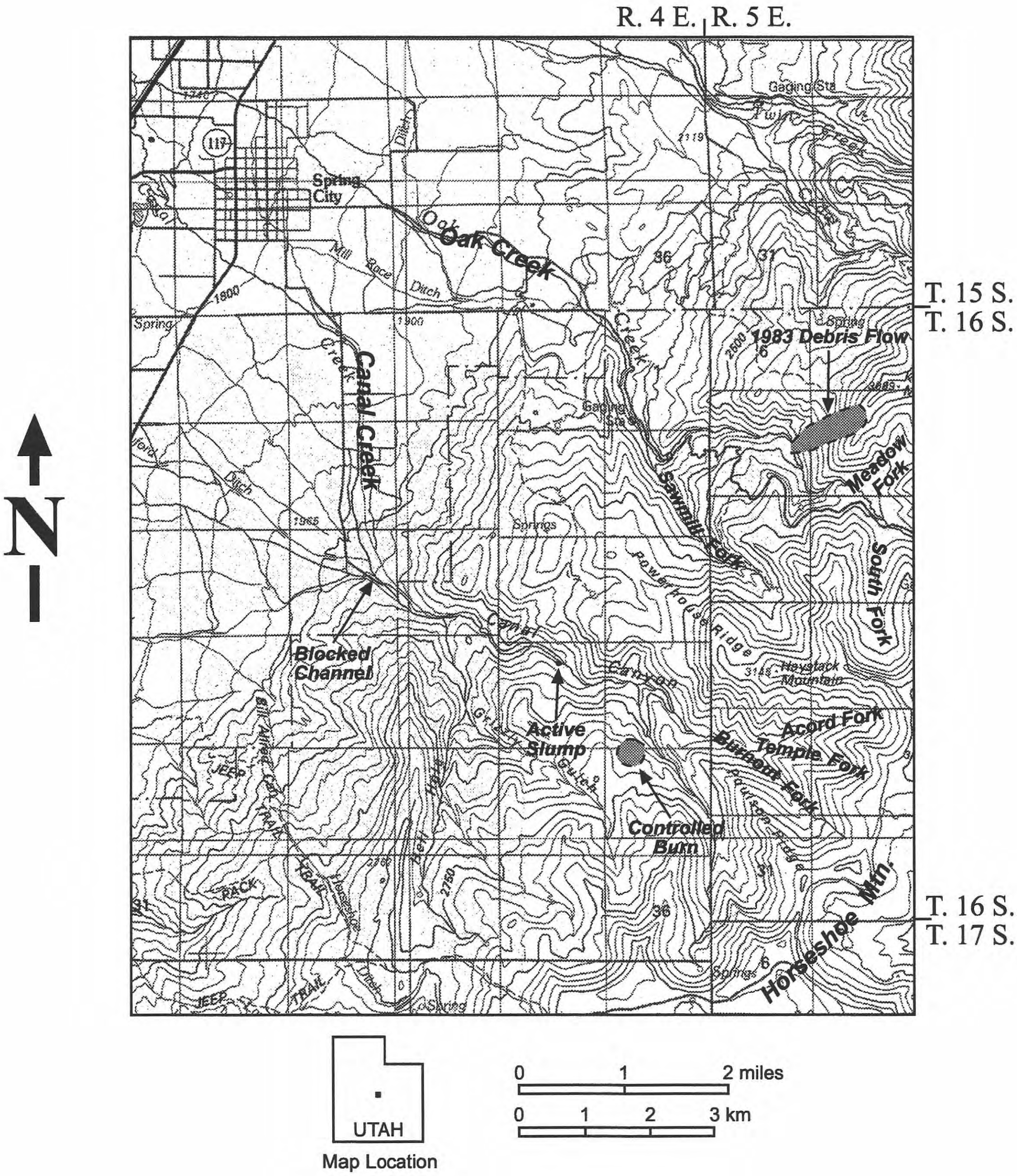
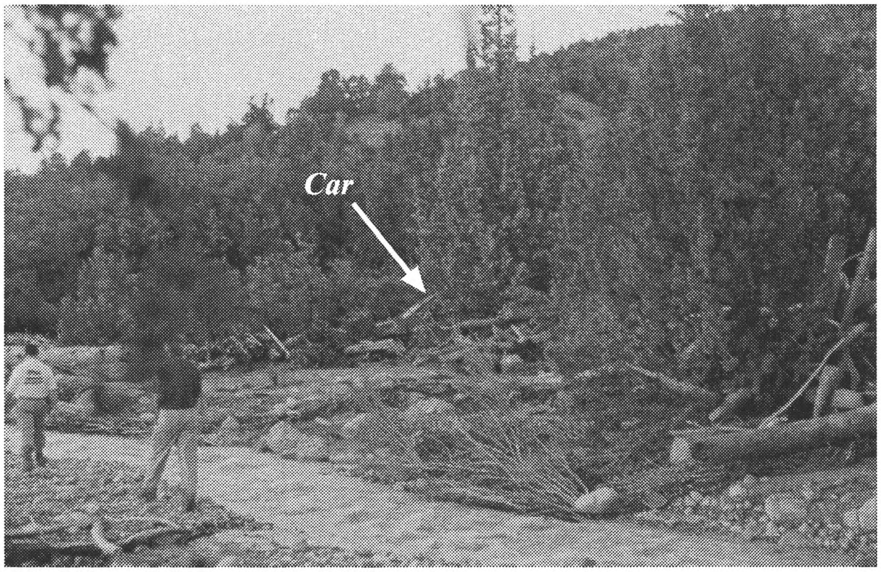
Attachment 1
Job No. 98-34

Base map from MANTI, U.S.G.S. 30x60
minute topographic quadrangle.

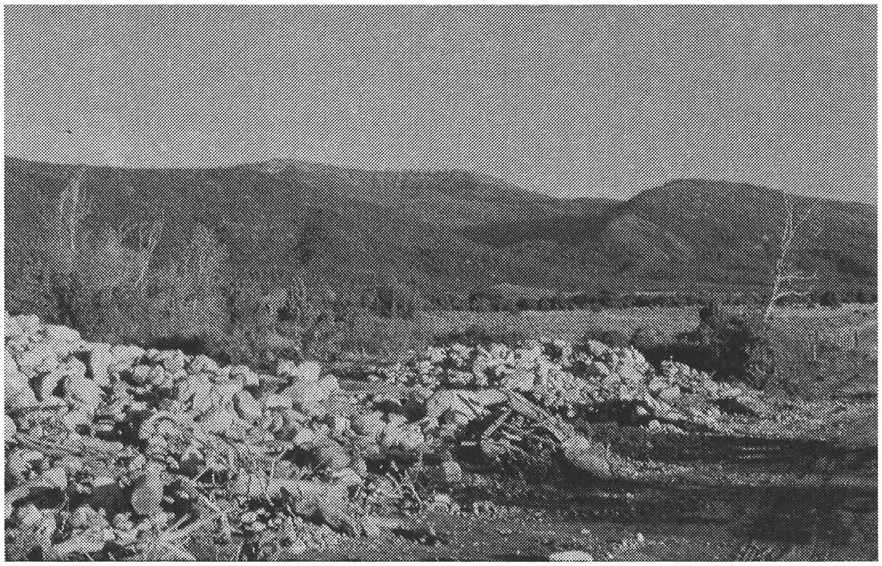


Attachment 1. Location map showing Spring City, Canal and Oak Creeks, active slump along Canal Creek, controlled-burn area in Canal Canyon, principal blockage of Canal Creek, and 1983 debris flow along Oak Creek.



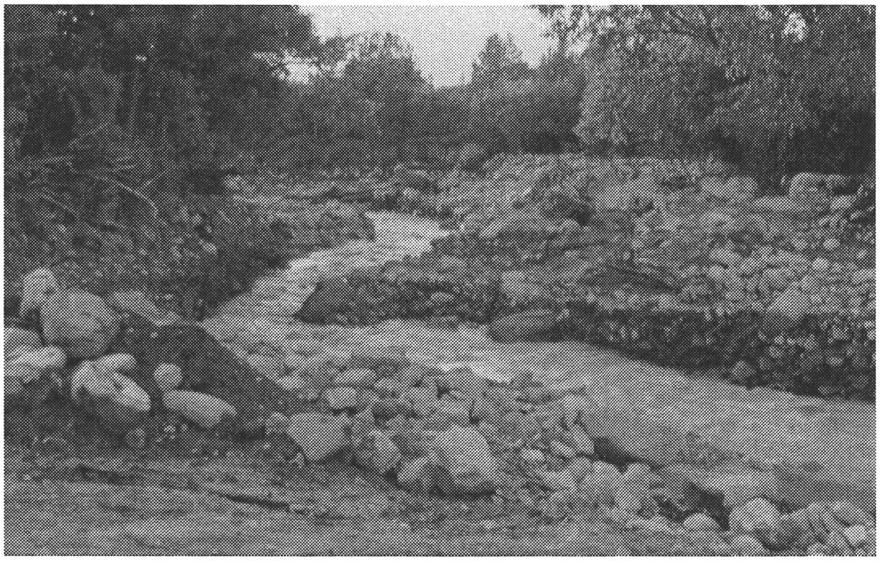
Attachment 2. A car belonging to campers was washed downstream and left stranded atop a mound of debris near the mouth of Canal Canyon on July 22.

Attachment 3. Residual mud deposited during July 22 flooding of property adjacent to an irrigation ditch crossing the southern part of Spring City. The ditch flows from Canal Creek.

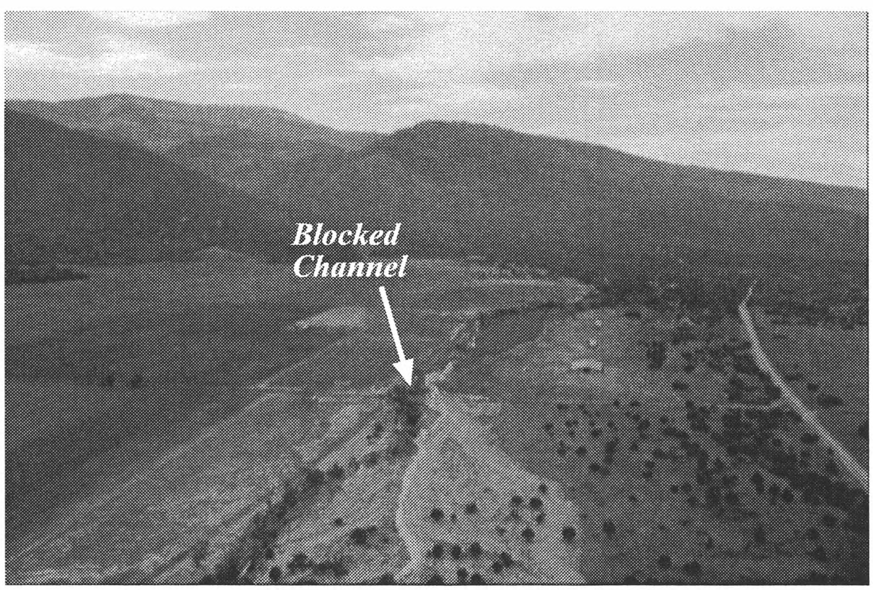


Attachment 4. Southeast view of Horseshoe Mountain at the head of Canal Canyon. Bouldery debris in the foreground was removed from Canal Creek by emergency-response teams after the July 22 flood.

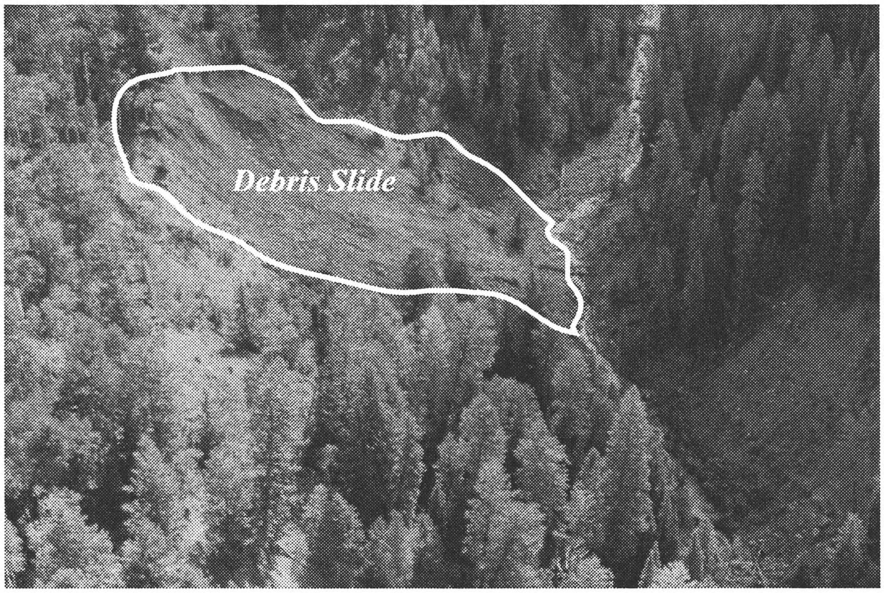
Attachment 5. Exposures of the North Horn Formation at the steep head of Temple Fork in upper Canal Canyon. The North Horn Formation is covered by colluvium and dense pine forest downslope.



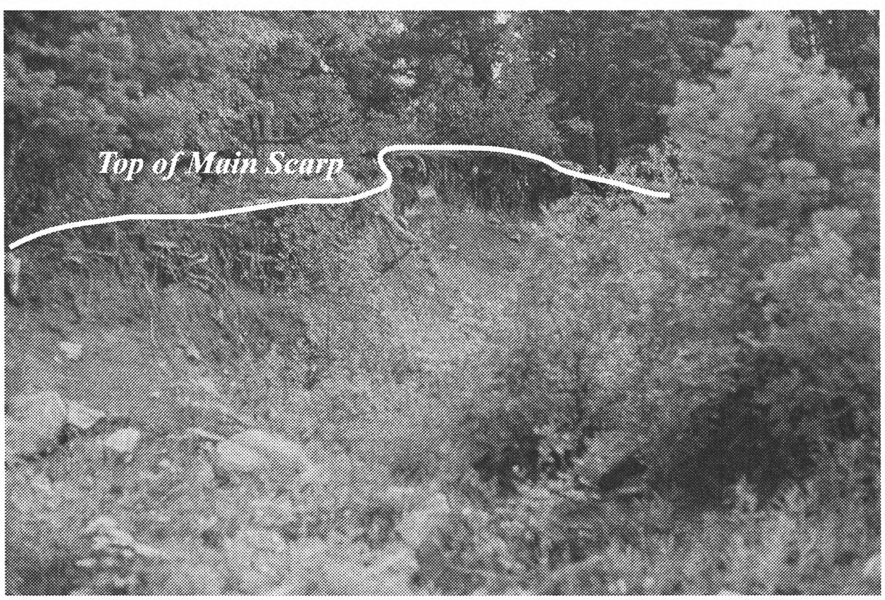
Attachment 6. Bouldery alluvial deposits in the incised flood plain of Canal Creek at the canyon mouth.



Attachment 7. Sheet flooding on Canal Creek on July 22 downstream of a channel blocked by debris, about 3 miles (5 km) southeast of Spring City.

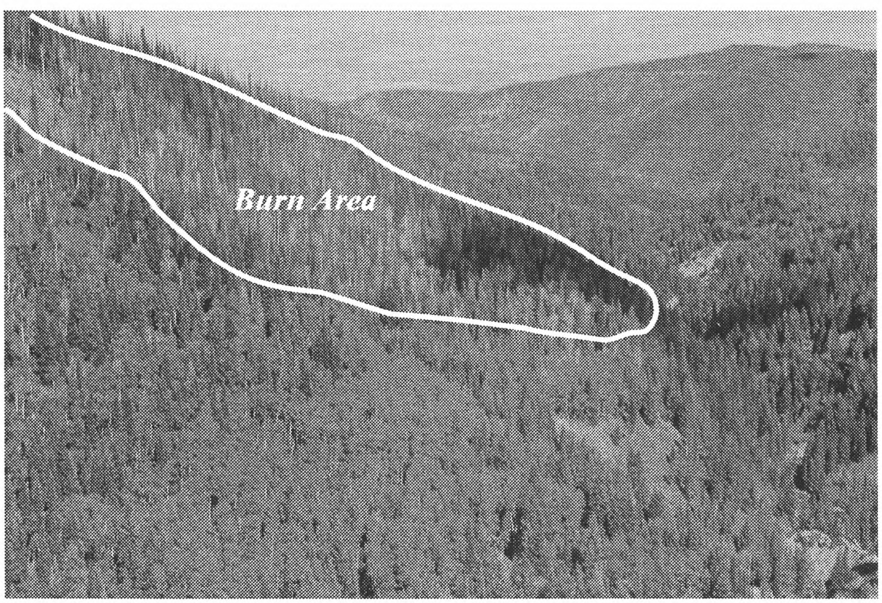


Attachment 8. A typical debris slide in upper Canal Canyon that was active during the July flooding. The creek is deflected around the slide toe, but material appears to have been rapidly eroded from the channel. No evidence exists of a landslide dam or ponding at this location.



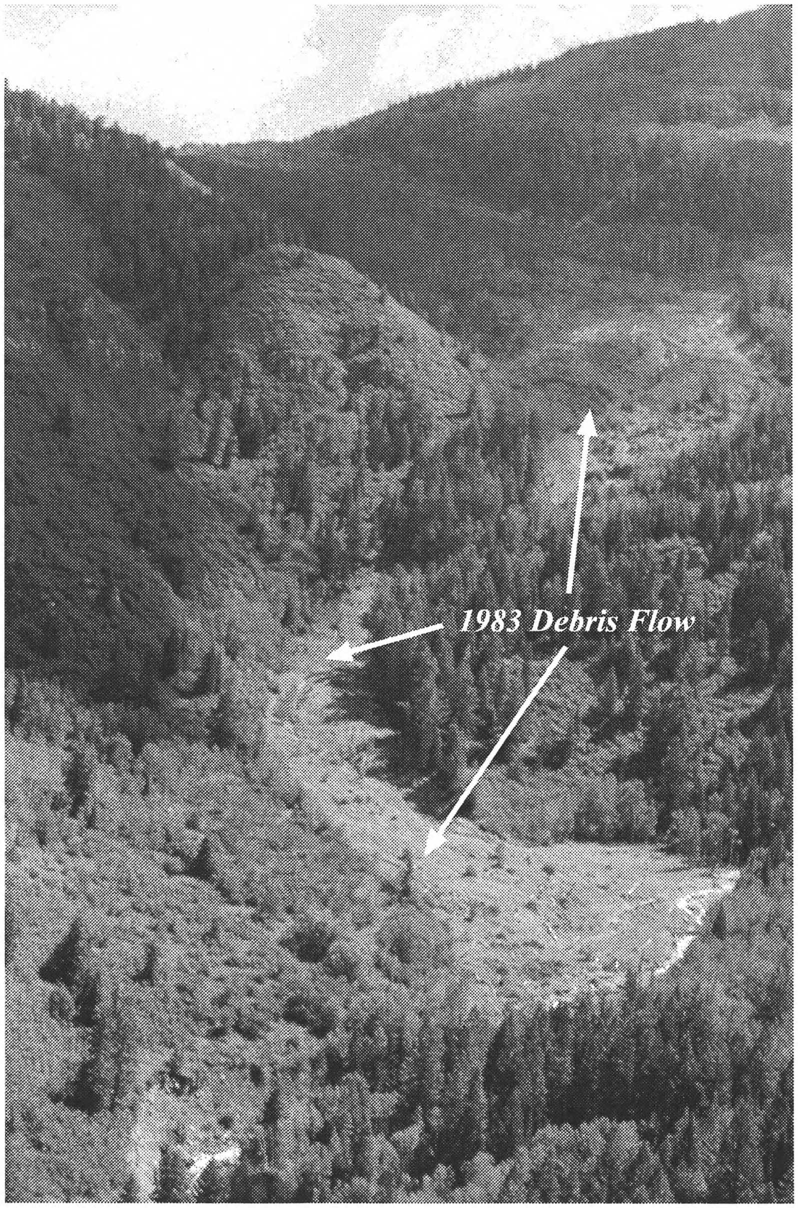
Attachment 9. The main scarp of an active slump near Canal Creek. The scarp is about 10 feet (3 m) high at this location. Most of the movement on the main scarp apparently predates the recent torrential rainfall, but a smaller secondary scarp downslope (not visible in this photo) recently moved.

Attachment 10. Active en-echelon tension cracks near the secondary scarp of the landslide pictured in attachment 9. Cracks are generally less than 1 inch (2.5 cm) wide, but reach widths of up to 3 inches (8 cm).



Attachment 11. Area of a controlled burn conducted in 1996 or 1997 on the slopes of upper Canal Canyon. Although burned areas are susceptible to slope instability, this area was stable during recent torrential rainfall.

Attachment 12
Job No. 98-34



Attachment 12. An inactive debris flow on the flank of Knob Mountain above Oak Creek. Movement occurred during a period of rapid snowmelt in 1983.

REVIEWS

<table>
<tr><td colspan="3">Project:
Review of "Geotechnical study Bitterman residence, lot 1302, Timber Lakes subdivision, Heber, Utah"</td><td>Requesting Agency:
Wasatch County Planning Office</td></tr>
<tr><td>By:
Barry J. Solomon</td><td>Date:
1-22-98</td><td>County:
Wasatch</td><td rowspan="2">Job No:
98-01
(R-1)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Center Creek (1126)</td><td>Number of attachments:
none</td></tr>
</table>

In response to a request from Anthony Kohler, Wasatch County Planning Assistant, I reviewed the geotechnical report for Timber Lakes lot 1302 by Earthtec Engineering (1997). I received the report on December 30, 1997. Lot 1302 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 ensure that the report was adequate and consistent with Utah Geological Survey (UGS) recommendations for slope-stability studies in western Wasatch County, submitted to the Wasatch County Planning Office in a memorandum dated September 24, 1997. In that memorandum, we recommended the minimum level of study to evaluate the stability of slopes based upon the landslide-hazard map units shown on plate 1 of UGS Open-File Report (OFR) 319 (Hylland and others, 1995). The scope of work for my review included interpretation of air photos (1:20,000 scale, 1962; 1:40,000 scale, 1987) and review of literature. No field visit was performed. The foundation recommendations in the Earthtec Engineering (1997) report should be reviewed by a qualified geotechnical engineer.

The map units on plate 1 (landslide hazards) of Hylland and others (1995) depend on the presence or absence of existing landslides, the slope, and the types of geologic material. Lot 1302 lies within map unit M, denoting a moderate landslide hazard. This relative-hazard designation indicates that the slope and geology suggest a moderate potential for landslides, although no landslides were mapped in the area. In map unit M areas, we recommend at a minimum a site-specific geologic study and, if necessary, a site-specific preliminary geotechnical-engineering slope-stability study. Because the ability to map landslides for OFR 319 was limited by the scale of the investigation, the site-specific geologic study of a lot must include an assessment of the presence of landslides at or near the lot, and their implications for lot stability, by a qualified engineering geologist. Such a study should include an air-photo analysis and a site visit to document surface and shallow subsurface conditions, as outlined in UGS Circular 92 (Hylland, 1996). Earthtec Engineering (1997) did not indicate that they performed this geologic study to identify landslides and, although they excavated two test pits to document subsurface conditions, their report made no mention of evidence for or against the presence of landslides. Their report also did not include a discussion of the geology and landslides in the site vicinity. My brief review of air photos of the area indicates possible landslides in the northern parts of adjacent lots to the west, where geologic and topographic conditions may be similar to those at lot 1302. The report did include the results of a quantitative slope-stability analysis, but this analysis did not consider landslides on or near the site. If these were considered, parameters used for the analysis may be incorrect and conclusions of the analysis may differ.

Even if no landslides are found during the geologic study, the slope-stability analysis contained in Earthtec Engineering (1997) needs further supporting information. Earthtec Engineering (1997) does not include a graphical output for the analysis showing the topographic profile and the types of failures considered. Without this output, I cannot adequately evaluate their analysis. Similar reports submitted to us for other Timber Lakes lots have analyzed slope stability using deep circular failure planes that extend into underlying bedrock, and have not used an infinite-slope model of potential failure planes that considers the possibility of shallow debris slides in unconsolidated material overlying the bedrock. Shallow debris slides represent a significant landslide hazard and must be considered. The placement of a septic-tank soil-absorption system and its effect on slope stability must also be considered in the analysis to ensure proper estimation of soil-moisture conditions.

Another concern for the determination of slope stability on lot 1302 is the stability of permanent cut or fill slopes. Earthtec Engineering (1997) states that the proposed structure will be a single-story home with a walk-out basement. This suggests the possibility that permanent cut slopes may be excavated. For any permanent cut or fill slopes greater than 5 feet high, we recommend that the geotechnical engineer provide engineering-design recommendations. Where cut or fill slopes are less than 5 feet high, we recommend final slopes no steeper than 2H:1V.

In summary, I recommend a geologic study by an engineering geologist to determine the existence of landslides on lot 1302 and the implications for the site of possible nearby landslides. If the geologic study finds landslides, a new quantitative geotechnical-engineering slope-stability analysis should be performed by a geotechnical engineer using new data. To ensure accurate evaluation of the new analysis by the UGS, supporting information should be submitted with the analysis related to topographic profile, types of failures considered, and placement of a septic-tank soil-absorption system. Even if no landslides are found during the geologic study, the supporting information should be resubmitted with the existing slope-stability analysis. Also, if permanent cut or fill slopes greater than 5 feet high are planned, I recommend that the geotechnical engineer provide engineering-design recommendations.

REFERENCES

Earthtec Engineering, 1997, Geotechnical study Bitterman residence, lot 1302, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 5 p.

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.

----editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Project: Review of "Geotechnical investigation - Moon Ranch development, Woodland, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning Office
By: Barry J. Solomon	Date: 2-17-98	County: Wasatch	Job No: 98-02 (R-2)
USGS Quadrangle: Woodland (1166)		Number of attachments: none	

At the request of Sharon Mayes-Atkinson, Assistant Director of Planning for Wasatch County, I reviewed geologic-hazards portions of a geotechnical report by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 1998) for the proposed Moon Ranch development, Woodlands, Wasatch County, Utah. I received the report on January 26, 1998. The proposed development is located in the SE1/4 section 12, T. 3 S., R. 6 E., and sections 7, 18, and 19, T. 3 S., R. 7 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the AGEC (1998) report should be reviewed by a qualified geotechnical engineer, but appear adequate for the proposed construction.

The AGEC (1998) report adequately addresses sulfates in soils and earthquake ground shaking. AGEC tested one soil sample from the site for sulfates, and test results indicated a negligible sulfate content. AGEC (1998) concludes that sulfate-resistant cement is not needed. The report recommends that buildings be designed and constructed to at least meet Uniform Building Code (UBC) seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking. I agree with the conclusions regarding sulfates in soils and with the recommendation regarding earthquake ground shaking contained in AGEC (1998).

AGEC encountered shallow ground water (less than 10 feet deep) in two test pits excavated along the northern edge of the property. The area of shallow ground water apparently coincides with the 100-year flood plain of the Provo River delineated by the Federal Emergency Management Agency (FEMA, 1983). Although AGEC (1998) did not recommend any restrictions within the flood plain, I recommend adherance to guidelines established by the Federal Insurance Administration's National Flood Insurance Program for development within the FEMA 100-year flood plain. Such restrictions will also reduce the hazard posed by shallow ground water. The shallow ground water saturates poorly graded gravel with sand and silt, which may pose a liquefaction hazard during strong ground shaking. Anderson and others (1994) indicate a moderate liquefaction potential in this zone of shallow ground water along the Provo River. From soil descriptions, it is difficult to determine if liquefiable layers may be present. The potential liquefaction hazard should be assessed if development is planned for the flood plain.

I believe additional local flood hazards are also present on site that are not addressed by AGEC (1998). Hylland and Bishop (1995) map an alluvial-fan-flood hazard along Bench Creek Road in section 13, T. 3 S., R. 6 E., just west of the Moon Ranch development. Although the map of Hylland and Bishop (1995) does not extend onto the development, topography suggests that the alluvial fans do extend into section 18, T. 3 S., R. 7 E., south of the Provo River. Alluvial-fan flooding and debris flows may occur on alluvial fans in this area and their potential should be evaluated and hazard areas mapped prior to development. Hylland and Bishop (1995) also map a stream-flood hazard in the upper reaches of Herd Hollow. This drainage extends into the development in section 19, T. 3 S., R. 7 E., and is joined there by a tributary. The potential for stream flooding in Herd Hollow and its tributary should also be evaluated and flood-hazard areas delineated prior to development.

AGEC (1998) found no evidence of landslides or other slope-stability problems at the proposed development. However, the report notes that the south half of the development, south of Bench Creek Road, is underlain by Tertiary volcanic rocks. These rocks are mapped by Bryant (1990) as the Keetley Volcanics, a geologic unit susceptible to landslides (Hylland and Lowe, 1997). Hylland and Lowe (1995) designate a moderate landslide hazard on similar, adjacent slopes to the west that adjoin the proposed development. This moderate landslide hazard is based upon the type of geologic material and a critical slope inclination of 25 per cent (Hylland and Lowe, 1997). Although AGEC (1998) found no on-site landslides, Hylland and Lowe (1995) map landslides in the Keetley Volcanics about 2 miles west of the site and Bryant (1990) maps a similar landslide less than 1 mile south of the site. Given the steep slopes (which I estimate to be locally greater than 40 percent) and potentially unstable rocks of the Keetley Volcanics beneath the southern part of the site, I recommend that all slopes greater than 25 percent be mapped. If structures are planned on these steeper slopes, at least a geologic and, if necessary, a preliminary geotechnical engineering slope-stability study should be conducted by a qualified engineering geologist and/or geotechnical engineer to evaluate slope stability. Guidelines for these studies are outlined in Utah Geological Survey Circular 92 (Hylland, 1996). The slope-stability analysis should include an assessment of potential failure planes that considers the possibility of shallow debris slides in unconsolidated material overlying the bedrock, if such material is found. Once analyzed, potentially unstable slopes and appropriate setbacks should be mapped. The analysis should consider the cumulative effects of development in the area, including the wetting of soils caused by effluent from septic-system drain fields and lawn watering.

AGEC (1998) notes the potential limitations of low-permeability clayey soils for placement of septic systems on part of the site, and the limitations posed by highly permeable granular soil and the proximity of the Provo River. The report recommends additional field study to determine suitable areas for septic-system drain fields, and I concur. The additional study should also consider limitations posed by shallow bedrock, shallow ground water, and stream and alluvial-fan flooding. Hylland (1995) indicates that generally suitable areas for septic-tank soil-absorption systems are between the Provo River on the north and outcrops of the Keetley Volcanics on the south, in the area underlain by the Quaternary alluvial-terrace gravels mapped by Bryant (1990). Other areas may be determined to be locally suitable after further study.

