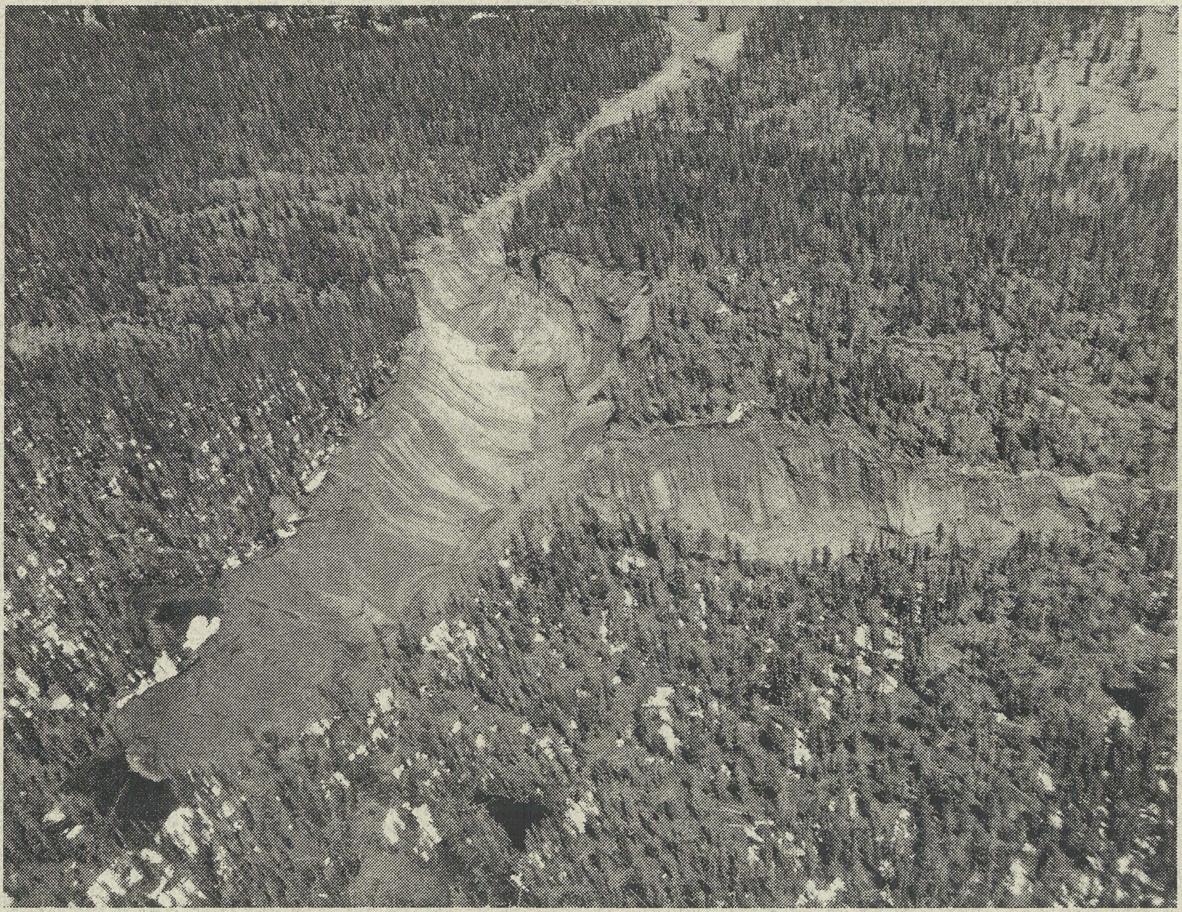
TECHNICAL REPORTS FOR 1997
APPLIED GEOLOGY PROGRAM

compiled by
Bea H. Mayes



REPORT OF INVESTIGATION 236
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
March 1998

Cover photo: Erosional ravines cut as water from a canal breach flowed from Mosby Mountain into Dry Fork Canyon, Uintah County (aerial photo, view to the east, down slope).
Photo credit: Mike Royce

PREFACE

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

Dissemination of information is a major goal of the UGS. Studies of interest to the general public are published in several UGS formats. We present projects that address specific problems of interest to a limited audience in a technical-report format, which we distribute on an as-needed basis. We maintain copies of these reports and make them available for inspection upon request. This Report of Investigation presents, in a single document, the Applied Geology Program's 26 technical reports completed in 1997 (figure 1). The reports are grouped by topic, and each report identifies the author(s) and requesting agency. Minor editing has been performed for clarity and conformity, but I have made no attempt to upgrade the original graphics, some of which were produced on a copy machine. This is the eleventh compilation of the Applied Program's technical reports.

Bea H. Mayes
February 17, 1998

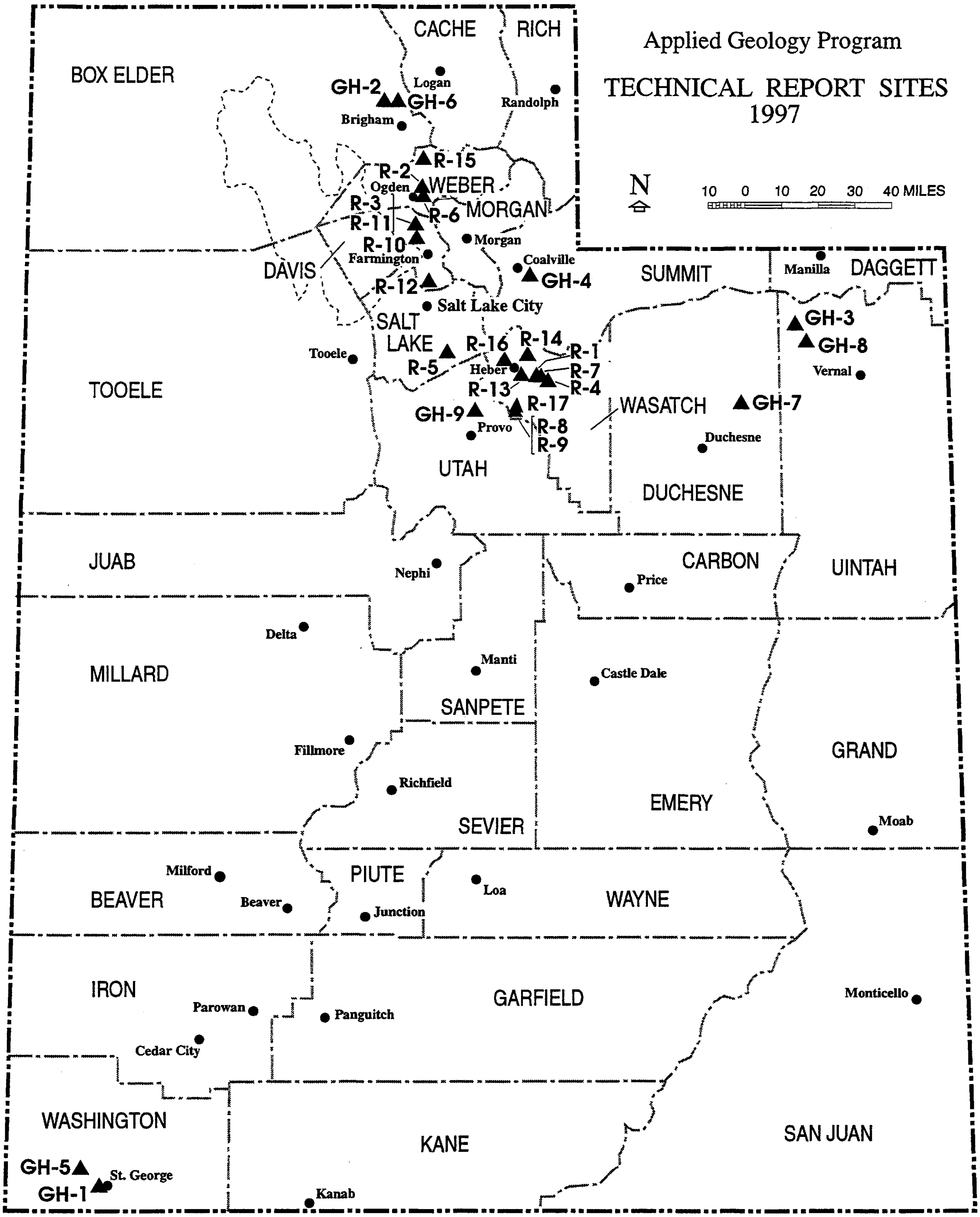


Figure 1. Locations of 1997 Technical Report Sites.

CONTENTS

Illustration

GEOLOGIC HAZARDS

Project: Reconnaissance of flood effects, January 3, 1997, storm, St. George, Utah			Requesting Agency: Emergency Response
By: William R. Lund	Date: 2-21-97	County: Washington	Job No: 97-01 (GH-1)
USGS Quadrangle: St. George		Number of attachments: Eight	

INTRODUCTION

On January 3, 1997, an intense winter thunder and rain storm struck the city of St. George in Washington County. The storm produced extensive flooding in St. George and surrounding communities. The purpose of this investigation was to document the effects of the storm and look for evidence of debris flows and debris floods. I contacted several local, state, and federal agencies regarding the effects of the storm and made a one-day reconnaissance of the area on January 7, 1997.

THE STORM

The National Weather Service (NWS) weather station at the St. George airport on West Black Ridge (attachment 1, **A**) recorded 2.38 inches (6.04 cm) of precipitation in an eight-hour period beginning at 3:00 a.m. and ending at 11:00 a.m. on January 3, 1997 (William Alder, NWS, verbal communication, January 8, 1997). Precipitation from the event was unevenly distributed through time, with the heaviest rainfall, 1.87 inches (4.75 cm), occurring between 8:00 and 11:00 a.m. (see table). Other precipitation totals reported by NWS observers in the area included 2.08 inches (5.28 cm) near the St. George LDS Tabernacle; 2.42 inches (6.15 cm) in Bloomington; 1.53 inches (3.89 cm) in Santa Clara; 1.08 inches (2.74 cm) in Zion National Park; and 1.07 inches (2.72 cm) in the city of Hurricane about 15 miles (24 km) northeast of St. George. Both the NWS and local government agencies noted the localized nature of the most intense part of the storm, which was centered directly over the St. George urban area. The NWS has declared the storm to be a 100-year event for the St. George area (Bill Alder, NWS, verbal communication, January 8, 1997). The most precipitation previously recorded at St. George during a 24-hour period was 2.4 inches (6.10 cm) on August 31, 1909.

Table. Hourly precipitation during January 3, 1997, storm, St. George, Utah. Precipitation measured at National Weather Service weather station, St. George airport.

Hour a.m.	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	Total 8 hrs
Precip. inches	0.03	0.01	0.07	0.25	0.15	0.52	0.99	0.36	Total* 2.38 in

* *The Spectrum* (St. George daily newspaper) reported a precipitation total for the storm in excess of 4 inches (10.2 cm). However, according to William Alder, NWS Chief Meteorologist in Salt Lake City, that figure is in error and the values presented above are correct.

STORM EFFECTS

During and immediately after the heaviest part of the storm (8:00 to 11:00 a.m.), flooding due to sheet flow and runoff from paved areas was widespread in the St. George urban area (Ludwig and Van Winkle, 1997; Reese and Murvosh, 1997). Numerous streets and intersections flooded, particularly in the southwestern (lower) part of town and in the Bloomington area. Between 200 (St. George City estimate; Larry Bullock, City Engineer) and 400 (Washington County estimate; Dean Cox, Washington County Disaster Prevention Coordinator) basements received water, many from sewer lines that backed up due to surcharging through manhole covers along flooded streets. A dike along a normally dry drainage canal north of and uphill from the St. George City Building and the adjacent Hall of Justice breached, causing parking lots (attachment 1, **B**; attachment 2) and some rooms on the ground floor of the Hall of Justice to flood. Dixie College sent students home at 11:00 a.m. after minor flooding in some campus buildings. Water cascaded off the airport bench and down the east side of West Black Ridge eroding a narrow gully in the hillslope (attachment 1, **C**; attachment 3). One hundred-thirty cars received water damage at an automobile dealership on south Bluff Street (attachment 1, **D**) when a culvert plugged and the dealership lot flooded so quickly employees were unable to move the cars. As the overland flow became concentrated, runoff caused erosion and gullying in many areas, particularly where new construction had created fresh, unprotected cut slopes (attachment 4). As a consequence, the water carried considerable sediment and St. George street crews were still clearing gutters and culverts along many streets at the time of my reconnaissance five days after the storm.

River gauges showed that the Virgin River rose 5.5 feet (1.7 m) in 2.5 hours at Hurricane, 3 feet (0.9 m) in 5 hours at St. George, and 8 feet (2.4 m) in 6 hours at Bloomington (Bill Alder, NWS, verbal communication, January 8, 1997). Discharge in the Santa Clara River at its confluence with the Virgin River peaked at 5,000 ft^3/sec (141.6 m^3/sec), well above its average January discharge of 13.6 ft^3/sec (0.4 m^3/sec) (Dale Wilberg, U.S. Geological Survey, verbal communication, January 10, 1997). Overbank flooding occurred along the lower reaches of the Santa Clara River and the bridge on Valley View Drive (Attachment 1, **E**) was overtopped. A St. George city worker trying to clear debris from the bridge during the storm fell into the river and narrowly escaped drowning (*The Spectrum*, January 4, 1997). Along the west side of the river, portions of Dixie Drive were covered by water (Attachment 1, **F**; Attachment 5), as were a city park and a riding stable (Attachment 1, **G**; Attachment 6).

The storm appears to have had little immediate effect on the Truman Drive landslide in Santa Clara. The most recent layer of asphalt where the street crosses the right flank of the landslide is cracked and displaced 2 to 3 inches (5.1-7.6 cm) down to the southwest. However, the cracks do not appear fresh and probably have been there for some time. I did not observe fresh cracks or scarps on the surface of the slide, nor was there evidence of recent road repair. It remains to be seen what impact the precipitation that infiltrated on the Santa Clara Bench may eventually have on the landslide.

The landslide at the southeast end of the Santa Clara Bench adjacent to the city Little League baseball field is clearly active. The concrete retaining wall at the toe of the slide is freshly broken in some areas (attachment 7) and tilted steeply outward (attachment 8) in others. Water is draining from the toe of the slide in several places; I estimate the total flow was 20 to 25 gallons per minute (75 - 100 L/min) at the time of my reconnaissance. Glen Vernon, Santa Clara City Manager, stated that the landslide is a continuing problem, but that city crews have reported no particular effect on the landslide from the recent storm. The city plans to install drains in the slide within the next 30 to 40 days in an attempt to stabilize the slope by drying it out

DEBRIS FLOWS AND FLOODS.

I looked for evidence of debris flows or debris floods associated with the January 3, 1997, storm. I observed none during my reconnaissance nor were any reported by the media. In discussions with representatives of Washington County (Dean Cox, Washington County Disaster Prevention Coordinator), the city of St. George (Larry Bullock, City Engineer), the city of Santa Clara (Glen Vernon, City Manager), the NWS (Bill Alder, Chief Meteorologist), and the Utah Division of Parks and Recreation (Gordon Topham, Southern Regional Manager), I asked if they were aware of any debris flows or floods caused by the storm. All responded in the negative, and indicated that to their knowledge the damaging effects of the storm were related entirely to sheet wash and overland flow of runoff water concentrated in the immediate vicinity of St. George. The lack of debris flows and floods is probably due to the localized nature of the most intense part of the storm, which was centered on the St. George urban area missing the surrounding mountains and canyons.

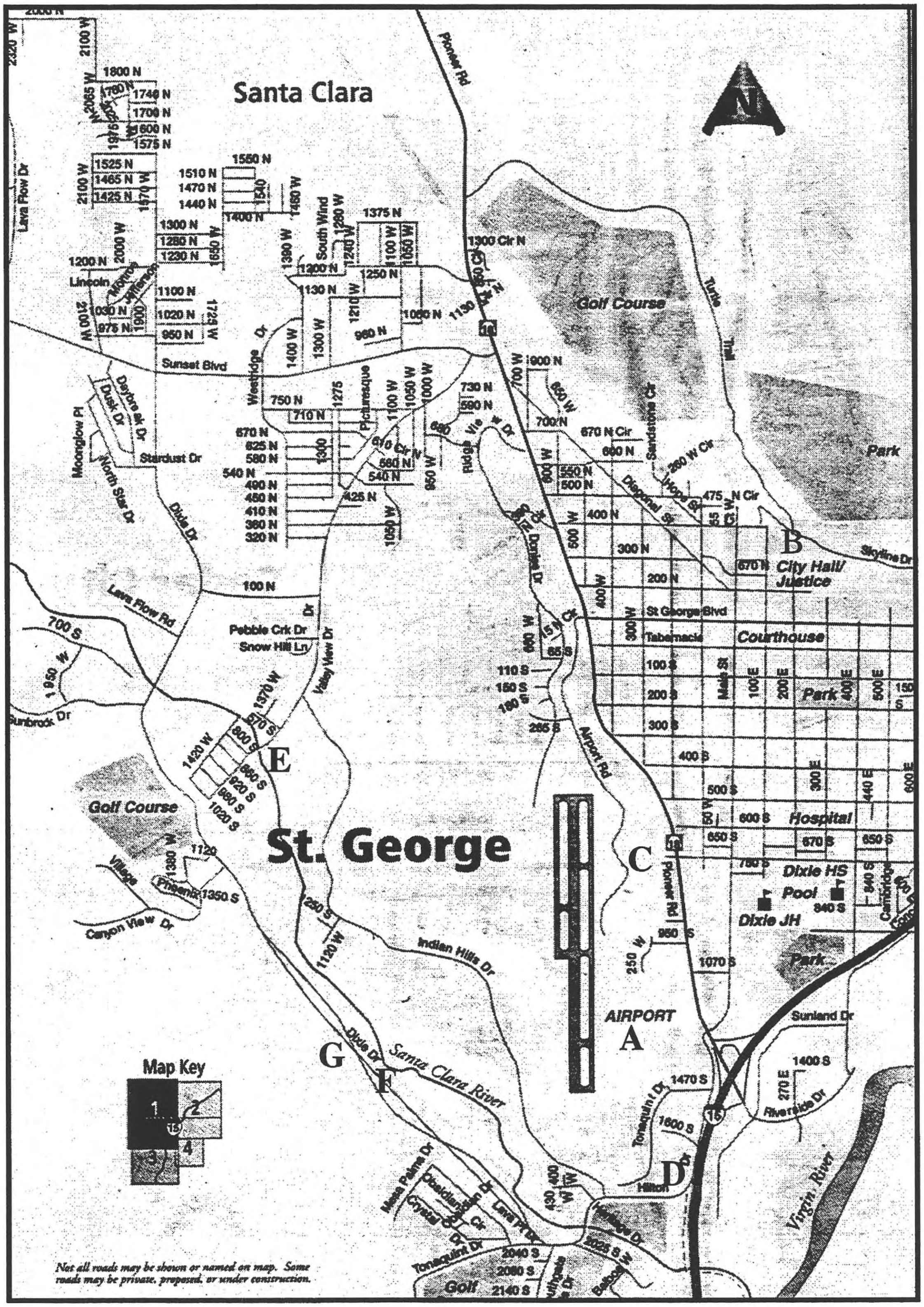
SUMMARY

An unusually intense winter thunder and rain storm on January 3, 1997, produced 2.38 inches (6.05 cm) of precipitation in an 8-hour period at the St. George airport. Some precipitation amounts reported by NWS observers at other locations within the St. George urban area were even higher, causing the NWS to declare the storm a 100-year event for the St. George area. Flooding and associated erosion and sedimentation caused by storm runoff was widespread in and around St. George, but the event produced no known debris flows or debris floods.

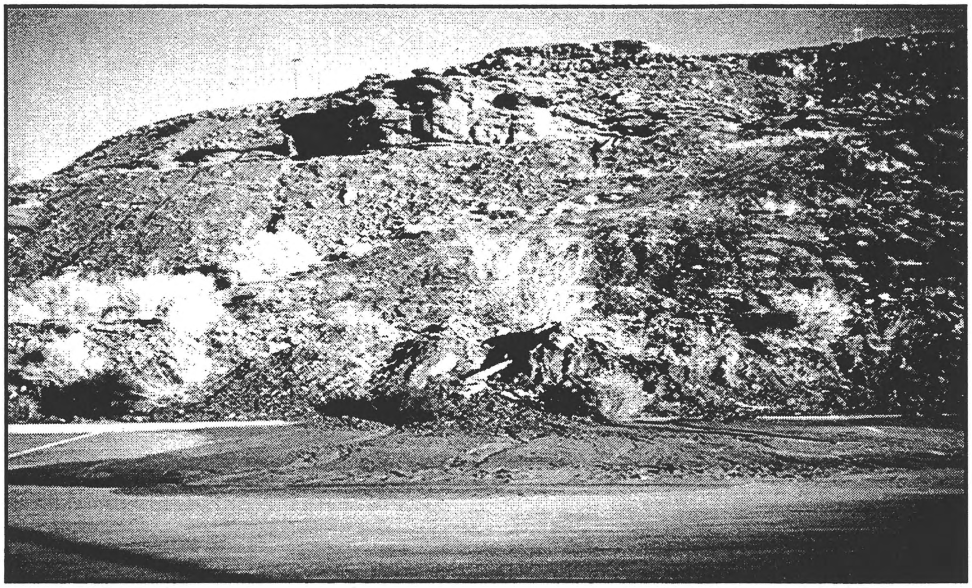
REFERENCES

Ludwig, Fred, and Van Winkle, Scott, 1997, Problems from heavy rainstorm continue to trickle into St. George residents' lives: *The Spectrum*, v. 30, no. 325, p. A1 - A2.

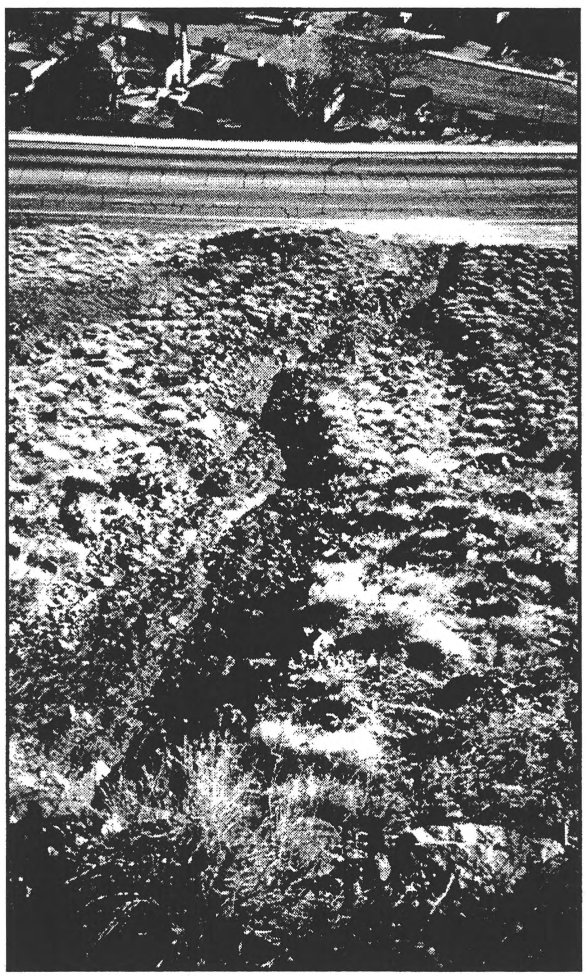
Reese, Benjamin, and Murvosh, Marta, 1997, Rains keep crews busy in St. George: *The Spectrum*, v. 30, no. 317, p. A1 and A3.



Attachment 1. Map of the western part of St. George; area where the affects of the January 3, 1997, storm were the most pronounced. Bold capital letters refer to locations mentioned in the text (map modified from US West phone directory for Southern Utah, November 1996/1997).

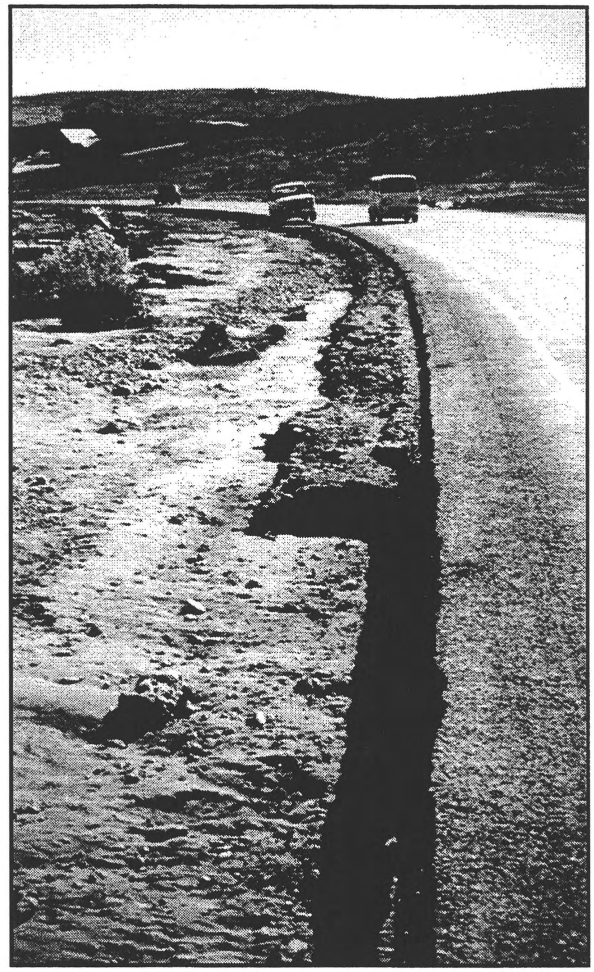


Attachment 2. Breached drainage canal north of the St. George City Building; sediment deposited in parking lot by flood waters (location **B** attachment 1).

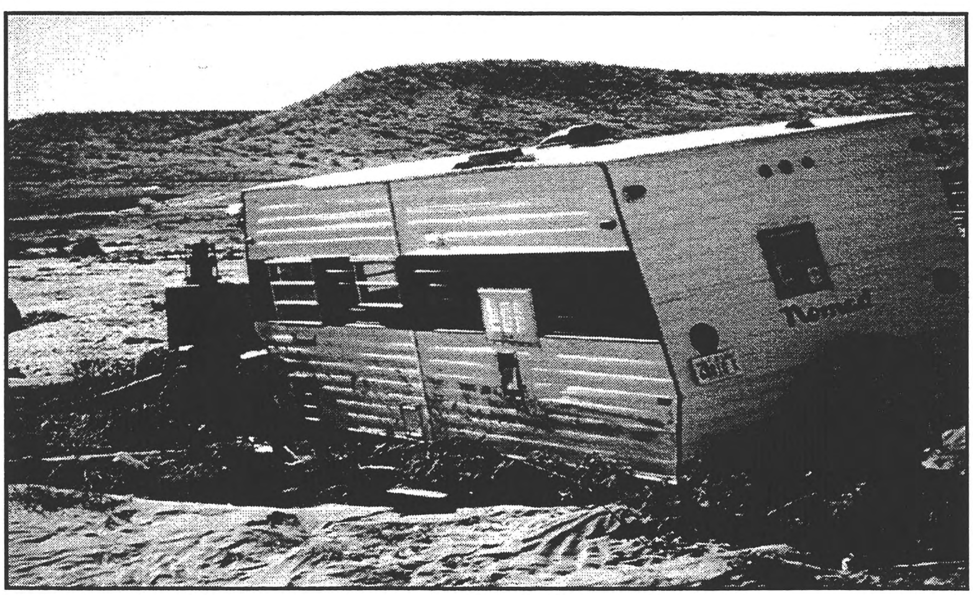


Attachment 3. Gully eroded into the east side of West Black Ridge by storm runoff cascading from the airport bench (location **C** attachment 1).

Attachment 4. Erosion produced by storm runoff in an area of new construction in southwestern St. George.



Attachment 5. Section of Dixie Drive flooded when the Santa Clara River overtopped its banks (location **F** attachment 1).



Attachment 6. Trailer at a riding stable along Dixie Drive damaged by flood waters from the Santa Clara River (location **G** attachment 1).

Attachment 7. Broken retaining wall at the toe of the Santa Clara Little League field landslide (north end); water draining from the landslide is flowing in a shallow ditch in front of the wall.

Attachment 8. Tilted retaining wall at the toe of the Santa Clara Little League field landslide (south end).

Project: Reconnaissance of a landslide along the Bear River, Honeyville, Utah			Requesting Agency: Emergency Response
By: F.X. Ashland	Date: 5-17-97	County: Box Elder	Job No: 97-07 (GH-2)
USGS Quadrangle: Honeyville (1446)		Number of attachments: 2	

On January 3, 1997, a landslide occurred in a bluff along the east side of the Bear River in Honeyville, Utah, partially blocked the river, and caused erosion along the river bank and part of the adjoining field on the west side of the river. The slide was first reported in a local newspaper titled "The Leader" on January 22, 1997 (Myers, 1997). On March 11, 1997 I visited the slide with Utah Geological Survey geologist Bill Black. The purpose of the investigation was to determine the physical characteristics of the slide. This report addresses the hazard implications from future slides along the Bear River.

The landslide is in the SE1/4SE1/4 section 30, T. 11 N., R. 2 W., Salt Lake Base Line and Meridian, and is visible from the Interstate-15 bridge that crosses the Bear River downstream and about 3,000 feet (910 m) to the southwest (attachment 1). The slide is on private farm property owned by the Bingham family in the northwestern part of Honeyville. The property is along the outside of a broad meander in the river. A point bar exists to the west across the river and is used as cultivated farmland. Cattle, sheep, and horses are raised on the Bingham property. No buildings are adjacent to the slide, but several farm buildings are several hundred feet to the south and southeast and upslope of the slide. A concrete watering trough is crossed by the main scarp of the slide and its concrete foundation was partly overhanging the scarp at the time of my visit. In addition, several wood fence posts were suspended in midair, held by the barbed wire that connected them, above the scarp area.

The landslide is a relatively shallow, complex earth slide-earth flow (Varnes, 1978; Cruden and Varnes, 1996) and is somewhat box shaped in plan view. It is about 340 feet (104 m) wide at its main scarp. The length of the surface of rupture (failed slope) is about 140 feet (43 m). The zone of accumulation at the base of the failed slope extends more than midway into the river a distance of about 75 feet (23 m), thus the entire slide is about 215 feet (66 m) long. I estimate the total height of the pre-failed slope to be about 50 feet (15 m). The pre-failure slope angle (toe of surface rupture to crest of scarp) was therefore about 20 degrees, with local slopes up to 40 degrees in the upper part.

The landslide occurred in a bluff bounding the river (attachments 1 and 2) which formed as the river cut into lacustrine sand, silt, and clay deposits of the old bed of Lake Bonneville (Oviatt, 1986). In-situ soils in the scarp of the slide consist of thinly bedded layers of fine- to medium-grained sand, clayey silt, and silty clay, and are consistent with the soil descriptions of Oviatt (1986). Colluvium derived from the lacustrine soils and local fill forms a veneer on the embankment slope. Oviatt (1986) mapped a landslide scarp along the outside edge of the entire meander indicating the most recent landslide occurred in an area prone to slope failure (attachment 1).

Landsliding was likely triggered by a combination of factors including undercutting of the toe on the outside of the meander in the Bear River, and wetting of the slope soils. Wetting may have, in part, resulted from the discharge of seeps at different levels in the slope. The seeps are associated with perched ground water above clayey silt and silty clay layers in the lacustrine deposits.

The landslide caused the Bear River to deflect to the west around the zone of accumulation that pushed out more than midway into the river. Eventually the river will erode the foot of the slide, where it has pushed into the original river channel, as river levels rise in the late spring. Until then, some erosion may continue on the opposite (west) bank of the river. As the foot of the slide is eroded, the main body of the slide may continue to slide downslope into the river, but this will likely occur gradually. Some sloughing may also continue in the steeply sloping scarp area and this may eventually completely undermine the watering trough unless it is relocated or its foundation reinforced from below.

This slide illustrates the potential for future slides in the outside of meanders along the Bear River. These slides may partially or completely dam the river and pose a subsequent flood hazard to areas downstream if the river is temporarily dammed. Future landslides along the Bear River should be quickly assessed by local, county, and state emergency-response officials, with the assistance of state geologists, and appropriate actions taken, including warning downstream property owners of potential flood hazards.

REFERENCES

Cruden, D.M., and Varnes, D.J., 1996, Landslide types and processes *in* Turner, A.K. and Schuster, R.L., editors, Landslides - investigation and mitigation: Washington, D.C., National Research Council, Transportation Research Board Special Report 247, p 36-75.

