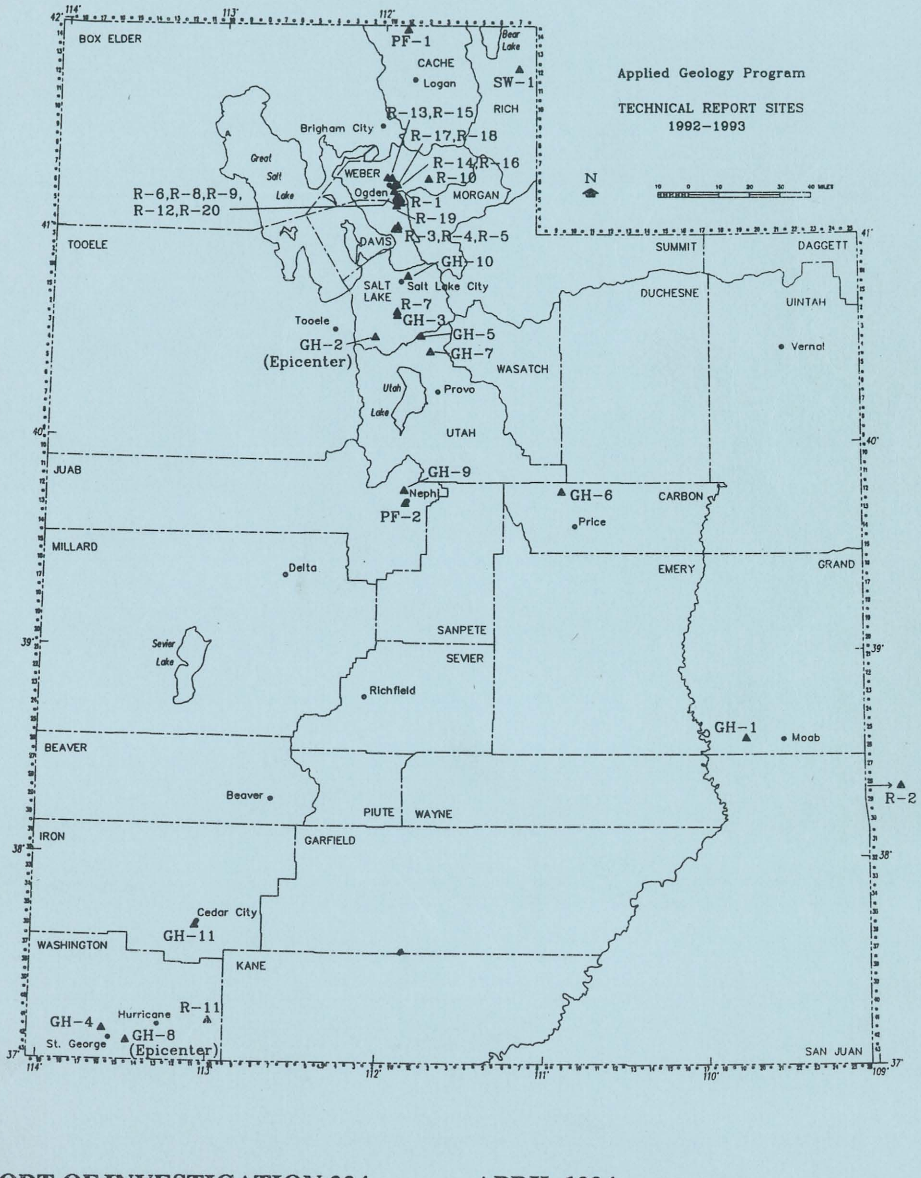
TECHNICAL REPORTS FOR 1992 - 1993
APPLIED GEOLOGY PROGRAM

compiled by
Bea H. Mayes and Sharon I. Wakefield



REPORT OF INVESTIGATION 224 APRIL 1994

UTAH GEOLOGICAL SURVEY

a division of

UTAH DEPARTMENT OF NATURAL RESOURCES

UTAH CENTENNIAL 1896-1996

TAKE *Pride* IN UTAH

This Report of Investigation has undergone UGS review but may not necessarily conform to formal technical and editorial criteria. The material represents investigations limited in purpose.

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PREFACE

The Applied Geology Program of the Utah Geological Survey (UGS) maps and defines geologic hazards in the state and provides assistance to tax-supported entities (cities, towns, counties, and their engineers, planning commissions, and 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 sites, 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 or hydrologic questions from state and local government agencies, principally involving the evaluation of hazards from debris flows, shallow ground water, rock falls, landslides, problem soils, and earthquakes. In addition to performing engineering-geologic studies, we review and comment on geologic reports submitted to state and local government agencies for residential lots, subdivisions, and private waste-disposal facilities.

Information dissemination 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 a need-to-know 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 34 technical reports completed in 1992 and 1993 (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, most of which were produced on a copy machine. This is the eighth compilation of the Applied Program's technical reports.

Bea H. Mayes
April 12, 1994

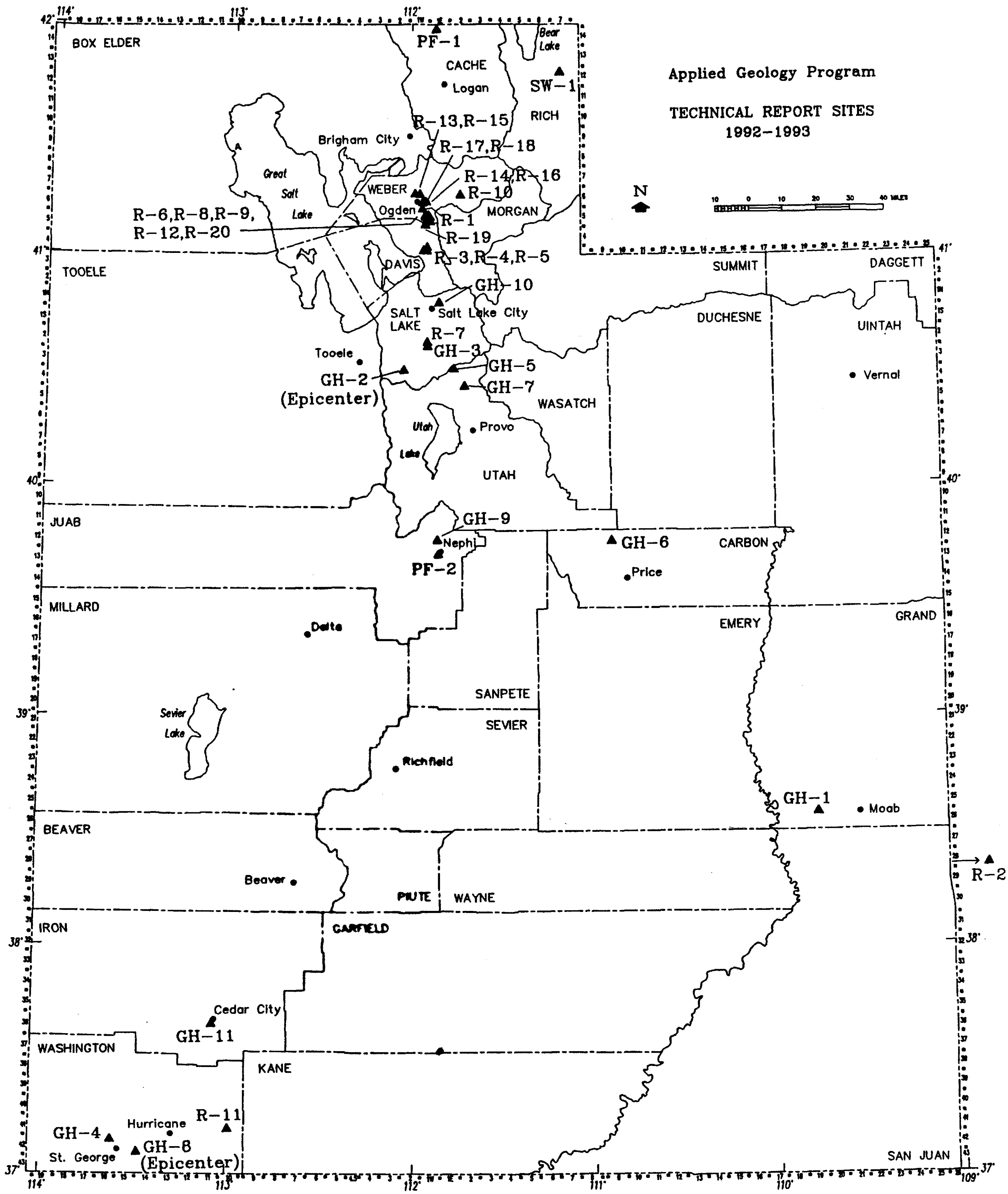

Figure 1. Location map.

CONTENTS

Geologic Hazards (continued)

Reviews (continued)

Reviews (continued)

Illustration

PUBLIC FACILITIES

Project:			Requesting Agency:
Geologic hazards investigation for a proposed fire station site in Lewiston, Cache County, Utah			Lewiston City/ Cache County Fire Department
By: Bill D. Black, Gary E. Christenson	Date: 2-25-92	County: Cache County	Job No: 92-02 (PF-1)
USGS Quadrangle: Richmond (1494)			

PURPOSE AND SCOPE

The Utah Geological Survey conducted a geologic-hazards investigation of a proposed site for a fire station in Lewiston City, Cache County, Utah (attachment 1). Gerald Smith (Fire Chief, Lewiston City) and Kelly Pitcher (Fire Chief, Cache County Fire Department) requested the investigation. The purpose of this investigation was to identify potential geologic hazards at the fire-station site which Lewiston City and the Cache County Fire Department should consider prior to construction. This report should be made available to the project engineers to ensure proper design and construction. The scope of work included a literature review, examination of maps, and a field inspection on February 10, 1992. No test pits were dug at the site. Gerald Smith was present during the field inspection.

SETTING AND SITE DESCRIPTION

The proposed fire-station site is in Lewiston City, in the NW1/4 NW1/4 sec. 9, T.14 N., R.39 E., SLBM (attachment 1). It is at an elevation of approximately 4505 feet and east of an existing fire station constructed in 1948. Vegetation at the site consists of grass; the site was snow covered at the time of the field inspection.

GEOLOGY AND SOILS

Surficial deposits at the fire-station site are of Quaternary age (attachment 2) (McCalpin, 1989). The site is underlain by unconsolidated silt and fine sand deposited in the Bear River delta during the Provo stage of Lake Bonneville in late-Pleistocene time (McCalpin, 1989). Soil consists of fine sandy loam of the Lewiston series, which exhibits moderately-rapid permeability, low shrink-swell potential, low to medium compressibility, and low to medium shear strength (Erickson and Mortensen, 1974). In the Unified Soil Classification System (USCS), the Lewiston series is a silty sand or silt (SM or ML). Depth to ground water is less than 10 feet (Bjorklund and McGreevy, 1971).

GEOLOGIC HAZARDS

Attachment 3 is a summary checklist of potential geologic hazards at the site. All hazards considered are shown and discussed below. A glossary of geologic-hazards terminology is included (attachment 4) to aid in explanation of any unfamiliar terms included in this report.

Earthquake Hazards

The site is in the Intermountain Seismic Belt (ISB), a generally north-south trending zone of seismic activity that bisects the state. Associated with the ISB are a number of earthquakes in the Cache Valley area, the largest of which was a Richter magnitude 5.7 earthquake in 1962 approximately 8 miles northeast of Lewiston (Arabasz and others, 1987), probably associated with the East Cache fault or a subsidiary fault (Smith and Lehman, 1979). The 1962 Cache Valley earthquake (the most damaging in Utah's history) damaged 75 percent of the houses in Richmond and caused major structural damage to large buildings in Logan, 12 miles (19 km) from the epicenter (Rogers and others, 1976). The total dollar loss was estimated at $1 million (Rogers and others, 1976). The existing fire station in Lewiston was also damaged during the 1962 earthquake (Gerald Smith, oral communication, Feb. 10, 1992), and shows evidence of stair-stepped cracks in the brick veneer on the east side of the building.

There are three potentially active fault zones identified within 30 miles (48 km) of the fire-station site which could be sources for future large earthquakes. These include: (1) the East Cache fault zone, which extends 48 miles (77 km) along the eastern side of Cache Valley from Preston, Idaho, to southeast of Avon, Utah (McCalpin, 1989), (2) the Clarkston Mountain and Collinston segments of the Wasatch fault zone, which combined extend about 30 miles (49 km) along the western side of the Malad Range from north of the Utah-Idaho border to southeast of Honeyville, Utah (Machette and others, 1987), and (3) the West Cache fault zone, which extends roughly 33 miles (53 km) along the western side of Cache Valley from north of the Utah-Idaho border to south of Wellsville, Utah (Cluff and others, 1974; Oviatt, 1986a, 1986b). Geomorphic evidence and trench data suggest that the last surface faulting event on the East Cache fault zone occurred from 6,000 to 9,000 years ago, although evidence indicates that the northern segment of this fault zone is less active (McCalpin, 1989). No movement younger than 15,000 years has occurred on the Collinston and Clarkston Mountain segments of the Wasatch fault zone, which are thought to be older and less active than the central segments of the fault south of Brigham City (Machette and others, 1987). Although paleoseismic evidence on the West Cache fault zone is sketchy, an exposure south of Cutler Reservoir shows evidence of late Quaternary offset in Lake Bonneville sediments (Oviatt, 1986b).

Ground Shaking

A major hazard at the site is ground shaking resulting from a moderate-to-large earthquake on the East Cache fault or a nearby fault such as the Wasatch fault. Ground shaking at the fire-station site could result in damage to the structure or its foundation.

Three levels of design ground motions are outlined below, based on: (1) probabilistic peak horizontal motions that have a 10 percent chance of being exceeded in a 50-year period, (2) probabilistic peak horizontal motions that have a 10 percent chance of being exceeded in a 250-year period, and (3) the minimum design motions specified in the 1991 Uniform Building Code (UBC). Under level 1 at the proposed site, the peak ground acceleration in bedrock of 0.2 g has a 10 percent chance of being exceeded in a 50-year period (Youngs and others, 1987; Algermissen and others, 1990). At soil sites such as Lewiston, the peak acceleration for this exposure time is approximately 0.15 g (Youngs and others, 1987). Under level 2, the peak ground acceleration in bedrock of 0.4 - 0.6 g has a 10 percent chance of being exceeded in a 250-year period (Youngs and others, 1987; Algermissen and others, 1990). Youngs and others (1987) indicate accelerations at soil sites of less than 0.4 g for the 250-year exposure time. Under level 3, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The proposed fire-station site is within UBC seismic zone 3. For zone 3, design calculations require a Z-factor of 0.3, which effectively corresponds to a peak acceleration on rock of 0.3 g. An S_3 site coefficient is specified in the UBC where soil profiles are not well known. However, nearby driller's well logs indicate that thick clays may be present at the site, and that an S_4 soil profile may exist (McGreevy and Bjorklund, 1970). The soil profile can only be accurately established by a geotechnical investigation.

Liquefaction

Liquefaction is a phenomenon that occurs when loose, saturated, fine-sand deposits are subjected to earthquake shaking, causing loss of shear strength (Anderson and others, 1982). The liquefaction potential at the site is moderate to low (Anderson and others, 1990). Four types of ground failure may occur during liquefaction (Anderson and others, 1982; Tinsley and others, 1985): (1) flow landslides (slopes greater than 5 percent), (2) lateral-spread landslides (slopes from 0.5 to 5 percent), (3) ground oscillation (slopes less than 0.5 percent, liquefaction at depth), and (4) bearing-capacity failures (slopes less than 0.5 percent, liquefaction shallow). Because the site is flat, liquefaction may result in ground oscillation or a bearing-capacity failure that could damage the structure.

Other Earthquake Hazards

There are no mapped faults close enough to the site to present a hazard from surface fault rupture. The nearest known potentially active fault is 5 miles (8 km) away. The hazard from tectonic subsidence is unknown, but is probably low due to the distance from the nearest fault and low probability of a surface-faulting earthquake. Due to the site topography and distance from slopes, the hazard from earthquake-induced slope failure is low.

Shallow Ground Water

Shallow ground water is a significant hazard at the fire-station site and could damage the structure's foundation. Depth to shallow ground water is less than 10 feet (Bjorklund and McGreevy, 1971). Due to shallow ground-water problems, most houses and buildings in Lewiston do not have basements (Gerald Smith, oral communication, Feb. 10, 1992). Proper foundation design and drainage can reduce any hazard caused by shallow ground water.

Other Hazards

The hazard from slope failure and rock fall is low because of the site topography and distance from slopes. The hazard from problem soil such as expansive clay, collapsible soil, and soluble soil/rock is low. There are no documented occurrences of problem soil in the area (Mulvey, in press). Federal Emergency Management Agency maps (1980) show the site to be in Zone C, an area of low flood hazard. However, fluctuations in the ground-water table may cause localized surface flooding. The radon hazard at the site is unknown, but is probably low due to shallow ground water and low uranium content of soil materials. Gamma-ray spectrometer measurements taken during the field inspection showed uranium concentrations of from 1.8 ppm to 3.1 ppm. Only one indoor-radon measurement (1.0 pCi/L) has been recorded in the Lewiston area (Sprinkel and Solomon, 1990); the Environmental Protection Agency (1986) has established 4 pCi/L as the indoor-radon concentration above which mitigation is recommended.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the fire-station site which would make it unsuitable. Earthquake ground shaking may affect the fire station in the future. Information on three earthquake-resistant design options is presented: (1) probabilistic peak horizontal ground acceleration in soil of 0.15 g that has a 10 percent chance of being exceeded in a 50-year period, (2) probabilistic peak horizontal ground acceleration in soil of less than 0.4 g that has a 10 percent chance of being exceeded in a 250-year period, and (3) the minimum design ground motions for seismic zone 3 as designated by the UBC. Although ground motions in the second option have a low chance of occurring, Lewiston City and the Cache County Fire Department should be aware that such ground motion from a large earthquake could occur at any time. It is recommended that, at a minimum, ground-motion levels expected for seismic zone 3 be used in design of the fire station (option 3 above).

A standard soil/foundation investigation is recommended to provide information on depth to ground water and soil properties required to design the structure's foundation. Although regional liquefaction potential maps indicate a moderate-to-low potential, the site-specific soil/foundation investigation should also address liquefaction potential.

The hazard from surface fault rupture, slope failure, rock fall, flooding, and problem soil is low. Although unknown, the hazard from tectonic subsidence and radon are probably also low.

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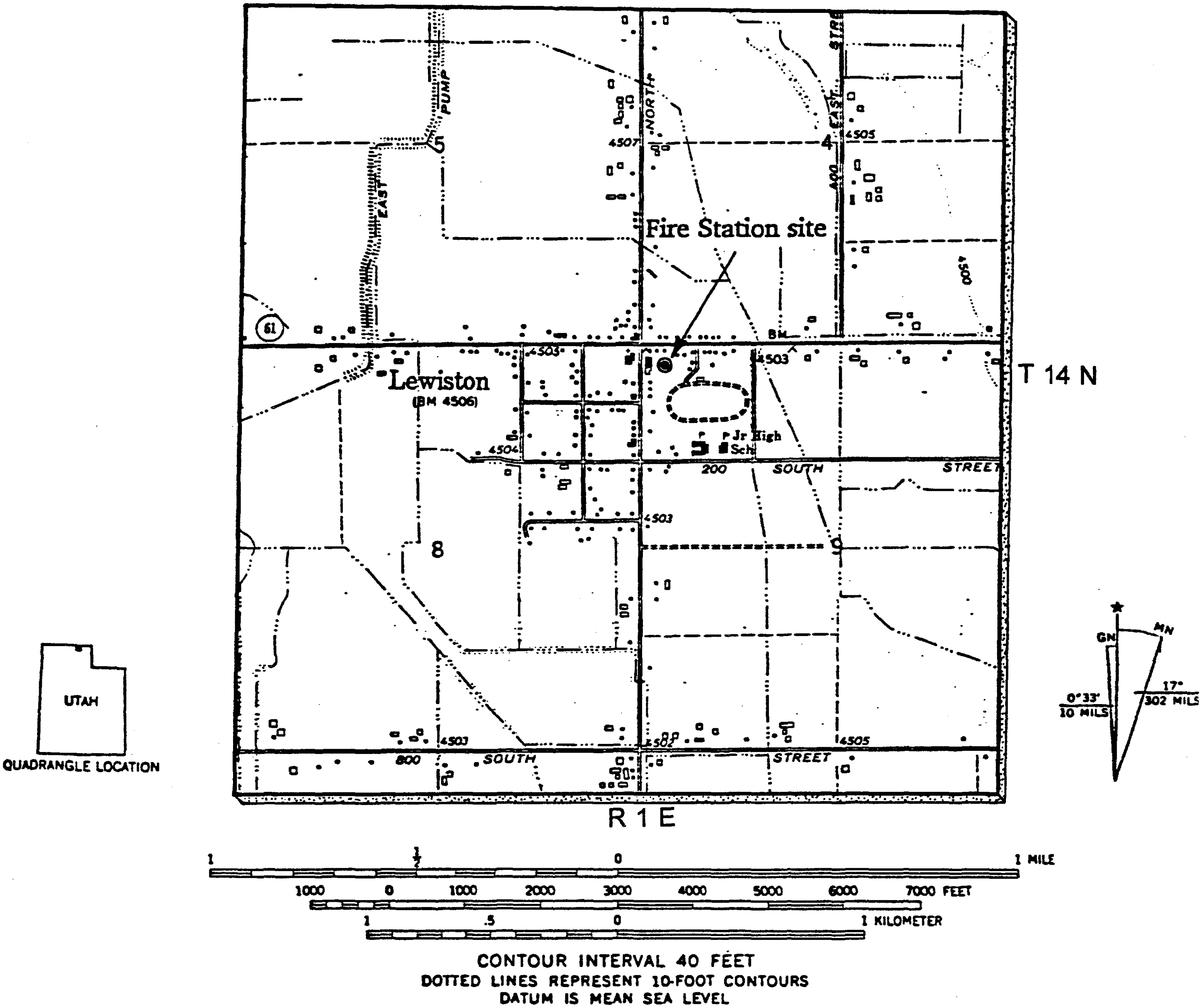
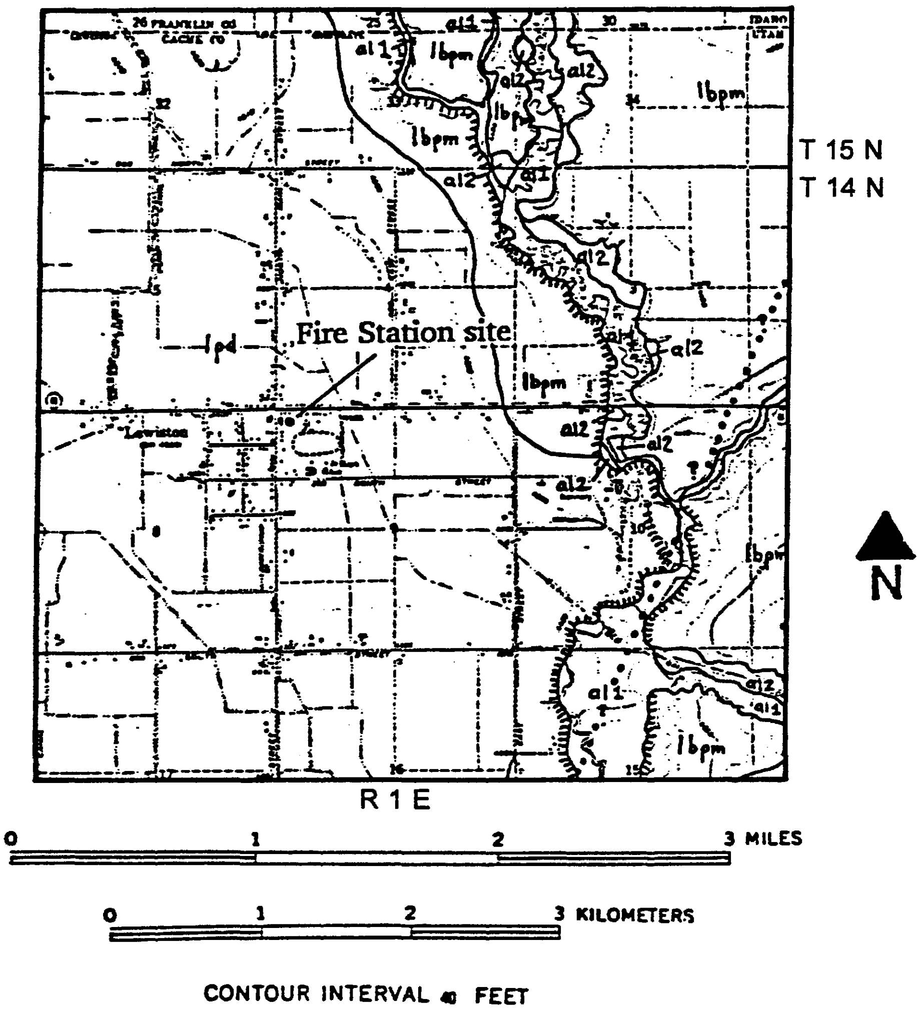
Attachment 1.   Job No. 92-02

Base map from RICHMOND,
U.S.G.S. topographic quadrangle



Attachment 1. Location map.

Base Map from RICHMOND U.S.G.S.
7-1/2' topographic quadrangle



al1	Stream alluvium (upper Holocene)
al2	Stream alluvium (middle Holocene to uppermost Pleistocene)
lpd	Deltaic deposits related to Provo and younger shoreline (uppermost Pleistocene)
lbpm	Lacustrine silt and clay related to Provo and Bonneville shoreline (upper Pleistocene)

Contact
Normal fault - Dotted where concealed; queried where origin is uncertain.
Topographic escarpment

Attachment 2. Geologic map (McCalpin, 1989).

SUMMARY OF GEOLOGIC HAZARDS
Lewiston Fire-Station SITE

Hazard	Hazard Rating*			Further Study Recommended**
	Prob-able	Pos-sible	Un-likely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction		X		S
Slope failure			X	
Flooding			X	
Sensitive clays			X	
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			S
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.

GLOSSARY OF GEOLOGIC-HAZARDS TERMINOLOGY

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Attachment 4 (cont)

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Attachment 4 (cont)

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

Project: Preliminary geologic-hazards evaluation of a proposed site for a Public Safety Complex near Nephi, Juab County, Utah.			Requesting Agency: Juab County
By: Kimm M. Harty	Date: 6-16-92	County: Juab	Job No: 92-11 (PF-2)
USGS Quadrangle: Nephi (884)			

INTRODUCTION

At the request of Glenn Greenhalgh, Zoning Administrator for Juab County, the Utah Geological Survey performed an in-office, preliminary geologic-hazards evaluation of a proposed site for the Juab County Public Safety Complex. The proposed site is 1.2 miles (2.0 km) south of Nephi in the SE 1/4 section 17, T. 13 S., R. 1 E., Salt Lake Baseline and Meridian (attachment 1). The purpose of the report was to identify geologic hazards that may be present at the proposed site. Identification of geologic hazards is particularly important for this project because Public Safety buildings are critical facilities that must remain functional during natural disasters. The scope of work for this report included a review of literature and maps; no field work was performed.

For this preliminary evaluation, no geolgic hazards were identified at the site that would make the site unsuitable for the Public Safety Complex. However, a soil-foundation investigation of the proposed site should be undertaken prior to construction of this project.

GEOLOGIC HAZARDS

Geologic hazards believed to potentially exist at or near the proposed site are discussed below. Hazards that need to be considered in a soil-foundation investigation are also noted in this report. Geologic terms are defined in the glossary (attachment 2).

Flooding and Debris Flows

No major drainage channels are near the proposed site, so the hazard from stream flooding is low. However, a recent geologic map (Biek, 1991) shows the proposed site on a young, active alluvial fan. Alluvial fans are formed by periodic deposition of rock and earth materials by debris flows and floods exiting canyons. Because this fan is considered active, the proposed site may be subject to debris-flow and debris-flood hazards. The site could also be subject to clear-water alluvial-fan flooding from minor ephemeral channels during high-intensity cloudburst storms. Additionally, due to its location in a topograghically low area between highways, the site may be subject to ponding during rainstorms or snowmelt.

Problem Soils

Soil maps for the Nephi area (Trickler and Hall, 1984) show the proposed site to be in the Juab loam, a well-drained soil developed on alluvial fans sloping from 4 to 8 percent. The erosion hazard of this soil is classified as slight; the soil has a low shrink-swell potential and a moderate potential for heaving by frost action (Trickler and Hall, 1984). The site could be in an area of collapsible soils. Collapsible-soil maps have been completed for the Nephi area (Owens and Rollins, 1990), but the map coverage ends north of the proposed site. However, an alluvial fan about 1,000 feet (305 m) north of the site is rated as having a high collapse potential (Owens and Rollins, 1990; Rollins and others, in preparation). The alluvial fan at the proposed Public Safety Complex site may also be prone to collapse. Because the site is between two highways, non-engineered fill may be at the site. This material can be subject to settlement.

Radon Gas

A generalized radon-hazard-potential map of Utah (Black and Solomon, in preparation) indicates the proposed site is in a moderate-hazard-potential area for radon gas. The rating is based on three factors: soil permeability, depth to ground water, and uranium content of the soil. In general, the radon-gas hazard is highest where soil permeability is high, ground water is deep, and soils are uranium rich. The moderate-hazard rating assigned to the area is likely due to a possible high uranium content in soils at the site derived from Tertiary volcanic rocks in the San Pitch Mountains to the east. In addition, the water table is likely deep, and permeability of the Juab loam is considered moderate for radon gas (B. Black, Utah Geological Survey, verbal communication, 1992). The proposed site was not tested for radon gas, therefore the moderate rating is only a preliminary estimate of the radon-hazard potential.

Earthquake Hazards

The Nephi area lies in the Intermountain seismic belt (ISB), a generally north-south trending zone of active seismicity that traverses the central part of the state. Associated with the ISB have been a number of moderate-sized earthquakes (magnitude 4.0 - 6.0) in the Nephi area in historical time (1850-present) (Arabasz and others, 1979). The closest large historical earthquake (magnitude 6.5) occurred approximately 65 miles (105 km) to the south, in the Richfield area in 1901.

The proposed site is near the surface projection of an inferred, buried trace of the Wasatch fault as mapped by Biek (1991).

However, the precise location of the fault in this area is unknown because Quaternary deposits conceal the fault, and it has not ruptured the surface during Holocene time (within the last 10,000 years) (Biek, 1991; Jackson, 1991). The last rupture of this portion of the fault may have been during the late Pleistocene or earlier (Jackson, 1991). Because the precise location of this buried fault is unknown, but it is believed to be near the proposed site, a surface-fault rupture hazard may be present. North and east of Nephi, the Wasatch fault shows evidence of surface rupture in late Holocene time. The closest surface rupture is about 2 miles (3.2 km) northeast of the proposed site (Biek, 1991). Based on a number of geologic studies (Machette, 1984; Schwartz and Coppersmith, 1984; Jackson, 1991; Machette and others, 1991), the Wasatch fault last ruptured the surface in this area sometime within approximately the last 1,200 years, and perhaps as recently as 300-500 years ago. The Wasatch fault zone is associated with earthquakes up to magnitude 7.5, which occur about once every 400 years somewhere along the fault.

The greatest earthquake hazard at the site is likely ground shaking resulting from either a moderate earthquake which could occur anywhere in the area, or from a large earthquake along a known fault. Three levels of design ground motions for the site are outlined below based on: 1) probabilistic motions that have a one in 10 chance of being exceeded in a 250-year period, 2) the minimum design motions specified in the 1991 Uniform Building Code (UBC) for seismic zone 3, and 3) the minimum design motions specified in the 1991 UBC for seismic zone 4. Under level 1 at the proposed site, a peak horizontal ground acceleration on soil of 0.6 g has a one in 10 chance of being exceeded in a 250-year period (Youngs and others, 1987). This figure approximates the probable maximum acceleration that the site may experience. Under level 2, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. These standards are based on design ground motions with a one in 10 chance of being exceeded in a 50-year period. The proposed Public Safety Complex is in UBC zone 3. For this zone, the Z-factor value is 0.3, corresponding to an effective peak ground acceleration on rock of 0.3 g. Under level 3, corresponding to UBC zone 4, the Z-factor value is 0.4.

The ground-motion levels described above represent three levels of design. Designing a building to level 1 is the most conservative (that is, it incorporates the most seismic resistance) of the options presented. Level 2 represents the minimum ground-motion design required by law in Utah, and is the least conservative of the three levels. Level 3 is the most realistic. It reflects recent ground-motion data (Youngs and others, 1987) that indicates the central Wasatch Front area, including Nephi, meets the criteria to be classified into UBC seismic zone 4 (Olig, 1991). Although not required by law, the Utah Geological Survey recommends designing critical facilities along the Wasatch Front in accordance with UBC seismic zone 4 specifications.

The hazard from flooding caused by earthquake-induced tectonic subsidence is very low, although such subsidence may accompany surface faulting in the area. Maps of soil liquefaction potential show the proposed site to be in a very low hazard zone (Anderson and others, 1990).

CONCLUSIONS AND RECOMMENDATIONS

For this preliminary evaluation, no geologic hazards were identified at the site which would make the site unsuitable for the Public Safety Complex. However, some hazards that could affect the Public Safety Complex in the future are discussed below with recommendations.

The proposed site is on an active alluvial fan and may be subject to deposition from debris flows and debris floods. In addition, alluvial-fan flooding could occur at the site during severe cloudburst rainstorms. Measures to assess, and if necessary, reduce these potential hazards should be taken. Collapsible soils may be present at the proposed site; a soil-foundation investigation needs to be done to determine the existence and possible extent of this hazard. The evaluation should be performed by a qualified soil engineer. Generalized data indicate the proposed site is in a moderate radon-hazard-potential area. Radon-resistant design in the building could minimize this potential hazard. The proposed site is near a concealed fault (Biek, 1991) whose exact location is unknown. Because this fault has not fractured the ground surface in Holocene time, the surface-rupture hazard, considering the probable lifetime of the Public Safety Complex and the uncertain location of the concealed fault, is considered low. Finally, because the Public Safety Complex is a critical facility that should remain functional during natural disasters, the Utah Geological Survey recommends that the complex be built under UBC design specifications for seismic zone 4, to provide a measure of earthquake resistance above the minimum required by law.

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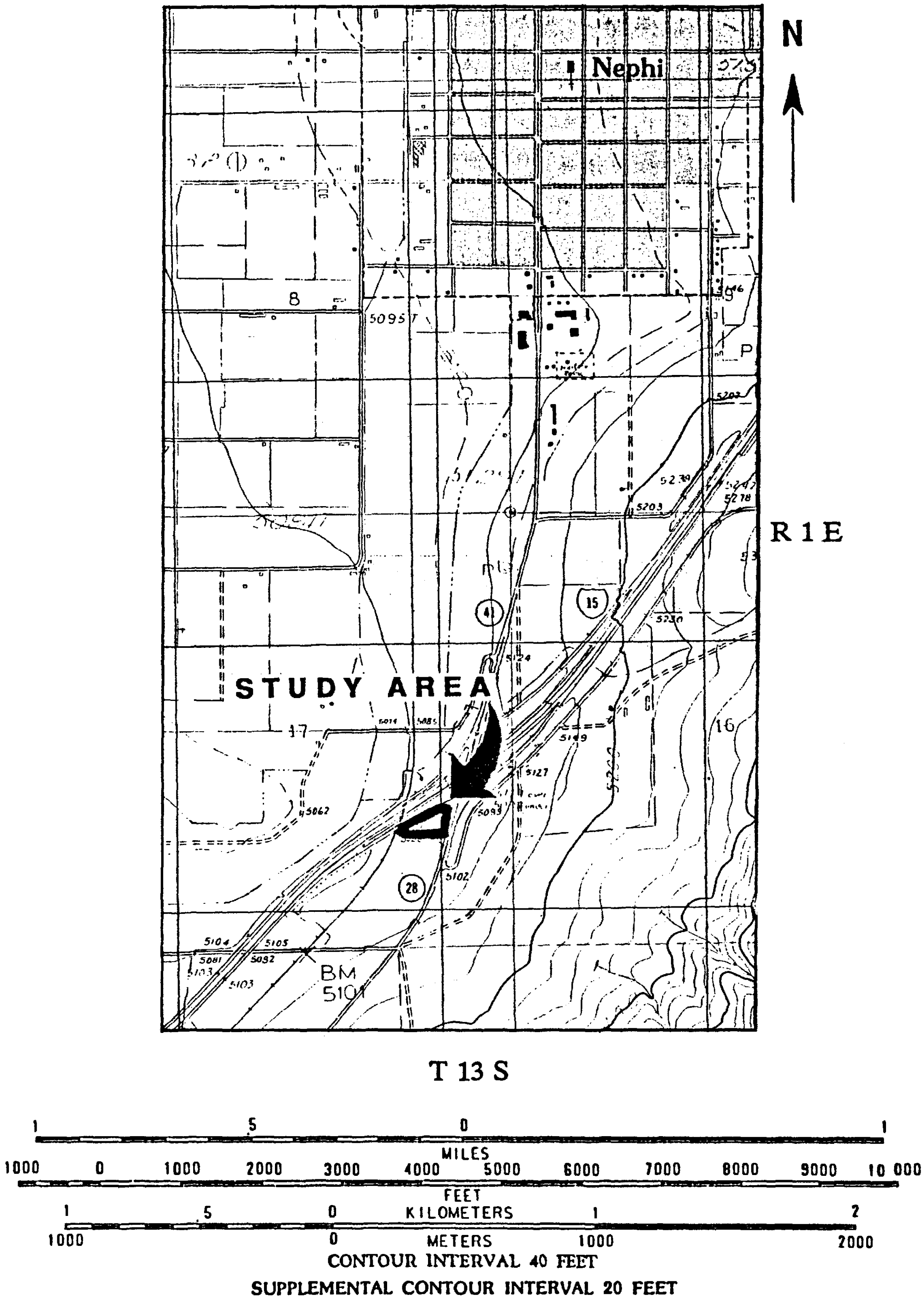
Base Map from NEPHI, U.S.G.S.
7-1/2' topographic quadrangle



Attachment 1. Proposed Juab County Public Safety site.

GLOSSARY OF GEOLOGIC HAZARDS TERMS

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Attachment 2 (cont)

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

SOLID WASTE DISPOSAL

Project: Investigation of faults near Sage Creek Junction solid waste disposal site, Rich County, Utah			Requesting Agency: Bear River Association of Governments
By: Barry J. Solomon	Date: 7-7-93	County: Rich County	Job No: 93-07 (SW-1)
USGS Quadrangle: Woodruff (1414), Randolph (1439), Sage Creek (1464)			

INTRODUCTION

Rich County is developing a Solid Waste Management Plan (SWMP) to ensure adequate capacity for disposal of municipal solid waste during the next thirty years or more. The preferred option in the SWMP is the continued use, and eventual expansion, of the present landfill site near Sage Creek Junction (attachment 1). Minimum performance standards for the proper management of solid wastes in Utah have been proposed (Utah Department of Environmental Quality, 1993), and the SWMP must be consistent with these standards, if implemented. Proposed rule R315-302-1, section (2)(b)(i) states, "A new facility or a lateral expansion of an existing facility shall not be located within 200 feet of a Holocene fault unless the owner or operator demonstrates...that an alternative setback distance of less than 200 feet will prevent damage..." (Utah Department of Environmental Quality, 1993, p. 8). Roger C. Jones, Executive Director of the Bear River Association of Governments, is assisting Rich County in the development of the SWMP, and was notified of mapped faults at the Sage Creek Junction site (Dover, 1985) which may be of Holocene age. At the request of Mr. Jones, a field investigation was conducted to determine if Holocene surface rupture occurred along these faults and if further investigations are necessary to address fault hazards.