Another concern for the determination of slope stability on the Moon Ranch development is the stability of permanent cut or fill slopes. AGEC (1998) states that preliminary site grading plans indicate cut and fill heights will be less than 10 feet. For any permanent cut or fill slopes greater than 5 feet high, the UGS recommends the use of either standard UBC recommendations or other specific engineering-design recommendations provided by the developer's geotechnical engineer. Where cut or fill slopes are less than 5 feet high, we recommend final slopes no steeper than 2H:1V unless engineering studies indicate otherwise.

The Keetley Volcanics are also the source of problems with foundation soils, including expansive and collapsible soils. AGEC (1998) recognizes the presence of expansive soils and recommends appropriate foundation design and site grading to address this hazard. AGEC (1998) further recommends additional investigation of this hazard in the Herd Hollow area, where clay extended beyond the depth of exploratory test pits, and I concur. However, AGEC (1998) did not consider the potential for collapsible soils. Collapsible soils were encountered above Keetley Volcanics in a proposed development in western Wasatch County (Dames & Moore, 1988), and are typically found in Holocene alluvial-fan deposits derived from Keetley Volcanics, such as those noted above along Bench Creek Road (Hylland and Bishop, 1995). If structures are planned on the Keetley Volcanics or alluvial fans in the southern half of the proposed development, I recommend that the potential for collapsible soils be evaluated.

Volcanic rocks are commonly a source of elevated levels of indoor radon because of their relatively high uranium content. AGEC (1998) did not consider the potential for indoor radon, but Black (1993) maps a high radon-hazard potential on the southern part of the proposed development that coincides with outcrops of the Keetley Volcanics. Elsewhere on the development, Black (1993) maps a moderate radon-hazard potential. I believe that the radon-hazard potential should be disclosed to prospective property buyers. I further recommend that radon-resistant construction techniques be incorporated in new-home construction, particularly within the high-hazard area. Preventing radon from entering a structure is an effective method of hazard reduction, but restricting radon entry is difficult in existing homes. Features can be incorporated during construction that facilitate radon removal after home completion, but such features are less expensive to incorporate during, rather than after, home construction. Radon-resistant construction techniques are described by Clarkin and Brennan (1991).

In conclusion, I recommend adherance to guidelines established by the National Flood Insurance Program to address the potential for flooding and shallow ground water in the 100-year flood plain of the Provo River. The potential liquefaction hazard in saturated, granular soils should be assessed if development is planned for the flood plain. The potential for alluvial-fan flooding and debris flows along Bench Creek Road should be evaluated prior to development, as should the potential for stream flooding in Herd Hollow and its tributary. I recommend all slopes greater than 25 percent underlain by Keetley Volcanics south of Bench Creek Road be delineated. If structures are planned on these slopes, site-specific geologic studies and, if necessary, preliminary geotechnical engineering slope-stability studies should be conducted to determine slope stability and recommend appropriate setbacks. Additional field study is needed to determine areas suitable for septic-tank soil-absorption systems, and the placement of such systems must be considered in the slope-stability analysis. For permanent cut or fill slopes greater than 5 feet high, the developer's geotechnical engineer should provide engineering-design recommendations or use standard UBC recommendations; for cut or fill slopes less than 5 feet high, final slopes should be no steeper than 2H:1V unless engineering studies indicate otherwise. Additional investigation is needed to assess the potential for both expansive soils and collapsible soils in the southern half of the development in areas underlain by the Keetley Volcanics and alluvial-fan deposits derived from them. I believe that the moderate to high radon-hazard potential should be disclosed to prospective property buyers, and that radon-resistant construction techniques be incorporated in new-home construction, particularly within the high-hazard area in the southern part of the proposed development underlain by the Keetley Volcanics.

The mapping recommended above should be completed by the developer's consultant at a scale suitable for subdivision planning and lot layout. This map should define buildable areas based on mapped hazard areas and should reflect mitigation recommendations. Additional lot-specific hazard evaluations should not be necessary. Only soil-foundation studies for foundation design (addressing expansive, collapsible, and liquefiable soils), and septic-tank soil-absorption-system studies for final Health Department approval should be done at a lot-specific level.

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Hylland, M.D., and Bishop, C.E., 1995, Flood hazards, earthquake hazards, and problem soils, western Wasatch County, Utah, *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 2B, scale 1:24,000.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard, western Wasatch County, Utah, *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 1B, scale 1:24,000.

----1997, Regional landslide-hazard evaluation using landslide slopes, western Wasatch County, Utah: Environmental & Engineering Geoscience, v. III, no. 1, p. 31-43.

Project: Review of "Geotechnical study - Provo Elementary School, 200 South 2530 West, Provo, Utah"			Requesting Agency: Provo City School District
By: Barry J. Solomon	Date: 2-17-98	County: Utah	Job No: 98-04 (R-3)
USGS Quadrangle: Provo (1047)		Number of attachments: 1	

At the request of Phil Lott, Director of Facilities and Transportation for the Provo City School District, I reviewed geologic-hazards portions of a geotechnical report by Earthtec Engineering, P.C. (Earthtec, 1997) for the proposed Provo Elementary School, Provo, Utah County, Utah. I received the report on December 16, 1997. The proposed school is located at the southwest corner of the intersection of 200 South and 2350 West in the NE1/4NW1/4 section 10, T. 7 S., R. 2 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the Earthtec (1997) report should be reviewed by a qualified geotechnical engineer.

My evaluation considered the potential for a wide variety of geologic hazards, listed on attachment 1. The attachment includes my assessment of the hazard potential and, where a significant potential exists, a recommendation for further study. I found a significant potential for earthquake ground shaking, liquefaction, shallow ground water, flooding, and tectonic subsidence. A potential for ground subsidence due to sensitive clays may be present, but cannot be determined until further sampling and testing is conducted. These hazards should be considered by the architect's engineering consultants for the design of the building. I found a low potential for other geologic hazards listed on the attachment.

The Earthtec (1997) report recognizes that the school site is in an area with a moderately high risk of experiencing strong earthquake ground shaking. Earthtec (1997) recommends that the proposed structure be designed and constructed in accordance with Uniform Building Code (UBC) seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking, and I concur. This is the minimum design level specified in the UBC. However, such levels are below those expected in a major local earthquake on the Wasatch fault zone, and design to UBC seismic zone 4 levels would provide additional safety.

Earthtec encountered saturated, poorly graded, granular soils in foundation borings. This material is mapped as middle Holocene to uppermost Pleistocene stream alluvium deposited by the Provo River (Machette, 1992). The Earthtec (1997) report indicates the soils are susceptible to liquefaction-induced settlement during strong earthquake ground shaking. I agree that liquefaction-induced settlement is a potential hazard, and this evaluation is consistent with the high liquefaction potential mapped by Anderson and others (1994). However, Earthtec's estimate of the liquefaction potential is apparently based on the presence of loose, liquefiable sands encountered at depths of from 13 to 15.5 feet in boring TH-4, and their recommendations for foundation reinforcement to reduce the potential damage from liquefaction are apparently based on the presence of denser soils overlying the loose sands. To reduce the potential damage from liquefaction, Earthtec (1997) recommends the building be supported by spread and spot footings placed on these denser soils. I do not believe that the liquefaction potential and effects have been accurately assessed. Saturated, loose granular soils may be liquefied from sufficiently strong earthquake ground shaking to depths of 30 feet. Earthtec's foundation borings were drilled to maximum depths of only 15.5 feet, and the presence of liquefiable sands in the bottom of boring TH-4 indicates a significant potential for additional liquefiable material at greater depth. I recommend drilling deeper foundation borings, to a minimum depth of 30 feet, and sampling and testing of granular materials encountered in these borings to further evaluate the potential liquefaction hazard. I also recommend review of the foundation design by a geotechnical engineer prior to construction.

Although granular stream alluvium was found at the site at the shallow depths encountered in Earthtec foundation borings, the alluvium may be underlain by fine-grained sediments deposited by latest Pleistocene Lake Bonneville (Machette, 1992). Some fine-grained Lake Bonneville sediments along the Wasatch Front are classified as sensitive clays (Parry, 1974). Sensitive clays experience a particularly large loss of strength when subjected to strong earthquake ground shaking. When deeper foundation borings are drilled to investigate the liquefaction potential, I recommend sampling and testing fine-grained sediments, if encountered below the granular material, to determine the potential for ground failure due to sensitive clays.

One prerequisite for both liquefaction of granular soils and ground failure due to sensitive clays is shallow ground water. Although shallow ground water contributes to those hazards, it poses additional hazards even in the absence of earthquake ground shaking. Such hazards include flooding of subsurface facilities such as basements, and destabilization of excavations and foundations. Earthtec (1997) encountered ground water in foundation borings at depths as shallow as 3 feet below the ground surface and recommends specific engineering-design features to address hazards posed by shallow ground water. I believe these recommendations are appropriate but should be reviewed by a geotechnical engineer prior to construction.

The proximity of the school site to the Provo River, Utah Lake, and Deer Creek Dam pose flood hazards not addressed by Earthtec (1997). The site is in the 100-year flood plain of the Provo River, delineated by the Federal Emergency Management Agency (FEMA, 1988). Although the area is protected from the 100-year flood by levees, dikes, or other flood-control structures, these structures require periodic maintenance to be effective. If the structures are not properly maintained, the site may be subject to a significant flood hazard. Moreover, flood-control structures may not prevent losses from great and infrequent floods that exceed design criteria. At a minimum, I recommend adherance to guidelines established by the Federal Insurance Administration's National Flood Insurance Program for development within the FEMA 100-year flood plain. Although the site is above the maximum projected flood level for Utah Lake (Harty and Christenson, 1988), the site may be subject to lake flooding following a strong earthquake due to inundation along the lake shore caused by tectonic subsidence (the warping, lowering, and tilting of a valley floor) if the lake level is at or above an elevation of 4,495 feet at the time of the earthquake (Keaton, 1986). Ponding of water and disruption of buried facilities may also be caused by tectonic subsidence. Other potential causes of flooding at the site are earthquake-induced seiches in Utah Lake and the failure of Deer Creek Dam, upstream at the head of Provo Canyon (Case, 1985; U.S. Bureau of Reclamation, 1985).

However, the probability of flooding due to tectonic subsidence or seiche is low and would depend upon the occurrence of a large earthquake at a time of high lake level.

In conclusion, I believe that the proposed school should be designed and constructed, at a minimum, in accordance with UBC seismic zone 3 requirements to minimize the risk from earthquake ground shaking; zone 4 levels would provide additional safety. I believe that liquefiable sediments underlie the proposed school at greater depths than those tested in foundation borings, and recommend that additional foundation borings be drilled to a minimum depth of 30 feet to fully evaluate the liquefaction potential. If fine-grained sediment is encountered below the granular material in the additional foundation borings, I recommend sampling and testing to determine the potential for ground subsidence due to sensitive clays. The foundation design should be reviewed by a geotechnical engineer prior to construction. Earthtec (1997) recommendations for specific engineering-design features to address hazards posed by shallow ground water appear appropriate to me, but should also be reviewed by a geotechnical engineer prior to construction. I recommend adherance to guidelines established by the National Flood Insurance Program to address the potential for flooding in the 100-year flood plain of the Provo River, but urge the Provo School District to consider the potential for loss should flood-control structures fail due to improper maintenance. The site may also be subject to flooding from inundation along the shore of Utah Lake during a strong earthquake and from failure of Deer Creek Dam.

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Attachment 1
Job No. 98-04

SUMMARY OF GEOLOGIC HAZARDS
Provo Elementary School

Hazard	Hazard Rating*			Further Study Recommended**
	Prob-able	Pos-sible	Un-likely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence		X		
Liquefaction	X			G
Slope failure			X	
Flooding		X		
Sensitive clays		X		G
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow bedrock			X	
Shallow ground water	X			
Flooding				
Streams		X		
Alluvial fans			X	
Lakes			X	
Dam failure		X		
Canals/ditches			X	
Radon			X	

*Hazard Ratings - Probable, evidence is strong that the hazard exists and mitigation measures should be taken; Possible, hazard possibly exists, but evidence is equivocal, based only on theoretical studies, or was not observed and further study is necessary as noted; Unlikely, no evidence was found to indicate that the hazard is present.

**Further study (S-standard soil/foundation; G-geotechnical/ engineering; H-hydrologic) is recommended to address the hazard.

Project: Review of "Engineering geology/slope stability evaluation, Phase I and Phase II Deer Crest development, northwest Wasatch County, near Park City, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 3-16-98	County: Wasatch	Job No: 98-05 (R-4)
USGS Quadrangle: Park City East (1209)		Number of attachments: none	

At the request of Bob Mathis, Director of Planning for Wasatch County, I reviewed the geologic-hazards portions of an engineering-geologic report by AGRA Earth and Environmental (AGRA, 1998) for phases I and II of the proposed Deer Crest development, Wasatch County, Utah, near Park City. I received the report on March 12, 1998. The proposed development is located in the S1/2 section 14, SE1/4 section 15, NE1/4 section 22, N1/2 section 23, and NW1/4 section 24, T. 2 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the AGRA (1998) report should be reviewed by a qualified geotechnical engineer.

AGRA (1998) considered the potential for earthquake ground shaking, flooding, snow avalanches, and slope stability. I believe this to be a complete list of potential geologic hazards with the exception of the potential for expansive soils. The Keetley Volcanics, which underlie the southeastern part of the development, are a common source of expansive soils. Dames & Moore (1988) encountered a soil sample with a high swell potential in this area. The presence of expansive soils does not preclude development, but their effect should be evaluated by the architect's engineer prior to final design.

The AGRA (1998) report recognizes that the site is in an area with a moderately high risk from strong earthquake ground shaking. The report recommends that the proposed structures be designed and constructed in accordance with Uniform Building Code (UBC) seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking, and I concur. This is the minimum design level specified in the UBC. However, such levels are below those expected in a major local earthquake on the Wasatch fault zone, and design to UBC seismic zone 4 levels would provide additional safety.

The AGRA (1998) report maps alluvial flood-plain deposits that may be subject to flooding during periods of high precipitation or snowmelt, but states that no homesites appear to be proposed within the drainages. However, figure 3 of the report shows one proposed homesite (lot 117) on flood-plain deposits in the north drainage, in the northeast corner of the development. At a minimum, I recommend adherance to guidelines established by the Federal Insurance Administration's National Flood Insurance Program for development within a 100-year flood plain.

The AGRA (1998) report found no evidence of active snow-avalanche processes at the site, although AGRA did observe three inactive snow-avalanche tracks. AGRA (1998) speculates that proposed site improvements will provide additional stability to snowpacks, thus minimizing the potential for future avalanches. To ensure additional stability, the potential for snow avalanches should be considered in site design.

AGRA (1998) did not observe any geologic evidence of slope failures. The report includes preliminary geotechnical-engineering analyses, using the computer program PCSTABL5 and estimated material properties, to characterize the static and dynamic slope stability of seven profiles scattered throughout the site. From the results of the slope-stability analyses, AGRA (1998) concluded that factors of safety exceeded the minimum acceptable levels for stable slopes under both static and dynamic conditions. This conclusion is consistent with the results of the analyses, but may occurr as a consequence of AGRA's use of non-conservative estimates of material properties. AGRA (1998, p. 18) states that the material properties were "very conservative," but typical material properties presented by West (1995, p. 83) indicate that AGRA's estimates are not conservative. For example, West (1995) considers the friction angle for shale to typically fall within the range of 15 to 30 degrees, but AGRA (1998) assigns a value of 38 degrees. West (1995) considers the friction angle for limestone to typically fall within the range of 35 to 50 degrees, suggesting that the 45 degree value used by AGRA (1998) is not conservative. AGRA (1998) also assigns values of cohesion that may be high and therefore not conservative. Moreover, AGRA (1998) states that ground water is expected to be at least 100 feet deep, and thus does not model a static ground-water table in the analyses. This assumption may be incorrect. Our experience, based on a UGS ground-water assessment in the area (Ashland and others, 1996), indicates that gound-water occurrence is controlled by local geologic structures and stratigraphy. The Thaynes Formation and Woodside Shale commonly contain water, particularly in the spring, as snowmelt infiltrates and collects above impermeable beds or other geologic barriers to flow. Seasonal shallow ground water is thus likely at the site and should be considered in modeling slope stability.

If more conservative values for friction angle, cohesion, and ground-water depth are used to model slope stablity with PCSTABL5, factors of safety may locally be less than acceptable. However, this should not preclude approval of the plat for the proposed Deer Crest development. Rather, it reinforces the idea that assessment of slope stability for this development is more appropriate at a localized level. The seven scattered profiles analyzed by AGRA (1998) may not accurately reflect the specific conditions found on many individual lots, particularly for rock slopes. Geologic studies on lot clusters are the recommended minimum level of study to address this topic, but if geologic conditions suggest potential instability or if extensive slope modifications are proposed, geotechnical-engineering studies will be necessary on individual lots. Slope stability assessments should be conducted prior to development, with the results of the analyses used to determine buildable areas and appropriate setbacks or other mitigation measures. Because the potential for slope failures is for both shallow debris slides in colluvium and slab or wedge failures in bedrock, and must consider cut slopes specific to proposed site designs, a slope-stability analytical technique appropriate for each condition should be used. The use of deep, circular failure planes with PCSTABL5 may be inappropriate because failure planes associated with shallow debris slides are not deep, and failure planes associated with slab or wedge failures in bedrock are rarely circular.

In conclusion, I believe that the AGRA (1998) report adequately addresses ground shaking, but design to UBC seismic zone 4 levels would provide additional safety. I recommend that the potential for expansive soils in the southeastern part of the development, on the Keetley Volcanics, be evaluated by the architect's engineer prior to final design. At a minimum, I recommend adherance to guidelines established by the Federal Insurance Administration's National Flood Insurance Program for development within flood plains. Finally, I believe geologic assessment of slope stability for this development is more appropriate at a local level. If geological-engineering studies are needed on specific lots, the studies should use site-specific values for friction angle, cohesion, and ground-water depth, and should consider proposed site design to analyse the potential for slope failures as both shallow debris slides in colluvium and slab or wedge failures in bedrock.

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Ashland, F.X., Bishop, C.E., Lowe, Mike, and Mayes, B.H., 1996, The geology of the Snyderville basin and its relation to ground-water conditions: Utah Geological Survey Open-File Report 337, 124 p.

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<table>
<tr><td colspan="3">Project:
Review of "Observations and reconnaissance report, engineering geology investigation, Lot #2 proposed Keough subdivision, Salt Lake County, Utah"</td><td>Requesting Agency:
Salt Lake County Planning</td></tr>
<tr><td>By:
Richard E. Giraud</td><td>Date:
3-19-98</td><td>County:
Salt Lake</td><td rowspan="2">Job No:
98-06
(R-5)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Draper (1171)</td><td>Number of attachments:
none</td></tr>
</table>

At the request of Craig Nelson, Salt Lake County Geologist, I reviewed an engineering-geology report by AGRA Earth & Environmental Inc. (AGRA, 1998) for lot #2 of the proposed Keough subdivision, Salt Lake County, Utah. Lot #2 lies at the mouth of Big Willow Canyon in the NE1/4SW1/4 section 23, T. 3 S., R. 1 E., Salt Lake Base Line and Meridian. Big Willow Creek is along the north side of the lot. The purpose of this review was to evaluate if the debris-flow hazard was adequately addressed and, where necessary, to provide additional comments and recommendations. The scope of work for the review included interpretation of aerial photographs (1958), a review of flood insurance rate maps, and a field visit of the site on March 16, 1998, with Gary Christenson (Utah Geological Survey), Craig Nelson, and David Keough, lot owner.

AGRA (1998) provides a background chronology of previous engineering-geology studies for the site, and performed a literature review, site reconnaissance, and analysis of aerial photographs for their study. AGRA concludes "because the site is covered with glacial deposits believed to have been deposited over 20,000 years ago, we believe the likelihood of a [sic] future debris flow processes impacting the site to be very unlikely."

From my review, I believe that lot #2 lies on a small stream terrace adjacent to Big Willow Creek. The terrace is inset into surrounding older deposits. It has a flat surface and smooth graded longitudinal profile, and was probably formed by stream flow and debris flows in Big Willow Creek during late Holocene time. The terrace is covered with large boulders of quartz monzonite and is incised by Big Willow Creek. Although AGRA (1998) mapped these and surrounding older surficial deposits in the area as glacial moraine/till deposits of late Pleistocene age, Personius and Scott (1992) mapped the surficial deposits forming the terrace as debris-flow deposits of late Holocene age, similar to my interpretation, and the surrounding older deposits as debris-flow deposits of middle Holocene to latest Pleistocene age.

The AGRA report focused on the possible glacial origin of deposits in the area and did not specifically investigate the stream terrace deposits at lot #2 relative to the debris-flow hazard. Therefore, I believe the debris-flow hazard is not adequately addressed because AGRA (1998) does not identify the stream terrace, consider the potential for debris-flow deposition on the terrace given close proximity to the creek, or evaluate deposits underlying the terrace relative to a debris-flow origin. Adequate debris-flow studies for this type of site generally consider: 1) the age and stratigraphy (origin and thickness of depositional units) of the terrace deposits and their implication for Holocene alluvial and debris-flow activity in Big Willow Creek, 2) potential debris sources along the Big Willow Creek channel and in the canyon, 3) the gradient of Big Willow Creek and potential to transport debris, and 4) debris-flow and flood-water travel paths and the potential of channel plugging relative to effects of culverts and stream-channel diversions just upstream of the site.

Regarding flooding, the flood insurance rate map of the area indicates that Lot #2 is in zone A (FEMA, 1985), a special flood hazard area subject to inundation by the 100-year flood. Detailed hydraulic analyses were not performed for the map so no base flood elevation or depths are indicated. FEMA (1989) states that mandatory flood insurance purchase requirements apply. The AGRA (1998) background chronology listed an August 23, 1996 report by Wilding Engineering that discussed flooding. I recommend, if not previously considered, that the Wilding Engineering report be reviewed with respect to FEMA zone A and the effects of upstream diversion and channel alterations on the flood hazard at the site.

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Project: Review of "Engineering-geology report for Higley subdivision, Uintah, Utah"			Requesting Agency: Weber County Planning
By: Richard E. Giraud	Date: 4-3-98	County: Weber	Job No: 98-07 (R-6)
USGS Quadrangle: Ogden (1345)		Number of attachments: none	

INTRODUCTION

At the request of Jim Gentry, Weber County Planning Commission, I reviewed an engineering-geology report by Bruce N. Kaliser on the Higley Estates subdivision, Uintah area, Weber County, Utah. The 32-lot subdivision lies east of Uintah at 6500 South Bybee Drive in the NW1/4 section 25 and the NE1/4 section 26, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of this review was to evaluate if geologic hazards were adequately addressed and, where necessary, to provide additional comments and recommendations. The scope of work for the review included interpretation of aerial photographs, a literature review, and inspection of published geologic maps and Weber County geologic-hazard maps. I did not conduct a field inspection of the property.

Kaliser (1997) addresses problem soils, shallow ground water, rock falls, slope stability, debris flows, flooding, and faulting. Recommendations concerning problem soils, shallow ground water, and rock falls are adequate for a residential subdivision. However, the report does not adequately address slope stability, debris flows, alluvial-fan flooding, and surface fault rupture. I include recommendations on radon-gas hazards in this review.

SLOPE STABILITY

The subdivision lies on the Weber River delta, an area in which steep slopes in delta sediments are typically prone to landsliding, and slope conditions involving addition of water often contribute to slope instability (Kaliser, 1969; Gill, 1981; Lowe, 1985). Although Kaliser states "[there is] an absence of deleterious slope conditions anywhere on the site," he does not include a discussion of slope steepness, likely slope-failure types and travel distances, or quantitative slope stability under wet conditions in the northern property area. He indicates the presence of ancient landslide debris in the "bowl" in the western property area and states that "slopes are everywhere on the property uniform and unbroken with morphology that could denote rapid or creeping movements" (Kaliser, 1997, p. 6), but appears to conclude that slopes are stable. However, in his conclusions, he states that "future development of land at higher elevation on the slopes bordering the property on the north should be monitored for potential impact upon the plotted lots" (Kaliser, 1997, p. 9), suggesting that he recognizes the potential for human-induced slope failure. These comments suggest to me that further study of slope stability is necessary. The "buildable area" shown on Kaliser's figure 2 appears to be based on a slope criterion, but I do not know if the "buildable area" considers possible effects of failures upslope. Kaliser also states that "slopes are comprised of granular materials with no apparent intercalated clay layers or perched ground-water zones." Because he does not identify the origin of the deposits (for example, Lake Bonneville or Weber River deltaic deposits) in the test-pit logs, I am not sure if he encountered any of the units that typically include clay beds. However, clay beds are present throughout the Weber River delta, including in areas west (Lowe, 1985) and across the valley to the southwest (Lowe, 1987), so it seems likely that they are present at this site. Kaliser (1969) documents a slope failure and residential damage due to water-saturated very fine sand and silt beds at 6302 Bybee Drive, north of the Higley subdivision. This further suggests the potential slope instability in this geologic setting.

The report also does not address if subdivision modifications such as grading, excavation, drainage-channel relocation, landscape irrigation, and effluent from possible septic-tank soil-absorption systems will destabilize local slopes. Utah Division of Water Quality (1996) regulation R317-502-17.1 indicates that approval of a septic system can be denied if the system may cause slope instability. I agree with the report recommendation that a community wastewater system would be prudent.

DEBRIS FLOWS AND FLOODING

Kaliser (1997) states that the debris-flow potential on the eastern alluvial fan is minimal based on the absence of debris-flow deposits in alluvial-fan test holes, and the absence of Holocene or historical debris-flow geomorphic features on the fan. The absence of an historical debris flow does not necessarily preclude or lower the risk presented by future debris flows, and in fact Williams and Lowe (1990) suggest that drainage basins having potential to produce future large debris flows are basins that have not produced historical debris flows. Kaliser's evaluation did not consider slope conditions in the debris source area in the Broad Hollow drainage or debris volume in the drainage channel. Although he states that he identified no debris-flow deposits in test holes, he does not document the age of the test-hole deposits to show what part of the Holocene is represented. Qualitatively, a lack of debris-flow deposits in the test holes reduces concern over debris flows, but a hazard from sediment-laden stream flows may still exist. The thickness of alluvial-fan depositional units may suggest the typical size and nature of sedimentation events on the fan for use in designing site drainage.

The Kaliser (1997) report addresses water runoff in the western "bowl," on the eastern alluvial fan, and flow from Hamre Spring. The report recommends that the siting of structures take into account existing drainages. Some buildable lot areas shown in figure 2 (Kaliser, 1997) are platted across small drainages. A subdivision drainage design must account for these drainages; considerable surface grading may be required to reroute surface-water runoff.

The report did not specifically address the alluvial-fan flooding potential from the Broad Hollow drainage, but such flooding and associated sediment deposition as discussed above should be considered in the design of subdivision drainage. The subdivision is in an area of minimal flooding (zone C; FEMA, 1982) from the principal source (Broad Hollow drainage). However, FEMA (1989) states that buildings in this zone could be flooded by severe, concentrated rainfall coupled with inadequate local drainage systems. Flood insurance is available in participating communities but is not a requirement by regulation in this zone. FEMA does not impose any building restrictions in this zone.

SURFACE-FAULT-RUPTURE HAZARDS

Test trenches #2 and #3 were excavated to evaluate the surface-fault-rupture hazard. The fault location in trench #2 corresponds to a mapped fault of Nelson and Personius (1993). The proposed setback distance of 50 feet may be adequate, but because the report includes no trench logs, the type, extent, and amount of deformation in the fault zone, on which setbacks are based, is unknown. Without trench logs showing locations of faults, I cannot assess if trench length is adequate to address the hazard for the lots within the surface-fault-rupture study-area boundary (Lowe, 1988). Kaliser does not show the location of trench #3 on figure 2. Without the location and a log of trench #3, I cannot determine if the trench adequately addresses the hazard of a subparallel fault mapped by Nelson and Personius (1993).

RADON GAS

The site is in an area of moderate radon-hazard potential (Black and Solomon, 1996). Radon gas represents a possible health hazard where structures intended for human occupancy are planned. Radon-resistant construction techniques should be considered for incorporation into residential structures.

SUMMARY AND RECOMMENDATIONS

Kaliser's (1997) recommendations for problem soils, shallow ground water, and rock-fall hazard are adequate. I recommend that at least a preliminary geotechnical-engineering slope-stability evaluation (Hylland, 1996) be performed for slopes greater than 30 percent along the northern portion of the property, including a detailed description of slope materials, to estimate factors of safety and if failures may affect "buildable areas" under varying suspected ground-water conditions. Also, a geotechnical engineer should provide design recommendations for any planned permanent cut or fill slopes greater than 5 feet high.

Kaliser described the debris-flow hazard as minimal due to the lack of debris-flow deposits at the site. This should be confirmed by observations in the debris-flow source area in Broad Hollow drainage. The potential for sediment-laden debris floods and alluvial-fan flooding from Broad Hollow should be considered in the design of site drainage on the eastern alluvial fan. The surface-fault-rupture-hazard study evaluates only a small portion of the surface-fault-rupture study area. Trench logs must be submitted for review so that I can judge the adequacy of the investigation and proposed setbacks. Given a moderate radon-hazard potential, I recommend that radon-resistant construction techniques be considered in residential construction. I also recommend that the Kaliser report and this review be disclosed to future lot and/or home buyers.

REFERENCES

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Project: Review of "Geotechnical and engineering geology study, residential lot 453 on Green Briar Road, Timber Lakes subdivision, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 4-7-98	County: Wasatch	Job No: 98-08 (R-7)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: none	

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed the geologic-hazards portions of a geotechnical and engineering-geologic report by AGRA Earth & Environmental, Inc. (AGRA, 1998) for a proposed homesite in the Timber Lakes subdivision, Wasatch County, Utah. I received the report on March 25, 1998. The proposed homesite is located in the NW1/4 section 14, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazard maps (Hylland and others, 1995), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the AGRA (1998) report should be reviewed by a qualified geotechnical engineer.

The AGRA (1998) report lists earthquake ground shaking, shallow ground water, and landslides as potential geologic hazards on the property. The report recommends that the proposed structures be designed and constructed to at least meet Uniform Building Code seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking. The report projects a static ground-water table at a minimum depth of 15 feet, but recognizes the potential for local perched ground water at shallower depths and for seasonally shallow ground water. The report found no evidence of recent on-site slope failure and, because of gentle to moderate slopes on the site and surrounding vicinity, considers the potential for deep-seated slope failure unlikely. However, the report acknowledges that shallow slope failures may occur where earthwork modifications oversteepen slopes cut into soils.