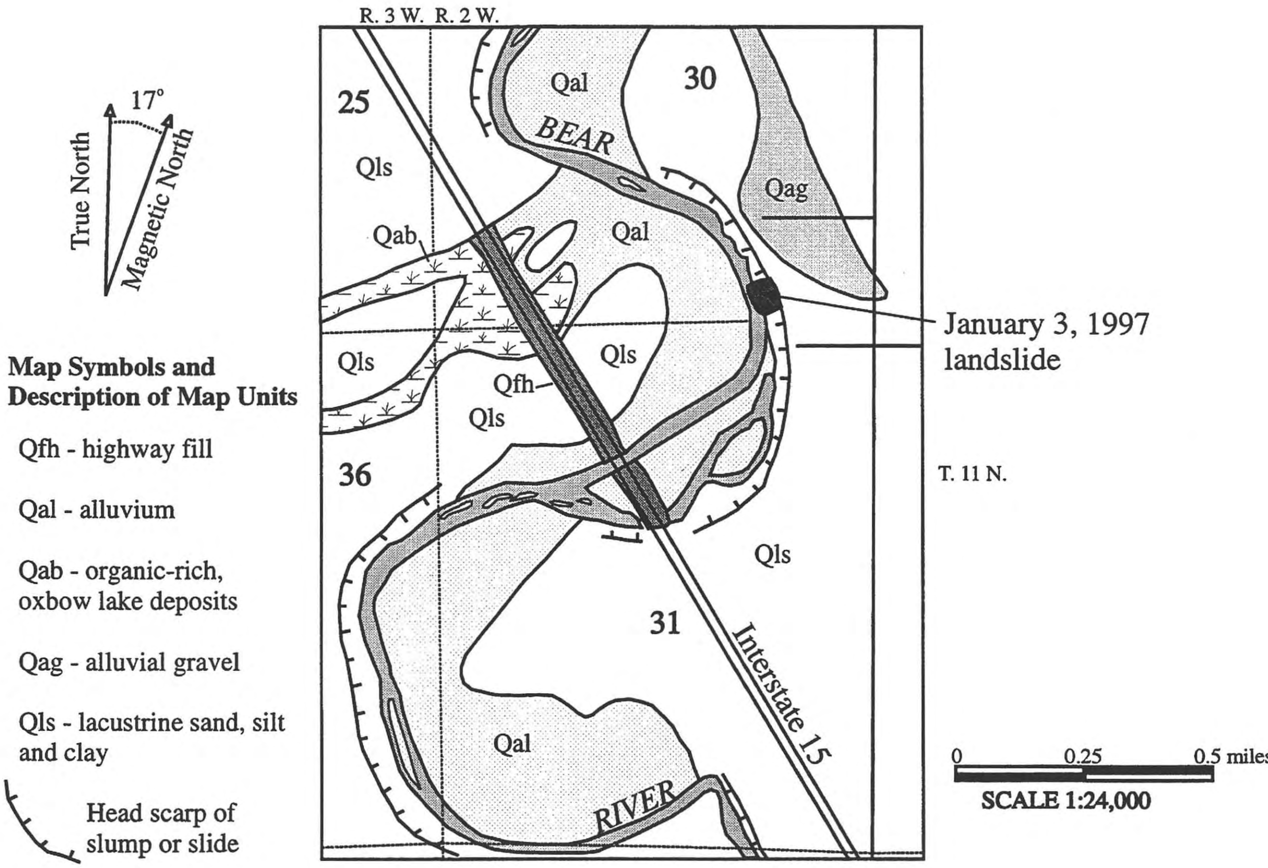
Myers, D.H., 1997, 400-foot sluff [sic: slough] near Honeyville damages farm: The Leader, January 22, v. 78, no. 4, p. 1 and 3.

Oviatt, C.G., 1986, Geologic map of the Honeyville quadrangle, Cache and Box Elder Counties, Utah: Utah Geological Survey Map 88, scale 1:24,000, 13 p. pamphlet.

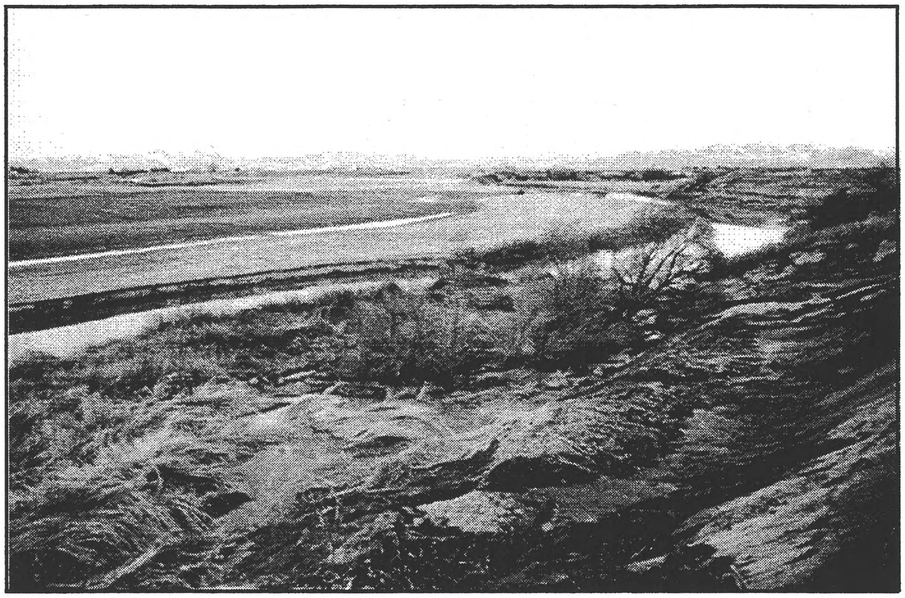
Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R.J., editors, Landslides - analysis and control: Washington, D.C., National Research Council, Transportation Research Board Special Report 176, p. 11-33.

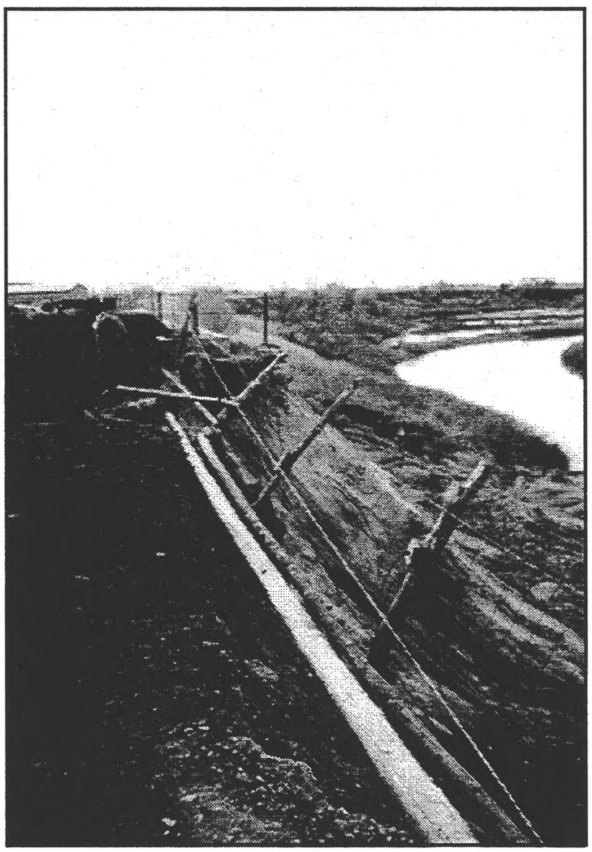
Attachment 1. Job No. 97-07

Base map from UGS Map 88, Geologic map of the Honeyville quadrangle



Attachment 1. Location and geologic map (modified from Oviatt, 1986) of the January 3, 1997 landslide.





Attachment 2. Photographs of the January 3, 1997 landslide along the Bear River, Honeyville, Utah. Top photograph is a view to the north-northwest. Zone of accumulation extends into the river about 75 feet. Landsliding partially blocked the river causing it to be deflected to the west and erode the opposite bank. Bottom photograph shows damage to a fence and watering trough above the main scarp of the landslide. Fence posts are suspended in air and the watering trough foundation is partly overhanging as a result of landsliding. View is to the south.

Project:			Requesting Agency:
Investigation of erosional ravines in Dry Fork Canyon, Uintah County, Utah			Utah Division of Comprehensive Emergency Management
By: Gary E. Christenson	Date: June 6, 1997	County: Uintah	Job No: 97-09 (GH-3)
USGS Quadrangle: Paradise Park (1197), Marsh Peak (1196)		Number of attachments: 5	

INTRODUCTION

At the request of Fred May, Utah Division of Comprehensive Emergency Management (CEM), I visited an area of Dry Fork Canyon, 23 miles northwest of Vernal, where two erosional ravines had been cut as water from a canal breach flowed from Mosby Mountain into Dry Fork Canyon (attachments 1 and 2). Erosion of the ravines contributed much sediment to Dry Fork, contaminating drinking- and irrigation-water supplies in the Vernal area. The purpose of my visit was to provide information on geologic factors related to the erosional event and help determine if it posed additional hazards to downstream residents. I flew over the site on Tuesday, May 20, at about 7:00 a.m. and again around 12:30 p.m. I also traveled up Dry Fork Canyon on May 20 to where flow over the road had deposited sediment and made it impassable about 4 miles northwest of the Dry Fork settlement (attachment 1). Because of time, access, and safety constraints, I did not visit the area of the erosional ravines on the ground.

The chronology of the event, as reported by local residents and responders, is as follows. Red sediment was first noticed in water in irrigation canals in the Vernal area on Sunday, May 18, and perhaps as early as Saturday night, May 17. By Sunday night, it was apparent a major event had occurred upstream in Dry Fork Canyon, and on Monday, May 19, local emergency-response officials and personnel from the Vernal office of the Utah Division of Water Rights began an investigation into the cause of the increased sediment in Dry Fork. Irrigators reported that some of their diversion structures in Dry Fork were in danger of damage from erosion and sedimentation, and that sediment was causing problems with canals and pressure-irrigation systems. Also, a water-treatment plant which receives water from springs in Ashley Canyon reported sediment in the springs and was forced to close. Although the springs are upstream from the confluence of Ashley Creek and Dry Fork (attachment 1), they are recharged by Dry Fork. State officials from CEM flew over the site on Monday, May 19, and contacted me that afternoon with their observations. Officials from the irrigation company that operates the Mosby Canal on Mosby Mountain recognized on Monday that a breach in their canal just upstream from Julius Park (attachment 2) was the principal source of water causing the erosion. Monday afternoon they closed the Blanchett Park headgate on the canal about 4.5 miles above the breach. However, flow from the breach continued because snowmelt below the headgate was contributing significant flow to the canal. The canal was repaired Tuesday afternoon, May 20, and flow into the erosional ravines was greatly reduced.

SETTING AND GEOLOGY

The area of the Mosby Canal on Mosby Mountain is relatively flat and characterized by high alpine bogs and marshes, particularly between the canal and the top of the slope forming the west side of Dry Fork Canyon (attachment 2). These marshes fill with water each spring and overflow into Dry Fork Canyon in a series of shallow drainages. Much of the area that previously fed water to these marshes is now cut off by the Mosby Canal, so only a narrow area between the canal and Dry Fork Canyon now feeds the marshes (attachment 2).

The material in Dry Fork Canyon and on top of Mosby Mountain in the area of the ravines is mapped as glacial till, more than 100 feet thick, of the late Pleistocene Pinedale and Bull Lake glaciations (Carrara, 1980). Sedimentary rocks of the Precambrian Uinta Mountain Group are found upstream, and Oligocene sedimentary and volcaniclastic rocks of the Bishop Conglomerate cap Mosby Mountain south of the breach area (Rowley and others, 1985).

Because of safety concerns due to the instability of the ravine walls, material exposed in the ravines was only viewed from the air. It appears to consist of red sand and silt with gravel, cobbles, and boulders, and is at least 600 feet thick, extending from the top of the northern ravine to the bottom. The material is unconsolidated and highly erodible. The deposits show horizontal bedding and may be glacial in origin, as mapped, but may also be poorly consolidated sediments of other origins. No competent bedrock is exposed in the ravines. Careful observations of the ravine walls will be necessary to accurately describe the material and determine its nature and origin.

THE EVENT

Flow from the breach in the Mosby Canal initially flooded marshes on Mosby Mountain, which were probably already full from spring snowmelt and were overflowing into existing drainages into Dry Fork Canyon. The additional overflow from the marsh area caused by water from the canal breach was concentrated initially in at least two places as evidenced by the two major ravines cut into the hillside (attachments 2 and 3). The southern ravine was later beheaded by the northern one, which ultimately captured all of the flow (attachment 4). Enlargement of the northern ravine continued until the canal was repaired and flow was reduced (attachment 5). The ravine is presently about 250 feet deep at its deepest point, up to 500 feet wide, and about 2,400 feet long. About 1.5 million cubic yards of material was removed from the two ravines and deposited onto the flood plain of Dry Fork (attachment 5).

As the ravines enlarged, their over steepened walls began to fail as large blocks collapsed into the ravines and disintegrated. This material, as well as that eroded from the bottom of the ravine, was transported in a thick sediment slurry and deposited in alluvial fans on the flood plain of Dry Fork. The material in the alluvial fans is red silt and sand with gravel, cobbles, and boulders. Much of it was deposited by debris flows and debris floods, although during the waning stages of flow and at present the material is being deposited by sediment-laden stream flows. The alluvial fan from the northern ravine forced Dry Fork to the east side of its flood plain, and has partially blocked the stream and formed a small pond upstream. The pond has an outlet along the east side of the canyon. Flow is over the toe of the alluvial fan, with some undercutting of a talus deposit at the base of the slope on the eastern stream bank.

STREAM FLOW IN DRY FORK

Prior to this event, stream flow in Dry Fork was high due to spring snowmelt but was below flood stage. On Monday, May 19, flow significantly increased, flooding the highway at the Dry Fork settlement and the gravel road upstream in Dry Fork Canyon. Emergency-response officials observed this flood and characterized it as a possible "surge" which had subsided by Monday night. The level of the highest flow was 4-5 feet above the previous (pre-event) level, and was probably caused by several factors: 1) flow of canal water into Dry Fork, which may have peaked Sunday night or Monday but was reduced by Monday night with closing of the headgate at Blanchett Park; 2) possible additional release from marshes and ponds as the head cut at the top of the ravine encroached into the marsh area; 3) reduced channel capacity caused by sedimentation; and 4) possible breakout flooding as the sediment initially blocking Dry Fork was eroded, causing a release of ponded stream water. Evidence for the latter cause was cited by Robert Leake (Utah Division of Water Rights, verbal communication, May 22, 1997) as a "high-water" mark above the present level of the pond in Dry Fork above the alluvial fan from the ravine. Flow in Dry Fork has now returned to previous levels, but the high, sediment-laden flows caused considerable bank erosion, sedimentation, and channel shifting, as well as overbank flow in several localities. An embankment of a small irrigation pond at the Dry Fork settlement was damaged by bank erosion by Dry Fork.

HAZARDS

Now that the canal breach is repaired, flow in the northern ravine is reduced. Erosion of the bottom of the ravine and deposition on the alluvial fan at its mouth are also reduced. Deposition on the alluvial fan is probably insufficient to cause significant additional blockage of Dry Fork. However, sediment will continue to be delivered to Dry Fork both from the ravines and from erosion of sediment in the flood plain. Because the ravines have such a small drainage area (less than 0.5 square mile) between the canal and edge of the canyon (attachment 2), little flow should occur except from snowmelt, local storms, or another canal breach. Head cutting of the northern ravine will continue at a reduced rate, and may eventually reach the canal. If another canal breach occurs in this area, the head cut may quickly reach the canal and then migrate upstream along the canal.

Landsliding and erosion will continue in the walls of the ravines as they attempt to achieve a stable slope angle. The slopes are presently about 1 horizontal:1 vertical (100 percent) or steeper. Over the long-term, stable slopes in this type of unconsolidated granular material are typically a maximum of 2:1 (50 percent). Natural slopes in this material in the area presently range from 1.6:1 to 2.4:1, averaging about 2:1. Thus, the widths of the ravines will ultimately be about twice what they are today. The slopes will probably be unstable for decades.

Material from the walls of the ravines may temporarily block the now-reduced flow in the bottoms, causing local ponding and breakout flooding. However, because the ravine walls are so steep and the ravines so narrow, impoundment of enough water to cause significant flooding downstream in Dry Fork is unlikely. However, sediment from such a breakout flood may cause further temporary blockage of Dry Fork, although it would likely be quickly removed.

Ultimately, the pond on Dry Fork on the upstream side of the alluvial fan will drain as Dry Fork cuts though the alluvial fan to regain its grade. Down cutting into the alluvial fan by Dry Fork will likely be gradual because the alluvial fan and associated flood-plain deposits extend far downstream. Down cutting may occur as a progression of one or more knickpoints or head cuts which begin downstream and migrate upstream. The amount of water ponded is relatively small, however, and the likelihood of rapid erosion causing a breakout flood is low.

Bank erosion by Dry Fork damaged the northern embankment of an irrigation pond downstream at the Dry Fork settlement. Although the pond is relatively small, failure could cause local flooding and erosion downstream.

Sediment levels in Dry Fork and the streams into which it flows will likely remain high. Increased sediment can be expected during periods of high runoff each spring and after storms in the area. During low flows, sediment levels will be reduced but it is difficult to predict when flows may again be clear. Bank cutting and channel-bed erosion and deposition will continue until channels stabilize and adjust to the new sediment load. Continued channel shifting and local flooding should be expected.

RECOMMENDATIONS

The ravine head cut near the Mosby Canal must be monitored to determine its rate of retreat under present conditions and evaluate the hazard it poses to the canal. The canal should be inspected and maintained regularly to ensure that it does not breach again. The Dry Fork channel where it crosses the alluvial fan and drains the upstream pond should be monitored to evaluate the potential for flooding as it cuts through the fan. Also, flow in Dry Fork should be monitored and if significant, unexplained decreases in flow are observed downstream, the possibility of a temporary blockage and subsequent breakout flood should be investigated. The damaged embankment of the irrigation pond at the Dry Fork settlement should be evaluated and repaired, if necessary.

The walls of the erosional ravines are unstable and pose a life-safety threat. Access to the area should be restricted and appropriate warnings posted. Sediment-laden flow and channel instability in Dry Fork should be expected for years to come. Much sediment remains in the flood plain, and heavily sediment-laden flows should be expected each spring and after storms anywhere in the Dry Fork headwaters. Shifting channels in the Dry Fork flood plain may cause local undercutting of canyon walls, possibly destabilizing slopes. Areas of such undercutting should be monitored for slope failures.

Over the longer term, geologic investigations to determine the nature and extent of the highly erodible hillside material are needed. Such information will be critical for land-use management in the area to prevent further erosion.

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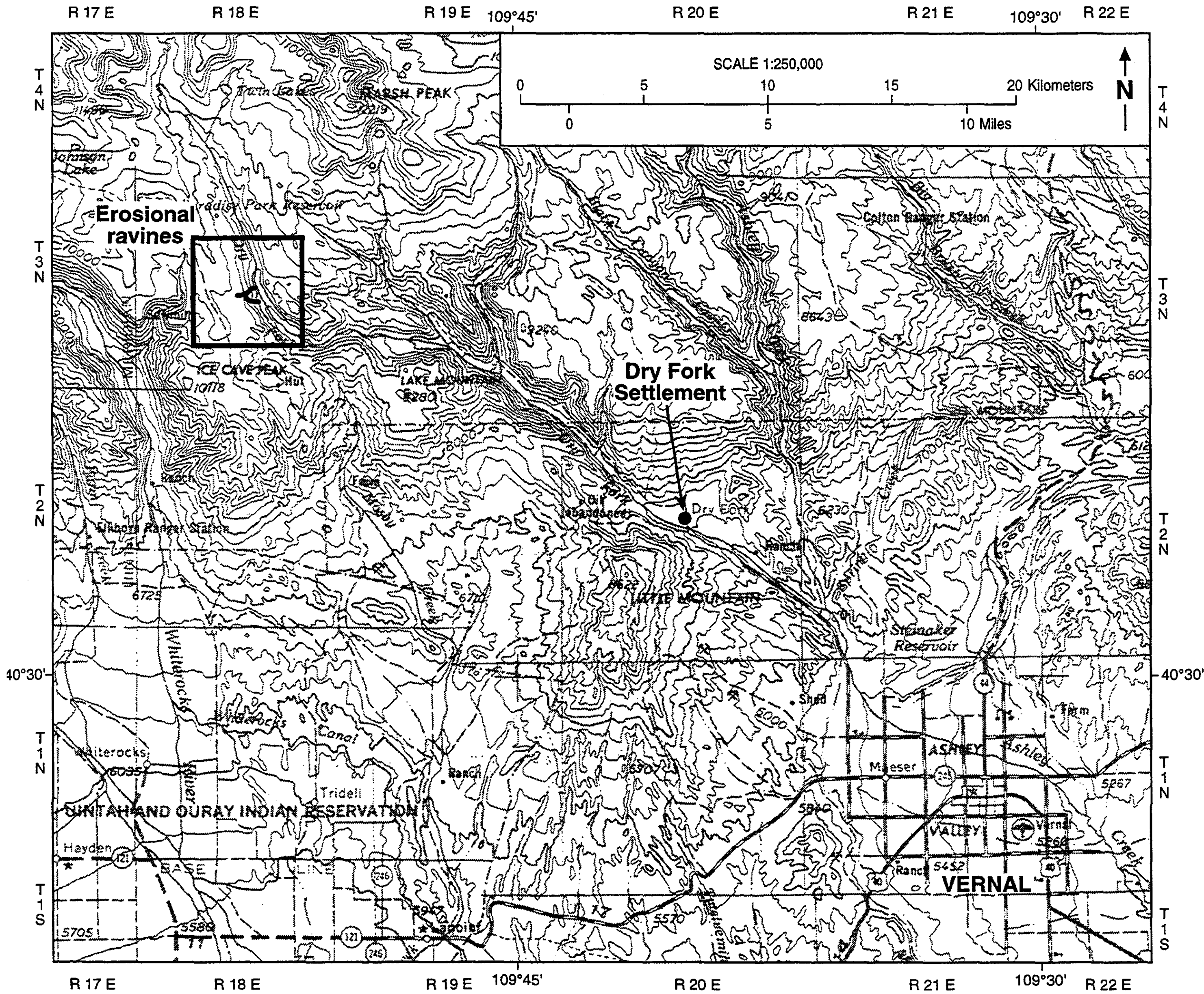
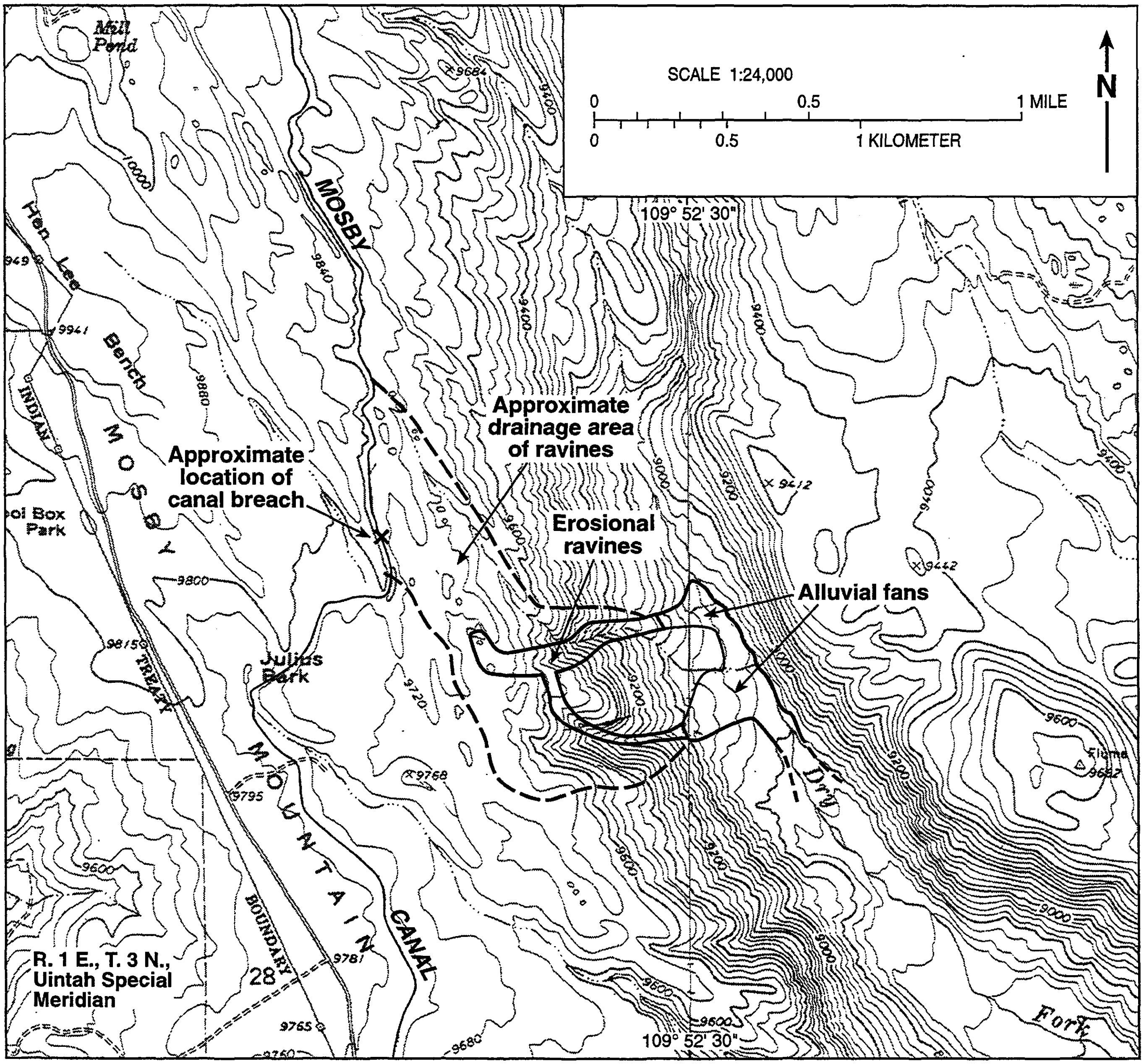
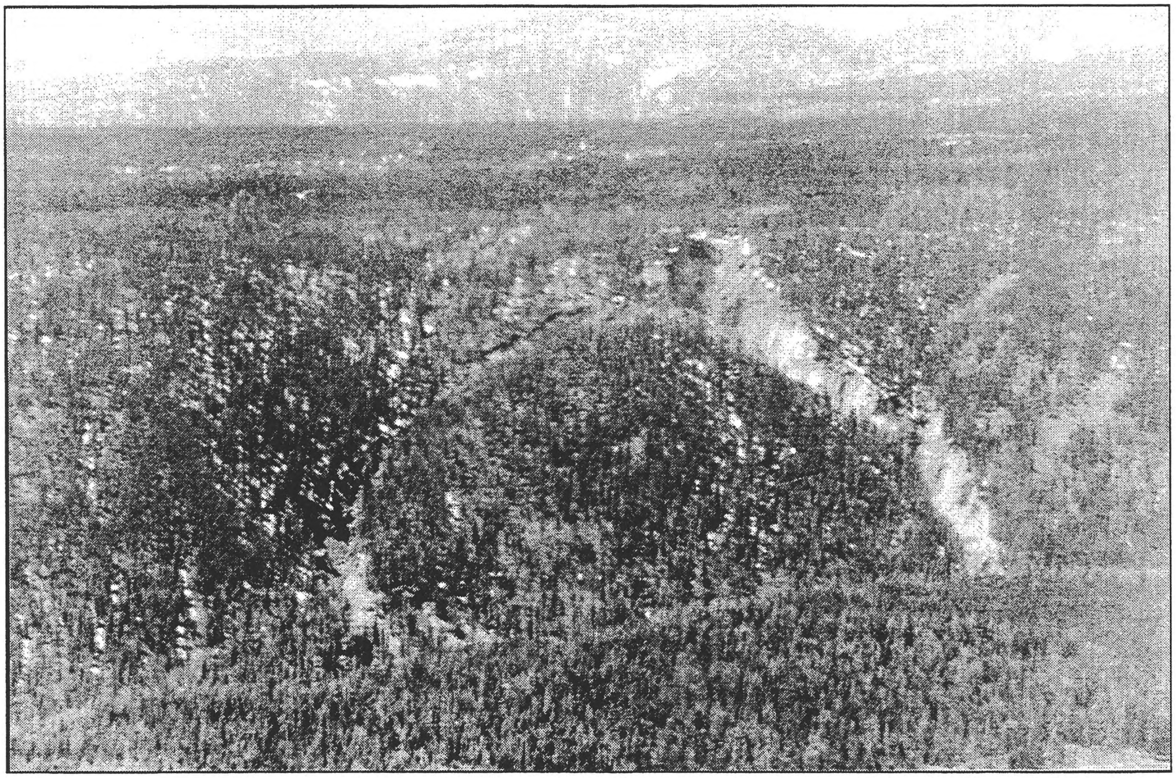
Base Map from VERNAL U.S.G.S. 1:250,000 topographic quadrangle



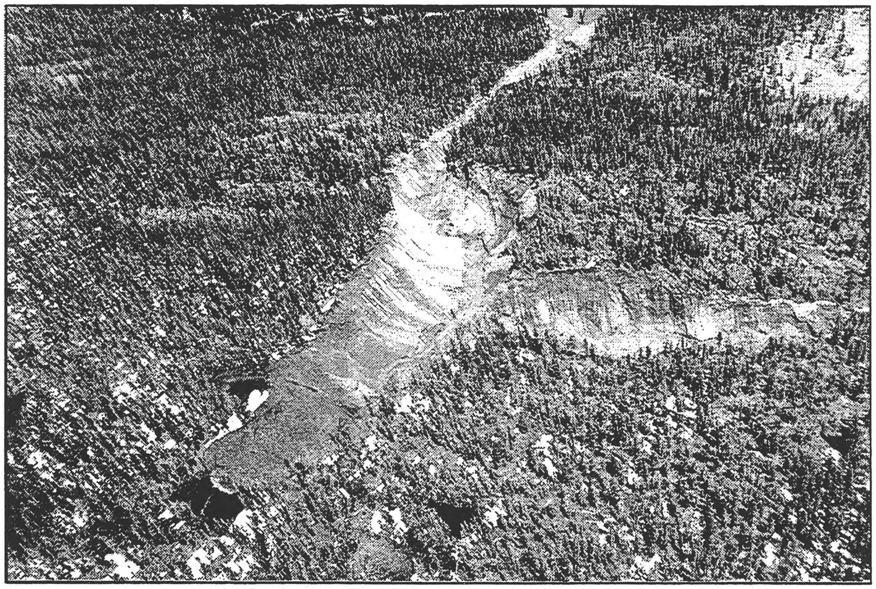
Attachment 1. Location map, box is area shown in attachment 2.



Attachment 2. Location map showing erosional ravines, alluvial fan, canal breach, and the approximate drainage area of ravines.



Attachment 3. Westward view of erosional ravines (photo by Mike Royce, Utah Highway Patrol; May 19, 1997).



Attachment 4. Eastward view (looking down slope) of head area of ravines showing capture of flow in the southern (right) ravine by the northern (left) ravine (photo by Mike Royce, Utah Highway Patrol. May 19, 19, 1997).

Attachment 5. Eastward view (looking down slope) of northern ravine and alluvial fan deposited on the flood plain of Dry Fork (photo by Mike Royce, Utah Highway Patrol, May 19, 1997). By May 20, the head of the ravine had migrated northward into pond in lower left corner of photo.

Utah Geological Survey

Project: Reconnaissance of a landslide along Chalk Creek, Summit County, Utah			Requesting Agency: Emergency Response
By: F.X. Ashland	Date: 7-8-97	County: Summit	Job No: 97-11 (GH-4)
USGS Quadrangle: Turner Hollow (1290)		Number of attachments: 11	

INTRODUCTION

On May 28, 1997, I began a reconnaissance of an active landslide along Chalk Creek in Summit County, Utah. The landslide is located about 3-1/2 miles east of Coalville, Utah in the NW1/4SE/14 section 12, T. 2 N., R. 5 E., Salt Lake Base Line and Meridian (attachment 1). The landslide (attachment 2) was brought to my attention by Fred May of the Utah Division of Comprehensive Emergency Management. The landslide was initially investigated by Norm Evenstad (1997) of the U.S. Department of Agriculture Natural Resources Conservation Service on May 22, 1997, at the request of a property owner, Mr. David Wright. Mr. Wright was concerned that movement of the slide could cause damage to a bridge across Chalk Creek about 75 feet downstream of the left flank (looking downslope) of the slide. The purpose of this investigation was to determine the physical characteristics of the slide and evaluate its hazard potential, including the possibility that the slide could divert or dam Chalk Creek resulting in a potential breakout flood hazard. As part of this investigation, I revisited the site on June 4 with Mr. Al Cooper, Summit County Emergency Management Director.

PHYSIOGRAPHY AND GEOLOGY

The landslide occurred on the lower part of a northwest-facing slope on the south side of Chalk Creek. The toe of the slope and the slide are cut by Chalk Creek which flows to the southwest and was flowing at a high rate at the time of my visits. The average slope across the slide is about 15 percent but the left side of the slide is locally flatter. The right flank of the slide coincides with an unnamed dry wash. A Questar gas pipeline presently crosses Chalk Creek about 100 feet upstream of the lower right corner of the slide outside the slide area.

The geology in the vicinity of the landslide has not been mapped in detail, however Bryant (1990) indicates that the slope is underlain by the Cretaceous Kelvin Formation. The Kelvin Formation is comprised primarily of sandstone, siltstone, and claystone. Byrant (1990) mapped a northeast-striking, high-angle fault at the toe of the slope and adjacent to Chalk Creek. Harty (1992) indicates that most of the northwest-facing slope consists of undifferentiated landslides and colluvium. The soils exposed in scarps and cuts in the vicinity of the landslide range from silty fine sand (Unified Soil Classification System - SM) to sandy silt (ML) typically with a small amount of boulders and cobbles of sandstone (likely derived from the Kelvin Formation). Evenstad (1997) indicated that a clay layer (CL) is exposed along Chalk Creek near the center of the slide. The layer overlies an apparent outcrop of shale or claystone.