GEOLOGIC SETTING

The landfill site is about 1.5 miles (2.4 km) northwest of Sage Creek Junction, in the eastern foothills of the Wasatch Range west of the Bear River (attachment 1). The first comprehensive geologic map of the site and vicinity (Richardson, 1941) shows the lower slopes of the foothills adjacent to the valley floor covered by Quaternary, unconsolidated deposits of "hill wash," consisting of fragments of outcropping rocks in the highlands. Upper foothill slopes are underlain by the Eocene Wasatch Formation, consisting primarily of conglomerate and sandstone, with lesser amounts of shale, limestone, and tuff. Richardson (1941) did not map any faults near the site.

The area was later remapped by Dover (1985), who revised the Tertiary stratigraphy to reflect units described by Oriel and Tracey (1970) in the Fossil Basin of southwestern Wyoming, about 20 miles (30 km) to the east. Dover (1985) also mapped rocks underlying the upper foothill slopes as the Wasatch Formation, but assigned isolated tuffaceous outcrops on the lower slopes to the overlying Eocene Fowkes Formation. Where lower slopes are covered by younger deposits, the surficial material was mapped as Holocene gravel, "derived as a lag concentrate from erosion of nearby or underlying rocks" (Dover, 1985, p. 1). Significantly, Dover also mapped numerous northwest- and northeast-striking normal faults in the foothills. The northeast-striking faults on the lower slopes trend toward and through the landfill site. Most of these faults, including those that intersect the site, offset only Eocene rocks. The Wasatch and Fowkes Formations are commonly in fault contact, although the formations are rarely in depositional contact with apparently east-dipping beds of the Wasatch Formation underlying those of the Fowkes Formation. However, some of the faults between the towns of Randolph and Woodruff, between 10 and 16 miles (16 and 26 km) south of the site, are mapped by Dover (1985) as offsetting the Holocene gravel. Because these faults indicate possible Holocene movement and connect with faults in Eocene rocks at the landfill site, it is possible that faults at the site may have actually moved during the Holocene despite the absence of Holocene material there to indicate such recency of movement.

DISCUSSION

I investigated two lines of evidence to determine the potential for Holocene faulting at the site. Faults in Eocene rocks on-site were inspected for evidence of Holocene faulting, and faults to the south were inspected to determine if faulting actually offset Holocene material as mapped by Dover (1985).

On-site faults in the Wasatch Formation separate resistant, coarse-clastic rocks on northwestern, upthrown blocks from similar rocks on the lower slopes of southeastern, downthrown blocks which are overlain by less resistant fine-grained rocks. Fault traces were inspected to determine the qualitative degree of scarp degradation. Initially steep fault scarps are degraded by weathering to progressively gentler and more rounded slopes through time. A number of variables affect the degradation, but one of particular significance at the landfill site is the physical properties of the material. Conglomerate and sandstone of the Wasatch Formation are competent materials that, if recently offset, should resist degradation. Topography in the immediate vicinity of the fault traces, represented by a slope break and ephemeral stream channel, was rounded. This suggests that on-site faults are older than Holocene, although their precise age cannot be determined.

Faults to the south of the landfill site were also mapped at a break in slope. However, whereas faults between Woodruff and Randolph are shown by Dover (1985) as offsetting Holocene gravel as well as rocks of the Fowkes Formation, faults to the north between Randolph and the landfill site, also mapped at a break in slope, are shown by Dover (1985) as concealed beneath the gravel, offsetting rocks of both the Wasatch and Fowkes Formations.

Inspection of both areas did not reveal any scarps with topographic appearances to suggest Holocene offset, indicating that faults in both areas, if present, are not Holocene but significantly older. Rounded topographic benches on either side of fault traces between Woodruff and Randolph are capped by a gravel veneer which is a lag concentrate from erosion of underlying conglomerates in the lower Fowkes Formation. Soil on side slopes is silty, typical of residual soils on fine-grained rocks in the Fowkes Formation. The erosion-resistant conglomerates are apparently the reason for preservation of the benches, and may either be the same bed at different elevations separated by a pre-Holocene fault, or different beds at two stratigraphic levels, in which case a fault may or may not exist. Rock exposures are nonexistent in the immediate vicinity of the fault, and shallow dips of rocks further away are inconclusive for structural interpretations.

CONCLUSION

The term "gravel" as used by Dover (1985) is somewhat of a misnomer for the map unit on the lower foothill slopes between Woodruff and Randolph. The unit should probably be mapped as the Fowkes Formation, offset by pre-Holocene faults. The "gravels" of Dover (1985) are actually a residual soil formed by in-place weathering of the underlying Fowkes Formation after subaerial exposure of the unit. There is no evidence that the residual soil has been faulted during the Holocene, nor is there evidence that Eocene rocks have been subjected to Holocene faulting either on-site or to the south. The landfill site satisfies the performance standard related to Holocene faulting (Utah Department of Environmental Quality, 1993) and further work to consider these faults is not necessary.

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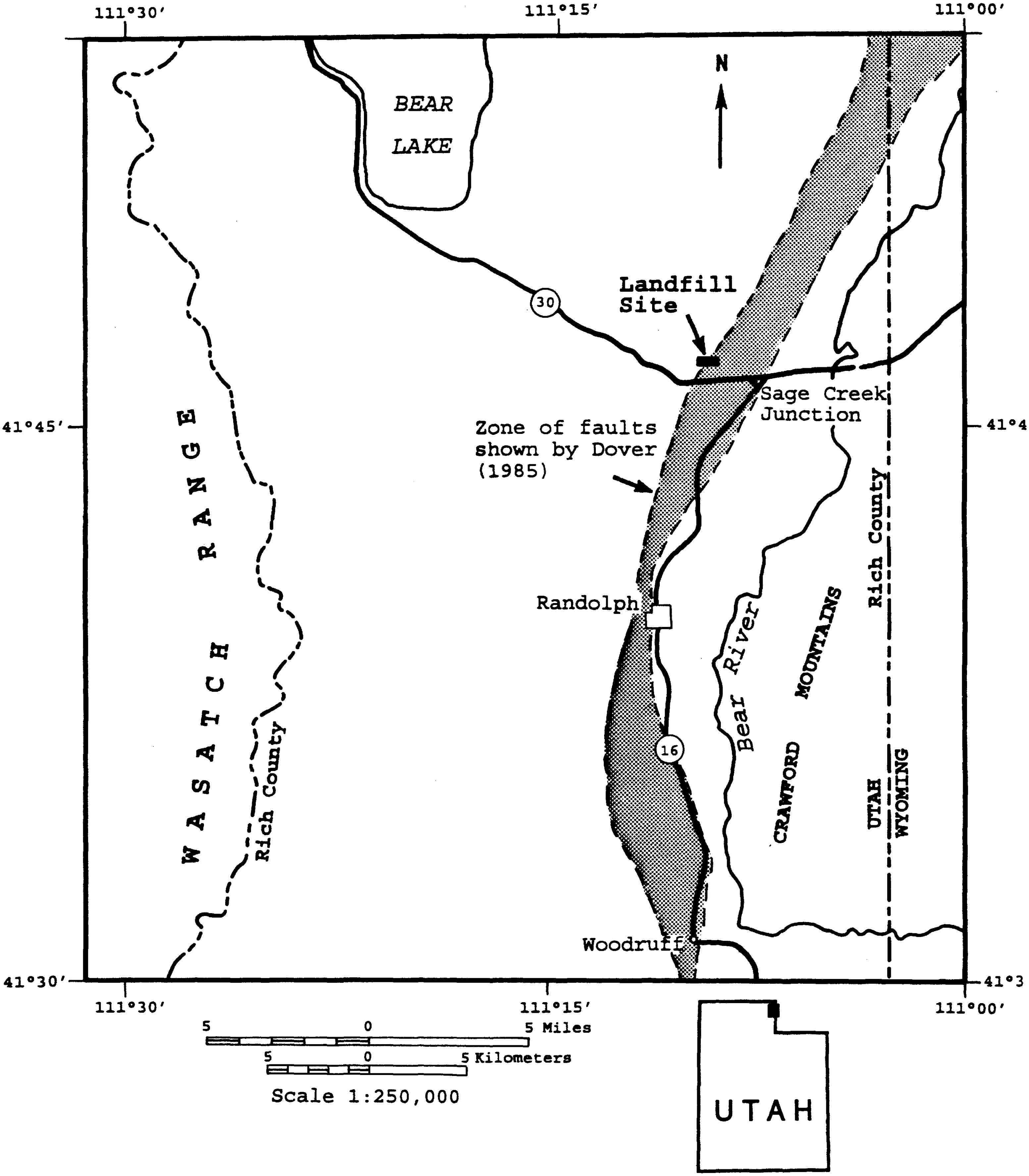
Richardson, G.B., 1941, Geology and mineral resources of the Randolph quadrangle, Utah-Wyoming: U.S. Geological Survey Bulletin 923, 54 p., scale 1:125,000.

Utah Department of Environmental Quality, 1993, Proposed administrative rules -- solid waste permitting and management rules -- R315-301 through 319: Salt Lake City, Utah Department of Environmental Quality, Division of Solid and Hazardous Waste, 78 p.

Attachment 1 Job No. 93-07 Base Map modified from OGDEN U.S.G.S. 1° x 2° topographic quadrangle.



Attachment 1. Location map.

GEOLOGIC HAZARDS

Project: Geologic-hazards investigation of a parcel of school trust land in section 2, T. 26 S., R. 19 E., Grand County, Utah.			Requesting Agency: State Lands and Forestry
By: W.E. Mulvey	Date: 1-6-92	County: Grand County	Job No: 92-01 (GH-1)
USGS Quadrangle: The Knolls (BLM 499)			

PURPOSE AND SCOPE

At the request of Karl F. Kappe, Policy Integration Manager, Division of State Lands and Forestry, the Utah Geological Survey (UGS) conducted a geologic-hazards investigation of a parcel of school trust land in section 2, T. 26 S., R. 19 E., Salt Lake Base Line and Meridian, in Grand County (attachment 1). The purpose of the investigation was to identify potential geologic hazards that may affect future development on the property. The scope of work included a literature, air photograph, and map review, and field inspection on December 30-31, 1991.

SETTING AND SITE DESCRIPTION

Regional topography of the area is a gently warped tableland with deeply incised canyons (Doelling and others, 1991). The land is located on the east side of State Highway 313, approximately 4 miles northeast of the entrance to Dead Horse Point State Park. Terrain consists of a low broad ridge along the west edge of the property, with drainage to the east (attachment 1). Vegetation is pinyon-juniper woodland with mixed grasses and shrubs. Several dirt roads pass through the parcel providing access to the Gemini Bridges area, 5 miles southeast of the site.

GEOLOGY AND SOILS

Two bedrock units are present at the site, the Jurassic-age Kayenta Formation and the overlying Navajo Sandstone (Doelling, 1985). These formations are generally flat-lying, forming low buttes near Highway 313. The study area is at the northwestern end of the Cane Creek anticline, which has no visible effect on the dip of local rocks. Quaternary deposits consist of eolian sheet sand and alluvium.

The Kayenta Formation is predominately sandstone with lenses of conglomerate, siltstone, and shale. The sandstone is a moderate orange-pink and the mudstone is a dark reddish brown to grayish red (Doelling and others, 1991); both are exposed on the parcel. The formation is highly resistant to erosion, forming ledges and small cliffs.

Along Highway 313, erosional remnants of the Navajo Sandstone are present as resistant ledges and small buttes east of the road. The Navajo Sandstone is a massive sandstone, orange to light gray in color (Doelling and others, 1991).

Quaternary deposits are present throughout the study area as a thin mantle of residual and transported material weathered from the local bedrock. These deposits are predominantly eolian sand and alluvium. Most Quaternary deposits are stabilized with a vegetative cover of pinyon-juniper, shrubs, and grasses. However, well-developed gullies (2-3 feet) in these deposits occur along drainages in the parcel.

Soil developed on the Quaternary deposits consists of a fine sandy loam which is well drained and easily eroded, with moderately rapid permeability and severe limitations for individual wastewater disposal systems due to shallow bedrock (Hansen, 1989). Quaternary deposits are composed of fine sands, silts, and some clays weathered from the Kayenta and Navajo Formations. These deposits are thin, discontinuous, and present in low and flat areas to the east of Highway 313. In the Unified Soil Classification System (USCS), these deposits are silty sand (SM), and silty sand-clayey sand (SM-SC). Shales in the Kayenta Formation weather to form clayey soils observed in road cuts along the dirt road in the southwestern part of the parcel. Although clay in the soil generally has a low shrink-swell potential (Hansen, 1989), soils with a high shrink-swell potential occur locally.

GEOLOGIC HAZARDS

Attachment 2 is a summary checklist of potential geologic hazards at the parcel. All hazards considered are shown and those present are discussed below.

Earthquake Hazards

The region is low in historical earthquake activity, with the majority of earthquakes attributed to coal-mining and mining activities around the Cane Creek mine at Potash, just south of the parcel (Wong and Humphrey, 1989). Regional seismicity was studied by Wong and Humphrey (1989) who determined that, in general, earthquakes in the Colorado Plateau are small to moderate magnitude, and occur infrequently. The strongest recorded earthquake in the area occurred on February 1, 1967 (magnitude M_L 3.8) near Upheaval Dome.

The closest major fault is the Moab fault, located approximately 10 miles (16 km) to the northeast. Movement during Quaternary time (last 1.6 million years) is suspected on this fault, and is probably related to salt dissolution beneath Moab and Spanish Valleys, but may have a tectonic component (Hecker, in prep).

Ground Shaking

The potential for strong ground shaking due to earthquakes at the site is low, with peak ground acceleration on rock with a 10 percent probability of being exceeded in 50 years of less than .05 g (Algermissen and others, 1990). The 1991 Uniform Building Code (UBC) designates this area as seismic zone 1.

Other Earthquake Hazards

The surface fault rupture hazard is low because no known active faults traverse the site. Liquefaction potential is low because of shallow bedrock, deep ground water, and low earthquake activity. Rock falls may be triggered by earthquakes of magnitude 4.0 or greater (Keefer, 1984), but even earthquakes of this low magnitude are rare in this area (see Slope Failure section below).

Slope Failure

Low buttes of Navajo Sandstone along Highway 313 have cliff faces 20-to 30-feet (6-9-m) high which may present a localized rock fall hazard. Rock debris along the base of the buttes indicates that rock falls do occur, but they do not affect a large area. Gentle slopes and the pinyon-juniper forest surrounding the buttes minimize rock fall runout distances. This hazard is most significant to development at the base of the cliffs.

The flat topography and competent rock make the hazard from other types of slope failures low.

Problem Soil

Shallow soils will limit the use of conventional trench-type wastewater disposal systems. Also, disruption of the natural drainage by construction may accelerate erosion by water and wind. Runoff from paved surfaces may also increase erosion and affect land downstream by increasing and concentrating runoff. Disturbing stabilized sand dunes can create a persistent maintenance problem if dunes are reactivated. Clayey soils at the site are listed by the SCS as low plasticity (CL), however soils I observed locally were quite plastic (CH) and probably highly expansive.

Because of shallow soil, foundations at the site will be in or on bedrock. Below-ground utilities, foundations, and wastewater disposal systems may require blasting or ripping.

Other Hazards

Ground water at the site is probably deep, and should not be encountered in foundations or excavations. Because of the location along a broad, low-relief ridge, the potential for flooding is low except in ephemeral stream channels. Local sheet-flow runoff may occur during cloudburst thunderstorms, but the site is well drained and little ponding should occur. The Kayenta and Navajo Formations and the soil derived from them are not known sources of radon. Therefore the potential for dangerous indoor radon levels in structures at the site is low.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the site which would pose an acceptable risk for development. The greatest limitation to development is the lack of soil, if on-site buried wastewater disposal systems are planned. Detailed investigations may be required to identify a suitable area for such systems, and suitable sites may not be present. Current regulations list three types of alternative systems usable in shallow bedrock conditions, the Wisconsin Mound, Low Pressure Pipe, and evapotranspiration systems. These systems are more expensive than conventional trench-type systems, and require special installation permits and procedures. All of these alternative systems require specific types of engineered fill (John Kinington, Division of Water Quality, Department of Environmental Quality, State of Utah, verbal commun., January 8, 1992).

Prior to construction, the UGS recommends a soil-foundation investigation to determine soil types and thickness for foundations. It is likely that excavations in bedrock may be required. Also, expansive clays are found locally that may require removal or special foundation design.

Erosion is potentially a problem, and care should be taken in designing site drainage to minimize erosion hazards. Although the area affected by rock fall is small, if development is planned near the buttes, the area affected by rock fall should be determined. Techniques for reducing rock-fall hazards may include avoidance, rock stabilization (bolting, cable lashing, and burying rocks, and grouting discontinuities), and removal or break-up of potential rock clasts. Deflection berms, slope benches, and rock-catch fences may also stop or at least slow down falling rocks.

Other hazards from earthquakes, slope failures, problem soil, shallow ground water, flooding, and radon are low.

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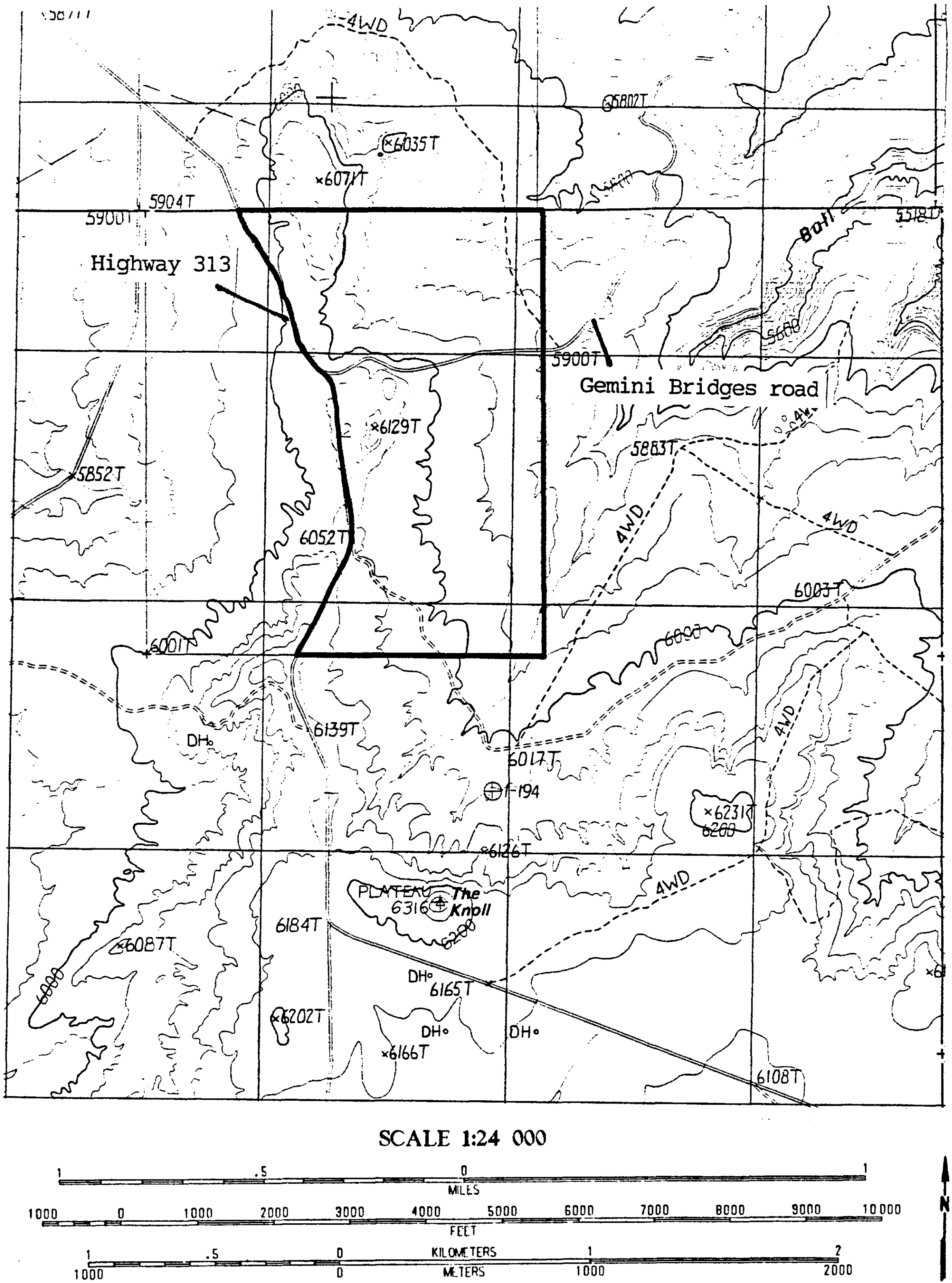
Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, p. 406-421.

Wong, I.G., and Humphrey, J.R., 1989, Contemporary seismicity, faulting, and the state of stress in the Colorado Plateau: Geological Society of America Bulletin, v. 101, n. 9, p. 1127-1146.

Base map from The Knolls U.S.G
7.5' topographic quadrangle.



Attachment 1. Location of State Lands and Forestry School Trust Lands in section 2, T. 26 S., R. 19 E., Grand County, Utah.

SUMMARY OF GEOLOGIC HAZARDS
School Trust Lands, Sec 2, T.26 S., 19 E., Grand County, Utah

Hazard	Hazard Rating*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				
Ground shaking			X	
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction			X	
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall				G
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive		X		S
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion	X			
Active sand dunes		X		
Mine subsidence			X	
Shallow bedrock	X			S
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: Investigation of geologic effects of the M_L 4.3 March 16, 1992, earthquake, Salt Lake County, Utah			Requesting Agency: Emergency Response
By: Susan S. Olig and William E. Mulvey	Date: 4-9-92	County: Salt Lake	Job No: 92-03 (GH-2)
USGS Quadrangle: Tickville Springs and Jordan Narrows (BLM #1132 & 1131)			

INTRODUCTION

An M_L 4.3 earthquake occurred at 7:42 a.m. (MST) on March 16, 1992 near Camp Williams, Salt Lake County (attachment 1). This is a report of our investigation for physical geologic effects associated with the earthquake. On March 16, W.E. Mulvey and Bill Black searched the Traverse Mountains west of Camp Williams for rock falls and other effects, and Susan Olig and Bea Mayes investigated the banks of the Jordan River for liquefaction features and slope failures (attachment 1).

The earthquake was too small to expect significant geologic effects, except perhaps for nearby rock falls or bank caving, and neither team found any geologic effects that could be attributed to the earthquake. Olig and Mayes observed new cracks in the Utah National Guard building in Draper. In an unrelated investigation on March 17, 18, and 19, Kimm Harty investigated a reservoir at about 9400 South along the Jordan River, which had been drained after the earthquake, and found possible evidence for liquefaction (see Applied Geology Technical Report 92-04 by Kimm Harty).

TRAVERSE MOUNTAINS

The investigation included a driving and walking reconnaissance of the Traverse Mountains to the east, south, and north of the epicenter, looking for evidence of surface fault rupture and other ground cracks, rock fall, and landsliding (attachment 1). We also observed streams, springs, and seeps for turbidity, to see if the earthquake disturbed the local ground-water system. Much of the reconnaissance was on Camp Williams, and we were accompanied by Captain Ronald Haskell and Sargent First Class Doug Mooneyham of the Utah National Guard.

Vegetation in the area consists of oak brush-maple, and sagebrush-grassland communities. Terrain is mountainous, with steep hillslopes and narrow drainages. Bedrock is Pennsylvanian-Permian sandstone and limestone, and Tertiary volcanic rocks (Hintze, 1980). Quaternary deposits consist of alluvium along stream drainages, and colluvium on slopes. Soils are thin over weathered bedrock. Outcrops are few, and consist of sandstone and limestone.

We concentrated our investigations in the area south of the epicenter, in the vicinity of Beef Hollow and Tickville Springs. Throughout this area there was no evidence for surface fault rupture, ground cracks, or landslides caused by the earthquake. Outcrops had talus slopes below them, making it difficult to identify fresh rock-fall debris. We examined numerous outcrops and found no evidence for rock falls.

Streams, springs, and seeps were checked for water clarity. Streams in Beef Hollow were turbid, but the cause was runoff from graded roads paralleling the drainage. Tickville Spring, approximately one mile south of the epicenter, was clear. We checked a small earth dam approximately one mile below the spring for damage and found none. Sloughing of stream banks was observed in the Tickville Spring drainage. This is the only evidence we observed that could represent geologic effects possibly caused by the earthquake, but it could also be attributed to normal erosional processes.

We viewed the north side of the Traverse Range, driving up Rose Canyon and side roads leading to drainages north of the epicenter. In these areas no evidence for surface fault rupture, landslides, or rock falls were observed. Streams, springs, and seeps were clear. Mine dumps at the Kennecott operation just north of Rose Canyon also appeared undisturbed by the earthquake.

JORDAN RIVER

The investigation included reconnaissance of the banks of the Jordan River from Bluffdale south to Camp Williams (attachment 1). The banks along this section of the river are well vegetated with willow, sage, and grasses. Slopes along the banks are moderate to steep, with cliffs over 100 feet (30 meters) high at Jordan Narrows. The river cuts through a semi-consolidated conglomerate at Jordan Narrows and gravel deposits are common along the river channel. We did not observe any sand boils, cracks, fissures, fresh scarps, or any feature related to liquefaction. We did observe some sloughing along steeper banks, but this is most likely due to ongoing erosion. It is possible that the earthquake triggered very small movements of material in these areas, but there is no conclusive evidence of earthquake-induced slope failure in the vicinity.

UTAH NATIONAL GUARD BUILDING

The Utah National Guard building is a one- to two-story concrete building located at 12953 Minute Man Drive in Draper. The site is flat and underlain by fine-grained Lake Bonneville deposits (Personius and Scott, 1990). We met with Major Paul D. Harrell and various maintenance personnel who gave us a tour of the facility on March 16, 1992.

Two types of damage were observed: cracks along expansion joints in the concrete walls, and shear cracks in a second-story concrete floor. The cracks along expansion joints were observed throughout the building and varied in width from less than 1/16th inch to more than 1/8th inch (1 to 3 mm). Patching of old cracks had recently been completed and maintenance personnel were certain that these new cracks formed during the earthquake.

The shear cracks were extending out from the corners of openings in the floor for columns. The cracks varied in width from less than 1/16th inch to nearly 1/8th inch (1 to 3 mm). Maintenance personnel were certain that the cracks formed during the earthquake because the area is swept daily and small pieces of loose concrete were visible along the cracks. No other damage was observed.

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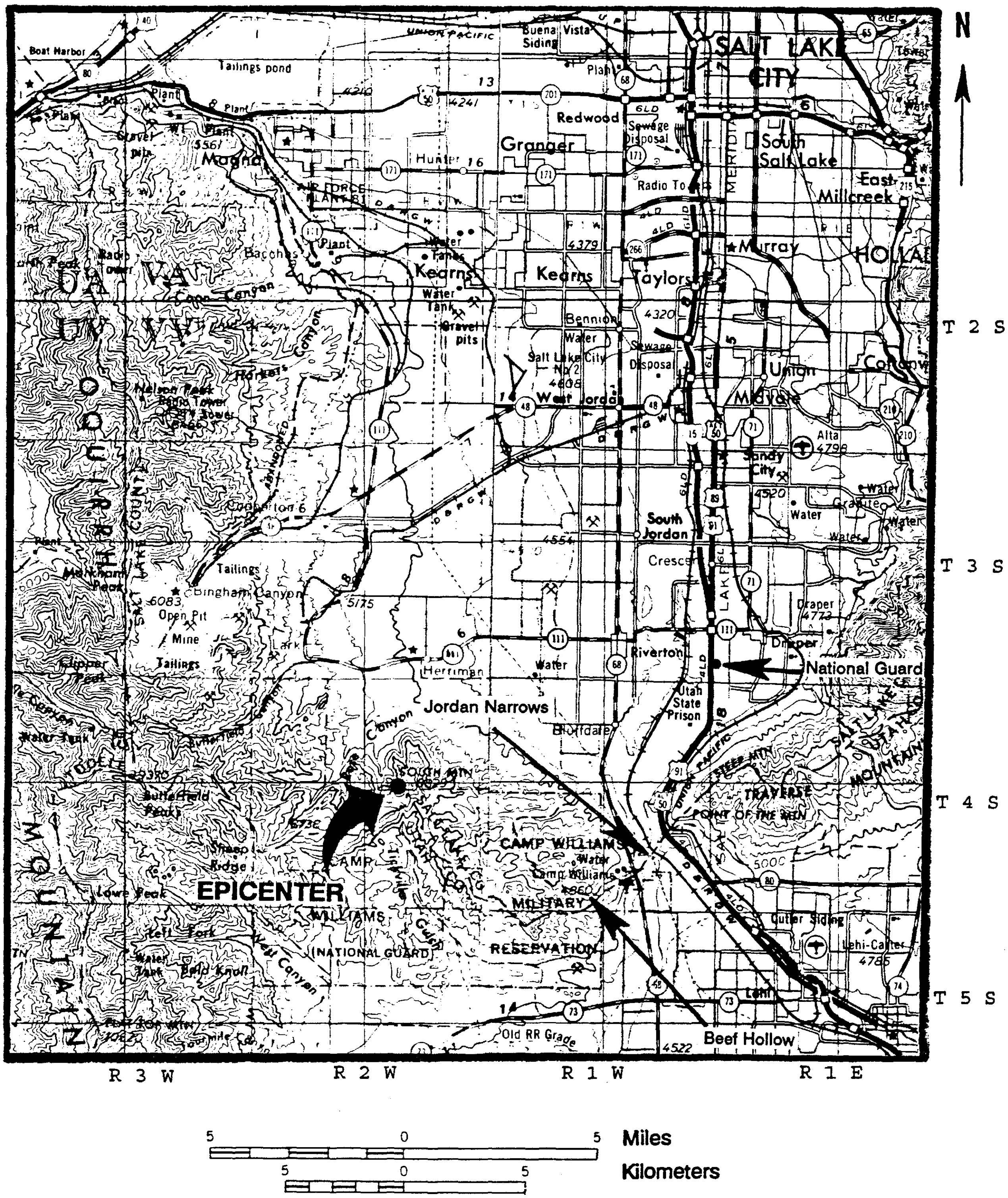
Personius, S. F., and Scott, W. E., 1990, Preliminary surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U. S. Geological Survey Miscellaneous Field Studies Map MF-2114, scale 1:50,000.

Attachment 1. Job No.92-03

Base Map from TOOELE and SALT LAKE CITY
U.S.G.S. 1:250,000 topographic quadrangles



Attachment 1. Location map.

Project:			Requesting Agency:
Investigation of Jordan River discoloration and possible liquefaction at the 9400 South dam and reservoir, Salt Lake County, Utah.			Emergency Response
By: Kimm M. Harty	Date: 4-8-92	County: Salt Lake	Job No: 92-04 (GH-3)
USGS Quadrangle: Midvale (1172)			

INTRODUCTION

On March 17th, 1992, John Hollenhorst (KSL TV reporter) called the Utah Geological Survey (UGS) to report a fish kill and "black water" flowing in the Jordan River between approximately 10000 and 7800 South Streets, Salt Lake County. He also reported seeing numerous small holes in sediment exposed in the 9400 South reservoir, in the vicinity of the discolored section of the river. On March 17th, I investigated the reservoir area to determine whether geologic phenomena could have caused or been a factor in discoloring the water. Bea Mayes (UGS) accompanied me in the field on March 17th. While investigating the river discoloration, I observed the reported holes in recently exposed sediments adjacent to the river channel. I examined these features on March 18th and 19th, in an effort to determine if they may have been caused by liquefaction during a magnitude 4.3 earthquake that had occurred in the Traverse Mountains on March 16th, 1992.

JORDAN RIVER DISCOLORATION

I observed the blackened color of the Jordan River where it intersects 7800 and 9000 South Streets. At the river bank near the latter location, we met and spoke to a fisheries biologist (Doug Sakaguchi) and regional habitat manager (John Fairchild) from the Utah Division of Wildlife Resources (DWiR). They had just returned from inspecting the river near the 9400 South dam (attachment 1), owned by the North Jordan Canal Company (NJCC). This dam regulates flow in the Jordan River, and it and several other associated structures divert river water into the North Jordan canal (attachment 1). According to DWiR personnel, the NJCC opened the gates on the dam the previous day (March 16th) to release water into the canal. DWiR investigators attributed both the fish kill and the darkening of the water to scouring and mixing of the organic-rich de-oxygenated sediment that had accumulated behind the dam, triggered by the sudden release of water from the reservoir.

My subsequent investigations of the dam, reservoir, and areas farther upstream confirmed the hypothesis of the DWiR personnel. Between 9:00 and 10:30 a.m. on March 18th, I observed blackened flow in the river as far upstream as 10000 South Street (attachment 1), where the water became much clearer, exhibiting a greenish, rather than blackish color. Between the dam and 10000 South Street (a distance of nearly 1.5 km [0.9 mi]), point bars and channel bars exposed by the rapid water-level decline showed signs of recent and active scour. In addition, recently exposed bottom and bank sediments, particularly those within about 300 m (328 yd) of the upstream side of the dam, showed evidence of extensive cracking and slumping. Unlike the brown and light-brown sediments in areas near and upstream of 10000 South Street, those downstream from this point were dark gray to black, and fetid, indicative of organic accumulation and anoxic sediments in the stilled waters behind the dam. The rapid draw-down of water behind the dam eroded and entrained much of the dark sediment, and this, in combination with slumping of newly exposed sediments into the river, caused the discoloration of the water. Although still darkened, water in the river was noticeably clearer on March 19th.

POSSIBLE LIQUEFACTION FEATURES

Modern sediments in the reservoir exposed after the water release were covered with numerous small holes averaging about 1 cm (0.4 in) in diameter. I observed these holes on nearly every surface that had been submerged before the water release. No holes were found downstream of the dam, nor upstream of the farthest extent of the reservoir (about 10000 South Street) (attachment 1). In addition, holes were limited to generally flat, recently exposed point and channel bars; no holes were observed on the river-bank slopes. The density of holes was variable, with relatively few holes on some bars, and many on others. Hole density seemed the least on bars nearest the dam, and greatest on bars in the upper reaches of the reservoir. Some holes were rimmed with a small cone of sediment, indicating the upward movement of sediment through the holes. There appeared to be more sediment cones around holes in the upper reaches of the reservoir than in the lower reaches.

On March 19th, I examined these holes more closely to determine if they may have been caused by liquefaction during the earthquake. Sediment ejected from the holes appeared to be the organic-rich fine-grained sediment forming the surface of all newly exposed features. In cross-section, the holes appeared shallow, with the deepest of the four I excavated extending vertically only about 5 cm (2 in) below the surface. Sectioning holes in the saturated, black sediment caused smearing and closure, thus some holes may extend deeper than 5 cm (2 in). However, the holes did not appear to extend below the layer of saturated organic sediment. I examined the sediment using a microscope (50X magnification) and classified it in accordance with the visual/manual procedures outlined in ASTM Standard D-2487-83. The sediment is a clayey silt (ML) and contains a small amount (<5 percent) of fine sand.

To reach some of the holes for sampling, sectioning, and photographing, I stood on a plywood board placed over the organic-rich sediments. On one occasion, loading caused by stepping on the board forced water and sediment out of the existing holes, indicating the organic sediments were still saturated and that the holes may have formed by extrusion of water and sediment from below.

Possible explanations for the formation of the holes and sediment cones surrounding the holes include: 1) crayfish (or some other animal/insect) burrowing, 2) gas bubbles, 3) de-watering of the sediments, 4) earthquake-induced liquefaction, and 5) a combination of processes. These possibilities are each discussed below.

To obtain information on crayfish and other burrowing creatures (possibility 1), I spoke to Dr. Chris Luecke, a limnologist in the Department of Biology, and to Dr. Todd Crowel, College of Natural Resources, Utah State University. Both Dr. Crowel, who has conducted extensive research on crayfish, and Dr. Luecke discounted the animal/insect-burrowing theories based on my descriptions of the holes and sediment conditions. The main reasons given to discount the burrowing theory include:

- **Anoxic sediment conditions**. Crayfish and most other burrowing creatures (for example, clams) are not adapted to living in de-oxygenated sediments.

- **Hole Size**. Crayfish typically leave burrow holes about the size of a quarter (2.5 cm [1 in]). The holes averaged about 1 cm (0.4 in) in diameter, but many smaller holes were observed. The 1-cm (0.4-in) holes are too large to have been made by chironmid (fly) larvae, a burrowing insect adapted to living in anoxic sediments.

- **Hole geometry**. Crayfish burrow horizontally as well as vertically, but no horizontal tunnels were observed in the near subsurface.

- **Type of sediment**. Crayfish usually burrow into firm clays that maintain tunnel shape. The sectioned holes in the low-strength sediments closed quickly.

- **Cone texture and symmetry**. Crayfish excavate sediment with their back legs, piling it asymmetrically around the holes. The observed cones were smooth and nearly symmetrical.

- **Lack of physical evidence**. Crayfish usually leave behind molts; crayfish and other burrowing creatures may leave tracks. No molts, bodies, or tracks other than from birds and small mammals were observed around the holes or on the exposed bars I examined.

The possibility that gas bubbles formed the holes cannot be dismissed (possibility 2). A strong fetid odor permeated the area upstream of the dam, indicating the presence of hydrogen sulfide

(H_2S) gas. In addition, the exposed bottom sediments were rich in iron sulfide, which contributes to the black color of anoxic sediments. Dissolved H_2S most likely existed in the waters at the bottom of the reservoir, and in interstitial water within the bottom sediments. Saturation of dissolved gases, including H_2S, varies with temperature, salinity, and pressure. Removal of the reservoir waters above the anoxic, H_2S-rich sediment resulted in a decrease in the hydrostatic pressure in the water-saturated bottom sediments. This decrease in pressure may have caused the formation of H_2S gas bubbles within the sediments, which then rose to the surface, forming the holes. That the holes were not observed to extend below about 5 cm (2 in) may be due to structural collapse shortly after their formation. Although this scenario well explains the formation of the holes, it does not adequately explain the sediment cones surrounding some of the holes. Rising gas bubbles may be capable of deforming sediments around the perimeters of the holes, but the sediment cones were clearly depositional, not deformational features, and rising bubbles likely do not carry or expell much sediment. Thus, the formation of gas bubbles cannot fully explain the origin of the sediment-rimmed holes.