I believe that the report provides a complete listing of the potential geologic hazards at the site. I concur with AGRA's recommendations regarding these hazards. Placement of the house on the flatter southern part of the lot eliminates the need for further study of slope stability. I recommend careful construction monitoring to assure that the site plan is followed and AGRA's recommendations are implemented. To minimize the potential for shallow slope failures from cut slopes, I recommend following the general guidelines for Timber Lakes to make permanent cut slopes that are less than 5 feet high no steeper than 2H:1V. If cut slopes higher than 5 feet are planned, a geotechnical study should be required. I also recommend disclosure of the presence of the lot in an area mapped as part of an older landslide complex (Hylland and others, 1995), which underlies much of the Timber Lakes subdivision.

REFERENCES

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Project:			Requesting Agency:
Review of "Geologic and geotechnical investigation, eight residential lots, Deer Crest development near Deer Valley Resort, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 4-7-98	County: Wasatch	Job No: 98-09 (R-8)
USGS Quadrangle: Park City East (1209)		Number of attachments: none	

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed the geologic-hazards portions of an engineering-geologic report by Applied Geotechnical Engineering Consultants (AGEC, 1998) for eight residential lots in the proposed Deer Crest development, Wasatch County, Utah. I received the report on March 11, 1998. The lots are located in the NE1/4SE1/4 section 22, NW1/4SW1/4 section 23, and SE1/4NW1/4 section 23, T. 2 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the AGEC (1998) report should be reviewed by a qualified geotechnical engineer.

AGEC (1998) considered the potential for collapsible and expansive soils, mining-related hazards, earthquake ground shaking, and slope stability. AGEC (1998) found no field evidence for collapsible or expansive soils, and considered local bedrock unlikely to be source material for these types of soils. Therefore, they did not consider these soils to be a hazard for the proposed development, and I concur. AGEC (1998) also found no evidence of mine shafts, adits, prospect pits, or underground workings on the property, and concludes that no mining-related hazards are present. However, a field inspection may not be adequate to determine the presence of mining-related hazards, particularly underground workings which extend beneath the property from offsite openings. I recommend that AGEC supplement their field inventory of mining-related hazards by inspecting maps and records of mining sites maintained by the Utah Division of Oil, Gas, and Mining.

The AGEC (1998) report recognizes that the site is in an area with a moderately high risk from strong earthquake ground shaking. The report recommends that the proposed structures be designed and constructed to at least meet Uniform Building Code (UBC) seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking, and I concur. The report describes the Frog Valley fault, about 0.5 mile northwest of the property along the east side of Deer Valley Meadow, as late Cretaceous to early Tertiary in age according to Gill and Lund (1984). Subsequent work by Sullivan and others (1988) has found that the fault likely postdates middle Quaternary deposits, although they could not conclusively determine a minimum age of faulting. The ground-shaking hazard posed by this fault is not sufficient to indicate a need for upgrade of seismic design beyond the minimum.

AGEC (1998) states that no evidence of landslides or other stability problems was identified. No landslides are shown in Hylland and others (1995) in this area. However, in addition to identifying landslides, a slope-stability assessment must identify the potential for slope failure under conditions that will exist during and after construction and, if necessary, recommend further site-specific studies. I do not believe that the AGEC report does this.

The AGEC (1998) description of geology on the property is not consistent with published geologic mapping, resulting in recommendations for the design of cut slopes which may be inadequate. AGEC excavated seven test pits to investigate shallow subsurface conditions on the properties. Their report describes bedrock encountered in the test pits as interbedded sandstone and siltstone, with "some shaly beds." However, they did not log the test pits in detail, and information on the proportion and condition of the various lithologies is lacking. Their report states that the site is underlain by the Thaynes Formation, consisting primarily of sandstone and siltstone, but Bromfield and Crittenden (1971) map Woodside Shale on lots 1U and 2U. The AGEC report (1998) concludes that much of the development is planned on ridges, "where stability will not be a major concern, due to the presence of shallow bedrock and relatively flat lying bedding." However, slopes on much of the development are between 25 and 40 percent, and I cannot determine the slope on much of lot 1U because of incomplete topographic contours on figure 1 of their report. AGEC's characterization of bedding as "flat lying" does not coincide with bedding attitudes mapped by Bromfield and Crittenden (1971), who map beds dipping east from 15 to 25 degrees near lots 1U and 2U, and beds dipping both west and east from 40 to 80 degrees near lots 3U through 8U. The latter dips, steep and in opposing orientations, may indicate evidence of slope failure or unmapped geologic structure. I believe that the lack of detailed and accurate lithologic information, the presence of shale (which could represent a failure-prone lithology, even if not dominant), steep slopes, and moderate to steep dips of varying orientation indicate a potential for slope failure that has not adequately been characterized.

Additional slope-stability assessments should be conducted prior to development, with the results used to determine buildable areas, appropriate setbacks, slope designs, or other mitigation measures. Because the potential for slope failures is for both shallow debris slides in colluvium (where present) and slab or wedge failures in bedrock, and may depend upon cut slopes specific to proposed site designs, a slope-stability analytical technique appropriate for each condition should be used. Such studies must be performed on a lot-by-lot basis once specific slope designs are proposed. In these studies, the use of deep, circular failure surfaces may be inappropriate because failure surfaces associated with shallow debris slides are not deep, and failure surfaces associated with slab or wedge failures in bedrock are rarely circular. Conservative values for friction angle, cohesion, and ground-water depth should be used to model slope stability to ensure determination of suitable factors of safety under both static and dynamic conditions. Particular attention should be given to assumptions concerning ground-water depth. AGEC states that no subsurface water was encountered in test pits to their maximum depth of 9 feet. However, the test pits were excavated in July and December. Our experience, based on a Utah Geological Survey ground-water assessment in the area (Ashland and others, 1996), indicates that ground-water occurrence is controlled by local geologic structures and stratigraphy. The Thaynes Formation and Woodside Shale commonly contain water, particularly in the spring, as snowmelt infiltrates and collects above impermeable beds or other geologic barriers to flow. Seasonal shallow ground water is thus likely at the site and should be considered in modeling slope stability.

In conclusion, I believe that the AGEC (1998) report adequately addresses the potential for collapsible and expansive soils, and I agree with the AGEC (1998) recommendation for minimum design to UBC seismic zone 3 levels to minimize the risk from earthquake ground shaking. However, I recommend that AGEC supplement their field inventory of mining-related hazards by inspecting maps and records of mining sites maintained by the Utah Division of Oil, Gas, and Mining. I further recommend additional study to inventory existing landslides on lots 3U through 8U. Once complete, the potential for slope failure still must be evaluated on a lot-specific basis. The evaluation should use conservative site-specific values for friction angle, cohesion, and ground-water depth, and should consider proposed site design to analyze the potential for slope failures as both shallow debris slides in colluvium, where present, and slab or wedge failures in bedrock.

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Bromfield, C.S., and Crittenden, M.D., Jr., 1971, Geologic map of the Park City East quadrangle, Summit and Wasatch Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-852, scale 1:24,000.

Gill, H.E., and Lund, W.R., 1984, Engineering geology of Park City, Summit County, Utah: Utah Geological and Mineral Survey Special Study 66, 42 p.

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, scale 1:24,000.

Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1988, Central Utah regional seismotectonic study for USBR dams in the Wasatch Mountains: Denver, U.S. Bureau of Reclamation Seismotectonic Report 88-5, 269 p.

Project:			Requesting Agency:
Review of "Preliminary geologic and geotechnical evaluation, Pinecreek Road alignment, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 5-1-98	County: Wasatch	Job No: 98-10 (R-9)
USGS Quadrangle: Heber City (1168) and Brighton (1169)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed the geologic-hazards portions of a preliminary geologic and geotechnical report by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 1998) for a proposed realignment of Pinecreek Road (Highway 224), Wasatch County, Utah. I received the report on April 8, 1998. The proposed realignment extends between the northern edge of the Wasatch Mountain State Park Golf Course, Midway, on the south and the intersection of Highways 152 and 224 at Bonanza Flat on the north. The proposed realignment is located in section 32, T. 2 S., R. 4 E., and sections 4, 9, 15, 16, and 22, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support the proposed realignment. The scope of work included a review of geologic and geologic-hazard maps, but I did not inspect the property. Conclusions pertaining to grading and slope reinforcement in the AGEC (1998) report should be reviewed by a qualified geotechnical engineer.

The AGEC (1998) report discusses geologic setting, slope gradient, and landslide potential. The report states that the realignment is predominantly on Quaternary alluvial and glacial deposits, surrounded and underlain by Cretaceous and Tertiary intrusive rocks and Precambrian to Triassic sedimentary rocks. The sedimentary rocks mostly consist of resistant quartz, limestone, and sandstone fractured and faulted by the igneous intrusions. This description of the geologic setting is consistent with the geologic maps of Baker and others (1966) and Bromfield and others (1970). Although the AGEC (1998) report does not indicate the age of the faults, neither of the previously published geologic maps of the area show displaced Quaternary material, and the faults are not shown as active in the Quaternary by Hecker (1993). The AGEC (1998) report states that slopes vary from gentle to steep along the realignment, with steepest slopes in the central portion. I concur with this description of slopes. Slopes along the realignment measured on 1:24,000-scale topographic maps rarely exceed 25 percent, and the steeper, central portion of the realignment is traversed by a series of switchbacks with limbs subparallel to topographic contours. AGEC (1998) refers to the lack of significant landslides in the area on the landslide map of Utah (Harty, 1991), and I agree with this description.

The AGEC (1998) report does not consider the potential for problem soils, flooding, or shallow ground water. Problem soils are not mapped in the area by Mulvey (1992) and, although hazard mapping by Hylland and others (1995) does not extend into the realignment area, the mapping does not show problem soils in adjacent areas with similar geology. Hylland and others (1995) map a stream-flood hazard north of the realignment in the stream that drains Bonanza Flat, and this hazard is likely in the remainder of the stream and in nearby Pine Creek. The proposed realignment crosses the Bonanza Flat drainage just north of its confluence with Pine Creek in the

SW1/4 section 4, T. 3 S., R. 4 E., and crosses Pine Creek in the NE1/4 section 16, T. 3 S., R. 4 E. Hylland and others (1995) also map shallow ground water south of the proposed realignment, and shallow ground water may extend beneath the realignment in section 22, T. 3 S., R. 4 E.

With the exception of potential stream flooding and shallow ground water, I believe that the AGEC (1998) report adequately characterizes geologic hazards at a level suitable for a preliminary evaluation. A more detailed field investigation of soils and slope stability will be required should the project proceed. This is consistent with recommendations in the AGEC (1998) report for "subsurface investigation...once weather conditions permit access to the site (p. 1)," and for "field reconnaissance, subsurface investigation, and engineering analysis...to determine if stability is a concern along the proposed alignment (p. 3)." The field investigation should include, but not be limited to, shallow borings and laboratory analyses to determine the potential for problem soils. I also recommend a geotechnical study for the design of earthwork modifications and site drainage. Once the geotechnical study is complete, the design of significant cut and fill slopes and, if needed, slope reinforcement should be reviewed by a qualified geotechnical engineer to minimize the potential for shallow slope failures, and drainage design should be reviewed by a qualified engineer to minimize the potential for flooding from streams and shallow ground water.

REFERENCES

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Baker, A.A., Calkins, F.C., Crittenden, M.D., Jr., and Bromfield, C.S., 1966, Geologic map of the Brighton quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-534, scale 1:24,000.

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Harty, K.M., 1991, Landslide map of Utah: Utah Geological Survey Map 133, 28 p., scale 1:500,000.

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Mulvey, W.E., 1992, Soil and rock causing engineering geologic problems in Utah: Utah Geological Survey Special Study 80, 23 p., scale 1:500,000.

Project:			Requesting Agency:
Review of "Draft report--Engineering geology and geotechnical evaluation, lot 116 of Interlaken development, Heber City, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 6-16-98	County: Wasatch	Job No: 98-15 (R-10)
USGS Quadrangle: Heber City (1168)		Number of attachments: none	

INTRODUCTION

At the request of Anthony Kohler, Wasatch County Planning Assistant, I reviewed a draft engineering geology and geotechnical report (Dames & Moore, 1998) for lot 116 of the Interlaken development in Heber City, Wasatch County, Utah. I received the report on June 2, 1998. Lot 116 is located in the NW1/4SE1/4 section 22, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Dames & Moore (1998) adequately identified and addressed geologic hazards that could potentially affect the lot. My scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in Dames & Moore (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

Landsliding

Dames & Moore (1998) indicates that the area including the property is mapped with a moderate landslide potential by Hylland and Lowe (1995), but Dames & Moore staff did not observe any evidence of slope instability on the property during their field reconnaissance. Because the house to be built on the lot will be founded on bedrock, Dames & Moore (1998) reports results of quantitative slope-stability analyses which assess the likelihood of circular failures in rock. Dames & Moore (1998) concludes that this type of landsliding seems unlikely and, consequently, considers the landslide hazard for the property to be low.

Although I concur with the report conclusion that the likelihood of circular failures in rock is low, I do not believe that Dames & Moore (1998) addresses the most likely failure modes for the subsurface conditions described at this site. Black and Ashland (1998) reviewed a geotechnical evaluation (Dames & Moore, 1997) for lot 146 of the Interlaken development, about 0.4 mile south of lot 116. Subsurface conditions at the two lots are similar, consisting of a layer of topsoil, colluvium, and weathered rock overlying Paleozoic rock on steep slopes. Black and Ashland (1998) stated that the most likely failure mode for these subsurface conditions is shallow debris sliding of the slope soils and weathered rock along the rock interface, and I agree. Hylland and Lowe (1995) map a slide of this type in the slope roughly 300 feet south of lot 146. Because failure surfaces associated with such debris slides are shallow and not circular, the quantitative slope-stability analyses of Dames and Moore (1998) do not consider these failures. Using an infinite-slope analysis, Black and Ashland (1998) estimated a static factor of safety of 1.1 for shallow slides on steep slopes (about 30 percent grade) of lot 146 under dry conditions. On the steeper slopes (about 40 percent grade) of lot 116, and with seasonal infiltration from snowmelt or rainstorms and undercutting by road and building-pad cuts, stability could be reduced even further. I therefore do not agree with the Dames & Moore (1998) characterization of the landslide hazard as low.

Other failure modes not considered by Dames & Moore (1998) are slab or wedge failures along bedrock discontinuities such as bedding planes or fractures. Because failure surfaces associated with slab or wedge failures in bedrock are rarely circular, the use of circular failure surfaces in the quantitative slope-stability analyses of Dames and Moore (1998) is inappropriate for consideration of these slab or wedge failures. 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 for lot 116.

The potential for slope failures and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. The importance of these design and construction considerations is acknowledged by Dames & Moore (1998), which makes several relevant recommendations. I agree with the general scope of the recommendations, but their adequacy cannot be determined until after final site design of grading and drainage. Careful consideration should be given to the potential impact of site drainage on downslope roads and structures.

Other Geologic Hazards

In addition to landslides, Dames & Moore (1998) addresses the potential for earthquake ground shaking, surface fault rupture, liquefaction, rock fall, and debris flows and flooding. The report identifies earthquake ground shaking as a potential hazard and recommends that, at a minimum, all buildings be designed and constructed to meet Uniform Building Code (UBC) Seismic Zone 3 criteria. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. Dames & Moore (1998) indicates no active faults have been mapped at the property and they observed no evidence for active faulting in their field reconnaissance. Based on these data, Dames and Moore (1998) believes the risk from surface faulting is low. Dames & Moore (1998) also believes that the liquefaction potential is very low because of the lack of saturated granular sediment, the rock fall potential is low because of the lack of fallen rock clasts and perched boulders, and the debris-flow and flooding potential is low because of the lack of major alluvial fans or large drainage channels. I believe that the assessment of these geologic hazards by Dames and Moore (1998) is complete and accurate.

RECOMMENDATIONS

I agree with the Dames & Moore (1998) assessment that deep-seated circular bedrock failures are unlikely at the site, but recommend they also evaluate the potential for:

- shallow debris slides in thin soils and weathered rock, including assessing their impact on the proposed building and on downslope development, and
- failures along rock discontinuities such as inclined bedding planes or fractures in cuts exposing rock, particularly in cuts greater than 5 feet high.

I also recommend that:

- final site design of grading and drainage consider the impact of site drainage on slope stability and erosion affecting downslope roads and structures, and
- recommendations pertaining to foundation design and site grading in the Dames & Moore (1998) report and subsequent studies recommended above be reviewed by a qualified geotechnical engineer.

REFERENCES

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----1998, Draft report--Engineering geology and geotechnical evaluation, lot 116 of Interlaken Development, Heber City, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 11 p.

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Project:			Requesting Agency:
Review of "Review of Wasatch County issues, Jordanelle Heights subdivision, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon and Francis X. Ashland	Date: 6-18-98	County: Wasatch	Job No: 98-16 (R-11)
USGS Quadrangle: Heber City (1168)		Number of attachments: none	

INTRODUCTION

At the request of Sharon Mayes-Atkinson, Assistant Director of Planning for Wasatch County, we reviewed a geotechnical report by Kleinfelder, Inc. (Kleinfelder, 1998) for the proposed Jordanelle Heights subdivision, Wasatch County, Utah. The proposed subdivision is located in the W1/2 section 31, T. 2 S., R. 5 E., Salt Lake Base Line and Meridian. We received the report on May 21, 1998. The report responds to the concerns of Wasatch County, raised during approval reviews for the project, regarding the potential for surface fault rupture and slope instability. An earlier geotechnical report related to the proposed subdivision (Terracon Consultants Western, 1995) was reviewed by Ashland (1997). The scope of work for our review included an evaluation of geologic-hazards literature, but we did not inspect the property. Recommendations pertaining to site grading in the Kleinfelder (1998) report should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The Kleinfelder (1998) report states that the western portions of several lots on which single-family houses are to be constructed lie within the surface fault-rupture special-study zone for the Bald Mountain fault (Hylland and Bishop, 1995). The lots are within about 500 feet of the mapped fault trace. The Kleinfelder (1998) report infers that a water-storage tank also will be within the special-study zone, although the exact location of the proposed tank is not indicated. Because Sullivan and others (1986) found no evidence of Holocene activity associated with the Bald Mountain fault, Hylland and Bishop (1995) recommend that the surface fault-rupture hazard need only be considered for essential facilities within the special-study zone. Kleinfelder (1998) recommends that a fault study be performed for the water-storage tank prior to construction because it is an essential facility needed for emergency operations. The report states that a fault study is not necessary prior to construction of the single-family houses, which are not considered essential facilities, but recommends that foundation excavations for houses within the special-study zone be inspected by an engineering geologist prior to placement of any reinforcing steel or concrete. We agree with the recommendations in the Kleinfelder (1998) report related to the surface fault-rupture hazard.

The Kleinfelder (1998) report addresses three aspects of slope stability: (1) cut-slope design, (2) the stability of large fill slopes along roads, and (3) the stability of embankments adjacent to detention basins. The report recommends cut-slope designs for bedrock, weathered bedrock, and soil, for slopes both greater and less than 10 feet in height. These recommendations for cut-slope design should be reviewed by a qualified geotechnical engineer. Our evaluation suggests that the bedrock cut-slope recommendations may be inadequate because they ignore possible rock discontinuities. Such discontinuities may include steep, east-dipping bedding planes within Paleozoic sedimentary rocks, with dips near the site that range from 55 to 60 degrees (Bromfield and others, 1970), and fractures in rocks near the Bald Mountain fault. The stability of large fill slopes along roads, evaluated by Kleinfelder (1998) with PCSTABL 5M, appears satisfactory, but the Kleinfelder (1998) analysis of embankment stability near the detention basins is apparently in error. Kleinfelder (1998) models the rapid drawdown of the basin assuming a friction angle of 0 in embankment fill, indicating they performed an unconsolidated-undrained analysis. However, if constructed properly, soils in the basin embankment are consolidated. Therefore, a consolidated-undrained analysis is appropriate to model the rapid drawdown of reservoir slopes (Holtz and Kovacs, 1981, p. 556). The inappropriate use of an unconsolidated-undrained analysis results in a higher factor of safety calculated for the rapid-drawdown condition than for a full reservoir, an improbable scenario.

RECOMMENDATIONS

We agree with the recommendations in the Kleinfelder (1998) report related to the surface fault-rupture hazard:

- a fault study should be performed for the water-storage tank prior to construction, and
- foundation excavations for houses within the surface fault-rupture special-study zone for the Bald Mountain fault should be inspected by an engineering geologist prior to placement of any reinforcing steel or concrete.

In addition, we recommend that:

- cut-slope recommendations be reviewed by a geotechnical engineer,
- cut-slope designs in bedrock consider rock discontinuities such as inclined bedding planes and fractures,
- lot-specific studies be required for all permanent cuts greater than 5 feet high in which rock is exposed, if discontinuities in rock are found to be important to cut-slope stability, and
- the stability of embankments adjacent to detention basins be modeled using a consolidated-undrained analysis, with analysis results reviewed by a qualified geotechnical engineer.

REFERENCES

Ashland, F.X., 1997, Review of "Report of subsurface soils exploration - proposed Jordanelle subdivision near Jordanelle Dam, Utah," *in* Mayes, B.H., compiler, Technical Reports for 1996 Applied Geology Program: Utah Geological Survey Report of Investigation 231, p. 123.

Bromfield, C.S., Baker, A.A., and Crittenden, M.D., Jr., 1970, Geologic map of the Heber quadrangle, Wasatch and Summit Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-864, scale 1:24,000.

Holtz, R.D., and Kovacs, W.D., 1981, An introduction to geotechnical engineering: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 733 p.

Hylland, M.D., and Bishop, C.E., 1995, Flood hazards, earthquake hazards, and problem soils, western Wasatch County, Utah, *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, 12 plates, scale 1:24,000.

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Sullivan, J.T., Nelson, A.R., LaForge, R.C., Wood, C.K., and Hansen, R.A., 1986, Regional seismotectonic study for the back valleys of the Wasatch Mountains in northeastern Utah: Denver, Colorado, U.S. Bureau of Reclamation Seismotectonic Section, 317 p.

Terracon Consultants Western, 1995, Report of subsurface soils exploration - proposed Jordanelle subdivision near Jordanelle Dam, Utah: Salt Lake City, Utah, unpublished consultant's report, 9 p.

Project: Review of "Geotechnical study, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 6-22-98	County: Wasatch	Job No: 98-17 (R-12)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Anthony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report by Earthtec Testing & Engineering (Earthtec, 1998) for lot 1369 of the Timber Lakes subdivision, Wasatch County, Utah. I received the report on June 1, 1998. Lot 1369 is located in the SE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review was to assess whether Earthtec (1998) adequately addressed the potential for landsliding on the lot. My scope of work included a review of published geologic-hazard maps (Hylland and Lowe, 1995) and aerial photographs (1987, 1:40,000 scale), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in Earthtec (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

Lot 1369 lies on a steep slope adjacent to the south edge of a landslide deposit (Utah Geological Survey, unpublished mapping). The close proximity of this lot to the landslide, and the likelihood that material from the lot contributed to the landslide deposit, indicates a potential for instability. Earthtec (1998) estimates the slope gradient at lot 1369 to be as much as 45 percent near the center of the lot, decreasing to 18 percent to the northwest and 23 percent to the southeast. Subsurface conditions at the lot consist of a layer of topsoil, colluvium, and weathered rock overlying bedrock. Because of the steep slope, Earthtec (1998) conducted a preliminary geotechnical-engineering slope-stability analysis consistent with the recommendations of Hylland (1996). The analysis used the computer program SB-Slope by Geosystem Software to model slope stability with the simplified Bishop's method of slices. Earthtec (1998, figures 6 and 7) modeled three potential failure surfaces: two shallow, circular failures in the soil above bedrock (failures 1 and 2) and one deep circular failure that extends to depths below the top of bedrock encountered in three test pits (failure 3). I believe that Earthtec (1998) assumed realistic estimates of soil factors, based on laboratory testing and observation of soils exposed in the test pits, to model slope stability. These factors include a depth to ground water of 5 feet, representing the influence of a septic-tank soil-absorption (STSA) system. Under these assumptions, Earthtec (1998) considers the slope to be stable under both static and pseudo-static conditions.

Although I concur with the report conclusion that circular failures are unlikely, I do not believe that Earthtec (1998) addresses other potential failure modes for the subsurface conditions described at this site. A likely failure mode for these subsurface conditions is shallow debris sliding of the slope soils and weathered rock along the rock interface. Because failure surfaces associated with such debris slides are not circular, the quantitative slope-stability analyses of Earthtec (1998) do not consider these failures. Earthtec (1998) also does not address typical bedrock failure modes, including slab or wedge failures along bedrock discontinuities such as bedding planes or fractures. Because failure surfaces associated with slab or wedge failures in bedrock are rarely circular, the use of circular failure surfaces in the quantitative slope-stability analyses of Earthtec (1998) is inappropriate for consideration of these slab or wedge failures. Earthtec (1998) does not discuss bedding or fracture attitudes, spacing, or continuity to determine whether analysis of these failure modes is warranted. The potential for such bedrock slope failures may be particularly important in permanent cuts exposing bedrock if cut-slope heights greater than 5 feet are planned for lot 1369.

The potential for slope failures and erosion can be reduced by proper site drainage, reduction of runoff and moisture infiltration into site slopes, and the use of retaining walls. Earthtec (1998) makes several recommendations related to surface and subsurface drainage. However, their recommendations related to surface drainage are concerned with diverting drainage from foundation walls, and do not address the potential impact of site drainage on slope stability and downslope roads and structures. Earthtec (1998) also recommends the installation of a foundation drain along basement walls to divert subsurface drainage, grading of the drain to a proper outlet, and design of the upslope basement wall as a retaining structure. The design of foundation drains and basement retaining walls is beyond the scope of my review, but I agree with the general scope of the recommendations. As with the design of surface drainage, particular attention should be paid to grading of the foundation-drain outlet to ensure consideration of its potential impact on slope stability and downslope roads and structures. The adequacy of design features cannot be determined until after final site design of grading and drainage.

Site design must also consider the placement of a STSA system and its influence on slope stability. Utah Division of Water Quality (UDWQ, 1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability. Earthtec (1998) input a shallow ground-water depth in their slope-stability analyses for circular failures to represent the influence of a STSA. A similar shallow depth should be used to analyze other modes of slope failure discussed above. In addition, much of the site slope exceeds the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems (25 percent). Flatter areas of the lot are limited and, with setbacks imposed by UDWQ and Wasatch County, may be inadequate for a STSA system. Shallow bedrock on lot 1369 may further restrict placement of a STSA system.

RECOMMENDATIONS

I agree with the Earthtec (1998) assessment that circular slope failures are unlikely at the site, but recommend they also evaluate the potential for:

- shallow debris slides in thin soils and weathered rock, including assessing their impact on the proposed building and on downslope development, and
- if warranted, failures along rock discontinuities such as inclined bedding planes or fractures, particularly in permanent cuts greater than 5 feet high exposing rock.

I also recommend that:

- final site design of grading and drainage consider the impact of site drainage and placement of a STSA system on slope stability and erosion affecting downslope roads and structures, and
- recommendations pertaining to foundation design and site grading in the Earthtec (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

REFERENCES

Earthtec Testing & Engineering, 1998, Geotechnical study, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 5 p.

Hylland, M.D., 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Project: Review of report "Geologic and geotechnical investigation, Rancho Vista subdivision, 1000 North Mountain Road, Ogden, Utah."			Requesting Agency: Ogden City
By: Bill D. Black	Date: June 25, 1998	County: Weber	Job No: 98-19 (R-13)
USGS Quadrangle: North Ogden (1370)		Number of attachments: None	

INTRODUCTION

This report is a review of the geologic-hazards sections of a report by Applied Geotechnical Engineering Consultants (AGEC) for the Rancho Vista subdivision (AGEC, 1998) located at approximately 1000 North Mountain Road in Ogden City (NE1/4NE1/4 section 9, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian), Weber County, Utah. John Mayer (Planner, Ogden City) requested the review. The report was received by the Utah Geological Survey on June 11, 1998. The purpose of this review is to evaluate whether geologic hazards were adequately addressed. The scope of work consisted of a literature review and examination of 1:24,000-scale aerial photos (1985). No site visit was made.

DISCUSSION

Surface fault rupture and ground shaking are potential earthquake hazards affecting the property (AGEC, 1998). AGEC (1998) did not conduct a surface-fault-rupture-hazard investigation because it was beyond the scope of their report. The main trace of the Wasatch fault zone (WFZ) is along the eastern edge of the property approximately 500 feet (152 m) east of Mountain Road. The property is also in a special-study zone on unpublished Weber County Planning Department maps (Lowe, 1989a) where studies are recommended to evaluate surface-faulting hazards. Therefore, studies are needed to address the hazard from surface fault rupture, including trenching across the subdivision to identify faults and fault-related deformation to provide appropriate setbacks for occupied structures. To reduce the risk from ground shaking, AGEC (1998) recommends that all buildings be designed and constructed to meet Uniform Building Code (UBC) seismic zone 3 criteria. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. AGEC (1998) indicates the property is in a mapped area of very low liquefaction potential, which they believe is appropriate based on the subsurface conditions they encountered. I concur with this assessment.

AGEC (1998) indicates that the numerous rock-fall boulders on the property from bedrock outcrops in steep slopes above and to the east suggest rock fall is a hazard. Computer modeling conducted by AGEC (1998) indicates rocks from these outcrops having sizes typical of those found at the property may run out to the central part of the property and have bounce heights up to 8 feet (2.4 m). To reduce the risk from rock falls, AGEC (1998) recommends constructing a berm or barrier at least 10 feet (3 m) high along the east side of the property. I concur with their assessment and recommendation, but add that care should be taken to maintain proper drainage behind (east of) the berm.

AGEC (1998) indicates the southeastern part of the property is underlain by an active alluvial fan that may be subject to debris flows. The nearest major debris-flow source is Jumpoff Canyon 0.5 miles (0.8 km) to the south (AGEC, 1998). Because of the distance of the property from the canyon mouth and topography of the channel, AGEC (1998) believes debris flows are not a potential hazard. I concur that the risk from a debris flow or flash flood reaching the site from Jumpoff Canyon appears low. However, a cloudburst rainstorm could cause a debris flow or flash flood in the unnamed drainage southeast of the property that could reach the property. The rock-fall berm (if properly designed) could serve a dual purpose and be extended along the southern edge of the property (along the portion on the alluvial fan) to deflect debris and/or floodwaters. However, care would be required to ensure that such a measure would not increase hazards to adjacent properties.