PHYSICAL CHARACTERISTICS

The landslide (attachment 2) is likely a composite slide, its lower part consisting of a series of rotational slides, or slumps, whereas its upper part is probably a translational slide. The overall slide is about 340 feet long and 380 feet wide along Chalk Creek, and is thus about 14,000 square yards in area. If the slip surface is about 30 feet deep on average, the estimated slide volume is about 140,000 cubic yards. The most prominent feature related to recent movement is a graben at the head of the slide. Other recently active landslide features include a right-lateral scarp that runs along the northeast bank of the dry wash, and the main and right-lateral scarps of the uppermost slump below the graben. Movement may also have occurred on the lower slumps next to Chalk Creek but the extent of recent activity was difficult to discern. Excluding the possibility of movement of the slumps in the lower part of the slide, most of the active landslide features are on the right side of the slide, possibly suggesting counterclockwise rotation of the slide mass.

Graben

A southwest-trending graben (attachment 3) at the head of the landslide is 135 feet long and 44 feet across where it is crossed by a jeep road that parallels the dry wash on the right side of the slide. The main scarp of the slide, and graben, is generally less than 2 feet high and horizontal separation across the scarp locally exceeds 1 foot. Scarp height and separation of the antithetic scarp is similar to that of the main scarp. The two scarps merge to the southwest. Both scarps continue to the northeast of the jeep road to the dry wash. On May 28, the main scarp could only be traced to the bottom of the wash; however, by June 4, a zone of deformation could be identified extending across the bottom of the wash and downslope from the tip of the May 28 scarp trace.

To the west of the graben, a set of left-stepping ground cracks trend generally to the west and obliquely down a moderately steep slope below the graben. The cracks terminate near the base of the slope above a relatively flat grass-covered area on the left side of the slide.

Right-Lateral Scarp

The antithetic scarp of the graben merges with a right-lateral scarp (attachment 4) which can be followed downslope for about 195 feet along the northeastern bank of the dry wash. Separation across the scarp is locally about an inch or greater, however right-lateral offset appears to be minimal. The scarp trace terminates upslope of the intersection of the wash and an old northeast-trending jeep road.

Uppermost Slump

Farther downslope, recent movement along the right side of the slide occurred on the right-lateral scarp of the uppermost slump (attachment 5). Where the scarp crosses the jeep road, the surface of the slump is downdropped as much as 15 inches. The scarp extends about 100 feet downslope from the edge of the road to the creek. About midway between the road and the creek, the sense of offset of the ground surface reverses at a hinge point. Downslope of the hinge point, the slump is heaved upward slightly. The right-lateral scarp bifurcates toward the creek with similar heave distributed across both strands. At the point of intersection of the scarp with the creek an obvious deflection of about 3 to 4 feet in a boulder line is visible that was likely caused by the recent landsliding. The landsliding narrowed the creek channel, causing erosion and sloughing of the opposite river bank. Upslope of the jeep road, the right-lateral scarp merges with the main scarp of the slump which also appeared to have recently moved.

Slumps Along Chalk Creek

The lower part of the slide consists of a series of thin slumps (attachment 6) along Chalk Creek below the active uppermost slump. All of these slumps are downslope of the jeep road that crosses the slide. Scarps are locally greater than 15 feet but are generally less than 10 feet high. The slumps in the lower part of the slide are wider than they are long. Individual slump block lengths are generally less than 25 feet, however I estimate that widths are 3 to 4 times that distance. To the southwest, the scarps of the slumps intersect the creek at an acute angle. Antithetic scarps cut most of the slump blocks forming small grabens. Horizontal separation across some of the scarps and the lack of crack infilling suggests the slumps were recently active.

GROUND-WATER CONDITIONS

Evenstad (1997) reported seepage above the shale/claystone layer exposed along Chalk Creek on May 22. On May 28, soils near this area were moist but I observed no seepage. The ground surface was generally dry in the vicinity of the slide and no water flowed in the right-flank wash. Evenstad (1997) speculated that the fault mapped by Bryant (1990) may act as a ground-water conduit that discharges into the slide mass. However, because the fault intersects only the lowest part of the slide it is unlikely the fault contributes greatly to wetting the slide mass. In the early part of June, following my last visit on June 4, periodic heavy precipitation fell in the vicinity of the slide. Mr. Al Cooper reported that by June 9 the surface materials on the slide had become wet as a result of the rains; however, the affect of precipitation on ground-water levels in the slide is unknown.

MONITORING OF LANDSLIDE MOVEMENT

Qualitative observations of landslide features combined with quantitative measurements indicated continued movement of the landslide between May 28 and June 4. Field observations on June 4, including an apparent increase in the deflection of the boulder line along Chalk Creek and additional downdropping along the upslope part of the right-lateral scarp, suggested additional movement in the lower part of the slide. Increases in the amount of horizontal separation and downdropping across the graben-bounding scarps at the head of the slide and ground cracks to the west were also visible and confirmed by measurements.

Horizontal separation across the main scarp and a ground crack west of the graben was measured during both my visits on May 28 and June 4. During the seven days between the measurements, scarp separation at the southernmost point where the main scarp intersects the jeep road increased 4-1/2 inches. The corresponding finite linear strain (Baum and others, 1988) over the time interval was about 47 percent, yielding an average strain rate of about 7 percent per day. The average daily extension across the scarp was about 0.6 inches per day indicating a slow rate of sliding. Separation across the ground crack (attachment 7) also increased by 1/8 inch over the time period. The corresponding finite linear strain over the time interval was 4 percent, yielding an average strain rate of 0.6 percent per day. The average extension across the crack was about 0.02 inch per day indicating a very slow rate of sliding. Because extension was not measured at all scarps and cracks downslope, the estimated rates of movement are lower bound values.

On June 4, I installed five survey stakes on and adjacent to the more active right side of the landslide, including one in the uppermost slump, one between the slump and the graben, one near the center of the graben, and one upslope of the main scarp (attachment 8). A fifth stake was located outside the slide along the right flank. Subsequent surveying of the stakes by Summit County indicated no discernable movement (Al Cooper, verbal communication, June 18, 1997), despite the periodic heavy precipitation in the area. Mr. Cooper indicated that the county will continue to survey the stakes for evidence of movement, on a weekly basis, throughout the month of June.

PROBABLE CAUSE(S) OF RECENT MOVEMENT

The 1997 landslide movement may have been caused by rapid downcutting of the slide's toe by Chalk Creek. The rapid downcutting is likely the result of the high flow rate in the creek. The seepage reported by Evenstad (1997) also suggests that relatively high ground-water levels in the slide may also have contributed to movement. Previous movement of the older slumps is likely due to ongoing removal of support by downcutting along Chalk Creek.

HAZARD POTENTIAL

The preliminary information suggests that following the first movement of the landslide in May, the rate of subsequent movement decreased. If rapid downcutting at the toe was the trigger for the landsliding, then additional downcutting by the creek may be required before further movement occurs. Because July and August are traditionally relatively dry months, ground-water levels will likely drop in the slide, thus increasing its stability. However, temporary rises in the ground-water level should be anticipated after heavy precipitation from intense rainstorms and could destabilize the slide. Ongoing surveying of the slide should be useful in determining whether movement becomes suspended (movement ceases within less than a year following the first movement) (Cruden and Varnes, 1996) during the summer.

Because the toe of the slide is likely in Chalk Creek, further downcutting could trigger additional movement that would further narrow the channel. Whereas movement may not occur in the remainder of this year, recurrent movement should be anticipated in subsequent years, particularly in the spring following the seasonal snowmelt and during the high flow periods for Chalk Creek.

As little as 20 to 30 feet of movement, particularly if it occurs rapidly, could dam or divert Chalk Creek. Although the present evidence suggests the likelihood of this amount of movement is low, it is nevertheless possible and thus the potential consequences of such an event should be considered. The immediate effects of the landslide damming the creek would be diversion of the creek flow across the road and flooding of the low-lying area north of the road (attachment 9). Ponding in this area may also affect the buried Questar pipeline. The Big Robinson irrigation ditch flows along the northern edge of this area and crosses the road through a buried pipe culvert. Although this culvert would act as a drain, its capacity is considerably less than the current flow in the creek. Water would therefore likely flow over the road once the water level in the low-lying area rose to the road elevation. The sudden release of this ponded water back into the downstream portion of the creek channel could pose a breakout flood and sedimentation hazard to downstream properties, including the engineering test facility (attachment 10) along the creek and directly downstream of the landslide. A breakout flood could also trigger additional landsliding if steep colluvial slopes in The Narrows about 3/4 miles downstream are undercut (attachment 11). These landslides could cause secondary damming of the creek.

RECOMMENDATIONS

The possibility that continued movement could divert or dam Chalk Creek, although low, warrants monitoring of landslide activity until it is shown to be suspended. The ongoing weekly monitoring of the UGS survey stakes by Summit County should be adequate to determine whether the slide continues to move during the summer. I also recommend that if the June survey data show that movement of the slide has suspended, the stakes be surveyed occasionally after intense rainstorms. Recurrent movement is possible in the future, particularly in the late winter and spring. If no movement is indicated over the next year, the slide can be considered dormant (no movement over a period of a year, however the conditions for renewed movement remain) (Cruden and Varnes, 1996).

The classification of the landslide as dormant does not preclude the potential for future movement. However, it may be possible and economically feasible to take remedial measures to stabilize the slide, including relocating the creek away from the toe of the slide, or taking measures to reduce the potential for future downcutting. A detailed geotechnical-engineering slope-stability investigation (Hylland, 1996) of the slide will be required to establish the effectiveness of any proposed remedial measures.

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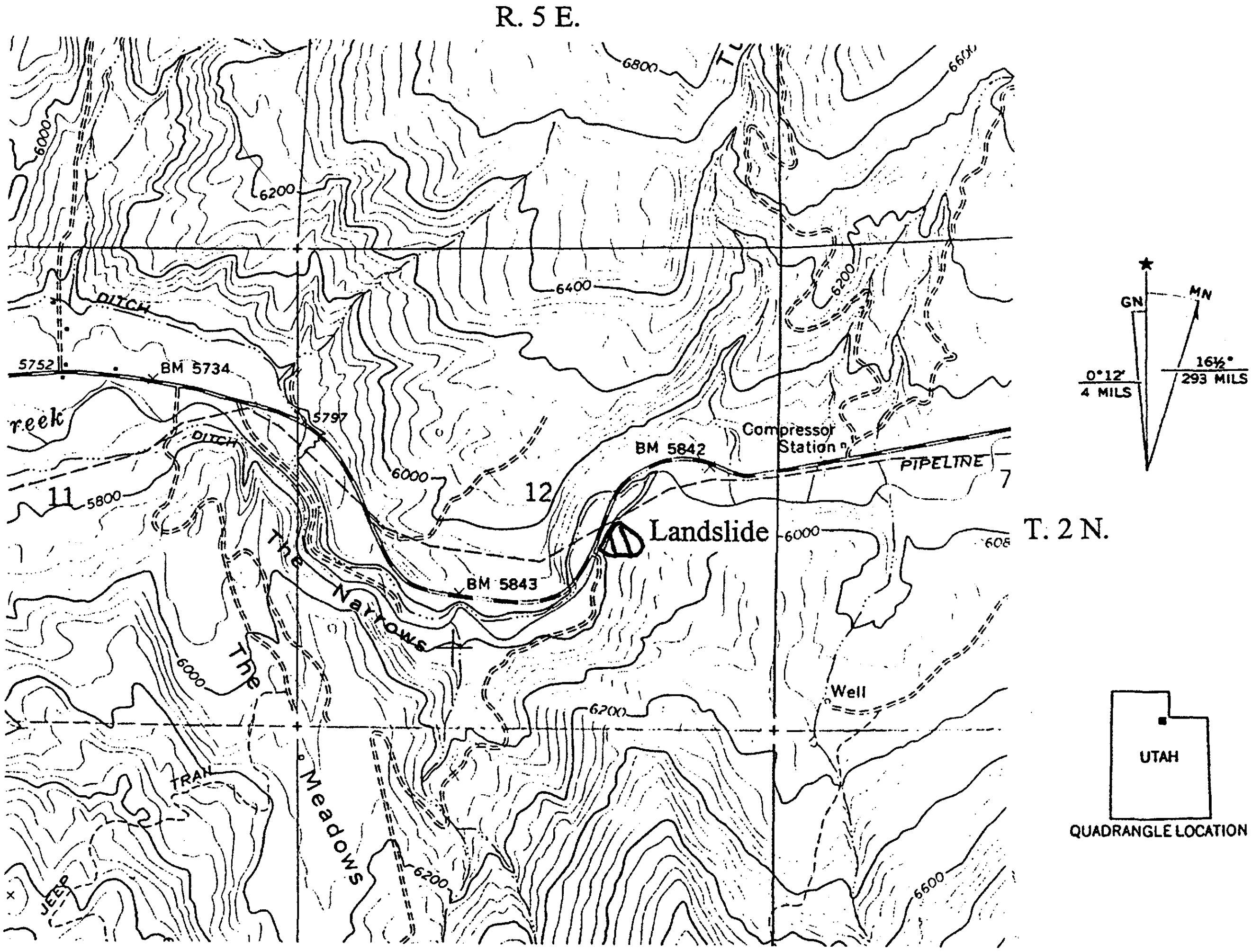

SCALE 1:24 000

1 ½ 0 1 MILE

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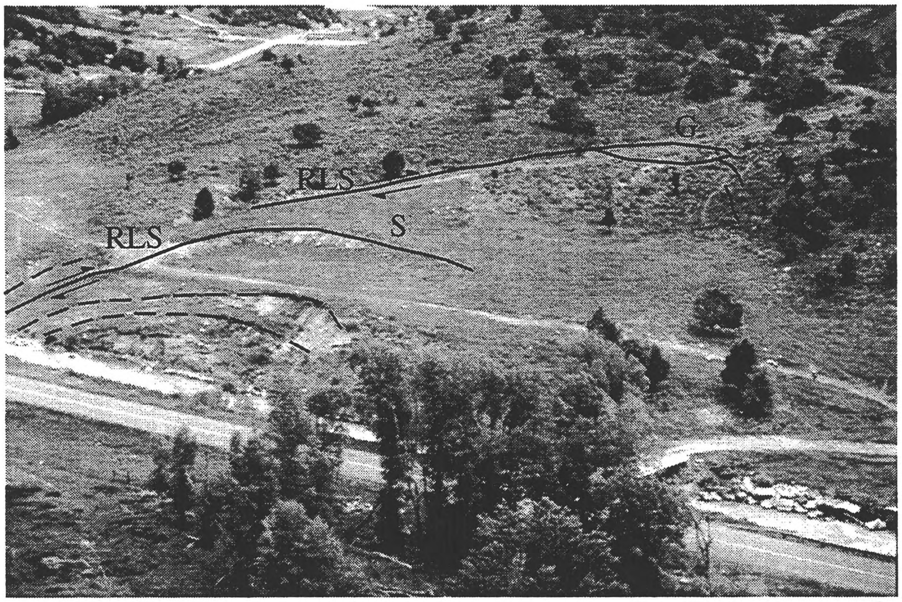
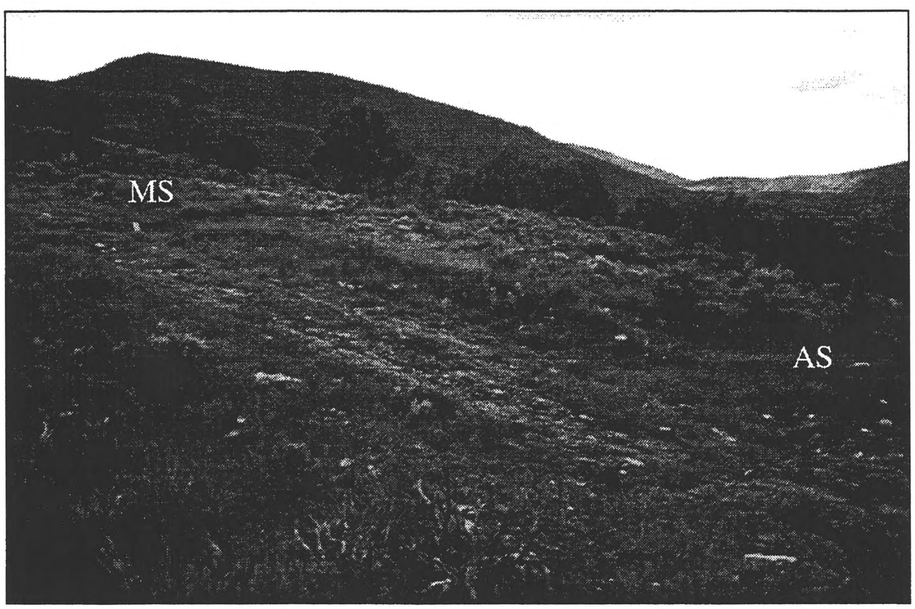
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

Attachment 1. Location map of landslide along Chalk Creek, Summit County, Utah.

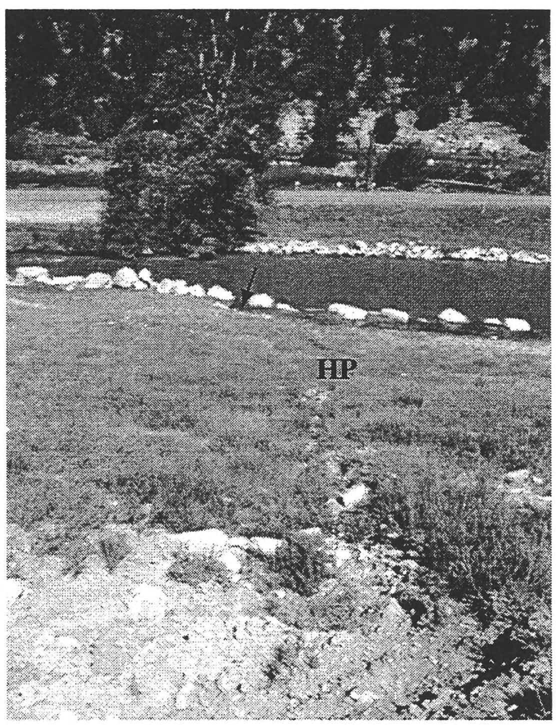


Attachment 2. Oblique view of landslide along Chalk Creek. Active landslide features (solid lines) include the scarps bounding the graben (G), right-lateral scarps (RLS), and main scarp of the uppermost slump (S). The extent of recent movement of the lower slumps and lower part of right-lateral scarp (dashed lines) is uncertain. Traces of all features are approximate and representation of ground cracks near graben is schematic. View is to the east.

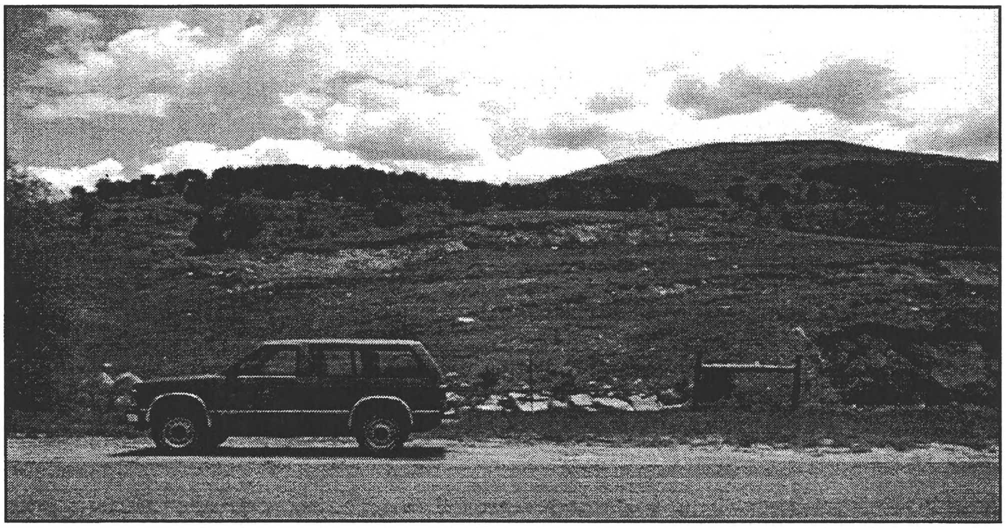


Attachment 3. Southwest-trending graben at head of landslide. Graben is 135 feet long and 44 feet across along the centerline of the jeep road (center of photograph). Main scarp (MS) is generally less than 2 feet high and horizontal separation across the scarp locally exceeds 1 foot. Antithetic scarp (AS) merges with the right-lateral scarp northeast of jeep road. Scarps merge to the southwest. Field book (below 'MS') shown for scale. View is to the southwest.

Attachment 4. Downslope view of active right-lateral scarp from point where it merges with antithetic scarp of graben. Scarp (RLS) can be followed about 195 feet downslope along northeastern (right side) bank of the dry wash. Field book is about 7-1/2 inches long. View is to the northwest.

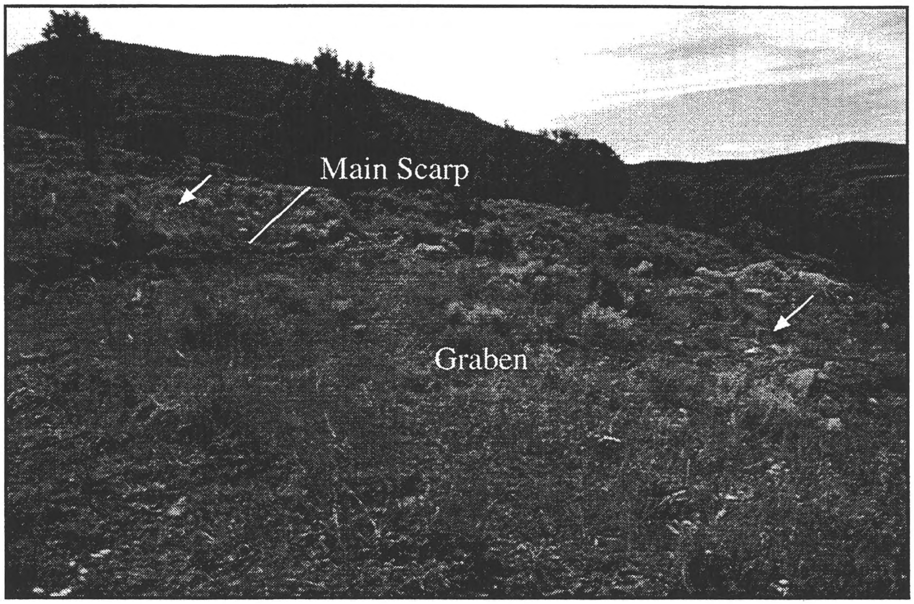


Attachment 5. Downslope view of internal, active right-lateral scarp. Note outward deflection in the boulder line of about 3 to 4 feet along the edge of the creek where the scarp intercepts Chalk Creek (arrow). Right-lateral scarp bifurcates about two-thirds the distance to the creek. Also note the hinge point (HP) about midway to the creek. Southeast (upslope) of this point, the ground surface is downdropped on the left side of the scarp, but to the northwest (downslope) the ground surface is heaved upward on the left side. View is to the northwest.

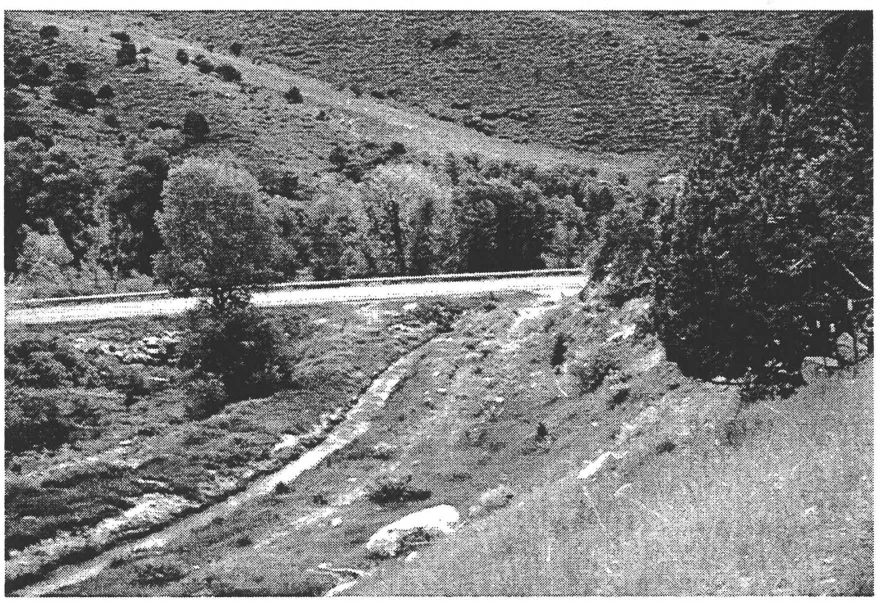


Attachment 6. View of slumps in lower part of landslide along Chalk Creek. View is to the southeast.

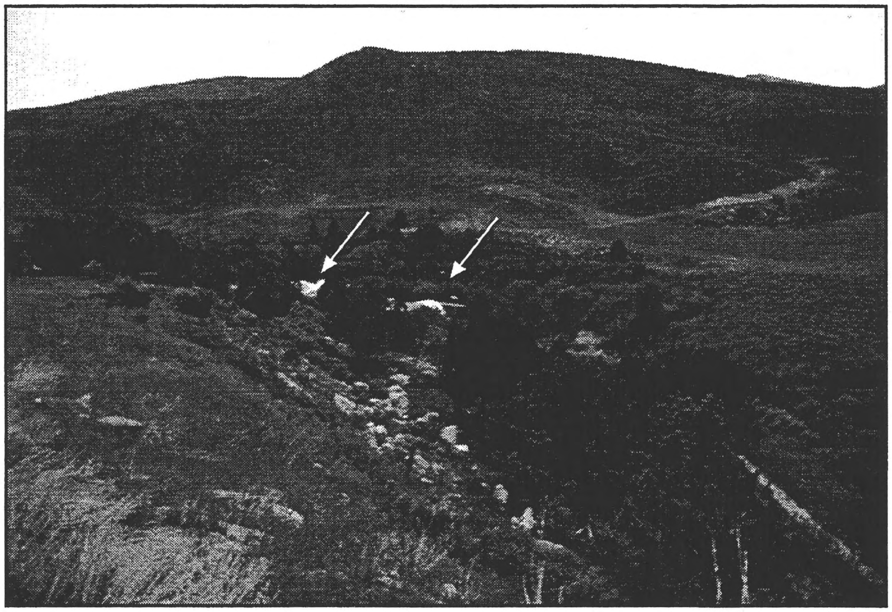
Attachment 7. Separation across a ground crack downslope and west of the graben. Separation across the crack increased from 3-1/8 inches on May 28 to 3-1/4 inches on June 4.



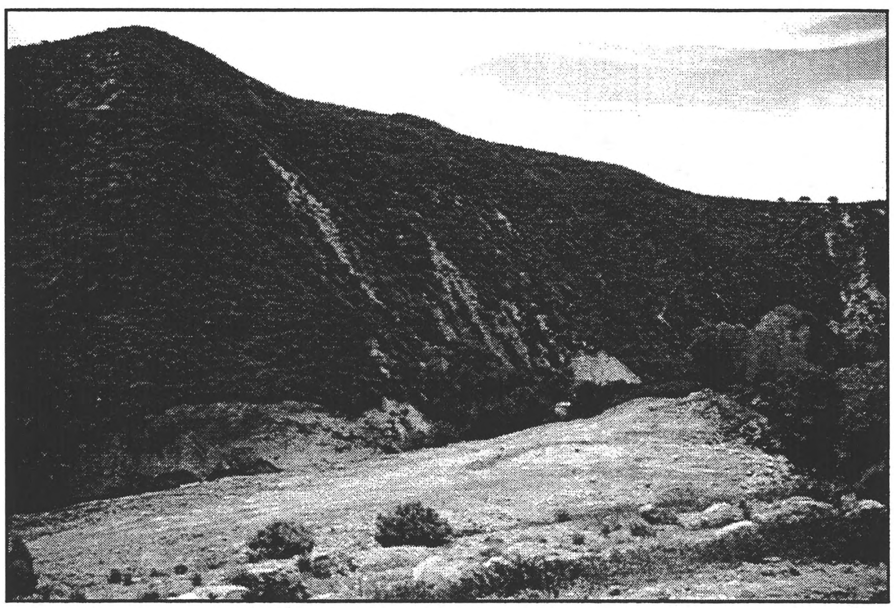
Attachment 8. Stakes installed by Utah Geological Survey to monitor movement of landslide. Upslope stakes (arrows) span main scarp of the graben. Although separation across the main scarp locally increased by as much as 4-1/2 inches over the period between May 28 and June 4, subsequent surveying by Summit County has indicated no discernable movement of the slide despite periodic heavy rain. View is to the southwest.



Attachment 9. View to the southwest of Big Robinson irrigation ditch northwest of road. Bridge and landslide are to the left of photograph on opposite side of road. Instantaneous movement of the landslide in excess of 20 or so feet could dam creek, forcing the creek to flow across the road and flood this area. Water would eventually spill over the road and re-enter the creek channel.



Attachment 10. Engineering test facility directly downstream of the landslide. Arrows indicate buildings and structures. View is to the east-southeast.



Attachment 11. View to the west of The Narrows. Chalk Creek cuts a narrow canyon through this area about 3/4 mile downstream of the landslide. Note oversteepened cut banks at the base of steep colluvial slope and evidence of debris sliding. A landslide-induced breakout flood could rapidly cut into the steep slope and cause further debris slides that, if large enough, could dam the creek in this area.

Project: Geologic-hazards investigation, three proposed school sites, Ivins, Washington County, Utah			Requesting Agency: Washington County School District
By: William R. Lund	Date: August 6, 1997	County: Washington	Job No: 97-17 (GH-5)
USGS Quadrangle: Santa Clara (79)		Number of attachments: 6	

INTRODUCTION

The purpose of this study is to assess geologic hazards and soil conditions at three sites being considered by the Washington County School District (WCSD) as possible locations for a new elementary and middle school complex in the town of Ivins, Washington County, Utah. Two sites are on privately owned land in Ivins; the third is on U.S. Bureau of Land Management (BLM) land south and west of town (attachment 1). Each site encompasses approximately 50 to 60 acres (124 - 148 hectares). None of the sites presently belong to WCSD, so maps showing actual site boundaries and the location of proposed facilities were not available for this study. Mr. Chris Blake, Mayor of Ivins, pointed out the approximate property boundaries during an initial site reconnaissance on June 23, 1997.

The scope of work for this study included a literature review, aerial-photo analysis, and a field investigation on July 10, 1997. Test pits were excavated at the two sites in Ivins; investigation of the BLM site was restricted to surface reconnaissance due to the poorly defined site boundaries, the need to obtain a BLM Special Use Permit to dig test pits, and the fact that bedrock either crops out or is at shallow depth across most of the site.

GEOLOGIC SETTING

Ivins is on a broad pediment surface at the base of an escarpment that forms the south edge of the Red Mountains. The pediment is covered with a layer of fine-grained, wind-blown, quartz sand, and extends southward about 2.5 miles (4 km) to Graveyard Wash, an intermittently flowing tributary of the Santa Clara River. Bedrock in the study area consists of a thick section of Mesozoic sedimentary rocks that dip gently (5 - 10 degrees) to the northeast (Willis and Higgins, 1996). More resistant rock units form cliffs and moderate to steep slopes (Kayenta and Navajo Formations in the escarpment); less resistant formations have been eroded and underlie the pediment surface (Chinle and Moenave Formations). South of Graveyard Wash, the land surface rises on a dip slope of the resistant Shinarump Member of the Chinle Formation. This moderately north-sloping surface has been deeply incised by the southeast-flowing Santa Clara River about 1.5 miles (2.4 km) south of Ivins. A series of flood-control dikes at the base of the Red Mountains escarpment control flash floods from narrow steep canyons in the cliff face.

SITE CONDITIONS

Site A - 200 West and Center Streets

Site A occupies the northwest corner of the intersection of Center Street and 200 West Street in Ivins (SW 1/4 sec. 31, T. 41 S., R. 16 W. ; attachment 1). The property extends about 4 blocks west and 2 blocks north from the intersection. A privately held parcel that borders Center Street from about 300 West to 400 West and extends from Center Street a few hundred feet north is not part of the proposed school site. As a result, Site A has an upside-down U shape. The property is on the pediment surface and slopes gently to the south. The elevation at the south end of the property near Center Street is about 3,070 feet (936 m). Total change in elevation across the site from north (higher) to south (lower) is less than 40 feet (contour interval on the Santa Clara 7.5 minute topographic map; attachment 1). No major stream channels cross the property, site drainage is chiefly accommodated by sheet wash and rill flow, and the flood-control dikes at the base of the Red Mountains control runoff from the area upslope of the site. No structures or other major improvements are on the property. A small area of the western part of the property has been cultivated in the past, and connectors for irrigation pipes are present along the south edge of the field parallel to Center Street. The area has not been cultivated for several years (Tom Oliphant, Town of Ivins, verbal communication, 7/10/97). The remainder of the site is covered with desert grass and low shrubs.