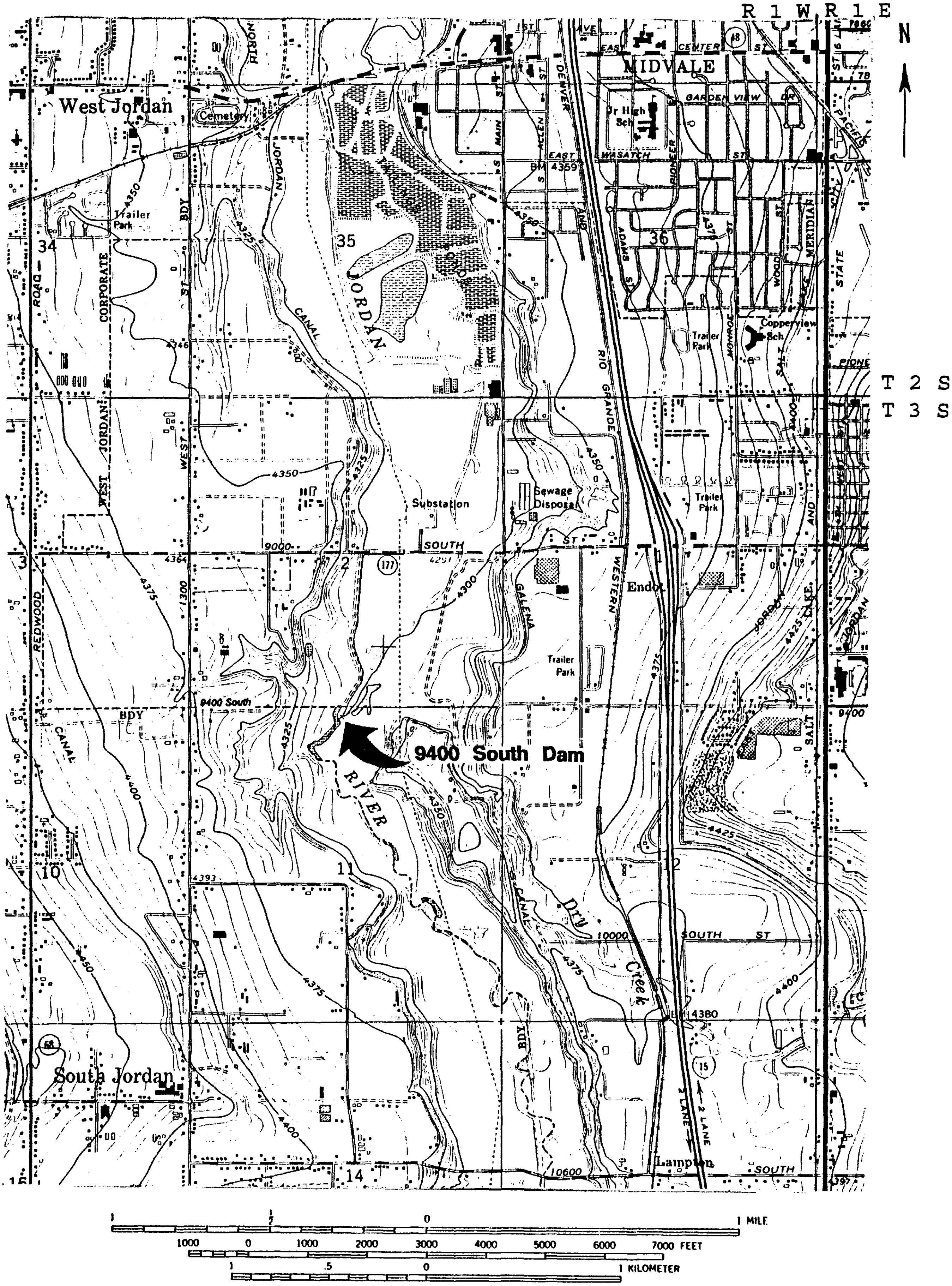
De-watering of the sediments upon removal of the reservoir waters (possibility 3) may explain the formation of the holes and cones. As the water table drops (in this case as a result of release of reservoir waters), ground water usually migrates downward and/or laterally down gradient. However, if ground water becomes confined and cannot drain freely, the weight of the overlying de-watering sediment may force upward flow, particularly if open flow paths (cracks, holes) are present. If the holes were formed by rising gas bubbles, loading pressures from the weight of the draining sediment may have been sufficient to partially de-water the sediment through the existing holes, creating the sediment cones. R.C. Rasely (U.S. Soil Conservation Service, oral communication, April 1992) has observed similar sediment-rimmed holes in de-oxygenated bottom sediments of partially drained reservoirs in Indiana. He attributed the formation of those holes to de-watering processes.

The possibility that the holes and cones were formed by liquefaction during earthquake ground shaking (possibility 4) also cannot be discounted. "Sand boils," "mud volcanoes," and "blow holes" have been observed after numerous moderate to large earthquakes throughout the world. Evidence suggests that the sediments in the reservoir were likely highly susceptible to liquefaction. Prior to the opening of the dam on March 16, 1992, the reservoir had been accumulating sediment since the dam's last opening in the late summer of 1991 (Al Pendleton, NJCC, oral communication, March, 1992). These recent sediments contained much silt, were loose and saturated, and thus susceptible to liquefaction. Although liquefaction is not commonly reported in earthquakes smaller than magnitude 5, I believe it is possible that these susceptible sediments liquefied and formed the small boils during the magnitude 4.3 earthquake, whose epicenter was only 20.0 km (12.4 mi) southwest of the reservoir.

The formation of the holes and sediment cones is probably related to a combination of processes (possibility 5). The most plausible explanation is that draining of the reservoir created gas bubbles that formed the holes, which then served as conduits for water and sediment expulsion from liquefaction, de-watering, or a combination of the two processes. The amount of upward force needed to expell material through pre-existing holes by de-watering or liquefaction would be less than that required to create new holes. Furthermore, stepping on the plywood board did not create any new holes; water and sediment exited only through existing holes. Release of reservoir waters commenced at approximately 7:30 a.m.; the earthquake occurred 12 minutes later, at 7:42 a.m. According to Al Pendleton, draining of the reservoir lasted about two hours. At the time of the earthquake, only those sediments in the upper reaches of the reservoir would have been exposed. This may explain why there appeared to be more sediment cones on bars in the upper reaches of the reservoir; the cones were less likely to remain preserved submerged in water.

As previously mentioned, some of the exposed sediments, particularly those closest to the dam, showed evidence of cracking and slumping. I observed most of the cracks and shallow slope failures in the recently exposed bars immediately adjacent to the river channel. Although these features were likely caused by changes in pore-water pressures in the sediments resulting from draw-down of the reservoir, liquefaction may also have contributed to the formation of these features. Because of this and possible expulsion of sediment from holes beneath the reservoir, it is possible that liquefaction contributed to discoloration of the water in the Jordan River.

Base Map from MIDVALE
U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location map.

Project: Geologic reconnaissance of a landslide affecting Truman Drive, Santa Clara, Washington County, Utah.			Requesting Agency: Kimball N. Wallace, Santa Clara City Engineer
By: Mike Lowe	Date: 5-26-92	County: Washington County	Job No: 92-08 (GH-4)
USGS Quadrangle: Santa Clara (79)			

INTRODUCTION

In response to a request to the Utah Geological Survey by Kimball N. Wallace, Santa Clara City Engineer, I conducted a geologic reconnaissance from May 18-20, 1992, of a landslide on the north side of Truman Drive, Santa Clara, Utah. The landslide is in the NW1/4 section 16, T. 42 S., R. 16 W., Salt Lake Base Line and Meridian (figure 1). The landslide, which has been moving since early May, 1992, is along a south-facing bluff at the southern margin of the Santa Clara Bench, adjacent to the left flank of another landslide which occurred in 1981 (Lund, 1981). Truman Drive has periodically been partially blocked by the toe of the 1992 landslide since movement began (Kimball N. Wallace, verbal communication, May 18, 1992), and a chain-link fence and utility lines in the back yard of the Willard residence at the top of the bluff were undermined by the main scarp of the landslide on May 17, 1992.

The purpose of the investigation was to assess the stability, hazard potential, and potential causes of the landslide. The scope of work included a review of pertinent literature, and six visits to the landslide. Kimball N. Wallace (Santa Clara City Engineer), David R. Black (Kleinfelder), Guy Bird (Mayor of Santa Clara City), and Karen Willard and Marge Gillespie (owners of lots being affected by the landslide) were present during portions of the field reconnaissance.

GEOLOGY AND HISTORY OF LANDSLIDING

The direction of movement of the landslide is almost due south on the 80-foot high south-facing bluff that forms the southern margin of the Santa Clara Bench. The bluff was formed by downcutting of the Santa Clara River. Three geologic units are exposed in the side of the bluff at the landslide. From youngest to oldest (top to bottom) these units are: (1) loose, reddish-brown, silty sand of probable eolian origin (Lund, 1981) which is generally less than 3 feet (1 m) thick; (2) moderately to well-cemented fluvial sand and gravel (Christenson and Deen, 1983) of variable thickness; and (3) northeast-dipping, purple-gray shale of the Petrified Forest Member of the Triassic Chinle Formation (Christenson and Deen, 1983). The contact between the Quaternary sand and gravel and the shale was not exposed, but Lund (1981) estimates that the shale comprises approximately the lower 2/3 of the bluff.

Shallow ground water occurs at many locations along the bluff and has caused soil-foundation problems and basement flooding in the vicinity of the landslide (Guy Bird, verbal communication, May 19, 1992). Following the landslide, Kleinfelder drilled in the back yard of the Willard residence at the top of the bluff about 15 feet north of the main scarp of the landslide and encountered water at 14 feet below the ground surface (Guy Bird, verbal communication, May 19, 1992). The occurrence of perched shallow ground water is evidently due to the low permeability of the Chinle Formation which prevents downward percolation of the water.

The bluff along the south and east margins of the Santa Clara Bench has been the site of previous landsliding. In 1981, a landslide which "disrupted Truman Drive causing the pavement to drop and buckle in several places" occurred adjacent to the right (west) flank of the 1992 Truman Drive landslide (Lund, 1981). A smaller landslide occurred on the bluff about 30 feet east of the left flank of the 1992 Truman Drive landslide "a few years ago" (Marge Gillespie, verbal communication, May 19, 1992). Landsliding has also occurred in recent years about a mile to the east along the east-facing bluff of the Santa Clara Bench above the Santa Clara Little League baseball diamond (Guy Bird, verbal communication, May 19, 1992).

LANDSLIDE DESCRIPTION

The Truman Drive landslide is a rotational slump and earthflow (figure 2) measuring approximately 200 feet in length and 70 (near the main scarp) to 100 feet (near the toe) in width. The main scarp is approximately 8-10 feet high and the toe of the landslide is up to 10-15 feet thick. The landslide deposit contained several minor scarps with vertical offsets up to 3 feet. Transverse cracks were present along the right flank of the landslide. The landslide was still moving at a very slow, almost imperceptible, rate at the time of my last reconnaissance at 2:00 p.m. on May 20, 1992.

Most of the material in the landslide deposit is eolian sand and fluvial sand and gravel, but I observed material derived from the Chinle Formation along the right flank of the landslide. The surface of the landslide deposit was for the most part dry, but a seep issuing approximately 2 gallons of water per minute occurred at the toe of the landslide along the right flank. Prior to the landsliding a seep issued about the same amount of water from an area near the position of the left flank of the landslide (Kimball N. Wallace, verbal communication, May 18, 1992). This seep dried up after the landslide occurred and the new seep appeared along the right flank of the landslide.

LANDSLIDE CAUSES

The 1992 Truman Drive landslide most likely occurred as a result of a combination of conditions. The main factors contributing to the failure include: (1) the steep pre-failure slope of the bluff, (2) the presence of the relatively impermeable, weak, weathered shale which underlies most of the bluff slope, (3) removal and steepening of parts of the slope during the widening of Truman Drive, and (4) water perched on the shale unit which is saturating slope materials along the bluff.

Although none of these factors can be identified as the principle cause of the landsliding, the temporal relationship between the landslide and the cutting of the slope during widening of Truman Drive indicates that cutting the slope was likely a factor. Lund (1981) recognized the sensitivity of the slopes along Truman Drive to modification and recommended that "major improvements to Truman Drive (paving, widening, etc.) or the installation of underground utilities along the roadway should be preceded by a thorough engineering study so that further slope stability problems may be either avoided or properly mitigated."

Although ground water has exited the bluff slope at this location for as long as residents can remember (Kimball N. Wallace, verbal communication, May 18, 1992), water was probably another major factor in the occurrence of the landsliding. Water increases the potential for landsliding because it increases the weight of the landslide material upon which gravitational forces are acting, and it increases pore pressures in the slope material which decreases shear resistance. The water is probably from multiple sources. Above-normal precipitation occurred during the spring of 1992 in the Washington County area and soil-foundation problems related to shallow ground water are occurring in Santa Clara in areas underlain by the Chile Formation. As development of the Santa Clara Bench continues, more and more lawn water is being added to the ground-water system. Also, two culinary water pipelines are located up-gradient from the landslide and one or both may be leaking (Guy Bird, verbal communication, May 19, 1992). Landsliding and soil-foundation problems related to shallow ground water will probably continue to occur as development continues on the Santa Clara Bench.

HAZARD POTENTIAL AND RECOMMENDATIONS

Although movement on the 1992 Truman Drive landslide was still occurring as of 2:00 p.m. on May 20, 1992, it is unlikely that landsliding will reach the Willard home north of the landslide. It is also unlikely that the landslide will reach homes at the base of the bluff. It is possible that the landslide will continue to impact Truman Drive. If this occurs, removal of the toe of the landslide to keep the road clear may cause further landsliding.

Measures can be taken to stabilize the landslide, and it is my understanding that Santa Clara City has contracted with Kleinfelder to identify these measures. It is most likely that they will involve a combination of buttressing the toe of the landslide with granular material, dewatering the landslide, and terracing or grading of the landslide. Terracing or grading, especially near the main scarp, will help prevent the main scarp from retreating farther upslope and further affecting residential lots at the top of the slope.

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Varnes, D.J., 1978, Slope movement types and processes, in Schuster, R.L., and Krizek, R.S., editors, Landslides, analysis and control: Washington D.C., National Academy of Sciences, Transportation Research Board, Special Report 176, p. 12-33.

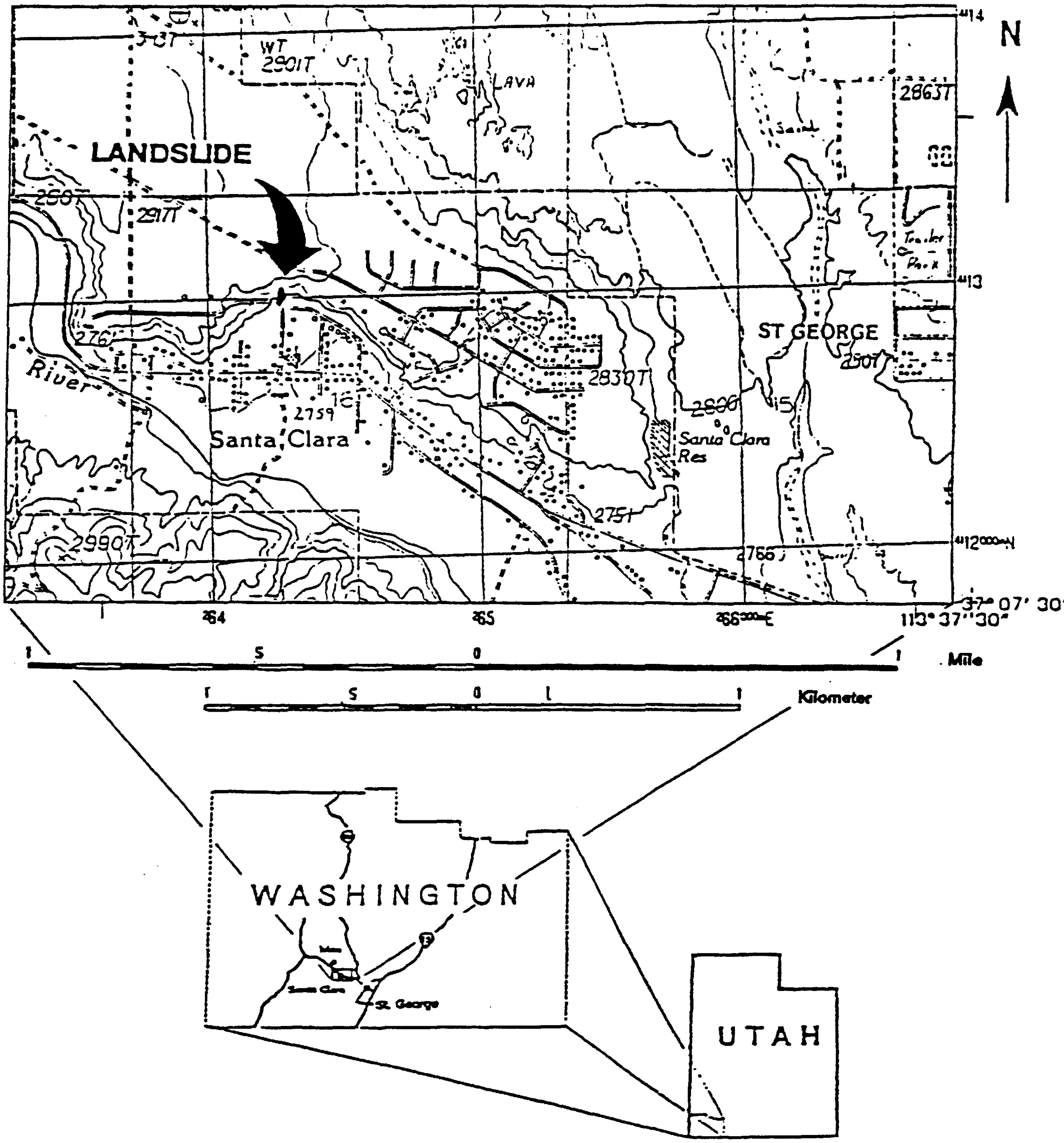


Figure 1. Location map of 1992 Truman Drive landslide.

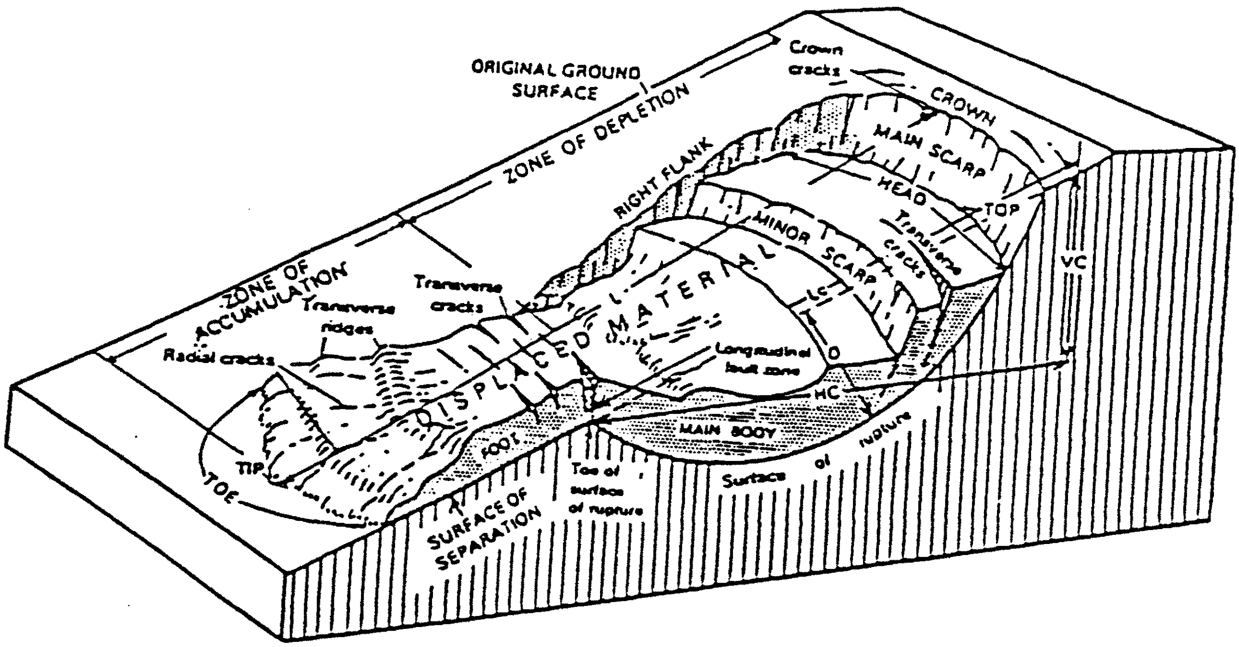


Figure 2. Block diagram of features commonly associated with a rotational slump and earthflow (adapted from Varnes, 1978).

Project: Debris-flow and debris-flood potential in the Big Hollow burn area north of Alpine, Utah County, Utah			Requesting Agency: Emergency Response
By: Barry J. Solomon	Date: 7-9-92	County: Utah County	Job No: 92-12 (GH-5)
USGS Quadrangle: Lehi (1130)			

INTRODUCTION

On June 29, 1992, a wildfire burned approximately 600 acres (240 ha) of vegetation near Big Hollow, about one mile (2 km) north of Alpine. No houses were involved and no lives were lost. Removal of vegetative cover, however, results in increased runuff and may significantly increase erosion during periods of rain or snowmelt. A site investigation was conducted on July 2, 1992, to determine whether any residents or structures are at risk from the increased potential for erosion and possible resultant debris-flow and debris-flood hazards.

The burn area consists of a northeast-trending ridge bounded on the west by Fort Canyon and east by Dry Creek (attachment 1). The northeastern part of the ridge is underlain by the Oquirrh Formation of Permian to Pennsylvanian age, which consists primarily of sandy limestone in the burn area (Bullock, 1958). The remainder of the ridge is underlain by the Salt Lake Formation of Pliocene and Miocene age, which consists of sandstone and conglomerate in the burn area. Unconsolidated middle to upper Pleistocene alluvial, lacustrine, and glacial deposits surround the ridge (Machette, 1989). The only material of Holocene age within the burn area is a small alluvial-fan deposit about one-quarter mile (0.4 km) southwest of the mouth of Big Hollow (attachment 1). Holocene stream alluvium occurs in the channels of Fort and Dry Creeks, west and east of the ridge, but is not within the burn area.

Natural vegetative cover within the burn area consists primarily of grass and scrub oak, with lesser amounts of sagebrush, cactus, and other unidentified varieties. Not all of the vegetation within the boundaries of the fire was burned, and plant roots were generally preserved. Significant stands of relatively undamaged vegetation were present in Big Hollow and in the small unnamed drainage from which the Holocene alluvial-fan deposit, noted above, was derived. Soils on hill slopes are gravel to boulder sandy loam and loam, with a significant coarser residual component derived from underlying sandstone and sandy limestone. Except where bedrock is overlain by Pleistocene and younger deposits on the ridge foothills, soils are thin and bedrock is either visible in outcrop or is evident at the surface in colluvium.

The potential for debris-flow and debris-flood damage to houses, which are scattered around the western and southeastern rim of the ridge, appears slight. Only one Holocene alluvial fan was identified in this reconnaissance and in previous mapping (Machette, 1989), and its surface remains vegetated even after the fire. There are no houses on the fan surface, but houses are present on the east and south margin of the fan toe. Big Hollow is the only other significant drainage within the burn area, and relatively unburned scrub oak remains within the drainage. There is also a well-defined alluvial channel cut in Big Hollow which is not filled with debris from past upland erosion. No alluvial-fan deposits were noted at its mouth, which suggests that sediment derived from slopes is transported in the channel and is directed to uninhabited areas of Dry Creek to the southeast. There are few gullies and side channels to contribute flow into Big Hollow. Soil cover in the burn area is generally shallow which minimizes the potential for significant source material to erode and move downslope, and the high percentage of rock fragments help armor the soil against erosion.

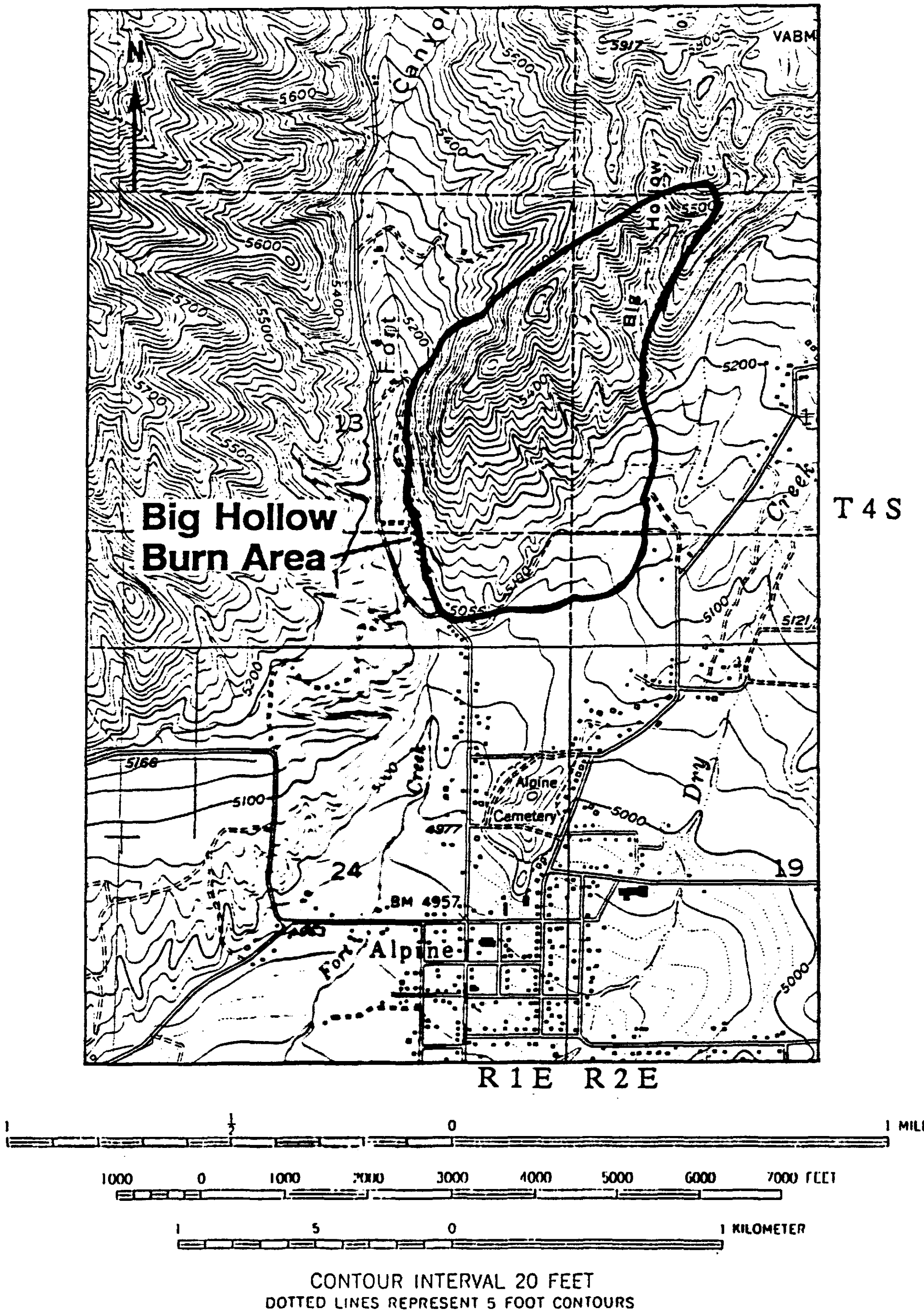
Denudation of hill slopes by the fire may increase runoff until vegetation has been reestablished, and post-fire runoff will carry considerable ashy debris, but local geology suggests that increased runoff and debris will be contained within channels. There appears to be little potential for a significant increase in the debris-flow and debris-flood hazard to local residents resulting from this fire.

REFERENCES CITED

Bullock, R.L., 1958, The geology of the Lehi quadrangle, Utah: Brigham Young University Research Studies, Geology series, v. 5, no. 3, 59 p.

Machette, M.N., 1989, Preliminary 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 Field Studies Map MF-2109, scale 1:50,000.

Base Map from LEHI U.S.G.S.
7-1/2' topographic quadrangle



Attachment 1. Location map.

Project: Aerial reconnaissance of fracture in cliffs west of Castle Gate, Price Canyon, Carbon County			Requesting Agency: Emergency Response
By: Mike Lowe	Date: 7/27/1992	County: Carbon	Job No: 92-14 (GH-6)
USGS Quadrangle: Standardville (877)			

INTRODUCTION

On July 21, 1992, I participated in an aerial reconnaissance of a fracture in cliffs in Price Canyon west of Castle Gate, Carbon County (NW¼ SE¼ section 35, T. 12 S., R. 9 E., SLBM; attachment 1). The fracture was brought to the Utah Geological Survey's attention on July 20, 1992, by Mike Royce, Chief Pilot, Utah Department of Public Safety Aero Bureau, who noticed the fracture while flying down Price Canyon. The purpose of the aerial reconnaissance was to assess potential slope-failure hazards associated with the fracture. The scope of investigation consisted of the aerial reconnaissance in a light airplane piloted by Mr. Royce, an examination of 1963 1:20,000-scale aerial photographs, and computer simulation of possible rock-fall runout paths. Albert Spensko and Archie Hamilton, Utah Department of Transportation District Four Office, also participated in the aerial reconnaissance.

The fracture, which is readily visible and appears quite fresh from the air, is oriented north-south and crosses sandstone cliffs which form the point of a ridge. The fracture is vertical and is visible on the top and on both sides of the ridge point. It was not possible to estimate the width of the fracture from the air. A lineament, presumably the fracture, is visible at this location on 1963 1:20,000-scale aerial photographs of the area, but I could not determine the freshness or width of the fracture. Thus, the current apparent freshness of the fracture may indicate recent opening of a pre-existing crack. Doelling (1972) indicates that the mined-out portion of a coal mine is located beneath the ground surface below the crack, and subsidence in this mine is one possible cause of the widening of the fracture, if widening has indeed occurred.

Doelling (1972) maps the sandstone cliff as Castlegate Sandstone of the Cretaceous Mesaverde Group. The Castlegate Sandstone is overlain by less-resistant sandstone, shaly sandstone, and shale of the Price River Formation, and is underlain by less-resistant sandstone, shale, and coal of the Blackhawk Formation, which are also units of the Cretaceous Mesaverde Group (Hintze, 1988). Several fresh scars were visible on the cliff face indicating recent mass wasting. Other fractures, which did not appear as wide or fresh, are visible in other cliffs in the area, where slopes are covered with sandstone blocks which indicate that rock falls, topples, and slides are the predominant form of mass wasting.

If the fracture widens and the ridge point fails as a rock slide, topple, or fall, the principle risk is to U.S. Highway 6 to the east in Price Canyon. The Denver and Rio Grande Railroad tracks are located across the Price River farther to the east. The fractured point is approximately 1,200 feet from the highway for rocks rolling into a small canyon on the north side of the point, and approximately 2,000 feet from the highway for rocks rolling into a larger canyon on the south side of the point (attachment 1). The approximate elevation of the highway is 6150 feet. The fractured ridge point has an elevation of approximately 7200 feet.

The Colorado Rock-fall Simulation Program (Pfeifer and Higgins, 1988) was used to assess the potential for rock falls from the fractured ridge point reaching the highway. Three potential rock-fall paths (attachment 1) were chosen for the simulation and slope profiles were constructed from U.S. Geological Survey 7.5-minute topographic quadrangle maps (Standardville and Helper). Values for rock-fall clast and slope characteristics (rock shape, surface roughness, and tangential and normal coefficients) were estimated based on observations from the air. Rock radii chosen for the simulations were 5 and 10 feet. Boulders of this size were observed on mountain slopes in the area. For path 1 (attachment 1), no rocks with a radius of 5 or 10 feet rolled to the highway. For path 2, the 5-foot-radius boulders generally did not reach the highway but the 10-foot-radius boulders did. For path 3, both 5- and 10-foot-radius boulders reached the highway. Based on the computer simulation, it appears that large boulders could reach U.S. Highway 6 if the fractured ridge point fails, either as a large slide or as a continuing series of individual rock falls and topples.

At this time, the likelihood and probable mechanism of failure, and need for hazard-reduction measures, is undetermined. Such a determination will require ground studies such as monitoring of crack width, measuring of fracture spacing in the sandstone cliff, and more accurate modeling of rock-fall runout. Christian Rohrer, Utah Department of Natural Resources Division of Oil, Gas, and Mining, has been notified of the possible mine subsidence, and will perform field investigation to further evaluate this possibility (Christian Rohrer, verbal communication, July 29, 1992). Mr. Spensko (verbal communication, July 29, 1992) indicates that the crack is visible from Highway 6 and that personnel from the Utah Department of Transportation District Four Office will visually monitor the cliff and fracture from the highway. Mr. Royce (verbal communication, July 29, 1992) indicates that he and other Department of Public Safety Aero Bureau pilots will monitor the cliff and fracture from the air when flying over the area. If any activity is noted, further study is warranted.

REFERENCES CITED

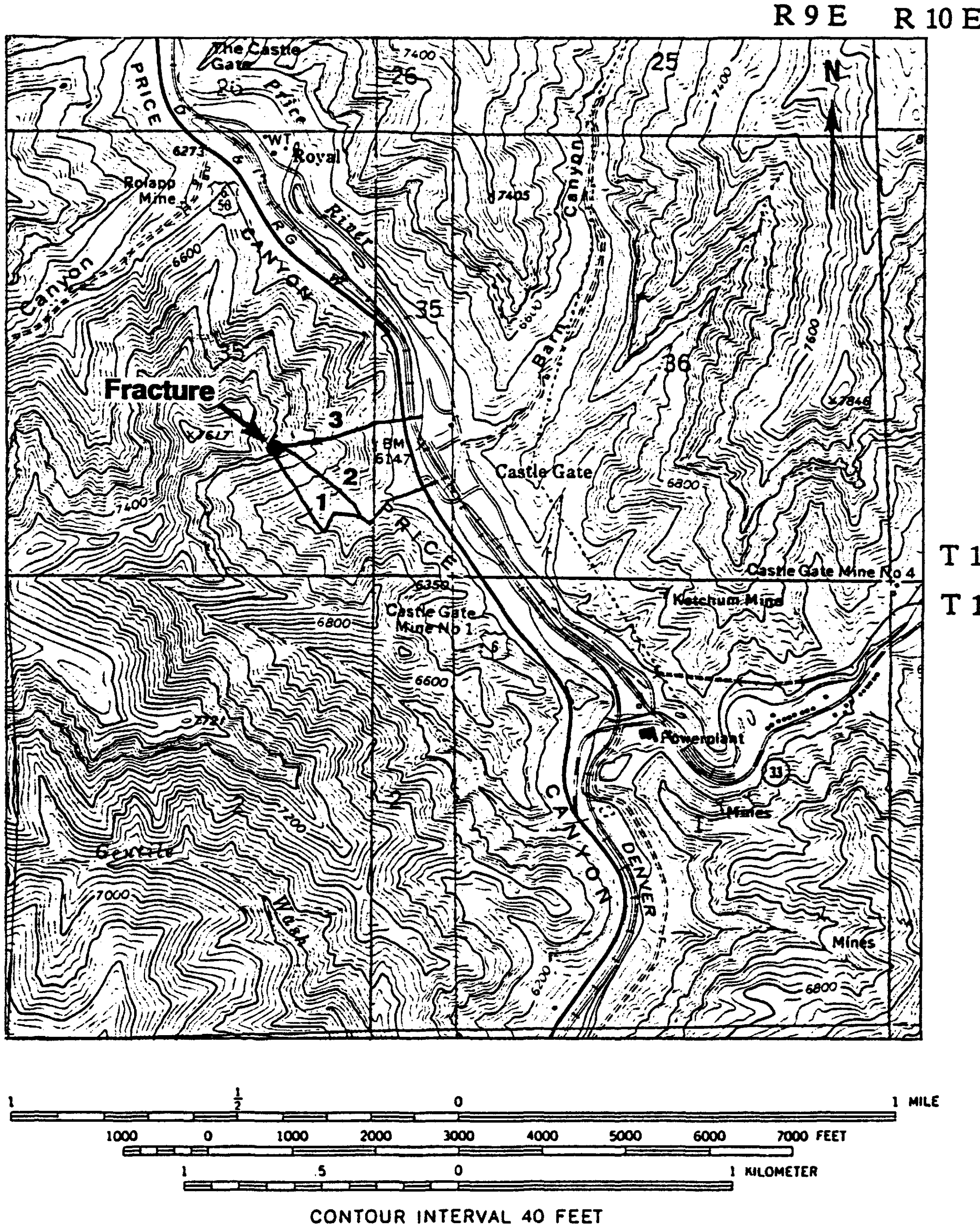
Doelling, H.H., 1972, Central Utah coal fields--Sevier-Sanpete, Wasatch Plateau, Book Cliffs and Emery: Utah Geological Survey Monograph Series No. 3, 571 p.

Hintze, L.F., 1988, Geologic history of Utah, a field guide to Utah's rocks: Brigham Young University Geology Series Special Publication 7, 202 p.

Pfeiffer, T.J., and Higgins, J.D., 1988, Colorado rock-fall simulation program users manual: Final report prepared for the Colorado Department of Highways, 107 p.

Attachment 1. Job No. 92-14

Base Map from STANDARDVILLE and HELPER, U.S.G.S. 7-1/2' topographic quadrangles



Attachment 1. Location map showing potential rock-fall runout paths 1, 2, and 3.

Project: Debris-flow and debris-flood potential in the Mahogany Mountain burn area north of Pleasant Grove, Utah County, Utah			Requesting Agency: Emergency Response
By: Barry J. Solomon	Date: 8-7-92	County: Utah	Job No: 92-15 (GH-7)
USGS Quadrangle: Timpanogos Cave (1129)			

INTRODUCTION

On July 29, 1992, a wildfire burned approximately 790 acres (320 ha) of vegetation on the southwest slope of Mahogany Mountain, about two miles (3 km) north of Pleasant Grove. No houses were involved and no lives were lost. Removal of vegetative cover, however, results in increased runoff and may significantly increase erosion during periods of rain or snowmelt. A site investigation was conducted on July 30, 1992, to determine whether any residents or structures are at risk from the increased potential for erosion and possible resultant debris-flow and debris-flood hazards.

The burn area consists of a southwest-facing slope bounded on the west by the Provo Reservoir Canal, north by Heisetts Hollow, east by the crest of Mahogany Mountain, and south by Grove Creek (attachment 1). The geology of the burn area includes two deposits which underlie distinctive topographic terrains, separated by the Wasatch fault zone. The steep, upper slopes of Mahogany Mountain are underlain by the Upper Mississippian Great Blue Limestone (Baker and Crittenden, 1961). This unit includes limestone and shaly limestone, with basal black shale. The mountain foothills in the southwestern burn area are underlain by unconsolidated fan alluvium and debris-flow deposits (Machette, 1989). The fan alluvium is of upper and middle Pleistocene age, while the debris-flow deposits are uppermost Pleistocene to Holocene in age.

Natural vegetative cover within the burn area consists primarily of grass and scrub oak on the northern margin; grass on the steep, upper mountain slopes; and grass, sagebrush, and shrubs elsewhere. Not all of the vegetation within the boundaries of the fire was burned, and plant roots were generally preserved. Significant stands of relatively undamaged vegetation are present in foothill drainages, and the area underlain by upper Pleistocene to Holocene debris-flow deposits was only lightly burned. A heavily burned area is present to the southeast. Soils on hill slopes are gravel to boulder sandy loam and loam, with a significant coarser residual component derived from underlying limestone. Except where bedrock is overlain by Pleistocene and younger deposits in the foothills, soils are thin and bedrock is either visible in outcrop or is evident at the surface in colluvium.

There are no houses to the east of the Provo Reservoir Canal, and the potential for debris-flow and debris-flood damage to houses on the west side of the canal appears slight. Soil cover in the areas of heaviest burn is shallow, which minimizes the potential for significant source material to erode and move downslope. The high percentage of rock fragments help armor the soil against erosion, and relatively unburned vegetation remains within drainages. Alluvial channels are not filled with debris from past upland erosion, and any sediment derived from the range-front is transported to the canal and directed northward. There are few gullies and side channels to contribute flow into the principal drainages.