The remaining area of the property not on the alluvial fan is on a landslide shown on unpublished Weber County Planning Department maps (Lowe, 1989b). AGEC (1998) indicates this landslide shows no evidence of recent movement, and they believe it is likely an old deposit. Based on this, AGEC (1998) believes the hazard from landslides is low. Mike Lowe (former Weber County geologist, verbal communication, June 1998) and I agree with their assessment. Slopes on the property are generally gradual and do not exceed 30 percent on AGEC's (1998) site map. However, improper site grading could cause localized failures (possibly exacerbated by landscape irrigation). AGEC (1998) recommends permanent unretained cut slopes up to 15 feet (4.6 m) high be no steeper than 2:1 (horizontal to vertical), higher cut slopes be no steeper than 3:1, and that slopes on the east side of the property should not be steepened beyond their present slope. Cuts showing seepage should also be re-evaluated (AGEC, 1998). These recommendations appear reasonable, but should be reviewed by a geotechnical engineer. I further recommend Ogden City ensure AGEC's recommendations are followed and that no unplanned cuts (such as for landscaping) are made.

AGEC (1998) encountered shallow ground water (from ground surface to 4 feet [1.3m] deep) in two test pits in the northeastern portion of the property, and indicates perched water may be a problem in the area. AGEC (1998) recommends buildings with floor levels extending below grade and within 3 feet (0.9 m) of the water level be protected with an underdrain system. I concur with their assessment and recommendation. AGEC (1998) recommends minimum requirements for the underdrain system, and these recommendations appear reasonable but should also be reviewed by a geotechnical engineer.

SUMMARY AND RECOMMENDATIONS

AGEC (1998) identifies hazards from surface faulting, earthquake ground shaking, rock fall, debris flows/flash floods, and shallow ground water. Regarding AGEC's (1998) recommendations to reduce the risk from these hazards, I recommend:

- a surface-fault-rupture-hazard investigation be conducted;

- rock-fall and debris-flow/flash-flood hazard-reduction measures be taken, ensuring they do not affect adjacent properties; and
- foundation, grading, and underdrain recommendations be reviewed by a qualified geotechnical engineer.

REFERENCES

Applied Geotechnical Engineering Consultants Inc., 1998, Geologic and geotechnical investigation--Rancho Vista Subdivision, 1000 North Mountain Road, Ogden, Utah: Salt Lake City, unpublished consultant's report, 20 p.

Lowe, Mike, 1989a, Potential surface fault rupture sensitive area overlay zone--North Ogden quadrangle: unpublished Weber County Planning Department Map, scale 1:24,000.

----1989b, Slope-failure inventory map--North Ogden quadrangle: unpublished Weber County Planning Department Map, scale 1:24,000.

Project:			Requesting Agency:
Review of "Geotechnical study for Rasmussen development, 2975 Melanie Lane, Ogden, Weber County, Utah"			Weber County Planning
By: Richard E. Giraud	Date: 6-25-98	County: Weber	Job No: 98-20 (R-14)
USGS Quadrangle: Ogden (1345)		Number of attachments: none	

INTRODUCTION

At the request of Jim Gentry, Weber County Planning Commission, I reviewed a geotechnical report by Earthtec Engineering, P.C. (Earthtec) for a lot at 2975 Melanie Lane in the Rasmussen subdivision, Ogden, Utah. The lot is located in the NW1/4 SW1/4 section 24, T. 5 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 interpretation of aerial photographs (1985; scale 1:24,000), a literature review, and inspection of published geologic maps and Weber County geologic-hazard maps. I did not conduct a field inspection of the property. Recommendations pertaining to foundation design and site grading should be reviewed by a qualified geotechnical engineer.

Earthtec (1998) addresses problem soils, shallow ground water, slope stability, and faulting. Recommendations concerning problem soils and shallow ground water are adequate. However, the report does not adequately address slope stability and surface fault rupture.

SLOPE STABILITY

Sediments at the site were deposited in Lake Bonneville as part of the Weber River delta. Steep slopes in these delta sediments are typically prone to landsliding, and slope conditions involving addition of water often contribute to slope instability (Lowe, 1985, 1990).

The topography of the site is dominated by a steep southwest-facing slope. The slope gradient averages 51 percent with steeper portions up to 75 percent. The slope is 90 feet high. Earthtec (1998) states that there were "no visually evident signs of unstable slopes or existing springs." However, considerable evidence is present in the area for landslides in slopes similar to the slope at the lot. Nelson and Personius (1993) map a landslide escarpment on the lot's steep southwest-facing slope, and several other escarpments on the same slope north and south of the lot. They also show large areas of landslides in similar slopes southwest of the site. Lowe (1988a) maps two active landslides, in similar geologic materials, on the southwest-facing slope immediately south of the site. Recent landslide deposits are present southwest of the site at 6100 South 2850 East in the Uintah Highland homesites (SHB AGRA, Inc., 1993). Kaliser (1969) documents a slope failure in water-saturated fine-grained sediments that caused residential damage south of the site at 6302 Bybee Drive. Because of these concerns, the site is within an area where a landslide-hazard special study is recommended (Lowe, 1988b).

Regarding ground water, Earthtec indicates no existing evidence for springs, but they refer to a spring collection system in the area (Earthtec, 1998; p. 1) and suggest "ground water poses a serious constraint on the site and should be controlled." I agree, and believe ground-water conditions must be understood to assess slope stability.

A building location is not specified in the report, but I understand it is planned at the top of the slope on the east side of the property (Matt Rasmussen, land owner, verbal communication to Gary E. Christenson, June 19, 1998). The evidence for landsliding in the vicinity of the lot suggests to me that a detailed study of slope stability is necessary to evaluate the landslide hazard and to determine a setback from the top of the steep slope. Earthtec (1998) addresses the stability of planned cuts and fills but not the stability of the steep slope. Earthtec (1998) also does not address whether subdivision modifications such as grading, excavation, and landscape irrigation will destabilize the natural steep slope.

In my review of aerial photographs, I noted that the upper eastern part of the lot is on a bench separated from the slope to the east by a scarp on the east side of Melanie Lane. The scarp trends northwest and may be landslide-related but may also be fault- or erosion-related. The origin of the bench and the scarp east of Melanie Lane should be investigated as part of the detailed slope-stability investigation. If the scarp is landslide-related, the proposed building site would be on the head of an existing landslide, the stability of which would need to be addressed.

SURFACE-FAULT-RUPTURE HAZARDS

Earthtec (1998) states that, based on published literature, the Wasatch fault is located 250 feet east of the site and that a secondary fault trace appears to end at the northeast corner of the lot. Earthtec does not cite a reference for this fault location, but it is incorrect. Nelson and Personius (1993) map the main trace of the Wasatch fault along the east side of Uintah Reservoir (Bybee Pond) at the toe of the steep slope on the lot. The steep slope is a fault scarp that has formed by repeated movement on the Weber segment of the Wasatch fault.

The site is within a surface-fault-rupture hazard special-study area (Lowe, 1988c). Within the special-study area, trenching studies are recommended to assess the impacts of faulting on the site and, if necessary, to determine an appropriate setback from the fault. Geologic logs of the trenches are required to show the type, extent, and amount of deformation in the fault zone and provide a basis for setback recommendations. As mentioned above, the scarp east of Melanie Lane may be fault-related, thus the site may be between two faults.

SUMMARY AND RECOMMENDATIONS

Earthtec's (1998) recommendations for problem soils and shallow ground water are adequate. I recommend that a detailed geotechnical-engineering slope-stability evaluation, as outlined in Hylland (1996), be performed to evaluate both static and seismic slope-stability conditions. The slope-stability evaluation should determine:

- depth to ground water and soil conditions to at least the base of the slope,
- slope performance under estimated development-induced (landscape irrigation) ground-water conditions,
- an appropriate setback distance from the top of the steep southwest-facing slope, and
- the likely origin of the bench and scarp east of Melanie Lane and its relation to landsliding.

The slope-stability evaluation and recommendations should be reviewed by a qualified geotechnical engineer.

I also recommend a fault investigation including, at a minimum, trenching to assess whether a fault underlies the building footprint. Although I agree with Earthtec's recommendation to inspect the foundation excavation for faults, I recommend trenching first, to identify faults in case setbacks are needed to locate the house. I also recommend that the Earthtec report, this review, and any subsequent geologic-hazards reports for this lot be disclosed to future lot and/or home buyers.

REFERENCES

Earthtec Engineering, P.C., 1998, Geotechnical study, Rasmussen Development, 2975 Melanie Lane, Ogden, Utah: Ogden, unpublished consultant's report for Matt Rasmussen, 11 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Kaliser, B.N., 1969, Preliminary reconnaissance of a landslide, Uintah, Weber County: Utah Geological and Mineralogical Survey Report of Investigation 43, 2 p.

Lowe, Mike, 1985, Report of geologic reconnaissance - landslide southwest of Gibbons and Reed Co. North pond, west of Uintah, Weber County, *in* Black, B.D., and Christenson, G.E., compilers, Technical reports of the Wasatch Front county geologists, June 1985 to June 1988: Utah Geological and Mineral Survey Report of Investigation 218, p. 76-77.

---1988a, Natural hazards overlay zone - slope-failure inventory map, Ogden quadrangle: Weber County Planning Department unpublished map, scale 1:24,000.

---1988b, Natural hazards overlay zone - landslide hazard map, Ogden quadrangle: Weber County Planning Department unpublished map, scale 1:24,000.

---1988c, Natural hazards overlay zone - potential surface fault rupture, Ogden quadrangle: Weber County Planning Department unpublished map, scale 1:24,000.

---editor, 1990, Geologic hazards and land-use planning - background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Utah Geological and Mineral Survey Open-File Report 197, 70 p.

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 Miscellaneous Investigations Series Map I-2199, 22 p. pamphlet, scale 1:50,000.

SHB AGRA, Inc., 1993, Report, fault rupture, landslide, and ground water hazards evaluation, Uintah Highland homesites, approximately 6100 South 2850 East and 6100 South Osmond Lane, Weber County, Utah: Salt Lake City, unpublished consultant's report, 9 p.

Project:			Requesting Agency:
Review of "Engineering geology site reconnaissance, single-family residential lot, lot 1003 on Spring Creek Drive, Timber Lakes subdivision, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 7-2-98	County: Wasatch	Job No: 98-22 (R-15)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Anthony Kohler, Wasatch County Planning Assistant, I reviewed an engineering-geology report by AGRA Earth & Environmental, Inc. (AGRA, 1998) for lot 1003 of the Timber Lakes subdivision, Wasatch County, Utah. I received the report on June 19, 1998. Lot 1003 is located in the NE1/4 section 15, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether AGRA (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards literature (EarthStore, 1988; Hylland and Lowe, 1995, 1997) and aerial photographs (1987, 1:40,000 scale), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in AGRA (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The AGRA (1998) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. I believe the report adequately addresses these potential geologic hazards and I concur with AGRA's conclusions and recommendations related to them.

The AGRA (1998) report also addresses landslides and slope stability. AGRA states that the nearest mapped landslides are from 2,700 to 4,400 feet away, bordering Lake Creek. Slope profiles across the lot (AGRA, 1998, figures 3A and 3B) show the lot to consist of a narrow ridge top separating a slope of about 30 percent to the west from a slope of about 50 percent to the east. AGRA's analysis indicates that the only area of potential slope instability is the steeper, eastern slope. AGRA recommends placing the proposed house on the western part of the site, beyond a 2H:1V setback line projected from the base of either the eastern slope or road cut near the base of this slope, whichever is more conservative. AGRA (1998, p. 5) considers this setback to be reasonable based on their interpretation of a lack of active landsliding and minimal stream erosion at the base of the slope.

I believe that the AGRA (1998) report does not adequately support its proposed setback recommendation. Hylland and Lowe (1995) map the area as part of a large landslide complex and assign a moderate landslide hazard to the western slope and a high landslide hazard to the eastern slope because of the slope gradients and underlying landslide deposits. AGRA (1998, p. 4) stated that their analysis indicated potential slope instability on the steeper eastern slope, but the AGRA report did not include a quantitative slope-stability analysis either to support this conclusion or to justify the proposed 2H:1V setback along the eastern slope.

The potential for slope instability and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. AGRA (1998, p. 5) recommends that final grading direct water flow away from the eastern slope. Site design must also consider the placement of a septic-tank soil-absorption (STSA) system and its influence on slope stability. Utah Division of Water Quality (UDWQ, 1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability. AGRA (1998, p. 5) recommends that STSA drainfields be "established away from the steep east slope," but does not give setback recommendations. Both the eastern and western slopes (with slopes of about 50 and 30 percent, respectively) exceed the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems (25 percent). Flatter areas of the lot are limited and, with setbacks imposed by UDWQ and Wasatch County, may be inadequate for a STSA system.

RECOMMENDATIONS

The geologic evaluation in AGRA (1998) indicates a potential for instability of the eastern slope, but the evaluation does not adequately document that the recommended 2H:1V setback is sufficient to prevent damage on lot 1003. I therefore recommend:

- at least a preliminary geotechnical-engineering evaluation of the eastern slope at the site, consistent with the recommendations of Hylland (1996), to assess the potential impact of landslides on the proposed building and on downslope development, and
- that the evaluation include a topographic map at a scale suitable for site planning, created by a qualified surveyor, showing recommended building setbacks, non-buildable areas, the STSA-system location, and any site-design features to reduce hazards.

I also recommend that:

- final site design of grading and drainage consider the impact of site drainage and placement of a STSA system on slope stability and erosion that could affect downslope roads and structures, and
- recommendations pertaining to foundation design and site grading in the AGRA (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

REFERENCES

AGRA Earth & Environmental, Inc., 1998, Engineering geology site reconnaissance, single-family residential lot, lot 1003 on Spring Creek Drive, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 7 p.

EarthStore, 1988, Geotechnical/engineering geology study - plats 19A, 19B, 20A, and 20B, Timber Lakes development, located approximately seven miles east of Heber, Utah, in Wasatch County: Salt Lake City, Utah, unpublished consultant's report, 14 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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

----1997, Regional landslide-hazard evaluation using landslide slopes, western Wasatch County, Utah: Environmental & Engineering Geoscience, vol. 3, no. 1, p. 31-43.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Project:			Requesting Agency:
Review of "Geotechnical investigation, Oak Dell subdivision, 2400 North 2700 East, Layton, Utah."			Layton City
By: Bill D. Black	Date: 07-07-98	County: Davis	Job No: 98-23 (R-16)
USGS Quadrangle: Kaysville (1320)		Number of attachments: None	

INTRODUCTION

This report is a review of a geotechnical investigation conducted by Applied Geotechnical Engineering Consultants, Inc. (AGEC) for the former Oak Dell (now Deer Haven) subdivision (AGEC, 1997) at 2400 North 2700 East, Layton (NE1/4SE1/4 section 11, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian), Davis County, Utah. Doug Smith (Planner, Layton City Planning Department) requested the review. The report was received by the Utah Geological Survey on June 11, 1998. The purpose of this review is to assess whether AGEC (1997) adequately identified and addressed geologic hazards that could potentially affect the subdivision. The scope of work consisted of a literature review and examination of 1:24,000-scale aerial photos (1985). No site visit was made.

DISCUSSION

AGEC (1997) indicates that liquefaction and earthquake ground shaking are the principal geologic hazards affecting the subdivision (AGEC, 1997). AGEC (1997) indicates the property is in an area of mapped high liquefaction potential, but they did not conduct any site-specific liquefaction analyses. AGEC (1997) observed no evidence for shallow ground water in their subsurface investigation and, based on the lack of water, they believe natural soils at the property are not susceptible to liquefaction. However, AGEC (1997) also indicates shallow perched ground-water conditions could develop at the site. Natural seasonal water-level variations and/or landscape irrigation could cause areas of perched ground water and conditions conducive to liquefaction. Therefore, I recommend AGEC assess the liquefaction hazard assuming shallow ground-water conditions and, if necessary, provide recommendations to reduce the risk of damage from liquefaction. To reduce the risk from ground shaking, AGEC (1997) recommends that all buildings be designed and constructed to meet minimum Uniform Building Code (UBC) seismic zone 3 criteria. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards.

Shallow (perched) ground water and cut-slope instability are also possible hazards at the subdivision (AGEC, 1997). To reduce the risk from shallow ground water, AGEC (1997) recommends that buildings with below-grade floor levels have underdrain systems and I concur. The subdivision is in the bottom of a drainage flanked by steep slopes to the north and south. A plat map of the subdivision provided to me by Layton City shows buildings are planned on the lower portion of slopes less than 30 percent, generally on the north side of the drainage. Minor cuts are anticipated in these areas for buildings and roads (AGEC, 1997). To reduce the risk of cut-slope instability, AGEC (1997) recommends areas having slopes less than 30 percent (3.3:1 horizontal:vertical) have no permanent unretained cut and/or fill slopes higher than 10 feet (3 m) and steeper than 2:1; larger and/or steeper cuts should be considered on an individual basis. These recommendations should be reviewed by a qualified geotechnical engineer.

Although AGEC (1997) addressed cut-slope stability, stability of the natural slopes was not assessed. Significant grading or addition of ground water could cause the natural slopes to fail and possibly damage homes both at the top and base of the slope. I recommend that AGEC assess static and seismic stability of natural slopes at and above the buildable lots, using estimated development-induced ground-water conditions. Hylland (1996) provides guidelines for evaluating landslide hazards. In areas where significant cuts are planned, AGEC not only needs to assess cut-slope stability but also the effects of cut slopes on stability of the natural slope. Measures for maintaining stability should be provided as needed. I further recommend Layton City devise a means to ensure that the consultant's recommendations are followed and no unplanned cuts (such as for landscaping) are made.

The site is in an unnamed drainage separated from its headwaters by the fill for Mountain Road. Federal Emergency Management Agency (1982) flood insurance rate maps show the site is in an area of minimal flood hazard. Recommendations in AGEC (1997) regarding site drainage appear adequate, though care should be taken to avoid directing drainage toward disturbed areas (such as cut slopes) or adjacent properties.

SUMMARY AND RECOMMENDATIONS

AGEC (1997) identifies hazards from liquefaction, earthquake ground shaking, shallow ground water, and cut-slope instability. Regarding AGEC's (1997) recommendations to reduce the risk from these hazards, I further recommend:

- the liquefaction hazard be assessed assuming shallow ground-water conditions and, if necessary, recommendations be provided to reduce the risk of damage from liquefaction;
- static and seismic stability of the natural slopes be evaluated, assuming shallow (development-induced) ground-water conditions;
- the stability of significant cuts, and their effect on natural slope stability, be evaluated and measures be provided to maintain stability as needed; and
- foundation, grading, and underdrain recommendations be reviewed by a qualified geotechnical engineer.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 1997, Geotechnical investigation--Oak Dell subdivision, 2400 North 2700 East, Layton, Utah: Midvale, unpublished consultant's report, 13 p.

Federal Emergency Management Agency, 1982, Flood insurance rate map--City of Layton, Utah, Davis County: National Flood Insurance Program, Community-Panel No. 490047 0003 B, approximate scale 1:6,000.

Hylland, M.D., 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Project:			Requesting Agency:
Review of "Geotechnical reconnaissance study, proposed residential structure, lots 24 and 25, K & J subdivision, southwest portion of section 17, Range 4 East, Township 3 South, Snake Creek area of Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 7-20-98	County: Wasatch	Job No: 98-24 (R-17)
USGS Quadrangle: Brighton (1169)		Number of attachments: none	

INTRODUCTION

At the request of Anthony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report by AGRA Earth & Environmental, Inc. (AGRA, 1998) for lots 24 and 25 of the K & J subdivision, Wasatch County, Utah. I received the report on June 29, 1998. Lots 24 and 25 are located in the SW1/4 section 17, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether AGRA (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards literature (Gill, 1986; Klauk and Mulvey, 1987; Hylland and Lowe, 1995, 1997), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in AGRA (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The AGRA (1998) report addresses landslides and slope stability. AGRA (1998, p. 3) states that there is "no evidence of past or imminent slope instability...on or immediately adjacent to the site." However, the report (AGRA, 1998, figure 1) indicates that lots 24 and 25 are on part of a large landslide complex mapped by Klauk and Mulvey (1987). Three shallow debris slides occurred within this complex, upslope and about 500 to 1,000 feet west of lots 24 and 25, during periods of above-normal precipitation between 1982 and 1985 (Gill, 1986; Klauk and Mulvey, 1987). The AGRA (1998) report does not include a topographic map of the lots at a scale suitable for site planning, but the report states that the slope on most of the site is about 2.5-3H:1V, or flatter, except for a slope of about 1.5H:1V near the eastern edge of the lots. AGRA (1998) recommends placing the proposed house on the western part of the site, beyond a 2H:1V setback line projected from the base of the steep eastern slope and set back at least 15 to 20 feet from the crest of the slope.

I believe that the AGRA (1998) report does not adequately support its proposed setback recommendation. The report does not include a description of site soils and does not provide the height of the eastern slope and amount of elevation change across the site. Also, the report does not address the overall stability of the larger landslide complex underlying the subdivision, except to state that it "exhibits no historical mass slope instability (AGRA, 1998, p. 4)." A lack of historical activity is insufficient to demonstrate long-term stability. The landslide may be susceptible to at least partial reactivation from wet periods, earthquakes, and/or the cumulative affects of development. Hylland and Lowe (1995) assign a high landslide hazard to much of the landslide complex, including the lots, because of the type of geologic material, the presence of underlying landslide deposits, and a slope gradient that commonly exceeds the critical slope inclination. The critical slope inclination is a statistically derived measure for individual geologic units (Hylland and Lowe, 1987); late Holocene landsliding in western Wasatch County has typically occurred on slope gradients greater than the critical slope inclination. According to AGRA (1998), most on-site slopes are at least 3H:1V (33 percent) and thus exceed the critical slope inclination (25 percent) of the underlying deposits of glacial till.

The potential for slope instability and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. AGRA (1998, p. 5) recommends construction of a perimeter foundation/chimney drain to divert water away from the house, discharging into the drainage to the north and east of the house. Site design must also consider the placement of a septic-tank soil-absorption (STSA) system, particularly in relation to the perimeter drain, and the system's influence on slope stability. The perimeter drain must not intercept and discharge inadequately treated effluent. Also, Utah Division of Water Quality (UDWQ, 1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability. Slopes on lots 24 and 25 commonly exceed the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems (25 percent). Flatter areas of the lot are limited and, with setbacks imposed by UDWQ and Wasatch County, may be inadequate for a STSA system.

RECOMMENDATIONS

The geologic evaluation in AGRA (1998) indicates a potential for instability of the eastern slope, but the evaluation does not adequately document that the recommended setback is sufficient to prevent damage on lot 24 and 25. I therefore recommend:

- at least a preliminary geotechnical-engineering evaluation of slopes at the site to justify setback recommendations, and of the larger landslide complex at and above the site, consistent with the recommendations of Hylland (1996),
- evaluation of the cumulative affect of development, particularly STSA systems, on the local slope stability and overall stability of the landslide complex,
- assessment of the potential for, and impact of, shallow debris slides on or above the lots on the proposed buildings and on downslope development, and
- inclusion of a topographic map at a scale suitable for site planning, created by a qualified surveyor, showing recommended building setbacks, non-buildable areas, the house and STSA-system locations, and any site-design features to reduce hazards.

The long-term stability of the larger landslide complex, and cumulative effects of development on stability, are difficult to assess in a lot-specific study such as this, but I recommend they be addressed before permitting additional development on the landslide at the K & J subdivision.

I also recommend that:

- final site design of grading and drainage consider the impact of site drainage and placement of a STSA system on the perimeter drain, and on slope stability and erosion that could affect downslope roads and structures, and
- recommendations pertaining to foundation design and site grading in the AGRA (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

REFERENCES

AGRA Earth & Environmental, Inc., 1998, Geotechnical reconnaissance study, proposed residential structure, lots 24 and 25, K & J subdivision, southwest portion of section 17, Range 4 East, Township 3 South, Snake Creek area of Wasatch County, Utah: Salt Lake City, Utah, unpublished consultant's report, 6 p.

Gill, Harold, 1986, Investigation of a debris flow near the K & J subdivision, Wasatch County, Utah, in Mulvey, W.E., compiler, Technical reports for 1985 Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation 208, p. 272-274.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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

----1997, Regional landslide-hazard evaluation using landslide slopes, western Wasatch County, Utah: Environmental & Engineering Geoscience, v. 3, no. 1, p. 31-43.

Klauk, R.H., and Mulvey, William, 1987, Study of landslides west of the K & J subdivision in Snake Creek Canyon, Wasatch County, Utah: Utah Geological and Mineral Survey Report of Investigation 214, 28 p.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Project: Review of "Geotechnical study, lot 1388, plat 13, Timber Lakes subdivision, Heber, Utah"			Requesting Agency: Wasatch County Planning
By: Barry J. Solomon	Date: 7-22-98	County: Wasatch	Job No: 98-25 (R-18)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report by Earthtec Testing & Engineering, P.C. (Earthtec, 1998) for lot 1388 of the Timber Lakes subdivision, Wasatch County, Utah. I received the report on July 7, 1998. The geotechnical report includes an addendum by American Geological Services, Inc., describing the results of a geological reconnaissance of the lot. Lot 1388 is located in the NW1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether Earthtec (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards maps (Hylland and others, 1995), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in Earthtec (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The Earthtec (1998) report lists earthquake ground shaking, shallow ground water, and landslides as potential geologic hazards on the property. The report addendum notes that the property lies within Uniform Building Code seismic zone 3. I concur, and recommend that structures on the property be designed and constructed to at least meet seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking. The report addendum projects a static ground-water table at a minimum depth of 20 feet. I believe this to be a reasonable estimate, but local perched and seasonally shallow ground water may periodically occur. The report addendum found no evidence of on-site slope failure. However, because of slopes as great as 30 percent, Earthtec (1998) conducted a preliminary geotechnical-engineering slope-stability analysis consistent with the recommendations of Hylland (1996). The analysis modeled slope stability using circular slip surfaces and also an infinite-slope procedure. I believe Earthtec (1998) assumed realistic estimates of soil parameters, based on laboratory testing and observation of soils exposed in test pits, to model slope stability. Earthtec (1998) considers the slope to be stable under both static and pseudo-static conditions, and I concur. Earthtec (1998) also found no evidence for preferential failure planes in bedrock encountered at the base of the test pits, and considered the potential for bedrock slab or wedge failures to be low.

The potential for slope instability and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. Earthtec (1998) recommends construction of a foundation drain to divert water away from the house. Site design must consider the placement of a septic-tank soil-absorption (STSA) system in relation to this foundation drain, to avoid intercepting and discharging inadequately treated effluent. Also, Utah Division of Water Quality (UDWQ, 1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability. Although Earthtec (1998) considered the influence of a STSA in its analysis of slope stability, slopes on lot 1388 commonly exceed the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems (25 percent). Flatter areas of the lot are limited and, with setbacks imposed by UDWQ and Wasatch County, may be inadequate for a STSA system. In addition, shallow bedrock may be encountered over much of the lot, making it difficult to find a suitable location for a STSA system.

RECOMMENDATIONS

I believe that Earthtec (1998) provides a complete listing of the potential geologic hazards at the site. I concur with Earthtec's conclusions that slopes on lot 1388 are stable under both static and pseudo-static conditions and a house can be safely placed on the lot. I therefore recommend that:

- recommendations pertaining to foundation design and site grading in the Earthtec (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer, and
- the potential for shallow slope failures from cut slopes be minimized by adherance to the general guidelines for Timber Lakes to make permanent cut slopes that are less than 5 feet high no steeper than 2H:1V; cut slopes higher than 5 feet should be designed by a geotechnical engineer.

Because shallow bedrock, steep slopes, and proximity to foundation drains may severely limit the area suitable for a STSA system, placement of the system should be consistent with guidance provided by the UDWQ and the Wasatch City-County Health Department.

REFERENCES

Earthtec Testing & Engineering, P.C., 1998, Geotechnical study, lot 1388, plat 13, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 6 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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, scale 1:24,000.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Project:			Requesting Agency:
Review of "Geotechnical study addendum, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 7-22-98	County: Wasatch	Job No: 98-26 (R-19)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report addendum by Earthtec Testing & Engineering, P.C. (Earthtec, 1998b) for lot 1369 of the Timber Lakes subdivision, Wasatch County, Utah. I received the addendum on July 15, 1998. The addendum responds to my review (Solomon, 1998) of a geotechnical report for the lot (Earthtec, 1998a). Lot 1369 is located in the SE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review of the addendum is to assess whether Earthtec (1998b) adequately addressed my recommendations for further study of potential geologic hazards on the lot.

DISCUSSION

My review of the Earthtec (1998a) geotechnical report recommended an evaluation of the potential for:

- shallow debris slides in thin soils and weathered rock, including assessing their impact on the proposed building and on downslope development, and
- if warranted, failures along rock discontinuities such as inclined bedding planes or fractures, particularly in permanent cuts greater than 5 feet high exposing rock.

Earthtec (1998b) modeled slope stability using an infinite-slope procedure to determine the potential for shallow debris slides. I believe this procedure is appropriate, and Earthtec (1998b) assumed realistic estimates of soil parameters, based on laboratory testing and observation of soils exposed in test pits (Earthtec, 1998a), to model slope stability. Earthtec (1998b) considers the slope to be stable, and I concur. Earthtec (1998b) also found no evidence for preferential failure planes in bedrock encountered at the base of the test pits, and considered the potential for bedrock slab or wedge failures to be low.

RECOMMENDATIONS

I agree with the conclusions in the Earthtec (1998b) addendum that slopes on lot 1369 are stable and a house can be safely placed on the lot. The potential for shallow slope failures can be minimized by adherance to the general guidelines for cut slopes in the Timber Lakes subdivision. However, as stated in my earlier review (Solomon, 1998), flatter areas of the lot are limited and, with setbacks imposed by the Utah Division of Water Quality (UDWQ) and Wasatch County, may be inadequate for a septic-tank soil-absorption (STSA) system. Shallow bedrock and proximity to foundation drains may further restrict placement of a STSA system. I therefore recommend:

- adherance to guidelines for Timber Lakes to make permanent cut slopes that are less than 5 feet high no steeper than 2H:1V; cut slopes higher than 5 feet should be designed by a geotechnical engineer, and
- placement of a STSA system consistent with guidance provided by the UDWQ and the Wasatch City-County Health Department.

I also repeat the recommendation of Solomon (1998) that:

- recommendations pertaining to foundation design and site grading in the Earthtec (1998a) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

REFERENCES

Earthtec Testing & Engineering, P.C., 1998a, Geotechnical study, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 5 p.

----1998b, Geotechnical study addendum, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 2 p.