Ownership of Site A is distributed among several individuals. Permission was obtained to dig test pits on the properties that comprise both legs of the U, but not for the portion of the site that connects the legs. Two test pits were excavated on the east leg and three on the west leg (attachment 1). All test pits were excavated to the total depth possible with the backhoe (12 feet; 3.7 meters), and exposed similar loose to medium dense, very fine-grained, red, eolian (wind blown) sand (attachment 2) with a few thin (<1 foot; 30 cm), discontinuous stringers of gravel and rare cobbles. Only in test pit 1 did the soil become more clayey and slightly moist below a depth of 10 feet (3 m) (attachment 2). Neither ground water nor bedrock were encountered in any of the test pits. Depth to the permanent water table at the site is probably near or below the level of the Santa Clara River (elevation about 2,875 feet; 877 m). Bedrock beneath the site is either the upper part of the Petrified Forest Member of the Chinle Formation or the lower part of the overlying Moenave Formation. Because depth to bedrock is greater than the backhoe could dig, test borings would be required to determine which formation is present. Both the Chinle and Moenave Formations contain fine-grained rock types (shale and mudstone) and are relatively impermeable. Therefore, a shallow perched water table may be present on top of bedrock in places beneath the site. Test borings would be required to determine if a perched water table is present.

Site B - Industrial Park

Site B is immediately west of 400 West Street and south of Highway 91 in the Ivins Industrial Park (SW1/4 sec. 6, T. 42 S., R. 16 W.; attachment 1). The property parallels Highway 91 for several hundred feet to the northwest and extends to the southwest across Graveyard Wash onto the northeast side of Land Hill (attachment 1). North of Graveyard Wash, the property occupies the southern end of the pediment surface that extends southward from the Red Mountains. The elevation there is about 3,000 feet (915 m). The surface of the site then slopes gently toward the flood plain of Graveyard Wash to an elevation of about 2,950 feet (899 m), and then rises irregularly onto the flank of Land Hill to an elevation of about 3,080 feet (939 m). Slopes on the site are all gentle to moderate. There are no cliffs or steep rock outcrops. Graveyard Wash contains an intermittent stream that shows evidence of recent flow in response to periodic cloudburst storms. The frequency of such flows is low, but flow likely will occur several times during the life of a school at this site. Adjacent to Highway 91, the industrial park has paved streets and some underground utilities in place; south of Graveyard Wash no grading or development has taken place and the site is covered with grass and low desert shrubs.

Seven test pits were excavated at Site B: four north of Graveyard Wash in the developed part of the industrial park, and three south of the wash on undeveloped land (attachment 1). None of the test pits could be excavated to the 12 foot (3.7-m) depth capability of the backhoe. North of the wash, refusal occurred in a resistant, caliche-cemented cobble and boulder horizon overlain by varying thicknesses of red sand or clayey sand (attachment 2). The Petrified Forest Member of the Chinle Formation crops out over much of the area south of the wash (Willis and Higgins, 1996), where it consists of variegated, pale-brownish-gray, pale-greenish-gray, and grayish-purple, bentonitic shale with lenticular beds of pale-yellowish-brown sandstone up to several feet thick. The test pits there were an attempt to find the deepest soil cover in that part of the site, but all three excavations encountered bedrock at shallow depth (0.2 feet [0.06 m] to 4.7 feet [1.4 m], attachment 2). The backhoe could dig through the upper layer of weathered rock, but made no headway after encountering unweathered bedrock. All seven test pits were dry. Depth to the permanent water table is probably near or below the level of the Santa Clara River to the south.

Site C - BLM Site

Site C is south of Ivins on BLM land in the W1/2 of section 8, T. 42 S., R. 16 W. (attachment 1). The boundaries of this property are poorly defined; the site generally occupies an area along both sides of an intermittent tributary stream that joins Graveyard Wash from the southwest. Topography across the site is irregular with numerous small hills, draws, washes, and cuesta ridges. Drainage is to the east from Land Hill, which forms the high ground to the west. Elevations on site range from a high of about 2,960 feet (902 m) on the flank of Land Hill to about 2,900 feet (884 m) along the tributary to Graveyard Wash. Land Hill and other high points near the property reach elevations up to 3,200 feet (976 m). Slopes on site are gentle to moderate and lack cliffs or steep rock outcrops. The tributary to Graveyard Wash and several smaller draws that drain to the tributary all show evidence of intermittent stream flow, and can be expected to carry water during cloudburst storm events. Other than an unimproved dirt track that crosses the site from northwest to southeast, the property is undeveloped. Vegetation consists of grass and low desert shrubs.

The field investigation at Site C was limited to a surface reconnaissance. Test pits were not excavated because: (1) shallow bedrock crops out over much of the site; the only appreciable thickness of unconsolidated material is along stream bottoms and a few dissected remnants of old pediment-mantle deposits near Graveyard Wash (Willis and Higgins, 1996), (2) the vague nature of the site boundary made it difficult to know what areas would or would not be included in a property exchange with the BLM, and (3) excavating test pits with mechanized equipment requires a Special Use Permit from the BLM. Bedrock at the site is the Petrified Forest Member of the Chinle Formation, which chiefly consists of easily eroded, grayish-purple shale and mudstone with one or more resistant, yellowish-brown sandstone layers up to several feet thick. The bedrock dips between 7 and 10 degrees to the northeast and the sandstone layers, because they are more resistant, hold up several small cuesta ridges adjacent to the site. Soils are thin to absent in most places. Where present, they consist chiefly of reddish brown clayey sand and sandy clay derived from erosion of the shale and siltstone. In several places, large, semi-polygonal ground cracks up to an inch (2.5 cm) wide have formed in the reddish-brown soils indicating that they change volume readily (shrink or swell) with changes in water content. North of the main tributary channel that crosses the site, a few thin deposits of orangish-brown eolian sand have accumulated on the lee side of some low hills. The hills are capped by the remnants of coarse pediment-mantle deposits containing cobbles and boulders of the Navajo Sandstone and Kayenta Formation. The nearest outcrops of those two formations are in the Red Mountains nearly 3 miles (4.8 km) to the north. No springs or other evidence of shallow ground water are present on site. Depth to the permanent water table is probably near or below the level of the Santa Clara River south and west of the site.

HAZARD ASSESSMENT

Geologic hazards considered for this study include: problem soils and rock, flooding, slope instability, shallow ground water, earthquake hazards, and radon gas. A check list for each site (attachments 3, 4, and 5) summarizes the geologic hazards at each of the three properties. A more detailed discussion of the hazards is provided below.

Problem Soil and Rock

The varicolored shales and siltstones of the Petrified Forest Member that crop out or are present in the shallow subsurface over much of Sites B and C contain bentonitic clay derived from the weathering of volcanic ash. Bentonite absorbs water readily and can undergo large volume changes with changes in moisture content. Shrinking and swelling of the Petrified Forest Member and the soils derived from it can cause serious foundation problems for structures. Volume changes that accompany repeated wetting and drying of the bentonite can crack foundations and walls and cause floors to buckle. Numerous foundation problems related to the Petrified Forest Member are documented from the Santa Clara Bench and Green Valley areas (Christenson and Deen, 1983; Christenson, 1992; Mulvey, 1992), where this unit is known locally as the "blue clay." Strict control of moisture content is required in areas of expansive soil and rock, and special foundation designs typically are necessary in such areas, even in some cases where the clay is buried at shallow depth by non-expansive surficial soil.

Although consisting chiefly of relatively soft shale and siltstone, the Petrified Forest Member also contains several resistant sandstone horizons that may be up to 10 feet (3 m) thick. Gently north-dipping sandstone crops out over a considerable portion of Site C and to a lesser extent over Site B. Resistant bedrock at shallow depth may cause excavation problems for foundations and underground utilities. Caliche-cemented coarse-grained soils at Site B may also present excavation difficulties.

The poorly graded eolian sand that covers Site A to a depth of at least 12 feet (3.7 m) presents no special foundation problems. It would, however, be subject to erosion where exposed in moderate to steep cut slopes and is susceptible to piping (removal of loosely compacted material [generally fine sand and silt] by subsurface flow of water) adjacent to cuts where seepage water can exit the subsurface through a cut free face.

Flooding

Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (1986) for Washington County exclude Ivins, so information is not available for Site A regarding federally designated flood-hazard zones. Because no major stream channels cross the property, and because the site is protected by flood-control dikes at the base of the Red Mountains, the flood hazard at Site A is considered low. Both Sites B and C are in areas classified on FEMA Flood Insurance Rate Maps as Zone C, "Areas of minimal flooding." This classification is likely correct for large regional floods caused by the rapid melting of a heavy snow pack in the surrounding mountains or by prolonged heavy precipitation, because neither site is on a major stream course with a correspondingly large drainage area. However, both sites are crossed by smaller ephemeral streams that flow in response to local cloudburst-storm events. Both sites likely would experience several such flow events during the projected life of a school; precautions regarding site grading and placement of facilities are necessary at Sites B and C to avoid flooding.

Slope Instability

Site A is generally flat with a gradual slope to the south. No landslide or other slope- stability problems exist at that site. The potential for debris flows from off-site sources is also low. Site B is generally flat along its northern edge, but south of Graveyard Wash the property is inclined moderately to the north on a dip slope formed on the Shinarump Member of the Chinle Formation. No cliffs or excessively steep slopes exist on site, and bedrock either crops out or is in the shallow subsurface throughout the area. There is no evidence of previous slope instability and all natural slopes appear stable. Ephemeral stream flooding may be a hazard at this site (see above), but there is insufficient unconsolidated material on the slopes and in the stream channels at or around Site B to generate debris flows. Site C is the most topographically irregular of the three proposed school sites. Slopes there range from low to moderate and are chiefly north or northeast facing. Bedrock crops out or is in the shallow subsurface across the site and there is no evidence of pre-existing slope failures on the property. The thickness of the thin colluvial and alluvial deposits on or around Site C is insufficient to generate debris flows. While natural slopes on Sites B and C are stable, the irregular land surface at both locations will require considerable grading to accommodate a large school complex. Depending on facility layout, cuts several feet high in the weak shale and siltstone of the Petrified Forest Member of the Chinle Formation may be required at both sites. If so, the cuts should be carefully evaluated for stability, especially if they will be permanent.

Shallow Ground Water

Depth to the water table beneath all three sites is likely near or below the level of the Santa Clara River (elevation about 2,875 feet; 877 m), a minimum of 125 feet (38 m) at all three sites. No phreatophytic vegetation or other evidence of a shallow perched water table was observed at any of the sites. Slopes at sites B and C are sufficient for shallow subsurface water to drain away. It is possible, particularly on a seasonal basis or from lawn watering accompanying development, that water could pond in the shallow subsurface on top of low- permeability bedrock at Site A. However, at present no surface evidence of a shallow water table exists at the site and all five test pits were dry.

Earthquake Hazards

The nearest known potentially active fault to the three proposed school sites is the Washington fault that trends north-south through Washington City (Hecker, 1993). Because all three sites are 9 or more miles (14 km) from the fault, the hazard from surface fault rupture at the sites is low. However, St. George is located near the south end of the Intermountain seismic belt, a zone of diffuse earthquake activity extending from northwestern Montana to southern Utah and eastern Nevada (Christenson and Nava, 1992). Historical earthquakes have reached magnitudes of 6 to 6.5 in southwestern Utah. The 1992 St. George earthquake (M_L 5.8) is the largest instrumentally recorded earthquake in the area (Pechmann and others, 1995). The Washington fault and other seismogenic faults in the region have the potential to produce earthquakes in the 7 to 7.5 magnitude range. Therefore, all of the proposed sites are in Uniform Building Code (UBC) (1997) seismic zone 2B, a zone of moderate earthquake hazard with a maximum Modified Mercalli intensity of VII expected in a building's design lifetime. Such ground shaking may cause negligible damage in buildings of good design and construction, slight to moderate damage in well-built ordinary structures, and considerable damage in poorly built or badly designed structures. At a minimum, structures at all three sites should be designed in accordance with current UBC seismic requirements for zone 2B. Based on test pit excavations and surficial geology, it is estimated that Site A is in UBC soil profile type S_D, whereas Sites B and C have a range of soil profile types from S_A to S_C. Because of the lack of shallow ground water and steep slopes at the three sites, the hazard from soil liquefaction and earthquake-induced slope instability is low.

Radon Gas

The three sites are all in areas of low (Site C) or moderate (Sites A and B) radon-hazard potential, primarily due to deep ground-water levels and moderate-permeability soils (Solomon, 1995). No indoor-radon measurements are available from Ivins, but indoor measurements from areas of moderate hazard elsewhere have locally exceeded the U.S. Environmental Protection Agency recommended action level of 4 picocuries/liter (148 Bg/m^3).

CONCLUSIONS AND RECOMMENDATIONS

From a geologic perspective, Site A is the most favorable of the three sites being considered for a new school complex. Soils there present no particular foundation problems; the hazard from flooding is low; the site is nearly flat, so no slope stability problems exist; and depth to ground water is greater than 12 feet (3.7 m) and probably greater than 125 feet (38 m). The level of earthquake-related hazards, recommended minimum seismic design, and radon hazard are essentially the same at all three sites. Both Sites B and C have potential for foundation problems related to expansive clay in the Petrified Forest Member of the Chinle Formation, and for intermittent stream flooding in response to cloudburst storms. Moderate slopes and through-going drainages at both sites would require considerable grading to accommodate a large school complex. Bedrock either crops out or is present in the shallow subsurface at both sites and could present excavation problems for foundations and utilities during construction. This is particularly true at Site C, the most rugged of the three sites. Neither Site B nor C shows evidence of shallow ground water, and natural slopes are stable at both locations. With other geologic factors being about equal, the more rugged topography and consequent greater amount of site grading and associated problems with shallow bedrock at Site C, makes Site B the second- best geologic alternative for a school complex.

Once a final site is chosen, a geotechnical soil-foundation investigation should be performed to determine seismic soil-profile types, identify adverse soil conditions, and provide recommendations for foundation design. Site drainage should be planned to minimize the possibility of flooding and soil piping. Although radon-resistant construction is not required, such methods are relatively inexpensive and if incorporated into the structure would minimize the hazard. Indoor-radon testing should be conducted following construction.

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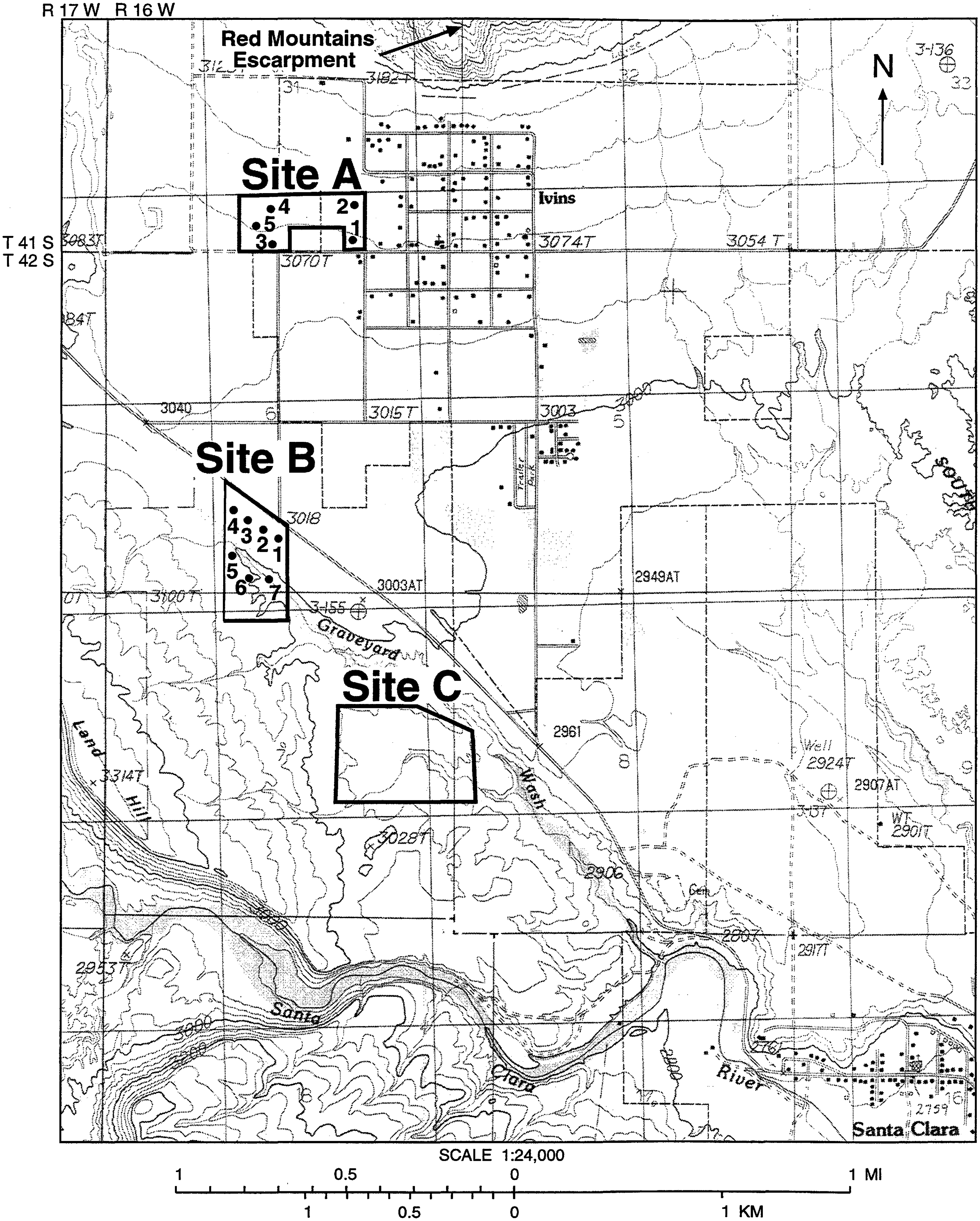
Base Map from SANTA CLARA, U.S.G.S.
7-1/2' topographic quadrangle



Attachment 1. Proposed school site locations, Ivins, Utah. Sites A and B show location of soil-test pits. All site boundaries are approximate.

ATTACHMENT 2
Logs of Test Pits
Washington County School Sites
Town of Ivins, Utah

Site A - 200 West and Center Streets (east side of property)

Test Pit No. 1

0' - 10'	Silty sand (SM); red (10YR 5/8), fine grained, loose to medium dense, nonplastic, dry, noncemented; includes a few thin, discontinuous gravel stringers with some small cobbles; chiefly eolian sand with minor alluvium.
10'-12'	Clayey sand (SC); reddish brown (2.5 YR 3/4), fine grained, firm to medium dense, slight to moderate plasticity, moist, noncemented; chiefly eolian sand with minor alluvium.

Test Pit No. 2

0-12'	Silty sand (SM); red (10YR 5/8), fine grained, loose to medium dense, nonplastic, dry, noncemented; includes a few thin, discontinuous gravel stringers with some small cobbles; chiefly eolian sand with minor alluvium.

Site A - 200 West and Center Streets (west side of property)

Test Pit No. 3

0-12'	Silty sand (SM); red (10YR 5/8), fine grained, loose to medium dense, nonplastic, dry, noncemented; includes a few thin, discontinuous gravel stringers with some small cobbles; chiefly eolian sand with minor alluvium.

Test Pit No. 4

0 - 12'	Silty sand (SM); red (10YR 5/8), fine grained, loose to medium dense, nonplastic, dry, noncemented; includes a few thin, discontinuous gravel stringers with some small cobbles; chiefly eolian sand with minor alluvium.

Test Pit No. 5

0-12'	Silty sand (SM); red (10YR 5/8), fine grained, loose to medium dense, nonplastic, dry, noncemented; includes a few thin, discontinuous gravel stringers with some small cobbles; chiefly eolian sand with minor alluvium.

Site B - Industrial Park Site

Test Pit No. 1

0' - 1.3'	Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.
1.3' - 2.4'	Clayey sand (SC); reddish brown (2.5YR 4/4), fine grained, firm to dense, low plasticity, dry, noncemented; chiefly eolian sand
2.4' - 3.1'	Caliche-cemented cobbles and gravel; well-indurated stage III caliche cementing stream-rounded cobbles and gravel with a few small boulders; backhoe unable to penetrate cemented layer; fluvial deposits related to Graveyard Wash.

Test Pit No. 2

0' - 2.1'	Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.
2.1' - 4.0'	Silty sand (SM); red (2.5YR 4/6) with white mottling, fine grained, loose to dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); eolian sand.
4.0' - 5.6'	Gravelly silty sand (SM); red (2.5YR 4/6) with white mottling, medium to coarse grained, dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); estimate 30 percent gravel to about 3 inches in long dimension; mixed stream alluvium and eolian deposits.
5.6'	Refusal; backhoe stopped by caliche-cemented boulders and cobbles, could only scrape the surface, no penetration; fluvial deposits related to Graveyard Wash (?).

Test Pit No. 3

0" - 2.6'	Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.
2.6' - 6.2'	Gravelly silty sand (SM); red (2.5YR 4/6) with white mottling, medium to coarse grained, dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); estimate 30 percent gravel to about 3 inches in long dimension; mixed stream alluvium and eolian deposits.
6.2'	Refusal; backhoe stopped by caliche-cemented boulders and cobbles; fluvial deposits related to Graveyard Wash (?).

Test Pit No. 4

0' - 2.4'	Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.
2.4' - 4.5'	Silty sand (SM); red (2.5YR 4/6) with white mottling, fine grained, loose to dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); eolian sand.
4.5' - 5.6'	Gravelly silty sand (SM); red (2.5YR 4/6) with white mottling, medium to coarse grained, dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); estimate 30

percent gravel to about 3 inches in long dimension and a few cobbles to 6 inches in diameter; fluvial deposits related to Graveyard Wash.

5.6' Refusal; backhoe stopped by caliche-cemented cobbles and boulders; fluvial deposits related to Graveyard Wash.

Test Pit No. 5

0' - 0.2' Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.

0.2 -1.5' Weathered shale; reddish brown (2.5YR 4/4), soft, medium plasticity.

1.5' Refusal; backhoe could not penetrate unweathered bedrock.

Test Pit No. 6

0' - 0.8' Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.

0.8' - 4.2 Weathered shale; reddish brown (2.5YR 4/4), soft, medium plasticity.

4.2' - 5.9 Weathered sandstone; red (2.5YR 4/6) to reddish brown (2.5YR 4/4); soft to moderately resistant, nonplastic.

5.9' Refusal; backhoe could not penetrate unweathered sandstone.

Test Pit No. 7

0' - 1.9' Silty sand (SM); red (2.5YR 4/6), fine grained, loose to medium dense, nonplastic, dry, noncemented; eolian sand.

1.9' - 4.7' Silty sand (SM); red (2.5YR 4/6) with white mottling, fine grained, loose to dense, nonplastic, dry, moderately cemented (stage II caliche accumulation); eolian sand.

4.7' - 5.9' Weathered shale; reddish brown (2.5YR 4/4), soft, moderate plasticity.

5.9' Refusal; backhoe could not penetrate unweathered bedrock.

SUMMARY OF GEOLOGIC HAZARDS
Site A, Washington County School District SITE

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

*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.

SUMMARY OF GEOLOGIC HAZARDS
Site B, Washington County School District SITE

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

*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

SUMMARY OF GEOLOGIC HAZARDS
Site C, Washington County School District SITE

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

*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.

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.

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.

Soil profile type-soil 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.

Solyble 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 deformed by fault displacement, tilting, or downdropping

Project:			Requesting Agency:
Reconnaissance of landslide reactivation along the Bear River, Honeyville, Box Elder County, Utah			Emergency Response
By: Barry J. Solomon	Date: 9-22-97	County: Box Elder	Job No: 97-21 (GH-6)
USGS Quadrangle: Honeyville (1446)		Number of attachments: none	

On January 3, 1997, a landslide in a bluff along the east side of the Bear River in Honeyville, Utah, partially blocked and constricted the river, causing erosion of the opposite river bank and adjoining field. In late August or early September 1997, additional landsliding occurred at the same site. Utah Geological Survey (UGS) geologists Frank Ashland and Bill Black inspected the original slide on March 11, 1997, and their observations are reported in Ashland (1997). The UGS was informed of the reactivation by Darwin Bingham, a member of the family owning the property on which the slide is located, and Frank Ashland and I inspected the reactivated slide on September 5, 1997. This report documents our observations and recommendations.

The landslide is in the SE1/4SE1/4 section 30, T. 11 N., R. 2 W., Salt Lake Base Line and Meridian, on the west-facing concave bluff on the outside of a meander bend in the Bear River. Landslides in this setting are common along this portion of the Bear River in Box Elder County (Dames & Moore, 1986). The original slide in January 1997 deflected the river to the west, causing subsequent erosion of the point bar on the opposite bank. Ashland (1997) believed that the river would eventually erode the foot of the slide as river levels rose in the late spring, leading to additional sliding. However, significant erosion of the slide has not yet occurred. Rather, erosion of the opposite bank continued as a secondary, east-facing meander formed around the toe of the slide, causing loss of cultivated farmland on the point bar. Ground-water seeps were evident in the main scarp of the landslide, indicating that additional sliding was probably caused by wetting of soils in an oversteepened slope in the main scarp of the January 1997 slide. The seeps discharge from perched ground water above clay and silt layers in otherwise sandy Lake Bonneville deposits (Oviatt, 1986), leading to spring sapping and retrogressive sliding progressing eastward from the main scarp. No erosion-related destabilization of the existing slide debris is apparent.

The new landslide, like the original, is a complex earth slide-earth flow (Varnes, 1978; Cruden and Varnes, 1996). It is about 165 feet (50 m) wide at its main scarp, extending across the southern half of the pre-existing 340-foot- (104-m-) long scarp of the original slide. The main scarp of the new slide is nearly vertical and about 15 feet (5 m) high. Ground-water seeps were visible near the base of the main scarp 15 feet (5 m) below its crown, and within the landslide debris about 25 feet (8 m) below the crown, with ponded ground water accumulating in depressions within the body of the slide from its center to its toe. The crown of the main scarp retrogressed about 40 feet (12 m) eastward from the crown of the original main scarp. New landslide debris extends westward from the new main scarp for a distance of about 240 feet (73 m) to within 15 feet (5 m) of the toe of the original landslide.

The near-vertical main scarp, continuing ground-water seeps, and sloughing of additional material from the main scarp during our visit suggest a significant potential for continued slope failure. Mr. Bingham indicated that agricultural fields to the north were irrigated prior to the new landslide activity, and the area has been subject to considerable summer monsoonal rainfall. This additional moisture may have triggered the most recent event, but more landsliding should be anticipated. No structures are immediately threatened by additional sliding, but agricultural land will be lost and a few farm buildings several hundred feet upslope of the slide could be endangered if slope failure is left unchecked. The concrete watering trough that crossed the main scarp of the original slide (Ashland, 1997) was destroyed by the new slide. The portion of fence that was suspended in midair across the original scarp after the initial movement was detached by the new movement and included in the landslide debris.

Mr. Ashland and I recommended to Mr. Bingham that the slope be stabilized before any further movement occurs. Our preferred stabilization technique would be to terrace the slope from above, creating a stable slope angle, and replant the slope with appropriate vegetation to increase stability. We stressed that care should be taken with the use of heavy equipment to ensure the safety of the operators and equipment, and that a qualified geotechnical engineer should be consulted for proper slope design. An additional hazard-reduction technique would be reinforcement and weighting of the base of the landslide scarp with boulders, but the cost of this technique may be prohibitive. Erosion of the point bar on the opposite river bank would need to be reduced if prevention of additional loss of farmland is desired.

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Project:			Requesting Agency:
Reconnaissance of a landslide along Bluebell Road, Duchesne County, Utah			Duchesne County Road Department
By: F.X. Ashland	Date: 10-6-97	County: Duchesne	Job No: 97-22 (GH-7)
USGS Quadrangle: Bluebell (1076)		Number of attachments: 3	

INTRODUCTION

On September 30, 1997, I conducted a reconnaissance of an active landslide along Bluebell Road in the Dry Gulch Creek area in Duchesne County, Utah. The landslide is located about 2-1/2 miles southeast of Bluebell, Utah in the NW1/4 section 1, T. 2 S., R. 3 W., Uinta Base Line and Meridian (attachment 1). According to Douglas Nielsen, Duchesne County Road Supervisor, the landslide began moving in early August and was likely triggered by unusually heavy precipitation during the summer. Since that time, the landslide has posed a significant maintenance problem for the county road department, as well as a traffic hazard. The purpose of this investigation was to determine the physical characteristics of the slide and evaluate its hazard potential. The scope of my investigation includes a site investigation, a preliminary slope-stability analysis, and a review of published geologic literature.

PHYSIOGRAPHY AND GEOLOGY

The landslide occurred on a steep, northeast-facing bluff on the edge of a northwest- trending mesa in the Dry Gulch Creek area (attachment 1). The bluff is about 130 feet high and has an average slope of about 50 percent. Bluebell Road, an important paved county road connecting Altamont, Bluebell, and Roosevelt, Utah, is at the base of the slope. The bluff is mostly covered with short juniper trees, cactus, and grasses. Locally, phreatophytes occur in small areas downslope of seeps.

The geology in the vicinity of the landslide has not been mapped in detail, however Bryant (1992) indicates that the southernmost part of the mesa and the bluff are underlain by the Tertiary Brennan Basin Member of the Duchesne River Formation. The Brennan Basin Member is comprised primarily of sandstone and siltstone, and crops out in several locations in the bluff in the vicinity of the landslide. Bryant (1992) shows a contact between the overlying Dry Gulch Member and the Brennan Basin Member to the north and to the west of the landslide. The Dry Gulch Member is comprised of red to gray sandstone, siltstone, and claystone. Bryant (1992) indicates that the top of the western part of the mesa is covered by Quaternary glacial outwash deposits. These deposits are comprised of mostly gravel and sand. Bryant (1992) mapped the deposits northeast of the road along Dry Gulch Creek as Holocene alluvium and colluvium.

My observations indicate that the bluff consists of light yellowish brown sandstone, most likely the Brennan Basin Member, overlain by colluvium. Colluvium consists of mostly fine-grained sand and silt with lesser amounts of cobbles and boulders. On the surface however, the colluvium is mantled by a thin veneer of mostly rounded cobbles and boulders derived from the glacial outwash on top of the mesa. The colluvium is typically light brown to brown in the majority of the landslide, but is red to gray in the northern part of the slide, suggesting that colluvium in the northern part is locally derived from the Dry Gulch Member.

PHYSICAL CHARACTERISTICS

The landslide is likely a rotational slide or slump (attachment 2). The slide is about 900 feet wide and varies between approximately 100 to over 200 feet long, and thus is about 15,000 square yards in area. If the slip surface is approximately 30 feet deep on average, the estimated slide volume is about 150,000 cubic yards. A discontinuous main scarp (attachment 3), which locally exceeds 10 feet high, is the most prominent landslide feature. The discontinuous nature of the main scarp appears to be related, at least in part, to the irregular distribution of intact rock beneath the scarp. In the northern part of the slide, the main scarp steps downslope to a vertical rock face at the base of an outcrop in the bluff. Elsewhere, blocks of rock are contained within the slide mass or have slabbed off the main scarp. In general, at least several feet of colluvium overlies rock where it is exposed in the main scarp. This upslope colluvium has likely been destabilized by the removal of lateral support. Thus, additional landsliding is possible upslope of the present main scarp, regardless of the initial control of scarp location by underlying rock.

Other landslide features include a series of grabens that parallel the main scarp in the head of the slide and contain numerous transverse (perpendicular to the direction of movement) ground cracks and scarps. Horizontal separation across the ground cracks and scarps locally exceeds two feet. In some areas, the spacing between individual ground cracks and scarps is less than 5 feet. Thin slivers of disrupted ground are thus bounded by either ground cracks or scarps. The toe of the landslide is at the base of the bluff in the northern part, but appears to be about 70 to 100 feet upslope from the base in the remainder of the slide.

GROUND-WATER CONDITIONS

The presence of seeps, moist surficial soils, phreatophytes, or thin fine-grained seepage-related deposits along most of the landslide indicate high ground-water levels. In the northern part of the landslide, seeps are about 15 to 30 feet below the slide's crown. Downslope, flow of ground water appeared to be greater near the toe of the slide than near the head, suggesting additional seeps lower in the slide which were buried by landslide deposits. Prior to my visit, the county had placed a culvert under the road to drain ground water seeping from the northern part of the slide. The amount of seepage decreased to the south, but moist surficial soils, phreatophytes, and thin deposits of mostly silt and fine-grained sand suggested recent seepage in the southern part of the slide. In this part, most of the seepage was near the toe of the slide and about 100 feet upslope of the road. I also observed seeps and moist soils at the rock/soil interface where it was exposed in the main scarp.

PROBABLE TRIGGER AND CAUSE OF MOVEMENT

The landslide movement appears to have been triggered by high ground-water levels resulting from infiltration of unusually high precipitation during the summer. The steepness of the bluff also contributed to the slope failure. At such a steep slope, my preliminary slope-stability analysis indicates the colluvium was only marginally stable, and thus the increased ground-water level this year was sufficient to trigger slope movement.

HAZARD POTENTIAL

In my opinion, the landslide poses a continuing hazard to traffic along the county road. Future movement of part or the entire slide may occur following periods of heavy precipitation or snowmelt. I believe a heightened possibility for continued movement exists at least through the end of next spring or until the slope dries. In addition, the recent landsliding has removed the lateral support at the base of the colluvium in the upper part of the slope, thus likely destabilizing it. Downslope movement of this upper colluvium could load the landslide deposits in the lower slope and cause additional movement lower in the bluff. It is likely that if movement continues, landslide deposits may move onto the road and pose a traffic hazard.