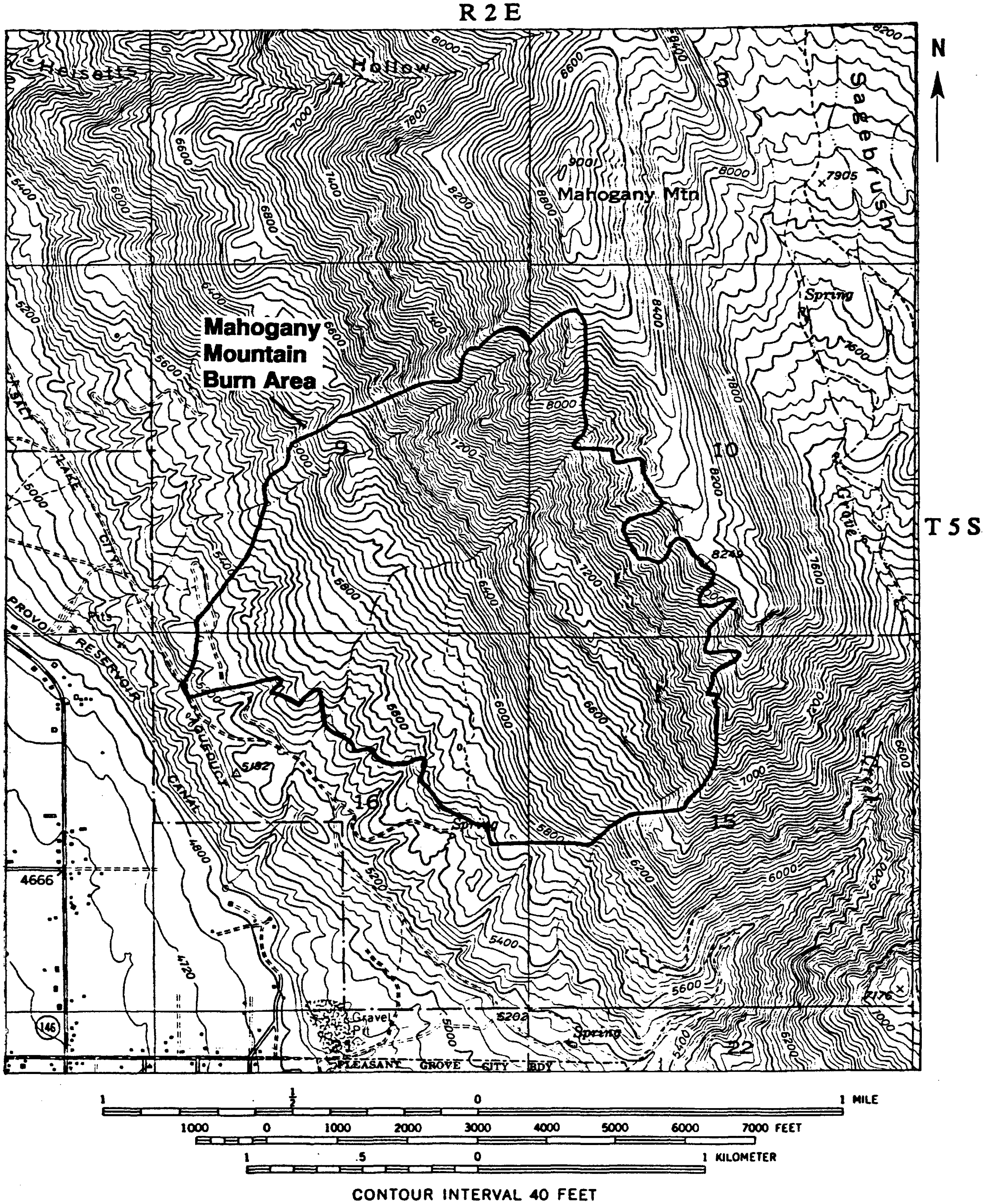
Denudation of hill slopes by the fire may increase runoff until vegetation has been reestablished, and post-fire runoff will carry considerable ashy debris into the Provo Reservoir Canal. However, local geology suggests that increased runoff and debris will be contained within channels. There appears to be little potential for a significant increase in the debris-flow and debris-flood hazard to local residents resulting from this fire.

REFERENCES CITED

Baker, A.A., and Crittenden, M.D., Jr., 1961, Geology of the Timpanogos Cave quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-132, scale 1:24,000.

Machette, M.N., 1989, Preliminary 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 Field Studies Map MF-2109, scale 1:50,000.

Base Map from TIMPANOGOS CAVE, U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location map.

Project: Investigation of geologic effects associated with the September 2, 1992, St. George earthquake, Washington County, Utah			Requesting Agency: Emergency Response
By: Bill D. Black William E. Mulvey Mike Lowe Barry J. Solomon	Date: 9-24-92	County: Washington	Job No: 92-17 (GH-8)
USGS Quadrangle: Springdale West (74), Springdale East (73), St. George (37), Washington Dome (36), Harrisburg Junction (77)			

INTRODUCTION

A Richter magnitude (M_L) 5.9 earthquake occurred at 4:26 a.m. (MDT) on September 2, 1992. The epicenter was about 5 miles (8 km) southeast of St. George, Washington County, Utah (attachment 1; Arabasz, Pechmann, and Nava, 1992). The Utah Geological Survey (UGS) conducted a field investigation for geologic effects associated with the earthquake, and the purpose of this report is to document those investigations. The UGS inspected a landslide in the Town of Springdale, searched the epicentral area for evidence of rock falls and liquefaction, searched the Washington and Hurricane faults for evidence of surface fault rupture, and observed changes to Dixie hot springs resulting from the earthquake (attachment 1).

Damage resulting from the St. George earthquake was caused primarily by ground shaking and slope failures. Although there were no deaths or serious injuries, the earthquake caused damage in communities within about 35 miles (56 km) of the epicenter (Arabasz, Pechmann, and Nava, 1992). A destructive landslide in the Town of Springdale, hereafter referred to as the Balanced Rock Hills landslide, destroyed three homes and forced the evacuation of condominiums and businesses in the path of the slide (attachment 1). Early reports also indicated structural damage to buildings in Hurricane and New Harmony, and minor damage in St. George and other communities (Arabasz, Pechmann, and Nava, 1992).

In this report, measurements and distances are generally given in english units followed by metric units in parentheses. However, where measurements were reported in metric units or equations required metric units, these units are given first followed by english equivalents in parentheses.

UGS RESPONSE

On September 2, 1992, the UGS responded to the scene of the Balanced Rock Hills landslide in Springdale. Barry J. Solomon arrived at the landslide at approximately 9:00 a.m., where he inspected: (1) damage to and blockage of SR 9; (2) destroyed homes and damaged roads in the Balanced Rock Hills subdivision; and (3) the main scarp and fissures in the landslide. He advised emergency response personnel and local government officials at the scene regarding the hazard posed by the landslide. Mike Lowe and Bill Black arrived at approximately 4 pm and began mapping the landslide. On the evening of September 2, we advised Washington County officials of the possibility of continued movement of the slide and the risk to nearby buildings and their occupants.

On September 3, Barry J. Solomon met with U.S. Geological Survey and Utah Department of Transportation geologists, participated in an aerial reconnaissance of the Balanced Rock Hills landslide, and then completed mapping the landslide while Mike Lowe and Bill Black searched the area around the epicenter for effects of the earthquake. The search included examining: (1) the Washington and Hurricane faults for evidence of surface fault rupture; (2) rock falls in the steep cliffs along SR 9, and along the Red Hills and West Black Ridge in St. George; and (3) two historical landslides in Santa Clara for any evidence of renewed movement. On September 2 and 3, Mike Lowe and Bill Black also stopped in at the city/town offices of Hurricane, St. George, and Santa Clara to offer assistance and document earthquake effects. Along with Barry Solomon, they also coordinated with Fred May of the Utah Division of Comprehensive Emergency Management to assess the risk from the landslide.

On September 9-10, William E. Mulvey and Mike Lowe made a further reconnaissance of the Balanced Rock Hills landslide, and examined evidence of liquefaction along the Virgin River east of St. George, which was initially reported by Matthew Mabey of the Oregon Department of Geology and Mineral Industries. Small lateral spreads and sand blows caused by liquefaction were observed along a 15 mile (24 km) stretch of the Virgin River, from one mile (2 km) south of the town of Bloomington upriver to the St. George and Washington Canal diversion structure. The features were mapped and measured to determine amounts of movement on liquefaction-induced lateral spreads. On September 11, William Mulvey and Mike Lowe performed further reconnaissance of the Hurricane fault, looking for evidence of surface fault rupture.

On September 15-16, Bill Black assisted the Town of Springdale in establishing eleven survey-monitoring stations on the Balanced Rock Hills landslide and searched for additional effects of the earthquake. The search included further inspecting the Hurricane fault for evidence of surface fault rupture and examining evidence of liquefaction along the Virgin River east of the St. George and Washington Canal diversion dam. Rock falls and changes to the springs at Dixie Hot Springs were also observed.

A Modified Mercalli Intensity (MMI) survey was placed in local newspapers (Spectrum, Deseret News) following the earthquake to conduct a detailed evaluation of ground-shaking effects. Results will be used along with post-office survey results from the U.S.

Geological Survey National Earthquake Information Center to determine maximum MMIs and produce an isoseismal map.

GEOLOGIC EFFECTS

The principal earthquake hazards in southwestern Utah are ground shaking, surface fault rupture, tectonic subsidence, liquefaction, slope failure, and flooding (Christenson and Nava, 1992). The St. George area is at the southern end of the Intermountain Seismic Belt (ISB), a generally north-south trending zone of seismic activity that bisects the state. The largest prior historical earthquake in the St. George area was an estimated magnitude 6 earthquake that occurred on November 17, 1902 in Pine Valley (Arabasz, Pechmann, and Nava, 1992). Earthquake hazards associated with the St. George earthquake were ground shaking, slope failures, and liquefaction. There were no reports of flooding due to dam or canal failure, ground-water discharge, seiches, or tectonic subsidence.

Ground Shaking

Ground shaking is the most widespread and damaging of the earthquake hazards. All of southwestern Utah is in UBC seismic zone 2B, the zone in which design is based on peak horizontal ground accelerations of 0.1 to 0.2 g on bedrock with a 10% chance of being exceeded in 50 years. Maximum peak horizontal ground accelerations (PHA) during the earthquake were calculated using attenuation relations of Campbell (1987) and assuming a dipping fault and sediment depth less than 10 meters (30 ft). The maximum calculated PHA for St. George is 0.21 g (Susan Olig, verbal communication, September 11, 1992). Ground shaking probably triggered the landslides in Springdale (calculated maximum PHA of 0.068 g), 28 miles (45 km) northeast of the epicenter, and was responsible for the numerous rock falls. Ground shaking also caused liquefaction along the Virgin River and property damage in communities within 35 miles (56 km) of the epicenter. Further study of ground-shaking effects will be undertaken as MMI survey results are obtained and compiled.

Surface Fault Rupture

Although no surface-faulting earthquakes have occurred in the St. George area in historical time, two faults in the vicinity of the epicenter have evidence of Quaternary movement: (1) the Washington fault, and (2) the Hurricane fault (attachment 1). It has been estimated that up to 1 foot (0.3 m) of offset may accompany a magnitude 6.0 earthquake on these faults, with an expected recurrence interval on each fault of 200-300 years (Earth Science Associates, 1982). Both faults are capable of generating earthquakes of magnitude 7.0 to 7.5 (Earth Science Associates, 1982). Preliminary seismological data indicate that the probable source of the St. George earthquake was the Hurricane fault (Arabasz, Pechmann, and Nava, 1992).

The UGS examined the Washington and Hurricane faults for surface fault rupture following the earthquake. The investigation was conducted by driving and walking the fault traces. The Washington fault was followed for approximately 5 miles (8 km) south and 2 miles (3 km) north of the epicenter (attachment 1). The Hurricane fault was followed south approximately 12 miles (18 km) from where it crosses the Virgin River to the Utah-Arizona border (attachment 1). No evidence of surface cracks or offset was found on either fault.

Slope Failures

Balanced Rock Hills Landslide

The most damaging result of the St. George earthquake was the Balanced Rock Hills landslide in Springdale, which destroyed two water tanks (one of which was abandoned), several storage buildings, and three homes in the Balanced Rock Hills subdivision, and ruptured buried and above-ground utilities in the subdivision and along SR 9 (attachments 1 and 2). A smaller landslide west of the Balanced Rock Hills landslide, referred to as the Paradise Road landslide (attachment 2), was also triggered by the earthquake but caused no damage. The Balanced Rock Hills landslide blocked SR 9 and forced temporary closure of the west gate of Zion National Park.

The Balanced Rock Hills landslide is a complex coherent slide involving both rotational and translational elements. It measures roughly 1625 feet (495 m) from main scarp to the toe, with a width of about 3595 feet (1096 m). The slide plane does not appear to daylight in drainages which dissect the landslide. Using a calculated surface area of 4.4 million square feet (400,000 m^2) and an estimated average depth of 110 feet (34 m), the total volume of material involved is about 18 million cubic yards (14 million m^3). The average gradient of the slope prior to the slide was 30 percent. The landslide has a clearly-defined main scarp, as high as 80 feet (24 m) in places, numerous smaller secondary scarps, and fissures up to 30 feet (9 m) deep (attachment 3). Secondary scarps antithetic to the main scarp also formed a graben (downdropped area) on the northeastern edge of the landslide (attachment 3). These scarps and fissures seem to indicate that the landslide moved in at least three, and possibly several, coherent pieces.

Three geologic units are mapped in the bluffs north of Springdale (Cook, 1960) (attachment 4): (1) the Jurassic-age Kayenta Formation, a light-gray to light-brown siltstone, pale reddish-brown silty mudstone, and mottled dark reddish-brown mudstone (Averitt, 1962); (2) the Triassic-age Moenave Formation, which consists of an upper massive reddish-brown sandstone that weathers into prominent ledges (Springdale Sandstone Member) and a lower reddish-orange lenticular sandstone (Dinosaur Canyon Member) (Harshbarger and others, 1957); and (3) the Triassic-age Chinle Formation (Petrified Forest Member), a structureless claystone, clayey siltstone, and cross-bedded clayey sandstone with color ranging from light greenish-gray to grayish purple (Stewart and others, 1972).

The Balanced Rock Hills landslide involved the lower Dinosaur Canyon Member of the Moenave Formation and the Petrified Forest Member of the Chinle Formation, and included colluvium containing rock-fall boulders derived from the Kayenta Formation and Springdale Sandstone Member of the Moenave Formation. Although the Moenave Formation is not known to be susceptible to landsliding, the underlying Petrified Forest Member of the Chinle Formation contains abundant clay and is susceptible to landsliding; a significant number of deep-seated landslides occur in the Petrified Forest Member in Utah (Harty, 1991). The basal slide plane is likely within the Petrified Forest Member, and numerous older landslides in this unit are present in the Springdale area (Harty, 1990). A geologic reconnaissance of the Southern Utah Bicentennial Amphitheater, in Black's Canyon west of the Balanced Rock Hills landslide (attachment 2), also noted potential slope instability hazards in this unit (Kaliser, 1975).

Previous studies have investigated landsliding in the Springdale area and noted a correlation with precipitation. The Balanced Rock Hills landslide first moved in the late 1960's (Jim Fraley, verbal communication, September 15, 1992). Kaliser (1975) cites a verbal communication with Wayne Hamilton, a geologist with Zion National Park, who indicated that the hill on which the Springdale water tank rests in the Balanced Rock Hills subdivision was differentially moving on the order of two to three inches (5-8 cm) per year. Hamilton (1992) also noted a correlation between movement of the landslide and precipitation in a study from August, 1974, to June, 1975. During this period, there was 10 inches (25 cm) of precipitation and 1.3 inches (3.3 cm) of movement on the landslide (Hamilton, 1992). Another landslide in Springdale in May, 1988, was also attributed to increased precipitation (Harty, 1990). The 1988 landslide occurred following a total of 4.33 inches (11 cm) of precipitation in a 10-day period in April of that year (Harty, 1990).

A combination of long-term marginal stability and earthquake ground shaking is the most likely cause of the landslide. The slide is roughly 28 miles (45 km) from the epicenter of the earthquake; Keefer (1984) predicts a maximum distance of approximately 20 miles (32 km) for coherent landslides to occur from the epicenter of a M_L 5.9 earthquake. However, if failure of a slope is imminent before an earthquake, a landslide could be initiated even by weak ground shaking (Keefer, 1984). Increased precipitation in 1992 may have contributed to instability of the slide. Precipitation is 121 percent of normal for the current water year in the Dixie region (Utah Climate Center, 1992). Weather records from Zion National Park, the closest weather station to Springdale, show only 0.67 inches (1.7 cm) of precipitation between August 15th, 1992, and September 1st, 1992. However, Al Warneke (verbal communication to Gary E. Christenson, September 8, 1992) reported 0.9 inches (2.3 cm) of precipitation in Springdale in 20 minutes on August 25, 1992, causing local flooding along SR 9 near the slide. Other possible sources of water include effluent from septic systems or leaking water lines or tanks in the Balanced Rock Hills subdivision. The role of water from these sources is unclear, particularly in light of the Paradise Road landslide in an undeveloped area lacking any of these potential sources.

Rock Falls

Numerous rock falls were observed along the steep cliffs above SR 9 from Toquerville to Springdale, along the Hurricane Cliffs, and along the Red Hills and West Black Ridge in St. George. In most cases, these rock falls either occurred in uninhabited areas (causing no damage) or fell onto roads and were quickly cleared away by road crews. However, a truck was hit by one boulder and destroyed, and in St. George a boulder crashed through a wall and damaged a compact car (unpublished Utah Division of Comprehensive Emergency Management final field report). In Hurricane, rock falls also caused damage to footpaths and irrigation lines at Pah Tempe resort (Dixie Hot Springs) and blocked an unused section of the Hurricane Canal. Numerous fresh rock-fall scars, probably from rock falls caused by the earthquake, were also noted in cliffs of the Moenkopi Formation along the Hurricane fault near the Arizona Border.

Liquefaction

Liquefaction occurred in alluvium along a 15-mile (24 km) stretch of the Virgin River south of St. George and Washington (nos. 1-16, attachment 5), and at one location 4 miles (6 km) west of Hurricane, Utah (no. 17, attachment 5). Sediments involved were poorly-graded sands, thinly covered at some sites by overbank deposits of silt and clay. Features observed were lateral spreads, sand blows, and caved stream banks. Lateral spreads were present at all sites, and sand blows at all but two sites. The investigation covered the area along the Virgin River from 1 mile (1.6 km) southwest of the wastewater disposal plant south of Bloomington east to Hurricane (attachment 5).

Lateral spreads occurred on flat to gently-sloping (.5-3 degrees) alluvial sands along the modern flood plain of the Virgin River. Most were arcuate shaped, extending 15 to 20 meters (49-65 feet) parallel, and 5 to 8 meters (16-26 feet) perpendicular to the river. The largest extended along the river for 60 meters (196 feet) and perpendicular to the river for 20 meters (65 feet) (no. 5, attachment 5). Lateral spreads were the most common liquefaction feature observed.

Sand blows were small, commonly 1 to 5 centimeters (0.5-3 in) in diameter, and occurred singly, in groups, and along cracks associated with lateral spreads. The largest sand blow was 50 centimeters (20 in) in diameter. Sand blankets ejected from the sand blows were as large as a meter (3 ft) across and those below the Fort Pierce Bridge contained pea-size gravel. This area had recently been disturbed by construction and the liquified material was man-made fill. Sand blows were most numerous where a thin layer (1-2 centimeters [0.5-1 in]) of overbank deposits (silt and clay) covered the sands that liquified.

Data from 17 lateral spread features were used to determine Liquefaction Severity Index (LSI) values in the area affected by the earthquake. The LSI was derived to quantitatively measure the effect of liquefaction due to earthquake ground shaking (Youd and Perkins, 1987) and Mabey and Youd (1989) have applied it to Utah (see equation, table 1). It is an index that measures the maximum lateral ground failure displacement likely to occur in gently-sloping Holocene flood-plain deposits, such as those along the Virgin River. The LSI relates the maximum displacement that is not likely to be exceeded (Mabey and Youd, 1989). In this investigation, the distance from the epicenter was used in the LSI calculation.

Table 1 compares actual measured lateral displacements (column 2, cumulative crack widths) with calculated LSI values (column 4). Values in table 1 indicate that the calculated LSI more accurately predicted the actual displacements at greater distances from the epicenter, but displacements close to the epicenter were generally less than the calculated values. One unusually high value was measured south of St. George (no. 5, table 1) and may relate to thickness of alluvium and amplified affects of ground shaking. This area has the thickest alluvium in the vicinity of St. George (Christenson and Dean, 1983).

OTHER EFFECTS

An additional effect of the St. George earthquake was a change in the hydrology of Dixie (La Verkin) hot springs at Pah Tempe resort, 2 miles (3 km) north of Hurricane, Utah (attachment 1). The springs occur along the Hurricane fault and issue from cavities in the Kaibab limestone and in the stream bed of the Virgin River, where joints and faults of small throw provide outlet for ground water (Gregory, 1950; Mundorff, 1970). The source of heat is probably an abnormally high geothermal gradient that resulted from volcanic activity during Quaternary time (Mundorff, 1970). Combined flow was measured in 1966 at 5206 gpm, with a temperature ranging from 100° to 108° F (Mundorff, 1970).

Following the St. George earthquake, flow from the springs on the south side of the Virgin River decreased dramatically, while flow from the springs in and on the north side of the river tripled and quadrupled (Ken Anderson, verbal communication, September 16, 1992). One spring in Pah Tempe resort, which had been issuing from a cavity in bedrock, was totally dry and warm moist air was blowing out of the cavern. There was also an increase in sulfur from the springs. The Utah Division of Water Resources has been monitoring the springs annually and is investigating the changes.

ACKNOWLEDGEMENTS

The authors wish to thank Denny Davies and Larry Wiese of Zion National Park, who donated a copy of "Sculpturing of Zion" by Wayne Hamilton. Randy Jibson and Ed Harp of the U.S. Geological Survey provided helpful assessments of the Springdale landslide. The Utah Department of Transportation allowed us to participate in their aerial reconnaissance, and Ed Keane (UDOT) provided information on the UDOT's plans regarding SR 9. Valuable information was provided by several people with local experience in the area, including Wayne Hamilton, James Roberts, and Al Warneke. Matthew Mabey (Oregon Department of Geology and Mineral Industries) reported on his reconnaissance of geologic effects, particularly liquefaction, and provided advice regarding interpretations of LSI.

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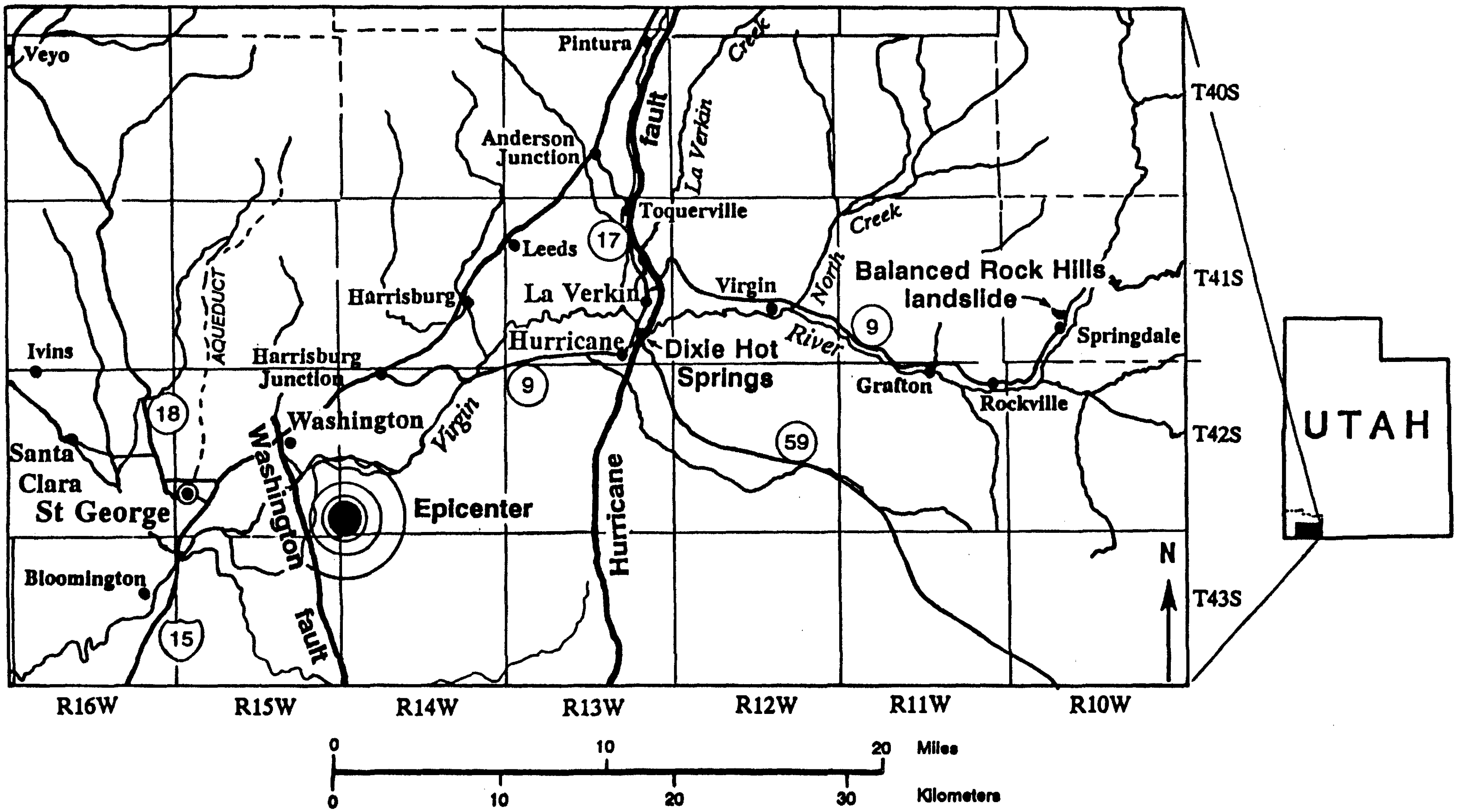
Table 1. Liquefaction Severity Index (LSI) values for the St. George earthquake.

$\log(LSI) = -3.53 - 1.60\log(R) + 0.96M_W$ (See note below.)			
Site (figure 11)	Cumulative crack width in inches	Distance from epicenter in kilometers	Calculated LSI
1	1.4	13	1.4
2	1.5	13	1.4
3	6.4	10	2.2
4	3.7	10	2.2
5	19.4	8	3.1
6	0.9	7	3.9
7	10.6	7	3.9
8	3.5	7	3.9
9	1.3	7	3.9
10	1.8	4	9.5
11	1.8	4	9.5
12	10.0	4	9.5
13	0.3	4	9.5
14	2.1	4	9.5
15	0.4	4	9.5
16	0.7	5	6.7
17	0.1	17	0.9

Note: R is the distance in kilometers from fault surface rupture (in this case, distance from the epicenter was used); M_W is moment magnitude of the earthquake (5.7 for the St. George earthquake).

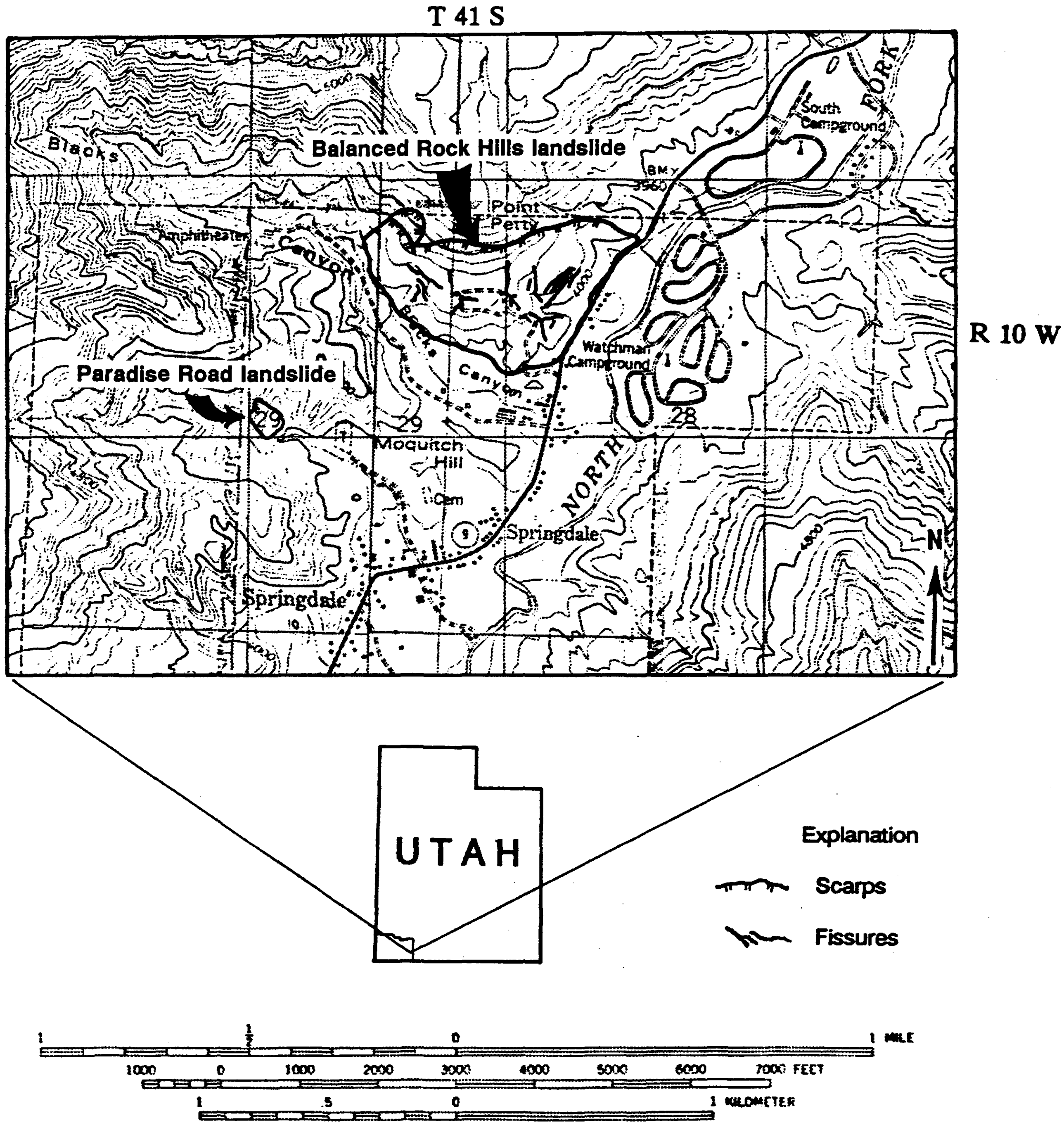
Attachment 1. Job No. 92-17

Base Map from U.S.G.S.
STATE OF UTAH topographic map, 1988

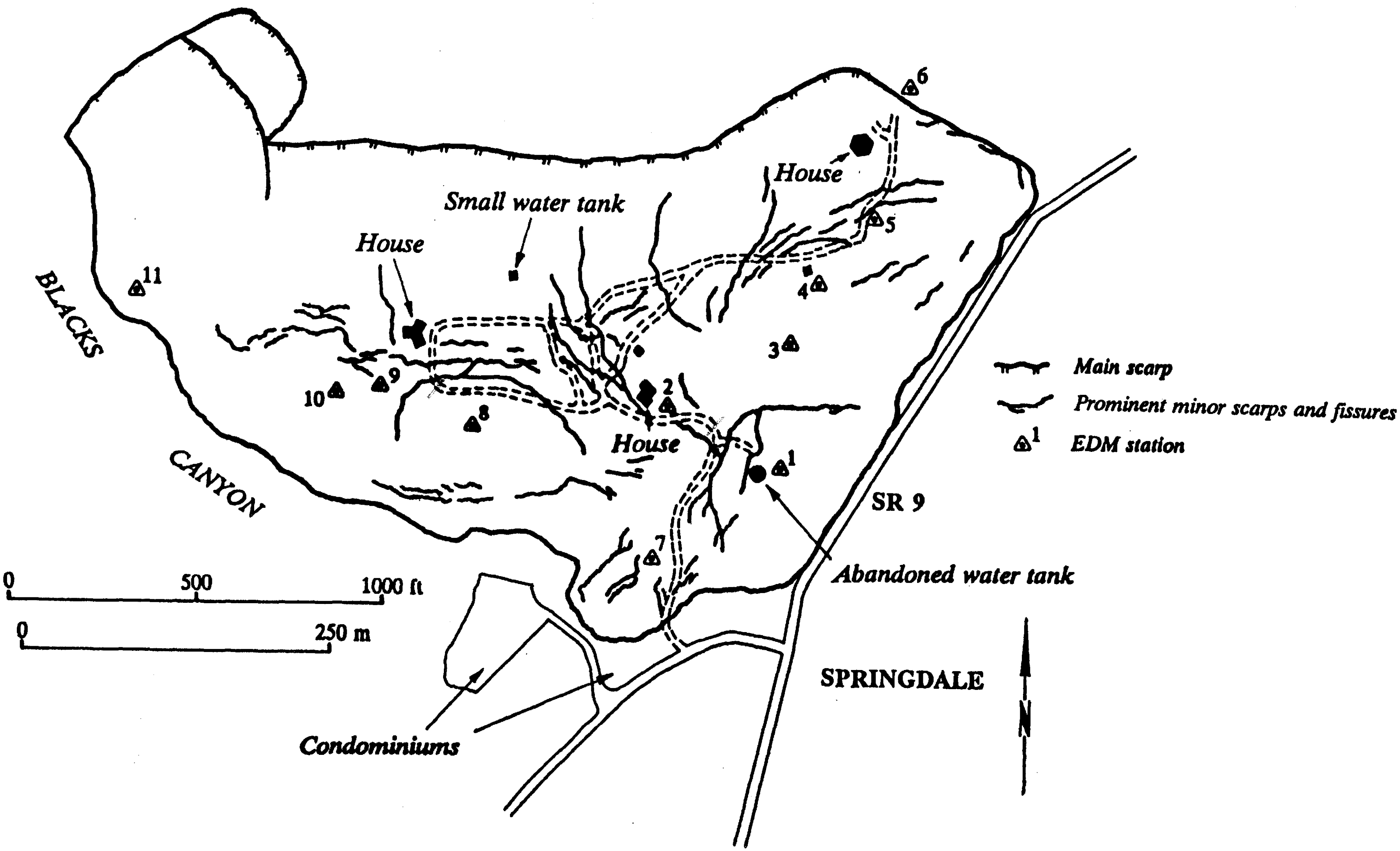


Attachment 1. Location map.

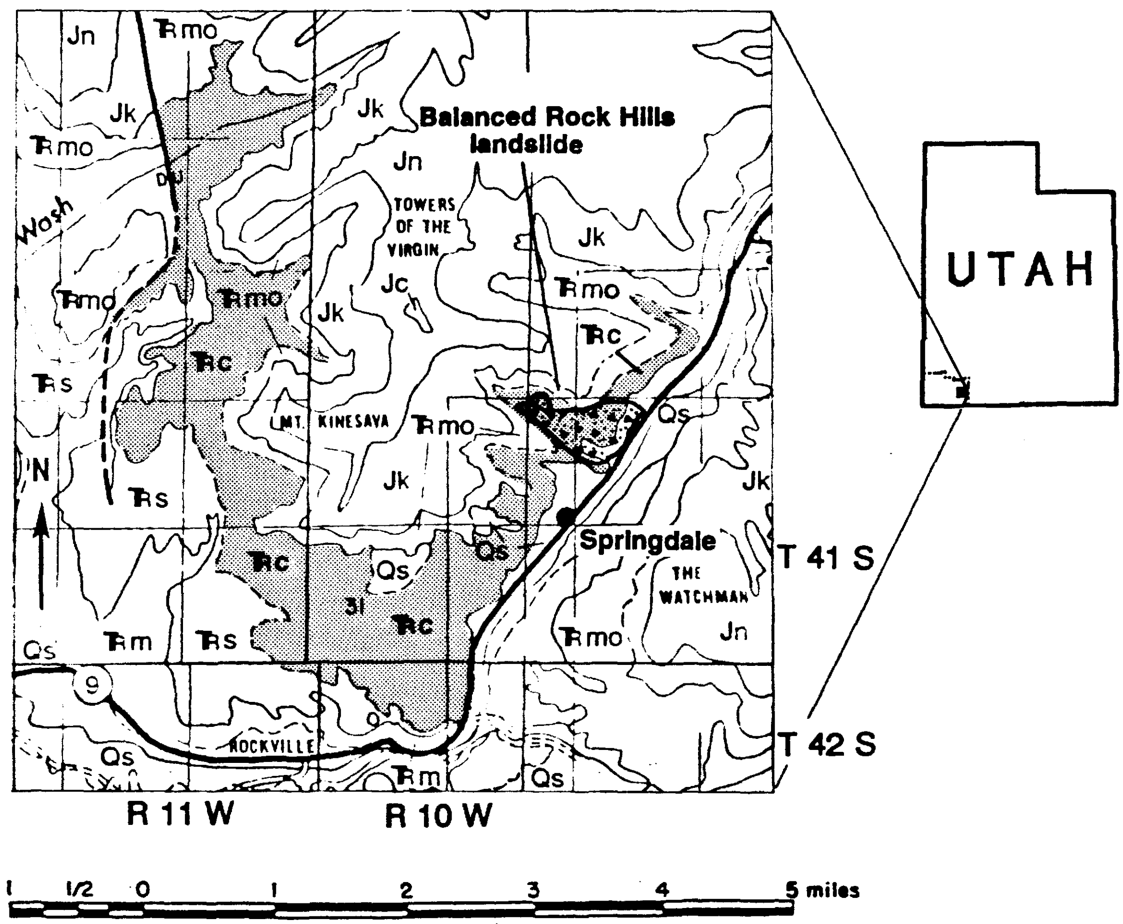
Base Map from SPRINGDALE EAST and SPRINGDALE WEST, U.S.G.S. 7-1/2' topographic quadrangles



Attachment 2. Balanced Rock Hills and Paradise Road landslides.



Attachment 3. Main scarp, prominent minor scarps and fissures, and location of EDM reflector stations on the Balanced Rock Hills landslide.