Solomon, B.J., 1998, Review of "Geotechnical study, lot 1369, plat 13 amended, Timber Lakes subdivision, Heber, Utah": Utah Geological Survey Technical Report 98-17, 3 p.

Project: Review of addendum to "Geotechnical study for Rasmussen development, 2975 Melanie Lane, Ogden, Weber County, Utah."			Requesting Agency: Weber County Planning
By: Bill D. Black	Date: 07-29-98	County: Weber	Job No: 98-27 (R-20)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

INTRODUCTION

This report is a review of a follow-up geologic and geotechnical investigation by Earthtec Engineering, P.C. (Earthtec) for a lot in the Rasmussen subdivision at 2975 Melanie Lane, Ogden, Utah (Earthtec, 1998b). The lot is located in the NW1/4SW1/4 section 24, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The follow-up investigation is an addendum to a previous geotechnical investigation for the lot (Earthtec, 1998a), which was reviewed by the Utah Geological Survey (UGS) and found inadequate with regard to slope stability and surface fault rupture (Giraud, 1998). Jim Gentry, Weber County Planning Commission, requested the original review. The purpose of my review is to assess whether recommendations in Giraud (1998) regarding slope stability and surface-fault-rupture hazards were adequately addressed by Earthtec (1998b). The scope of work for my review consisted of a literature review, examination of 1:24,000-scale aerial photos (1985), and computer slope-stability analyses based on data in Earthtec (1998b). No site visit was made.

DISCUSSION

Giraud (1998) indicates landsliding is a potential hazard at the lot, which is in a special study area where studies to address landslide hazards are recommended. Based on this, Giraud (1998) recommended a detailed study to determine soil and ground-water conditions in the slope and evaluate static and seismic slope stability. Earthtec (1998b) drilled, logged, and sampled one test hole at the site to gather soil and ground-water data for evaluating slope stability. The test hole shows roughly 27 feet (8.2 m) of lacustrine sediments overlying bedrock (Earthtec, 1998b). No ground water was encountered. Using an estimated soil strength from their samples, Earthtec (1998b) conducted a preliminary slope-stability analysis and estimated factors of safety for the natural slope of 1.5 and 1.1 under static and seismic conditions, respectively. Earthtec (1998b) performed no soil-strength testing to provide hard data for detailed analyses.

Soil data in Earthtec (1998b) are limited, but their estimated soil strength appears reasonable and my slope stability analyses using these estimates support their results. However, both Earthtec's (1998b) and my analyses are not based on hard data. Earthtec (1998a, 1998b) recommended footings be at least 18 feet (5.5 m) from the face of the steep southwest-facing slope and 8 feet (2.4 m) below existing grade, and I concur. This setback distance appears minimal, but adequate (under both dry and estimated development-induced ground-water conditions) to reduce the risk of a landslide undermining the structure. Estimated factors of safety from their analyses are also minimum that are acceptable. Therefore, because the setback is critical, I recommend Earthtec inspect the foundation excavation and provide written documentation to Weber County stating that their setback recommendations were followed. Weber County must also ensure that no unauthorized slope alterations are made. Water from landscape irrigation or other sources could still cause shallow slope failures, particularly if perched ground-water conditions develop. Such slope failures could damage landscaping and remove lateral foundation support, possibly causing eventual damage to the house.

Earthtec (1998b) believes the scarp east of Melanie Lane is related to the highstand of Lake Bonneville. However, Earthtec (1998b) provides no evidence to support such a relation. The scarp is below the highest lake shoreline, and thus I believe it is probably not related to the lake highstand, though it could be related to other lake phases or differential erosion. However, the scarp may also be a subsidiary fault trace east of the main Wasatch fault trace or a landslide main scarp. Earthtec (1998a) indicates a secondary fault trace appears to end at the northeast corner of the lot. This scarp would project toward the scarp east of Melanie Lane. The presence of shallow bedrock at the site, and overlying mostly undeformed deposits, indicate the scarp is not likely a landslide main scarp.

Giraud (1998) indicates surface fault rupture is a potential hazard at the lot and trenching studies are needed to identify faults and fault-related deformation. Based on this, Giraud (1998) recommends trenching beneath at least the proposed building footprint to identify faults. Earthtec (1998b) excavated and logged two trenches at the lot. The trenches exposed a generally flat-lying, unfaulted sequence of lacustrine sand and gravel deposits, although the westernmost trench shows minor folding that Earthtec (1998b) believes is related to local slumping following the retreat of Lake Bonneville. I concur with Earthtec's (1998b) assessment, but add that if the scarp east of Melanie Lane is a fault scarp, the lot would be within a zone of deformation between fault traces. Although no evidence of faulting was found in Earthtec's (1998b) trenches, Black and others (1996) show that surface rupture can occur unpredictably anywhere in a wide zone of deformation. Therefore, future faulting cannot be precluded based on the present investigation.

SUMMARY AND RECOMMENDATIONS

Earthtec (1998b) adequately addresses recommendations in Giraud (1998) with regard to surface fault rupture. Regarding slope stability, Earthtec's (1998b) analyses appear reasonable but are only estimates and not based on hard data. I recommend:

- following the recommended setback distance for footings of 18 feet (5.5 m) from the slope face and 8 feet (2.4 m) below existing grade,
- Earthtec inspect the foundation excavation and provide written documentation to Weber County confirming adherence to these building-setback recommendations,
- Weber County ensure that no unauthorized slope alterations are made, and
- disclosing to future buyers the existence of the Earthtec reports and UGS reviews.

REFERENCES

Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.E., and Mayes, B.H., 1996, Paleoseismic investigation on the Salt Lake City segment of the Wasatch fault zone at the South Fork Dry Creek and Dry Gulch sites, Salt Lake County, Utah, *in* Lund, W.R., editor, Paleoseismology of Utah, Volume 7: Utah Geological Survey Special Study 92, 22 p.

Earthtec Engineering, P.C., 1998a, Geotechnical study, Rasmussen Development, 2975 Melanie Lane, Ogden, Utah: Ogden, unpublished consultant's report, 11 p.

----1998b, Geologic and geotechnical consultation, Rasmussen development, 2975 Melanie Lane, Ogden, Utah: Ogden, unpublished consultant's report, 10 p.

Giraud, R.E., 1998, Review of "Geotechnical study for Rasmussen development, 2975 Melanie Lane, Ogden, Weber County, Utah": Utah Geological Survey unpublished technical report, 4 p.

Project:			Requesting Agency:
Review of "Geotechnical study, lot 991, plat 9, Timber Lakes subdivision, Heber, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 8-24-98	County: Wasatch	Job No: 98-28 (R-21)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report by Earthtec Testing & Engineering, P.C. (Earthtec, 1998) for lot 991 of the Timber Lakes subdivision, Wasatch County, Utah. I received the report on August 18, 1998. The geotechnical report includes an addendum by American Geological Services, Inc., describing the results of a geological reconnaissance of the lot. Lot 991 is located in the SW1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether Earthtec (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards maps (Hylland and others, 1995), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in Earthtec (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The Earthtec (1998) report lists earthquake ground shaking, shallow ground water, and landslides as potential geologic hazards on the property. The report addendum notes that the property lies within Uniform Building Code seismic zone 3. I concur, and recommend that structures on the property be designed and constructed to at least meet seismic zone 3 requirements for earthquake-resistant design to minimize the risk from earthquake ground shaking. The report states that ground water was not observed in two test pits excavated at the site to a depth of 9.5 feet, but acknowledges that local perched and seasonally shallow ground water may periodically occur. The report addendum identifies a "slump block" on the steeper, southwestern part of the lot. Because of the presence of this slump and slopes as great as 38 percent, Earthtec (1998) conducted a preliminary geotechnical-engineering slope-stability analysis consistent with the recommendations of Hylland (1996). The analysis modeled slope stability using circular slip surfaces and also an infinite-slope procedure. I believe, with the exception noted below regarding thickness of colluvium, that Earthtec (1998) assumed realistic estimates of soil and rock parameters, based on laboratory testing and observations in test pits, to model slope stability. Earthtec (1998) concludes from the analysis that the slope is stable under both static and pseudo-static conditions. However, Earthtec (1998) recommends that no structure or septic-tank soil-absorption system be constructed on the steeper, southwestern slope because of the mapped landslide and its implication for future slope instability. Earthtec (1998) also found no evidence for preferential failure planes in bedrock encountered at the base of the test pits, and considered the potential for bedrock slab or wedge failures to be low.

I believe that the potential for shallow slope failures in colluvium near the crest of the steep slope (line B-B′ on Earthtec [1998] figure 2) is not adequately addressed in the Earthtec report. This potential may be more significant than indicated in Earthtec's infinite-slope analysis because of the possibility of thicker colluvium near the crest than encountered in the two test pits on the flatter portion of the lot. Thick deposits of upslope colluvium are likely the source of the mapped slump. If thick colluvium is present near the slope crest, a setback from the crest would be appropriate.

The potential for slope instability and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. Earthtec (1998) recommends construction of a foundation drain to divert water away from the house. Site design must consider the placement of a septic-tank soil-absorption (STSA) system in relation to this foundation drain, to avoid intercepting and discharging inadequately treated effluent. Also, Utah Division of Water Quality (UDWQ, 1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability. Although Earthtec (1998) considered the influence of a STSA in its analysis of slope stability, slopes on lot 991 commonly exceed the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems (25 percent). Flatter areas of the lot are limited and, with setbacks imposed by UDWQ and Wasatch County, may be inadequate for a STSA system. In addition, shallow bedrock may be encountered over much of the lot, making it difficult to find a suitable location for a STSA system.

RECOMMENDATIONS

I believe that Earthtec (1998) provides a complete listing of the potential geologic hazards at the site. Earthtec (1998) makes a prudent recommendation to prohibit construction on the steeper, southwestern slope of lot 991, despite analytical evidence presented in the report for slope stability. However, I believe that the potential for shallow slope failures in colluvium near the crest of the steep slope is not adequately addressed. I therefore recommend that either:

- an appropriate setback from the crest be determined by measuring the thickness of colluvium in a new test pit excavated near the crest and, if the thickness is significantly greater than that measured in test pit 2, conducting a new infinite-slope analysis with the new data, or
- construction be set back from the slope crest to at least the area of demonstrable shallow bedrock near test pit 2; a house can be safely placed near and upslope of test pit 2.

I further recommend that:

- recommendations pertaining to foundation design and site grading in the Earthtec (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer, and

- the potential for shallow slope failures from cut slopes be minimized by adherance to the general guidelines for Timber Lakes to make permanent cut slopes that are less than 5 feet high no steeper than 2H:1V; cut slopes higher than 5 feet should be designed by a geotechnical engineer.

Because shallow bedrock, steep slopes, and proximity to foundation drains may severely limit the area suitable for a STSA system, placement of the system should be consistent with guidance provided by the UDWQ and the Wasatch City-County Health Department.

REFERENCES

Earthtec Testing & Engineering, P.C., 1998, Geotechnical study, lot 991, plat 9, Timber Lakes subdivision, Heber, Utah: Orem, Utah, unpublished consultant's report, 6 p.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

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, scale 1:24,000.

Utah Division of Water Quality, 1996, Individual wastewater disposal systems - R317-501 through R317-513, Utah Administrative Code: Department of Environmental Quality, 59 p.

Project:			Requesting Agency:
Review of "Geologic investigation for lots 52 and 53 on Snow Basin Road, Heavens Estates subdivision, Weber County, Utah."			Weber County Planning
By: Bill D. Black	Date: 08-31-98	County: Weber	Job No: 98-30 (R-22)
USGS Quadrangle: Snow Basin (1344)		Number of attachments: 0	

INTRODUCTION

This report is a review of a geologic investigation (Kaliser, 1996a) for lots 52 and 53 in the Heavens Estates subdivision on Snow Basin Road, Weber County, Utah. The lots are located in the NE1/4SE1/4 section 23, T. 6 N., R. 1 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission, requested the review. I received the report on August 10, 1998. The purpose of my review is to assess whether geologic hazards possibly impacting the property are adequately addressed. The scope of work for my review consisted of a literature review and examination of 1:16,000-scale aerial photos (1980). No site visit was made.

DISCUSSION

Kaliser (1996a) indicates landsliding may be a hazard at the property. The property is located on a northeast-southwest-oriented ridge underlain by various lithologies of the Tertiary Norwood Tuff, and is bounded on the southeast by a possible landslide (Kaliser, 1996a). The property is also bounded on three sides by cuts for Snow Basin Road, which are up to 10 feet (3 m) high and have steep 1:1 (horizontal:vertical) slopes. No field measurements of natural slopes at the property are included in the report, but they measure to be about 4:1 on 1:24,000-scale topographic maps. Kaliser (1996a) indicates observing no evidence of instability at the property, in road cuts bounding the property, or in the possible landslide, but observed cracks up to 57 inches (145 cm) deep filled with organic-rich material in two test pits at the property. Kaliser (1996a) believes the cracks are from roots or periglacial weathering, and not due to slope movement in the past 10,000 years. Based on the above observations and the lack of evidence for ground water in the test pits, Kaliser (1996a) therefore presumably believes the risk from landsliding is low.

Aerial photos and maps by Harty (1992) and Mike Lowe (unpublished Utah Geological Survey map of Ogden Valley) show numerous landslides in the Norwood Tuff in the vicinity of the property. In addition, Kaliser (1996b) observed three small slope failures in shallow colluvium overlying the Norwood Tuff roughly 1,000 feet (305 m) west of the property, which he believes probably initiated from increased precipitation during the 1983-84 wet years. The cracks found in the test pits at the property may also be evidence of recent instability; Kaliser (1996a) provides no evidence supporting his belief the cracks are old or from root decay. Furthermore, Black (1996) indicates that failed slopes in the Norwood Tuff near Olympeak Estates roughly 1 mile (1.6 km) to the southwest are as gentle as 15 percent (6.7:1), which is less steep than slopes at the property.

Both the northwest- and southeast-facing slopes at the property appear to me to be main scarps of older landslides, and may indicate a weak stratigraphic unit within the Norwood Tuff at this locality.

The large number of landslides in the Norwood Tuff, steep slopes at the property, and evidence of possible recent instability suggest to me that the hazard from landsliding may be high. Although Kaliser (1996a) indicates observing no evidence of recent slope movement at the property, he does not address long-term slope stability. I recommend a detailed geotechnical-engineering slope-stability study be performed, following guidelines in Hylland (1996), to determine both static and seismic stability of southeast and northwest-facing slopes at and below the property based on site-specific soil, rock, and ground-water data. The study should assess the potential for both circular and planar failures in rock, and shallow failures in overlying colluvium and weathered rock, under both natural and estimated development-induced (higher) ground-water conditions.

I further recommend a site-specific geotechnical investigation be conducted to obtain soil data to provide recommendations regarding foundation design and site grading. Kaliser (1996a) includes no such recommendations, particularly with regard to site grading. Because poor drainage or non-engineered slope modifications could destabilize slopes, site grading recommendations are critical. The geotechnical recommendations should be reviewed by a qualified geotechnical engineer.

Kaliser (1996a) indicates expansive-clay soils may also be a hazard at the property. These soils are common in the Norwood Tuff and have been found nearby (Earthtec Testing and Engineering, 1996). Kaliser (1996a) recommends inspecting the foundation excavations for evidence of expansive clay, but I recommend that the potential for expansive-clay soils be evaluated in a soil-foundation investigation prior to construction. In addition to causing possible foundation and pavement damage, expansive soils may also cause problems for septic-tank soil-absorption (STSA) systems because swelling clay can reduce permeability or possibly damage systems. Because Earthtec Testing and Engineering (written communication to Richard Evans, September 1996, appended to Kaliser [1996a]) indicates tests at the property show marginally acceptable to unacceptable percolation rates, the presence of expansive-clay soils should be evaluated before an STSA system is approved. The combination of low percolation rates, possible expansive-clay soils, and steep slopes poses a significant challenge in locating a suitable site for a STSA system.

Earthquake ground shaking is another hazard at the property. The property is located in Uniform Building Code (UBC) seismic zone 3, and all structures should be designed and constructed (at a minimum) in accordance with seismic zone 3 requirements for earthquake-resistant design.

SUMMARY AND RECOMMENDATIONS

Hazards from landsliding, expansive-clay soils, and earthquake ground shaking may be present at the property. Kaliser (1996a) adequately identifies but does not adequately address the potential hazard from expansive-clay soils; hazards from landslides and earthquake ground shaking are inadequately identified and addressed, and no recommendations are made regarding foundation design or site grading. Therefore, I recommend:

- a detailed geotechnical-engineering slope-stability analysis be conducted using site-specific data and considering the location of the STSA system;
- a geotechnical investigation be conducted to evaluate the presence of expansive-clay soils and provide site-grading and foundation-design recommendations;
- future geotechnical data and recommendations be reviewed by a geotechnical engineer;
- at a minimum, houses be built to UBC seismic zone 3 specifications;
- suitable areas for STSA systems be delineated; and
- the existence of the Kaliser (1996a) report, this review, and any subsequent reports and reviews 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.

Earthtec Testing and Engineering, 1996, Geologic evaluation of a building lot off Snow Basin Road, Weber County, Utah: Ogden, Utah, unpublished consultant's report, 6 p.

Harty, K.M., 1992, Landslide map of the Ogden 30' x 60' quadrangle, Utah: Utah Geological Survey Open-File Report 247, scale 1:100,000, 11 p. pamphlet.

Hylland, M.D., editor, 1996, Guidelines for evaluating landslide hazards in Utah: Utah Geological Survey Circular 92, 16 p.

Kaliser, B.N., 1996a, Geologic investigation for lots 52 and 53 on Snow Basin Road, Heavens Estates subdivision, Weber County, Utah: Salt Lake City, Utah, unpublished consultant's report, 7 p.

----1996b, Geologic evaluation of a single residential lot along Snow Basin Road, Weber County, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Project:			Requesting Agency:
Review of "Geologic reconnaissance, Interlaken Estates, lot 10, north of Midway, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 8-31-98	County: Wasatch	Job No: 98-31 (R-23)
USGS Quadrangle: Heber City (1168)		Number of attachments: none	

INTRODUCTION

At the request of Tony Kohler, Wasatch County Planning Assistant, I reviewed a geotechnical report by Applied Geotechnical Engineering Consultants, Inc. (AGEC, 1998) for lot 10 of Interlaken Estates, Wasatch County, Utah. I received the report on August 25, 1998. Lot 10 is located in the NW1/4SW1/4 section 23, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether AGEC (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards maps (Hylland and others, 1995), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in AGEC (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The AGEC (1998) report lists earthquake ground shaking and shallow ground water as potential geologic hazards on the property. The report notes that the property lies within Uniform Building Code seismic zone 3. AGEC (1998) recommends that structures on the property be designed and constructed in accordance with seismic zone 3 criteria for earthquake-resistant design to minimize the risk from earthquake ground shaking, and I concur. The report states that evidence for shallow ground water was not identified at the site, but acknowledges that local perched ground water may occur.

The AGEC (1998) report also discusses the potential for landslides on the property. AGEC (1998) found no evidence of landslides or unstable slopes in the site vicinity. The report characterizes site bedrock as shallow sandstone, mapped as the Park City Formation by Bromfield and others (1970), and considers this suggestive of stable slope conditions. The report describes overlying soil as sandy clay with gravel and occasional cobbles that appears to be at least 3 feet thick, but no subsurface exploration was conducted to accurately determine soil thickness. AGEC (1998) describes bedrock west of the site (at an unspecified distance) striking approximately N. 55° E. (approximately parallel to the slope) and dipping 48 degrees (111 percent) to the southeast (downslope). Bromfield and others (1970) map bedrock about 500 feet northwest of the site with about the same strike, dipping 30 degrees (57 percent) to the southeast. I calculate site slopes ranging from about 30 to 50 percent from surveyed site topography.

AGEC (1998) does not adequately address the potential for landslides on lot 10. The most likely failure mode on steep, colluvium-covered slopes underlain by bedrock is shallow debris sliding of slope soils and weathered rock along the soil-rock interface. The potential for shallow debris sliding depends, in part, on an accurate assessment of colluvium thickness. Slab or wedge failures along bedrock discontinuities may also occur. 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 for lot 10, or if, as on lot 10, bedding planes may be locally subparallel to the slope. The lack of evidence for past onsite slope failures does not preclude the potential for future failures. Hylland and Lowe (1997) estimate this potential by calculating a critical slope angle from slopes of landslides in each geologic unit in western Wasatch County. Late Holocene landsliding typically occurs on slopes with inclinations greater than the critical slope angle. Hylland and Lowe (1997) calculate a critical slope angle of 35 percent for the Park City Formation in western Wasatch County. Because slopes on lot 10 (from 30 to 50 percent, and usually greater than 40 percent) are commonly greater than the critical slope angle for the Park City Formation (35 percent), I consider a potential for landsliding to exist which warrants further consideration.

The potential for slope instability and erosion can be reduced by proper site drainage and reduction of runoff and moisture infiltration into site slopes. AGEC (1998) recommends construction of a foundation drain to divert water away from the house. Careful consideration should be given to the potential impact of site drainage on downslope roads and structures.

RECOMMENDATIONS

AGEC (1998) provides a complete listing of the potential geologic hazards at the site. However, the potential for landslides is not adequately addressed. I therefore recommend that:

- a preliminary geotechnical-engineering slope-stability analysis be conducted consistent with the recommendations of Hylland (1996);
- as part of this analysis, subsurface exploration should be conducted to accurately determine the thickness of colluvium and the location and orientation of planes of weakness (bedding, fractures, and faults) in underlying rock;
- if colluvium is relatively thin, the potential for shallow debris sliding should be addressed using an infinite-slope analysis, or other appropriate procedure, to account for shallow, non-circular failure surfaces;
- if colluvium is relatively thick or if rock is highly fractured and deeply weathered, the potential for deep, circular failures should be analyzed; and
- the potential for slab or wedge bedrock failures should be analyzed, particularly if permanent cut-slope heights greater than 5 feet are planned and planes of weakness will be exposed in the cuts.

Slope-stability analyses should consider the potential effect of seasonal infiltration from snowmelt or rainstorms and undercutting by road and building-pad cuts. I further recommend that:

- recommendations pertaining to foundation design and site grading in the AGEC (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

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Project:			Requesting Agency:
Review of "Supplemental geotechnical investigation--Green Hill Country Estates Phase VI, part of sections 4 and 9, T6N, R2E SLB&M, Weber County, Utah."			Weber County Planning
By: Bill D. Black	Date: 09-03-98	County: Weber	Job No: 98-32 (R-24)
USGS Quadrangle: Browns Hole (1368)		Number of attachments: None	

INTRODUCTION

This report is a review of a supplemental geotechnical investigation for Green Hill Country Estates Phase VI by Applied Geotechnical Engineering Consultants (AGEC) (1998). The subdivision is located in the S1/2 section 4 and N1/2 section 9, T. 6 N., R. 2 E., Salt Lake Base Line and Meridian. Jim Gentry, Weber County Planning Commission requested the review. I received the report on August 7, 1998. Previous reports for this subdivision include an AGEC (1996) geotechnical and landslide report, a Utah Geological Survey review of AGEC's report (Ashland, 1996), and a report regarding a new landslide in the subdivision and its implications regarding AGEC's (1996) recommendations (Black, 1998). The purpose of this review is to assess if AGEC (1998) adequately addresses potential expansive-soil problems and slope-stability concerns in the subdivision. The scope of work consisted of a literature review.

DISCUSSION

Landsliding is a potential hazard at the property. AGEC (1996) observed four existing landslides in permanent 3:1 (horizontal:vertical) road cuts in the subdivision, and speculated these failures were triggered by a reduction in strength when soils became wet during infiltration of spring runoff. To maintain stability of road cuts and other cut slopes at the site, AGEC (1996) recommended final cut-slope angles in the natural clay soils at the subdivision be lower (4:1), existing landslides be stabilized, and surface drainage be directed away from the cut slopes. AGEC (1996) provided several options to stabilize the road-cut failures: (1) excavation and replacement, (2) regrading to flatter slopes, or (3) regrading to natural slope angles in combination with subsurface interceptor drains. Ashland (1996) believed these recommendations were adequate if construction was carefully monitored, and he also believed AGEC's (1996) assessment of the landslide hazard at the property appeared thorough, well documented, and supported by data.

A new slope failure occurred in 1998 in a 4:1 road cut in the eastern part of the property due to infiltration of spring runoff (Black, 1998), which suggested that cuts conforming to AGEC's (1996) recommendations may fail. Therefore, Black (1998) advised that slope-stability recommendations in AGEC (1996) be reviewed and revised. AGEC (1998) indicates existing slides at the property also enlarged this spring, and all of these slides probably resulted from reduced stability due to slope disturbance (from road cuts). AGEC (1998) also reiterates that the property is prone to slope movement unless site grading, slope retention, and drainage are carefully planned. Based on this, AGEC (1998) recommends: (1) failed slopes in existing slide areas, including the new slide, be stabilized; (2) site grading be carefully planned and lot-specific geotechnical investigations be conducted to evaluate stability of proposed and existing cuts, fills, and retaining systems; and (3) recommendations in AGEC (1996) for maintaining slope stability be followed. I concur with AGEC's (1998) recommendations, but add that the recommendation for site-specific studies should also be followed for new road cuts. Restoring long-term slope stability in the existing (and new) landslide areas may be challenging and could require engineered retaining systems. Designs for such systems should be submitted to Weber County for approval and reviewed by qualified engineers prior to construction. Although infiltration of spring runoff is the principal cause of the landslides, landscape irrigation will also contribute to slope instability. Thus, I also recommend landowners consider low-irrigation methods (such as xeriscaping) to reduce infiltration of water from landscaping. Weber County should also devise means to ensure that no unplanned slope modifications are made, and that existing failed slopes are adequately stabilized.

Expansive-clay soils are also a potential hazard at the subdivision (AGEC, 1998). To reduce the risk from expansive-clay soils, AGEC (1998) recommends: (1) conducting lot-specific soil-foundation investigations, (2) following drainage recommendations in AGEC (1996), and (3) using drilled-pier foundations in areas where highly expansive soils are found. I concur with their assessment and recommendations. In addition to improving slope stability, minimizing landscape irrigation will also reduce the risk from expansive soils.

SUMMARY AND RECOMMENDATIONS

AGEC (1998) addresses potential hazards from landsliding and expansive-clay soils in the subdivision. AGEC's (1998) recommendations should be followed, and I further recommend that:

- site-specific investigations be performed for all new road cuts to provide recommendations ensuring their stability;
- Weber County devise means to ensure that no unplanned slope modifications are made, and that existing failed slopes are adequately stabilized;
- designs for engineered slope-retaining systems, if needed, be submitted for approval to Weber County and reviewed by qualified engineers;
- landowners minimize landscape irrigation; and
- the existence of AGEC (1996, 1998), Ashland (1996), Black (1998), this review, and any subsequent reports and reviews be disclosed to future buyers.

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Project:			Requesting Agency:
Review of geologic-hazard and geotechnical reports for the Hidden Hollow No. 3 subdivision, Layton, Utah			Layton City Planning
By: F.X. Ashland	Date: 9-18-98	County: Davis	Job No: 98-33 (R-25)
USGS Quadrangle: Kaysville (1320)		Number of attachments: None	

INTRODUCTION

At the request of Doug Smith, Layton Planning Department, I reviewed the geological-hazard aspects of a geotechnical report by Earthtec Engineering (Earthtec) (1998) and an attached geologic report (Kaliser, 1998) for the Hidden Hollow No. 3 subdivision in Layton, Utah. The proposed subdivision is in the S1/2 section 10, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian. The site is on a southeast-facing bluff of the North Fork of Kays Creek. The purpose of this review is to determine if geologic hazards have been adequately addressed to support proposed development plans at the site. The scope of my evaluation consisted of a review of available engineering-geologic reports, maps, and aerial photographs; a site reconnaissance on August 11, 1998; and a preliminary geotechnical-engineering slope-stability evaluation using the PC-STABL5M computer program. The two reports were received on August 7, 1998. Additional materials necessary to complete the review were received separately on August 13 and 24, 1998.

GEOLOGIC HAZARDS

Kaliser (1998) describes the general geology at the site and addresses some potential geologic hazards including landslides, soil erosion, and shallow ground water. Kaliser (1998) also includes information in appendices and figures related to other geologic hazards, not specifically addressed in the body of the report, including liquefaction and soil piping. The report also raises a general concern by describing geologic conditions at the site as "anomalous." In addition to landslides and shallow ground water, Earthtec (1998) also addresses earthquake ground shaking, liquefaction, and moisture-sensitive soils.

Shallow Ground Water

Kaliser (1998) indicates the water level in an existing well at the site is about 10 feet below the ground surface. Earthtec (1998) concludes that this level may represent the potentiometric surface (the total head of the ground water intercepted by the screened portion of the well) rather than the actual shallow ground-water table (below which all soils would be saturated). Kaliser (1998) also indicates ground water was encountered at about 9.8 feet in the middle segment of a trench excavated across the site.

Kaliser (1998) also describes an area of phreatophytes (vegetation that grows in areas of shallow ground water) in the southern part of the site. A test pit excavated near the phreatophytes as part of the Kaliser (1998) study indicated perched ground water that discharged onto the slope in the vicinity of the phreatophytes. Kaliser (1998) speculates that the water could originate from the storm drain that crosses the site upslope of the test pit or from natural perched ground water. During my reconnaissance I observed that surface runoff from rainstorm events entered the northern part of the site from 1400 East and eventually ponded in the southern part of the site upslope of the phreatophytes. Thus, infiltration from the pond area could also contribute to this perched ground-water condition.

The absence of ground water less than 10 feet deep is likely explained, in part, by the timing of the site investigations in November 1997. Precipitation data from nearby Hill Air Force Base indicate that the five months preceding November are generally the driest months of the year, and thus, ground-water levels were likely to be low at the time of the investigation. Ground-water levels are generally shallowest following the spring snowmelt (March-May) and thus, lacking other evidence, explorations would be required during this time period to accurately assess the potential for shallow ground water.

Earthtec (1998) makes design recommendations to handle potential shallow ground water including foundation drains for structures, three 12-foot deep trench drains that would cross the entire site, and a ground-water collection system at the phreatophyte area. These measures, if constructed according to design, should reduce the potential for basement flooding in proposed houses if surface-drainage design is adequate throughout the proposed subdivision. However, local perched shallow ground water may still occur periodically due to excessive snowmelt, rainfall, or landscape irrigation.