RECOMMENDATIONS

Continued movement of the landslide poses a traffic hazard along this section of the county road, thus I recommend that if use of the road is continues, that appropriate warning signs be posted in both directions. These signs should indicate *Slide Area*, *Landslide Area*, or equivalent so that motorists are aware of the hazard. These warning signs could be combined with lowering the speed limit in the area, which would hopefully persuade motorists to be more cautious. These recommendations are only interim measures until some other actions are taken to reduce the risk to motorists or until landslide movement ceases.

Even if landslide movement stops, a potential for reactivation will still exist and the landslide will pose a continuing threat to the road. In my opinion, stabilization of the landslide would be difficult and expensive. Factors contributing to the cost of mitigation include size of the landslide, steepness of the bluff, and necessity to perform detailed subsurface investigations to establish a stable design. Therefore, other alternatives should also be considered including re-routing of the road.

REFERENCES

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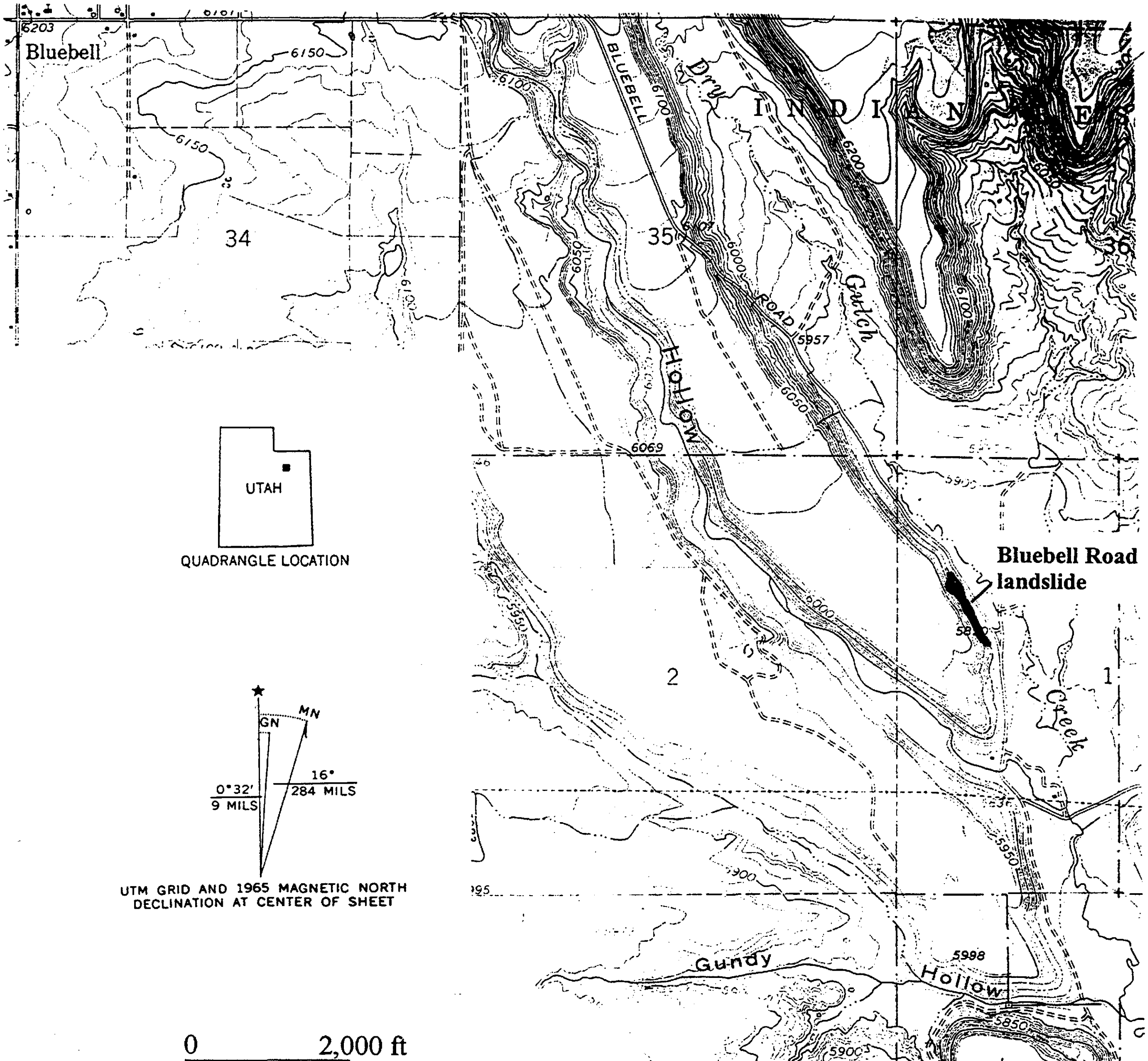
Varnes, D.J., 1978, Slope movement types and processes, *in* Schuster, R.L., and Krizek, R.J., editors, Landslides - analysis and control: TRB Special Report 176, p. 11-33.

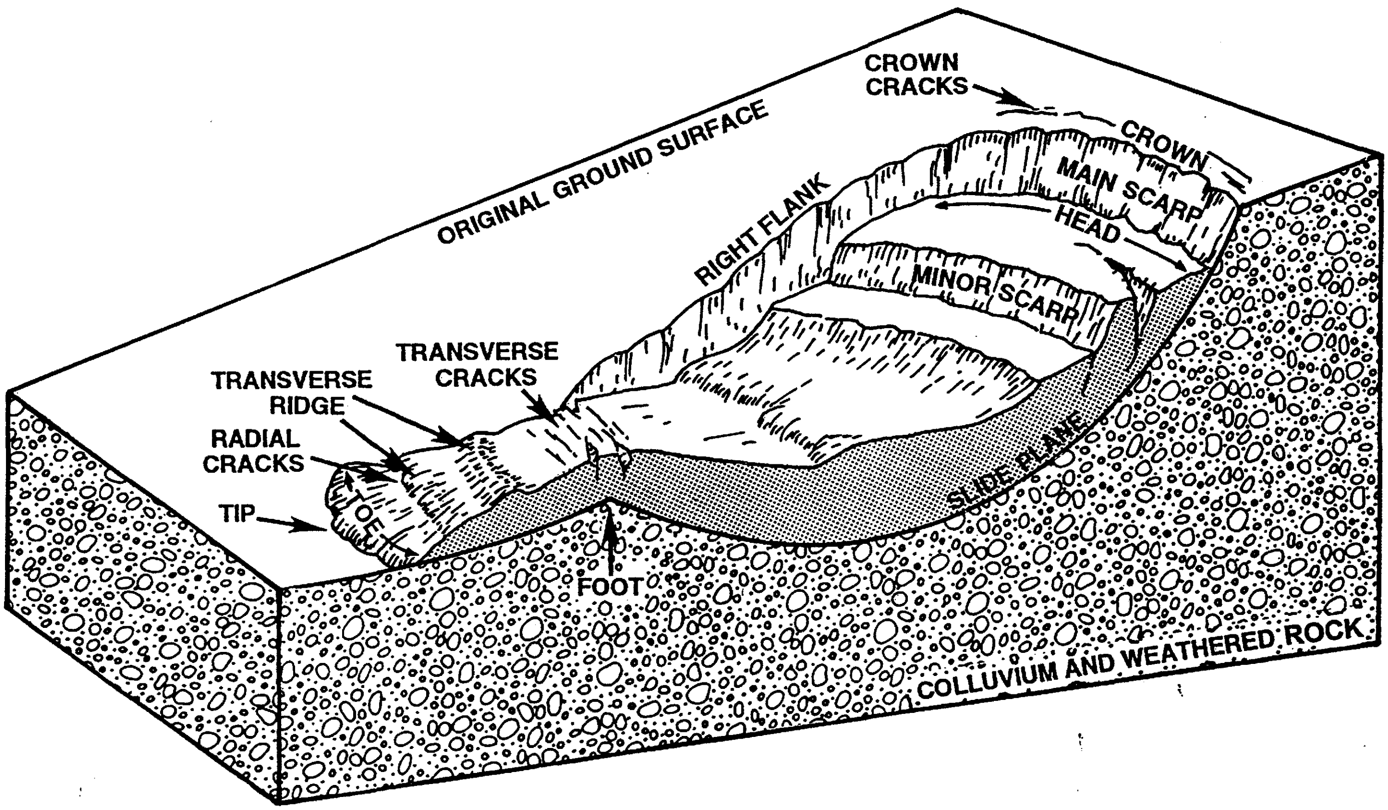
Base Map from BLUEBELL,
U.S.G.S. 7-1/2' topographic quadrangle



0 2,000 ft

Scale 1:24,000

Attachment 1. Approximate location of landslide along Bluebell Road, Duchesne County, Utah.



Attachment 2. Schematic diagram describing typical rotational landslide features. Modified from Varnes, 1978.

Attachment 3. Discontinuous main scarp of northern part of landslide. Crown (top) of scarp is about 60 feet below crest (top) of mesa. Colluvium upslope of scarp is likely destabilized by removal of lateral support. Note that the steepness of the slope is likely a contributing factor to the failure.

Project: Geologic reconnaissance of an active landslide in Dry Fork Canyon near Vernal, Uintah County, Utah			Requesting Agency: Emergency Response
By: Richard E. Giraud	Date: 12-1-97	County: Uintah	Job No: 97-24 (GH-8)
USGS Quadrangle: Marsh Peak (1196) and Lake Mountain (1155)		Number of attachments: 2	

INTRODUCTION

The Utah Geological Survey (UGS) was informed of an active landslide in Dry Fork Canyon by Darlene Koermer, U.S. Forest Service (USFS), and Robert Rasely, Natural Resources Conservation Service (NRCS), who were both concerned about the potential damming of Dry Fork. Gary Christenson (UGS), Darlene Koermer, and I visited the landslide site on September 23, 1997. The landslide is 20 miles northwest of Vernal, Utah (attachment 1) in the Ashley National Forest. A May 1997 flood in Dry Fork Canyon eroded an old landslide toe, initiating active movement. The landslide has not displaced the creek channel and to date the creek has removed the landslide material. The purpose of this study is to document the active landslide and evaluate the potential for the landslide to dam Dry Fork.

USFS and NRCS personnel performed a site reconnaissance on August 7, 1997, and concluded the active landslide could dam Dry Fork and that breaching of such a landslide dam is a potentially life-threatening hazard to residents living downstream (Rasely, 1997). The communities at greatest risk are the Dry Fork settlement 9 miles downstream and other residents downstream along Dry Fork and Ashley Creek in the Vernal area. No residents or structures are in the immediate vicinity of the landslide (attachment 2). The USFS has installed and surveyed stakes to monitor movement and is calculating the landslide volume.

MAY 1997 FLOOD EVENT

In May 1997, a canal located in the upper portion of the Dry Fork drainage, breached and flowed into Dry Fork. The event is described by Christenson (1997) and Leake (1997). The breaching of the canal resulted in erosion and incision of two ravines on the west slope of Dry Fork. The eroded unconsolidated valley-margin materials were deposited as two alluvial fans and as channel/flood-plain alluvium in the Dry Fork drainage. One alluvial fan partially dammed Dry Fork forming a pond upstream. Leake (1997) indicates that the alluvial-fan dam failed on May 19, 1997, releasing an estimated 100 acre-foot flood of muddy water down Dry Fork. The floodwaters eroded an old landslide toe, triggering movement.

SETTING AND GEOLOGY

The active landslide is on the north side of Dry Fork Canyon and the south side of Sink Ridge (attachment 2). The landslide outline observed on September 23, 1997, is shown on attachment 2.

The bedrock geology is mapped at 1:250,000 scale by Rowley and others (1985). In the vicinity of the active landslide the bedrock consists of undivided Mississippian and Pennsylvanian rocks. The Mississippian rocks include the Doughnut Shale, Humbug Formation, and Madison Limestone. The Pennsylvanian rocks include the Morgan Formation and Round Valley Limestone. The bedrock strikes northwest and dips five degrees to the southwest.

The surficial geology is mapped at 1:250,000 scale by Carrara (1980). Pleistocene glacial moraines are mapped from the head of the Dry Fork Canyon down to an elevation of 7,960 feet. A large area of Holocene and Pleistocene landslide deposits are mapped on the south side of Sink Ridge (attachment 2). These landslides appear to be related to a weak stratigraphic horizon approximately 200 feet above the canyon floor. The stratigraphic horizon is not exposed, but colluvium and landslide deposits indicate a black shale unit, probably the Doughnut Shale. Portions of these large landslides were reactivated in 1983, and main scarps are still apparent (Darlene Koermer, verbal communication, 1997). In a 0.4 mile-long section south of Sink Ridge, the landslides have moved downslope and reached the canyon floor. The active landslide is within this section, and another area about 1,400 feet to the east has also reactivated this year (attachment 2) but does not pose a threat of damming Dry Fork.

DESCRIPTION OF OLDER AND ACTIVE LANDSLIDES

The active landslide is a reactivated portion of an older landslide within the area of Holocene and Pleistocene landslide deposits (attachment 2). The older landslide had previously advanced to the canyon floor diverting the flow of Dry Fork around the landslide toe. The active landslide and older landslide relative ages are distinguished by preservation of landslide features.

Older Landslide

The relative age of the older landslide is distinguished from the younger active landslide by larger conifer trees, up to one foot in diameter, and lichen-covered surface lag boulders, present on the older landslide flanks. This older landslide has a lobate toe that displaces the creek channel, subdued hummocky topography, and numerous back-tilted surfaces. The upper portion of the older landslide reactivated in 1983 (Darlene Koermer, verbal communication, 1997) and the recent scarps are covered with young sagebrush and grass.

Active Landslide

The active landslide is within a topographic swale near the center of the older landslide. The landslide and the topographic swale display younger features than the older landslide including less subdued hummocky topography, no lichens on surface lag boulders, and younger conifer trees. The landslide toe lies at an elevation of 8,020 feet where it advances into the creek. The average landslide slope angle is 24 degrees.

Active landslide movement started at the toe as it was undercut by floodwaters. The landslide is enlarging as extensional cracking progresses upslope along the swale within the older landslide. Fresh transverse extensional cracks, toppled trees, and landslide material displaced downslope into the creek indicate active movement. Ground-water seepage was observed in extensional cracks and some extensional cracks were water filled.

The Dry Fork channel is not noticeably displaced by the advancing landslide. Apparently the erosion and transportation rates are sufficient to remove the landslide material delivered to the creek. The landslide material observed in extensional cracks is a brown to black clay with minor weathered shale clasts, probably weathered Doughnut Shale.

SUMMARY, HAZARD POTENTIAL, AND RECOMMENDATIONS

The active landslide in Dry Fork resulted from a May 1997 flooding event associated with breaching of a canal. Floodwaters eroded the toe of an old landslide, reactivating movement. Extensional cracking is progressing upslope enlarging the active landslide. The landslide will continue to enlarge until it reaches a stable configuration. I saw no evidence of ground cracks on lateral flanks indicating lateral progression of movement. The relative ages of landslide movement are broadly constrained by conifer tree age, lichen cover on surface lag boulders, and geomorphic freshness of landslide features. The USFS is calculating the rate of landslide movement and the landslide volume.

The active landslide has a potential to advance into and dam Dry Fork. The likelihood of damming depends on the rapidity of movement, landslide volume, and interaction between fluvial and slope processes. The creek and landslide interaction to date indicates the creek is keeping pace with the rate of landslide advance by eroding and transporting material downstream. The active landslide has not displaced the creek, however low stream flows or a faster rate of landslide advance could change this relationship.

The creek channel realignment around the older landslide toe indicates a prehistoric landslide advance into the creek. Although I saw no apparent evidence of prehistoric landslide damming from my review of aerial photographs or the reconnaissance field traverse, I was unable to cross the creek to search for landslide deposits on the opposite bank. Even though the active landslide has the potential to advance and dam the creek, the creek channel could realign and accommodate landslide advance without damming.

I recommend continued monitoring to determine the rate of landslide movement, the landslide volume, and interactions of fluvial and slope processes. Movement rates give an indication of the likelihood of rapid failure. The landslide volume can be used to assess the extent of possible creek damming and to estimate the volume of water storage behind the dam. This storage volume could then be used to determine the likely extent of downstream flooding. Establishing a relationship between the rates of landslide advance and creek erosion will provide an understanding of the stream's ability to keep pace with landslide advance. With this understanding, decisions regarding landslide-damming potential can be made based on measured behavior. This potential likely changes seasonally and following storms as rates of stream flow and landslide movement change in response to moisture conditions.

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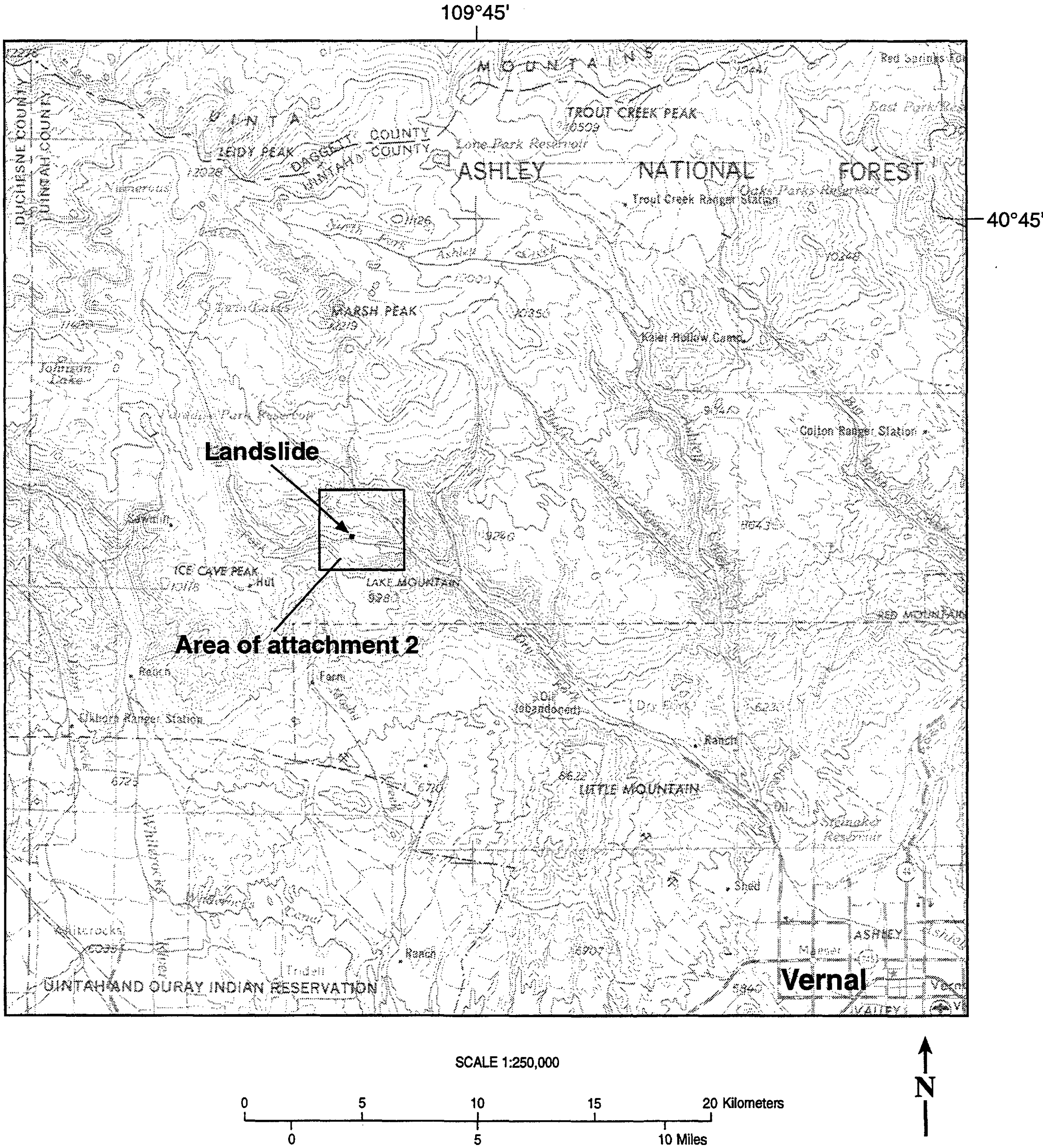
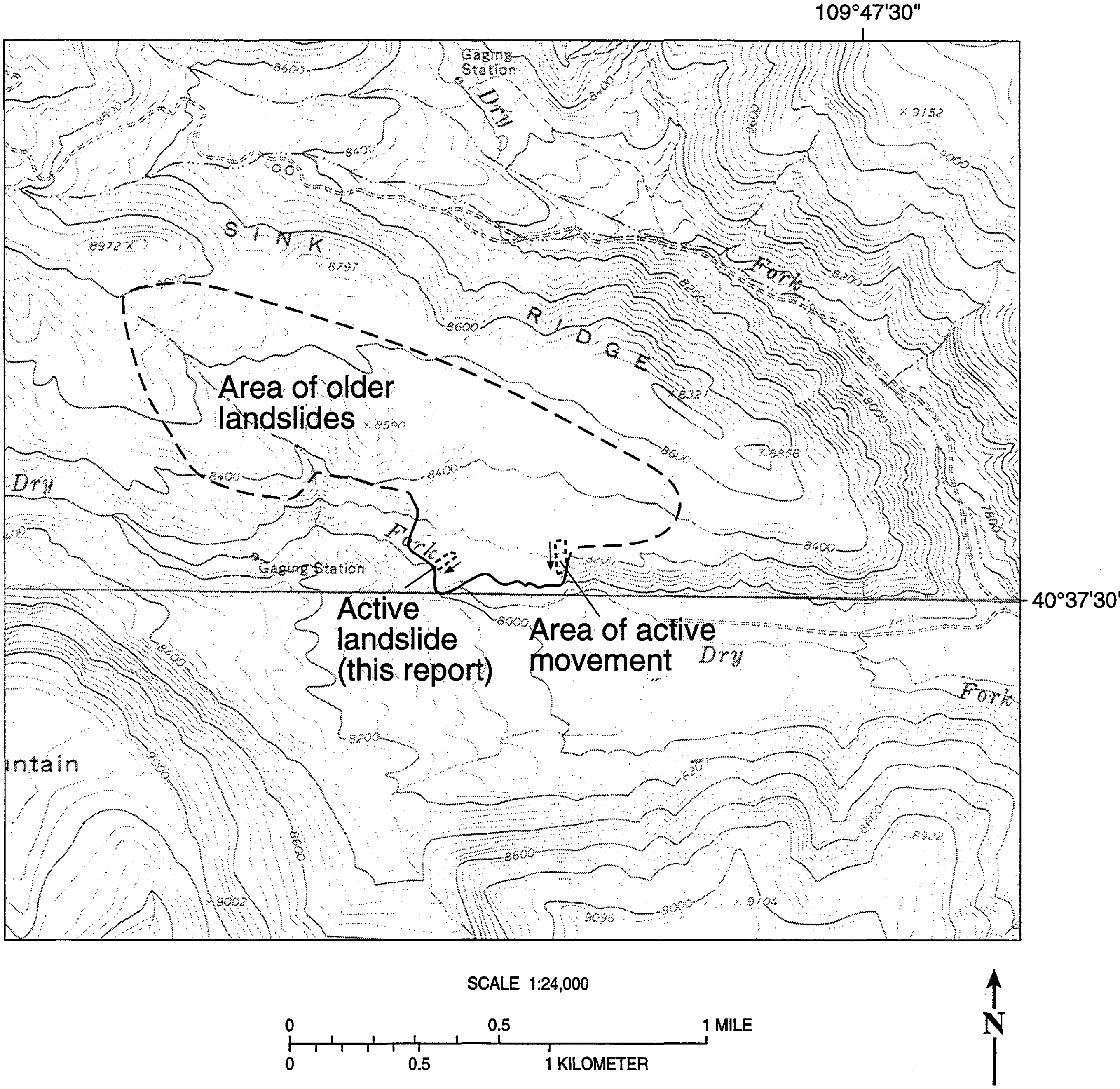


Attachment 1. Location map of the Dry Fork landslide, box is area shown in attachment 2.



Attachment 2. Location map showing approximate outline of older landslides (modified from Carrara, 1980) and active landslide movement, September 23, 1997.

Project:			Requesting Agency:
Reconnaissance of a debris flood in Orem, Utah County, Utah			Emergency Response
By: Barry J. Solomon and Richard E. Giraud	Date: 11-24-97	County: Utah	Job No: 97-25 (GH-9)
USGS Quadrangle: Orem (1088)		Number of attachments: 2	

On August 5, 1996, a wildfire spread up the mountain slopes above Orem, Utah. The fire, in the Timpanogos State Wildlife Management Area northwest of Provo Canyon, burned about 2,500 acres during several days. The area was subjected to a low-intensity burn that left plant roots intact and viable, with regrowth expected between the fall of 1996 and mid-spring 1997 (Rasely, 1996). However, Rasely (1996) identified two small watersheds above Orem that posed a threat to downslope houses from potential floods, debris floods, and debris flows generated by intense thunderstorms, particularly during the period of regrowth. Flow-control dikes existed in channels within the watersheds, but the dikes had either been breached or otherwise damaged and were considered by Rasely (1996) to be insufficient protection against future floods. Rasely (1996) recommended repairing or upgrading the dikes and obtained funds from the Emergency Watershed Protection Program (EWPP) of the U.S. Natural Resources Conservation Service to accomplish this activity. Funds from the EWPP were provided to the city of Orem, who installed erosion-control structures in the two watersheds. The structures consist of wire fencing and geofabric attached to fence posts and suspended across ephemeral stream channels.

On September 7, 1997, torrential rainfall from a thunderstorm initiated a debris flood from the ravine within the larger of the two watersheds identified by Rasely (1996) (attachment 1). This watershed, the southernmost of the two, encompasses about 96 acres. The head of the ravine is on the southwest flank of Mount Timpanogos in the SE1/4 section 36, T. 5 S., R. 2 E., and the ravine trends southwest and exits the range front in the NW1/4 section 1, T. 6 S., R. 2 E., Salt Lake Base Line and Meridian. The ravine mouth opens onto a paved road that trends to the southwest about 0.2 miles, where the road meets the intersection of 16th North Street, trending west, and 8th East Street, trending south. The paved road, the intersection, and the immediate vicinity of the ravine mouth are underlain by an alluvial fan of Holocene to uppermost Pleistocene age (Machette, 1992). Development on the fan surface includes the headquarters of Novell, Inc., on the southwestern corner of the intersection of 16th North Street and 8th East Street, and part of the Orem Cemetary east of 8th East Street. Infrastructure on the fan surface includes city streets, a storm-sewer system, buried and above-ground utilities, and the Murdock Canal.

The debris flood traveled down the ravine and was channeled downslope along 8th East Street southward for about 0.4 miles, and then westward another 0.4 miles to about 200 West along 12th North Street. A news report in the Salt Lake Tribune (Horiuchi, 1997) stated that the debris flood was mainly confined to the streets, with flooding reported in only one yard, and no flood damage to the inside of any home. We inspected the ravine and debris-flood site on September 8 and 24, 1997, and this report documents our observations and recommendations.

Both slopes and the floor of the ravine are underlain by interbedded sandstone and limestone of the Oquirrh Formation of Pennsylvanian and Permian age (Baker, 1964). We observed considerable amounts of sandstone and limestone rock fragments on the ravine slopes, but did not observe any bedrock outcrops. The lack of outcrops and presence of extensive debris evidently suggested to Machette (1992) that much of the southwestern slopes of Mount Timpanogos, including the ravine, were underlain by landslide deposits of upper Pleistocene to upper Tertiary (?) age. However, the debris flood scoured several pits in the channel floor. These pits are up to 4 feet deep and 3 feet in diameter, with jointed bedrock commonly exposed in their floors. We believe that the ravine walls are also underlain by bedrock at shallow depth, but exposures are obscured by a layer of colluvium formed from weathering of jointed bedrock, downslope creep, and shallow debris slides, rather than by large-scale slope failure. We observed a shallow debris slide near the head of the ravine on its eastern slope, and three other debris slides farther downslope. The slide near the ravine head was largest, and was about 150 feet long and 10 feet wide. The smaller slides were less than 30 feet long and 6 feet wide.

Colluvium and alluvium has accumulated in the ephemeral channel within the ravine to a thickness of up to 4 feet, and has been repeatedly transported down the channel during periods of torrential rainfall like the episode that caused the debris flood of September 1997. Sandstone and limestone clasts within the channel are subrounded to subangular and commonly range in size from 2 to 6 inches in diameter, although we observed boulder-sized clasts up to 2 feet in diameter. Clast-supported debris is common on the surface of the channel as a lag deposit, but underlying material includes a fine- to medium-grained sandy matrix. Most vegetation on the slopes is grass, with rare clusters of oak brush and other small shrubs. Isolated clusters of oak brush are also present within the channel, most commonly in the upper half of the ravine. Near the canyon mouth, we observed 14 erosion-control structures. The wire fencing across three of the structures was torn down, apparently by the debris flood. Deposits of mud, sand, and coarse debris had accumulated behind all of the structures. Coarser rock fragments and plant debris were suspended in the wire fencing of many of the structures. We estimate the volume of material retained behind each structure to be about 200 cubic yards, for a total retained volume of 2,800 cubic yards. Additional data on the drainage basin, channel conditions, alluvial-fan conditions, and the debris-flood deposit are included in the debris-flood data sheets (attachment 2).

The intense rainfall of September 7, 1997, removed the most easily erodible material from the channel and hillsides within the burned watershed. Nearly all of the coarse-grained material was trapped behind erosion-control structures constructed across the channel floor near the head of the alluvial fan. However, large amounts of sediment remain in the drainage and are retained behind the erosion-control structures, and debris-flow and debris-flood hazards persist. This sediment could be mobilized and incorporated into debris flows or debris floods by future intense-rainfall or rapid-snowmelt events. The remaining erosion-control structures may be buried or unable to withstand the impact of a large volume of debris and could fail in future debris flows or debris floods. Facilities at risk to future debris-flow and debris-flood hazards on the alluvial fan include the Novell facility, the Orem Cemetary, the Murdock Irrigation Canal, and the surrounding infrastructure. Fortunately, mud-laden floodwaters of the September 1997 event were channeled through an element of that infrustructure, the city streets, and were diverted away from the site of the Novell facility which lay in the natural flowpath directly downslope of the ravine mouth.

We recommend removing sediment and debris trapped behind the erosion-control structures to reduce the amount of material that could be incorporated into future debris flows and debris floods, and repair or reconstruction of damaged erosion-control structures. These actions will reduce future debris-flow and debris-flood hazards. We commend the recommendation of Rasely (1996) to repair existing flow-control dikes and construct new erosion-control structures, and believe the funding of this activity by the EWPP and implementation by the city of Orem was a successful example of interagency cooperation to reduce the impact of natural hazards. Their actions resulted in minimal destruction of property from the 1997 debris flood. However, significant property damage was also averted by the diversion of floodwaters down city streets and away from the Novell facility. This was a fortunate but perhaps unintended consequence of the street layout. A larger event, or a more debris-laden flow, may not be restrained by streets, indicating that debris-flood and debris-flow hazards must be considered in land use on this and other alluvial fans.

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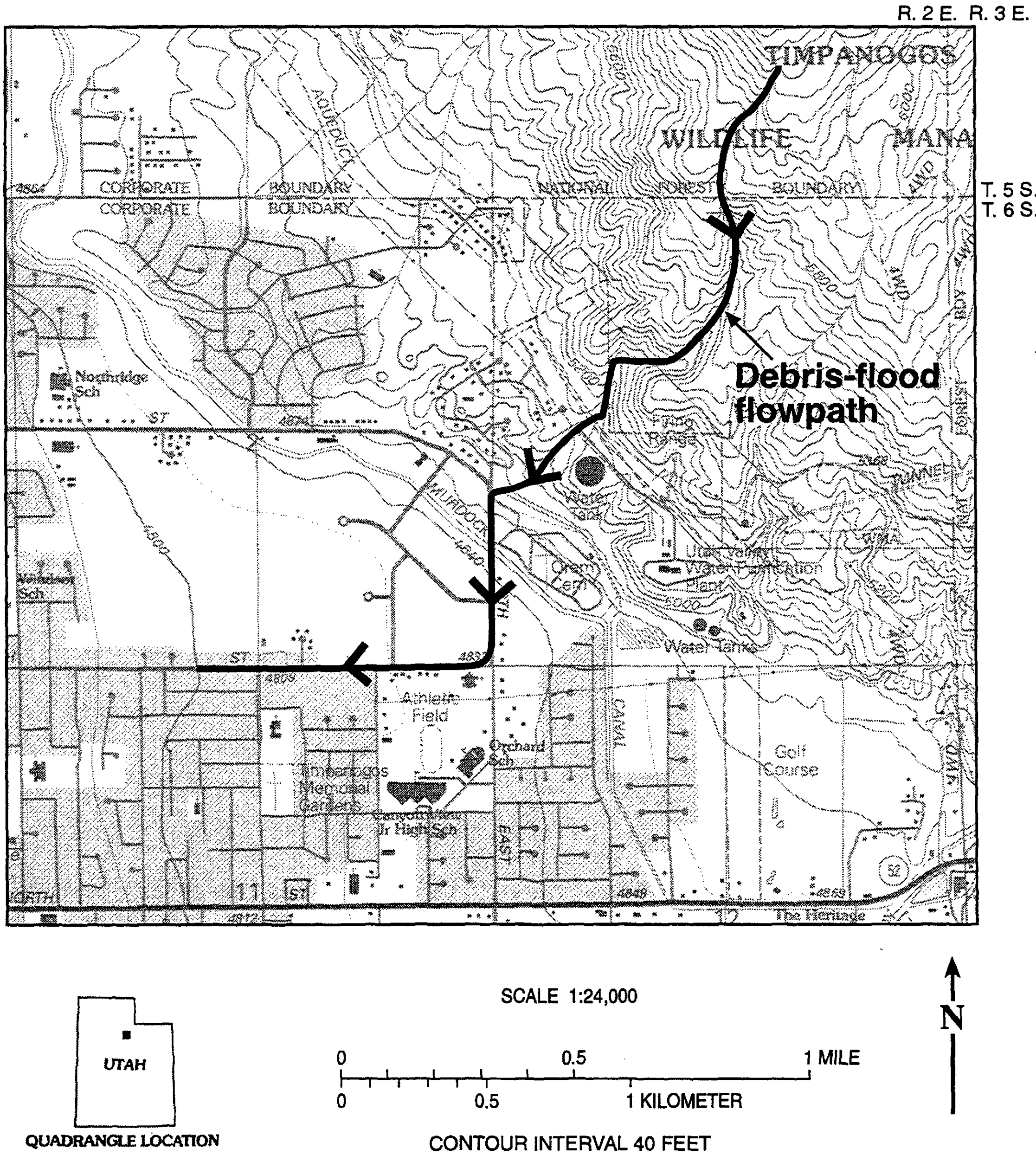

Attachment 1. Location of debris flood of September 7, 1997, in Orem, Utah County, Utah.