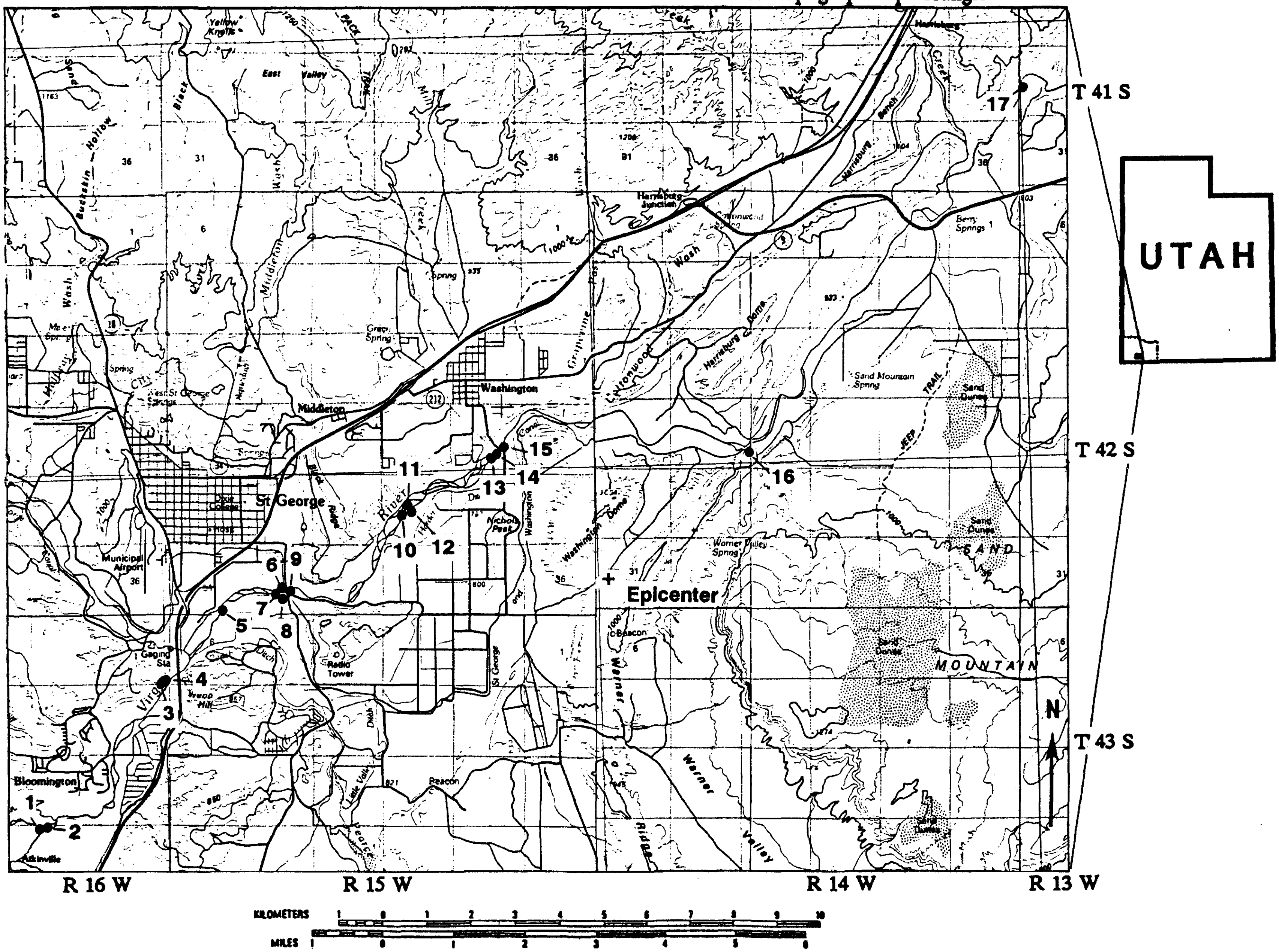


EXPLANATION

Qs	*Alluvium, gravel, sand, landslide material*
Jc	*Carmel Formation*
Jn	*Navajo Formation*
Jk	*Kayenta Formation*
TR mo	*Moenave Formation*
TR c	*Chinle Formation (Petrified Forest Member)*
TR s	*Chinle Formation (Shinarump Member)*
TR m	*Moenkopi Formation*
	Contact
U / D	*Fault, dashed where approximate, D-Downthrown side, U-Upthrown side*
	Balanced Rock Hills landslide

Attachment 4. Geologic map of the Springdale area (modified from Cook, 1960).

Base Map from ST. GEORGE, U.S.G.S.
30' x 60' topographic quadrangle



Attachment 5. Location of liquefaction features investigated along the Virgin River.

Project: Geologic-hazards evaluation for the Nephi Industrial Park, Juab County, Utah			Requesting Agency: Nephi City Planning Commission
By: Kimm M. Harty	Date: 10-26-92	County: Juab	Job No: 92-19 (GH-9)
USGS Quadrangle: Nephi (884)			

INTRODUCTION

At the request of Glenn Greenhalgh of the Nephi City Planning Commission, the Utah Geological Survey (UGS) performed a geologic-hazards evaluation of the Nephi Industrial Park (NIP). The site is in the northern part of the city of Nephi and covers portions of sections 32 and 33, T. 12 S., R. 1 E., Salt Lake Baseline and Meridian (attachment 1). The NIP currently contains a few businesses with ample space for expansion. The NIP as outlined in attachment 1 includes some land that the city intends to acquire in the near future. The purpose of the evaluation was to identify geologic hazards that may be present at the entire site. Identification of geologic hazards is particularly important for industrial parks, as they may house businesses that handle environmentally sensitive material. The scope of work for the evaluation included a review of geologic maps, literature, and 1:12,000-scale air photos, and a field reconnaissance on July 31, 1992. This report should be made available to project engineers to ensure proper design and construction of future proposed structures within the NIP.

GEOLOGIC SETTING

The ground surface in the NIP slopes gently to the northwest. A recent geologic map of the area (Biek, 1991) shows most of the NIP to be covered by coalesced alluvial fans consisting of poorly to moderately sorted boulder- to clay-sized sediments. In the NIP, these sediments consist mainly of fined-grained clay, silt, and sand. A sample of surface soil from the NIP is classified as a clayey silt (ML); some of the silt component is likely loess (wind-deposited sediment). Soil color is yellowish brown (10 YR 5/4). Sediment in most areas contains well-rounded to angular gravel, generally less than one inch (2.5 cm) in diameter. Cobbles were observed on the ground surface in a number of areas, but are most numerous in the northeast part of the NIP, which is mapped as an active alluvial fan (attachment 1) (Biek, 1991). Some of the gravel and cobbles are derived from the Quaternary-Tertiary-age Salt Creek Fanglomerate, which crops out extensively in the San Pitch Mountains just over one mile (1.6 km) east of the site.

GEOLOGIC HAZARDS

Geologic hazards that potentially exist at or near the proposed site are discussed below. Hazards that need to be considered in soil-foundation investigations are also noted in this report, and on an enclosed summary sheet (attachment 2). Geologic terms are defined in the glossary (attachment 3).

Flooding

No major drainage channels are near the Industrial Park, so the hazard from stream flooding is low. Federal Emergency Management Agency (1987) maps show the site to be in Zone C, an area of low stream-flood hazard. However, the site could be subject to alluvial-fan flooding. The northeast part of the site is on, and the rest of the site is near, the distal part of an active alluvial fan formed at the mouth of Quaking Asp Canyon by the deposition of material from past debris flows and debris floods (attachment 1). The possibility exists that debris and water carried by floods could reach the NIP, although the amounts would likely be small.

Problem Soil

Many of the Holocene-age alluvial fans at the base of the mountains east of Nephi contain collapsible soil. A number of drainages in the mountains to the east and southeast of the NIP, including Quaking Asp Canyon, contain the Jurassic-age Arapien Shale, which is thought to contribute to the formation of collapsible soils in the Nephi area (Rollins and others, 1992). Collapsible-soil hazard maps show most of the NIP to be in an area of "low" hazard (Owens and Rollins, 1990; Rollins and others, 1992). The hazard is labeled "very high," however, on the active alluvial fan in the northeast part of the NIP. As part of a geotechnical study for siting of the Ecotech building in the northeast part of the NIP, approximately 10 borings were drilled to a maximum depth of 40 feet (12.2 m). The borings revealed moderately collapsible soil within the upper 20 feet (6.1 m) of the surface (J. Bishop, SHB-AGRA, verbal communication, September, 1992). Despite being mapped in a low collapsible-soil-hazard area, the presence of collapsible soil in the northeast part of the NIP, and the fact that it is also on alluvial-fan material, points to a likelihood that collapsible soil may exist in other parts of the NIP.

Radon Gas

A generalized radon-hazard-potential map of Utah (Black, in preparation) indicates the NIP is in a moderate-hazard-potential area for radon gas. The rating is based on three factors: soil permeability, depth to ground water, and uranium content of the soil. In general, the radon hazard is highest where soil permeability is high, ground water is deep, and soils are uranium rich. The moderate-hazard rating assigned to the area is likely due to a possible high uranium content in soils at the site derived from: 1) Tertiary volcanic rocks in the San Pitch Mountains to the southeast of Nephi, and/or 2) the Permian-age Phosphoria Formation that is a producer of low-grade uranium in Utah and crops out in the mountains northeast of the site. In addition, the water table is deep, about 100-200 feet (30.5-61 m) below the ground surface (Bjorkland, 1967; Hecker and others, 1988), and the permeability of the Juab loam is considered moderate for radon gas (B. Black, Utah Geological Survey, verbal communication, September, 1992). The Industrial Park was not tested for radon gas, therefore the moderate rating is only a preliminary estimate of the radon-hazard potential.

Earthquake Hazards

The Nephi area lies in the Intermountain seismic belt (ISB), a generally north-south trending zone of active seismicity that traverses the central part of the state. Associated with the ISB have been a number of moderate-sized earthquakes (magnitude 4.0 - 6.0) in the Nephi area in historical time (1850-present) (Arabasz and others, 1979; Goter, 1990; Nava and others, in preparation). Two moderate earthquakes ranging in magnitude between 5.0-5.9 occurred in historical time near the cites of Eureka and Elberta 22 and 16 miles (35 and 26 km) northwest of Nephi. The closest large historical earthquake (magnitude 6.5) occurred approximately 65 miles (104 km) to the south, in the Richfield area in 1901 (Arabasz and others, 1979; Goter, in preparation).

The NIP is near the surface trace of the Wasatch fault as mapped by Cluff and others (1973) and Biek (1991) (attachment 1). At its closest, the fault is about 600-650 feet (183-198 m) from the northeast corner of the NIP. Near the NIP, surface expression of this fault has been modified by development and agricultural activity. No surface expression of the fault was observed in the NIP, and the site is probably outside the deformation zone of this fault, where the ground adjacent to the principal surface-fault rupture may experience cracking, faulting, tilting, and ground movement that can damage structures. Based on a number of geologic studies (Machette, 1984; Schwartz and Coppersmith, 1984; Jackson, 1991; Machette and others, 1991), the Wasatch fault in the Nephi area last ruptured the surface sometime within approximately the past 1,200 years, and perhaps as recently as 300-500 years ago. The Wasatch fault zone is associated with earthquakes up to magnitude 7.5, which occur about once every 400 years somewhere along the fault (Machette and others, 1991).

The greatest earthquake hazard at the site is ground shaking resulting from either a moderate earthquake which could occur anywhere in the area, or from a large earthquake along a known fault such as the Wasatch fault. Three levels of design ground motions for structures in the NIP are outlined below based on: 1) probabilistic motions that have a one in 10 chance of being exceeded in a 250-year period, 2) minimum design motions specified in the 1991 Uniform Building Code (UBC) for seismic zone 3, and 3) minimum design motions specified in the 1991 UBC for seismic zone 4. Under level 1, a peak horizontal ground acceleration on stiff soil of 0.6 g has a one in 10 chance of being exceeded in a 250-year period (Youngs and others, 1987). This figure approximates the probable maximum acceleration that the site may experience assuming the presence of stiff soil at the site. Under level 2, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. These standards are based on design ground motions with a one in 10 chance of being exceeded in a 50-year period. The Industrial Park is in UBC zone 3. For this zone, the Z-factor value is 0.3, corresponding to an effective peak ground acceleration on rock of 0.3 g. Under level 3, corresponding to UBC zone 4, the Z-factor value is 0.4.

In both seismic zones 3 and 4, the site coefficient (S-factor) must be determined (International Conference of Building Officials, 1991, p. 184). The site coefficient takes into account possible ground-motion amplification by soft soils. An S_3 site coefficient is specified in the Uniform Building Code (UBC) where soil profiles are not known. The soil profile can only be accurately established by a geotechnical investigation, and it is posssible that the site coefficient at the NIP may be S_2 (stiff soil with less amplification than S3) or S_4 (soft soils with greater amplification).

The ground-shaking levels described above represent three levels of design. Designing a building to level 1 is the most conservative (that is, it incorporates the most seismic resistance) of the options presented. Level 2 represents the minimum ground-motion design required by law in Utah, and is the least conservative of the three levels. Level 3 is the most realistic. It reflects recent ground-motion data (Youngs and others, 1987) that indicate the central Wasatch Front area, including Nephi, meets the criteria to be classified into UBC zone 4 (Olig, 1991). Although not required by law, the Utah Geological Survey recommends designing essential, hazardous, and special-occupancy facilities (International Conference of Building Officials, 1991, p. 185) along the Wasatch Front in accordance with UBC seismic zone 4 specifications.

The hazard from flooding caused by earthquake-induced tectonic subsidence is very low, although such subsidence may accompany surface faulting in the area. Maps of soil liquefaction potential show the NIP to be in a zone of very low potential (Anderson and others, 1990).

Other Hazards

The hazard from slope failure and rock fall at the NIP is low because of site topography and distance from slopes. Debris flows issuing form the mouths of canyons would likely not reach the NIP. The hazard from problem soils such as expansive clay and soluble soil/rock is low, and there are no documented occurrences of soil problems other than collapsible soil in the area (Mulvey, in press). The static water table in the Nephi area is deep, thus the hazard from shallow ground water is low.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards were identified at the Nephi Industrial Park which would make the site unsuitable for development. However, hazards that could affect the NIP are discussed below with recommendations.

The NIP is near an active alluvial fan and may be subject to alluvial-fan flooding during severe cloudburst rainstorms and rapid spring snowmelt. Measures to assess, and if necessary reduce these potential hazards should be taken. Collapsible soil is likely present at the NIP; a soil-foundation investigation should to be done by a qualified soil engineer prior to construction of new buildings to determine the existence and extent of this hazard. Generalized data indicate the site is in a moderate radon-hazard-potential area. Radon-resistant designs in buildings could minimize this potential hazard. The proposed site is near a branch of the active Wasatch fault (Biek, 1991), but is probably outside the potential deformation zone. Because of new information indicating greater ground shaking than previously thought and the proximity of the NIP to an active fault, the UGS recommends that future buildings be constructed under design specifications for seismic zone 4, to provide a measure of earthquake resistance above the minimum required by law.

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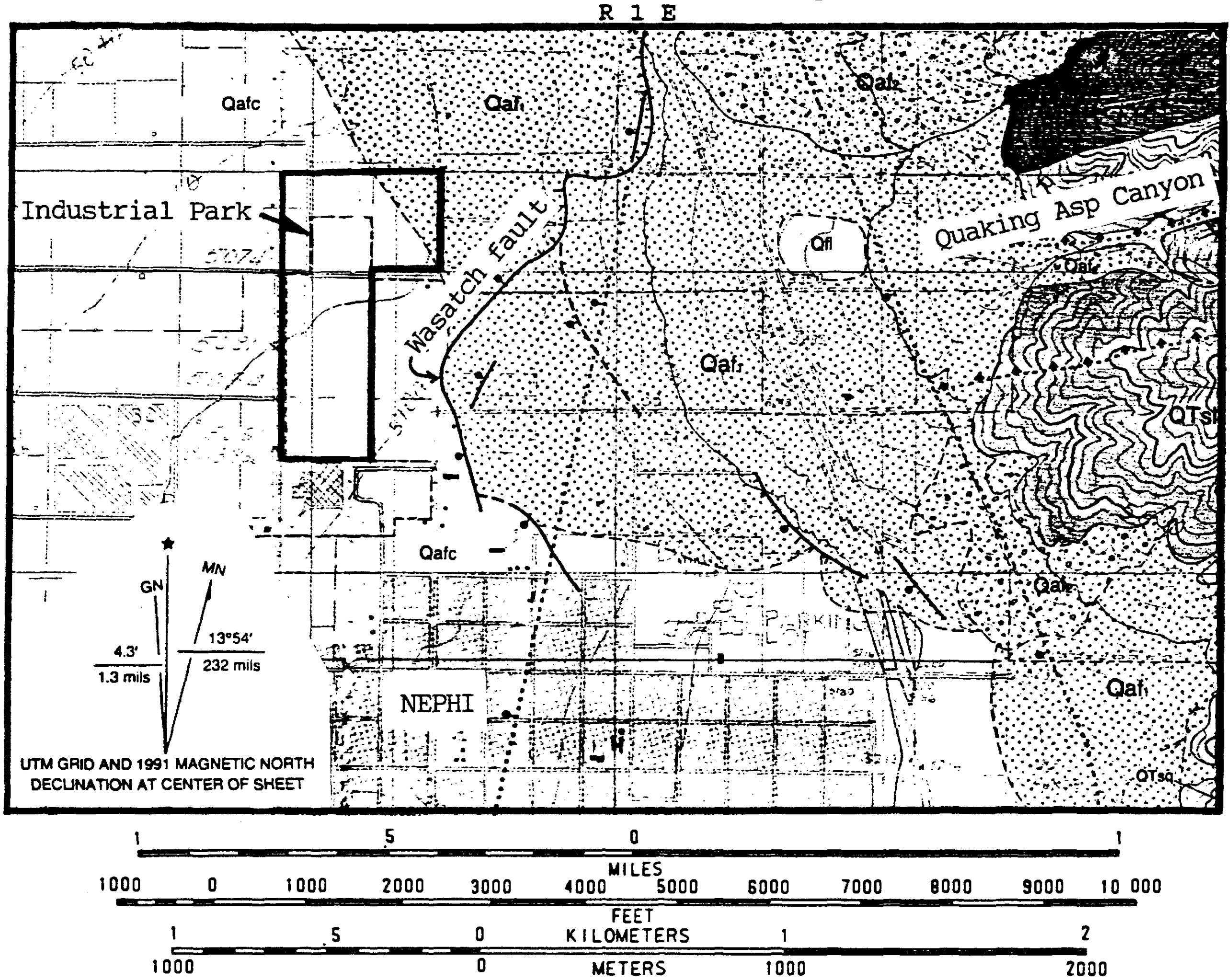
Attachment 1, Job No. 92-19

Base map from USGS $7\frac{1}{2}$' topographic quadrangle, "Nephi"



CONTOUR INTERVAL 40 FEET

SUPPLEMENTAL CONTOUR INTERVAL 20 FEET

DESCRIPTION OF MAP UNITS

QUATERNARY

Qfl — Artificial deposits: *Fill used to build dams, retaining ponds, and other man-made structures.*

Qaf₁ — Level 1 alluvial-fan deposits: *Moderately to poorly sorted, locally derived material deposited at or near current base level near the mouths of canyons. Most fans are small and still actively forming.*

Qaf₂ — Level 2 alluvial-fan deposits: *Moderately to poorly sorted, locally derived boulder- to clay-sized material deposited at or near the mouth of canyons. These deposits have been incised and isolated by down-cutting streams.*

Qafc — Coalesced alluvial-fan deposits: *Poorly to moderately well-sorted boulder- to clay-sized material deposited in large alluvial fans extending into Juab Valley. The material is coarser near the mountain fronts and becomes finer grained toward the center of the valley.*

QUATERNARY-TERTIARY

QTsq — Quartzite-rich unit of Salt Creek Fanglomerate; *Polymodal conglomerate, dominant quartzite with lesser limestone clasts; locally well cemented.*

QTsl — Limestone-rich unit of Salt Creek Fanglomerate: *Polymodal, polymictic conglomerate lacking quartzite clasts.*

MAP SYMBOLS

Note: Symbols dashed where approximate, dotted where concealed.

Contact

Normal fault; bar and ball on downthrown side, hachures show scarp

Normal fault inferred from air photos; may be slump scarp

Thrust fault; teeth on upper plate

Attachment 1. Nephi Industrial Park and surrounding geology (modified from Biek, 1991).

SUMMARY OF GEOLOGIC HAZARDS
Nephi Industrial Park SITE

Hazard	Hazard Ratings*			Further Study Recom-mended
	Prob-able	Pos-sible	Unlikely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction			X	
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow		X		
Avalanche			X	
Problem soils/subsidence				S
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.

GLOSSARY OF GEOLOGIC-HAZARDS TERMS

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

Project: Preliminary investigation of a lineament near Shriners Hospital for Crippled Children, Salt Lake City			Requesting Agency: Utah Geological Survey
By: Susan S. Olig	Date: 3-22-93	County: Salt Lake	Job No: 93-03 (GH-10)
USGS Quadrangle: Fort Douglas (BLM No. 1253)			

An addition is being considered for the Shriners Hospital for Crippled Children on the northwest corner of Virginia Street and Fairfax Road (attachment 1). David Tilson, consulting geologist, initially contacted William Lund, Utah Geological Survey (UGS), regarding a lineament in the vicinity of the hospital that Mr. Tilson discovered while studying aerial photographs for an unrelated residential development to the east (the Block "U" Parcel). The lineament trends southwest through a residential area and ends west of Holy Cross Hospital. Because of the life-safety issues associated with the hospital, homes, and other hospitals in the area, the Utah Geological Survey conducted a preliminary investigation to determine if this lineament is related to faulting and if further investigation of potential fault surface-rupture hazards at the Shriners Hospital site is warranted. Our investigation included discussions with Mr. Tilson and review of material provided by him, review of existing topographic and geologic maps of the area, interpretation of 1937 and 1958 aerial photographs, and discussions with Brian Bryant, Salt Lake County geologist, and Jeffrey Keaton, SHB AGRA, Inc. SHB AGRA was conducting the geotechnical investigation for the proposed addition and we contacted Dr. Keaton to find out about the scope and results of this investigation. Finally, we field checked the lineament area by car to look for topographic evidence of a fault scarp.

The hospital is at an elevation of just over 4,600 feet. It lies on young alluvial-fan deposits at the mouth of Limekiln Gulch (Personius and Scott, 1992). The fan surface slopes about 4 degrees to the southwest and the channels on the fan generally trend northeast-southwest, parallel to the lineament.

The lineament is visible on both the 1937 and 1958 aerial photographs, although it is more easily visible on the 1937 photographs. It traverses northeast through an area that showed extensive development even in the 1937 photographs (attachment 1). The northern end of the lineament is about 1,000 feet south of the Shriners Hospital. The lineament appears on the photos as a darker linear zone that appears to be associated with vegetation differences and coincides with one of the many small channels dissecting the alluvial fan of Limekiln Gulch. There is no apparent scarp morphology associated with the lineament on the photographs (G. E. Christenson, Utah Geological Survey, verbal communication, 1993). The ground surface at the proposed hospital addition appears relatively undisturbed in the 1937 photographs. No scarps were visible and the lineament did not extend onto the site. Our field reconnaissance also did not reveal any evidence of a scarp.

Personius and Scott (1990, 1992) and Scott and Shroba (1985) did not include the lineament as a fault on their geologic maps of the area. They do show the Virginia Street fault approximately 250 meters to the north. This short fault strikes east-west and dips to the south. They also mapped the easternmost splay of the East Bench fault roughly 2,200 feet southeast of the hospital site. In this vicinity, the East Bench fault strikes northeast and dips northwest. The surface fault rupture special study area map of Salt Lake County (available from Salt Lake County Planning Division) also does not show the lineament as a fault. In fact, the map shows the hospital site outside of the special study areas where fault investigations are required prior to most types of development.

Borehole information provided by Dr. Keaton indicated that the alluvial-fan deposits are 30 to 40 feet deep and they overlie Lake Bonneville sediments at the site. Dr. Keaton had done a reconstruction of the contact between the fan and Lake Bonneville deposits from the borehole information, and had concluded that this contact was probably not faulted, at least any appreciable amount (verbal communication, 1993).

All available evidence suggests that the lineament is not associated with a fault scarp. However, we cannot be absolute in our conclusion due to the extensive development in the area and the difficulty in identifying subtle geomorphic features in the extensively modified landscape. The lineament appears to be a vegetation difference perhaps associated with a channel in the alluvial-fan deposits, a buried geologic contact, or an older buried fault lacking significant Holocene displacement. The borehole information suggests that the later possibility is less likely, at least in the immediate vicinity of the hospital and proposed addition. The borehole information also suggests that a subsurface investigation involving trenching to identify potential buried faults in the Lake Bonneville sediments would not be practical due to the depth of the overlying alluvial-fan sediments.

The available information indicates that the lineament does not represent an active fault, and that further detailed investigation of the lineament is not warranted. As a prudent added precaution, Dr. Keaton indicated that SHB AGRA would inspect the foundation excavations for the hospital addition for any evidence of faulting and that he would notify our office when the excavations where open.

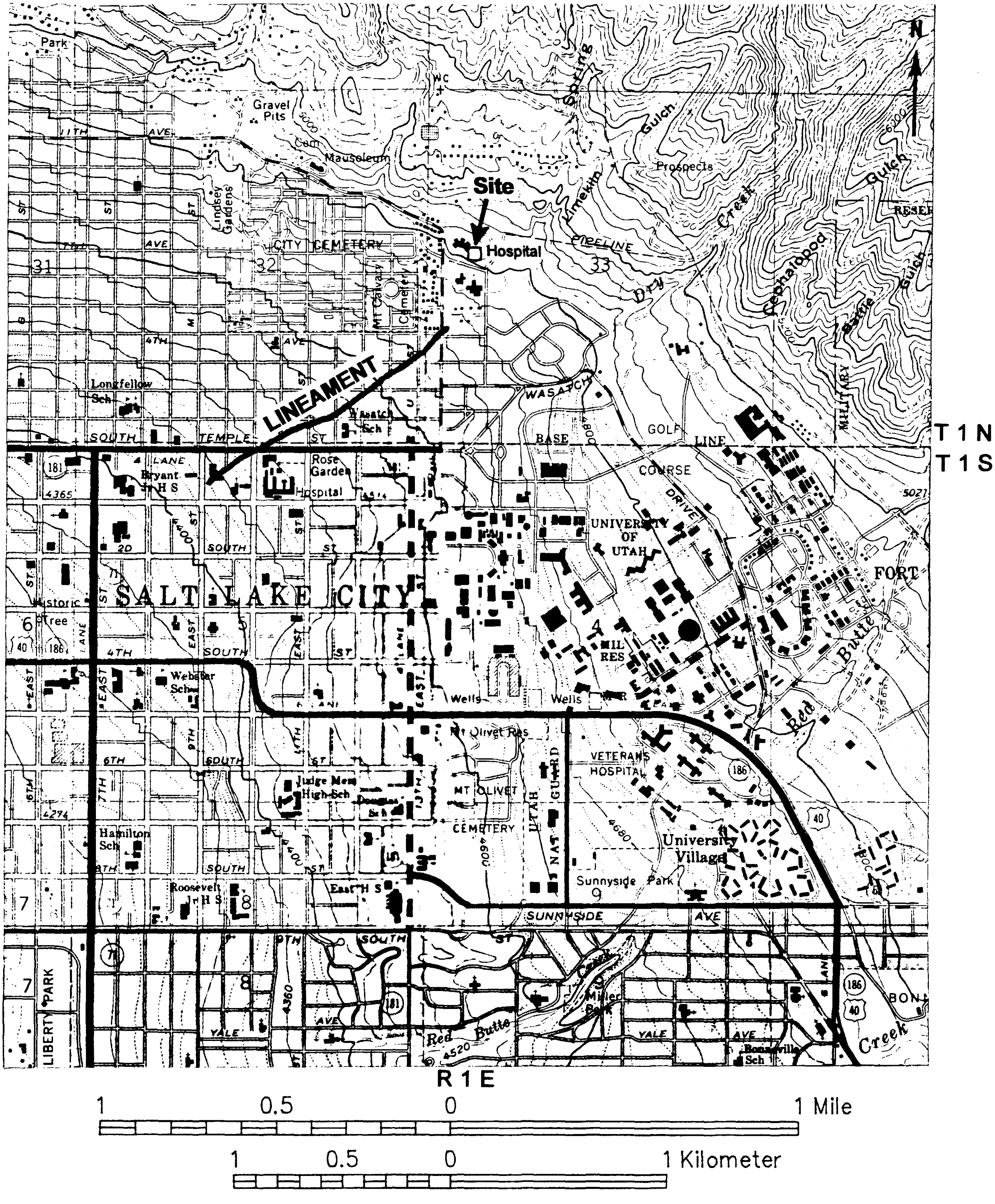
REFERENCES

Personius, S. F., and Scott, W. E., 1990, Preliminary surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U. S. Geological Survey Miscellaneous Field Studies Map MF-2114, scale 1:50,000.

Personius, S. F., and Scott, W. E., 1992, Surficial geologic map of the Salt Lake City segment and parts of adjacent segments of the Wasatch fault zone, Davis, Salt Lake, and Utah Counties, Utah: U. S. Geological Survey Miscellaneous Investigations Series Map I-2106, scale 1:50,000.

Scott, W. E., and Shroba, R. R., 1985, Surficial geologic map of an area along the Wasatch fault zone in the Salt Lake Valley, Utah: U. S. Geological Survey Open-File Report 85-448, scale 1:24,000, 18 p.

Attachment 1. Job No. 93-03 Base Map from FORT DOUGLAS and SUGARHOUSE U.S.G.S. 7-1/2' topographic quadrangles



Attachment 1. Location map of proposed addition to Shriners Hospital for Crippled Children. Lineament was transferred from 1937 aerial photographs.

Project: Geologic-hazard investigation for a parcel of state-owned land in the Cross Hollow area, near Cedar City, Utah			Requesting Agency: State Lands and Forestry
By: W.E. Mulvey	Date: 4-9-93	County: Iron County	Job No: 93-06 (GH-11)
USGS Quadrangle: Cedar City (238)			

PURPOSE AND SCOPE

The Utah Geological Survey (UGS) conducted a geologic-hazards investigation of state-owned property southwest of Cedar City, Utah (attachment 1). The northeast corner of the property is a telecommunications site, but the remainder is being considered for residential development. The inspection was requested by Doug Fullmer of the Cedar City office of the Division of State Lands and Forestry. The purpose of the investigation was to identify potential geologic hazards on the property that should be considered prior to developing the site. The scope of the investigation included a literature search, air-photo interpretation, and a visit to the property on April 5-6, 1993. No test pits were excavated for this investigation, but trenches for soil-foundation investigations and sewer lines in nearby properties were examined during the field visit.

SETTING AND SITE DESCRIPTION

The property covers 40 acres in the SW1/4SW1/4 section 15, T. 36 S., R. 11 W., SLBM, and is 1/2 mile (0.8 km) west of Cedar City on the crest of the Cross Hollow Hills (attachment 1). The land slopes gently to the west and east from the crest, and is vegetated with sagebrush and pinon-juniper. Average annual precipitation is 10 to 12 inches (25-30 cm).

GEOLOGY AND SOILS

Averitt (1962) and Averitt and Threet (1973) mapped the geology of the Cedar City area, including the property considered in this investigation. Their maps show fanglomerate and basalt on the property (attachment 2). The fanglomerate is thought to be latest-Tertiary or earliest-Quaternary age (5 to 1 million years ago). Material in the fanglomerate ranges in size from small pebbles to boulders 10 feet (3 m) in diameter. The fanglomerate includes clasts of Navajo Sandstone and Kolob latite, limestone from the Wasatch Formation, and quartzite from the Kaiparowits Formation. The basalt is reported to be similar in age to one dated at a million years old in the North Hills just south of the site (Anderson and Christenson, 1989). The basalt overlies the fanglomerate in the southeastern corner of the property. However, I found evidence in a newly graded road that the fanglomerate overlies the basalt in places, and may therefore be the same age as, or in part younger than the basalt.

Soils on the property are thin with a well-developed carbonate horizon at a depth of 17 inches (43 cm) (U.S. Soil Conservation Service, 1975). The soil is primarily gravel and sand, with minor amounts of clay and silt. Field observations at the site and in test pits and excavations for sewer lines southeast of the property confirmed this. The carbonate horizon is well developed and forms a hardpan, but is not impermeable or difficult to excavate. The shallow soils over the carbonate horizon have a moderate erosion potential (U.S. Soil Conservation Service, 1975).

GEOLOGIC HAZARDS

Attachment 3 is a summary checklist of potential geologic hazards at the site. All hazards considered are shown and discussed below. A glossary of geologic-hazards terminology is included (attachment 4) to explain any unfamiliar terms included in this report.

Earthquake Hazards

The site is in the Intermountain seismic belt (ISB), a generally north-south trending zone of seismic activity that bisects the state. Associated with the ISB are a number of earthquakes in the Cedar City area, the largest being the 1902 Pine Valley earthquake with an estimated magnitude of 6.3 (Pechmann and others, 1992). The most recent earthquake was the M_L 5.8 (revised) St. George earthquake of September 2, 1992 (Pechmann and others, 1992) which was felt in Cedar City. Patios, brick veneer, and masonry were cracked in Cedar City as a result of the St. George earthquake (S.S. Olig, Utah Geological Survey, verbal communication, April 7, 1993).

There are several Quaternary faults within 30 miles (48 km) of the site. The closest faults are mapped by Anderson and Christenson (1989) on slopes immediately east and west of the property, offsetting the million-year-old basalt. Because they offset the basalt, the faults are thought to be early to middle Pleistocene in age (1.6 million to 130,000 years ago). However, Hecker (1993) reports that other researchers estimated the faults to be late Pleistocene based on carbonate development in a faulted soil. A fault exposed in a trench east of the site appeared to be overlain by an unfaulted, well-developed pedogenic carbonate horizon, indicating at least a pre-Holocene age for the most recent faulting.

The Hurricane fault is 1.5 miles (2.4 km) to the east of the property. There is no evidence of Holocene (10,000 years B.P. to present) movement on the Hurricane fault near Cedar City, but long-term slip rates calculated for the fault near Hurricane indicate that it may have been active during the Holocene. The possible occurrence of the September 2, 1992, St. George earthquake on the Hurricane fault (Pechmann and others, 1992) also indicates that at least the segment of the fault near Hurricane may be active.

The youngest faults in the area are associated with the Enoch graben, 8 miles (13 km) north of the property. These faults cut strata subjacent to a soil radiocarbon dated at 9,500 yr B.P., and Anderson and Christenson (1989) and Hecker (1993) suggest the faults are late Pleistocene and possibly Holocene in age.

Ground Shaking

The strongest ground shaking at the site would likely occur in a large (surface-faulting) earthquake on the Hurricane fault, although damaging ground shaking may occur from a moderate-to-large earthquake anywhere in the area. Ground shaking at the property could result in damage to structures and their foundations.

Three levels of design ground motions are outlined below, based on: (1) probabilistic peak horizontal motions that have a 10 percent chance of being exceeded in a 50-year period, (2) probabilistic peak horizontal motions that have a 10 percent chance of being exceeded in a 250-year period, and (3) the minimum design motions specified in the 1991 Uniform Building Code (UBC). Under level 1 at the proposed site the peak ground acceleration in bedrock of 0.16 g has a 10 percent chance of being exceeded in a 50 year period (Algermissen and others, 1990). Under level 2, the peak ground acceleration in bedrock of 0.43 g has a 10 percent chance of being exceeded in a 250-year period (Algermission and others, 1990). Under level 3, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The state lands in this investigation are in UBC seismic zone 2B. For zone 2B, design calculations require a Z-factor of 0.20, which effectively corresponds to designing for a peak acceleration on rock of 0.20 g. Soil properties at depth are not known in detail, but are likely bedrock and shallow stiff soil. Soil profile S_1 for site coefficients should be used in structure design.

Other Earthquake Hazards

The faults mapped near the site are estimated to be early to middle Pleistocene, and show no evidence of Holocene surface fault rupture. There is no surficial evidence of faulting at the site. The nearest faults which have possibly been active in Holocene time are 1.5 miles (2.4 km) away, and thus the hazard from surface fault rupture is low. The hazard from tectonic subsidence is unknown, but is probably low due to topographic conditions and the long recurrence intervals between surface-faulting earthquakes on near-by faults. Due to site topography, the hazard from earthquake-induced slope failure is low. There is no liquefaction hazard due to deep ground water and shallow depths to bedrock.

Collapsible Soils

Williams and Rollins (1991) mapped collapsible soils in the Cedar City area. Their mapping showed no collapsible soils on the property. Looking in test pits south of, and in a sewer line excavation east of the property, I also found no evidence of collapsible soils. Soils are mostly older (late Pleistocene), clast-supported gravels not subject to hydrocompaction.

Radon

The radon hazard at the site is unknown, but may range from low to moderate due to the high permeability of the soil and deep ground water (Black, in press). Five indoor-radon measurements from homes in Cedar City range from 0.6 to 2.1 pCi/L (Black, in press), all of which are below the EPA action level of 4 pCi/L. Mitigation is recommended for radon levels above 4 pCi/L. The closest reading (1.5 pCi/L) is 1 mile to the north, from a home built on the same Tertiary fanglomerate present at the property. This may indicate that although soils are permeable, and ground water is deep, the radon hazard in the fanglomerate is low.

Other Hazards

The hazard from slope failure and rock fall is low because of the site topography and distance from slopes. The hazard from expansive clay, collapsible soil, and soluble soil/rock is low. There are no flooding or shallow ground-water hazards.

Conclusions and Recommendations

No geologic hazards are present at the property that would make it unsuitable for residential development. Earthquake ground shaking may affect the area in the future. Information on the three earthquake-resistant design options is presented in the section on ground shaking. It is recommended that, at a minimum, any structures on the property be designed to meet the seismic provisions of UBC seismic zone 2B (level 3 in the ground shaking section).

A standard soil/foundation investigation is recommended to provide information on soil properties required to design building foundations. The indoor-radon measurement from the home built on the Tertiary fanglomerate 1 mile north of the property is 1.5 pCi/L, which is below the EPA's 4 pCi/L action level, suggesting that the need for radon-resistant construction methods is low. Homeowners concerned about radon may choose to conduct an indoor radon test after construction to determine the need for further action.

The hazard from surface fault rupture, slope failure, rock fall, flooding, and collapsible soil is low. Although unknown, the hazard from tectonic subsidence is also probably low.