Soil Erosion

Kaliser (1998) indicates local "significant erosion" at the site. During my site reconnaissance, I noted several gullies up to 16 inches deep that originated in the northern part of the site at the edge of the pavement on 1400 East. The gullies generally trend north-south and end in a shallow depression in the southern part of the site. In addition, recent erosion and flooding appear to have impacted lots to the northeast and east of the site. I observed evidence of recent soil erosion and landscaping repair on steep slopes at lots directly northeast of the site. This is particularly significant because of the apparent similar steepness of several of the lots at the proposed Hidden Hollow No. 3 subdivision, shown by Earthtec's map to locally exceed 30 percent. Houses east of the site were also impacted by flooding and erosion in 1998 as indicated by sandbags at the house at 1426 East 2250 North and soil deposits in the adjacent streets and driveways. Fine-grained soils at and near the site are susceptible to erosion that can be significant during intense rainstorms because of the local steep slopes. Earthtec (1998) recommends that runoff should be directed to lined canals to reduce problems with erosion, and I concur. However, consideration of recent intense rainstorm events should be part of any engineered drainage/erosion control measures. A recent storm in the area on August 26, 1998, dropped 1.05 inches of rain in about 20 minutes and a total of 1.67 inches of rain during the entire brief event.

Earthquake Ground Shaking and Liquefaction

Although Earthtec (1998) does not specifically address the potential for earthquake ground shaking, it recommends that proposed structures be designed in accordance to seismic zone 3 of the Uniform Building Code (UBC). If proposed houses are designed and constructed to these standards, they would meet the minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards.

Earthtec (1998) indicates that shallow soils have a low risk of liquefaction during earthquake ground shaking and that deeper soils have a moderate risk. Anderson and others (1994) indicate a moderate liquefaction potential at the site. Although their study was of regional scale, it included two nearby subsurface exploration sites showing either shallow ground water or shallow liquefiable soils. Trench logs included in the Kaliser (1998) report suggest the site has experienced prehistorical liquefaction. The logs show a sand-gravel dike that was possibly injected into overlying fine-grained soils during liquefaction, although Kaliser (1998) did not characterize the geologic significance or origin of this feature. In addition, fault-like features shown on the logs could be related to lateral-spread (landslide) deformation during liquefaction. Even if shallow ground-water levels are maintained at or below 12 feet by drains as recommended by Earthtec, a liquefaction susceptibility may still exist in deeper soils. This susceptibility has not been adequately addressed in the reports.

Moisture-Sensitive Soils

Earthtec (1998) indicates that soils at the site are moisture sensitive (volume changes occur during wetting or drying of the soils) and makes irrigation/drainage recommendations to prevent the wetting of soils near foundations. Earthtec (1998) does not explain the nature of the moisture-sensitive soils (expansive versus collapsible) or quantify the potential volume change or ground displacement. Although Earthtec's recommendations in combination with the proposed trench and foundation drains may help prevent foundation soils from becoming wet, they do not necessarily provide protection for proposed roads and utilities.

Piping

Field notes included in the Kaliser (1998) report indicate the presence of features, including small depressions, that may be associated with soil piping (the subsurface erosion of soils by ground-water flow); however, no discussion of this potential hazard is made in the body of the report. Certain conditions exist at the site that make it susceptible to piping, including the presence of fine-grained easily erodible soils, ample ground water (from landscape and agricultural irrigation upslope and intense rainstorms and snowmelt events), adequate local relief to develop high hydraulic gradients, and the presence of multiple free faces including cuts in the slope both onsite and below the property.

Landslides

Kaliser (1998) and Earthtec (1998) indicate that historical landslides have occurred on or in the vicinity of the site. Kaliser (1998) reports that a landslide occurred in June 1978 as a result of grading activities in the vicinity of a buried water pipeline in the lower part of the site. Two separate reports (Dames & Moore [1983] and John Call Engineering [1983]) indicate that this landslide actually occurred in May 1983. The two reports conclude that the factors contributing to the landslide were modifications to the existing slope, including surcharge loads added from fill placed over the steep slope, and shallow ground-water conditions following above-normal precipitation in 1982 and 1983. The landslide affected an area about 300 feet wide and 100 feet long (perpendicular to the slope) and offset the ground surface above a buried pipeline about 4 feet (Dames & Moore, 1983). The toe of the landslide was about 40 feet above the base of the slope, likely in the lots immediately east of the proposed Hidden Hollow No. 3 subdivision.

Earthtec (1998, figure 2) indicates a more recent landslide occurred sometime in the early 1990s downslope of the proposed subdivision in the vicinity of lot 30. The landslide was visible during my site reconnaissance and had formed about a 8 to 10 inch-high scarp. Earthtec indicates the landslide was caused by oversteepening of the slope due to excavation at its base.

In addition to the relatively recent historical landslides, the site is at least partly underlain by prehistorical landslides which abut the property to the north, east, and south. Kaliser (1998) identifies a landslide complex north of the site and indicates that the site may be partly underlain by these landslide deposits. Lowe (1989) mapped a prehistorical landslide at the base of the slope that borders the site on the southeast. Kaliser (1998) also identifies another possible landslide in the vicinity of the site west of the buried pipeline. My review of 1985 aerial photographs confirmed that most of the bluff east and northeast of the site is likely a landslide area. Unfortunately, grading on the site in the 1980s obscured surficial evidence of the origin of deposits underlying the site. West-dipping soil layers in trenches excavated as part of the Kaliser study also suggest possible landsliding at the site.

During my site reconnaissance, I observed numerous ground cracks and scarps on the lower slope that suggested active earth movement. An open ground crack/scarp is present directly upslope of the buried pipeline, suggesting possible earth movement along nearly the entire east-southeast boundary of the site. In several areas, ground cracks are also present downslope of the buried pipeline. These cracks are mostly transverse cracks perpendicular to the slope. I observed cracks in the vicinity of a benched rock wall east of the site (lot 29). Heave in driveway slabs and tilting of fence posts in lots 28 and 29 (Country Hollow subdivision) may also be associated with landsliding. Open ground cracks were also apparent along the edges of the trenches excavated as part of the Kaliser (1998) study. The cracks appeared to indicate either failure of the backfill in the trenches or general landsliding in which the trenches were coincident with the flank of the landsliding. I prefer the latter interpretation because cracks extend between trenches through untrenched ground. Also, the trenches were excavated above the right (south) flank of the rock wall where I observed numerous transverse ground cracks, probably related to landsliding.

As part of its study, Earthtec conducted a slope-stability analysis of the site using actual soil-strength data from clay-soil samples collected from shallow excavations at the site. Using these values, Earthtec concluded the slope was stable and indicated the static factor of safety is at least 1.5. Although I believe this was a reasonable preliminary attempt to determine the stability of slopes at the site, the Earthtec analysis has some critical limitations. One significant limitation is that it does not explain the susceptibility of the slope to landsliding as demonstrated by the two recent slope failures. In my slope-stability analysis, I modeled conditions resulting in the 1983 landslide by adding a surcharge load to the slope in the vicinity of the buried pipeline. My surcharge loads were in agreement with estimated loads in the John Call Engineering (1983) report. Using soil strengths obtained in the Earthtec study, my preliminary analysis indicates that the slope should not have failed. These results suggest that either:

1. the soil strengths determined for the shallow soils are not representative of strengths of clay soils at depth in which failure occurred,

2. other weaker soil types control slope stability, and/or

3. ground-water conditions are significantly different than assumed in either my or Earthtec's slope-stability analyses.

In addition, Earthtec (1998) performed a pseudo-static analysis using a horizontal ground acceleration with a 35 percent probability of exceedence in 50 years and calculated a factor of safety of 1.0. This probability of exceedence is unacceptably high, and if a lower probability is used, such as the more typical 10 percent probability of exceedence in 50 years, the factor of safety may drop below 1.0. These uncertainties justify a more thorough investigation of actual site conditions which should be incorporated into a detailed geotechnical-engineering slope-stability analysis.

Earthtec (1998) make several recommendations to prevent slope instability, including flattening existing steep slopes below the site (lots 28 to 31) and constructing trench drains. Whereas these measures will likely enhance stability, without a better understanding of actual slope stability I am uncertain whether they are sufficient to prevent future landsliding. For instance, Earthtec recommends that slopes be flattened to 2H:1V; however, better site characterization and supporting slope stability analysis are needed to show whether this is flat enough. One purpose of the trench drains is to intercept ground water and prevent shallow ground-water levels which could cause instability. However, given that Earthtec's more general drainage recommendations do not address water from downspouts and landscape irrigation that may cause ground-water levels to rise between the drains, these trenches alone may be inadequate. If the slope is marginally stable, the measures proposed by Earthtec may be inadequate.

Kaliser (1998) recommends no construction in the lower part of the site (below an elevation of 4,660 feet) where possible landslide features are present. This recommendation is likely inadequate given the potential for landsliding to extend upslope and impact proposed houses.

SUMMARY AND RECOMMENDATIONS

Whereas the design recommendations in the Earthtec (1998) report adequately address shallow ground water and earthquake ground shaking, other hazards, particularly the potential for landslides require additional study. Given the apparent active landsliding in the lower part of the site and because landslides could pose a life-safety threat and cause severe property damage to proposed homes, existing homes downslope, and buried utilities, I recommend that a more detailed geotechnical-engineering slope-stability investigation (Hylland, 1996) be conducted. This investigation should:

- Explain the discrepancy between Earthtec's calculated static factor of safety and the apparent marginal stability of the slope based on recent historical landslides triggered by site modifications.

- Characterize geologic conditions at the site and include detailed geologic cross sections of soil deposits. The cross sections should be constructed by a qualified engineering geologist with experience in landslides, liquefaction features, and Lake Bonneville stratigraphy.

- Include laboratory soil-strength testing of all principal soil types, particularly weak layers and existing zones of landslide deformation/movement, encountered in the subsurface at the site to a depth equivalent to the relief of the bluff.

- Determine ground-water conditions at the site, particularly in the late winter and early spring, including the presence/absence of perched, unconfined, and confined ground water.

- Consider the effects of site modifications including cuts, fill-related surcharge loads, or the potential rise in ground-water levels due to landscape irrigation.

- Consider the potential for earthquake/liquefaction-induced landsliding.

In the absence of a study, as described above, and its favorable review by our office, I do not recommend development at this site. Depending on the results of the study, the city may wish to consider a hillslope management plan that addresses subdivision design and places some restrictions on landowners to reduce the likelihood of landsliding.

In the event that slope-stability concerns are adequately addressed in a subsequent study and incorporated into subsequent engineering design such that development is feasible, other geologic hazards need additional study as well, including soil erosion, liquefaction, moisture-sensitive soils, and piping. With respect to these hazards, I recommend the following.

- A qualified engineer should review erosion/flooding problems at this site and abutting subdivisions and design a surface runoff collection system that can adequately handle the precipitation received during an intense rainstorm, such as that which occurred on August 26, 1998.

- The susceptibility for liquefaction should be assessed at the site by a qualified engineering geologist and/or geotechnical engineer with experience in investigating liquefaction features and assessing liquefaction susceptibility and liquefaction-induced ground failure.

- A study should address the potential for and nature of, if present, moisture -sensitive soils at the site. The study should include laboratory testing of soil samples so that engineers can recommend adequate hazard-reduction measures in foundation, pavement, and utility design.

- A study should assess the potential for piping at the site. The study should include a site investigation for potential piping-related features and an assessment of the potential for future piping at the site, and, if necessary, provide recommendations to reduce the hazard.

The recommended studies listed in the last three items above will require subsurface exploration and laboratory testing, which could be conducted in conjunction with the recommended slope-stability study.

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Project:			Requesting Agency:
Review of "Engineering geology site reconnaissance, preliminary geotechnical slope stability analysis, single-family residential lot, lot 1129 on Ridge Lake Drive, Timber Lakes subdivision, Wasatch County, Utah"			Wasatch County Planning
By: Barry J. Solomon	Date: 10-26-98	County: Wasatch	Job No: 98-35 (R-26)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

INTRODUCTION

At the request of Anthony Kohler, Wasatch County Planning Assistant, I reviewed an engineering-geology report by AGRA Earth & Environmental, Inc. (AGRA, 1998) for lot 1129 of the Timber Lakes subdivision, Wasatch County, Utah. I received the report on September 28, 1998. Lot 1129 is located in the NW1/4 section 10, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of my review is to assess whether AGRA (1998) adequately addressed the potential for geologic hazards on the lot. My scope of work included a review of published geologic-hazards maps (Hylland and Lowe, 1995), but I did not inspect the property. Recommendations pertaining to foundation design and site grading in AGRA (1998) should be reviewed by a qualified geotechnical engineer.

DISCUSSION

The AGRA (1998) report addresses earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. I believe the report adequately addresses these potential geologic hazards and I concur with AGRA's conclusions and recommendations related to them.

The AGRA (1998) report also addresses landslides and slope stability. Lot 1129 lies on one of several deep-seated landslides in the Timber Lakes subdivision (Hylland and Lowe, 1995; Utah Geological Survey unpublished mapping). The landslide, herein referred to as the Witts Lake landslide, is bounded on the south by Witts Lake, on the north and east by Lake Creek, and on the west by the Pine Ridge landslide. AGRA (1998) analyzes the stability of both the Witts Lake landslide and the relatively steep slopes at lot 1129 along Lake Creek on the northeastern margin of the landslide. AGRA (1998) used the guidelines of Hylland (1996) for their analyses.

Hylland (1996) describes three levels of study for evaluating landslide hazards. Each level depends, in part, upon site-specific conditions and the availability of representative field data. AGRA (1998) used the level of study designated by Hylland (1996) as a preliminary geotechnical-engineering evaluation. This type of evaluation includes a quantitative slope-stability analysis using estimated, rather than measured, input parameters. Because of the uncertainties associated with using estimated parameters, Hylland (1996) recommends using low-range strength values and conservative ground-water levels. The main purpose of the preliminary geotechnical-engineering evaluation is to determine whether a detailed geotechnical-engineering evaluation, involving drilling and soil testing, is necessary. If a preliminary evaluation shows that the slope is stable using conservative input parameters, then a detailed evaluation is not necessary.

The Witts Lake landslide is within Pleistocene glacial till. AGRA (1998) characterizes the till as brown, gravelly sand with clay, silt, and cobbles. Ashland and Hylland (1997) analyzed the stability of similar glacial till in the Pine Ridge landslide, west of the Witts Lake landslide. They back-calculated friction angles ranging from 24 degrees (residual strength) to 39 degrees (peak strength), conservatively assuming no cohesion and a shallow water table. In the absence of soil-test data from, or measurements of ground-water depth in, the glacial till in Timber Lakes, I consider the back-calculated values and conservative estimates of Ashland and Hylland (1997) to be the best available conservative input parameters for use in a preliminary geotechnical-engineering evaluation of the till. A lack of cohesion is consistent with the minimum values for cohesion of dense silty sand and granular glacial till (clayey sand) reported by Hammond and others (1992, table 5.5) in their compilation of measured geotechnical parameters. A shallow water table is consistent with the observation by Ashland and Hylland (1997) of nearby springs in a debris slide on steep slopes along Lake Creek.

The AGRA (1998) analysis of the stability of the Witts Lake landslide uses soil-strength parameters that are consistent with the conservative values used by Ashland and Hylland (1997). However, AGRA's (1998) estimate of ground-water depth is probably a maximum rather than a minimum depth, and is not consistent with Ashland and Hylland's (1997) observation. AGRA (1998) reports that no evidence of shallow ground water or springs was observed on lot 1129 during their site inspection, but the observation was made during the driest part of the year in late summer. Nearby springs above the creek level were observed by Ashland and Hylland (1997) during the late fall. Thus, a conservative estimate of ground-water depth should assume that shallow ground water may be present beneath the site due to seasonal variations in ground-water depth and possible perched ground water. Assuming shallow ground water, the water table within the Witts Lake landslide would intersect the steep slope face along Lake Creek, rather than coinciding with the creek at the slope base as shown in the analysis of AGRA (1998, figures 5 and 6). Increased pore pressure in shallow, saturated soils may reduce the factor of safety calculated in a slope-stablity analysis to an unacceptable level, considerably below the factors of safety calculated in the analyses by AGRA (1998).

The AGRA (1998) analysis of the stability of the steep slopes along Lake Creek on lot 1129 uses values for soil cohesion and ground-water depth which I do not consider sufficiently conservative. AGRA (1998) assumes that glacial till on lot 1129 has a friction angle of 30 degrees and a cohesion of 200 pounds per square foot, "based on index soil strength ranges typical for the soils observed on the site" (AGRA, 1998, p. 6). However, the validity of a preliminary geotechnical-engineering evaluation depends upon the use of values that are conservative, and not necessarily typical, indicating that the cohesionless estimate of Ashland and Hylland (1997) is appropriate. The observation by AGRA (1998) that nearby road cuts and an excavation have not failed is inadequate evidence to support an estimate of 200 pounds per square foot cohesion in on-site soils. Slope failure on lot 1129 will likely occur in the weakest soil layer, which may not be exposed in the cut slopes. Although AGRA (1998) models shallow, saturated soils to simulate the influence of a septic-tank soil-absorption system (STSA), the zone of saturation is modeled as a mound directly beneath the proposed system location above the crest of the relatively steep slope along Lake Creek. Beneath the slope, AGRA (1998) models ground water at depths of up to about 50 feet. At these depths, ground water is consistently below the most critical failure surface in the site-specific static slope-stability analysis (AGRA, 1998, figure 7). Although this critical failure surface has an acceptable factor of safety when modeled with deeper ground water and higher cohesion, the factor of safety may be unacceptable with more conservative values. To evaluate setbacks from steep slopes along Lake Creek on the Pine Ridge landslide, Ashland and Hylland (1997, p. 23) defined the zone in which factors of safety were 1.5 using the residual and peak strengths listed above, with a shallow water table. I recommend a similar approach here.

RECOMMENDATIONS

AGRA (1998, p. 7) concludes "that the possibility of slope failure causing irreparable damage to the proposed structure location is slight." This conclusion is based on a quantitative slope-stability analysis, conducted by AGRA as part of a preliminary geotechnical-engineering evaluation. I believe that values used for cohesion and ground-water depth by AGRA (1998) in the analysis are inconsistent with guidance provided by Hylland (1996) for this type of evaluation, and are not sufficiently conservative. I therefore recommend:

- that the quantitative slope-stability analysis be conducted using sufficiently conservative input parameters, as described above for consistency with the recommendations of Hylland (1996), to determine the stability of the Witts Lake landslide and the slope along Lake Creek. If inadequate factors of safety for the landslide, or an unacceptable safe setback distance from the Lake Creek slope, are obtained, a detailed geotechnical-engineering evaluation will be necessary.

I also recommend that:

- the evaluation include a topographic map at a scale suitable for site planning showing recommended building setbacks, non-buildable areas, the STSA-system location, and any site-design features to reduce hazards;
- the ground-water depth estimates in the evaluation should consider the impact of site drainage and placement of an STSA system, and
- recommendations pertaining to foundation design and site grading in the AGRA (1998) report and any subsequent studies be reviewed by a qualified geotechnical engineer.

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Project: Review of "Geotechnical investigation, Town Homes at Sun Ridge Hills, Provo, Utah County, Utah"			Requesting Agency: City of Provo
By: Richard E. Giraud	Date: 10-27-98	County: Utah	Job No: 98-36 (R-27)
USGS Quadrangle: Provo (1047), Springville (1046)		Number of attachments: none	

INTRODUCTION

At the request of Nicholas Jones, Provo City Engineer, I reviewed a geotechnical report by RB&G Engineering, Inc. (RB&G, 1995) for the Alpine Brook Town Homes, Provo, Utah (formerly called Town Homes at Sun Ridge Hills). The subdivision is located at approximately 1200 South Slate Canyon Drive in the NW1/4 NE1/4 section 17, T. 7 S., R. 3 E., Salt Lake Base Line and Meridian. I received the report on October 7, 1998. 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 soil, geologic, and Utah County natural-hazard overlay maps. I did not conduct a field inspection of the property. Recommendations pertaining to foundation design and site grading should be reviewed by a qualified geotechnical engineer.

RB&G (1995) addresses problem soils, shallow ground water, faulting, and slope stability. Recommendations concerning problem soils and shallow ground water are adequate. However, the report does not adequately address surface fault rupture and slope stability. In addition, debris-flow, flooding, and rock-fall hazards may exist at the site but were not addressed.

SURFACE FAULT RUPTURE

The most recent published geologic map of the area (Machette, 1992) shows a trace of the Wasatch fault through the northern portion of the subdivision. This fault follows the steep slope that crosses the site in a northeast direction. The steep fault scarp is also mapped as an escarpment by Swenson and others (1972) in their soil mapping of the area. Machette (1992) maps another strand of the Wasatch fault east of the site. The faults shown on Machette's (1992) map are also on Utah County's fault-rupture overlay map.

RB&G performed a fault study of the subdivision area. Four trenches were excavated on the site but only three were logged because one trench caved. Only trench 1 is labeled on the subdivision map (RB&G, 1995, figure 2); other trench locations are shown but are not labeled. The trenches were not excavated across the fault scarp mapped by Machette (1992), although three trenches were excavated southeast of the fault scarp on a projected trend of a fault shown on the subdivision map (RB&G, 1995, figure 2). Two of the three trenches were offset to accommodate terrain, and do not have sufficient overlap to account for variations in the expected fault trend. As a result, the trenches as configured leave gaps through which faults may pass.

Faulting was identified in trench 4 displacing Lake Bonneville deposits, but is inferred to be "fairly old." The age of a younger geologic unit not displaced by the fault is not discussed, so no supporting evidence is presented to preclude Holocene displacement on the fault. It therefore must be considered active. As shown on the log, the fault has reverse movement which is possible in the zone of deformation (Yeats and others, 1997, p. 267) although uncommon in the extensional tectonic environment of the Wasatch fault. Such displacements are commonly found at the toes of landslides, but this possible origin is not discussed. RB&G (1995) states that "smaller faults, like that in trench 4 should be expected"; however, no recommendation is given to further evaluate the presence of small faults. RB&G further states that "it is not expected that these small faults will be any problem to the development." These statements are not compatible with the 4 to 5 feet of offset of Lake Bonneville deposits discussed for the fault in trench 4. Fault displacements of 4 to 5 feet will generally cause severe damage to overlying structures.

The log of trench 1 shows several high-angle contacts between Lake Bonneville deposits and colluvial deposits. The report states that these high-angle contacts are believed to be erosional and not fault related. However, these high-angle contacts may be part of a graben west of the main fault scarp. Two normal faults are shown by dashed lines with bar and ball symbols on the subdivision map (RB&G, 1995, figure 2) near trench 1. The western fault coincides with the high-angle contacts on the log of trench 1. The eastern fault coincides with the fault mapped by Machette (1992), but trench 1 does not extend far enough east to encounter this fault.

Machette (1992) describes the Provo section of the Wasatch fault as multiple, parallel to branching fault strands that form a fault zone. Machette (1992) also states that the pattern of ground rupture south of Slate Canyon (the subdivision area) is complicated by fault scarps that predate the Bonneville lake cycle, fault scarps that were modified by the rise and fall of Lake Bonneville, and faults that were reactivated during the Holocene. The above information clearly indicates the potential for surface fault rupture at the site and the need to thoroughly evaluate the fault-rupture hazard.

The entire subdivision is within the Utah County fault-rupture overlay zone (Robison, 1990). 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 to locate faults and determine appropriate setbacks. Geologic logs of the trenches are required to show the type, extent, and amount of deformation in the fault zone and provide a basis for setback recommendations. RB&G's recommendation to observe footing excavations to further assess the fault hazard is advisable, but is not a substitute for a complete investigation prior to subdivision approval because some footing excavation depths may not be deep enough to encounter the fault plane. Also, if a fault is encountered in a footing excavation, it is extremely difficult to adjust the building footprint and subdivision plan.

The information presented by RB&G is inadequate to evaluate the surface-fault-rupture hazard of the subdivision. Existing trench information may be inaccurate with respect to: the age(s) of fault displacement, the origin of high-angle contacts between some geologic units that may be fault contacts, and the interpretation that the reverse displacement in trench 4 is due to faulting rather than landsliding. Additional trenches may be necessary to resolve these issues. Unevaluated areas resulting from gaps between existing trenches should also be trenched. In addition, the existing trench information does not preclude the possibility of other faults on the property.

Because the entire subdivision is in the Utah County fault-rupture overlay zone, I recommend additional fault studies to identify all potential fault scarps including those in Machette (1992) and on Provo City/Utah County maps. Potential fault scarps should then be trenched to locate faults. Trenches should extend far enough from faults to define the zone of deformation and determine setbacks.

SLOPE STABILITY

The eastern portion of the subdivision is within the landslide-hazard overlay zone (Robison, 1990). RB&G (1995) noted that no indications of slope instability were found on the property, although the "fault" in trench 4 may indicate landsliding. RB&G (1995) did not perform a slope-stability analysis of slopes on the site or the steep mountain slopes to the east. Locally steep slopes are present in the subdivision. The fault scarp mapped by Machete (1992) has a maximum slope of 53 percent and is 30 to 40 feet high. Drill-hole logs within the proposed subdivision indicate clay interbedded with coarser clastic materials. Ground water may perch on these low permeability clay layers, weaken subsurface materials, and initiate landsliding. Ground water was not encountered in the drill holes but may be introduced by landscape irrigation. I recommend that a slope-stability evaluation be performed for subdivision slopes exceeding 30 percent, particularly slopes containing clayey soils. Also, at least a reconnaissance should be performed of the steep mountain slopes to the east to look for evidence of colluvial and rock-mass slope instability and to assess the potential for landslides that could impact the subdivision.

DEBRIS FLOWS AND FLOODING

The subdivision is within a debris-flow hazard overlay zone (Robison, 1990). RB&G (1995) acknowledges the presence of debris-flow deposits in their discussion of collapsible soils but does not discuss the potential of debris flows impacting structures or depositing debris in the subdivision. Machette (1992) maps both pre- and post-Lake Bonneville alluvial-fan material in the subdivision area and discusses alluvial-fan deposition by stream flow, debris floods, and debris flows. Swenson and others (1972) recognize that debris flows and mud flows have locally buried the surface of the mapped soil unit in the area (Pleasant Grove stony loam). An origin is not provided for the colluvial deposits described in the fault trenches but some of the material may represent debris flows. I recommend that the debris-flow hazard from the steep drainages east of the subdivision be evaluated.

Surface-water runoff from the steep mountain slopes and drainages east of the subdivision, associated with rapid snowmelt or intense rainfall, may cause alluvial-fan flooding. I recommend that the flooding potential from drainages and slopes east of the subdivision, and from subdivision runoff into areas downslope, be evaluated. Swenson and others (1972) indicate that some soils on the site are highly erodible, so soil erosion by floodwaters should also be addressed.

ROCK FALL

The subdivision is within a rock-fall hazard overlay zone (Robison, 1990), indicating a potential for rock fall from the steep mountain slopes east of the subdivision. I recommend that the rock-fall hazard be evaluated and the evaluation include an assessment of rock-fall sources, travel paths, and depositional areas.

SUMMARY AND RECOMMENDATIONS

RB&G's (1995) recommendations for problem soils and shallow ground water are adequate; however, additional study is needed for the evaluation of surface fault rupture, slope stability, and debris-flow, flooding, and rock-fall hazards. I recommend the following:

- Evaluate the surface-fault-rupture hazard associated with the Wasatch fault throughout the subdivision by further trenching to determine appropriate setbacks and to define buildable areas. Additional trenching should also evaluate the fault mapped by Machette (1992). If trenches are offset there must be sufficient trench overlap to accommodate for variations of the expected fault trend. If the age(s) of fault displacements is believed to be pre-Holocene, evidence confirming the interpretation must be presented.

- Perform at least a preliminary geotechnical-engineering slope-stability evaluation, as outlined in Hylland (1996), to evaluate the stability of subdivision slopes. A possible landslide origin for the fault in trench 4 should be investigated. Slope performance must be evaluated under appropriate earthquake ground-shaking and estimated development-induced (landscape irrigation) ground-water conditions. Potentially unstable slopes within the subdivision should be identified and either designated as unbuildable areas giving appropriate setbacks, or as buildable areas giving recommendations for safe development.

- Perform at least a reconnaissance of steep mountain slopes to the east to look for evidence of existing or potential colluvial and rock-mass instability.

- Evaluate the debris-flow hazard from drainages east of the subdivision. The evaluation should begin by defining areas of active deposition (post-Bonneville alluvial fans), followed by an estimation of the frequency and volume of flows, travel paths, and flow depths. Based on these data, recommendations for hazard-reduction measures should be provided, if necessary.

- Evaluate the flooding potential from drainages east of the subdivision, from mountain- slope surface-water runoff into the subdivision, and from subdivision runoff into areas downslope as part of the subdivision drainage plan. Potential erosion from floodwaters should also be addressed.

- Evaluate the rock-fall potential from mountain slopes east of the subdivision and provide recommendations for hazard reduction measures, if necessary.

I recommend that setbacks, hazard areas, and protective structures, determined from the above hazard evaluations, be shown on the subdivision plat map to delineate buildable areas. The locations of fault scarps, trenches, and boreholes must be clearly labeled on report figures. Specific recommendations and restrictions pertaining to site building design and lot development should be included in the report. All conclusions and recommendations must be supported with evidence. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer. I also recommend that the RB&G report, this review, and any subsequent geologic-hazards reports and reviews for this subdivision be disclosed to future lot and/or home buyers.

REFERENCES

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Project: Review of "Geologic and geotechnical consultation, lot 30, East Bench at 29th subdivision, Ogden, Utah."			Requesting Agency: Ogden City Planning Division
By: Bill D. Black	Date: 11-03-98	County: Weber	Job No: 98-37 (R-28)
USGS Quadrangle: Ogden (1345)		Number of attachments: 0	

INTRODUCTION

This report is a review of a geologic and geotechnical investigation (Earthtec Engineering, 1998) for lot 30 in the East Bench at 29th subdivision in Ogden City, Weber County, Utah. The lot is located in the SE1/4SE1/4 section 34, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian. Greg Montgomery, Ogden City Planning Division, requested the review. The Utah Geological Survey received the report on September 30, 1998. The purpose of my review is to assess whether geologic hazards possibly impacting the property are adequately identified and addressed. The scope of work for my review consisted of a literature review. No site visit was made.

Earthtec Engineering (1998) evaluated primarily the hazard from surface fault rupture at the property (Greg Montgomery, verbal communication, October 1998), but also discussed potential earthquake hazards from liquefaction and ground shaking, and slope-stability concerns. Other geologic hazards possibly impacting the property are not discussed and should be identified and addressed.