DEBRIS-FLOOD DATA SHEET (1 of 5)

LOCATION AND BACKGROUND INFORMATION

Form completed by Rich Giraud Date 9-24-97 UGS File 97-25

Date of Event: September 7, 1997

Debris Flood Location: East Orem, north of Orem Cemetery, northeast of the Novell facility, approximate street grid 15th North and 8th East.

County: Utah

Geographic Area: Benches and foothills on the lower west side of Mt Timpanogos.

USGS Quadrangle (BLM No.): Orem (1088)

Section, Township, Range: Sec. 1, T. 6 S., R. 2 E., and Sec. 36, T. 5 S., R. 2 E., Salt Lake Base Line and Meridian

Name of Drainage: Unnamed.

Triggering Event: Intense rainfall associated with a convective storm.

Other Background Information: The wildfire of 1996 is referred to as the "Orem, Utah, Tank Fire" (Rasely, 1996). See also Horiuchi (1997).

DEBRIS-FLOOD DATA SHEET (2 of 5)

DRAINAGE BASIN

Form completed by Richard Giraud Date 9-24-97 UGS File 97-25

Area: 0.15 square miles, 96 acres

Aspect: Southwest

Slope Steepness: Drainage-basin-hillslope angles range from 6 to 35 degrees (11-70 percent).

Elevation(s) of Debris-Flood Source(s): Top of drainage basin, 6,200 feet; alluvial fan, 5,040 feet; total relief=6,200 feet-5,040 feet=1,160 feet.

Vegetation: Mostly grass and scattered areas of burned oak brush. Some grass is very dense and may be the result of reseeding after the fire. The dense grass reduced hillslope erosion by intercepting and retaining rainfall.

Extent of Upland Erosion: Minor hillslope erosion in bare-soil areas. Rasely (1996) estimated a post-fire PSIAC annual sediment yield of 3.81 tons per acre, producing 366 tons (244 cubic yards) annually in the watershed. The pre-event PSIAC annual sediment yield estimate is 2.85 tons per acre, producing 274 tons (183 cubic yards) annually. The volume produced by small, shallow debris slides is estimated to be 85 cubic yards. The majority of sediment was derived from the channel.

Existing Landslide Masses: Machette (1992) maps surficial landslide deposits in the drainage but, other than shallow debris slides, no evidence of landslide deposits was found.

Bedrock Geology: Limestone and sandstone of the Pennsylvanian and Permian Oquirrh Group. Jointed bedrock is exposed locally by channel erosion.

Surficial Geology: Hillslopes are covered with sandstone and limestone colluvium. Local exposures of colluvium are found at the base of drainage sideslopes and in the channel.

Soils: Three main soil types in the drainage basin were mapped and described by the U.S. Soil Conservation Service (Swenson and others, 1972). The Hillfield-Layton Complex is a silt loam on 30 to 60 percent slopes. The Hillfield-Layton is well drained and moderately permeable, with rapid runoff and severe erosion potential. The Pleasant Grove Terrace Escarpment Complex is a stony sandy loam on 30 to 60 percent slopes, with common rills and shallow gullies. The Rake extremely stony loam is on 20 to 70 percent slopes and has moderate permeability, rapid runoff and severe erosion on slopes greater than 40 percent.

DEBRIS-FLOOD DATA SHEET (3 of 5)

CHANNEL CONDITIONS

Form completed by Richard Giraud Date 9-24-97 UGS File 97-25

Stream Flow: Ephemeral drainage. No flow estimate was made. Water on a street overflowed a curb.

Length: Total channel, 6,000 feet. Eroded channel, 3,700 feet.

Gradient: Above the alluvial fan, 8 to 9 degrees (14-16 percent). The upper, steeper channel reaches have gradients of 13 degrees (23 percent). Gradient of one of the tributary first-order drainages is 15 degrees (27 percent). The upper portion of some channels flatten to 6 degrees (11 percent).

Sinuosity: Curved channel length is 6,000 feet. Straight-line distance, upper alluvial fan to head of drainage is 5,400 feet. Sinuosity=6,000 feet/5,400 feet=1.11.

Morphology: At the mouth of the drainage the stream is a second-order drainage. The drainage contains four first-order tributaries. The channel morphology prior to the September 7, 1997 event is unknown.

Sediment Availability: Sediment was derived from the drainage channel. Lesser amounts of material were derived from shallow debris slides and colluvium at the toe of hillsides where outside meander bends migrated laterally into the hillside. The hillslope colluvium is loose and unconsolidated. Of the estimated 2,800 cubic yards trapped behind the erosion-control structures, an estimated 2,500 cubic yards were derived from the channel, 183 cubic yards were derived from hillslope erosion, and 85 cubic yards were derived from debris slides.

Sediment remains within the channel. Approximately 10 percent of the channel was eroded to bedrock. Sediment 1 to 2 feet thick, extending across a channel 6 to 10 feet wide, was observed above bedrock exposures. Sufficient sediment is present for future debris flows.

DEBRIS-FLOOD DATA SHEET (4 of 5)

ALLUVIAL-FAN CONDITIONS

Form completed by Richard Giraud Date 9-24-97 UGS File 97-25

Area: Because much of the water and fine sediment flowed down city streets and into storm sewers, the area covered by the deposit was not estimated. The fan unit mapped by Machette (1992) (younger fan alluvium, Holocene to uppermost Pleistocene) has an approximate area of 0.09 square miles (55 acres).

Gradient: Measured fan angle in field along road built on fan surface is 9 degrees (16 percent).

Surface Morphology: Mostly graded and altered by urbanization. At the fan apex there are 14 erosion-control structures constructed along the channel. There is very little channel length on the alluvial fan that has not been modified. The channel at the fan apex is incised 1 to 2 feet. Based on the September 7, 1997 event and the extent of Holocene debris-flow deposits (Machette, 1992), the fan is an active alluvial fan.

Vegetation: Urban landscaping; lawns, shrubs, and trees. Oak brush and grass are present along the channel at the fan apex.

Nature of Deposits: Debris material was not deposited on the fan because the coarse material was trapped upstream behind the 14 erosion-control structures in the drainage. The water and fine-sediment portion of the debris flood traveled down the streets and into the storm sewer. Some fine brown sand was present around storm-sewer grates and along the street-edge curb and gutter.

Material beneath the debris-flood deposits are mapped by Machette (1992) and consist of younger fan alluvium (Holocene to uppermost Pleistocene in age) overlying Lake Bonneville deposits (upper Pleistocene in age).

DEBRIS-FLOOD DATA SHEET (5 of 5)

DEBRIS-FLOOD DEPOSIT

Form completed by Richard Giraud Date 9-24-97 UGS File 97-25

Volume: Volume of material trapped by the erosion-control fences is estimated to be 2,800 cubic yards. A measurement was not possible for the fine sediment because it was washed down the storm sewer.

Material Contribution: Most material was derived from the channel. Lesser amounts of material were derived from thin debris slides and hillslope erosion. A back calculation was performed to estimate the volume of channel, debris-slide, and hillslope contributions. The estimated volumes are: channel contribution, 2,500 cubic yards; debris slide, 85 cubic yards; and hillslope erosion, 183 cubic yards; for an approximate total of 2,768 cubic yards. The channel contribution was estimated by approximate channel dimensions to produce the amount of sediment. The debris-slide contribution was estimated by debris-slide dimensions. The hillslope contribution was estimated by assuming the entire maximum annual pre-event PSIAC sediment yield of 2.85 tons per acre was eroded during the event. These estimates did not take a swell factor or the amount of fine sediment lost to the storm sewer into account.

Thickness: No deposit exists downstream from the erosion-control structures. The flood traveled down city streets into the storm sewer. The maximum depth deposited immediately upstream of the erosion-control structures is four feet.

Nature of Deposit: The sedimentary material deposited behind the erosion-control structures is boulder and cobble gravel with minor sand. The subangular to subrounded boulder and cobble gravel is composed of sandstone and limestone. Some boulders were up to two feet in diameter. The material forms a loose clast-supported deposit.

REVIEWS

Project:			Requesting Agency:
Review of "Geotechnical and engineering geology study - lot 1231 Ridgeline Drive, Timber Lakes subdivision, Wasatch County, Utah"			Wasatch County
By: F.X. Ashland	Date: 4-4-97	County: Wasatch	Job No: 97-02 (R-1)
USGS Quadrangle: Center Creek (1126)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a geotechnical and engineering geology report by AGRA Earth & Environmental (AGRA) (1996) for lot 1231 in Timber Lakes Estates, Wasatch County, Utah. The lot is located on Ridgeline Drive in the NW1/4NE1/4 section 8, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to issuing a building permit giving approval to construct a home on the lot. The scope of work included a preliminary geotechnical-engineering slope-stability evaluation using the PCSTABL5M limit-equilibrium slope-stability program, and a review of geologic-hazards literature (Hylland and others, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. With the exception of the potential for shallow ground water, I believe the report adequately addresses these potential geologic hazards and concur with AGRA's conclusions and recommendations. AGRA estimates the depth to the ground-water table to be about 30 feet at the site based primarily on the absence of ground water in two test pits (8 and 11 feet deep) excavated on the lot. However, I believe that the absence of evidence indicating shallow ground water may, in part, reflect the timing of AGRA's investigations near the end of the dry part of the year and does not support their estimate that the depth to ground water exceeds 30 feet. AGRA indicates that perched ground water is possible, especially during the late spring and early summer, and I concur.

The AGRA (1996) report also addresses landslides and slope stability and indicates no evidence of landsliding on the lot. AGRA believes that site grading and earthwork may cause "small shallow slope failures" if slopes are oversteepened, but does not specifically address whether other site modifications, including landscape irrigation and effluent from a septic-tank soil-absorption (STSA) system, may destabilize the slopes. Utah Division of Water Quality (UDWQ) (1996) regulations indicate that approval of a STSA system can be denied if water from the effluent may cause slope instability and I believe this issue should be addressed because of moderate slopes at the lot. AGRA indicates slopes range from 25 to 35 percent, exceeding the maximum slope allowed by UDWQ regulations for STSA systems. It is possible that flatter areas exist on the lot, but the location of the proposed STSA-system drain field is not identified in the AGRA report.

AGRA concludes that the site is "not exposed to undue geologic hazards," but does not specifically address the potential for slope instability resulting from site modifications other than grading, including landscape irrigation and a STSA system. AGRA makes recommendations for temporary cut slopes up to 8 feet. Additional recommendations will be needed if any cut slopes will exceed this height. Although not stated in the AGRA report, the upslope foundation wall may need to act as a retaining structure.

Lacking information on the location of the STSA-system drain field and the slope in the drain-field area, I cannot assess whether the report recommendations are adequate to address the related slope-stability issues. Regarding the homesite, if the upslope wall is to be a retaining structure, its design by a qualified engineer should alleviate slope-stability concerns. I recommend that the engineer provide written verification to the county of construction in accordance with design recommendations. If the upslope wall is not a retaining structure, the potential for slope failure above the cut for the wall needs to be evaluated with at least a preliminary geotechnical-engineering slope-stability analysis (Hylland, 1996). The analysis should consider the possibility of upslope soils becoming wet from seasonal perched water, landscape irrigation, or STSA-system effluent.

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Project: Review of "Debris flow and flood hazard investigation - proposed Eagles subdivision, Weber County, Utah"			Requesting Agency: Ogden City Planning Division
By: F.X. Ashland	Date: 4-17-97	County: Weber	Job No: 97-03 (R-2)
USGS Quadrangle: North Ogden (1370)		Number of attachments: none	

INTRODUCTION

At the request of Rick V. Grover, Ogden City Planning Division, I reviewed a geologic-hazards report by Great Basin Earth Science, Inc. (GBES) (1997) for the proposed Eagles subdivision in Ogden, Utah. The property is located on the east side of Harrison Boulevard in the NW1/4SW1/4 section 10, T. 6 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether debris-flow and flood hazards were adequately addressed to support proposed development plans on the property. The scope of work included a review of geologic-hazards literature and aerial photographs (1985, 1:20,000 scale), and two separate site visits, including one with Utah Geological Survey (UGS) geologist Gary Christenson.

The GBES (1997) report addresses debris-flow and flood hazards as recommended by the UGS (Solomon, 1996) in a review of a previous study (Earthfax, 1994) that addressed the surface-fault-rupture hazard at the property. Solomon (1996) also recommended that landslides be addressed in subsequent studies, but they are beyond the scope of the GBES (1997) report and are not addressed. The proposed lot layout (Reeve & Reeve, Inc., 1996) avoids known landslides and unstable slopes, so further work is unnecessary unless the lot layout is revised and lots are moved farther east. I comment on the potential for collapsible soils on the property in the latter part of this review.

DEBRIS-FLOW AND FLOOD HAZARDS

Debris Flows

The GBES (1997) report indicates that Nelson and Personius (1993) mapped a debris- flow deposit that is contained within the present main channel of the drainage or gulch from Jumpoff Canyon. In addition, Nelson and Personius (1993) indicated that the majority of the western part of the property is underlain by debris-flow deposits that range between upper Pleistocene (younger than about 14,000 years) to upper Holocene (past 5,000 years) in age. The youngest debris-flow deposits are mapped by Nelson and Personius (1993) in the northwestern part of the subdivision. The presence of the debris-flow units indicates episodic debris-flow (and debris-flood) deposition in the western part of the property with the most recent deposition taking place in the northwestern corner.

The GBES (1997) report states that the likelihood of a future debris flow leaving the present channel is low because the "channel is deeply incised ... continuously from the mouth of the canyon."

During my site visits, I observed that the channel is deeply incised upslope of the main scarp formed by the Wasatch fault. Between the main scarp and the canal that bounds the property to the east, the channel is deeply incised in sand- and gravel-rich lacustrine soils. Farther upslope and east of the canal, the channel is well incised into bedrock. In these areas, I concur with GBES that a debris flow would likely be contained in the channel. However, several areas exist where I believe a debris flow could escape the present channel. The most upslope of these areas is where the channel crosses the access road along the buried pipe which carries canal water across the Jumpoff Canyon drainage. In this location, runoff is directed through a culvert less than 24 inches in diameter beneath the road. A debris flow would most likely cross over the road at this location because of the limited capacity of the culvert and its susceptibility to blockage. It appears that the most probable directions a debris flow would move is down the existing channel and toward the northwest along a levee-lined swale. I observed a relatively young levee downslope and northwest of the road crossing which appeared to be about the same age as levees along the main channel that are likely associated with the youngest debris flow mapped by Nelson and Personius (1993). I observed at least two levees, probably of different ages, to the southwest of the crossing that would, however, lower the probability of a debris flow moving toward the southwest and the proposed Eagles subdivision.

A second area where a debris flow may escape the present channel is directly downslope of where it crosses the main scarp of the Wasatch fault. The trail that crosses the main channel would be a likely place for the debris flow to escape the channel and move toward the southwest and the proposed subdivision or toward the northwest and existing homes farther downslope. The GBES (1997) report describes the channel as being nearly 6 feet deep downstream of the trail. Whereas this is locally true, the channel depth is highly variable and generally less than 4 feet deep. In addition, whereas boulder levees exist on the south side of the channel, they are absent or more subdued to the north. Because of this, I believe the probability is greatest that a debris flow could escape the channel and flow to the north in this area.

About midway between the trail and Harrison Boulevard, the channel reaches its shallowest and a debris flow could likely escape the channel again. This location is approximately where the young alluvial fan broadens, likely as a result of debris flows and floods escaping their channels and forming the fan. The absence or subdued nature of levees on either side of the main channel in this area suggests that a debris flow could move either toward the south or north once it escapes the channel.

Farther to the west toward Harrison Boulevard, the channel deepens to the point where it intercepts the cut slope facing the road. The thalweg or bottom of the channel is about 10 feet above the road. A debris flow that stayed in the channel to this point would likely continue either across the road toward existing homes or down the road to the north eventually flowing across the road and to the west toward other existing homes.

The GBES (1997) report also indicates that no features associated with recent debris flows were observed "in the area of proposed development" including "levees, or accumulations of boulders." Most of these features I observed were within 150 feet of the channel and possibly north of the subdivision, but I believe this observation does not preclude the potential for a debris flow crossing any part of the young active fan that underlies the northern part of the property if it escapes the channel. GBES concludes that the debris-flow deposits elsewhere in the western part of the property are likely older, and are not part of the active fan, and I concur. I also concur with GBES's opinion that the canal on the eastern boundary of the property reduces the likelihood of a debris flow reaching the site from small drainages upslope and to the east.

Floods

The GBES (1997) report addresses the potential for flooding resulting from out-of- channel flow in Jumpoff Canyon and from two unnamed minor drainages that drain the slope on the east side of the property. The GBES (1997) report indicates that a Federal Emergency Management Agency (FEMA) flood study (1983) for Jumpoff Gulch predicted a 2-foot flow depth during a 100-year flood at the intersection of the gulch and the west side of Harrison Boulevard. The FEMA study area, unfortunately, did not extend to the east side of Harrison Boulevard and north of the subdivision. However, I believe it is reasonable to assume that the flood depth would likely increase gradually up-gradient from Harrison Boulevard. In several areas between Harrison Boulevard and the point where the channel crosses the main scarp of the Wasatch fault, the channel depth is only about 2 feet deep. In these areas, I anticipate out-of-channel flow and flooding is possible during a 100-year flood event. At the point where the trail near the base of the main fault scarp crosses and the channel, I believe it would be possible for out-of-channel flow to cause flooding both to the north and to the southwest toward the proposed subdivision. Mr. Ben Davies, owner of the property abutting the northwest corner of the subdivision, indicated he had observed water flowing down a secondary, southwest-draining swale or channel in the northwest part of the subdivision during high-flow periods. This observation supports the likelihood of out-of-channel flow from locations where the main channel is relatively shallow.

GBES also evaluated the potential for flooding from the two unnamed channels that drain the area upslope and east of the property. The GBES (1997) report indicates that 100-year flood-event flows from these drainages would be relatively small. Nevertheless, these flows would need to be accommodated by the subdivision's proposed storm-drain system because the drainages cross the property within the recommended "buildable" area outside the surface-fault-rupture- hazard building-setback zone proposed by Earthfax (1994).

COLLAPSIBLE SOILS

Holocene-age debris-flow deposits such as those than underlie most of the western part of the property are sometimes collapsible. Collapsible soils experience hydrocompaction, or settlement under loading conditions when they become saturated. Such conditions can result following construction of homes when lawns are irrigated. As the soils become saturated during irrigation, settlement occurs beneath the foundation. During my two site visits, I observed some soil structure that was characterized by open void spaces and possibly susceptible to collapse. A Delta Geotechnical Consultants Inc. (1985) study confirms the presence of collapsible soils on the property. Laboratory tests show that soils are subject to as much as 4 percent collapse under loads of 1,000 pounds per square foot (lbs/ft^2). Elsewhere in Utah soils with similar properties have caused severe damage to homes and other structures.

CONCLUSIONS AND RECOMMENDATIONS

The GBES (1997) report concludes that debris flows and floods emanating from Jumpoff Canyon would likely be contained within the main channel and therefore the hazard to the subdivision is low. Whereas I concur that the debris-flow and flood hazard to most of the subdivision is low, I believe that several areas exist where, lacking site modifications, debris flows and floods could escape the channel and possibly flow toward the southwest into the northern part of the subdivision. The GBES (1997) report also concludes that "design measures to reduce risk are unwarranted." In my opinion, construction of a containment/deflection berm along the south side of the main channel west of the main fault scarp would further reduce the flood and debris-flow hazard to future homes in the northern part of the proposed subdivision.

Soils susceptible to collapse have been identified on the property by Delta Geotechnical Consultants Inc. (1985). Because of the potential for damage to homes and other structures, I recommend that either lot-specific or additional subdivision-wide soil-foundation evaluations of this potential hazard be conducted to determine whether special foundation-construction techniques or land-use limitations are necessary.

REFERENCES

Delta Geotechnical Consultants Inc., 1985, Geotechnical evaluation - Northland property, Jumpoff Canyon, Ogden, Utah: Salt Lake City, unpublished consultant's report, 21 p.

Earthfax, 1994, Investigation of surface fault rupture hazard at the proposed Eagles subdivision, Ogden, Utah: Midvale, Utah, unpublished consultant's report, unpaginated.

Federal Emergency Management Agency, 1983, Flood insurance study and maps for City of Ogden, Weber County, Utah: scale 1:6,000.

Great Basin Earth Sciences, 1997, Debris flow and flood hazard investigation - proposed Eagles subdivision, Weber County, Utah: Salt Lake City, unpublished consultant's report, 9 p.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series, Map I-2199.

Reeve & Reeve, Inc., 1996, Preliminary plan - Eagles subdivision: Ogden, Utah, scale 1:600.

Solomon, B.J., 1996, Review of "Investigation of surface fault rupture hazard at the proposed Eagles subdivision, Ogden, Utah: Midvale, Utah" in Mayes, B.H., compiler, 1996, Technical Reports for 1994-1995, Applied Geology Program: Utah Geological Survey Report of Investigation 228, p. 120-123.

Project: Review of "Preliminary geotechnical investigation - proposed Heritage Place subdivision, Layton, Utah"			Requesting Agency: Layton Community Development Department
By: F.X. Ashland	Date: 5-8-97	County: Davis	Job No: 97-04 (R-3)
USGS Quadrangle: Kaysville (1320)		Number of attachments: none	

INTRODUCTION

At the request of Doug Smith, Layton Community Development Department, I reviewed geologic-hazards aspects of a geotechnical report by Huntingdon Engineering & Environmental, Inc. (Huntingdon) (1994) for the proposed Heritage Place (recently retitled Heritage Crest) subdivision in Layton, Utah. I received the report on April 21, 1997. The property is located west of State Highway 89 (Mountain Road) and northeast of Hobbs Reservoir in the SE1/4 section 2, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development plans on the property. The scope of work included a review of geologic-hazards literature and a site visit on April 30, 1997. During my site visit, grading operations were in progress including road subgrade work, and underground utilities had already been installed at the subdivision.

GEOLOGIC HAZARDS

The Huntingdon (1994) report addresses shallow ground water, surface fault rupture, earthquake ground shaking, erosion, landslides, and slope stability. In general, I concur with Huntingdon's conclusions and recommendations related to shallow ground water, earthquake ground shaking, and erosion. My comments related to the other geologic hazards are summarized below.

The Huntingdon (1994) report indicates that "there are no known active faults ...extending through the site" and describes the potential for surface fault rupture to be low. Detailed surficial geologic mapping by Nelson and Personius (1993) shows that an active antithetic fault (the downdropped side is opposite to that on the main Wasatch fault) crosses the eastern part of the property in the vicinity of proposed lots 1 and 19 (Ensign, 1996). Nelson and Personius (1993) indicate that the fault scarp is about 15 feet (4.5 m) high at the site and offsets a geomorphic surface about 10 feet (3 m). During my site visit I observed the scarp to the west of an abandoned trailer home (lot 19) and in the northeastern part of the property (lot 1), and concur that it is a possible active fault trace. Doug Smith (Layton Community Development Department, verbal communication, 1997) stated that the Davis Aqueduct crosses the site in the vicinity of the scarp. Whereas the aqueduct is parallel to the scarp across the eastern part of the site, I believe the 15-foot scarp height exceeds the probable maximum cut height for such an aqueduct. Nelson and Personius (1993) also show a fault trace to the south that possibly crosses the site because it projects slightly to the west of the fault that crosses near lot 19. The mapping by Nelson and Personius (1993) and my observations during my site visit suggest that a surface-fault-rupture hazard which is not addressed in the Huntingdon (1994) report may exist in the eastern part of the property. A map compiled by Davis County indicates the surface-fault-rupture sensitive-area overlay zone extends about 900 feet west of the eastern boundary of the property (Lowe, unpublished Davis County Planning maps). This zone defines the area that the county requires studies to evaluate the potential for surface fault rupture.

The Huntingdon (1994) report also addresses landslides and slope stability. The report indicates "no evidence of a landslide within the property" based on a field reconnaissance, and is consistent with unpublished landslide inventory mapping by former Davis County and present UGS geologist Mike Lowe. Lowe, however, shows numerous landslides in similar materials on similar slopes elsewhere in the vicinity of the subdivision. Nelson and Personius (1993) mapped a landslide escarpment near the northwestern part of the property in the vicinity of proposed lots 7 and 8. The Huntingdon (1994) report indicates that detailed evaluation of the landslide hazard was beyond the scope of its investigation, and this may partly explain the discrepancy between its report and the mapping by Nelson and Personius (1993).

Huntingdon (1994) performed an analysis of the stability of the steepest slope on the site using PCSTABL5M slope-stability computer software. Whereas the results of its analysis suggest the slope is relatively stable, I believe the input parameters used in the analysis were not necessarily conservative, and thus the report likely overestimates the stability of the slope. Huntingdon (1994) used a cohesion value of 500 lbs/ft^2 for lacustrine silty sand despite its soil classification as generally "non-plastic" or cohesionless in appendix B of the report. It is also unclear whether Huntingdon (1994) considered the potential for soils to become wet due to landscape irrigation or rapid local snowmelt in its analysis, a condition that could potentially reduce slope stability.

CONCLUSIONS AND RECOMMENDATIONS

The Huntingdon (1994) report adequately addresses shallow ground water, earthquake ground shaking, and erosion, but does not adequately address the potential for surface fault rupture or landsliding. I recommend that a detailed investigation be conducted to evaluate the possibility that the property is crossed by active fault traces. The study area should include all lots east of the surface-fault-rupture sensitive-area overlay-zone boundary and also identify fault-related deformation, such as ground tilting and cracking, that could cause property damage. In addition, I recommend that a more detailed slope-stability/landslide evaluation be conducted, particularly in the north-sloping area bounding the landslide escarpment identified by Nelson and Personius (1993) and elsewhere where slopes exceed 25 percent. The evaluation should consider all possible modifications to site conditions, including the possibility of slope soils becoming wet because of landscape irrigation, and make building-setback recommendations from the crest of steep slopes. I recommend that these studies be conducted and reviewed prior to the sale of individual lots.

REFERENCES

Ensign, 1996, Heritage Crest subdivision: Salt Lake City, unpublished site plan, scale 1:720.

Huntingdon Engineering & Environmental, Inc., 1994, Preliminary geotechnical investigation - proposed Heritage Place subdivision, Layton, Utah: North Salt Lake, unpublished consultant's report, 15 p.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2199, scales 1:50,000 and 1:10,000.

Project: Review of "Engineering geology site reconnaissance - single-family residential lot, lot 1018 on Deer Run Road, Timberlakes subdivision, Wasatch County, Utah"			Requesting Agency: Wasatch County
By: F.X. Ashland	Date: 5-8-97	County: Wasatch	Job No: 97-05 (R-4)
USGS Quadrangle: Heber Mountain (1125)		Number of attachments: none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed an engineering-geology report by AGRA Earth & Environmental (AGRA) (1996) for lot 1018 in Timber Lakes Estates, Wasatch County, Utah. I received the report on April 21, 1997. The lot is located on Deer Run Road in the NW1/4NE1/4 section 15, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to issuing a building permit giving approval to construct a home on the lot. The scope of work included a review of geologic-hazards literature (Hylland and others, 1995) and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1996) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

The AGRA (1996) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, liquefaction, and moisture-sensitive soils. I believe the report adequately addresses these potential geologic hazards and I concur with AGRA's conclusions and recommendations related to them.

The AGRA (1996) report also addresses landslides and slope stability and indicates no evidence of recent landsliding on the lot. However, AGRA states that the site was covered with as much as 10 inches of snow during its site reconnaissance, and landslide features may have been obscured or covered. AGRA indicates that the site sits on a large Quaternary landslide complex, presumably the one identified in Hylland and others (1995), but does not address its stability. The UGS has indicated to Wasatch County that the stability of this complex need not be addressed in lot-specific investigations, but its existence should be disclosed to lot owners (Hylland, 1995). A recent study by the UGS of an upper Holocene landslide (movement in the last 5,000 years) in this complex and northwest of the site (Ashland and Hylland, in press) suggests that the overall complex is relatively stable and does not pose a significant hazard to the site. However, I believe soils in this complex may be susceptible to landsliding if significant site modifications are made, and this is consistent with AGRA's opinion that site grading and earthwork may cause "small shallow slope failures" if slopes are oversteepened. AGRA, however, does not specifically address whether other site modifications, including landscape irrigation and effluent from a septic-tank soil-absorption (STSA) system, may destabilize the slopes. Utah Division of Water Quality (UDWQ) (1996) regulations indicate that approval of a STSA system can be denied if water from the drain field may cause slope instability. AGRA indicates maximum slopes range from 20 to 25 percent in the southeastern part of the lot and up to about 37 percent in the northern part. The latter slope angle exceeds the maximum slope allowed by Wasatch City-County Health Department regulations for STSA systems and the maximum slope allowed for home construction by Wasatch County, although flatter areas in the site may be suitable for siting the home and a STSA-system drain field.

AGRA concludes that the site is "not exposed to undue geologic hazards," but, because it was beyond the scope and purpose of its study, does not specifically address the potential for slope instability resulting from specific site modifications such as grading, landscape irrigation, and a STSA system. I recommend that the potential for slope instability resulting from site modifications be considered in support of a specific, proposed site-development plan. The study should address the potential for soils to become wet and unstable from landscape irrigation and effluent from a STSA-system drain field, provide slope-design recommendations for any permanent cut or fill slopes greater than 5 feet high, and address temporary foundation excavation stability. A second reconnaissance of the site for landslide features should also be made after all the snow has melted from the site.

REFERENCES

AGRA Earth & Environmental, 1996, Engineering geology site reconnaissance - single-family lot, lot 1018 on Deer Run Road, Timber Lakes subdivision, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 6 p.

Ashland, F.X., and Hylland, M.D., in press, Preliminary geotechnical-engineering slope-stability investigation of the Pine Ridge landslide, Timber Lakes Estates, Wasatch County, Utah: Utah Geological Survey Report of Investigation 232, 28 p.

Hylland, M.D., 1995, unpublished letter to R. Mathis, Wasatch County Planner, 2 p.

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

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

Project:			Requesting Agency:
Review of report "Fault study, proposed fire station, Steinke and Bair tree farm property, 8303 and 8201 South Wasatch Boulevard, Salt Lake County, Utah"			Salt Lake County Planning Division
By: Bill D. Black	Date: May 16, 1997	County: Salt Lake	Job No: 97-06 (R-5)
USGS Quadrangle: Draper (1171)		Number of attachments: None	

This report is a review of a fault-study report (Bryant, 1997) for a proposed fire station at 8303 and 8201 South Wasatch Boulevard (SE1/4 section 35, T. 2 S., R. 1 E., Salt Lake Base Line and Meridian) in Salt Lake County, Utah. Brian Bryant, Salt Lake County Planning Division, requested the review. The purpose of the review is to evaluate whether surface-fault-rupture hazards were adequately addressed to support the proposed land use. The scope of work consisted of a literature review and a field inspection of a trench at the site on March 20, 1997. Mr. Bryant was present during the field inspection.

Surface fault rupture is a potential hazard at the site (Bryant, 1997), and the site is in the surface-rupture special-study area on Salt Lake County Planning Division (1993) maps. Two traces of the Wasatch fault zone are found east of the site. The westernmost fault trace appears as a steep north-trending fault scarp near the eastern property boundary (Bryant, 1997). The easternmost fault trace is roughly 700 feet (213 m) east of the site. Bryant (1997) excavated one 128-foot (39-m) long trench from east to west across the property. The trench exposed silty fine to medium sandy alluvium showing no evidence of faulting, but the dip of bedding in these sediments suggests backtilting may have occurred at the site in one or more past surface-faulting earthquakes (Bryant, 1997). Bryant (1997) believes surface fault rupture is not a risk within the footprint of the proposed fire station, but recommends the structure be designed to withstand 1 to 2 degrees of backtilting from a nearby surface fault rupture to ensure it remains functional after a large earthquake. I concur with his assessment and recommendation, however evidence of possible backtilting indicates the site is in the zone of deformation and may also experience small offsets or ground cracks in a future surface-faulting earthquake.