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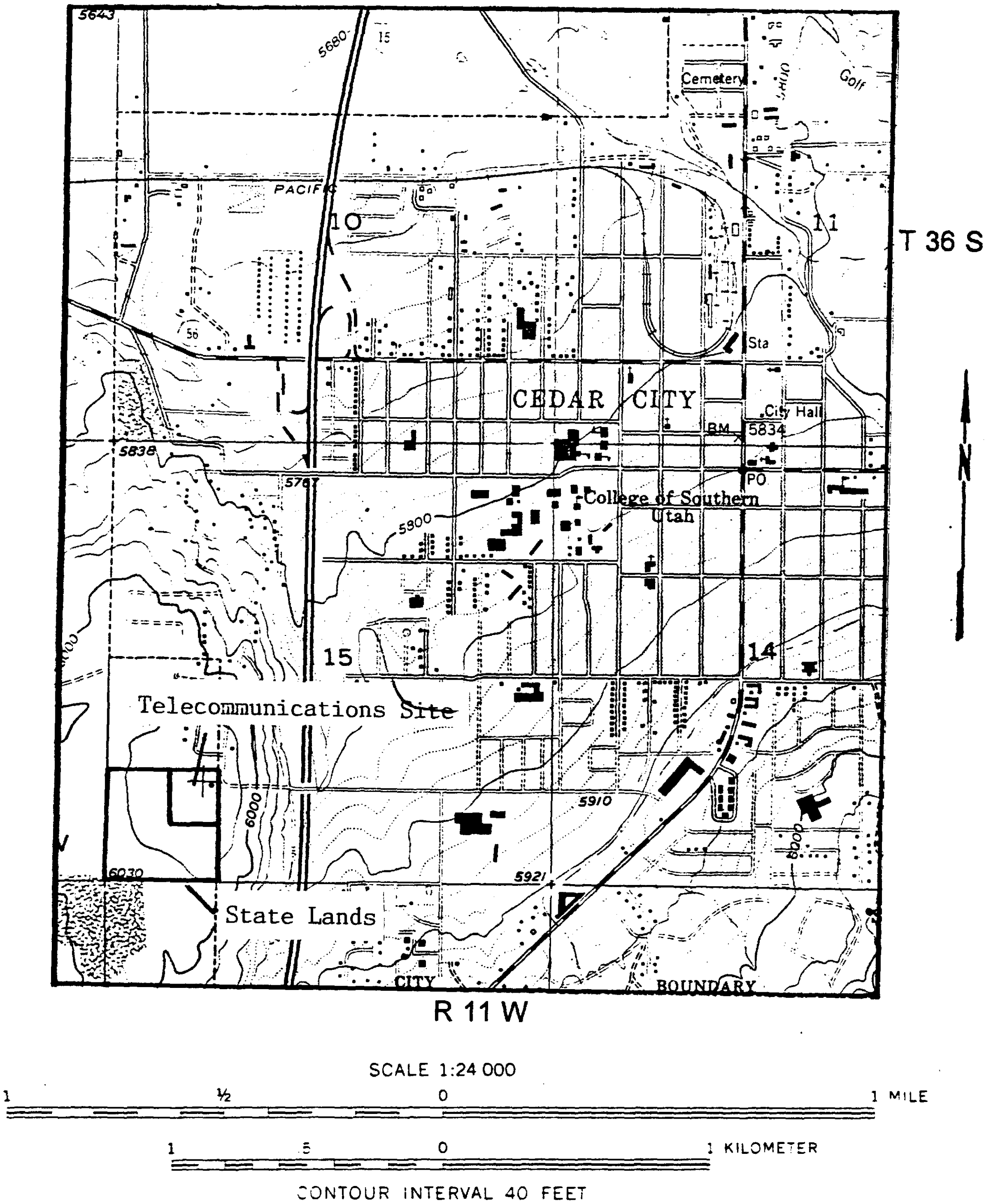
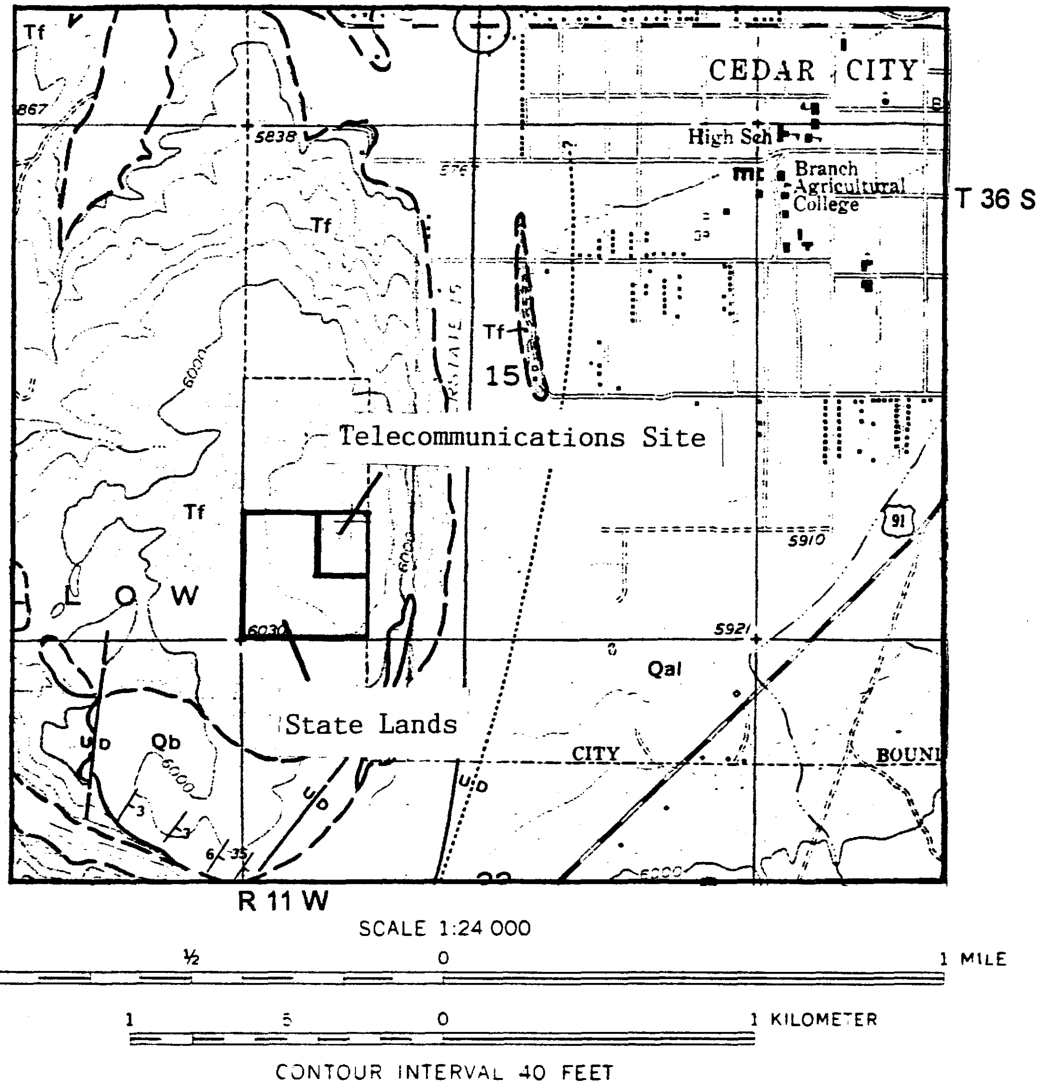
Williams, Tonya, and Rollins, K.M., 1991, Collapsible soil hazard map for Cedar City, Utah: Utah Geological Survey Contract Report 91-10, 37 p.

Base Map from CEDAR CITY
U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location map.



Qal Alluvium (Holocene and Pleistocene)

Qb Younger basalt (Holocene and Pleistocene)

Tf Fanglomerate deposit (Pliocene and Miocene [?])

Contact, dashed where approximate

U/D Fault, dashed where approximately located dotted where buried or concealed U upthrown side D downthrown side

3 Strike and dip of inclined beds

Attachment 2. Geologic map (modifed from Averitt and Threet, 1973).

SUMMARY OF GEOLOGIC HAZARDS
State Lands Cross Hollow Hills SITE

Hazard	Hazard Rating* Probable	Possible	Unlikely	Further Study Recommended**
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction			X	
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure			X	
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.

Attachment 4.
Job No. 93-06

GLOSSARY OF GEOLOGIC HAZARDS TERMS

Acceleration (ground motion) - The rate of change of velocity of an earth particle caused by passage of a seismic wave.

Active sand dunes - Shifting sand moved by wind. May present a hazard to existing structures (burial) or roadways (burial, poor visibility). Sand dunes usually contain insufficient fines to adequately renovate liquid waste.

Alluvial fan - A generally low, cone-shaped deposit formed by a stream issuing from mountains onto a lowland.

Alluvial-fan flooding - Flooding of an alluvial-fan surface by overland (sheet) flow or flow in channels branching outward from a canyon mouth. See also, alluvial fan; stream flooding.

Antithetic fault - Normal fault showing the opposite orientation (dip) and sense of movement as the main fault with which it is associated.

Aquifer - Stratum or zone below the surface of the earth capable of producing water as from a well.

Avalanche - A mass of snow or ice moving rapidly down a mountain slope.

Bearing capacity - The load per unit area which the ground can safely support without excessive yield.

Canal/ditch flooding - Flooding due to overtopping or breaching of man-made canals or ditches.

Collapsible soil - Soil that has considerable strength in its dry, natural state but that settles significantly when wetted due to hydrocompaction. Usually associated with young alluvial fans, debris-flow deposits, and loess (wind-blown deposits).

Confined aquifer - An aquifer for which bounding strata exhibit low permeability such that water in the aquifer is under pressure (Also called Artesian aquifer).

Debris flow - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Debris flows contain sufficient water to move as a viscous flow. Debris flows can travel long distances from their source areas, presenting hazards to life and property on downstream alluvial fans.

Debris slide - Generally shallow (failure plane less than 10 ft. deep) slope failure that occurs on steep mountain slopes in soil or slope colluvium. Chief mechanism of movement is by sliding. Debris slides generally contain insufficient water to travel long distances from their source areas; may mobilize into debris flows if sufficient water is present.

Earthquake - A sudden motion or trembling in the earth as stored elastic energy is released by fracture and movement of rocks along a fault.

Earthquake flooding - Flooding caused by seiches, tectonic subsidence, increases in spring discharge or rises in water tables, and disruption of streams and canals. See also, Seiche; Tectonic subsidence.

Epicenter - The point on the earth's surface directly above the focus of an earthquake.

Erosion - Removal and transport of soil or rock from a land surface, usually through chemical or mechanical means.

Expansive soil/rock - Soil or rock that swells when wetted and contracts when dried. Associated with high clay content, particularly sodium-rich clay.

Exposure time - The period of time being considered when discussing probabilistic evaluations of earthquakes and resulting hazards. Because earthquake occurrence is time dependent, that is, the longer the time period, the higher the probability that an earthquake will occur, the period of time being considered (usually 10, 50, or 250 years) must be specified.

Fault segment - Section of a fault which behaves independently from adjacent sections.

Fault - A break in the earth along which movement occurs.

Focus - The point within the earth that is the center of an earthquake and the origin of its seismic waves.

Graben - A block of earth downdropped between two faults.

Ground shaking - The shaking or vibration of the ground during an earthquake.

Gypsiferous soil - Soil that contains the soluble mineral gypsum. May be susceptible to settlement when wetted due to dissolution of gypsum. See also Soluble soil/rock.

Holocene - An Epoch of the Quaternary Period, beginning 10,000 years ago and extending to the present.

Hydrocompaction - see Collapsible soil.

Intensity - A measure of the severity of earthquake shaking at a particular site as determined from its effect on the earth's surface, man, and man's structures. The most commonly used scale in the U.S. is the Modified Mercalli intensity scale.

Intermountain seismic belt - Zone of pronounced seismicity, up to 60 mi (100 km) wide, extending from Arizona through Utah to northwestern Montana.

Karst - See Soluble soil/rock.

Lake flooding - Shoreline flooding around a lake caused by a rise in lake level.

Landslide - General term referring to any type of slope failure, but usage here refers chiefly to large-scale rotational slumps and slow-moving earth flows.

Lateral spread - Lateral downslope displacement of soil layers, generally of several feet or more, resulting from liquefaction in sloping ground.

Liquefaction - Sudden large decrease in shear strength of a saturated, cohesionless soil (generally sand, silt) caused by collapse of soil structure and temporary increase in pore water pressure during earthquake ground shaking.

Liquefaction severity index - Estimated maximum amount (in inches) of lateral displacement accompanying liquefaction under particularly susceptible conditions (low, gently sloping, saturated flood plains deposits along streams) for a given exposure time.

Magnitude - A quantity characteristic of the total energy released by an earthquake. Several scales to measure earthquake magnitude exist, including local (Richter) magnitude (M_L), body wave magnitude (m_b), and surface wave magnitude (M_s). The local or Richter scale is commonly used in Utah earthquake catalogs. It is a logarithmic scale based on the motion that would be measured by a standard type of seismograph 100 km from the epicenter of an earthquake.

Mine subsidence - Subsidence of the ground surface due to the collapse of underground mine tunnels.

Non-engineered fill - Soil, rock, or other fill material placed by man without engineering specification. Such fill may be uncompacted, contain oversized and low-strength or decomposable material, and be subject to differential subsidence.

Normal fault - Fault caused by crustal extension in which relative movement on opposite sides is vertically downdip.

Organic deposits (Peat) - An unconsolidated surface deposit of semicarbonized plant remains in a water-saturated environment such as a bog or swamp. Organic deposits are highly compressible, and have a high water holding capacity and can oxidize and shrink rapidly when drained.

Perched aquifer - An unconfined aquifer in which the underlying impermeable bed is not continuous over a large area and is situated at some height above the main water table.

Piping - Soil or rock subject to subsurface erosion through the development of subsurface tunnels or pipes. Pipes can remove support of overlying soil/rock and collapse.

Pleistocene - An Epoch of the Quaternary Period, beginning 1.6 million years ago and extending to 10,000 years ago.

Potentiometric surface - The level to which water rises in wells that tap confined aquifers. This level is above the upper surface of the confined aquifer (Also called Piezometric surface).

Quaternary - A period of geologic time extending from 1.6 million years ago to the present, including the Pleistocene and Holocene Epochs.

Radon - A radioactive gas that occurs naturally through the decay of uranium. Radon can be found in high concentrations in soil or rock containing uranium, granite, shale, phosphate, and pitchblende. Exposure to elevated levels of radon can cause an increased risk of lung cancer.

Recurrence interval - The length of time between occurrences of a particular event such as an earthquake.

Richter magnitude - see Magnitude

Rock fall - The relatively free falling or precipitous movement of a rock from a slope by rolling, falling, toppling, or bouncing. The rock-fall runout zone is the area below a rock-fall source which is at risk from falling rocks.

S factor - Site factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from thickness and type of sediment at a site and attempts to account for the effects of soils on earthquake ground motions.

Sand dunes - See Active sand dunes.

Scarp - A relatively steeper slope separating two more gentle slopes, usually in reference to a faulted surface marked by a steepening where a vertical fault displacement occurred.

Seiche - Standing wave generated in a closed body of water such as a lake or reservoir by an earthquake. Ground shaking, tectonic tilting, subaqueous fault rupture, or landsliding into water can all generate a seiche.

Seismicity - Seismic or earthquake activity.

Sensitive clay - Clay soil which experiences a particularly large loss of strength when disturbed and is subject to failure during earthquake ground shaking.

Shallow ground water - Ground water within about 30 feet of the ground surface. Rising ground-water tables can cause flooding of basements, and solid and liquid waste disposal systems. Shallow ground water is necessary for liquefaction.

Shear strength - The internal resistance of a body of soil or rock to shear. Shear is the movement of one part of the body relative to another along a plane of contact such as a fault.

Slope failure - Downslope movement of soil or rock by falling, toppling, sliding, or flowing.

Slump - A slope failure in which the slide plane is curved (concave upward) and movement is rotational.

Soluble soil/rock (Karst) - Soil or rock containing minerals which are soluble in water, such as calcium carbonate (principal constituent of limestone), dolomite, and gypsum. Dissolution of minerals and rocks can cause subsidence and formation of sinkholes. See also Gypsiferous soil.

Stream flooding - Overbank flooding of flood plains along streams; area subject to flooding generally indicated by extent of flood plain or calculated extent of the 100- or 500-year flood.

Strong ground motion - Damaging ground motions associated with earthquakes. Threshold levels for damage are approximately a Modified Mercalli Intensity of VI or an acceleration of about 0.10 g, but levels vary according to construction, duration of shaking, and frequency (period) of motions.

Subsidence - Permanent lowering of the ground surface by hydrocompaction; piping; karst; collapse of underground mines; loading, decomposition, or oxidation of organic soil; faulting; or settlement of non-engineered fill.

Surface fault rupture (surface faulting) - Propagation of an earthquake-generating fault rupture to the ground surface, displacing the surface and forming a scarp.

Tectonic subsidence - Subsidence (downdropping) and tilting of a basin floor on the downdropped side of a fault during an earthquake.

Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

Unconsolidated basin fill - Uncemented and nonindurated sediment, chiefly clay, silt, sand, and gravel, deposited in basins.

Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

Z factor - Seismic zone factor used in the Uniform Building Code to calculate minimum force levels for earthquake-resistant design. It is determined from a nationwide seismic zone map which attempts to quantify regional variations of the ground-shaking hazard on rock.

Zone of deformation - The zone in the immediate vicinity of a surface fault rupture in which earth materials have been disturbed by fault displacement, tilting, or downdropping.

REVIEWS

<table>
<tr><td colspan="3">Project:
Review of "Report, geoseismic study, lots 46 and 47, proposed phase 3, Oak View Estates subdivision, Ogden, Utah."</td><td>Requesting Agency:
Ogden City</td></tr>
<tr><td>By:
Mike Lowe</td><td>Date:
1-15-93</td><td>County:
Weber County</td><td rowspan="2">Job No:
93-01
(R-1)</td></tr>
<tr><td colspan="3">USGS Quadrangle:
Ogden (1345)</td></tr>
</table>

INTRODUCTION

The purpose of this report is to present the results of a review of an engineering-geologic report (SHB AGRA, 1992) for two residential lots located in the proposed Oak View Estates subdivision, Phase 3 (SW1/4NE1/4, section 10, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian), Ogden City, Utah. The review was requested by Greg Montgomery, Ogden City Planning Division. The scope of work included a literature review, examination of aerial photographs (1937, 1:20,000 scale), and a field visit on November 4, 1992. A previous engineering-geologic report by Dames and Moore (1987) was included in the literature review. Brian Bryant (Salt Lake County Geologist), Milt Bachman (Bachman Development Company), and Greg Schlenker (SHB AGRA) were present during the field visit, which was performed when trenches to evaluate surface-faulting hazards at the proposed subdivision site were open.

The SHB AGRA (1992) report and Lowe (1986, 1987) identify earthquake ground shaking, surface faulting, and landsliding as the principal potential geologic hazards to be considered in the area of the proposed subdivision. With respect to ground shaking, the SHB AGRA (1992) report recommends that "all structures be designed and constructed in full compliance with the applicable provisions of seismic zone 3 as described in the Uniform Building Code." This meets state and local government requirements for earthquake-resistant design for reducing earthquake-ground-shaking hazards.

The SHB AGRA (1992) report acknowledges that the proposed subdivision is located near the crest of a scarp of the Weber segment of the Wasatch fault zone. To determine if there is a surface-faulting hazard within the proposed subdivision, SHB AGRA (1992) excavated two exploration trenches down the upper part of the fault scarp. The report and trench logs adequately document that faults associated with the fault zone do not occur within the proposed subdivision and that therefore the surface-faulting hazard is low. The report concludes that the faults likely occur further to the west nearer the base of the fault scarp.

The SHB AGRA (1992) report does not specifically address landsliding, but an earlier Dames and Moore (1987) report for phase 2 of the proposed subdivision did. The Dames and Moore (1987) report states that "except for isolated locations of shallow surficial erosion associated with fairly recent earthwork and possibly shallow slumps, no signs of past, or imminent mass instability across the phase 2 area, were observed." The SHB AGRA (1992) report identifies prehistoric surface cracks (exposed in trenches) which are attributed to "minor slope movement west of the site" which probably occurred "several thousand years" ago. Nelson and Personius (1990), however, map landslide scarps to the east of the proposed subdivision site which may indicate that the lots are on part of a larger landslide. Similar surface cracks have been observed in other trenches near fault scarps and attributed to surface faulting origin. The evidence cited for the landslide origin of these cracks is inconclusive in my opinion. The report recommends that structures not be placed over the cracks, and I concur, whether they are of fault or landslide origin.

Nelson and Personius (1990) also map an older, buried landslide bordering the site to the south. I brought this landslide and the scarps east of the site to the attention of Jeffrey R. Keaton (SHB AGRA, formerly with Dames and Moore) as part of this review. Mr. Keaton said that he does not necessarily agree that the scarps are of landslide origin and stated that, if a landslide is present, stream dissection and lack of distinct morphology indicate that it is probably pre-Holocene (occurred more than 10,000 years ago) and was possibly caused by the rapid drawdown of Lake Bonneville (verbal communication, January 7, 1993). Therefore he believes the landslide, if it exists, does not pose a hazard to the proposed subdivision. Although I believe the scarps east of the subdivision mapped by Nelson and Personius (1990) are related to landsliding, I have no evidence which would contradict Mr. Keaton's conclusions regarding the age of the landslide or the level of hazard posed to the subdivision.

In conclusion, the SHB AGRA (1992) report indicates that the surface-faulting hazard to the proposed subdivision is low. Recommendations in the report for reducing hazards associated with earthquake ground shaking and ground displacement in the vicinity of the cracks should be implemented. For legal purposes, Ogden City may wish written supporting documentation for conclusions regarding the landslide hazard at the site. If such documentation is requested from the developer, we could review it, but based on our verbal communications with the developer's consultant, the Dames and Moore (1987) report's conclusions appear valid. The developer and Ogden City must understand that the possibility of slope failure at the site is not disproven, but rather that the landslide hazard is considered low. I recommend that, if the subdivision is approved, the existence of the Dames and Moore (1987) report, the SHB AGRA (1991) report, and this review be disclosed to potential lot buyers.

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Lowe, Mike, 1986, Oakview Estates, Phase 2: Unpublished Weber County Planning Commission Memorandum, 2 p.

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Nelson, A.R., and Personius, S.F., 1990, Preliminary surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2132, scale 1:50,000.

SHB AGRA, 1992, Report, geoseismic study, lots 46 and 47, proposed phase 3, Oak View Estates Subdivision, Ogden, Utah: Unpublished consultant's report, 7 p.

Project: Review of Radioactive Materials License 660-02S, Amendment Request, Uravan Project Disposal Site, Montrose County, Colorado			Requesting Agency: Utah Dept. of Environmental Quality, Div. of Radiation Control
By: Barry J. Solomon	Date: 3-11-93	County: Montrose, Colorado	Job No: 93-02 (R-2)
USGS Quadrangle: Atkinson Creek, Davis Mesa, Red Canyon, Uravan			

INTRODUCTION

In response to a request from Larry Anderson, Director, Division of Radiation Control, a review was performed of the geotechnical portion of the Radioactive Materials License 660-02S, amendment request to accept radioactive materials from sites located within the state of Colorado at the Uravan Project disposal site, Montrose Colorado, dated August 17, 1992. Also reviewed was the Preliminary Licensing Statement/Proposed License for the Uravan facility, prepared by the Colorado Department of Health, Radiation Control Division, January 28, 1993. During the review a supporting document (ERI Logan, 1986), which presents results of field investigations at the Uravan site in response to environmental contamination in the vicinity, was consulted. The purpose for review of these documents is to safeguard the health and safety of people downstream in southeastern Utah.

Two earlier reviews of documents related to a similar facility proposed for a nearby site were previously performed (Solomon, 1990a, 1990b). The site presently under consideration is herein referred to as the west site; the previously considered site is herein referred to as the east site (attachment 1).

The proposed license amendment requests approval for the disposal of additional low-level radioactive material at an existing uranium mill and tailings disposal site. The existing facility is on the eastern side of Club Mesa, about 16 miles (26 km) east of the Utah border and 1 mile (1.6 km) west of the previously proposed site. Both sites lie within the San Miguel River sub-basin, a portion of the Dolores River drainage basin. The Dolores River flows northwestward into Utah and joins the Colorado River about 15 miles (24 km) northeast of Arches National Park. If contaminants from the facility were released to surface water, a significant potential for degradation of water quality in the Colorado and Dolores Rivers in southeastern Utah would exist.

GEOLOGIC HAZARDS

Because of similar geologic and hydrologic environments at the two sites, questions raised in earlier reviews of the east site remain applicable to the west site. Whereas most concerns expressed in the earlier reviews have been resolved in the license amendment request for the west site, one geotechnical issue remains. Of primary importance to Utah is the potential for transport of leachate into ground and surface water and ultimate migration of contaminants into the state.

The proposed facility depends on a combination of natural and engineered barriers to prevent seepage into the regional Kayenta/Wingate aquifer. The engineered barriers consist of double synthetic liners, as well as a base of clayey material. The adequacy of engineered barrier design is beyond the scope of this review, but static and seismic design parameters specified in the amendment request appear realistic. However, if liners fail natural barriers should provide sufficient assurance against seepage. There is insufficient assurance provided in the amendment request. Whereas the long-term seepage rate of 0.091 feet per year, calculated by the applicant, is realistic and results in a travel time in excess of the 1000-year requirement for longevity of control, this rate assumes homogeneity of rocks in geologic units beneath the site and lack of physical discontinuities. This may not be so. Gravel channels may be present in the host rock, and their presence and significance as pathways for contaminant movement must be considered. A well-developed joint system in surficial sandstone beds is noted by the applicant, and these fractures may extend downward through the aquitard that separates surficial material and upper rock layers from the underlying aquifer. Should significant fracture permeability be present, ground-water travel times would not likely exceed the longevity requirement.

ERI Logan (1986) documented considerable on-site and off-site contamination of soil and water from activities at the west site. Soil contamination above levels known to be toxic to plants extends for a distance of 7,000 feet (2,000 m) from the Uravan mill site, and concentrations of contaminants in soil at levels above background were detected to a distance of 28,000 feet (8,500 m) from the site at the most distant points of data collection. The extent of measurable contamination in surface water extends at least 11 kilometers (6.8 mi) beyond the confluence of the Dolores and San Miguel Rivers, the farthest extent sampled. Airborne contamination was the primary mechanism for contamination of soil, and visible seeps from tailings, ponds, and precipitates were the primary mechanism for contamination of water (ERI Logan, 1986). Significantly, the potential for contamination of water resources by infiltration through fractured or channeled bedrock was not considered. "Samples were taken from sources whose pathways into the environment were directly observed or inferred. Not all potential sources were sampled because of time and monetary limitations" (ERI Logan, 1986, p. 1-5). No wells were drilled to investigate ground-water flow, or to establish baseline conditions, nor were existing well data studied. The license amendment request did present water quality data from two monitor wells in the west site, but geochemical analysis of the data was minimal; data presented in the request included only total dissolved solids and a trilinear plot and Stiff diagram of cations and anions. Given the diversity of chemicals in the source material, and the associated responses of the individual elements to competing processes controlling transport, transformations, and fate, a more complete analysis of samples would have been prudent. Only two monitor wells were drilled, and this appears to be insufficient to investigate the potential for fracture flow, a phenomenon which depends on inhomogeneities which may be vertical and very irregularly distributed.

CONCLUSIONS AND RECOMMENDATIONS

The license amendment requested by Umetco Minerals Corporation adequately addresses most geotechnical issues. However, the proposed amendment does not resolve the potential for ground- and surface-water contamination by rapid migration of leachate through fluvial channels or well-developed joints, nor was this issue even addressed in the investigation of contamination in the site vicinity (ERI Logan, 1986). Because of this deficiency, concerns remain regarding potential contamination which may affect southeastern Utah. We recommend that the state of Utah follow the progress of this amendment request and continue to comment where necessary to ensure that all prudent precautions are taken prior to development.

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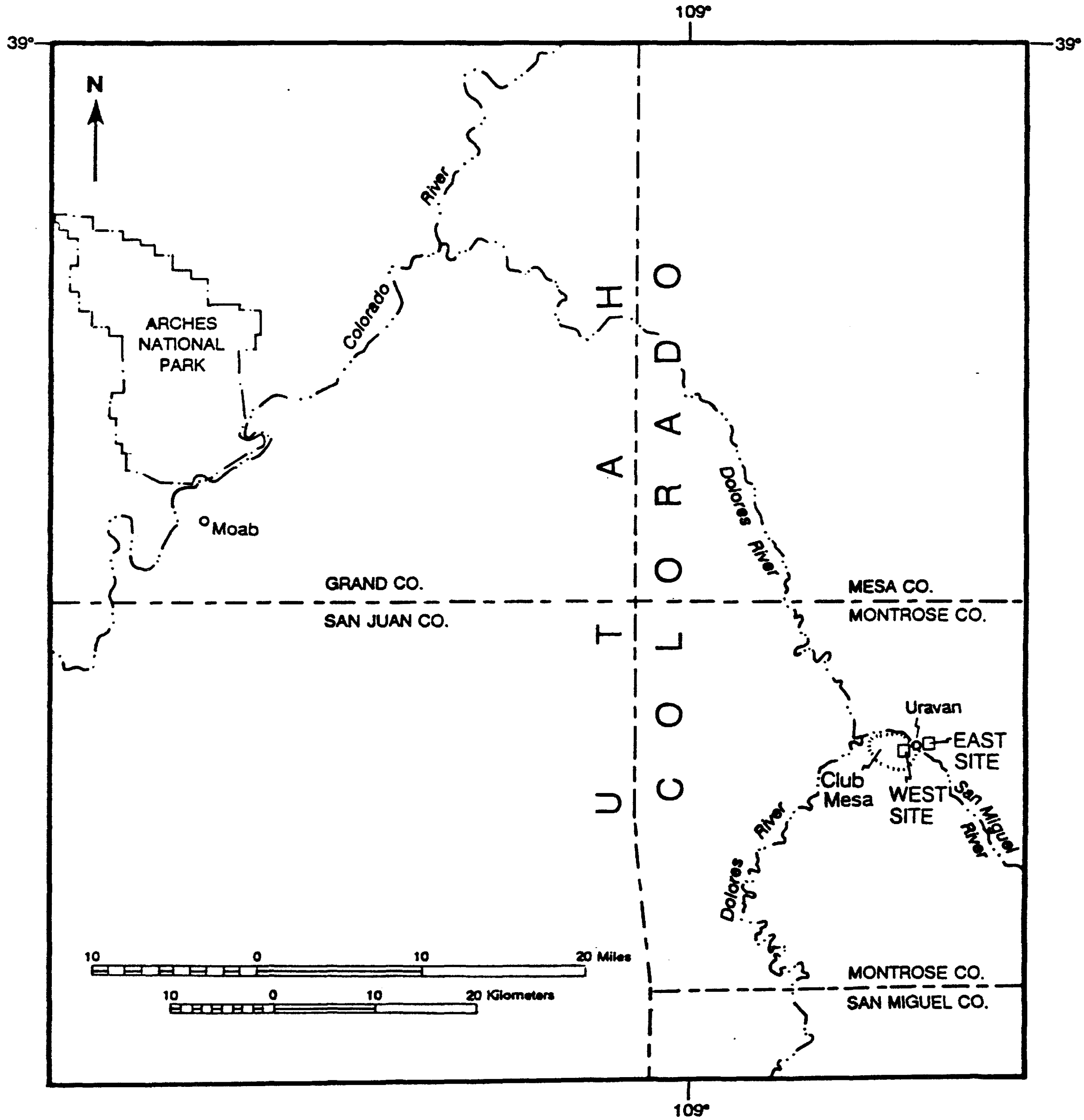
Solomon, B.J., 1990a, Review of radioactive material license application for regional low-level radioactive waste disposal facility, Montrose County, Colorado, in Black, B.D., compiler, Technical reports for 1989-1990 -- Applied Geology Program: Utah Geological and Mineral Survey Report of Investigation 220, p. 148-150.

---1990b, Review of Colorado Department of Health hearing exhibits related to a proposed low-level radioactive waste disposal facility, Montrose County, Colorado, in Black, B.D., compiler, Technical reports for 1989-1990 -- Applied Geology Program: Utah Geological and Mineral Survey Report of Investigation 220, p. 152-157.

Attachment 1. Job No. 93-02

Base Map from STATE OF UTAH and STATE OF COLORADO U.S.G.S. topographic maps.



Attachment 1. Location map.

Project: Review of "Report, geoseismic study, Ms. Elaine Fast residential home, 562 South East Oaks Drive, Lot 19, Plat B, East Oaks Subdivision, Fruit Heights, Utah".			Requesting Agency: City of Fruit Heights
By: Mike Lowe	Date: 5-4-92	County: Davis County	Job No: 92-05 (R-3)
USGS Quadrangle: Kaysville (1320)			

INTRODUCTION

The purpose of this report is to review the engineering geology aspects of a geotechnical report (Sergent, Hauskins, and Beckwith, 1992) for a residential lot located in the SW1/4NE1/4 section 1, T. 3 N., R. 1 W., SLBM, in the East Oaks subdivision at approximately 562 S. East Oaks Drive, Fruit Heights, Utah. The review was requested by Dallas Monsen, Fruit Heights City Public Works Director. The scope of work included a literature review, examination of aerial photographs (1937, 1:20,000 scale; 1985, 1:24,000 scale), and a field visit on April 29, 1992.

The Sergent, Hauskins, and Beckwith (1992) report identifies earthquake ground shaking and surface faulting as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. With respect to earthquake ground shaking, the Sergent, Hauskins, and Beckwith (1992) report recommends that, as a minimum, buildings be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. This is in accordance with requirements for earthquake-resistant design of buildings under the 1991 UBC.

With respect to surface faulting, an exploration trench was excavated just south of the proposed building site. Sergent, Hauskins, and Beckwith (1992) report that there was no evidence of surface faulting in the trench. Nelson and Personius (1990) map an approximately located scarp of the Wasatch fault zone along the east side of East Oaks Drive just south of the proposed lot, but the location of this scarp with respect to the lot is unclear. In any event, the lack of evidence for past surface faulting in the Sergent, Hauskins, and Beckwith (1992) trench indicates that secondary faulting is not common at this position on the fault scarp. In conclusion, the Sergent, Hauskins, and Beckwith (1992) report appears to adequately address the potential surface-faulting hazard at the site.

It is important to note that this trenching study reduces the likelihood that displacements will occur through the house at the site during future surface-faulting events, but it does not preclude the possibility. Although the slope at the site is too small to be shown on the Davis County Planning Commission (1989) Landslide Hazard Map - Kaysville Quadrangle, slope stability is a concern for any construction on or near a slope exceeding 30 percent. Although the slope appears stable now, it may be destabilized by slope alterations or addition of excessive quantities of water on or above the slope, and a setback from the edge of the scarp may be prudent. Unless geotechnical evidence is provided to indicate otherwise, I generally recommend a minimum setback to the point where a 2:1 slope (2 horizontal to 1 vertical) for dry granular soils, or a 2.5:1 slope for moist fine-grained soils, projected from the midpoint of the slope, intersects the ground surface at the top (Robison and Lowe, 1990). The type of soils and slope angle at the site should be evaluated to determine if a setback is necessary.

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Project: Review of "Report, surface-fault-rupture potential investigation, two single-family building lots located on the west side of 1800 East Street at approximately 300 South, East Oaks Subdivision, Fruit Heights, Utah".			Requesting Agency: City of Fruit Heights
By: Mike Lowe	Date: 5-4-92	County: Davis County	Job No: 92-06 (R-4)
USGS Quadrangle: Kaysville (1320)			

INTRODUCTION

The purpose of this report is to review the engineering-geology aspects of a geotechnical report (Sergent, Hauskins, and Beckwith, 1991) for two lots located in the NW1/4NE1/4 section 1, T. 3 N., R. 1 W., SLBM, in the East Oaks subdivision at approximately 300 S. 1800 E., Fruit Heights, Utah. The review was requested by Dallas Monsen, Fruit Heights City Public Works Director. The scope of work included a literature review, examination of aerial photographs (1937, 1:20,000 scale; 1985, 1:24,000 scale), and a field visit on April 29, 1992.

The Sergent, Hauskins, and Beckwith (1991) report identifies earthquake ground shaking and surface faulting as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. The report also addresses potential soil-foundation problems due to fill; these recommendations should be reviewed by a geotechnical engineer and are not considered in this review.

With respect to earthquake ground shaking, the Sergent, Hauskins, and Beckwith (1991) report recommends that, as a minimum, buildings be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. With respect to surface faulting, the report recommends that buildings be set back at least 50 feet from the crest of the Wasatch fault scarp near the western edge of the lots.

These recommendations are reasonable approaches to reducing the seismic hazards at the site. The recommendations for reducing surface-faulting hazards are in agreement with setback recommendations presented in Davis County Planning Commission (1991) and Lowe (1991) which define the crest of the scarp as the point where the scarp slope decreases to less than 30 percent. This setback should also help reduce potential slope instability problems related to post-surface-faulting raveling or landsliding. In conclusion, the Sergent, Hauskins, and Beckwith (1991) report appears to adequately address the potential seismic hazards at the site.

It is important to note that this setback reduces the likelihood that displacements will occur through the house at the site during future surface-faulting events, but it does not preclude the possibility. From my review, it appears likely that the scallop-shaped reentrant in the fault scarp at the west edge of the site is an old landslide scarp. If this is true, the fault setback may not be necessary, but a setback may still be prudent. Although the slope appears stable now, it may be destabilized by slope alterations or addition of excessive quantities of water on or above the slope. Unless geotechnical evidence is provided to indicate otherwise, I generally recommend a setback to the point where a 2:1 slope (2 horizontal to 1 vertical) for dry granular soils, or a 2.5:1 slope for moist fine-grained soils, projected from the midpoint of the slope intersects the ground surface at the top (Robison and Lowe, 1990).

REFERENCES CITED

Davis County Planning Commission, 1991, Geologic hazards and land-use planning: background, explanation, and guidelines for development in Davis County in designated geologic hazards special study areas: Unpublished Davis County Planning Commission Report, 78 p.

Lowe, Mike, editor, 1991, Geologic hazards and land-use planning: background, explanation, and guidelines for development in Davis County in designated geologic hazards special study areas: Utah Geological Survey Open-File Report 198, 78 p.

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Project: Review of "Preliminary geotechnical site assessment, Lot # 6, East Oaks Plat B, Fruit Heights, Utah."			Requesting Agency: City of Fruit Heights
By: Mike Lowe	Date: 5-4-92	County: Davis County	Job No: 92-07 (R-5)
USGS Quadrangle: Kaysville (1320)			

INTRODUCTION

The purpose of this report is to review the engineering geology aspects of a geotechnical report (CTC-Geotek, 1992) for a residential lot located in the NW1/4NE1/4 section 1, T. 3 N., R. 1 W., SLBM, in the East Oaks subdivision at approximately 402 S. East Oaks Drive, Fruit Heights, Utah. The review was requested by Dallas Monsen, Fruit Heights City Public Works Director. The scope of work included a literature review, examination of aerial photographs (1937, 1:20,000 scale; 1985, 1:24,000 scale), and a field visit on April 29, 1992. Geotechnical engineering aspects of the report, such as design of cut slopes and retaining walls, should be reviewed by a qualified geotechnical engineer.

The CTC-Geotek (1992) report identifies erosion and landsliding as the principal geologic hazards at the site. This is not a complete and accurate listing of the potential hazards; earthquake ground shaking and surface faulting are also potential hazards at this location. The report does not adequately address these hazards, and contains interpretations that are not consistent with published literature and field evidence.

The slope at the site is not an ancient Lake Bonneville terrace as the CTC-Geotek (1992) report states, but is a scarp of the Wasatch fault zone which has displaced both the lake deposits and the overlying middle Holocene to uppermost Pleistocene alluvial-fan deposits (Nelson and Personius, 1990). Lake deposits are exposed in the steeper portions of the slope due to surface faulting after lake and alluvial-fan deposition ceased.

The CTC-Geotek (1992) report states that "we observed no obvious embankments that could be interpreted as fault scarps at the site and surrounding neighborhoods." As I have pointed out above, the hill that was interpreted in the report to be "the slope of an ancient Lake Bonneville terrace" is in fact a scarp of the Wasatch fault zone. This is well documented in the published literature; reports clearly identifying the origin of the scarp include Swan and others (1980, 1981), Schwartz and Coppersmith (1984), and Nelson and Personius (1990).

The CTC-Geotek (1992) report states that "there is no evidence to suggest that an earthquake is imminent in the immediate vicinity of Fruit Heights." The word imminent is not defined, nor is the magnitude of the earthquake to which the report is referring. The Wasatch fault zone is considered capable of generating earthquakes up to magnitude 7.0-7.5 (Schwartz and Coppersmith, 1984; Machette and others, 1991). Earthquakes, generally too small to be felt, occur frequently along the Wasatch Front, including the Fruit Heights area, and an earthquake up to magnitude 6.0-6.5 could occur at any time along the Wasatch Front (Arabasz, 1991).