DISCUSSION

Surface faulting is a potential hazard at the property (Earthtec Engineering, 1998). The main trace of the Weber segment of the Wasatch fault zone is about 400 feet (122 m) east of the site. The property is in a surface-fault-rupture special-study zone as shown on unpublished Weber County Planning Department maps, and has a non-buildable zone along a lineament (possible fault) on the east side of the property; presumably the lineament is from Ogden City's hazard maps. Earthtec Engineering (1998) excavated one 70-foot (21-m) long trench in the eastern part of the property which exposed no evidence for faulting. Based on this, Earthtec Engineering (1998) believes the risk from surface faulting is low. Although the trench log shows no evidence of surface faulting, neither the proposed building footprint nor trench location is shown in the report. Without this information, I am uncertain if the hazard from surface faulting has been adequately investigated.

Liquefaction and earthquake ground shaking are also potential hazards at the property (Earthtec Engineering, 1998). The site is near the head of an inactive lateral-spread landslide (likely produced by liquefaction) (Harty and others, 1993; Nelson and Personius, 1993), and Earthtec Engineering (1998) suggests liquefaction may occur at depth at the site if saturated sandy soils possibly present are subjected to strong ground shaking. Earthtec Engineering (1998) did not assess the susceptibility of site soils to liquefaction, but indicates depth to ground water is greater than 29 feet (8.8 m) at the site and presumably therefore believes the risk from liquefaction is low (although they further recommend reinforcing footing and foundation walls). Anderson (1994) indicates liquefaction potential of the site is moderate to low. Because site soils consist of silty sand underlain by interbedded clay and sand, development of a perched water table resulting from landscape irrigation and seasonal snowmelt is likely, which may increase liquefaction potential. Regarding ground shaking, Earthtec Engineering (1998) indicates the site is located in Uniform Building Code seismic zone 3, and all structures should be designed and constructed (at a minimum) in accordance with seismic zone 3 requirements. This recommendation meets minimum standards for earthquake-resistant design.

The stability of the approximately 25-foot (7.6-m) high 1:1 (horizontal:vertical) cut slope on the west side of the property is a concern. Slope-stability analyses in Earthtec Engineering (1998) using assumed soil strengths, presumed existing ground-water levels, and a 28-foot (8.5-m) setback distance from the face of the cut, show minimum acceptable factors of safety. This suggests to me the slope may be potentially unstable if ground-water levels rise due to landscape irrigation or seasonal changes, or if strength of the interbedded sand and clay below 10 feet (3 m) is lower than assumed and failure occurred in this material. To maintain minimum stability levels, Earthtec Engineering (1998) recommends that (in addition to the setback) a foundation drain be incorporated to alleviate hydrostatic pressure from surface percolation and drainage be directed well away from the structure. I believe the slope-stability analysis should be redone using more conservative soil strengths and the shallowest possible water table given the site drainage recommendations. Hylland (1996) recommends using conservative strength values and ground-water levels when measured values are absent. Also, the recommended setback is designed to prevent failure of the foundation should the cut slope fail. However, removal of lateral support by such a failure could still eventually cause damage to the structure.

Debris flows are a potential hazard at the property. The property is located on a Holocene alluvial fan shown on Nelson and Personius (1993) and unpublished Weber County Planning Department maps that may be subject to flooding or sedimentation from debris flows and floods. The hazards from debris flows and alluvial-fan flooding were not addressed in Earthtec Engineering (1998), but should be evaluated.

SUMMARY AND RECOMMENDATIONS

Earthtec Engineering (1998) identifies and discusses potential hazards from surface faulting, liquefaction, ground shaking, and slope stability at lot 30 in the East Bench at 29th subdivision. Regarding Earthtec Engineering (1998), I recommend:

- the location of Earthtec's trench (excavated to evaluate the potential surface-fault-rupture hazard) be shown on a map, particularly with respect to all suspected fault traces, the surface-fault-rupture special-study zone, and the building footprint;

- the potential hazard from liquefaction be disclosed to future buyers;

- slope-stability analyses be redone using more conservative soil strengths and development-induced ground-water levels;

- previous reports for the subdivision be reviewed by Ogden City to determine if geologic hazards not identified or discussed in Earthtec Engineering (1998), particularly alluvial-fan flooding and debris flows, have been addressed and, if not, these hazards be addressed;

- Ogden City ensure the consultant's recommendations are followed; and

- the existence of Earthtec Engineering (1998), this review, and all previous and subsequent reports and reviews be disclosed to future buyers.

REFERENCES

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Project: Review of "Surface fault rupture study, The Pointe at Stone Mountain Phase 4, 1525 East 4850 South, Ogden, Utah."			Requesting Agency: Ogden City Planning Division
By: Bill D. Black	Date: 11-13-98	County: Weber	Job No: 98-38 (R-29)
USGS Quadrangle: Ogden (1345)		Number of attachments: 0	

INTRODUCTION

This report is a review of a surface-fault-rupture hazard study (Kaliser, 1998) for lots 44 and 45 in The Pointe at Stone Mountain Phase 4 development at 1525 East 4850 South, Ogden, Weber County, Utah. The property is in the N1/2 section 15, T. 5 N., R 1 W., Salt Lake Base Line and Meridian. Rick Grover, Ogden City Planning Division, requested the review. The Utah Geological Survey received the report on October 6, 1998. The purpose of my review is to assess whether potential hazards at the site, particularly surface fault rupture, have been adequately addressed. The scope of work for my review consisted of a literature review. No site visit was made.

DISCUSSION

Kaliser (1998) identifies surface faulting as a potential hazard at the property and indicates a relatively steep slope on the west end of the property is a scarp associated with a trace of the Wasatch fault. However, the property is roughly 3,600 feet (1,100 m) west of the main Wasatch fault trace (Nelson and Personius, 1993), and is west (outside) of the surface-fault-rupture special-study zone delineated on unpublished Weber County Planning Department maps. I am not aware of any published mapping that shows faults at the property or indicates the slope on the west end of the property is a trace of the Wasatch fault. Therefore, I consider the origin of the slope to be uncertain. Harty and others (1993) show a landslide scarp near the slope that may be related with the East Ogden lateral spread. Nelson and Personius (1993) also show a landslide scarp near this location apparently associated with liquefaction-induced lateral spreading. The slope may also be the western margin of the lower slide mass of the pre-Lake Bonneville Beus Canyon rockslide mapped by Pashley and Wiggins (1971).

To evaluate a presumed surface-faulting hazard, Kaliser (1998) excavated five trenches in and above the slope at the property. Kaliser (1998) concluded that two trenches exposed evidence of surface faulting (displaced convoluted lake sediments, commonly vertical and overturned in one trench), and a third trench exposed evidence of liquefaction (slightly displaced lake sediments and sand dikes). Each trench had "a different appearance and geomorphologic expression" (Kaliser, 1998). Surface faulting could produce some of the features in the first two trenches, but convoluted bedding and inconsistent displacement and deformation from one trench to the next are also features typical of liquefaction and/or landsliding. This style of deformation seems similar to that observed in trenches in liquefaction-induced landslide deposits near Harrisville, North Ogden, and Farmington, Utah (Harty and Lowe, 1995; Hylland and Lowe, 1998). This evidence, along with the lack of any mapped faults at the property and the great distance of the property from mapped fault traces, suggests to me that liquefaction and/or landsliding may be the causes of deformation, rather than surface faulting. However, Kaliser (1998) includes no trench logs or supporting evidence for me to evaluate his or alternate interpretations. Such evidence is critical, particularly since the hazard at the property is ambiguous. Statewide minimum standards for surface-fault-rupture hazard and engineering-geologic investigations indicate reports must include geologic evidence (and detailed trench logs, where excavated) supporting all conclusions and recommendations (Utah Section of the Association of Engineering Geologists, 1986, 1987; Nelson and Christenson, 1992).

Kaliser (1998) does not consider liquefaction and/or landsliding as alternate causes for the deformation observed in two of his trenches. Further work is needed to determine the cause of the deformation and its hazard implications. Kaliser (1998) indicates that although liquefaction produced minor deformation evident in a third trench, liquefaction is not likely to recur under present ground-water conditions. However, liquefaction potential and risk could increase if ground-water levels rise due to seasonal or development-induced conditions (such as landscape irrigation). Possible landslide deformation evident in Kaliser's (1998) trenches also suggests stability of the steep slope on the west side of the property may be a concern. I recommend stability of the slope be evaluated if subsequent site-specific studies conclude landsliding has occurred at the property or if slopes exceed 30 percent. The evaluation should consider not only existing but also probable development-induced ground-water conditions (shallowest likely water table).

Kaliser (1998) indicates the property is located in Uniform Building Code seismic zone 3, and recommends all structures be designed and constructed (at a minimum) according to seismic zone 3 requirements. This recommendation meets minimum standards for earthquake-resistant design.

CONCLUSIONS AND RECOMMENDATIONS

Kaliser (1998) identifies deformation at the property and attributes it to surface faulting in two trenches and to liquefaction in a third. However, I consider the origin of the deformation in the first two trenches to be ambiguous, and Kaliser (1998) provides insufficient evidence supporting his conclusions. Liquefaction and/or landsliding could have produced this deformation and are not considered. A hazard from slope instability may also be present that is not evaluated. Regarding lots 44 and 45 in phase 4 of the development, I recommend:

- the hazard from surface faulting be re-examined to determine if it is present, and other possible origins of the deformation be considered and their hazard implications evaluated;
- stability of the slope on the west side of the property be evaluated (considering the shallowest likely water table) if evidence of past landsliding at the property is found or if the slope is steeper than 30 percent; and
- the existence of Kaliser's (1998) report, this review, and all subsequent reports and reviews be disclosed to future buyers.

Adequate geologic evidence supporting all conclusions and recommendations should be provided in surface-fault-rupture hazard and engineering-geologic reports. Thus, I further recommend Ogden City require any fault or other geologic-hazard study involving trench excavations to include detailed trench logs.

REFERENCES

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Project: Review of "Geotechnical report, Sunset Drive landslide, Layton, Davis County, Utah"			Requesting Agency: Layton City Community Development Department
By: Richard E. Giraud	Date: 11-13-98	County: Davis	Job No: 98-39 (R-30)
USGS Quadrangle: Kaysville (1320)		Number of attachments: none	

INTRODUCTION

At the request of Scott Carter, Layton City Community Development Director, I reviewed a geotechnical report by Terracon Consultants, Inc. (Terracon, 1998) for the Sunset Drive landslide in Layton, Utah. I received the report on October 15, 1998. The Sunset Drive landslide is located at 1851 Sunset Drive in Layton in the SE1/4SE1/4 section 10, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of this review is to evaluate if the landslide hazard has been adequately addressed and, where necessary, to provide additional comments and recommendations. Recommendations pertaining to the design of the interceptor trench drain and the drilled-shaft-soldier-pile wall should be reviewed by a qualified geotechnical engineer.

Terracon (1998) performed a geotechnical-engineering slope-stability investigation of the Sunset Drive landslide. Landslide movement in 1998 was observed both in a scarp at the top of the northwest-facing slope (upper scarp) and in a small scarp on the lower portion (lower scarp) of the slope. A small landslide involving fill on the upper slope is indicated by the upper scarp and movement measured in the inclinometers. Movement in the upper slope has caused structural distress to houses and landscaping.

SLOPE STABILITY

Terracon (1998) analyzed the slope stability based on information from geologic logs of boreholes, ground-water depth measurements, geotechnical testing of subsurface samples, and inclinometer measurements. Two landslides were considered in the slope-stability analysis: (1) the small shallow landslide in the slope crest that extends from the upper scarp down to the toe of the fill, and (2) a possible large deep landslide that extends from the upper scarp down to the North Fork of Kays Creek at the toe of the slope. The stability of another possible small landslide in the lower slope that presumably extends from the lower scarp down to the North Fork of Kays Creek was not considered.

The inclinometer measurements indicate that the slip surface of the small shallow landslide in the slope crest is at depths of 10 to 13 feet. Movement has been continual but slowing from June to September 1998. Terracon (1998) does not address the cause of movement but states that above-average precipitation is expected to have contributed to movement. No conclusive movement was observed in inclinometers installed in the lower slope to monitor a possible large deep landslide.

Terracon (1998) models the static slope stability of both the small shallow landslide and a possible large deep landslide. The type of model used to perform the slope-stability analysis is not discussed but I assume the model uses the limit-equilibrium method where a factor of safety is determined by the ratio of forces resisting movement to those causing movement. The slope-stability modeling indicates lower factors of safety for a possible larger, deeper landslide than for the smaller, shallow landslide. Terracon states that because no recent movement was observed in inclinometers in the lower slope, the factor of safety for the larger landslide is greater than 1.0, although Terracon still considers the slope "marginally stable." Terracon concludes that landslide movement is occurring only in the upper slope and is primarily due to the fill material placed at the crest of the marginally stable slope. Terracon recommends a ground-water-interceptor trench and soldier-pile wall to improve both the stability at the slope crest and the stability of the entire marginally stable slope.

To evaluate the effectiveness of the interceptor drain, Terracon (1998) models the increase in stability of the small landslide and a possible large landslide by lowering the ground-water level in the slope. The modeling assumes the ground-water system behaves as one aquifer within the interbedded clay, silt, and sand lake sediments that underlie the slope. However, the piezometer data indicate that ground-water levels continually declined from June to September 1998 in the lower slope (P-2 and P-3), while levels at the slope crest were relatively unchanged during this same period (P-1 and P-4). These data suggest that ground-water levels behave independently with little hydraulic connection between the slope crest and lower slope areas, even though the areas are only 350 feet apart. This suggests the possibility of multiple aquifers: a shallow aquifer in the upper part of the slope defined by piezometers P-1 and P-4, and a lower aquifer within the lake sediments in the lower slope defined by P-2 and P-3. If little hydraulic connection exists between the slope crest and lower slope, dewatering the slope crest as recommended may not significantly increase the stability in the lower slope. Further evaluation of the ground-water system would be necessary to determine the degree of hydraulic connection, if any. Slope-stability modeling considering multiple aquifers may result in a higher factor of safety for a large landslide, and indicate that Terracon's single-aquifer model is conservative.

The marginally stable northwest-facing slope is mapped as prehistoric landslide deposits by Anderson and others (1982) and Lowe (1988). Deformation of bedding in lake sediments and possible shear zones are noted on the boring logs of B-1, B-2, and B-4 at depths of 16.5, 6 to 28, and 28 to 29 feet, respectively. The deformed bedding is a geologic indication of previous shallow landslide movement in the marginally stable slope. Terracon (1998) mentions that a deep-seated landslide has not been conclusively ruled out in this slope. No movement on deep slide surfaces was observed in slope inclinometers in the lower portion of the slope, but such movement may only occur during the spring when ground-water levels are highest. The stability of this slope is critical because it may adversely affect the recommended landslide-stabilization structures, houses along Sunset Drive, and a larger area than currently affected by the smaller landslide.

The small lower scarp that formed in the spring of 1998 indicates slope movement earlier this year in the lower slope. This scarp coincides with the elevation of springs in the slope, so this lower lide is probably related to the area of shallowest ground water and may represent movement of a small landslide that extends from the lower scarp down to the North Fork of Kays Creek. However, it may also reflect a response to movement elsewhere in the slope, such as oversteepening due to movement of a deep landslide.

SUMMARY AND RECOMMENDATIONS

Terracon's (1998) analysis of the landslide hazard is appropriate, given their scope of work. Their recommended stabilization techniques for the upper slope seem reasonable, but should be reviewed by a qualified geotechnical engineer. However, I believe the landslide hazard presented by a possible large landslide in the marginally stable slope requires further consideration. The Terracon and earlier Chen and Associates (1987) analyses both indicate that the slopes north of Sunset Drive do not meet generally accepted guidelines for slope stability (static factor of safety greater than 1.5 and earthquake factor of safety greater than 1.1 [Hylland, 1996]). Because of this, there is a risk of damage to landslide-stabilizing structures at the top of the slope. Based on my review I recommend the following:

- Additional modeling of the marginally stable slope with respect to a possible large landslide is needed to understand the effect of a multiple-aquifer system on slope stability, and the implications and risks with regard to the recommended interceptor trench and soldier-pile wall, houses at the slope crest, and underground utilities along Sunset Drive. The analysis should account for the geological indications of previous landslide-slip surfaces, landslide movement in the lower slope, and should determine the potentially unstable area at the top of the marginally stable slope.

- Slope performance for both the small landslide and a possible large landslide should be evaluated under appropriate earthquake ground-shaking conditions.

- If a multiple-aquifer system has a significant effect on slope stability, additional evaluation of the ground-water system is needed to determine if a hydraulic connection exists between the upper and lower slopes. Monitoring piezometers at least monthly over the next year will further characterize the ground-water system.

- Inclinometers should be monitored periodically in late winter and spring 1999 when the water table is the highest, and continued until movement (if any) stops.

- Layton City should consider a hillslope management plan that appropriately restricts excess landscape irrigation and properly directs surface-water drainage in the area to reduce the likelihood of landsliding on the marginally stable slope.

I also recommend that the Terracon report, this review, and any subsequent geologic-hazards reports and reviews for this subdivision be disclosed to future home buyers.

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Project: Review of report "Geologic and geotechnical investigation, proposed Canberra Heights Phase I subdivision, McKinley Drive and Canberra Drive, Lindon, Utah."			Requesting Agency: Lindon City
By: Bill D. Black	Date: 11-20-98	County: Utah	Job No: 98-40 (R-31)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

This report is a review of the geologic-hazards sections of a report by Applied Geotechnical Engineering Consultants (AGEC) for phase I of the Canberra Heights subdivision (AGEC, 1998) at McKinley Drive and Canberra Drive in Lindon (SE1/4 section 35, T. 5 S., R. 2 E., Salt Lake Base Line and Meridian), Utah County, Utah. Kevin Smith (Planning Director, Lindon City) requested the review. The report was received by the Utah Geological Survey on November 2, 1998. The purpose of my review is to evaluate whether geologic hazards at the property are adequately addressed. The scope of work consisted of a literature review. No site visit was made. AGEC (1998) also provides geotechnical recommendations that should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND COMMENTS

AGEC (1998) identifies possible hazards from surface fault rupture, ground shaking, landslides, debris flows, collapsible soil, and rock fall. This appears to be a complete list of possible hazards at the property. My comments regarding AGEC's (1998) assessment of these hazards and recommendations to reduce their risk are outlined below.

- Surface fault rupture: AGEC (1998) believes the risk of surface faulting is low, based on the distance of the property from the closest Wasatch fault trace (300 to 400 feet [91-122 m]) and lack of evidence of surface faulting. I concur, although a narrow wedge of the southeastern corner of the property is in the surface-fault-rupture special-study zone on unpublished Utah County Planning Department maps. The nearest mapped fault is a concealed trace on Machette (1992) shown to be inactive in the past 10,000 years. Because of the small area within the study zone, its location on the study-zone edge, lack of surficial evidence for faulting, and apparent fault inactivity, trenching studies to evaluate surface-faulting hazards are not needed.

- Ground shaking: AGEC (1998) indicates the property is located in Uniform Building Code (UBC) seismic zone 3, and all structures should be constructed according to zone 3 requirements using a soil-profile type of S-2. This recommendation meets minimum UBC requirements adopted by state and local governments for earthquake-resistant design.

However, AGEC's (1998) soil-profile type uses 1994 UBC site coefficients. The 1997 UBC uses a different system, and AGEC should indicate the 1997 UBC soil-profile type.

- Landslides: AGEC (1998) indicates Machette (1989, 1992) shows several large prehistorical landslides and bedrock susceptible to landsliding east of the property. However, AGEC observed no evidence of landsliding at the property and indicates slopes are generally gentle. Based on this, AGEC believes the risk from landsliding is low if proper site-grading practices are followed. Regarding site grading, AGEC (1998) recommends permanent cut-and-fill slopes up to 10 feet (3 m) high be no steeper than 2:1 (horizontal:vertical) and larger cuts be considered individually. I concur with AGEC's assessment and recommendations, and add that larger cuts or multiple smaller cuts could oversteepen slopes and cause potential instability, particularly if ground-water levels rise due to landscape irrigation or seasonal changes.

- Debris flows: AGEC (1998) indicates the property is located on an alluvial fan that may be subject to debris flows and flooding. A 17,500 cubic-yard (13,400-m^3) debris basin (constructed in 1984) is at the mouth of Dry Canyon at the apex of the fan, roughly 0.3 miles (0.5 km) east of the property, and presumably therefore AGEC believes the risk from debris flows is low. Although AGEC indicates Rollins Brown & Gunnell Engineering (RB&GE) performed a hydrologic analysis of the Dry Canyon drainage and the State of Utah Dam Safety Section is evaluating the safety of the debris basin, they do not indicate if the debris basin is adequate to contain a debris flow or 100-year sedimentation-event volume. Thus, I am uncertain if the risks from debris flows and flooding have been mitigated.

- Collapsible soil: AGEC (1998) observed localized areas at the property of soil susceptible to collapse if wetted. To reduce the risk from collapsible soil, AGEC (1998) recommends disclosing the hazard to future buyers, surface water be directed well away from structures, sprinkler lines and heads be at least 10 feet (3 m) away from foundation walls, and a geotechnical engineer inspect footing excavations prior to building. I generally concur with AGEC's assessment and recommendations, but believe that structural mitigation measures are needed if a significant thickness of collapsible soil is found at or below foundation levels.

- Rock fall: AGEC (1998) observed a small source of rock above the northernmost drainage east of the property that could pose a risk from rock fall. To reduce the risk, AGEC (1998) recommends removing the rock source, breaking it up into smaller clasts not likely to reach the property, or constructing a barrier at the top of the drainage (presumably to prevent rocks from entering the drainage and rolling into the property). I concur with AGEC's assessment and recommendations, though the latter recommendation is confusing and the location of the barrier should be clarified. Care should also be taken to maintain proper channel drainage through the barrier.

SUMMARY AND RECOMMENDATIONS

Regarding AGEC's (1998) hazards assessment and recommendations to reduce their risk, I recommend:

- AGEC provide the 1997 UBC soil-profile type;
- Lindon City devise means to ensure AGEC's (1998) site-grading recommendations are followed, no unplanned steeper or higher cuts (such as for landscaping) are made, and irrigation-induced higher ground-water levels, where likely, are considered in slope design;
- AGEC review RB&GE's hydrologic analysis, evaluate adequacy of the debris basin at the mouth of Dry Canyon, and recommend measures to reduce the risk from debris flows and flooding if the basin is found inadequate;
- a geotechnical engineer provide written documentation to Lindon City verifying that footing excavations were inspected and mitigation measures taken, where needed, to deal with collapsible soils, and Lindon City devise means to ensure site drainage and irrigation conform to AGEC's recommendations;
- a final rock-fall risk-reduction method be chosen and design recommendations be given;
- site grading, foundation, underdrain, and pavement recommendations be reviewed by a qualified geotechnical engineer; and
- the existence of AGEC (1998) and this review be disclosed to future buyers.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 1998, Geologic and geotechnical investigation, proposed Canberra Heights Phase I subdivision at McKinley Drive and Canberra Drive, Lindon, Utah: Midvale, Utah, unpublished consultant's report, 18 p.

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Project: Review of "Geotechnical investigation, Eagle View subdivision plat G, Provo, Utah County, Utah"			Requesting Agency: City of Provo
By: Richard E. Giraud	Date: 11-30-98	County: Utah	Job No: 98-41 (R-32)
USGS Quadrangle: Springville (1046)		Number of attachments: none	

INTRODUCTION

At the request of Nicholas Jones, Provo City Engineer, I reviewed a geotechnical report by RB&G Engineering, Inc. (RB&G, 1998) for the Eagle View subdivision plat G. Also included for review was a subdivision plat map with lot grading recommendations by Andreason and Associates (1998). The subdivision is located in the NW1/4 SE1/4 section 17, T. 7 S., R. 3 E., Salt Lake Base Line and Meridian. I received the report on October 30, 1998. 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 soil and geologic maps, Utah County natural-hazard overlay maps, and Provo City geologic-hazard maps. I did not conduct a field inspection of the property. Recommendations pertaining to foundation design and site grading should be reviewed by a qualified geotechnical engineer.

RB&G (1998) addresses problem soils, shallow ground water, and slope stability. Recommendations concerning problem soils and shallow ground water are adequate. However, the report does not adequately address slope stability. In addition, surface-fault-rupture, debris-flow, flooding, and rock-fall hazards may exist at the site but were not addressed.

SLOPE STABILITY

The eastern portion of the subdivision is within Utah County's landslide-hazard overlay zone (Robison, 1990) and a potential landslide zone on the Provo City geologic-hazard maps (International Engineering Company Inc. [IEC], 1984). RB&G (1998) addresses slope stability only by noting that the foundation performance of the built lots in the Eagle View subdivision has been satisfactory. RB&G (1998) did not perform a slope-stability analysis of the site slopes or the steep mountain slopes to the east. Machette (1992) maps an old (older than late Pleistocene) landslide deposit in alluvial-fan materials approximately 500 feet south of the subdivision. The presence of landslide deposits in materials similar to those within the subdivision indicates a potential for landsliding. I recommend that at least a preliminary geotechnical-engineering slope-stability evaluation, as outlined in Hylland (1996), be performed for subdivision slopes exceeding 30 percent. This should consider existing and planned cut and fill slopes. I also recommend that a reconnaissance be performed of the steep mountain slopes to the east to look for evidence of colluvial and rock-mass slope instability and to assess the potential for landslides that could impact the subdivision.

Andreason and Associates (1998) give grading recommendations without regard to slope stability and soil conditions. The grading recommendations focus on regrading lots with slopes greater than 25 percent. The recommendations do not address steep slopes on undeveloped areas between lots, grading around existing power poles, and grading of lots having an underground gas line (lots 54, 56, and 58). An existing 70 percent cut slope that partially surrounds a power pole between lots 62 and 64 may be unstable. There is also no discussion of scarifying and removing organic material prior to fill placement.

The grading recommendations are given by the land surveyor, Andreason and Associates, rather than RB&G, the geotechnical engineer or a civil engineer. RB&G (1998) states that a grading plan had not been developed for the proposed site at the time of their geotechnical investigation, and makes no recommendations for grading or cut and fill slopes. Because the grading recommendations are given without reference to site soil conditions and stable cut and fill slopes, I recommend that the grading recommendations be reviewed by a geotechnical engineer and brought into conformance with the Uniform Building Code ([UBC] 1997). I also recommend that a geotechnical engineer provide recommendations for cut and fill slopes to be included in a grading plan.

SURFACE FAULT RUPTURE

Two strands of the Wasatch fault are mapped in the subdivision area (Machette, 1992), one approximately 300 feet east of the subdivision and another approximately 600 feet west of the subdivision. The faults shown on Machette's (1992) map are also on Utah County's fault-rupture overlay map (Robison, 1990). Andreason and Associates (1998) show a fault 260 to 300 feet east of the eastern subdivision boundary, which is also shown on the Provo City geologic- hazard maps (IEC, 1984), that corresponds to Machette's fault east of the subdivision. RB&G (1998) does not address the surface-fault-rupture hazard within the subdivision.

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 assess the impacts of faulting. Site-specific studies should include detailed aerial-photo and field investigations to identify fault scarps, including trenching of fault scarps to locate faults and determine appropriate setbacks. Geologic logs of the trenches are required to show the type, extent, and amount of deformation in the fault zone and provide a basis for setback recommendations. Because the entire subdivision is in the Utah County fault-rupture overlay zone, I recommend a site-specific study to evaluate the surface-fault-rupture hazard.

DEBRIS FLOWS AND FLOODING

The subdivision is within the Utah County debris-flow hazard overlay zone (Robison, 1990). Provo City geologic hazard maps (IEC, 1984) indicate an alluvial fan with the potential of debris flows and flooding along the eastern subdivision boundary. Machette (1992) maps young fan alluvium (Holocene to uppermost Pleistocene) in the subdivision. The fan alluvium generally consists of pebble and cobble gravel in a matrix of sand and minor clay. The fan alluvium is deposited by intermittent stream flow, debris floods, and debris flows. Swenson and others (1972) recognize that debris flows and mud flows have locally buried the surface of the mapped soil unit in the area (Pleasant Grove stony loam). I recommend that the debris-flow hazard from the steep drainages east of the subdivision be evaluated.

Surface-water runoff from the steep mountain slopes and drainages east of the subdivision, associated with rapid snowmelt or intense rainfall, may cause alluvial-fan flooding. I recommend that the flooding potential from drainages and slopes east of the subdivision, and from subdivision runoff into areas downslope, be considered in the site drainage plan. Swenson and others (1972) indicate that site soils are highly erodible, so soil erosion by floodwaters should also be addressed.

ROCK FALL

The subdivision is within a rock-fall hazard overlay zone (Robison, 1990), indicating a potential for rock fall from the steep mountain slopes east of the subdivision. I recommend that the rock-fall hazard be evaluated and the evaluation include an assessment of rock-fall sources, travel paths, and runout areas.

SUMMARY AND RECOMMENDATIONS

RB&G's (1998) recommendations for problem soils and shallow ground water are adequate; however, additional study is needed to evaluate slope stability and site grading, and surface-fault-rupture, debris-flow, flooding, and rock-fall hazards. I recommend the following:

- Perform at least a preliminary geotechnical-engineering slope-stability evaluation, as outlined in Hylland (1996), of subdivision slopes greater than 30 percent. This should include existing slopes and any planned cut and fill slopes. Slope performance must be evaluated under appropriate earthquake ground-shaking and estimated development-induced (landscape irrigation) ground-water conditions. If the slope-stability analysis indicates unstable slopes within the subdivision, unstable areas will need to be designated either as unbuildable areas giving appropriate setbacks, or as buildable areas giving recommendations for safe development. A geotechnical engineer should also review the Andreason and Associates (1998) grading recommendations and provide recommendations for stable cut and fill slopes in conformance with the UBC.

- Perform at least a reconnaissance of steep mountain slopes east of the subdivision to look for evidence of existing or potential colluvial and rock-mass instability.

- Evaluate the surface-fault-rupture hazard associated with the Wasatch fault by identifying possible fault scarps or other evidence of active faulting. If there is evidence of active faulting, trenching must be performed to locate faults and determine appropriate setbacks.

- Evaluate the debris-flow hazard from drainages east of the subdivision. The evaluation should define areas of active deposition (post-Bonneville alluvial fans), followed by an estimate of the frequency and volume of flows, travel paths, and flow depths. Based on these data, recommendations for hazard-reduction measures should be provided, where pertinent.

- Evaluate the flooding potential from drainages east of the subdivision, from mountain- slope surface-water runoff into the subdivision, and from subdivision runoff into areas downslope as part of the subdivision drainage plan. Potential erosion from floodwaters should also be addressed.

- Evaluate the rock-fall potential from mountain slopes east of the subdivision and provide recommendations for hazard-reduction measures, where pertinent.