Ground shaking is also a potential earthquake hazard at the site. The site is in Uniform Building Code (UBC) seismic zone 3, but Bryant (1997) recommends the structure be built to greater than zone 3 minimum guidelines because it is a critical facility. Specifically, Bryant (1997) recommends design for a peak ground acceleration in the 0.6 to 0.7 g range. I concur with this recommendation, and it exceeds UBC minima and will significantly reduce ground-shaking hazards.

REFERENCES

Bryant, B.A., 1997, Fault study--Proposed fire station, Steinke and Bair tree farm property, 8303 and 8201 South Wasatch Boulevard, Salt Lake County, Utah: Unpublished Salt Lake County Planning Division report, 7 p.

Salt Lake County Planning Division, 1993 (revised 1997), Surface fault rupture and liquefaction potential study areas, Salt Lake County, Utah: Unpublished Salt Lake County Planning Division map, scale 1:43,000.

Project:			Requesting Agency:
Review of a geotechnical report for a lot at approximately 1975 Fillmore Avenue, Ogden, Utah			Ogden Planning Division
By: F.X. Ashland	Date: 6-4-97	County: Weber	Job No: 97-08 (R-6)
USGS Quadrangle: Ogden (1345)		Number of attachments: none	

This report summarizes my review, conducted at the request of Corvin Snyder, Ogden Planning Division, of a geotechnical report by Earthtec Testing and Engineering (Earthtec) (1997). I received the report on April 22, 1997. The scope of my review included a review of published literature but did not include a site visit; however I conducted a brief reconnaissance of the active landslide area to the north of the site earlier in the year.

The Earthtec (1997) report addresses only foundation-soil conditions and shallow ground water, and states that a slope-stability evaluation was beyond the scope of Earthtec's work. The foundation-soil recommendations should be reviewed by a geotechnical engineer, but appear adequate for typical residential construction. I concur with Earthtec's conclusions regarding the likely absence of shallow ground water. Regarding slope stability, an earlier SHB AGRA, Inc. (AGRA) (1993) report shows the northern part of the lot is crossed by a "buildable area line" north of which AGRA identifies active and "previously active" landsliding. The AGRA (1993) report also shows that two pre-historical landslide scarps cross the lot south of AGRA's "buildable area line." In a review of the AGRA report by the Utah Geological Survey (UGS) (Lowe, 1994), UGS geologist Mike Lowe questioned the stability of this area north and west of the scarps and recommended no construction in that area unless a detailed slope-stability investigation showed that landsliding was unlikely. Because a detailed evaluation of the slope stability was beyond the scope of the Earthtec (1994) study and, thus, was not addressed in the report, I recommend that the potential for instability be addressed in a subsequent study. At a minimum, the level of investigation should be equivalent to a preliminary geotechnical-engineering (slope-stability) evaluation as described in UGS Circular 92 (Hylland, 1996).

REFERENCES

Earthtec Testing and Engineering, 1997, Geotechnical consultation - lot @ 1975 Filmore Ave., Ogden, UT 84404: Ogden, Utah, unpublished consultant's report, 3 p.

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

Lowe, Mike, 1994, 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," *in* Mayes, B.H., and

Wakefield, S.I., compilers, 1994, Technical reports for 1992-1993, Applied Geology Program: Utah Geological Survey Report of Investigation 224, p. 162-163.

SHB AGRA Inc., 1993, 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 "Geotechnical and engineering geology study - lot 221 on Lake Pines Drive, Timberlakes subdivision, Wasatch County, Utah"			Requesting Agency: Wasatch County
By: F.X. Ashland	Date: 6-12-97	County: Wasatch	Job No: 97-10 (R-7)
USGS Quadrangle: Center Creek (1126)		Number of attachments: 1	

At the request of Margaret Stephens, Wasatch County Planning Office, I reviewed geologic-hazards aspects of a geotechnical and engineering-geology report by AGRA Earth & Environmental (AGRA) (1997) for lot 221 in Timber Lakes Estates, Wasatch County, Utah. I received the report on May 5, 1997. The lot is located on Lake Pines Drive in the NW1/4NW1/4 section 9, T. 4 S., R. 6 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed prior to issuing a building permit giving approval to construct a home on the lot. The scope of work included a review of geologic-hazards literature and aerial photographs (1987, 1:40,000 scale; 1962, 1:20,000 scale), but did not include a site visit. Recommendations pertaining to foundation design in the AGRA (1997) report should be reviewed by a qualified geotechnical engineer, but appear adequate for typical residential construction.

The AGRA (1997) report addresses shallow ground water, earthquake ground shaking, surface fault rupture, and liquefaction. I believe the report adequately addresses these potential geologic hazards and I concur with AGRA's related conclusions and recommendations.

The AGRA (1997) report also addresses landslides and slope stability and indicates "no obvious sign of slope instability" exists on the lot. A summary regarding my evaluation of the adequacy of AGRA's slope-stability assessment is shown in attachment 1. AGRA adequately addresses most lot-specific slope-stability issues, including the possible effects of a septic-system drain field and site grading. AGRA identified three known or possible landslides to the north, east, and southwest of the site, but did not recognize any landslides near the lot. As part of an investigation for lot 223, two lots south of lot 221, Klauber (1996) identified a landslide that underlies lot 223 and several adjacent properties including lot 221. A review of aerial photographs by me and other Utah Geological Survey (UGS) geologists confirms that a probable landslide underlies the site. The landslide is about 1,000 feet wide where it is crossed by Lake Pines Drive, and about 1,200 feet long. The subdued nature of the landslide features suggests it is likely of early Holocene age (latest movement older than 5,000 years) and would be classified as Mo/Ho on plate 1D of UGS Open-File Report 319 (Hylland and others, 1995). Because AGRA did not identify this possible landslide, it did not address the slide's stability or the potential for instability caused by local and cumulative effects of development in the area.

The AGRA (1997) report makes slope-angle recommendations for temporary and permanent cut slopes. AGRA recommends that temporary cut slopes greater than 4 feet but less than 8 feet high can be cut at a 1 horizontal: 1 vertical (1H:1V) slope, which is an acceptable slope angle for temporary cuts of short duration. Because supposed temporary cut slopes in Timber Lakes Estates, in some instances, have remained in place for over a year, this recommended temporary cut-slope angle should not be used where cut slopes may remain in place for long periods of time, particularly over the winter and spring months. In addition, AGRA recommends a 2H:1V cut-slope angle for permanent cuts. Whereas this recommendation may be suitable for undisturbed glacial till, in my opinion, because of the potential for landslide deposits at the site, the recommended slope angle is too steep unless supported with geotechnical soil-strength data.

In conclusion, I believe that AGRA's statement that the site is "...not exposed to undue geologic hazards" is based on a lack of recognition of a possible landslide at the site, resulting in an incomplete assessment of slope stability of the area. I recommend that the existence and, if present, the potential for instability of the landslide identified by Klauber (1996) be addressed in a subsequent study before issuing a building permit for this lot or other lots on the landslide. If the landslide is present, this study should be at least a preliminary geotechnical-engineering slope-stability evaluation (Hylland, 1996) and consider the cumulative effects of development in the area, including the wetting of soils caused by effluent from septic-system drain fields. In addition, AGRA may need to reassess its permanent cut-slope-angle recommendations, considering the possible landslide origin of site soils, or support its recommended 2H:1V slope angle with geotechnical data.

REFERENCES

AGRA Earth & Environmental, 1997, Geotechnical and engineering geology study - lot 221 on Lake Pines Drive, Timberlakes subdivision, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 13 p.

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

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

Klauber, William, 1996, Landslide reconnaissance of lot 223, Timber Lakes Estates, Wasatch County, Utah: West Jordan, Utah, unpublished consultant's report, 10 p.

Attachment 1 Job No. 97-10

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author AGRA Earth & Environmental Date Of Report April 30, 1997

Title Of Report Geotechnical and engineering study - lot 221 on Lake Pines Drive, Timberlakes subdivision, Wasatch County, Utah

UGS File No. Technical Report 97-10 Requesting Agency Wasatch County Planning County Wasatch

USGS 7.5' Quad(s) (BLM No.) Center Creek (1126) Sec., T., R. NW1/4NW1/4 section 9, T. 4 S., R. 6 E., SLB&M

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	N	
2. Vicinity map	A	
3. Site-planning map at suitable scale, showing:	A	plan showing proposed septic-system locations and homesite included
3a. proposed development	A	
3b. topography	A	topography included
3c. geology	N	
3d. subsurface exploration and cross section locations	A	sample locations shown
3e. surface water	N	
3f. landslide features	D	none identified by AGRA on lot, landslide features identified by Klauber (1996) not shown
3g. hazard-reduction features	N	
4. Description of site conditions:	D	
4a. slopes	A	described briefly in text
4b. slope materials	D	possible landslide origin not addressed
4c. subsurface planar features	N	
4d. surface/ground water	D	basis for projected depth to ground water not explained
4e. vegetation	A	described in text
4f. suspected landslide features	D	possible landslide origin of soils not addressed; does not identify possible landslide at site
4g. surficial processes	A	
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information*

Page 1 of 2

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT	Adequacy of report	**COMMENTS** (attach additional sheets if necessary)
5. Description of existing landslides, including items in (4) above, and:	D	landslide of Klauber (1996) not identified or addressed
5a. failed unit(s)	--	
5b. failure type(s)	--	
5c. scarp characteristics	--	
5d. age(s) of failure	--	
5e. cause(s) of failure	--	
6. Implications of nearby landslides	D	susceptibility of soils to landsliding not addressed
7. Geotechnical-engineering evaluation:	D	quantitative analysis necessary to assess stability of landslide, if present
7a. subsurface materials/ground-water characterization	--	
7b. laboratory testing	--	
7c. profiles/cross sections	--	
7d. static slope-stability analysis	--	
7e. seismic slope-stability analysis	--	
• input ground motions	--	
• effects on shear strength and pore pressures	--	
• liquefaction potential	--	
7f. post-earthquake stability analysis	--	
8. Conclusions regarding hazard	D	conclusions related to slope stability exclude assessment of existence and possible reactivation of landslide
9. Recommendations	D	slope-angle recommendations do not consider possible landslide origin of site soils

Additional comments:

Reviewed By Francis X. Ashland   Date Reviewed June 3, 1997

UGS.4/96   P. 2 of 2

Project: Review of "Geotechnical study - Canyon Meadows subdivision, Upper Provo Canyon area, Wasatch County, Utah"			Requesting Agency: Wasatch City/County Health Department
By: F.X. Ashland	Date: 7-8-97	County: Wasatch	Job No: 97-12 (R-8)
USGS Quadrangle: Aspen Grove (1128)		Number of attachments: none	

At the request of Tracy Richardson, Wasatch City/County Health Department, I reviewed a septic-tank-suitability report by Applied Geotechnical Engineering Consultants, Inc. (AGEC) (1997) for the Canyon Meadows subdivision, Wasatch County, Utah. I received the report on June 16, 1997. The Canyon Meadows subdivision is located on the Hoover landslide in the E1/2 section 12, T. 5 S., R. 3 E., and W1/2 section 7, T. 5 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate the adequacy of the report and comment on its implications.

The AGEC (1997) report (plat map 3) indicates that the majority of the Canyon Meadows subdivision is unsuitable for septic-tank soil-absorption (STSA) systems because of shallow ground water and local steep slopes. Isolated areas exist within the subdivision where these two factors do not preclude the use of STSA systems. However, based on the available soil and percolation-test data, AGEC believes some of the isolated areas, particularly those in the eastern and southwesternmost parts of the subdivision, are also unsuitable for STSA systems (plat map 4).

I believe the AGEC (1997) report adequately assesses septic-tank suitability at the Canyon Meadows subdivision; however, AGEC's results imply a potential health risk exists if STSA systems are used. Whereas individual STSA systems may perform adequately in the remaining isolated areas considered suitable by AGEC, these areas are surrounded by unsuitable areas, many with shallow ground water. Thus, although STSA systems may function in these areas, I believe a potential exists for shallow ground-water contamination and seepage of either effluent or contaminated ground water to the surface, potentially posing a health risk at homesites downslope.

REFERENCE

Applied Geotechnical Engineering Consultants, Inc., 1997, Geotechnical study - Canyon Meadows subdivision, Upper Provo Canyon area, Wasatch County, Utah: Sandy, Utah, unpublished consultant's report, 4 p.

Project:		Requesting Agency:
Review of "Preliminary slope stability analysis - Canyon Meadows subdivision, Upper Provo Canyon, Wasatch County, Utah"		Wasatch County

By:	Date:	County:	Job No:
F.X. Ashland	7-8-97	Wasatch	97-13 (R-9)
USGS Quadrangle:		Number of attachments:	
Aspen Grove (1128)		none	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a slope-stability report by Applied Geotechnical Engineering Consultants, Inc. (AGEC) (1997) for the Canyon Meadows subdivision, Wasatch County, Utah. I received the report on June 16, 1997. The report presents the results of a preliminary geotechnical-engineering slope-stability evaluation as described in Hylland (1996). The Canyon Meadows subdivision is located on the Hoover landslide in the E1/2 section 12, T. 5 S., R. 3 E., and W1/2 section 7, T. 5 S., R. 4 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate the adequacy of the preliminary slope-stability analysis and recommendations regarding the need for further work.

In the absence of detailed subsurface information in the vicinity of the Canyon Meadows subdivision, AGEC made several assumptions regarding subsurface conditions and soil strength. For the most part, AGEC's assumptions appear reasonable; however, they consider the landslide deposits to be alluvium. Whereas alluvium may exist below the subdivision along the Provo River, I believe the landslide deposits in the subdivision area are more likely altered Manning Canyon Shale and overlying slope soils consisting of residuum and colluvium. Because the AGEC report does not indicate specific soil properties used in its analyses, such as soil densities, it is unclear whether AGEC's interpretation of the nature of the landslide deposits influenced the results of the analyses. AGEC's use of soil/rock strengths obtained by Parsons Brinkerhoff Quade & Douglass, Inc. (PBQ&D) (1994) as part of the Utah Department of Transportation Highway 189 relocation study is appropriate because they represent the best available data in the slide. However, the PBQ&D strengths may not represent the lowest possible strengths of soils in the slide, and therefore the results of the study may not be overly conservative. AGEC also did not consider the potential for elevated pore pressures in the slide (PBQ&D, 1994), thus lower factors of safety are possible.

AGEC used the Geoslope slope-stability program to evaluate the Hoover landslide which I assume uses a limit-equilibrium approach (stability represented by the ratio of forces resisting movement to those causing movement) to determine a factor of safety. Whereas the limit-equilibrium approach is appropriate for slides, the Hoover landslide appears to move, at least in part, by flow (PBQ&D, 1994) (downslope movement similar to a viscous fluid), and the limit-equilibrium approach cannot explain the flow-related creep of the slide. The approach is likely adequate for preliminary stability-analysis purposes, however, noting that it may not yield overly conservative results (that is, it could suggest stability where gradual ground movement occurs by flow).

The AGEC (1997) report concludes that the Hoover landslide is marginally stable based on assumed conditions and using the lowest PBQ&D strength value, which yields a static factor of safety of about 1.2 with ground water at the ground surface. AGEC's earthquake analysis further indicates instability during earthquake ground shaking. As stated above, I believe that AGEC's opinion that the slide is marginally stable is not overly conservative and I concur with AGEC's recommendation that additional detailed geotechnical-engineering field investigation is needed to determine whether the subdivision is suitable for additional development.

REFERENCES

Applied Geotechnical Engineering Consultants, Inc., 1997, Preliminary slope stability study analysis - Canyon Meadows subdivision, Upper Provo Canyon, Wasatch County, Utah: Sandy, Utah, unpublished consultant's report, 4 p.

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

Parsons Brinkerhoff Quade & Douglass, Inc., 1994, Geotechnical engineering study - preferred alignment of the U.S.-189 Widening Project from Wildwood to Deer Creek Park, Provo Canyon, Utah: San Francisco, unpublished consultant's report, 74 p.

Utah Geological Survey

<table>
<tr><td colspan="3">Project:

Review of report "Geotechnical investigation, Cherry Hollow subdivision at 1700 North, 2200 East, Layton, Utah"</td><td>Requesting Agency:

Layton City Community Development Department</td></tr>
<tr><td>By:

Bill D. Black</td><td>Date:

July 15, 1997</td><td>County:

Davis</td><td rowspan="2">Job No:

97-14
(R-10)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
Kaysville (1320)</td><td>Number of attachments:
None</td></tr>
</table>

This report is a review of a geotechnical investigation conducted by Applied Geotechnical Engineering Consultants (AGEC) for the Cherry Hollow subdivision (AGEC, 1997a, b) located at 1700 North, 2200 East, in Layton (NW1/4 section 14, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian), Davis County, Utah. Doug Smith, Layton City Community Development Department, requested the review. The purpose of the review is to evaluate whether geologic hazards were adequately addressed in the report (AGEC, 1997a) and follow-up letter (AGEC, 1997b). The scope of work consisted of a literature review, examination of 1:20,000-scale aerial photos (1985), and telephone discussions with Doug Hawkes (AGEC Project Engineer). I also visited the site on July 2, 1997.

AGEC (1997a) gives recommendations for maintaining stability of cut slopes at the site, and outlines areas in the southern part of the subdivision where no building is recommended without significant stabilization efforts. Slopes bordering the southern part of the subdivision are potentially unstable (AGEC, 1997a), and these slopes are in a landslide special-study zone on unpublished Davis County Planning Division Maps (Lowe, 1988a). AGEC (1997a) recommends not constructing houses or cut slopes in these areas, and lowering ground-water levels (using subsurface drains) to improve stability of the slopes. AGEC (1997b) indicates several quantitative slope-stability analyses were performed to evaluate the stability of steep slopes in the property, based on soil data in AGEC (1997a), and estimates factors of safety exceed 1.5 if ground-water levels are lowered below building floor levels and no development takes place in the non-buildable areas. Preliminary slope-stability analyses by Frank Ashland (Utah Geological Survey, written communication, July 1997), using data in AGEC (1997a), confirm AGEC's (1997b) opinion that the slopes are potentially unstable. Soil parameters used in AGEC's analysis are based on lab-test results, which appear reasonable, and AGEC's (1997a, b) related recommendations are also reasonable based on their results. However, individual home drains may not effectively improve stability for the entire slope.

Although AGEC (1997a) delineates areas in the southern part of the subdivision (at the base of the potentially unstable slopes) where no building should occur, they make no recommendations to reduce the risk of debris deposition and/or flooding on the property from a failure. Slope failures in this area are principally earth slides and earth flows (for example, Lowe, 1988b), and past historical failures commonly liquefied following initial failure, resulting in sediment deposition and flooding at a distance from the base of the slope. In addition, toes of hypothetical slides in Frank Ashland's (written communication, July 1997) analyses occur near the northern boundary of the non-buildable area. Homes along the steep slopes in the eastern part of the property could be impacted by future slope failures, particularly those initiating outside the property where ground-water levels are not controlled and unapproved slope alterations may be made. Therefore, I believe AGEC should provide recommendations for engineering measures to improve safety of the homes bordering the unstable slopes. I further recommend disclosing to future buyers the potential for slope failures and their risk if Layton City cannot ensure protection for the unstable slopes.

An active landslide is shown in the eastern portion of the property on unpublished Davis County Planning Division maps (Lowe, 1986c). This slide was mapped by examination of aerial photographs, but no field investigation was conducted (Mike Lowe, former Davis County Geologist, verbal communication to Doug Hawkes, June 1997). AGEC (1997b) reviewed the aerial photographs and conducted a reconnaissance of the property. They indicate observing evidence for nearby landslide activity but no evidence for active landsliding in the property (AGEC, 1997b). From my site visit and review of air photos, I similarly found little evidence for the landslide and AGEC's (1997b) assessment appears reasonable.

Shallow ground water is a potential hazard at the property (AGEC, 1997a). Subsurface water was encountered in six of nine of AGEC's (1997a) test pits. Water levels in test pits where water was encountered ranged from near the ground surface to a depth of roughly 7.5 feet (2.3 m) (AGEC, 1997a). Based on these data, AGEC (1997a) recommends subsurface drains to improve site access and lower water levels below building floor levels, and recommends underdrain systems for buildings with floors which extend below grade. I agree with AGEC's (1997a) assessment and recommendations. Eckhoff, Watson & Preator Engineering (EWPE) indicates the developer will require foundation drains be used in areas of shallow ground water (Kenneth Watson, EWPE, written communication, June 1997). These drains must be maintained to ensure long-term effectiveness.

AGEC (1997a) identifies earthquake ground shaking as a potential hazard at the property. To reduce the risk from ground shaking, AGEC (1997a) recommends that all buildings be designed and constructed to meet Uniform Building Code (UBC) seismic zone 3 criteria. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. AGEC (1997a) also identifies liquefaction as a potential hazard at the property. The property is in an area of high liquefaction potential, but AGEC (1997a) conducted no site-specific liquefaction analysis. However, AGEC (1997b) indicates that the mapped liquefaction potential may be appropriate for the property based on subsurface conditions encountered. I agree with AGEC's (1997a, b) assessment, but because the property is in an area of recognized high potential, I believe AGEC (1997a) should provide recommendations for engineering measures (such as foundation designs) to reduce the risk of damage from liquefaction. At a minimum, Lowe (1990) recommends that the potential for liquefaction be disclosed to future buyers.

Portions of the northern lots at the property are in the 100-year flood zone on the Federal Emergency Management Agency (1982) Flood Insurance Rate Map. AGEC (1997b) indicates that EWPE plans to address the flood hazard for the proposed development. Layton City will need to review EWPE's plan for conformance to requirements of the National Flood Insurance Program. AGEC (1997a) also gives recommendations for drainage systems, foundations, subgrade preparation, and pavement design. These recommendations should be reviewed by a qualified geotechnical engineer.

REFERENCES

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----1997b, Geotechnical consultation--Cherry Hollow subdivision at 1700 North 2200 East, Layton, Utah: Sandy, unpublished letter to Smith Brubaker dated June 19, 1997, 2 p.

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Lowe, Mike, 1988a, Landslide hazard map--Kaysville quadrangle: unpublished Davis County Planning Division Map, scale 1:24,000.

----1988b, Country Oaks Drive landslide, *in* Black, B.D., and Christenson, G.E., compilers, Technical reports of the Wasatch Front County Geologists--June 1985 to June 1988: Utah Geological and Mineral Survey Report of Investigation 218, p. 7-8.

----1988c, Slope-failure inventory map--Kaysville quadrangle: unpublished Davis County Planning Division Map, scale 1:24,000.

----1990, Geologic hazards and land-use planning--Background, explanation, and guidelines for development in Davis County in designated geologic hazards special study areas: Utah Geological and Mineral Survey Open-File Report 198, 73 p.

Project: Review of geotechnical reports for the Apple Tree condominiums and senior center site, Layton, Utah			Requesting Agency: Layton City Community Development Department
By: Barry J. Solomon	Date: 7-9-97	County: Davis	Job No: 97-15 (R-11)
USGS Quadrangle: Kaysville (1320)		Number of attachments: none	

INTRODUCTION

At the request of Doug Smith, Current Planner for the Layton City Community Development Department, I reviewed geologic-hazard portions of two geotechnical reports for the proposed Apple Tree retirement condominiums and senior center site (Maxim Technologies, Inc. [Maxim], 1996, 1997). The proposed development is in the SE1/4 section 2, T. 4 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the Maxim (1996, 1997) reports should be reviewed by a qualified geotechnical engineer.

GEOLOGIC HAZARDS

The first geotechnical report (Maxim, 1996) addresses shallow ground water, sulfates in soils, surface fault rupture, ground shaking, and landsliding and slope stability. Conclusions and recommendations in the report are based on a site reconnaissance, logging of five shallow exploratory borings, and limited laboratory testing. The report states that ground water was not encountered to the maximum depth of 21.5 feet in exploratory borings, but expected variations due to seasonal weather patterns and rates of ground-water extraction could not be evaluated. The report also states that the amount of water-soluble sulfates measured in one sample is small and represents a negligible hazard to concrete exposed to foundation soils. Although the report states that the Weber segment of the Wasatch fault zone is less than 2.5 miles east of the site, Nelson and Personius (1993) map the segment within 0.5 mile of the site. However, this discrepancy does not affect the valid conclusion of Maxim (1996) that the potential for surface fault rupture at the site is low. The report notes that the site lies within Uniform Building Code (UBC) seismic zone 3, with a subsurface soil profile best represented by a site coefficient of 1.2. If structures are designed and constructed according to zone 3 standards, the structures will meet minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards.

The first geotechnical report (Maxim, 1996) also notes that the site is located in an area of potential landslide hazards. Although the report does not identify any landslide deposits, Nelson and Personius (1993) map landslide scarps in fine-grained lakebeds at the top of the slope which bounds the southern edge of the site, and Lowe (1988) recommends that landslide-hazard special studies be conducted along the slope. A preliminary slope-stability analysis was performed by Maxim (1996) using PCSTABL5M slope-stability computer software. The analysis yielded factors of safety between 1.0 and 1.8, indicating that some on-site slopes were unstable. Maxim (1996) recommended site-grading requirements to minimize landslide hazards, and recommended evaluation of setbacks from the top and toe of the slope by a geotechnical engineer. Additional slope-stability analyses were requested by Bill Flanders, Layton City Engineer.

Additional field observations and slope-stability analyses are given in Maxim's second geotechnical report (Maxim, 1997). Maxim (1997) found evidence of ground movement on the hillslope, including a landslide toe that overrode an aqueduct, and observed springs on the slope that appear to be contributing to the unstable conditions. Using PCSTABL6H computer software, Maxim (1997) performed slope-stability analyses along three cross sections traversing the slope. Input parameters assumed a cohesionless silty sand and, along two of the cross sections, a depth to ground water based on projections from the observed springs. These analyses indicated that the factor of safety in the upper part of the slope (1.56-2.63) was acceptable under the assumed conditions, but that the factor of safety in the lower part of the slope (0.96 to 1.0) was unacceptable. Maxim (1997) concluded that the stability of the lower slope must be improved prior to construction, but did not identify specific improvements.

CONCLUSIONS AND RECOMMENDATIONS

The Maxim (1996, 1997) reports adequately address shallow ground water, sulfates in soils, surface fault rupture, ground shaking, and landsliding and slope stability. Maxim (1996) found no evidence to suggest that shallow ground water, sulfates in soils, or surface fault rupture pose a significant hazard, although an estimate of future changes in ground-water levels was beyond the scope of their investigation. If structures are designed and constructed according to seismic zone 3 standards, the structures will meet minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards.

Maxim (1997) found surficial evidence of landsliding on the hillslope along the southern edge of the property, and their subsequent slope-stability analyses used realistic input parameters from field observations and laboratory testing to determine that the factor of safety along the lower part of the hillslope was inadequate. However, Maxim (1997) did not include slope-design recommendations to reduce the landslide hazard along the lower part of the slope. Such recommendations are needed not only to reduce the hazard along the lower slope but also to reduce the hazard in the adjacent upper slopes from upward propagation of failures in the lower slopes. Any future geotechnical recommendations, as well as geotechnical recommendations in Maxim (1996) regarding foundation design, site grading, and horizontal setbacks from the slope face, should be evaluated by a qualified geotechnical engineer. I recommend that this evaluation be conducted prior to construction, and it consider all planned modifications to site conditions.

REFERENCES

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Maxim Technologies, Inc., 1996, Geotechnical investigation - proposed senior citizens care facility and retirement condominiums, Layton, Utah: Salt Lake City, unpublished consultant's report, 19 p., 4 appendices.

Maxim Technologies, Inc., 1997, Additional geotechnical engineering study for the Apple Tree Condominiums and Senior Center site, Layton, Utah: Salt Lake City, unpublished consultant's report, 11 p.

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

Project:			Requesting Agency:
Review of a draft slope-stability evaluation and geologic-hazards report and supplemental information for the proposed Beck Street reclamation framework and foothill area plan, Salt Lake City, Utah			Salt Lake City
By: F.X. Ashland	Date: 7-23-97	County: Salt Lake	Job No: 97-16 (R-12)
USGS Quadrangle: Salt Lake City North (1254)		Number of attachments: none	

INTRODUCTION

At the request of Craig Hinckley, Salt Lake City Planner, I reviewed parts of a draft slope-stability evaluation and geologic-hazards report by Dames & Moore (in preparation). The report presents geologic information for the proposed Beck Street reclamation framework and foothill-area plan. Ongoing quarrying operations along Beck Street in Salt Lake and North Salt Lake Cities could eventually result in a highwall that locally exceeds 1,000 feet high. I received three chapters of the draft report on April 23, but did not receive supplemental information necessary to complete my review until June 3. The purpose of the review is to determine whether Dames & Moore's preliminary evaluation of the stability of the proposed highwall is adequate, and whether other geologic-hazard issues have been adequately addressed. The scope of this review included analysis using the limit-equilibrium slope-stability program PC-STABL5M and assessment of rock-mass-strength input parameters using a spreadsheet program that incorporates equations by Hoek and Brown (1988). This review presents my general comments regarding Dames & Moore's evaluation of the proposed highwall stability. I also made specific comments regarding technical details in a separate letter to Dames & Moore, dated July 23, 1997. I understand that a more detailed slope-stability evaluation will be performed once excavation has advanced farther into the slope, and many of my recommendations are related to the scope of work of the detailed study.

GEOLOGIC HAZARDS

The draft Dames & Moore report addresses earthquake ground shaking, surface fault rupture, and liquefaction, and I concur with its conclusions and recommendations pertaining to these specific geologic hazards, except where they relate to slope stability. Dames & Moore also identifies tectonic subsidence and seiches as possible earthquake hazards but does not make any hazard-specific recommendations.

SLOPE STABILITY

Chapter 5 of the draft Dames & Moore report evaluates the stability of the proposed highwall in four separate locations. In its evaluation, Dames & Moore estimated rock-mass strengths using empirical relationships between rock-mass classification and strength (Hoek and Brown, 1988). Dames & Moore used the Rock Mass Rating (RMR) System (Bieniawski, 1976) to classify rock-mass conditions. The estimated strength values were used to assess the likelihood of circular and nearly circular failures in the highwall. Whereas this approach is adequate, I recognize certain limitations in Dames & Moore's evaluation. The chapters of the report sent to me did not address other rock-slope failure mechanisms, particularly failure along discontinuities, although some data in the supplemental information provided me by Dames & Moore pertained to this issue.

The first limitation of the Dames & Moore study is that it incorporates little new data on actual rock-mass conditions, and therefore varies little from an earlier AGRA Earth & Environmental (AGRA) (1995) report. Dames & Moore used identical rock-mass classifications and intact rock strengths for the Tertiary conglomerates and related rocks and the older, underlying Paleozoic rocks. In my opinion, this is unreasonable because differences exist in rock types (conglomerate versus limestone) and deformation histories. Because Paleozoic rocks were folded and faulted by the Sevier Orogeny but Tertiary rocks were not, differences in rock-mass classifications are likely. The rock-mass classification and intact rock strength used in the analyses, and the resulting rock-mass strengths (table 1) are, however, generally conservative compared to published values, but are less conservative than those used in the AGRA (1995) report. Intense fracturing and rock alteration is possible in the vicinity of the proposed highwall, particularly adjacent to faults, and would yield lower values than those used in Dames & Moore's analyses. Van Horn (1981) identified a fault in Paleozoic rocks near the Staker property, and other unmapped faults may be buried by Tertiary units in the vicinity of the highwall. My preliminary evaluation of the stability of the highwall in Dames & Moore's profile A-A' indicates that a 50-percent reduction in the cohesion value of the lower limestone unit, all other conditions remaining the same, would lower the static factor of safety to an unacceptably low level. Because of the lack of actual rock-strength data and rock-mass-condition mapping, it is difficult to gauge how representative Dames & Moore's estimates of rock strengths are to actual conditions or anticipate variability in rock-mass conditions in the proposed highwall.

Table 1.
Comparison of Dames & Moore strength values with Hoek & Brown (1988) values.

Rock-Strength Parameter	Conglomerate	Limestone
Average friction angle from Dames & Moore's table 1 (degrees)	51	38
Average friction angle from Dames & Moore's STED output sheets (degrees)	44	37
Average friction angle using Hoek & Brown (1988) method (degrees)	50	33
Average cohesion from Dames & Moore's table 1 (kips per square foot)	12.7	17.6
Average cohesion using Hoek & Brown (1988) method (kips per square foot)	16.1	27.0

A second limitation of the Dames & Moore study is the assumption that the highwall will remain dry throughout the year. Observations indicate a lack of springs or seeps in the active quarries, but it is unclear whether observations during the winter and early spring have been incorporated into this assessment. The proposed highwall benches will not allow for snow or ice removal (J. Keaton, AGRA, verbal communication, August 2, 1995). Because of this, ice could form on the exposed highwall surface during the winter season, preventing drainage, and allow water to collect in the fractures behind the highwall. My preliminary analysis of circular and nearly circular failure surfaces suggests that the stability of the highwall is not overly sensitive to water in the lower part of the highwall. However, the presence of water behind the highwall could locally destabilize the highwall and produce wedge failures, a likely failure type in the Paleozoic units in the lower part of the highwall.