The CTC-Geotek (1992) report states that "the apparent lack of displacement indicates relative fault stability in this area." Evidence from the Kaysville trench site located 0.3 miles south of the site (just south of the south end of Vista Drive, Fruit Heights), indicates that recurrent ground displacements have occurred along this portion (Weber segment) of the Wasatch fault zone (Swan and others, 1980, 1981; Schwartz and Coppersmith, 1984). Lowe and others (1992) and McCalpin and others (in preparation) have reinterpreted ages of faulting at the Kaysville trench site, and conclude that: (1) the most recent surface-faulting event occurred slightly more than 700-930 years B.P. (before present), (2) the penultimate event occurred about 2,600-2,800 years B.P., and (3) the antepenultimate event occurred between 4,700 and 6,300 years ago. The last three faulting events were accompanied by vertical displacements ranging from 1.4 to 3.4 meters (4.6-11.2 feet), and the average recurrence interval for those events ranges from 1,600 to 2,100 years. At the East Ogden trench site, also on the Weber segment of the Wasatch fault zone, Nelson (1988) reports an average recurrence interval of 1,400 years for events occurring during the last 5,500 years.

The CTC-Geotek (1992) report identifies landsliding (minor blocking) and erosion as processes which are occurring within the boundaries of the proposed residential building lot. To evaluate the stability of the slopes at the Fruit Heights site, the CTC-Geotek (1992) report applies data gathered by Kaliser (1972) in Morgan County to the slopes of the fault scarp. In Morgan County, much of the material is coarse-grained lake deposits or consists of or is derived from the Norwood Tuff. At this site in Davis County, the material is alluvial-fan and fine-grained lake sediments derived primarily from the Farmington Canyon Complex. The geology is not similar, and therefore the Kaliser (1972) data may not apply. Historical landsliding has occurred at other locations along this fault scarp in Davis County (Davis County Planning Commission Slope-Failure Inventory Map, 1989, Landslides # LSa512, LSa513, LSa518, LSa524, and LSa525).

In conclusion, the CTC-Geotek (1992) report does not adequately address the potential geologic hazards at the site. Earthquake ground shaking could occur at the site, and as a minimum, buildings must be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC 1991 edition) seismic zone 3. The slope on which the proposed lot is located is a scarp of the Wasatch fault zone, and the fault likely crosses the site. I recommend that either a site-specific study be conducted to evaluate potential surface faulting with respect to the proposed building site, and/or that the potential hazard be disclosed to this and all subsequent buyers. The scope of investigation for site-specific fault studies is outlined in Davis County Planning Commission (1991) and Lowe (1991). Landsliding has been identified by CTC-Geotek (1992) to be affecting the proposed lot, and it appears that much site grading (cut and fill) will be required. Detailed grading plans should be prepared and reviewed by geotechnical engineers, and I recommend they be in compliance with chapter 70 of the UBC.

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Wasatch fault zone near Ogden, Utah, in Machette, M.N., editor, In the Footsteps of G.K. Gilbert -- Lake Bonneville and neotectonics of the eastern Basin and Range Province: Utah Geological and Mineral Survey Miscellaneous Publication 88-1, p. 33-37.

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Swan, F.H., III, Schwartz, D.P., Hanson, K.L., Knuepfer, P.L., and Cluff, L.S., 1981, Study of earthquake recurrence intervals on the Wasatch fault at the Kaysville site, Utah: U.S. Geological Survey Open-File Report 81-228, 30 p.

Project:			Requesting Agency:
Review of a slope-stability report for lots in the Eastwood Subdivision No. 8, Uintah, Weber County, Utah.			Weber County Planning Commission
By: Kimm M. Harty	Date: 5-29-92	County: Weber County	Job No: 92-09 (R-6)
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

In response to a request by Ed Reid, Weber County Planning Commission, the Utah Geological Survey (UGS) reviewed a consultant's report (Job No. F92-2167) by Sergent, Hauskins & Beckwith (SH&B) entitled "Slope stability reconnaissance, lots 7, 8, 9, 10, and 11, Eastwood Subdivision No. 8, Uintah, Weber County, Utah." The purpose of this review was to evaluate whether geologic hazards, particularly landslide hazards, were adequately addressed in the report. The subdivision is between Osmond Drive and 2858 E. Street in the town of Uintah, and is in sections 23 and 24, T. 5 N., R. 1 W., Salt Lake Baseline and Meridian. The scope of the review was limited to an evaluation of the SH&B report, and other geologic literature and maps available for the area. No field work was undertaken.

In general, the report satisfactorily explains the geologic conditions present at the site. However, there are some aspects of the report that warrant further comment.

Lowe (1988a) mapped an active landslide in the northern part of the subdivision that impacts lot 11 and possibly lot 10. This area is shown on SH&B figure 2 as an "area of abundant seepage and numerous landslide features." Because of the presence of a possible active landslide in this area, I concur with the statement in the report (p. 3) that development on lot 10 would require further site-specific study, and that lot 11 may require extensive remedial treatment that may be economically unfeasible.

Maps by Lowe (1988a), Nelson and Personius (1990), and the SH&B report all show a number of landslide scarps in and near the subdivision, although the locations of these scarps differ among reports. However, all three reports suggest that the entire subdivision is underlain by a landslide, and there is general agreement that the landslide is likely "old" and inactive. However, the SH&B report identified a number of small (4- to 6-inch-high) minor scarps in lot 8 (SH&B figure 2) that are believed to have formed by minor earth movements during the wet period of 1983-1984. Because the SH&B report characterizes these scarps (p. 3) as "relatively sharp and unvegetated", they may have formed even more recently that eight or nine years ago.

Because of the presence of a landslide underlying the lots, the

SH&B report recommends installing a network of subsurface drains to reduce the possibility of further rejuvenated movement of the landslide. The report also recommends (p. 5) that the lots be landscaped with natural vegetation to minimize the need for watering. Although the hazard-reduction measures detailed in the SH&B report are valid recommendations, instituting these measures may not preclude the possibility of further movement of the landslide or portions of the landslide in the future. This point is also made in the SH&B report (p. 4), which states, "The risk associated with potential reactivation of landslides at the site cannot be eliminated." Although not directly addressed in the report, the slope profile in figure 3 of the SH&B report shows portions of the subdivision to be on steep slopes of at least 25 degrees (nearly 2:1). Because the subdivision is in an area of steep slopes where recent landslide movement has occurred, I agree that the possibility of future landslide movement cannot be dismissed.

I concur with the statement on page 3 of the SH&B report that any grading at the eastern part of the subdivision be done without placing significant amounts of fill in the area, and I further recommend that <u>any</u> grading of the subdivision lots be done under the supervision of a qualified geotechnical engineer.

The SH&B report advises (p. 5) that "...rainwater and snowmelt collected on roofs and driveways should be conveyed into the drainage trenches without being allowed to pond or percolate into the subsurface." This recommendation may be interpreted as placing some responsibility for landslide-hazard reduction on potential homeowners. If this is the case, information on landslide hazards at the site, including the existence of this report, must be disclosed to all potential lot owners. Buyers of subdivision lots must be made aware that the lots are in a landslide-hazard area, and that homeowners are responsible for diverting water into designated drainage structures.

Another concern regarding rejuvenated landslide movement is the possible effect of water introduced into the landslide from areas outside the subdivision. The main body of the landslide extends farther upslope of these lots, and disturbance of the slope geometry and/or introduction of water into the subsurface in upslope areas could rejuvenate movement of the landslide and adversely impact the subdivision.

On page 4, the SH&B report states that "It is our opinion that design and construction at the site conforming to the recommendations described above will minimize the risk to a reasonable and acceptable level." This statement infers that the risk from landsliding will be reduced, but it does not define what is an acceptable level of risk, nor does the report attempt to quantify the current and potential risk at the site. Quantifying the stability of the landslide underlying the subdivision could be achieved by performing a factor-of-safety analysis, whereby landslide stability is determined by considering site factors such as soil conditions, hydrology, and failure geometry. This analysis could also evaluate the effects of earthquake ground shaking on slope stability. Varying the depth of the water table in the analysis could be done to determine under what hydrologic conditions the landslide may fail. The Utah Geological Survey recommends that a factor-of-safety analysis be performed at the subdivision to assess the current stability of the subdivision lots and to determine under what conditions the underlying landslide might reactivate. The results of this study would provide information that could be used by the town of Uintah and Weber County to assess whether or not the risk is acceptable to them.

Citing the work of Personius and Nelson (1990), the SH&B report states that the Weber segment of the Wasatch fault is about 1/4 mile (1,320 feet) east of the subdivision. However, both Lowe (1988b) and Nelson and Personius (1990) show the main trace of the fault to be about 900 feet to the east of the area, and an antithetic fault about 700 feet east of the lots in the southern part of the subdivision. Although traces of the Wasatch fault appear to be closer to the subdivision than stated in the SH&B report, no known fault traces have been identified within the subdivision. Due to a curve in the fault to the north of the subdivision, the 500-foot wide surface-fault-rupture-hazard zone as mapped by Lowe (1988b) encompasses the northeastern half of lot 11. If development on lot 11 is planned, further site-specific study of faulting as well as slope stability would be required.

With the exception of lot 11 of the subdivision being in a surface-fault-rupture-hazard zone, the SH&B report adequately outlines geologic hazards present at the proposed subdivision site. Although instituting the recommended landslide-hazard-reduction measures cited in the report will likely reduce the possibility of future landslide movements, the measures do not guarantee that the site will remain stable in the future. Additionally, the report states that instituting the recommended measures will minimize the risk from landsliding to a "reasonable and acceptable level" without defining or quantifying this level of risk. Performing a factor-of-safety analysis would help to assess the current stability of the landslide, thereby providing information to be used to determine if the risk is acceptable. However, because the subdivision is on a landslide that has shown evidence of recent movement, the possibility remains that the landslide could reactivate in the future, regardless of its current state of stability.

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Lowe, Mike, 1988b, Potential surface-fault rupture sensitive area overlay zone - Ogden quadrangle: Weber County Planning Commission unpublished map, scale 1:24,000.

Nelson, A.R., and Personius, S.F., 1990, Preliminary surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2132, 22 p., scale 1:50,000.

Project: Review of the Site Remediation Company proposal "Remediation Plan Sharon Steel Tailings"			Requesting Agency: Resource Development Coordinating Committee
By: William R. Lund	Date: 5-20-92	County: Salt Lake	Job No: 92-10 (R-7)
USGS Quadrangle: Midvale (1172)			

This memo was a review of the Site Remediation Company's proposed remediation plan for the Sharon Steel Tailings site, based on information received from Barry J. Solomon and J. Wallace Gwynn of the Utah Geological Survey.

State of Utah
DEPARTMENT OF NATURAL RESOURCES
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MEMORANDUM

TO Brad Barber, State Planning Coordinator

FROM: William Lund, Deputy Director

SUBJECT: Review of the Site Remediation Company proposal "Remediation Plan Sharon Steel Tailings"

DATE: May 20, 1992

INTRODUCTION

Site Remediation Company (SRC) has prepared a proposed remediation plan for the Sharon Steel tailings (an EPA Superfund site) that involves encapsulation of the hazardous material in a causeway to the south end of Antelope Island in the Great Salt Lake. The UGS has reviewed the proposal and has a number of concerns with the proposal which are presented below.

Our primary concern is that the proposed Remediation Plan be considered for what it is, a conceptual document - not a decision document. The proposal does a good job of presenting the basics of an idea, but does not contain the detailed information necessary to select the encapsulated causeway concept as the preferred tailings remediation alternative. Much of the technical information in the document is dated or inadequately referenced, making it impossible to evaluate the technical feasibility of the proposal. In addition, there is a lack of project-specific information regarding a variety of geochemical parameters critical to the plan, no site-specific geotechnical information regarding foundation and construction material suitability, and no information regarding a number of geologic hazards with the potential to adversely affect the proposed causeway.

GEOCHEMICAL CONCERNS

The proposed Remediation Plan assumes that the Great Salt Lake has the capacity to "cleanse itself" of potential contaminants should they enter the lake from the encapsulated tailings. However, a detailed chemical analysis of this assumption has not been undertaken. Factors to consider include:

- **Physical and chemical characterization of the tailings.** This should include the size distribution, mineralogy, petrology, and overall chemical composition of both thehazardous and nonhazardous tailings constituents. Consideration must also be given to the possible presence of any residual chemicals or agents remaining in the tailings from the milling process (cyanide, mercury, others?).

- **Characterization of the present-day physical and chemical properties of the Great Salt Lake.** This should include determining the lake's major- and trace-element composition, pH, Eh, dissolved gasses, density, temperature, and overall chemical characteristics. Of particular concern is the present-day absence of density stratification within the lake. The most recent (3-24-92) depth-density profile of the lake (UGS sampling site RT2) shows that both the physical and chemical characteristics of the South Arm brines have changed dramatically since the studies cited in the SRC proposal were performed. Lake waters now appear to be fully oxygenated from top to bottom (no density stratification or high H_2S zone) even in the deepest part of the lake.

- **Leachability of the tailings during slurry transport and under lake conditions should a causeway breach or inundation occur.** This should include identification of chemical reactions and rates, identification of both solid and dissolved species, chemical equilibria in Jordan River and lake water, and equilibrium times.

- **Detailed evaluation of the purported "self cleansing" mechanism(s) of the lake.** This should include a review of the various possible or potential "cleansing" mechanisms in the lake and the conditions necessary for them to operate. The evaluation should be specific to the actual conditions (chemical and physical) documented at the causeway site, not conditions that may or may not now exist in the deeper parts of the lake far removed from the tailings.

- **Long- and short-term effects of potential hazardous materials introduced into the lake on the lake's flora and fauna.** This should include the effects of leached heavy metals and introduced chemicals and/or reagents such as flocculants on brine shrimp, algae, water birds, and shore vegetation. The potential effect on water quality in the vicinity of the beaches along the south shore of the lake and on Antelope Island should also be analyzed.

GEOTECHNICAL CONCERNS

The Remediation Plan proposal does not address several significant geotechnical issues which could have a direct bearing on the success (feasibility and cost) of the remediation plan. They include:

- **Site-specific determination of the suitability of the lake-bottom sediments as foundation material for the causeway and as construction material for the adjacent low-permeability berms paralleling the causeway.** The plan states (p. 54) that the causeway "follows a natural sill alignment which resulted from deposition of both riverine and lakebed materials." If that is the case, the multiple sediment sources for the "sill" may have caused considerable variation in sediment types along the proposed causeway alignment. Such variability could significantly affect foundation characteristics and suitability of some lake-bottom sediments for constructing the low-permeability dikes (see discussion below in Geologic Hazards section on the possible presence of liquefiable sediments in the lake bed).

- **Evaluation of both static and dynamic design criteria that may affect the performance of the causeway.** This should include an evaluation of slope stability under both static and dynamic (earthquake) conditions, liquefaction potential of both the foundation materials and the tailings, and potential cracking of the soil cap (either from settlement, soil shrinkage, or ground shaking) and the consequences of the resultant infiltration of precipitation into the no longer encapsulated tailings.

- **Evaluation of the potential for dissolution of soluble foundation materials due to changes in local lake or ground-water chemistry and from eventual infiltration through the tailings.** Portions of the bed of the Great Salt Lake are underlain by precipitated salt deposits (chiefly mirabilite). Changes in lake-water or ground-water chemistry resulting from construction of the causeway may cause these deposits to dissolve. If present beneath the causeway, dissolution of these deposits could cause serious foundation problems and settlement.

GEOLOGIC HAZARDS

Regardless of the site chosen for final disposal of the tailings, there will be environmental and geologic hazards that must be mitigated. In some cases mitigation may mean long-term monitoring and maintenance of the disposal site. The mill tailings will never loose their harmful characteristics; therefore, the disposal site must remain safe forever (geologic time). Because the tailings will remain hazardous long after society's ability to guarantee institutional control over the site, the disposal alternative selected should be the one with the fewest known hazards and the one that requires the lowest level of monitoring and maintenance.

Lake-Level Fluctuations and Storm Events

As amply demonstrated during the wet years of 1983-1984, and as documented in the geologic record, the Great Salt Lake is a dynamic environment subject to large, rapid changes in lake level. Because of the long time frame considered for tailings disposal, the ability of the GSL pumps to regulate the lake level over the next 40 to 60 years is of no consequence when considering disposal site suitability. Placing the tailings in the bed of the lake will subject them to all future lake-level fluctuations, possibly leading to their partial or complete inundation. Additionally, destructive storms with recurrence intervals measured in years, or at most decades, are common on the lake. Although as proposed the causeway would be in a partially sheltered location during periods of low lake level, it is our opinion that storm events could erode or even overtop the causeway, particularly in high-water years. Therefore, we believe that there is a much greater potential for the tailings to remain in place at a dry land site than if they are subjected to the action of the Great Salt Lake over a long period of time.

Earthquake-Related Hazards

The Wasatch Front is an active earthquake area, a fact not mentioned in the Remedial Action proposal. Large earthquakes will occur in the future on the nearby Wasatch fault, on active faults beneath the lake, and on other active faults in the Salt Lake and Tooele valleys. Those seismic events will subject the proposed causeway to a variety of primary and secondary geoseismic hazards. Primary geoseismic hazards include surface fault rupture, strong ground shaking, and permanent tectonic deformation. Secondary hazards include landsliding and liquefaction caused by strong ground shaking and generation of seiche waves on bodies of standing water.

Although not likely to be affected by surface fault rupture, the proposed causeway would be subject to strong ground shaking in the event of a large earthquake on either of the nearby Weber or Salt Lake City segments of the Wasatch fault, the West Valley fault zone, the Northern Oquirrh Mountain fault zone, or one of the active faults beneath the lake. If strong enough and of long enough duration, the ground shaking may cause cracks to form in the causeway or induce settlement (see earlier recommendation for a dynamic analysis of the causeway).

Permanent ground deformation occurs when a basin is preferentially lowered on one side during an earthquake by displacement along a normal-slip fault. The lowering permanently tilts the ground surface toward the fault. In areas adjacent to bodies of standing water (in this case the Great Salt Lake), the tilting can result in the rapid inundation of large areas and the possible overtopping of dikes and other in-lake structures. There is evidence in the geologic record (several subparallel channels of the Jordan River progressively diverted toward the Wasatch Range) of permanent tectonic deformation and ground tilting in the vicinity of the proposed causeway.

Liquefaction occurs when shallow, saturated, clean sandy sediments are subjected to strong ground shaking. Pressure develops in the water occupying the voids between the sand grains, forcing the grains apart and causing the sand horizon to temporarily lose its bearing strength (form quicksand). When liquefaction occurs, there are a several possible results. Sand boils (volcanoes) may form that spew sand and water over the ground surface causing voids in the subsurface which may collapse; structures built on liquefiable soils may settle or even sink into the ground; and where liquefaction occurs beneath a slope of even a few degrees, lateral-spread ground failure may occur. In a lateral-spread failure, a block of ground slides laterally downslope on the liquefied horizon. Some ancient lateral-spread failures identified along the Wasatch Front have involved several hundred acres of ground, failed on slopes of less than 3 degrees, and moved several hundred to possibly thousands of feet downslope. A failure of that magnitude beneath the causeway could transport a large segment of the structure out into the lake. Previous drilling in the bed of the lake for the Great Salt Lake Antelope Island Diking Project in 1985 identified potentially liquefiable sand horizons near the proposed causeway alignment.

Wind generated seiche waves are common on the Great Salt Lake and can be severe in their own right. The greater density of the salty water increases wave energy and erosive capability. However, wind-generated wave amplitudes rarely exceed 1.5 to 2 feet with a total shoreline run up of about 7 feet. Seiches generated by earthquakes on the other hand can be large and potentially very destructive. Two earthquake-generated seiches have been reported in the Great Salt Lake, one in 1909 and the other in 1934. Both were caused by earthquakes with epicenters located in Hansel Valley at the north end of the lake. The 1909 wave is reported to have overtopped the old railroad causeway across the north end of the lake. Similar, and probably much larger waves (the Hansel Valley earthquakes were both less than M 7 events) can be expected to accompany large earthquakes in the future. Earthquake-generated seiches may overtop the causeway or cause considerable erosion unless the sides of the structure are protected with rip rap.

SUMMARY

The information presented in the SRC Remediation Plan for the Sharon Steel tailings is insufficient to determine the technical feasibility of the proposed project. Before this plan is accepted as the preferred tailings disposal alternative, a great deal of additional geochemical and geotechnical data must be collected and analyzed. The final disposal plan must also address the mitigation of a variety of geologic hazards with the potential to adversely affect the causeway. Additionally, the state must consider the advisability of tailings disposal at a site with potential long-term high maintenance and monitoring requirements. Protecting the causeway from the high-energy environment of the Great Salt Lake would likely require more maintenance than if the tailings are disposed of at a dry land site. The state's concern is twofold: first, protecting citizens from exposure to the hazardous materials, and second, the long-term cost and responsibility for site maintenance and monitoring.

The UGS has considerable historical and current chemical data and geotechnical information available for the Great Salt Lake and vicinity which we would be happy to share and/or discuss with any of the interested parties in the causeway remediation plan. In addition, Dr. J. Wallace Gwynn of our staff has spent much of the past 15 years studying the chemical and physical characteristics of the lake. He is available for consultation with anyone wishing to take advantage of his expertise.

cc: Bard Ferrin, DPR
Alton Frazier, DNR
Paul Gillette, Water Resources
Karl Kappe, DSL&F
Scott Manzano, DEQ
Rod Millar, RDCC
Catherine Quinn, Wildlife Resources

Project: Review of "Report, debris flow and fault hazard assessment, 0.51-acre lot, NW¼ NW¼ NW¼ SW¼ sec. 24, T. 5 N., R. 1 W. Uintah, Weber County, Utah, for Mr. Charles W. Richards."			Requesting Agency: Weber County Planning Department
By: Mike Lowe	Date: July, 16 1992	County: Weber County	Job No: 92-13 (R-8)
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

The purpose of this report is to present the results of a review an engineering geology report (Sergent, Hauskins, and Beckwith, 1992) for a residential lot located on the north side of 6025 South Street at about 2850 East (NW¼ SW¼ section 24, T. 5 N., R. 1 W.), Uintah Highlands, Weber County, Utah. The review was requested by Ed Reed, Weber County Planning Department. The scope of work included a literature review and examination of aerial photographs (1985, 1:24,000 scale). A field inspection of the site had been previously conducted in March, 1992. Craig Barker, Weber County Planning Department, and John W. Hansen, real estate broker, were present during the field inspection.

The Sergent, Hauskins, and Beckwith (SH&B) report identifies earthquake ground shaking, surface faulting, debris flows, and shallow ground water as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. With respect to earthquake ground shaking, the SH&B report recommends that, as a minimum, buildings be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. This is in accordance with requirements for earthquake-resistant design of buildings under the 1991 UBC.

With respect to potential shallow ground water, the SH&B report recommends that the proposed residential structure be constructed with both a basement dewatering system designed to drain by gravity to the storm sewer, and an automatically activated pump system designed to function should the gravity drain fail. Because the presence of springs in the vicinity of the lot indicates that shallow ground water may occur at the site, these recommendations are prudent. The plans for the dewatering systems should be reviewed by a geotechnical engineer.

The SH&B report concludes that, based on the distribution of boulders on the ground surface in the vicinity of the proposed building lot, past debris flow activity on the lot was restricted to the southern edge. To minimize potential damages the report recommends that structures for human occupancy be positioned on the lot outside of the area where boulders were observed, and that the open basement excavation be inspected to verify that no debris-flow deposits are present at the house location. If debris-flow deposits are identified in the excavation, the SH&B report recommends that basement windows be eliminated on the upslope side of the house and that a deflection wall be constructed to deflect flowing debris around the structure. Weber County does not pre-approve lots pending such inspections (Ed Reed, Weber County Planning Department, verbal communication, July 16, 1992), so the hazard must be addressed prior to Planning Commission approval. Because deposition of debris on alluvial fans is constantly shifting in location as earlier debris flows are deposited and deflect subsequent debris flows to new locations on the fan surface, the absence of boulders on the ground surface does not conclusively indicate that debris-flow hazards are not present at the site. For this reason, I recommend they either perform further studies to address the hazard, or be conservative and assume the hazard is present and implement the debris-flow-hazard mitigation measures recommended in the SH&B report. If the recommended hazard-reduction measures are taken, the design of the deflection wall must be evaluated to make sure that it is adequate and debris is not deflected into structures on other lots.

The SH&B report states that the absence of an east-facing fault scarp in non-bouldery deposits probably indicates that the secondary fault trace mapped on the east side of Uintah Reservoir dies out before reaching the site rather than being buried by deposits younger than the most recent event. Nelson and Personius (1990) have mapped east-facing scarps at approximately the same position with respect to the main west-facing scarp on interfluve ridges for some distance both to the north and south of the proposed building lot. Although these east-facing scarps are intermittently absent, particularly where eroded away by drainages flowing from the mountains to the east, the scarps indicate that faults may be present in the vicinity of the proposed building lot. Subsurface investigation at the site, through either trenching or geophysical methods, are required to determine the potential surface-faulting hazard at the site.

In conclusion, the SH&B report adequately addresses potential earthquake ground shaking. A geotechnical engineer should review dewatering system designs for the proposed residential building. With respect to potential debris-flow hazards, Weber County Planning Department policies require that hazards be addressed prior to Planning Commission approval. Thus, either further work is needed to assess the hazard prior to excavation of the foundation or recommended hazard-reduction measures can be implemented. In the latter case, design of the deflection wall should be reviewed by a geotechnical engineer prior to construction. I believe that the potential surface-faulting hazard at the site has not been adequately evaluated and recommend that either a site-specific study be conducted to evaluate potential surface faulting with respect to the proposed building site, and/or that the potential hazard be disclosed to this and all subsequent buyers. The scope of investigation for site-specific fault and debris-flow studies is outlined in Weber County Planning Commission (1991) and Lowe (1991).

REFERENCES CITED

Lowe, Mike, editor, 1991, Geologic hazards and land-use planning -- background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Utah Geological Survey Open-File Report 197, 70 p.

Nelson, A.R., and Personius, S.F., 1990, Preliminary surficial geologic map of the Weber segment of the Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Map MF-2132, scale 1:50,000.

Sergent, Hauskins, and Beckwith, 1992, Report, debris flow and fault hazard assessment, 0.51-acre lot, NW¼ NW¼ NW¼ SW¼ sec. 24, T. 5 N., R. 1 W., Uintah, Weber County, Utah, for Mr. Charles W. Richards: Unpublished consultant's report, 4 p.

Weber County Planning Commission, 1991, Geologic hazards and land-use planning -- background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Unpublished Weber County Planning Commission Report, 70 p.

Project: Review of an Addendum Report for a slope-stability reconnaissance of lots in the Eastwood Subdivision No. 8, Uintah, Weber County, Utah.			Requesting Agency: Weber County Planning Commission
By: Kimm M. Harty	Date: 8-12-92	County: Weber County	Job No: 92-16 (R-9)
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

In response to a request by Ed Reid, Weber County Planning Commission, the Utah Geological Survey (UGS) reviewed an addendum report (Job No. E92-2167) by Sergent, Hauskins & Beckwith (SH&B) entitled "Report - addendum, slope stability reconnaissance, lots 7, 8, 9, 10, and 11, Eastwood Subdivision No. 8, Uintah, Weber County, Utah." The purpose of this review was to evaluate whether the SH&B addendum report adequately addressed concerns expressed by the UGS in the review of the initial report for the subdivision (UGS Job No. 92-09). For this review, the two SH&B reports will be referred to as the "initial report" and the "addendum report." The scope of this review included an evaluation of 1:24,000-scale aerial photographs, the addendum report, and other geologic literature and maps available for the area. No field work was undertaken.

The SH&B addendum report consists of data and discussion of a boring drilled to a depth of 40 feet in lot 9, at the west edge of 2850 East Street along the same profile where SH&B excavated test pits (see figure 2 of SH&B initial report). The addendum report states that in the core, an approximate 16.5-foot interval (at a depth between about 10 to 26.5 feet) of layered sediments was observed in otherwise massive sediments, and that the layering was "consistently horizontal or nearly horizontal." According to the addendum report, the horizontal layering observed in the boring matches that found in the uppermost test pit, located about 100 feet downslope (west) from 2850 East Street (figure 3 - initial report). Based on these data, the addendum report concludes that "...the eastern part of lots 7, 8, and 9 probably have not been involved in past landsliding." Additionally, the report maintains that "the probable landslide headscarp shown on Figure 2 ... must represent either a shallow landslide that does not extend into the area of the boring and test pit, or a non-landslide feature."

The addendum report addresses some but not all of the of the concerns raised in the UGS review of the initial report. The concerns remaining are outlined below.

The horizontal or "nearly horizontal" bedding reported as observed in the core and uppermost test pit indicate that significant rotational (slump-type) landsliding has not occurred, and (as stated in the addendum report), the scarp east of the subdivision may be a "non-landslide feature" or a landslide that is shallow and may not extend into the area of the subdivision. Alternatively, however, the subdivision may lie on a deep-seated landslide that either has moved very little or moved as a translational rather than rotational slide. Could this "non-landslide feature" be a fault scarp? It is still uncertain whether the eastern part of the subdivision lies on a landslide.

In a July 31, 1992 telephone conversation with Jeffrey Keaton, the author of the initial and addendum reports, Dr. Keaton stated that the homes in the Eastwood Subdivision No. 8 were to be constructed just to the west of 2850 East Street, in the eastern parts of the lots. The initial report outlines a plan for the construction of a network of subsurface drains to remove water from the upslope (eastern) parts of the lots (figure 4 - initial report). The initial report recommends that the drains be placed approximately 15 feet below the surface. As the presence or absence of the "eastern" landslide has not been confirmed, placing drains 15 feet deep may be inadequate if a deep-seated landslide is present such that the slide plane is below this depth and ground water migrates laterally into this area at depths below 15 feet. The main scarp, head, and upper portion of this landslide are located in an existing subdivision (which presumably lacks drains) upslope of the Eastwood Subdivision No. 8. Thus there is a possibility that water could be introduced into the landslide from this area. In addition, water could migrate to the landslide from a reservoir about 300 feet upslope of the main scarp, 600 feet upslope from the Eastwood Subdivision No. 8.

As acknowledged in the initial report, and visible on air photos, the western parts of lots 7, 8, 9, and possibly 10, are on a landslide. The main scarp of the landslide traverses roughly north-south through the lots (figure 2 - initial report). The subsurface drain network, as described in the initial report, is designed to remove water from only the upper (eastern) parts of the lots, not the lower (western) parts that lie on this landslide. Neither the initial report or the addendum report has adequately assessed the current stability or potential for future movement of this landslide, and any movement of this landslide could adversely affect the stability of the eastern parts of the lots.

In conclusion, the information presented in the initial and addendum reports is inconclusive with regard to the nature and stability of the landslides at this site, and no information is provided to quantify the risk these landslides may present. Although the subsurface drainage network to be used in the eastern parts of the lots will likely reduce the hazard from landsliding in this area, it does not guarantee that landslides will not occur in this area or farther downslope, where drains are not planned. Should Weber County and/or the City of Uintah permit construction of homes on these lots, the UGS strongly recommends that potential buyers of the lots be made aware of the existence of the SH&B

reports and our reviews.

REFERENCES CITED

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

Nelson, A.R., and Personius, S.F., 1990, Preliminary surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Fields Studies Map MF-2132, 22 p., scale 1:50,000.

Project: Review of a geotechnical study for lot 79, Greenhill Country Estates Subdivision No. 5, Ogden Valley, Weber County, Utah			Requesting Agency: Weber County Planning Commission
By: Kimm M. Harty	Date: 10-2-92	County: Weber County	Job No: 92-18 (R-10)
USGS Quadrangle: Browns Hole (1368)			

INTRODUCTION

In response to a request by Edward Reid, Weber County Planning Commission, the Utah Geological Survey (UGS) reviewed a report (Job No. 92-190) by Earthtec Testing and Engineering (ETE) entitled "Geotechnical study, proposed Bill Vine residence about 8800 E. Pineview Drive near Huntsville, Utah." The purpose of this review was to evaluate whether geologic hazards were adequately addressed in the report. The property encompasses about 5 acres and is in the NW 1/4 section 9, T. 6 N., R. 2 E., Salt Lake Baseline and Meridian. The scope of work included an evaluation of sections of the report dealing with geologic hazards, interpretation of 1:20,000-scale air photos, and review of geologic maps available for the area. No field work was undertaken. Sections of the ETE report dealing with foundation design should be reviewed by a geotechnical engineer.

The report satisfactorily explains geologic hazards present at the site with respect to expansive soils and seismic concerns. However, aspects of the report dealing with landslides warrant further comment.

Figure A-2 of the ETE report shows an approximate boundary of a landslide toe, which covers the northern part of the property. Geologic maps (1:24,000 scale) by Lowe (in preparation) show a large landslide that wholly contains the 5-acre parcel. The ETE report states that the landslide extends about 1500 feet upslope from the desired location of the house. The landslide mapped by Lowe extends for about 2,400 feet upslope of this same location, and extends southward where it approximately coincides with the southern boundary of the property (attachment 1). Geologic mapping by Crittenden (1972) shows a smaller, Holocene-age landslide a few hundred feet from the northwest corner of the property (attachment 1). In 1991, an earth slump occurred at about the same elevation as the property, along the same slope about 0.5 miles to the southeast (Harty and Lowe, 1992), providing further evidence that slopes in the region are subject to instability. Furthermore, geologic units that exhibit expansive characteristics, as is the case for this site, are also highly susceptible to landsliding when other factors such as moderate to steep slope gradients are present.

The ETE report does not show the entire landslide on any map in the report, and only depicts the portion of the landslide toe within the 5-acre parcel. In addition, the report does not adequately characterize the landslide type (for example, rotational slump, translational failure, earth flow), thickness, age, or the geology of the failure. Nor does the report provide an adequate assessment of the stability of this landslide. The two test pits excavated into the landslide confirm that the northern part of the site is a landslide, but no test pits were excavated in the southern part. The test pits encountered only a few feet of material beneath the "landslide toe," and no evidence or interpretation of these units is given to support the conclusion that they were not involved in landsliding.

The ETE report states that evidence of recent movement of at least a part of the landslide, in the form of "parallel horizontal cracking" (p. 2) was observed where the road grade for Pineview Drive was excavated along the northern (upslope) boundary of the property. Acknowledging the possibility of continued movement of this landslide, the ETE report recommends that the north wall of the house be designed as a retaining wall. Further recommendations include installing a 4-inch diameter foundation drain, although the extent of the drain is not detailed in the report.

Because the landslide appears large, and most of it is upslope of the property, the possibility that a reactivated landslide could override the back retaining wall and possibly damage the house must be addressed. The ETE report (p. 4) stresses the importance of not disturbing the toe of the landslide, but does not mention that other actions upslope of the property could also cause movement of the slide. Such actions include grading, loading of the head area, and addition of water. Disturbance of the landslide by road construction has apparently already reactivated a portion of the landslide. A telephone conversation on September 25th, 1992, with Bill Vine, potential buyer of the property, revealed that excavations are occurring on the landslide upslope of the property, apparently with no consideration or knowledge of the landslide. Reactivation can also occur when water is added to a landslide such as from large rainstorms, snowmelt, or by lawn and landscape watering that accompanies subdivision development.

Further field work by a qualified engineering geologist is needed to adequately define the full extent and character of this landslide, and better assess its stability and potential impact on the property. As the landslide covers an area much larger than the 5-acre parcel covered in this report, it would be advisable to pool resources and involve other affected landowners and/or land developers in assessment of this landslide. Only when more information on the nature and stability of this landslide is presented, including identification of possible active portions of the landslide, can a decision be made as to the suitability of the land for subdivision development. The UGS recommends that Weber County have the foundation design evaluated for adequacy by a geotechnical engineer, particularly the drain and retaining wall designs and the lateral earth pressure coefficient, if these design recommendations are retained in the final report.

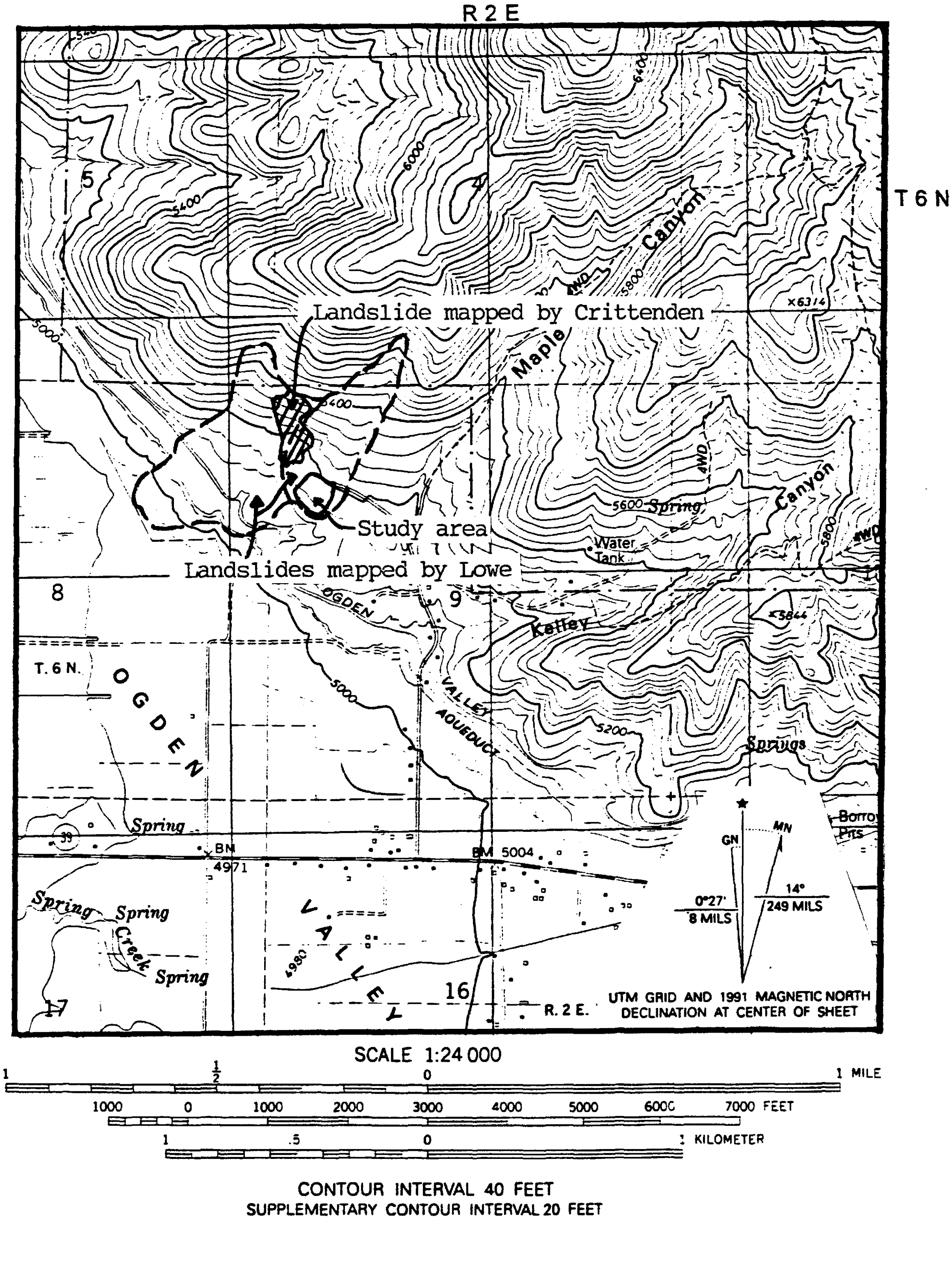
REFERENCES CITED

Crittenden, M.D., Jr., 1972, Geologic map of the Browns Hole quadrangle, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-968, scale 1:24,000.