I recommend that setbacks, hazard areas, and protective structures, determined from the above hazard evaluations, be shown on the subdivision plat map to delineate buildable areas. Specific recommendations and restrictions pertaining to site building design and lot development should be included in the report. All conclusions and recommendations must be supported with evidence. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer, as appropriate. I also recommend that the RB&G (1998) report, the Andreason and Associates (1998) map, this review, and any subsequent geologic-hazards reports and reviews for this subdivision be disclosed to future lot and/or home buyers.

REFERENCES

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Project: Review of "Fault rupture hazard and geotechnical study, The Hamptons Planned Urban Development, SW1/4 S. 14, T5N, R1W, SLBM, Ogden, Utah."			Requesting Agency: Ogden City
By: Bill D. Black	Date: 12-09-98	County: Weber	Job No: 98-42 (R-33)
USGS Quadrangle: Ogden (1345)		Number of attachments: None	

INTRODUCTION

This report is a review of the geologic-hazards sections of a report by AGRA Earth & Environmental, Inc. (AGRA, 1998) for The Hamptons Planned Urban Development in Ogden (SW1/4 section 14, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian), Weber County, Utah. The Ogden City Planning Department requested the review. The report was received by the Utah Geological Survey on November 18, 1998. The purpose of my review is to evaluate whether geologic hazards at the property are adequately addressed. The scope of work consisted of a literature review. No site visit was made.

DISCUSSION AND COMMENTS

AGRA (1998) discusses possible hazards from ground shaking, surface fault rupture, liquefaction, rock falls, debris flows, landslides, shallow ground water, and non-engineered fill. This appears to be a complete list of potential hazards at the property. AGRA (1998) concludes that the risk from liquefaction, rock-fall, and debris-flow hazards is low and I concur. I also agree with AGRA's (1998) recommendations that structures be designed, at a minimum, according to Uniform Building Code seismic zone 3 criteria, and to remove all non-engineered fill from proposed building areas. My comments regarding AGRA's (1998) assessment of the remaining hazards are outlined below. AGRA (1998) also provides geotechnical recommendations that should be reviewed by a qualified geotechnical engineer.

- Surface fault rupture: AGRA (1998) indicates the Wasatch fault zone poses a surface-fault-rupture hazard at the property, and two previous trenches at the northern property boundary (AGRA, 1996) exposed evidence of faulting. AGRA (1998) shows two main fault traces bounding the property on the east, and two subparallel secondary (antithetic) faults in the northern half of the property roughly 300 feet (90 m) west of the main faults. Nelson and Personius (1993) and Lowe (1988a) show a similar (though less detailed) pattern of faulting. AGRA (1998) excavated four trenches at the property to investigate the surface-faulting hazard; two of these trenches exposed evidence of displacement and deformation in a narrow zone along the antithetic faults. To reduce the risk from surface faulting, AGRA (1998) recommends:

  - structures for human occupancy be no closer than 15 feet (4.6 m) from the main fault traces, and no more than 10 feet (3 m) from secondary faults and deformation zones; and

- foundation excavations be inspected for evidence of faulting for any structure within 25 feet (7.6 m) of a fault or deformation zone.

I generally concur with AGRA's (1998) assessment and recommendations. However, AGRA's (1998, p. 10) setback recommendation regarding secondary faults and deformation zones states that buildings can be "no ***more*** than" 10 feet (3 m) from a fault or deformation zone, which appears to be an editorial error. I assume AGRA meant "no ***closer*** than" 10 feet (3 m), but they should clarify their recommendation. Furthermore, on the downdropped sides of the faults, AGRA's (1998) setback distances (when combined with low fault dips) may not prevent basements and building footings from extending below fault planes, where they would be at risk from damage during a surface-faulting earthquake. AGRA's setback distances should apply to all portions of human-occupied structures (including basements and footings), from not only surface traces of faults, but also fault planes in the subsurface projected from trenching data. Based on a minimum fault dip of 40 degrees (observed in trench T-1W; AGRA, 1996) and a basement/footing depth of eight feet (2.4 m), structures should be at least 20 feet (6 m) east of the westernmost antithetic fault at the property if the foundation of the structure is to be at least 10 feet (3 m) from the fault.

- Landslides: AGRA (1998) indicates a steep slope bounding the eastern side of the property (which is an eroded scarp produced by repeated surface faulting on the Wasatch fault zone) is in a landslide special-study zone mapped by Lowe (1988b). Lowe (1988b) shows no landslides in the slope at the property, but steepness of the slope generally exceeds 30 percent (0.3:1 horizontal:vertical). AGRA (1998) believes the risk from landsliding is low based on a lack of evidence of instability in the slope or landslide deposits at the property, and also states no disturbance of the steep slope is planned. I concur that the risk from landsliding seems low under current conditions, but the risk may increase if improperly engineered slope modifications (such as cuts for roads or landscaping) are made, or development above the slope or leakage from the reservoir increases ground-water levels. A failure in the steep slope could affect not only houses at its base, but also those at the top of the slope. The slope is also susceptible to erosion; changes in drainage above the slope may increase erosion and cause deposition of sediment on lots at the slope base.

- Shallow ground water: AGRA (1998) encountered shallow ground water in one test pit in the western part of the property, and anticipates ground-water levels may rise to within 6 feet (2 m) of existing grades in this vicinity. To reduce the risk from shallow ground water, AGRA (1998) recommends protecting buildings which are not at least 2 feet (0.6 m) above highest projected ground-water levels with subsurface drains. I generally concur with their assessment, but AGRA (1998) does not specify which lots may be affected or provide any subdrain designs. I believe AGRA should determine which lots will need the subdrains and provide some basic designs.

SUMMARY AND RECOMMENDATIONS

Regarding AGRA's (1998) hazards assessment and recommendations to reduce risk from hazards at the property, I recommend:

- AGRA provide greater surface-fault-rupture setback distances on the downthrown sides of faults to account for minimum observed fault dip and footing depth, and show nonbuildable zones (based on their setback distances from identified faults and deformation zones) on a map of the property;

- a geologist provide written documentation to Ogden City verifying that footing excavations of structures within 25 feet (7.7) of a fault or deformation zone at the property were inspected for evidence of surface faulting;

- AGRA determine which lots may be affected by shallow ground water and provide designs for subdrain systems;

- Ogden City devise means to ensure that AGRA's fault-setback recommendations are followed, subdrains are placed where needed, no unplanned slope modifications are made, and future development above the slope east of the property carefully addresses slope stability and erosion;

- geotechnical recommendations regarding foundation and pavement design, and site preparation, be reviewed by a qualified geotechnical engineer; and

- the existence of AGRA (1998) and this review be disclosed to future buyers.

REFERENCES

AGRA Earth & Environmental, Inc., 1996, Fault rupture hazard evaluation--Proposed Burch Creek Estates subdivision, W1/2 section 14, T5N, R1W, SLB&M, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 10 p.

----1998, Fault rupture hazard and geotechnical study--The Hamptons Planned Urban Development, SW 1/4 S. 14, T5N, R1W, SLBM, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 19 p.

Lowe, Mike, 1988a, Potential surface-fault rupture sensitive area overlay zone--Ogden quadrangle: Ogden, Utah, unpublished Weber County Planning Department Map, scale 1:24,000.

----1988b, Landslide hazard map--Ogden quadrangle: Ogden, Utah, unpublished Weber County Planning Department 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 Miscellaneous Investigations Series Map I-2199, scale 1:50,000, 22 p. pamphlet.

Project: Review of geotechnical reports, Waterford PD, Provo, Utah County, Utah			Requesting Agency: City of Provo
By: Richard E. Giraud	Date: 12-10-98	County: Utah	Job No: 98-43 (R-34)
USGS Quadrangle: Orem (1088)		Number of attachments: None	

INTRODUCTION

This report is a review of two geotechnical reports for the Waterford PD (formerly Lindahl) subdivision, Provo, Utah, by Earthtec Testing and Engineering, P.C. (Earthtec, 1998a, b). The subdivision is located on the west side of Foothill Drive at 4300 North (SE1/4 SE1/4 section 18, NE1/4 NE1/4 section 19, T. 6 S:, R. 3 E., Salt Lake Base Line and Meridian). Nicholas Jones (City Engineer, Provo City) requested the review. The reports were received by the Utah Geological Survey on November 19, 1998. The purpose of my review is to evaluate if geologic hazards at the subdivision are adequately addressed. The scope of work consisted of a literature review. No site visit was made. Earthtec (1998a) also provides geotechnical recommendations that should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND COMMENTS

Earthtec (1998a, b) addresses possible hazards resulting from surface fault rupture, ground shaking, landslides, and problem soils. This appears to be a complete list of possible geologic hazards at the subdivision. I concur with their recommendations regarding ground shaking and problem soils. My comments regarding Earthtec's (1998a, b) assessment of the other hazards and recommendations to reduce the risk of each hazard are outlined below.

- Surface fault rupture: Earthtec's (1998b) surface-fault-rupture investigation identified three faults in trench ST-2 on the west side of the property that displace Lake Bonneville deposits and therefore must be considered active. The fault displacements ranged from 2 inches to 1 foot down to the west. Bedding was back-tilted to the east about 5 degrees. Klauk (1985) identified a series of horsts and grabens and more than 35 "fractures," some having up to 2 feet of displacement (mostly down to the west), in the western part of the excavation for the athletic-club building 350 feet south of Earthtec's trench ST-2. Klauk (1985, attachment 1) shows the general strike of the fault zone to be northwest, parallel to the main Wasatch fault trace. Neither Earthtec (1998b) nor Klauk (1985) give measured fault orientations. Earthtec (1998b) interprets these faults to be related to past instability of steep slopes around the site, rather than tectonic surface faulting as indicated by Klauk (1985), but does not provide sufficient evidence to support this interpretation. I recommend further trenching and analysis (see Landslide section below) to determine the origin of these faults, including measurements of their orientation, linear trend, and continuity across the site. The variability in the intensity of faulting between the Earthtec trench ST-2 and athletic-club excavation, the distance of these faults from the nearest main fault traces, and the extent of back-tilting may be important in understanding the origin and hazard potential of these faults.

- Landslides: Two issues must be addressed with respect to landslides. One is the setback from steep slopes surrounding the site, and the other is the possible landslide origin of faults identified in trench ST-2 (Earthtec, 1998b) and the athletic-club excavation (Klauk, 1985). Slope stability is a concern because of the many steep, potentially unstable slopes in this area. The Sherwood Hills landslide complex, which includes a reactivated landslide in 1998 (probably in Lake Bonneville deposits similar to those at the site), is just across Foothill Boulevard to the east (Francis Ashland, UGS, verbal communication, November, 1998).

  Regarding setbacks, Earthtec (1998a) performed a preliminary geotechnical-engineering slope-stability analysis using assumed soil strengths (friction angle 32 degrees, cohesion 50 psf) and a deep water table, and recommended a 20-foot building setback. The weakest layers in the deposit are the silt and thin clay layers identified in boring logs, and Earthtec's assumed strength parameters do not seem sufficiently conservative to characterize these layers (Hammond and others, 1992). Also, because drill holes extended to only a 36.5-foot depth, the assumption that ground water is below the base of the slope (an approximate 60-foot depth) is not conservative, particularly in light of possible development-induced (landscape irrigation) increases in ground-water levels and possible perched ground water on the less permeable silt and thin clay layers. Unless site-specific soil-strength and ground-water data are collected, I recommend the setbacks from the preliminary analysis be re-evaluated using more conservative input parameters.

  If the recommended additional trenching indicates a possible landslide origin for faults at the site, a preliminary geotechnical-engineering analysis could be completed using the existing topography, fault locations (landslide slip surfaces), and assumed soil strengths to back-calculate the ground-water and/or earthquake conditions necessary to cause such landsliding. Because Earthtec (1998b) interprets the back-tilting observed in the trenches to be related to landsliding, a slump with a slip surface east of the trenches would also need to be modeled. The modeling analysis will help evaluate the feasibility of a landslide origin for faults and also help to better understand the effects of shallow ground water and earthquakes on general slope stability.

  Additionally, the landslide-prone Manning Canyon Shale may underlie the site at depths greater than the drilled depth of 36.5 feet. Machette (1992) maps Lake Bonneville sand deposits at the site and both alluvial-fan and landslide deposits east of the site. Baker (1964) maps the Manning Canyon Shale east of the site. The Manning Canyon Shale is a landslide-prone formation believed to be involved in landslides in Sherwood Hills and elsewhere on Provo's East Bench. I recommend at least a reconnaissance of the hillslopes and drainages at the site to evaluate the possibility that the shale unit underlies the site. If the shale unit is present, it must be considered in additional slope-stability analysis.

SUMMARY AND RECOMMENDATIONS

Regarding Earthtec's (1998a, b) hazards assessment and recommendations to reduce the risk of each hazard, I recommend:

- additional trenching to determine the origin of faults at the site, including measurements of their orientation and linear extent, to evaluate areas outside of existing trenches, determine the hazard potential of the faults, and recommend appropriate hazard-reduction measures;
- additional slope-stability analysis to re-evaluate recommended setbacks, model a possible landslide origin for faults (Earthtec, 1998b), and look for evidence of Manning Canyon Shale under the site;
- site grading, foundation, and pavement recommendations be reviewed by a qualified geotechnical engineer; and
- the existence of the Earthtec (1998a, b) and subsequent reports and this review be disclosed to future buyers.

REFERENCES

Baker, A.A., 1964, Geology of the Orem quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-241, 6 p. pamphlet, scale 1:24,000.

Earthtec Testing and Engineering, P.C., 1998a, Geotechnical study, Lindahl subdivision, Provo, Utah: Orem, Utah, unpublished consultant's report for Jeff Kimball, 10 p.

Earthtec Testing and Engineering, P.C., 1998b, Supplemental geotechnical report, Waterford Development, Provo, Utah: Orem, Utah, unpublished consultant's report for Jeff Kimball, 11 p.

Hammond, Carol, Hall, David., Miller, Stanley, and Swetik, Paul, 1992, Level I stability analysis (LISA) Version 2.0: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-285, Ogden, Utah, 190 p.

Klauk, R.H., 1985, Zone of deformation determination along a portion of the Wasatch fault in Provo, Utah: Utah Geological and Mineral Survey Report of Investigation 208, p. 261-265.

Machette, M.N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah Valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2095, 26 p. pamphlet, scale 1:50,000.

Project:			Requesting Agency:
Review of geotechnical and geologic reports, Lot 126 Interlaken Estates, Midway, Wasatch County, Utah			Wasatch County Planning Department
By: Richard E. Giraud	Date: 12-28-98	County: Utah	Job No: 98-44 (R-35)
USGS Quadrangle: Heber City (1168)		Number of attachments: None	

INTRODUCTION

This report is a review of a geotechnical study by Earthtec Testing and Engineering, P.C. (Earthtec, 1998) and a geologic reconnaissance report by American Geological Services, Inc. (AGS, 1998) for lot 126 in Interlaken Estates, 336 Interlaken Drive, Midway (SE1/4 section 22, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian). Anthony Kohler (Wasatch County Planner) requested the review. The report was received by the Utah Geological Survey on December 1, 1998. The purpose of my review is to evaluate if geologic hazards at the lot are adequately addressed. The scope of work consisted of a literature review. No site visit was made. Earthtec (1998) also provides geotechnical recommendations that should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND COMMENTS

Earthtec (1998) and AGS (1998) address possible hazards resulting from surface fault rupture, ground shaking, landslides, and problem soils. This appears to be a complete list of possible geologic hazards at the subdivision. I concur with their recommendations regarding surface fault rupture, ground shaking, and problem soils.

Regarding landslides, the site is underlain by shallow bedrock and Earthtec (1998) analyzed stability of site slopes for two types of bedrock failure: a circular failure and a block (planar) failure along bedding planes. High factors of safety were calculated for both types of failures. Earthtec (1998) concludes that slopes on the lot are stable under the analyzed bedrock conditions which appears reasonable. However, AGS (1998) states that topography on and adjacent to the lot suggests the entire site may be part of an "old slump feature." AGS (1998) does not outline the boundaries of the slump, discuss whether the slump displaced bedrock or colluvium, or assess the slump failure mechanism. AGS (1998) also states that two cuts on lots above the site display features that suggest landsliding, but does not discuss if these are part of the "old slump feature" or are related to a possible shallow debris slide in colluvium and weathered bedrock. Earthtec (1998) does not evaluate the stability of the "old slump feature" identified by AGS (1998) or the shallow debris-slide potential for slopes above the site where landslide features were observed. AGS (1998) states that the natural slopes on the site appear stable and there is no evidence of active landslide movement. This statement is relevant for current site conditions but it does not consider future stability or the possibility of movement of the "old slump feature" or debris sliding from above under conditions accompanying development.

Landslide hazards can be reduced by proper site drainage and minimizing the amount of precipitation infiltrating into site slopes. Earthtec (1998) acknowledges the importance of drainage design and provides pertinent recommendations; however, these recommendations are specific to the proposed structure. I recommend that site drainage considerations also address drainage onto and off the site and the potential effect on downslope road cuts and structures.

SUMMARY AND RECOMMENDATIONS

Regarding the Earthtec (1998) and AGS (1998) landslide-hazard assessment and recommendations to reduce the landslide risk, I recommend:

- the boundaries of the "old slump feature" be mapped, and the failure mechanism be determined;

- at least a preliminary geotechnical engineering slope-stability analysis of the "old slump feature" and an evaluation of the potential for and possible impacts from shallow debris slides above the lot be preformed using appropriate earthquake ground-shaking and estimated development-induced (landscape irrigation) and seasonal snowmelt-induced ground-water conditions;

- the site drainage design consider the impact of site drainage on slope stability and downslope roads and structures;

- site grading, foundation, and pavement recommendations be reviewed by a qualified geotechnical engineer; and

- the existence of the Earthtec (1998) and AGS (1998) reports, subsequent reports, and this review be disclosed to future buyers.

REFERENCES

American Geological Services, Inc, 1998, Geologic reconnaissance, 336 Interlaken Drive, Midway, Utah: Provo, Utah, unpublished consultant's report for Earthtec Engineering and Testing, P.C., 3 p.

Earthtec Testing and Engineering, P.C., 1998, Geotechnical study, Lot 126, Interlaken Estates, Midway, Utah: Orem, Utah, unpublished consultant's report for Harold Remund, 5 p.

Project:			Requesting Agency:
Review of "Preliminary geotechnical report for the Horrocks et al. properties, Mill Flat subdivision, sec. 17, T. 3 S., R. 4 E., Wasatch County, Utah."			Wasatch County
By: Bill D. Black	Date: 12-29-98	County: Wasatch	Job No: 98-45 (R-36)
USGS Quadrangle: Brighton (1169)		Number of attachments: None	

INTRODUCTION

This report is a review of a preliminary geotechnical (geologic) report (Hansen, 1998) for the Horrocks et al. properties in the Mill Flat subdivision (NW1/4 SW1/4 section 17, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian), Wasatch County, Utah. Robert Mathis (Planner, Wasatch County Planning Department) requested the review. The Utah Geological Survey received the report from Wasatch County on December 4, 1998. The scope of work included a literature review and examination of 1:40,000-scale aerial photos (1987). No site visit was made.

DISCUSSION AND COMMENTS

Hansen (1998) identifies landsliding as a potential hazard at the property. The property is on the eastern toe of an ancient landslide complex (Baker and others, 1966; Hylland and Lowe, 1995) that shows evidence of numerous smaller landslides, including three slope failures in the early to mid-1980s (Klauk and Mulvey, 1987). However, Hansen (1998) believes slopes are generally stable (and thus the risk from landsliding is low) based on his observations of shallow bedrock and a lack of evidence for active landsliding in the site vicinity. Hansen (1998) also identifies a potential hazard from uncontrolled drainage (causing flooding and erosion) along Snake Creek Road (State Road 220), and recommends the road be repaired to minimize flooding and/or erosion from future runoff. Hansen (1998) does not identify, and presumably did not assess, any other geologic hazards possibly present. As stated in the title, the Hansen (1998) report is preliminary and includes no site-specific soil data, detailed topographic or geologic maps, or geotechnical recommendations (such as for site grading or foundation design).

I concur with Hansen's (1998) assessment and recommendation regarding possible flooding and erosion from uncontrolled drainage along State Road 220. However, although repair of the road is not the landowner's responsibility (because the road is presumably under state jurisdiction), further work could be done to recommend methods at a subdivision level to reduce risk. More work is also needed to address slope failure and other possible hazards. Presumed in-place bedrock observed by Hansen (1998) west of the site may be bedrock blocks within landslide debris; he provides no evidence (such as bedding orientations consistent with the regional geology and outcrops outside the landslide complex) to dismiss a landslide origin. Also, a lack of evidence for active landsliding does not demonstrate slopes are stable; changes in environmental conditions or development on the landslide may reduce slope stability and increase the landslide risk. Furthermore, other geologic hazards may be present that are unevaluated and could pose a risk.

RECOMMENDATIONS

Regarding the Horrocks et al. properties and Hansen (1998), I recommend a detailed, site-specific geologic-hazards and geotechnical investigation be conducted to:

- assess all geologic hazards possibly affecting the property, including further analysis of slope stability and methods to reduce risk from flooding and erosion;
- assess the potential for (and risk from) slope failures above the property;
- evaluate the effects of development, particularly slope modifications and septic-tank soil absorption (STSA) systems, on local slope stability and overall stability of the landslide complex;
- obtain site-specific geologic and soil data for hazards evaluation and foundation design;
- recommend building setbacks from steep slopes, if necessary;
- identify non-buildable areas, and house and STSA system locations; and
- recommend any other site-design features needed to reduce risk from hazards present.

Although the long-term stability of the larger Snake Creek landslide complex (Klauk and Mulvey, 1987; Hylland and Lowe, 1995) and cumulative effects of development on slope stability are difficult to assess in lot-specific studies (such as I recommend above), they should be addressed in detailed studies before permitting development on the landslide. I also recommend a detailed topographic map of the site be made by a qualified surveyor, showing the identified setbacks, non-buildable areas, and building and STSA system locations as outlined above.

REFERENCES

Baker, A.A., Calkins, F.C., Crittenden, M.D., Jr., and Bromfield, C.S., 1966, Geologic map of the Brighton quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Series Map GQ-534, scale 1:24,000.

Hansen, L.A., 1998, Preliminary geotechnical report for the Horrocks et al. properties, Mill Flat subdivision, sec. 17, T. 3 S., R. 4 E., Wasatch County, Utah: West Jordan, Utah, unpublished consultant's report, 4 p.

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

Klauk, R.H., and Mulvey, W.E., 1987, Study of landslides west of the K & J subdivision in Snake Creek Canyon, Wasatch County, Utah: Utah Geological and Mineral Survey Report of Investigation 214, 28 p.

Project: Review of soil and ground-water investigation, proposed Canyon Creek Estates, Layton, Davis County, Utah			Requesting Agency: Layton City Community Development Department
By: Richard E. Giraud	Date: 12-30-98	County: Utah	Job No: 98-46 (R-37)
USGS Quadrangle: Kaysville (1320)		Number of attachments: None	

INTRODUCTION

This report is a review of a soils and ground-water report for the proposed Canyon Creek Estates subdivision, by George Toland Consulting Geotechnical Engineers (Toland, 1998). The subdivision is located on the east side of U.S. Highway 89 at 438 North, Layton, Utah (NW1/4 SW1/4 section 24, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian). Doug Smith (Planner, Layton City) requested the review. The report was received by the Utah Geological Survey on December 7, 1998. The purpose of my review is to evaluate if geologic hazards at the subdivision are adequately addressed. The scope of my review included a literature review and interpretation of aerial photographs (1985; scale 1:24,000 and 1989; scale 1:12,000). No site visit was made. Toland (1998) also provides geotechnical recommendations that should be reviewed by a qualified geotechnical engineer.

DISCUSSION AND COMMENTS

Toland (1998) addresses possible hazards resulting from surface fault rupture, shallow ground water, and problem soils. Additional hazards that could affect the site but were not addressed by Toland (1998) include earthquake ground shaking, landslides, debris flows, and alluvial-fan flooding. I concur with the recommendations regarding shallow ground water and problem soils. My comments and recommendations with regard to Toland's (1998) assessment of the surface-fault-rupture and other hazards are outlined below.

- <u>Surface fault rupture</u>: Toland's statement that the Wasatch fault is located more than 1,000 feet east of the site is incorrect. Lowe (1988a) and Nelson and Personius (1993) map a strand of the Wasatch fault passing through the subdivision. This strand is mapped along the west side of the water reservoir and is apparent on aerial photographs. Another fault strand is mapped along the east side of the reservoir and along the northeast boundary of lot 12. The subdivision is within a surface-fault-rupture hazard special-study area (Lowe, 1988a). Within this area, site-specific studies are recommended to identify faults and assess the impacts of faulting. Site-specific studies should include detailed aerial-photo and field investigations to identify fault scarps, and trenching of fault scarps to locate faults and determine appropriate setbacks. Geologic logs of the trenches are required to show the type, extent, and amount of deformation in the fault zone and provide a basis for setback recommendations. Because the Wasatch fault crosses the subdivision, I recommend a site-specific study to evaluate the surface-fault-rupture hazard.

- Earthquake Ground Shaking: Earthquake ground shaking is another potential hazard at the site. The subdivision lies within Uniform Building Code (UBC) seismic zone 3 (International Conference of Building Officials, 1997). I recommend that the buildings be designed and constructed to at least meet UBC seismic zone 3 criteria. Zone 3 criteria are the minimum standards adopted by state and local governments for reducing ground-shaking hazards.

- Landslides: Nelson and Personius (1993) show landslide scarps in steep slopes along the Wasatch fault scarp in deposits similar to those northeast of lots 11 and 12. If the fault scarp northeast of lots 11 and 12 exceeds 30 percent in steepness and abuts the lots, its slope stability should be addressed and appropriate setbacks determined.

- Debris Flows and Alluvial-Fan Flooding: The site is located on an alluvial fan at the mouth of Adams Canyon. The surficial geologic mapping of Nelson and Personius (1993) shows upper Holocene alluvial-fan deposits at the site. The deposits were formed by intermittent stream flows, debris flows, and debris floods. Based on the mapping of Nelson and Personius (1993), many of the cobbles and boulders (up to 3 feet in diameter) identified in test pits (Toland, 1998) are likely of debris-flow origin. Lowe (1988b) indicates that the subdivision is on an active alluvial fan where debris-flow studies are recommended. Lowe (1988b) also maps a historical debris flow in Adams Canyon above the site. I recommend that the debris-flow hazard from Adams Canyon be evaluated. The evaluation should define areas of active deposition, followed by an estimate of the frequency and volume of flows, travel paths, and flow depths to determine appropriate hazard-reduction measures as outlined in Lowe (1993).

  Surface-water runoff from Adams Canyon, associated with rapid snowmelt or intense rainfall, may cause alluvial-fan flooding. I recommend that the flooding potential from Adams Canyon be evaluated. Toland (1998) states that the sandy soils in the northeast portion of the site will erode rapidly if not protected by vegetation, so soil erosion by floodwaters should also be addressed.

SUMMARY AND RECOMMENDATIONS

Regarding Toland's (1998) assessment of surface-fault-rupture and other hazards at the site, I recommend the following:

- Evaluate the surface-fault-rupture hazard associated with the Wasatch fault by trenching fault scarps to determine the type, extent, and amount of deformation, and to determine appropriate setbacks where pertinent.

- At a minimum, design and construct buildings to meet UBC seismic zone 3 criteria.

- If the fault scarp northeast of lots 11 and 12 exceeds 30 percent in steepness and abuts the lots, perform a slope-stability analysis of this scarp and provide setbacks where appropriate.

- Evaluate the debris-flow and alluvial-fan flooding hazards from Adams Canyon and provide hazard-reduction measures where pertinent.

- Have a qualified geotechnical engineer review the foundation and pavement recommendations.

- Disclose the Toland (1998) report, subsequent reports, and this review to future buyers.

I recommend that setbacks, hazard areas, and protective structures, determined from the above hazard evaluations, be shown on the subdivision plat map to delineate buildable areas. Specific recommendations and restrictions pertaining to site building design and lot development should be included in the report. All conclusions and recommendations must be supported with evidence. The hazard evaluations should be performed by a qualified engineering geologist, hydrologist, and/or geotechnical engineer, as appropriate. 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 consulting geologist, hydrologist, or engineer indicating that their recommendations are followed.

REFERENCES

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

Lowe, Mike, 1988a, Natural hazards overlay zone - potential surface fault rupture, Kaysville quadrangle: Davis County Planning Department unpublished map, scale 1:24,000.

---1988b, Natural hazards overlay zone - debris-flow hazard map, Kaysville quadrangle: Davis County Planning Department unpublished map, scale 1:24,000.

---1993, Debris-flow hazards: A guide for land-use planning, Davis County, Utah: U.S. Geological Survey Professional Paper 1519, p. 143-150.

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 Miscellaneous Investigations Series Map I-2199, 22 p. pamphlet, scale 1:50,000.

Toland, G.C., 1998, Soil and ground water investigation, proposed Canyon Creek Estates, 438 North Highway 89, Layton, Utah: Orem, Utah, unpublished consultant's report for Kay Achter, 6 p.

APPENDIX

1998 Publications of the Applied Geology Program

Miscellaneous Publication Series

Lund, W.R., editor, 1998, Proceedings volume, Basin and Range Province Seismic-Hazards Summit: Utah Geological Survey Miscellaneous Publication 98-2, 204 p.

Reports of Investigation

Mayes, B.H., compiler, 1998, Technical Reports for 1997, Applied Geology Program: Utah Geological Survey Report of Investigation 236, 126 p.

Special Studies

Bishop, C.E., 1998, Radon-hazard potential of Beaver basin area, Beaver County, Utah: Utah Geological Survey Special Study 94, 39 p.

Hylland, M.D., and Lowe, Mike, 1998, Characteristics, timing, and hazard potential of liquefaction-induced landsliding in the Farmington Siding landslide complex, Davis County, Utah: Utah Geological Survey Special Study 95, 38 p.

Lund, W.R., and Black, B.D., 1998, Paleoseismic investigation at Rock Canyon, Provo segment, Wasatch fault zone, Utah County, Utah: Utah Geological Survey Special Study 93, 21 p., 2 pl.

Survey Notes

Black, B.R., 1998, Large earthquakes on the West Cache fault zone, Cache County, Utah: Utah Geological Survey Notes, v. 30, no. 3, p. 1-2.

Christenson, G.E., 1998, Spring landslides keep UGS busy: Utah Geological Survey Notes, v. 31, no. 1, p. 6-7.

Lund, W.R., 1998, Utah and Arizona Geological Surveys cooperate to evaluate seismic hazards: Utah Geological Survey Notes, v. 30, no. 3, p. 3-5.

Solomon, B.J., 1998, New evidence for the age of faulting on the West Valley fault zone: Utah Geological Survey Notes, v. 30, no. 3, p. 8, 13.