A third limitation of the Dames & Moore study is its use of 50 percent of the peak horizontal ground acceleration (PHGA) with a 500-year return period (equivalent to 10 percent probability of exceedence in 50 years). Whereas this return period is typically used in seismic design of buildings, I do not believe it is appropriate for a permanent unsupported highwall that must remain stable indefinitely. My preliminary analysis using 50 percent of the PHGA from an earthquake with a 2,500-year return period (2 percent probability of exceedence in 50 years) suggests instability of the proposed highwall during strong earthquake ground shaking even under dry conditions. Because an earthquake-induced landslide in the proposed highwall would be catastrophic, particularly if development occurs at the toe of the highwall, I believe the highwall design for earthquake-loading conditions should be conservative, and consider these longer return-period ground motions.

The parts of the Dames & Moore report sent to me for review did not present data on or adequately address the potential for rock-wedge failures. In my opinion, rock-wedge failures are possible, particularly in the Paleozoic rocks in the lower part of the highwall. Joint data presented in the AGRA (1995) report suggest rock wedges inclined to the west will occur in the highwall. Further collection of rock discontinuity (joints, faults, cleavage) data is therefore critical to completely assess the stability of the highwall.

CONCLUSIONS AND RECOMMENDATIONS

Dames & Moore (in preparation) concludes the "rock mass slope stability is not a limiting factor in reclamation design." I believe the data are insufficient to make this conclusion. The report identifies the need for and recommends future rock-mass-classification surveys, and I concur. In addition, I believe the sensitivity of highwall stability to rock-mass strength should be assessed to determine the lowest rock-mass classification that would support the proposed stable highwall. As excavation progresses, demonstration that the rock-mass classification is higher than the lowest acceptable level should be required. Relatively inexpensive laboratory testing of intact rock strengths in the project area would also be useful in assessing how conservative Dames & Moore's rock-mass strengths are, noting that overall, its strength values are less conservative than those used in the AGRA (1995) report. These analyses and laboratory tests were beyond the scope and budget of the Dames & Moore study, but are necessary to constrain the level of uncertainty in the proposed highwall design and the adequacy of Dames & Moore's conclusion. I also recommend further collection and analysis of discontinuity data, particularly in the underlying Paleozoic rocks, to assess the potential for rock-wedge failures. At a minimum, the recommended studies should be done as part of the proposed detailed slope-stability evaluation, but may be appropriate at an earlier phase to constrain uncertainties in highwall design and related reclamation plans.

Finally, because failure cannot be tolerated in the highwall during even the most severe ground shaking, I recommend the stability of the highwall during earthquake loading (ground shaking) conditions be further evaluated using a more conservative PHGA value. Both the AGRA (1995) and Dames & Moore (in preparation) reports used a less conservative PHGA value based on a 500-year return-period earthquake which I believe is inappropriate.

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

Project:			Requesting Agency:
Review of "Geotechnical engineering evaluation for lot 223, Timber Lakes Estates vicinity, Heber City, Utah"			Wasatch County
By: Bill D. Black	Date: 08-04-97	County: Wasatch	Job No: 97-18 (R-13)
USGS Quadrangle: Center Creek (1126)		Number of attachments: None	

This report is a review of a follow-up preliminary geotechnical-engineering evaluation (Geo Company, 1996) for lot 223 on Lake Pines Road (NW1/4NW1/4 section 9, T. 4 S., R. 5 E., Salt Lake Base Line and Meridian), Timber Lakes Estates, Wasatch County, Utah. Previous work for the lot consisted of an engineering-geology report (Klauber, 1996) and review (Black, 1996). The purpose of this review is to assess whether slope-stability concerns brought up in Black (1996) were adequately addressed by Geo Company (1996). Robert Mathis, Wasatch County Planner, requested the review. The scope of work consisted of a literature review. No site visit was made.

Klauber (1996) indicated the overall slope of the lot was 29 to 40 percent and identified landsliding as a potential hazard. Black (1996) agreed with this assessment. An old, deep-seated landslide encompasses much of the lot, and several small, shallow surficial slides are in steep slopes at the lot (Klauber, 1996). Black (1996) recommended at least a preliminary geotechnical-engineering slope-stability analysis to evaluate overall stability of the old landslide and the natural slopes.

Geo Company (1996) surveyed slopes at the lot and indicate they have an average steepness of 20 to 25 percent. Although this steepness is significantly lower than Klauber's (1996) overall steepness, it is based on surveying data and therefore is presumably accurate. However, these data cover only the lot (not the whole landslide) and indicate that Geo Company's (1996) evaluation addresses only the stability of the natural slopes and not the stability of the landslide. Stability of the landslide is the critical issue, and the results of that evaluation will largely determine whether or not the natural slopes need to be evaluated. Therefore, because Geo Company (1996) did not consider the stability of the old landslide beneath this and adjacent lots, taking into consideration long-term increases in ground-water levels from septic-tank effluent, the potential for movement of this slide still must be assessed.

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Geo Company, 1996, Geotechnical engineering evaluation for lot 223, Timber Lakes Estates vicinity, Heber City, Utah: Salt Lake City, unpublished consultant's report, 6 p.

Klauber, William, 1996, Landslide reconnaissance of lot 223, Timber Lakes Estates, Wasatch County, Utah: West Jordan, Utah, unpublished consultant's report, 10 p.

Project: Review of "Engineering geology reconnaissance and geotechnical study - proposed Area C, Wasatch County"			Requesting Agency: Wasatch County Planning Office
By: Barry J. Solomon	Date: 8-13-97	County: Wasatch	Job No: 97-19 (R-14)
USGS Quadrangle: Francis (1167)		Number of attachments: 1	

At the request of Sharon Mayes-Atkinson, Assistant Director of Planning for Wasatch County, I reviewed geologic-hazards portions of an engineering geology and geotechnical report by Dames & Moore (1997) for the proposed Area "C" development, Wasatch County, Utah. I received the report on August 6, 1997. The proposed development is located in sections 35 and 36, T. 2 S., R. 5 E., and sections 1, 2, 3, 10, and 15, T. 3 S., R. 5 E., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the Dames & Moore (1997) report should be reviewed by a qualified geotechnical engineer, but appear adequate for the proposed construction.

The Dames & Moore (1997) report addresses shallow ground water, sulfates in soils, surface fault rupture, earthquake ground shaking, rock fall, debris flows, and flooding. I believe the report adequately addresses these potential geologic hazards and I concur with Dames & Moore's related conclusions and recommendations.

The Dames & Moore (1997) report also addresses landslides and slope stability. A summary regarding my evaluation of the adequacy of Dames & Moore's slope-stability assessment is shown in attachment 1. Dames & Moore adequately addresses certain slope-stability issues, however some related issues remain unresolved.

Dames & Moore (1997) found no evidence of slope failures except for one small slump on the southern portion of the site. Dames & Moore (1997) mapped the slump and adjacent slopes as a "potential landslide/slope failure area." I agree with their identification of this slump as visible evidence of past slope failure and with their mapping of adjacent slopes as an area of potential future landslides. This "potential landslide/slope failure area" is based, in part, on the mapping of a moderate relative landslide hazard by Hylland and Lowe (1995), who also mapped the same hazard on steep slopes on the northern portion of the site. However, Dames & Moore (1997) did not similarly map a "potential landslide/slope failure area" to the north. The moderate hazard of Hylland and Lowe (1995) is based on the presence of a slope inclination greater than a statistically-derived critical slope inclination value (25 percent) specifically calculated for slopes underlain by the Keetley Volcanics in western Wasatch County (Hylland and Lowe, 1997). The hazard is designated for slopes on which there is no evidence of previous landsliding, and indicates the potential for future slope failures based on the slope inclination of existing landslides in the Keetley Volcanics elsewhere. Dames & Moore (1997) considers site slopes up to 30 degrees (60 percent) to be stable, but doesn't indicate how this value was determined. I believe the maximum stable slope angle will vary with geologic unit and therefore believe two additional parameters, the geologic unit subject to failure and slope angles related to that unit, must be identified in a site-specific study to adequately assess the landslide potential. A different hazard than that designated by Hylland and Lowe (1995) should be assigned only if supported by field data or quantitative analyses.

Dames & Moore (1997) has already provided additional information on the material underlying slopes on the northern portion of the site by mapping three units within the Keetley Volcanics. I agree that the flow rocks and welded tuffs (units Tk_1 and Tk_2) are sufficiently strong to support existing slopes and that they pose a low hazard. However, the greater depth of weathering, presence of expansive clays, and lower strength of the weakly welded tuffs (unit Tk_3) suggest that steeper slopes on the northwestern portion of the site may pose a higher landslide potential. If construction is planned on or near steeper slopes in these materials (unit Tk_3), these slopes should be analyzed with quantitative slope-stability techniques to determine maximum stable slope angles. Once analyzed, a slope map should be constructed to delineate areas of relatively high hazard, and appropriate setbacks should be mapped.

As part of the slope-stability evaluation, I recommend that additional study be conducted in the area of potential landslides on the southern portion of the site to further delineate the potential landslide hazard. The additional study, at a minimum, should determine the geologic unit that has failed in the slump mapped by Dames & Moore (1997) and, to the extent possible, in the landslide mapped by Hylland and Lowe (1995) just east of the property boundary. Once the failed unit is identified, the developer may conduct a quantitative slope-stability analysis and specify appropriate hazard-reduction techniques, or restrict development in the area already designated as an area of potential landslides by Dames & Moore (1997). The slope of the slump is about 35 percent, and any similar or steeper slopes in the failed unit elsewhere on the property should be similarly mapped as "potential landslide/slope failure areas," unless evidence is provided to indicate otherwise. Any further investigation of the landslide potential on the southern portion of the site should also consider the potential for slope failure on steep slopes of the contiguous area to the west that may affect the property. This contiguous area has thicker colluvium (unit C_3), similar to that covering slopes to the east, and may be underlain by bedrock susceptible to slope failure.

Because details of the development are still in the planning stage, no information was presented by Dames & Moore regarding wastewater disposal. The developer should be advised that Hylland (1995) designates most of the site as generally unsuitable for wastewater disposal in septic-tank and soil-absorption systems because of shallow bedrock. If such systems are under consideration, site-specific study must be conducted to determine if suitable conditions are present. The impact on slope stability of wetting of soils caused by effluent from septic-system drain fields should also be considered.

In conclusion, I recommend that if construction is planned on slopes steeper than 25 percent, the potential stability of such slopes, particularly in units Tk_3 and C_3, be addressed in a subsequent study. This study should be at least a preliminary geotechnical-engineering slope-stability evaluation (Hylland, 1996). I also recommend a subsequent study of the potential landslide area mapped by

Dames & Moore (1997) in the southern portion of the site to identify the failed geologic unit, provide hazard-reduction recommendations if necessary, and determine if the area of potential landslides in the failed unit should be extended elsewhere in the property. All studies should consider the cumulative effects of development in the area, including the wetting of soils caused by effluent from septic-system drain fields and lawn watering. Also, if cuts and fills greater than 5 feet high are planned, either standard Uniform Building Code recommendations or other specific engineering-design recommendations will be required.

REFERENCES

Dames & Moore, 1997, Engineering geology reconnaissance and geotechnical study - proposed Area C, Wasatch County: Salt Lake City, unpublished consultant's report, 17 p.

Hylland, M.D., 1995, Suitability for wastewater disposal in septic-tank soil-absorption systems, western Wasatch County, Utah, *in* Hylland, M.D., Lowe, Mike, and Bishop, C.E., 1995, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 319, plate 3B, scale 1:24,000.

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

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

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

Attachment 1.   Job No. 97-19

CHECKLIST FOR THE REVIEW OF LANDSLIDE-HAZARD REPORTS

Report Author Dames & Moore   Date Of Report July 28, 1997

Title Of Report Engineering geology reconnaissance and geotechnical study - proposed Area C, Wasatch County, Utah

UGS File No. Technical Report 97-19   Requesting Agency Wasatch County Planning   County Wasatch

USGS 7.5' Quad(s) (BLM No.) Francis (1167)   Sec., T., R. SLB&M sections 35 and 36, T. 2 S., R. 5 E., and sections 1, 2, 3, 10, and 15, T. 3 S., R. 5 E.

Adequacy Codes: A = adequate; **N** = not necessary; **D** = additional data, analysis, or justification needed

SUBJECT[1]	Adequacy of report	COMMENTS (attach additional sheets if necessary)
1. List of reference materials used	A	
2. Vicinity map	A	
3. Site-planning map at suitable scale, showing:	A	
3a. proposed development	A	details of the development are still in the planning stage
3b. topography	A	topography included
3c. geology	A	
3d. subsurface exploration and cross section locations	A	sample locations shown
3e. surface water	N	
3f. landslide features	A	
3g. hazard-reduction features	N	
4. Description of site conditions:	A	
4a. slopes	D	described briefly in text; slope map needed for hazard evaluation
4b. slope materials	A	
4c. subsurface planar features	N	
4d. surface/ground water	A	
4e. vegetation	A	described in text
4f. suspected landslide features	A	
4g. surficial processes	A	
4h. other	N	

table continued

[1] *Refer to UGS Circular 92, "Guidelines for Evaluating Landslide Hazards in Utah" (1996, M.D. Hylland [editor]) for supplemental information*

Attachment 1. (cont.)

Adequacy Codes: A = adequate; N = not necessary; D = additional data, analysis, or justification needed

SUBJECT		Adequacy of report	COMMENTS (attach additional sheets if necessary)
5.	Description of existing landslides, including items in (4) above, and:	A	only one small slump on site
5a.	failed unit(s)	D	mapped in colluvium but could be bedrock failure
5b.	failure type(s)	A	
5c.	scarp characteristics	A	
5d.	age(s) of failure	D	no age given
5e.	cause(s) of failure	A	
6.	Implications of nearby landslides	D	susceptibility of Keetley Volcanics to landsliding not addressed
7.	Geotechnical-engineering evaluation:	D	quantitative analysis necessary to assess stability of susceptible slopes
7a.	subsurface materials/ground-water characterization	--	
7b.	laboratory testing	--	
7c.	profiles/cross sections	--	
7d.	static slope-stability analysis	--	
7e.	seismic slope-stability analysis	--	
	• input ground motions	--	
	• effects on shear strength and pore pressures	--	
	• liquefaction potential	--	
7f.	post-earthquake stability analysis	--	
8.	Conclusions regarding hazard	D	conclusions related to slope stability exclude assessment of susceptible slopes, considering slope inclination and material
9.	Recommendations	D	determine maximum stable slope angles of various units

Additional comments:

Reviewed By Barry J. Solomon Date Reviewed August 13, 1997

UGS.4/96 P. 2 of 2

<table>
<tr><td colspan="3">Project:
Review of "Engineering geology reconnaissance and evaluation - proposed Emerson Hills subdivision, North Fork Ogden River, Ogden Valley, Town of Liberty, Weber County, Utah"</td><td>Requesting Agency:
Weber County Planning Commission</td></tr>
<tr><td>By:
Barry J. Solomon</td><td>Date:
8-19-97</td><td>County:
Weber</td><td rowspan="2">Job No:
97-20
(R-15)</td></tr>
<tr><td colspan="2">USGS Quadrangle:
North Ogden (1370), Mantua (1395)</td><td>Number of attachments:
none</td></tr>
</table>

At the request of Troy Herold, Planner for the Weber County Planning Commission, I reviewed geologic-hazards portions of an engineering geology report by AGRA Earth and Environmental, Inc. (1997) for the proposed Emerson Hills subdivision, Weber County, Utah. I received the report on July 7, 1997. The proposed development is located in the NE1/4 section 1, T. 7 N., R. 1 W., Salt Lake Base Line and Meridian. The purpose of the review was to evaluate whether geologic hazards were adequately addressed to support proposed development on the property. The scope of work included a review of geologic-hazards literature, but I did not inspect the property. Recommendations pertaining to foundation design and site grading in the AGRA (1997) report should be reviewed by a qualified geotechnical engineer, but appear adequate for the proposed construction.

The AGRA (1997) report addresses expansive soil and rock, slope stability, earthquake ground shaking, surface fault rupture, and flooding. I believe the report adequately addresses these potential geologic hazards and I concur with AGRA's related conclusions and recommendations.

The AGRA (1997) report also addresses liquefaction, shallow ground water, and indoor radon. AGRA adequately addresses most aspects of these hazards, however I have some additional recommendations.

Because of excessive snow cover, AGRA (1997) did not excavate test pits to examine subsurface soils, but states that subsurface soils at the site are projected to be either cohesive or coarse grained, and therefore not susceptible to liquefaction. I agree that residual soils on the Tertiary Norwood Tuff are cohesive, that Pleistocene glacial-till and alluvial-terrace deposits and residual soils on Proterozoic quartzitic bedrock are coarse grained, and that areas underlain by these materials will not be subject to a liquefaction hazard. However, although AGRA (1997) describes abundant cobbles in surficial exposures of alluvial flood-plain deposits, these deposits may have interbedded, well-graded sands and silts beneath the ground surface that may be subject to liquefaction when saturated. The flood plain will likely experience periods of shallow ground water, which will contribute both to the liquefaction hazard and to the potential for basement flooding and foundation damage. Because of the hazards posed by liquefaction and shallow ground water, construction within the flood plain would require further study and likely require special foundation design. However, AGRA (1997) recommends that habitable structures and septic-tank soil-absorption systems not be placed within the flood plain due to the threat of surface flooding, and I concur. If this recommendation is followed, additional study is not needed.

AGRA (1997) correctly states that the potential for elevated levels of indoor radon ranges from moderate in the northeast portion of the site to high in the southwest portion of the site. I agree with AGRA's recommendation to disclose the indoor-radon-hazard potential to prospective property buyers. However, I further recommend that radon-resistant construction techniques be incorporated in new-home construction, particularly within the high-hazard area. Preventing radon from entering a structure is an effective method of hazard reduction, but restricting radon entry is difficult in existing homes. Features can also be incorporated during construction that facilitate radon removal after home completion, and such features are less expensive to incorporate during, rather than after, home construction. Radon-resistant construction techniques are described by Clarkin and Brennan (1991).

In conclusion, I agree with the recommendation of AGRA (1997) that habitable structures and septic-tank soil-absorption systems not be placed within the flood plain because of the threat of surface flooding, and also encourage adherance to this recommendation because of the potential for liquefaction and shallow ground-water hazards within the same area. I also agree with the recommendation of AGRA (1997) to disclose the indoor-radon-hazard potential to prospective property buyers, and further recommend that radon-resistant construction techniques be incorporated in new-home construction, particularly within the high-hazard area. AGRA (1997) also recommends that geotechnical studies be conducted where site-development plans call for substantial earthwork modifications of site slopes. I agree, and recommend that such studies consider the cumulative effects of development in the area, including the wetting of soils caused by effluent from septic-system drain fields and lawn watering, on ground-water levels and slope stability. Also, if cuts and fills greater than 5 feet high are planned, either standard Uniform Building Code recommendations or other specific engineering-design recommendations will be required.

REFERENCES

AGRA Earth and Environmental, Inc., 1997, Engineering geology reconnaissance and evaluation - proposed Emerson Hills subdivision, North Fork Ogden River, Ogden Valley, Town of Liberty, Weber County, Utah: Salt Lake City, unpublished consultant's report, 10 p.

Clarkin, Mike, and Brennan, Terry, 1991, Radon-resistant construction techniques for new residential construction: U.S. Environmental Protection Agency, Office of Research and Development, EPA/625/2-91/032, 43 p.

Project:			Requesting Agency:
Review of "Draft report--Geotechnical evaluation, lot 146 of Interlaken Development, Heber City, Wasatch County, Utah"			Wasatch County
By: Bill D. Black and Francis X. Ashland	Date: 10-20-97	County: Wasatch	Job No: 97-23 (R-16)
USGS Quadrangle: Heber City (1168)		Number of attachments: None	

This report is a review of a draft geotechnical report (Dames & Moore, 1997) for lot 146 of Interlaken Development (SE1/4 section 22, T. 3 S., R. 4 E., Salt Lake Base Line and Meridian) in Heber City, Wasatch County, Utah. Anthony Kohler (Planner, Wasatch County Planning) requested the review. The purpose of this review is to assess whether Dames & Moore (1997) adequately identified and addressed geologic hazards that could potentially affect the lot. The scope of work consisted of a literature review and examination of 1:48,000-scale aerial photos (1987). No site visit was made.

LANDSLIDING

Dames & Moore (1997) indicates the area around the property is mapped as having a moderate landslide potential by Hylland and Lowe (1995), but they observed no evidence of slope instability at the property during their field reconnaissance. Dames & Moore (1997) also performed quantitative slope-stability analyses for their evaluation, and based on their results, believe the landslide hazard for the property is low. Because the house will be founded on bedrock, Dames & Moore (1997) quantitatively assessed the likelihood of circular failures in rock. They concluded that this type of landsliding seems unlikely, and we concur. However, we believe the most likely failure mode for the subsurface conditions described at this site (thin topsoil, colluvium, and weathered rock overlying Paleozoic rock on steep slopes) is shallow debris sliding of the slope soils and weathered rock along the rock interface. Hylland and Lowe (1995) show a slide of this type in the slope roughly 300 feet (90 m) south of the property. This slide is also visible on 1987 aerial photos.

The potential for such shallow debris sliding can be assessed using infinite-slope analysis. Our preliminary assessment of the stability at lot 146, using the friction angle estimated by Dames & Moore (1997), indicates the factor of safety for shallow slides on steeper parts of the slope can be as low as 1.1 under dry conditions. We also used PCSTABL5M software to analyze the potential for shallow slides and obtained similar results. These results are not necessarily conservative because they are for dry conditions only. Seasonal infiltration from snowmelt or rainstorms, in addition to drainage or irrigation, could reduce stability. Although a shallow failure should not impact the home because it is near the top of the slope and the foundation is in bedrock, such landsliding could impact structures and roads directly downslope. Because of this, we recommend that drainage at the homesite be carefully controlled so that the slope below the home is not artificially wetted. Even with such drainage control, construction downslope from lot 146 may be subject to a hazard from a slope failure on lot 146, including deposition of debris on properties at the toe of the slope. Wasatch County must take this into consideration when evaluating development either on the lower part of lot 146 or downslope from the lot.

OTHER HAZARDS

Dames & Moore (1997) identifies earthquake ground shaking as a potential hazard at the property. To reduce the risk from ground shaking, Dames & Moore (1997) recommends that all buildings be designed and constructed to meet Uniform Building Code (UBC) seismic zone 3 criteria. This recommendation meets minimum UBC requirements adopted by state and local governments for reducing ground-shaking hazards. Regarding surface fault rupture, Dames & Moore (1997) indicates no active faults have been mapped at the property and they observed no evidence for active faulting in their field reconnaissance. Based on these data, Dames & Moore (1997) believes the risk from surface faulting is low and we concur. Dames & Moore (1997) believes the risk from liquefaction is also low, based on the shallow thickness of surficial sediments at the site and lack of ground water. We also concur with this assessment.

Dames & Moore (1997) observed no evidence of fallen rock clasts at the property, or large, loose boulders perched above the planned building area, and therefore they believe the hazard from rock fall is low. Dames & Moore (1997) also indicates that no major alluvial fans or large drainage channels are present at the property, and they observed no evidence of debris-flow deposits during their field reconnaissance. Given the absence of large drainage channels and alluvial deposits, Dames & Moore (1997) believes the hazard from debris flows and flooding is also low. We concur with both assessments.

REFERENCES

Dames & Moore, 1997, Draft report--Geotechnical evaluation for lot 146 of Interlaken Development, Heber City, Wasatch County, Utah: Salt Lake City, unpublished consultant's report, 12 p.

Hylland, M.D., and Lowe, Mike, 1995, Landslide hazard plate 1A, Engineering geologic map folio, western Wasatch County, Utah: Utah Geological Survey Open-File Report 318, scale 1:24,000.

Project: Review of "Analysis of UDOT inclinometer data, Hoover slide area, U.S.-189 near Canyon Meadows residential development, upper Provo Canyon, Wasatch County, Utah"			Requesting Agency: Wasatch County Planning Department
By: Barry J. Solomon	Date: 12-4-97	County: Wasatch	Job No: 97-26 (R-17)
USGS Quadrangle: Aspen Grove (1128)		Number of attachments: None	

At the request of Robert Mathis, Wasatch County Planner, I reviewed a report (AGRA Earth and Environmental, 1997) analyzing inclinometer data recorded from borings in the vicinity of the Hoover landslide (SW1/4 section 7, T. 5 S., R. 4 E., Salt Lake Base Line and Meridian), Wasatch County, Utah. I received the report on October 27, 1997. The inclinometer data were collected by the Utah Department of Transportation (UDOT) on and adjacent to a section of Utah Highway 189, near the Canyon Meadows subdivision, to evaluate the stability of the existing roadway and alternative alignments for highway reconstruction. AGRA Earth and Environmental (1997) analyzed the data to evaluate possible causes of active landsliding adjacent to the highway at the toe of the Hoover landslide, and to look for evidence of movement in the main body of the Hoover landslide beneath the subdivision northwest of the toe. The purpose of my review was to evaluate the conclusions of the report and comment on their implications.

AGRA Earth and Environmental (1997) analyzes data from 19 inclinometers. The report divides the movement measured by the inclinometers into two classes: (1) discrete movement, characterized by relatively large-scale, unidirectional displacement in the upper parts of the borings and negligible displacement below; and (2) dispersed movement, characterized by relatively small-scale, multidirectional displacement that gradually decreases in magnitude from the top to the bottom of the borings. Maximum discrete movement ranges from 0.30 to 3.90 inches with most movements greater than 1.25 inches. Maximum dispersed movement ranges from 0.05 to 1.85 inches with most movements less than 0.75 inches. The time over which this movement occurred ranges from 9 to 50 months. The inclinometers showing discrete movement are all located along Highway 189; AGRA Earth and Environmental (1997) reports observations of ruptured and displaced soils and pavement on the highway surface and in adjacent downslope embankments. Most of the inclinometers showing dispersed movement are located upslope of Highway 189; AGRA Earth and Environmental (1997) reports an absence of ruptures and surface evidence of displacement upslope of the highway.

AGRA Earth and Environmental (1997) concludes that the magnitude and distribution of discrete movement indicates landslide displacement along the highway, primarily in embankment fill, native soil loaded by fill, and soil undercut by highway earthwork, and that these slope movements are directly related to earthwork for Highway 189. AGRA Earth and Environmental (1997) also concludes that the magnitude and distribution of dispersed movement does not indicate landslide displacement in the area upslope of the highway beneath the Canyon Meadows development. The report considers the magnitude of dispersed movement to be within the range of instrumental measurement error and possibly influenced by surface processes, including disturbance by people, and considers the multidirectional characteristic of the dispersed movement to be random. AGRA Earth and Environmental (1997) states that the magnitude and direction of the measured dispersed movement is inconsistent with slope movement.

I agree with the interpretation of AGRA Earth and Environmental (1997) that discrete movement indicates landslide displacement along Highway 189, most likely induced by road construction. The distinct depth-related change in magnitude of displacement and the unidirectional trend of displacement over time indicate discrete movement at the intersection of a local shear zone or failure plane with the inclinometer casing. However, I do not believe that the dispersed movement measured by other inclinometers in the vicinity of Canyon Meadows is necessarily inconsistent with downslope movement. The AGRA Earth and Environmental (1997) report attributes the dispersed movement to instrument error, but the report does not quantify the magnitude of error inherent in inclinometers. Mikkelsen (1996) states that probe inclinometers, the type used by UDOT, can measure changes in inclination on the order of 1.3 to 2.5 mm (0.05-0.1 inches) over a 33 m (110 ft) length of casing, resulting in a precision of about 1:10,000. Most dispersed movements reported by AGRA Earth and Environmental (1997) significantly exceeded this measurement precision, indicating that instrument error may not be an important factor affecting the measurement of dispersed movement. The report also states that the direction of dispersed movement is random, possibly indicating disturbance by people, but five of the six inclinometers exhibiting dispersed movement above the highway show a consistent cumulative direction of movement downslope to the southeast, with the sixth moving downslope to the northeast. The most recent measurements of these six inclinometers in May, 1997, exhibit a distinct reversal of movement direction, with three of the instruments deflected upslope toward the northwest and two upslope toward the northeast. This reversal may indicate internal adjustments within a moving slide mass, including localized rotation of the slide mass and subsequent backtilting of the inclinometers. The failure plane beneath Canyon Meadows is likely below the base of the inclinometer casings, resulting in dispersed, rather than discrete, movement.

AGRA Earth and Environmental (1997) concludes that the movement occurring in the Hoover landslide vicinity is restricted to the area along and adjacent to Highway 189. I agree that movement is occurring there, but also believe that the inclinometer data do not preclude the possibility that movement may extend farther upslope to the Canyon Meadows area. I recommend that additional slope monitoring be conducted in the Canyon Meadows area as part of a detailed geotechnical-engineering study to evaluate the overall stability of the landslide. To definitively evaluate whether the landslide is moving in the Canyon Meadows area, an inclinometer that penetrates the basal slide plane and/or repeated surveying of fixed points at the surface are needed. Even if the landslide is not found to be moving, a detailed geotechnical-engineering analysis of the stability of the landslide is still necessary. The geologic setting and history of the landslide suggest that the potential consequences of slope failure are too serious for development to proceed without proper precaution.

REFERENCES

AGRA Earth and Environmental, 1997, Analysis of UDOT inclinometer data, Hoover slide area, U.S.-189 near Canyon Meadows residential development, upper Provo Canyon, Wasatch County, Utah: Salt Lake City, unpubished consultant's report, 13 p.

Mikkelsen, P.E., 1996, Field instrumentation, *in* Turner, A.K., and Schuster, R.L., editors, Landslides - investigation and mitigation: National Research Council, Transportation Research Board Special Report 247, p. 278-316.

APPENDIX

1997 Publications of the Applied Geology Program

Map

Harty, K.M., Mulvey, W.E., and Machette, M.N., 1997, Surficial geologic map of the Nephi segment of the Wasatch fault zone, eastern Juab County, Utah: Utah Geological Survey M-170, 14 p., 1 pl., 1:50,000.

Public Information Series

Ashland, F.X., and Hylland, M.D., 1997, Stability of the Pine Ridge landslide at Timber Lakes Estates, Wasatch County, Utah: implications for future development and land-use planning: Utah Geological Survey Public Information Series PI-53, 4 p.

Reports of Investigation

Ashland, F.X., 1997, Reconnaissance of the Shurtz Lake landslide, Utah County, Utah: Utah Geological Survey Report of Investigation 234, 22 p.

Ashland, F.X., and Hylland, M.D., 1997, Preliminary geotechnical-engineering slope-stability investigation of the Pine Ridge landslide, Timber Lakes Estates, Wasatch County, Utah: Utah Geological Survey Report of Investigation 232, 29 p.

Lund, W.R., 1997, Report to the Utah Geological Survey on the 1996 Gobi-Altay, Mongolia, paleoseismology expedition: Utah Geological Survey Report of Investigation 233, 14 p. plus appendix.

Mayes, B.H., compiler, 1997, Technical reports for 1996, Applied Geology Program: Utah Geological Survey Report of Investigation 231, 183 p.

Survey Notes

Ashland, F.X., 1997, New strong-motion instruments will monitor earthquake ground shaking in Utah: Survey Notes, v. 29, no. 2, p. 4-5.

Ashland, F.X., 1997, Utah's newest big landslide: Survey Notes, v. 30, no. 1, p. 7.

Christenson, G.E., 1997, Massive erosion near Vernal: Survey Notes, v. 30, no. 1, p. 8.

Hylland, M.D., 1997, Hazard assessment of the Farmington landslide complex, Davis County, Utah: Survey Notes, v. 29, no. 2, p. 1-2.

Solomon, B.J., 1997, Mapping the West Cache fault zone: Survey Notes, v. 29, no. 2, p. 4-5.

Fault Line Forum

Carver, D., Jungblut, W., Porcella, R., Christenson, G., Ashland F., and Pechmann, J., 1997, NSMP researchers install strong-motion recorders: Fault Line Forum, v. 13, no. 1, p. 10, 11.

Jarva, J.L., 1997, Utah Seismic Safety Commission news, Arabasz elected chairman of USSC; licensing of plans examiners proposed: Fault Line Forum, v. 13, no. 2, p. 3, 4.

-----1997, Utah Seismic Safety Commission news, School officials address USSC; Arabasz calls for dialogue: Fault Line Forum, v. 13, no. 1, p. 6 +.

-----1997, Utah Seismic Safety Commission news, State seismic safety commissions can be insurance industry partners in promoting risk reduction: Fault Line Forum, v. 13, no. 1, p. 2, 3.

Mayes, B.H., 1997, Individuals, industry, local governments lead efforts in Utah earthquake safety: Fault Line Forum, v. 12, no. 4, p. 1-3.

-----1997, Strong-motion instrument goes to new site in Tremonton City: Fault Line Forum, v. 13, no. 2, p. 9.

-----1997, Utah Seismic Safety Commission Conference 97 highlights, earthquakes: mean business: Fault Line Forum, v. 13, no. 1, p. 1, 4 +.

Mayes, B.H., editor, 1997, Fault Line Forum v. 12, no. 4
v. 13, no. 1
v. 13, no. 2
v. 13, no. 3