Harty, K.M., and Lowe, Mike, 1992, Preliminary geologic evaluation of an earth slump in the Green Hill County Estates subdivision in Ogden Valley, Weber County, Utah, in Mayes, B.H., compiler, Technical reports for 1990-1991, Applied Geology Program: Utah Geological Survey Report of Investigation 222, p. 119-125.

Lowe, Mike, in preparation, Surficial geology of Ogden Valley: Utah Geological Survey Open-File Report, 69 p., scale 1:24,000.

Base map from USGS 7.5-minute topographic quadrangle "Browns Hole".



Attachment 1. Map showing study area and landslides mapped by Crittenden (1972) and Lowe (in preparation).

Project: Review of Southwest Testing report "Relationship of Springdale slide to proposed Watchman Theatre site."			Requesting Agency: Town of Springdale
By: Mike Lowe	Date: 10/23/1992	County: Washington	Job No: 92-20 (R-11)
USGS Quadrangle: Springdale West (74), Springdale East (73)			

The purpose of this report is to review a landslide-hazard-evaluation report (Southwest Testing, 1992) for the proposed Watchman Theater site in the NE1/4NW1/4 section 28, T. 41 S., R. 10 W., SLBM, Springdale, Utah. The review was requested by Paul A. Millett, Springdale Town Manager. The scope of work included a literature review. I had previously inspected the Balanced Rock Hills (Springdale) landslide in the field on September 2, September 9, and October 9, 1992, as part of the Utah Geological Survey's response to the September 2, 1992, magnitude 5.9 St. George earthquake (Black and others, 1992, attachment 1). The Southwest Testing (1992) report and this review address only the hazard posed to the proposed Watchman Theater site by the Balanced Rock Hills landslide; neither report addresses other hazards that may exist at the site.

The Southwest Testing report evaluates the potential threat of the Balanced Rock Hills landslide to the proposed Watchman Theater site which is approximately 225 feet (70 m) southeast of the toe of the landslide. The report indicates that the slide plane (surface of rupture) is up to 200 feet (60 m) below the surface of the slide mass in the northwest portion of the landslide, and that the landslide is intensely broken by open fissures which could channel any significant amount of water on the surface of the landslide down to the slide plane. The report concludes that the landslide will probably continue to move to the southeast at a rate that will vary depending on earthquake activity and precipitation. The report also concludes that, although the landslide will likely periodically override State Highway 9, the landslide will not reach the theater site unless a heavy rain producing 10 inches (25 cm) or more of water during a relatively short period of time occurs. The report states that if this heavy rain occurs, which has an "extremely remote" chance of happening but cannot be ruled out, a deeper surface of rupture may form and "the area between the highway and the Virgin River would become part of the slide mass" (Southwest Testing, 1992). The theater site is approximately midway between the toe of the landslide and the Virgin River.

To evaluate the conclusions presented in the Southwest Testing report, the data and slope-stability-analysis method used to reach the conclusions must be provided. This includes borehole or geophysical data used to identify the surface of rupture and determine ground-water conditions in the slide mass, and the results of laboratory tests used to evaluate rock and soil strengths. All input parameters used to calculate the stability of the landslide must also be provided and the slope-stability-analysis method identified. The geology of the landslide also should be discussed (see Utah Geological and Mineral Survey Miscellaneous Publication M, Guidelines for preparing engineering geologic reports in Utah). Also, a statement of qualifications of geologists and engineers conducting the investigation must be provided. Without this information, I have no basis to evaluate the report's conclusions.

If such data were not collected and evaluated, the investigation by Southwest Testing is inadequate to demonstrate that the site is safe. This does not necessarily mean that the report's conclusions are inaccurate, but rather that a sufficient technical basis for the conclusions has not been provided. Because of this, I do not recommend the town of Springdale approve the site on the basis of this report.

The town of Springdale should be aware of other potential hazards which occur in southwestern Utah which could be present at the proposed theater site, including earthquake ground shaking, liquefaction, rock fall, flooding, debris flows, expansive or collapsible soils, and other landslides. A potential hazard that should also be addressed is debris-laden flooding off the landslide which may affect the site. Regardless of conclusions concerning the hazard the landslide poses to the proposed Watchman Theater site, continued landslide movement and settlement, piping, erosion, and collapse and widening of fissures may cause further damage to structures on the landslide.

REFERENCES CITED

Black, B.D., Mulvey, W.E., Lowe, Mike, and Solomon, B.J., 1992, Investigation of geologic effects associated with the September 2, 1992, St. George earthquake, Washington County, Utah: Utah Geological Survey Technical Report 92-17, 10 p.

Southwest Testing, 1992, Relationship of Springdale slide to proposed Watchman Theater site: Unpublished consultant's report, 2 p.

Utah Section of the Association of Engineering Geologists, 1986, Guidlines for preparing engineering geologic reports in Utah: Utah Geological and Mineral Survey Miscellaneous Publication M, 2 p.

Project: Review of "Report, debris flow and fault hazard assessment, 1.27-acre lot, NW1/4 NW1/4 NW1/4 SW1/4 sec. 24, T. 5 N., R. 1 W. Uintah, Weber County, Utah, for Ms. Joan Malan."			Requesting Agency: Weber County Planning Department
By: Mike Lowe	Date: 3-30-93	County: Weber County	Job No: 93-04 (R-12)
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

The purpose of this report is to present the results of a review of an engineering geology report (Sergent, Hauskins, and Beckwith, 1992a) for a residential lot located on the east side of 2850 East at about 6025 South Street (NW1/4 SW1/4 section 24, T. 5 N., R. 1 W.), Uintah Highlands, Weber County, Utah. The review was requested by Ed Reed, Weber County Planning Department. The scope of work included a literature review and examination of aerial photographs (1985, 1:24,000 scale). A field inspection of the site had been previously conducted in March, 1992. Craig Barker, Weber County Planning Department, and John W. Hansen, real estate broker, were present during the field inspection. I have previously reviewed a similar report (Sergent, Hauskins, and Beckwith, 1992b) for a proposed residential lot adjacent to this site to the north.

The Sergent, Hauskins, and Beckwith (SH&B) report identifies earthquake ground shaking, surface faulting, debris flows, and shallow ground water as the principal geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. With respect to earthquake ground shaking, the SH&B report recommends that, as a minimum, buildings be designed and constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. This is in accordance with requirements for earthquake-resistant design of buildings under the 1991 UBC.

With respect to potential shallow ground water, the SH&B report recommends that the proposed residential structures in the shallow-ground-water areas shown on SH&B's figure 2 be constructed with both a basement dewatering system designed to drain by gravity to the storm sewer, and an automatically activated pump system designed to function should the gravity drain fail. Because the presence of springs in the vicinity of the lot indicates that shallow ground water may occur at the site, these recommendations are prudent. The plans for the dewatering systems should be reviewed by a geotechnical engineer.

The SH&B report concludes that, based on the distribution of boulders on the ground surface in the vicinity of the proposed building lot, past debris-flow activity on the lot was restricted to the northern half. To minimize potential damages the report recommends that structures for human occupancy be positioned on the lot outside of the area where boulders were observed, and that the open basement excavation be inspected to verify that no debris-flow deposits are present at the house location. If debris-flow deposits are identified in the excavation, the SH&B report recommends that basement windows be eliminated on the upslope side of the house and that a deflection wall be constructed to deflect flowing debris around the structure. Weber County does not pre-approve lots pending such inspections (Ed Reed, Weber County Planning Department, verbal communication, July 16, 1992), so the hazard must be addressed prior to Planning Commission approval. Because deposition of debris on alluvial fans is constantly shifting in location as earlier debris flows are deposited and deflect subsequent debris flows to new locations on the fan surface, the absence of boulders on the ground surface does not conclusively indicate that debris-flow hazards are not present at the site. For this reason, I recommend they either perform further studies to address the hazard, or be conservative and assume the hazard is present and implement the debris-flow-hazard mitigation measures recommended in the SH&B report. If the recommended hazard-reduction measures are taken, the design of the deflection wall must be evaluated to make sure that it is adequate and debris is not deflected into structures on other lots.

The SH&B report states that the absence of an east-facing fault scarp in non-bouldery deposits <u>probably</u> indicates that the secondary fault trace mapped on the east side of Uintah Reservoir dies out before reaching the site rather than being buried by deposits younger than the most recent event. Nelson and Personius (1990) have mapped east-facing scarps at approximately the same position with respect to the main west-facing scarp on interfluve ridges for some distance both to the north and south of the proposed building lot. Although these east-facing scarps are intermittently absent, particularly where eroded away by drainages flowing from the mountains to the east, the scarps indicate that faults may be present in the vicinity of the proposed building lot. Subsurface investigation at the site, through either trenching or geophysical methods, are required to determine the potential surface-faulting hazard at the site. However, because mapped fault traces project east of the site, and the report indicates no evidence of scarps on the site, disclosure of the existence of the SH&B report and this review is a reasonable alternative if further investigations are not performed.

In conclusion, the SH&B report adequately addresses potential earthquake ground shaking and shallow ground water. A geotechnical engineer should review dewatering system designs for the proposed residential buildings. With respect to potential debris-flow hazards, Weber County Planning Department policies require that hazards be addressed prior to Planning Commission approval. Thus, either further work is needed to assess the hazard prior to excavation of the foundation or recommended hazard-reduction measures can be implemented. In the latter case, design of deflection walls should be reviewed by a geotechnical engineer prior to construction. I believe that the potential surface-faulting hazard at the site has not been adequately evaluated and recommend that either a site-specific study be conducted to evaluate potential surface faulting with respect to the proposed building sites, and/or that the existence of the SH&B report and this review be disclosed to all subsequent buyers. The scope of investigation for site-specific fault and debris-flow studies is outlined in Weber County Planning Commission (1991) and Lowe (1991).

REFERENCES CITED

Lowe, Mike, editor, 1991, Geologic hazards and land-use planning -- background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Utah Geological Survey Open-File Report 197, 70 p.

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Sergent, Hauskins, and Beckwith, 1992a, Report, debris flow and fault hazard assessment, 1.27-acre lot, NW1/4 NW1/4 NW1/4 SW1/4 sec. 24, T. 5 N., R. 1 W., Uintah, Weber County, Utah, for Ms. Joan Malan: Unpublished consultant's report, 4 p.

Sergent, Hauskins, and Beckwith, 1992b, Report, debris flow and fault hazard assessment, 0.51-acre lot, NW1/4 NW1/4 NW1/4 SW1/4 sec. 24, T. 5 N., R. 1 W., Uintah, Weber County, Utah, for Mr. Charles W. Richards: Unpublished consultant's report, 4 p.

Weber County Planning Commission, 1991, Geologic hazards and land-use planning -- background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Unpublished Weber County Planning Commission Report, 70 p.

Project: Review of report on potential geologic hazards for the property at 670 North Van Buren Avenue, Ogden			Requesting Agency: Ogden City Community Development Department
By: Barry J. Solomon	Date: 4-20-93	County: Weber County	Job No: 93-05 (R-13)
USGS Quadrangle: North Ogden (1370)			

In response to a request from Greg Montgomery, Ogden City Current Planning Manager, a review was performed of a report on potential geologic hazards for the property at 670 North Van Buren Avenue, Ogden, Utah (Rentmeister, 1993). The scope of work also included a literature review, but not a field inspection of the site.

Rentmeister (1993) investigated the potential for three geologic hazards: debris flows, slope failure, and surface fault rupture. The potential for a fourth geologic hazard, rock fall, was not investigated. The potential for all of these hazards was previously addressed in geotechnical evaluations for adjacent properties (Dames & Moore, 1976; Delta Geotechnical Consultants, 1985). Maps of special study zones (Weber County Planning Commission, 1988; Lowe, 1989) delineate areas that may be subject to these geologic hazards. Surficial geology was mapped by Nelson and Personius (1990), who also interpreted the paleoseismic history of the Wasatch fault zone in the region. The potential for liquefaction-induced landslides was studied by Harty and others (in press).

The subject property is underlain by thin deposits of upper Holocene fan alluvium which overlie Pleistocene Lake Bonneville silt and clay (Nelson and Personius, 1990). The fan alluvium was deposited by intermittent streams, debris flows, and debris floods from Jumpoff Canyon to the east. The latest recorded debris flow from the canyon occurred on September 25, 1945, when boulders six to eight feet (2 to 2.5 m) in diameter were transported in a muddy matrix (Delta Geotechnical Consultants, 1985). Since then, Harrison Boulevard was constructed between the canyon mouth and the subject property. Rentmeister (1993) concludes that "the road would act as a channel" diverting future debris flows northward along the road. This conclusion may be, in part, correct. The road will likely reduce the potential debris-flow hazard, but may not eliminate it. The presence of upper Holocene fan alluvium, and the historical record of debris flows, suggests that this hazard will recur. Further information, to address both the potential for this hazard and the effectiveness of Harrison Boulevard as a diversion route, should be provided. If a hazard exists, hazard-reduction measures should be implemented in site design.

According to Rentmeister (1993), the subject property "sits on an old landslide." Weber County Planning Commission (1988) characterizes the site vicinity as underlain by a deep slope failure, consisting chiefly of slumps and earthflows. Nelson and Personius (1990) show these types of slope failure to be present on steep slopes northeast of the subject property. Dames and Moore (1976) did not note any evidence of slope failure on the property to the south, but Delta Geotechnical Consultants (1985) noted an "extensive, broken ground surface...interpreted as a possible inactive landslide area" to the southeast of the subject property. A landslide escarpment is mapped by Nelson and Personius (1990) about 100 feet (30 m) to the west of the subject property, and the same scarp has been remapped by Harty and others (in press) to be present on, or very near, the subject property. This feature probably represents the main scarp, buried by younger Holocene fan alluvium, of the liquefaction-induced North Ogden landslide complex. Parts of this complex may have moved during the Holocene (Harty and others, in press). All of these indications suggest that slope failure on the subject property may be possible. No quantitative data are given to support the conclusion of Rentmeister (1993) that "the earth material is stable." However, because the potential for slope failure is most likely related to earthquake-induced liquefaction, factors (shallow ground water and granular soils) which are conducive to this phenomenon need to be characterized. This has been done by Anderson and others (1990), who show the potential for liquefaction at the site to be very low. For single-lot subdivisions, this is sufficient to preclude the necessity for further work.

Rentmeister (1993) correctly states that "the main trace of the Wasatch fault lies some 800 feet to the east of the area in question" but also says that "there is no surficial evidence" to indicate closer surface fault rupture. This last statement appears incorrect. Dames and Moore (1976) did not find evidence of surface fault rupture on the adjacent property to the south, but a Quaternary fault is approximately located on that property by Weber County Planning Commission (1988), and this fault lies within 100 feet (30 m) of the eastern boundary of the subject property. Delta Geotechnical Consultants (1985) found "geologically recent" fault traces about 500 feet (150 m) east of the subject property, with displacements of about 25 feet (8 m). These fault traces appear to be the same as those mapped by Nelson and Personius (1990). The proximity of evidence for surface fault rupture suggests that subsurface investigations at the site, through either trenching or geophysical methods, would be prudent to determine the potential surface-faulting hazard at the site. However, because mapped fault traces do not project across the site, and Rentmeister (1993) indicates no evidence of scarps on the site, disclosure of the existence of the Rentmeister (1993) report and this review is a reasonable alternative if further investigations are not performed.

Although the potential for rock fall on adjacent sites was estimated to be remote (Dames & Moore, 1976; Delta Geotechnical Consultants, 1985), the subject property does lie within a rock-fall hazard special study zone (Lowe, 1989). Rock-fall and talus deposits, associated with undercutting of competent rock by Pleistocene Lake Bonneville wave action, are present along the range front about 0.25 mile (0.4 km) east of the subject property, and may serve as source material for rock-fall activity under favorable conditions. Determination of the potential for a rock-fall hazard at the site would be prudent. However, because the trajectory of dislodged rocks is difficult to predict and the probability that one would strike a specific building is low, disclosure of the existence of the Rentmeister (1993) report and this review is a reasonable alternative if further investigations are not performed.

In conclusion, Rentmeister (1993) has provided insufficient evidence to conclude that debris flows, slope failure, and surface fault rupture do not pose a threat to proposed development at the subject property. In addition, the potential for a rock-fall hazard was not addressed. Because Ogden City Community Development Department policies require that hazards be adequately addressed prior to planning commission approval, further work would be prudent to assess debris-flow hazards and to recommend hazard-reduction measures if needed. The scope of investigations for site-specific studies is outlined in Lowe (1991). For the potential surface-faulting and rock-fall hazards, disclosure of the Rentmeister (1993) report and this review to all subsequent buyers is an adequate substitute for site-specific study. Although not adequately covered by Rentmeister (1993), slope-failure hazards appear to be related to liquefaction and the liquefaction potential at the site is very low, so further work or disclosure is not necessary.

REFERENCES CITED

Anderson, L.R., Keaton, J.P., and Bay, J.A., 1990, Liquefaction potential map for the northern Wasatch Front, Utah: Logan, Utah State University Department of Civil and Environmental Engineering, unpublished final technical report to the U.S. Geological Survey, 150 p.

Dames & Moore, 1976, Report of engineering geology study, proposed Jumpoff Canyon subdivision, approximately 1000 feet north of North Street on Jackson Avenue, Ogden, Utah, for Mr. Elden H. Knudson: Unpublished consultant's report, Dames & Moore Job No. 6448-001-06, 9 p.

Delta Geotechnical Consultants, 1985, Geotechnical evaluation, Northland property, Jumpoff Canyon, Ogden, Utah, prepared for Ogden City Neighborhood Development Agency: Unpublished consultant's report, Delta Geotechnical Consultants Job No. 1571, 21 p.

Harty, K.M., Lowe, Mike, and Christenson, G.E., in press, Hazard potential and paleoseismic implications of liquefaction-induced landslides along the Wasatch Front, Utah: Utah Geological Survey final technical report submitted to the U.S. Geological Survey in fulfillment of National Earthquake Hazard Reduction Program Agreement No. 14-08-0001-G2058.

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Rentmeister, K.N., 1993, Evaluation of geologic hazards, 670 North Van Buren Avenue, Ogden, Utah: Unpublished consultant's report, 1 p.

Weber County Planning Commission, 1988, Geologic hazard sensitive area overlay zone maps, North Ogden quadrangle, Utah: Unpublished Weber County Planning Commission maps, scale 1:24,000.

Project: Review of "Report, geoseismic/geotechnical study, Shadow Mountain Subdivision, Phase I, Ogden, Utah."			Requesting Agency: Ogden City Department of Community Development
By: Mike Lowe	Date: 7-20-93	County: Weber County	Job No: 93-08 (R-14)
USGS Quadrangle: Ogden (1345)			

The purpose of this report is to present the results of a review of the engineering-geologic aspects of a report (SHB AGRA, 1993) for a proposed residential subdivision in Ogden City about one mile east of the intersection of Harrison Boulevard and Combe Road (near the center of the section line between sections 14 and 23, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian). The review was requested by Richard Frye, Ogden City Department of Community Development. The scope of work included a literature review and examination of aerial photographs (1985; 1:24,000 scale). Engineering aspects of the report should be reviewed by a qualified geotechnical engineer.

The SHB AGRA report identifies earthquake ground shaking, surface fault rupture, and debris flows as the principal potential geologic hazards at the site. The SHB AGRA report indicates that liquefaction, rock fall, and problem soils are hazards which do not occur at the site. Although not addressed in the SHB AGRA report, flooding could occur at the site and should be considered in the design of the subdivision.

The SHB AGRA report makes recommendations for reducing earthquake ground-shaking and surface-faulting hazards. These hazard-reduction recommendations are, based on the information provided in the report, appropriate and should be required if the proposed subdivision is approved.

The SHB AGRA report indicates the debris-flow hazard at the site is low because: (1) debris-flow deposits at the site are apparently old; (2) Federal Emergency Management Agency (FEMA) Flood Insurance Rate maps (1983) do not show a flood hazard for the unnamed drainage associated with the alluvial fan at the site; and (3) houses and roads uphill from the site have reduced the hazard. I agree that debris-flow hazards at the site are low, but flooding from the canyon east of the proposed subdivision may be possible. The lack of a mapped flood-hazard zone on the FEMA (1983) map does not necessarily mean that there is not a flood hazard at the site. The FEMA maps are not comprehensive and commonly do not delineate flood hazards from small ephemeral drainages. In order to evaluate the potential for clear-water and/or debris-laden floods, it would be necessary to calculate potential flood volumes and then evaluate the effects of houses, roads, and any channel modifications or flood-control measures upgradient from the proposed subdivision site. Flood hazards may be sufficiently reduced through proper design of drainages in the subdivision.

In conclusion, I believe that the SHB AGRA report adequately addresses geologic hazards at the site. Recommendations for reducing hazards from earthquake ground shaking and surface faulting should be required if the proposed subdivision is approved. The recommendations for reducing surface-faulting hazards may require redesign of the subdivision or elimination of some lots from the current subdivision design. Ogden City Building Inspectors should be notified of the fault setbacks so they can enforce them. The effectiveness of houses and roads upgradient from the proposed subdivision, existing flood-control measures, and drainage design of the proposed subdivision on reducing potential flood hazards needs to be reviewed by an engineer to determine if any further work is necessary. Engineering aspects of the report should be reviewed by a qualified geotechnical engineer.

REFERENCES CITED

Federal Emergency Management Agency, 1983, Flood Insurance Rate Map of Ogden, Utah: Federal Emergency Management Agency, Community Panel Number 490189-008B, scale 1:6,000.

SHB AGRA, 1993, Report, geoseismic/geotechnical study, Shadow Mountain Subdivision, Phase I, Ogden, Utah: Unpublished consultant's report, 16 p.

Project: Review of "Geologic hazards study for the proposed Dunkley residence, lot 27, Pole Patch Subdivision Phase II, Pleasant View, Utah."			Requesting Agency: Pleasant View Planning Commission
By: Mike Lowe	Date: 8-23-93	County: Weber County	Job No: 93-09 (R-15)
USGS Quadrangle: North Ogden (1370)			

At the request of the Pleasant View Planning Commission, I reviewed a Delta Geotechnical Consultants, Inc. (1993) report for the Dunkley property in the NE¼ NW¼ section 17, T. 7 N., R. 1 W., Salt Lake Base Line and Meridian, on the Pleasant View salient. The scope of work for this review included inspection of Weber County Planning Commission geologic-hazards maps, Pleasant View Sensitive Area Study maps, and aerial photographs (1985, 1:24,000 scale). No field inspection was performed.

Delta Geotechnical Consultants, Inc. (1993) identifies earthquake ground shaking, surface fault rupture, landslides, rock falls, debris flows, and floods as potential hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. Their assessment indicates that landslide and rock-fall hazards are low and that hazard-reduction measures are not necessary, but that earthquake ground-shaking, surface-faulting, debris-flow, and flooding hazards are present and that hazard-reduction measures are necessary. Their recommended measures to reduce these hazards should be followed. The recommendation to construct buildings to Uniform Building Code seismic zone 3 standards, at a minimum, to reduce earthquake ground-shaking hazards satisfies state requirements. The recommended setback from the identified fault scarp should significantly reduce surface-faulting hazards, and the recommended home-foundation excavation inspection is important to ensure that faults are not present.

To reduce flooding and debris-flow hazards, the Delta Geotechnical Consultants, Inc. (1993) report recommends construction of deflection berms and channelization of the currently active drainage. Although locations of the proposed berms are identified in the report, berm designs and depths of channelization are not provided. I recommend that the upper, easternmost berm be extended to the apex of the fan at the mouth of the canyon as this is the most likely location (above the home) for the currently active channel to be diverted to a new channel. An engineer experienced in flood control techniques should review the design for the deflection berms and channelization and evaluate their adequacy and potential effect on flooding downstream.

The report recommends that the final plans and specifications be reviewed by Delta Geotechnical Engineering, Inc., to determine whether the consultant's recommendations were properly understood and implemented. I concur with these recommendations, and recommend that the existence of the report and this review be disclosed to future lot or home buyers.

REFERENCES CITED

Delta Geotechnical Consultants, Inc., 1993, Geologic hazards study for the proposed Dunkley residence, lot 27, Pole Patch Subdivision Phase II, Pleasant View, Utah: Salt Lake City, Utah, unpublished consultant's report, 10 p.

Project: Review of "Geotechnical study, Evans development, Ogden, Utah" by Earthtec Testing and Engineering.			Requesting Agency: Ogden City Community Development Department
By: Gary E. Christenson	Date: 8-20-93	County: Weber County	Job No: 93-10 (R-16)
USGS Quadrangle: Ogden (1345)			

At the request of Richard A. Frye, Ogden City Planner, I reviewed an Earthtec Testing and Engineering (1992) report for the Evans property in the NW¼ section 14, T. 5 N., R. 1 W., Salt Lake Baseline and Meridian, on Ogden's east bench. The scope of work for this review included inspection of Weber County Planning Commission geologic-hazards maps and aerial photographs (1985, 1:24,000-scale). No field inspection was performed. I reviewed only the sections of the report addressing geologic hazards. Foundation and geotechnical aspects of the report should be reviewed by a qualified geotechnical engineer.

Earthtec Testing and Engineering (1992) identify rock falls, flooding, debris flows, surface faulting, earthquake ground shaking, and slope failures as potential hazards at the site. Their assessment indicates that surface-faulting and slope-failure hazards are low, but that rock-fall, flooding/debris-flow, and earthquake ground-shaking hazards are present. Their analyses appears complete and accurate, and their recommended measures to reduce these hazards should be followed. Removal of large rocks and setback of homes from the hillside with concrete barriers at the base of slopes should significantly reduce rock-fall hazards. They recommend diversion dikes and channelization of the drainage to the north to reduce flooding and debris-flow hazards, but do not include designs in the report. An engineer experienced in flood control techniques should review these designs when submitted and evaluate the potential effect of the channel alterations on flooding downstream. The recommendation to construct buildings to UBC seismic zone 3 standards, at a minimum, to reduce earthquake groung-shaking hazards satisfies state requirements.

The report recommends that a geotechnical engineer be present during site excavation and grading to inspect conditions. I concur with this recommendation, and suggest that the site be closely inspected to ensure that report recommendations are followed. The existance of the Earthtec Testing and Engineering (1992) report and this review should be disclosed to future lot or home buyers.

REFERENCES CITED

Earthtec Testing and Engineering, 1992, Geotechnical study, Evans development, Ogden, Utah: Draper, Utah, unpublished consultant's report, 19 p.

Project: Review of a geologic-hazards evaluation for the proposed Villa View Estates subdivision, Ogden, Utah.			Requesting Agency: Ogden City Planning Department
By: Mike Lowe	Date: 9-27-93	County: Weber County	Job No: 93-11 (R-17)
USGS Quadrangle: Ogden (1345)			

At the request of Richard A. Frye, Ogden City Community Development Department, I reviewed a 1993 report by Bruce N. Kaliser, Bruce N. Kaliser and Associates, for the proposed Villa View Estates subdivision in the NE¼NW¼ section 27, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian. The subdivision is north of and between the northern ends of Custer and Polk Streets, Ogden City, Utah. The scope of work for this review included inspection of Weber County Planning Commission geologic-hazards maps and aerial photographs (1985, 1:24,000 scale). No field inspection was performed.

Kaliser (1993) identifies landsliding as the principal potential geologic hazard at the site. Although not addressed in the Kaliser report, earthquake ground shaking could also occur at the site, and buildings should be constructed, at a minimum, to Uniform Building Code seismic zone 3 standards.

To reduce landslide hazards, Kaliser recommends a 25-foot (7.6-meter) setback from the slope break on the north side of the property. This slope break roughly corresponds to the 4,530-foot (1,381-meter) elevation contour on figure 1 of the Kaliser (1993) report. If the water line on the east side of the property remains in use, Kaliser also recommends a 25-foot (7.6-meter) setback from a concrete-lined manhole near the northeast corner of the property. These risk-reduction recommendations are, based on the information provided in the report, appropriate and should be required if the proposed subdivision is approved.

REFERENCE

Kaliser, B.N., 1993, Villa View Estates, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 5 p.

Project: Review of "Geotechnical/geoseismic feasibility study, proposed Burnham Woods residential development, irregular-shaped parcel north of 20th Street in the area between Pierce Avenue and Fillmore Avenue, Ogden, Utah."			Requesting Agency: Ogden City Planning Department
By: Mike Lowe	Date: 10-11-93	County: Weber County	Job No: 93-12 (R-18)
USGS Quadrangle: Ogden (1345)			

At the request of Kirk Smith, Ogden City Community Development Department, I reviewed a 1993 report by SHB AGRA, Inc., for the proposed Burnham Woods residential development in the NW¼NE¼ section 27, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian. The proposed development is north of and between the northern ends of Pierce and Fillmore Avenues, Ogden City, Utah. The scope of work for this review included inspection of Weber County Planning Commission geologic-hazards maps, examination of aerial photographs (1985, 1:24,000 scale), and a field inspection of trenches at the site on September 3, 1993. Gary Christenson (Utah Geological Survey), Greg Schlenker (SHB AGRA), and Owen Burnham (developer), were present during the field inspection.

The SHB AGRA (1993) report identifies earthquake ground shaking, surface faulting, liquefaction, and landsliding as the principal potential geologic hazards at the site. The report recommends that buildings be constructed, at a minimum, to Uniform Building Code seismic zone 3 standards, and indicates that a surface-faulting hazard is not present, and that the potential for liquefaction is low.

To reduce landslide risks, the SHB AGRA report identifies a "buildable area" south of a line delineated by projecting a 4 horizontal to one vertical slope from the toe of the landslide complex at the base of the bluff north of the proposed residential development. This "buildable area" line is meant to identify areas where slope retreat due to further landsliding in the "active" area is unlikely to occur, and I concur with this approach. However, this approach does not address the reactivation of "previously active" landslides on the property south of the line. As shown on figure 2 of the SHB AGRA report, the buildable area on the three westernmost lots in the proposed development is crossed by the main scarp of one of these "previously active" landslides. This area is labeled "stable but previously active" because SHB AGRA believes movement occurred more than a few hundred but less than 12,000 years ago (SHB AGRA, 1993, p. 9).

Although I agree with these estimates of the last movement, I do not necessarily consider such landslides stable. In general, I do not recommend construction in main-scarp areas of landslides of this age unless more information is available to demonstrate slope stability. I therefore recommend that either studies be performed to show that future movement of this landslide is unlikely, or that no structures be placed across or north of this scarp as shown in figure 2 of the SHB AGRA report.

The SHB AGRA report also recommends that surface-water drainage within the proposed development be directed away from the landslide complex, to the north and west of the site. The risk-reduction recommendations presented in the SHB AGRA report and this review are, based on the information provided in the SHB AGRA report, appropriate and should be required if the proposed subdivision is approved. Please feel free to contact me if you have any questions regarding landslide hazards at the proposed development site or this review.

REFERENCE

SHB AGRA, 1993, Report, geotechnical/geoseismic feasibility study, proposed Burnham Woods residential development, irregular-shaped parcel north of 20th Street in the area between Pierce Avenue and Fillmore Avenue, Ogden, Utah: Salt Lake City, Utah, unpublished consultant's report, 12 p.

Project: Review of "Report of slope stability analyses, Cedar Bench development, South Weber City subdivision, Weber County, Utah."			Requesting Agency: South Weber City
By: Mike Lowe	Date: 11-5-93	County: Davis County	Job No: 93-13 (R-19)
USGS Quadrangle: Kaysville (1320)			

At the request of Barry Burton, planner for Davis County and South Weber City, I reviewed a 1993 report by Huntingdon Chen-Northern, Inc. for the proposed Cedar Bench development in the SW¼SW¼ section 35, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian, in South Weber City, Davis County. The scope of work for this review included an inspection of Davis County Planning Commission geologic-hazards maps, a literature review, an examination of aerial photographs (1985, 1:24,000 scale), and a telephone conversation on November 4, 1993, with David Simon and Dr. K. N. Gunalan (Huntingdon Chen-Northern).

The Huntingdon Chen-Northern (1993) report is limited in scope and only presents slope-stability analyses for the steep bluff south and southwest of the proposed development. Potential geologic hazards at the site include slope failure along this bluff, and earthquake ground shaking. Unpublished 1988 Davis County Planning Commission geologic-hazards maps do not indicate the presence of other geologic hazards which should be addressed.

The slope-stability analyses presented in the Huntingdon Chen-Northern report are an engineering approach to slope-failure hazard assessment. As such, they should be reviewed by a qualified geotechnical engineer, rather than a geologist. Because much of the data used in the analyses are geologic, however, the appropriateness of these data can be addressed by an engineering geologist.

The Huntingdon Chen-Northern report indicates that the bluff has a slope of approximately 1.5 horizontal to 1 vertical. Under static (non-earthquake) conditions, Huntingdon Chen-Northern calculates the factor of safety for the slope to be 1.34. Under pseudostatic (earthquake) conditions, the calculated factor of safety is 1.02. "When the calculated safety factor is ≤ 1.0, the slope is considered unstable and is very likely to fail" (Costa and Baker, 1981). It is standard practice to take precautions with development when the calculated factors of safety are less than 1.5 under static conditions and 1.1 under pseudostatic conditions (Franklin, 1983).

For the calculation of factors of safety under both static and pseudostatic conditions, Huntingdon Chen-Northern used an assumed depth to ground water of 100 feet (30 m) (Dr. K. N. Gunalan, verbal communication, November 4, 1993). Gill (1984) determined that the depth to ground water near the Davis County Solid Waste Management and Energy Recovery Plant, located about 1.3 miles (2 km) southwest of the proposed development, ranged between 13 and 20 feet (4 and 6 m) below ground surface. If the depth to ground water at the top of the bluff above the proposed subdivision is less than 100 feet (30 m), the calculated factors of safety would be lower than those reported in the Huntingdon Chen-Northern report.

For the calculation of factors of safety under pseudostatic conditions, Huntingdon Chen-Northern used a seismic coefficient which corresponds to a peak horizontal ground acceleration of 0.15 g (15 percent of gravity). Youngs and others (1987) indicate that peak horizontal ground accelerations of 0.30 g and 0.60 g have a 10 percent probability of being exceeded at the site in 50 and 250 years respectively. These higher seismic coefficients would yield a lower pseudostatic factor of safety.

In conclusion, the factor-of-safety calculations presented in the Huntingdon Chen-Northern (1993) report indicate that precautions should be taken to reduce slope-failure hazards associated with the bluff to the south and southwest of the proposed subdivision. Geologic conditions which would further reduce the calculated factors of safety likely occur at the site. I recommend that measures be taken to increase the stability of the slope to acceptable levels (static factor of safety ≥ 1.5; pseudostatic factor of safety ≥ 1.1) and/or setbacks from the base of the slope be delineated to protect the development from the potential slope-failure hazard prior to approval of the proposed development by the South Weber City Planning Commission. In addition, buildings should be constructed, at a minimum, to Uniform Building Code seismic zone 3 standards to reduce the potential ground-shaking hazard.

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Franklin, R.T., 1983, Analysis of buttress fills, in Scullin, C.M., Excavation and grading code administration, inspection, and enforcement: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 268-288.

Gill, H.E., 1985, Davis Co. solid waste management project facility, in Harty, K.M., compiler, Technical reports for 1984 Site Investigation Section: Utah Geological and Mineral Survey Report of Investigation No. 198, p. 28-35.

Huntingdon Chen-Northern, Inc., 1993, Report of slope stability analyses, Cedar Bench development, South Weber City subdivision, Weber County, Utah: Salt Lake City, unpublished consultant's report, 8 p.

Youngs, R.R., Swan, F.H., Power, M.S., Schwartz, D.P., and Green, R.K., 1987, Probabilistic analysis of earthquake ground shaking hazard along the Wasatch Front, Utah, in Gori, P.L., and Hays, W.W., editors, Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah, volume II: U.S. Geological Survey Open-File Report 87-585, p. M-1 - M-110.

Project: Review of "Report, fault rupture, groundwater, and debris flow hazards evaluation, proposed home site, approximately 2850 East 6025 South, Weber County, Utah", by SHB AGRA, Inc.			Requesting Agency: Weber County
By: Mike Lowe	Date: 11-22-93	County: Weber County	Job No: 93-14 (R-20)
USGS Quadrangle: Ogden (1345)			

At the request of Ed Reed, Weber County Planning Department, I reviewed a 1993 report by SHB AGRA, Inc. for a proposed residential lot located on the north side of 6025 South Street at about 2850 East (NW¼SW¼ section 24, T. 5 N., R. 1 W., Salt Lake Base Line and Meridian), Uintah Highlands, Weber County, Utah. The scope of work included: (1) an inspection of Weber County Planning Commission geologic-hazards maps; (2) a literature review, including a previous consultant's report (Sergent, Hauskins, and Beckwith, 1992) for the site and a review (Lowe, 1992) of that report; (3) an examination of aerial photographs (1985, 1:24,000 scale); and (4) a field inspection of the site on August 23, 1993. Greg Schlenker, SHB AGRA, and Charles Richards, lot owner, were present during the field inspection.

The SHB AGRA report identifies earthquake ground shaking, surface faulting, debris flows, shallow ground water, and landsliding as potential geologic hazards at the site. This appears to be a complete and accurate listing of the potential hazards present. With respect to earthquake ground shaking, the SHB AGRA report recommends that, as a minimum, buildings be constructed in accordance with the provisions outlined for Uniform Building Code (UBC) seismic zone 3. The SHB AGRA report concludes, based on trenches excavated at the site, that surface faulting is likely not a hazard at the site and, therefore, risk-reduction measures for this hazard are not necessary. A debris-flow hazard is present at the site, but SHB AGRA considers the hazard to be very low ("minimal"). To reduce the risk from debris flows, SHB AGRA recommends that the structure be constructed with no basement windows or openings lower than existing grade on the north and east (up-slope facing) sides of the structure. SHB AGRA observed shallow ground water in trenches at the site at depths ranging from 5.0 to 7.5 feet. The report recommends that a subdrain system be placed around the perimeter of the proposed structure and that a basement dewatering system be placed below the structure. "Relatively ancient" landslide deposits were encountered in the eastern end of the northern trench excavated at the site, but SHB AGRA considers the potential for future movement of the landslide to be low. The SHB AGRA report concludes that the recommended ground-water control measures will also further reduce the landslide hazard.

In conclusion, the SHB AGRA report identifies earthquake ground shaking, debris flows, shallow ground water, and landslides as potential hazards at the proposed residential site, but determined that surface faulting is likely not a hazard at the site. Based on the information provided in the report, I concur with these conclusions. I believe the risk- and hazard-reduction measures recommended in the SHB AGRA report adequately address the potential geologic hazards and should be implemented if the proposed building lot is approved by Weber County. A geotechnical engineer should review dewatering-system designs for the proposed residential building. I recommend that the existence of the two consultant's reports for the lot (Sergent, Hauskins, and Beckwith, 1992; SHB AGRA, 1993) and my reviews of those reports (Lowe, 1992, and this review) be disclosed to future lot or home buyers.

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