TECHNICAL REPORTS FOR 1990 - 1991
APPLIED GEOLOGY PROGRAM

compiled by

BEA H. MAYES

Utah Geological Survey

REPORT OF INVESTIGATION 222 **JULY 1992**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

UTAH GEOLOGICAL SURVEY
2363 South Foothill Drive
Salt Lake City, Utah 84109-1491

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PREFACE

The Applied Geology Program is a part of the Utah Geological Survey (UGS). The program maps and defines geologic hazards in the state and provides assistance to tax-supported entities (cities, towns, counties, state agencies, and school districts) on matters of engineering-geologic concern. In these reports, the program places emphasis on site geologic evaluations of critical public facilities such as police and fire stations, water tanks, water treatment plants, solid waste disposal sites, and schools. The program also conducts investigations to answer specific geologic or hydrologic questions from state and local government agencies, such as evaluations of protection zones required for culinary springs, investigations of slope stability, evaluation of soil problems in developing areas, and the potential dangers of debris flows, water seeps, rock falls, earth slumps, dam-related construction, and seismic (earthquake-related) ground motion. The Applied Geology Program also conducts more detailed studies to meet specific needs on a cost-sharing basis. In addition to conducting engineering-geologic studies, the program reviews and comments on technical reports submitted by consultants to state and local government agencies, such as those dealing with evaluations of sites for disposal of radioactive materials.

Information dissemination is a major goal of the UGS. The Applied Geology Program publishes studies of interest to the general public in several UGS formats. The program commonly presents projects that address specific problems of interest to a limited audience in a technical report format, which we distribute on a need-to-know basis. The Applied Geology Program maintains copies of these reports and makes them available for inspection, upon request.

This Report of Investigation presents, in a single document, the Applied Geology Program's 31 technical reports given limited distribution during 1990 and 1991 (figure 1). It groups the reports by topic, and each report names the author(s) and requesting agency. Minor editing has been performed for clarity and conformity, but I have made no attempt to upgrade the original graphics, most of which were produced on a copy machine. This seventh compilation of Applied Geology Program investigations provides wide access to the program's geologic evaluations.

Bea H. Mayes
April 6, 1992

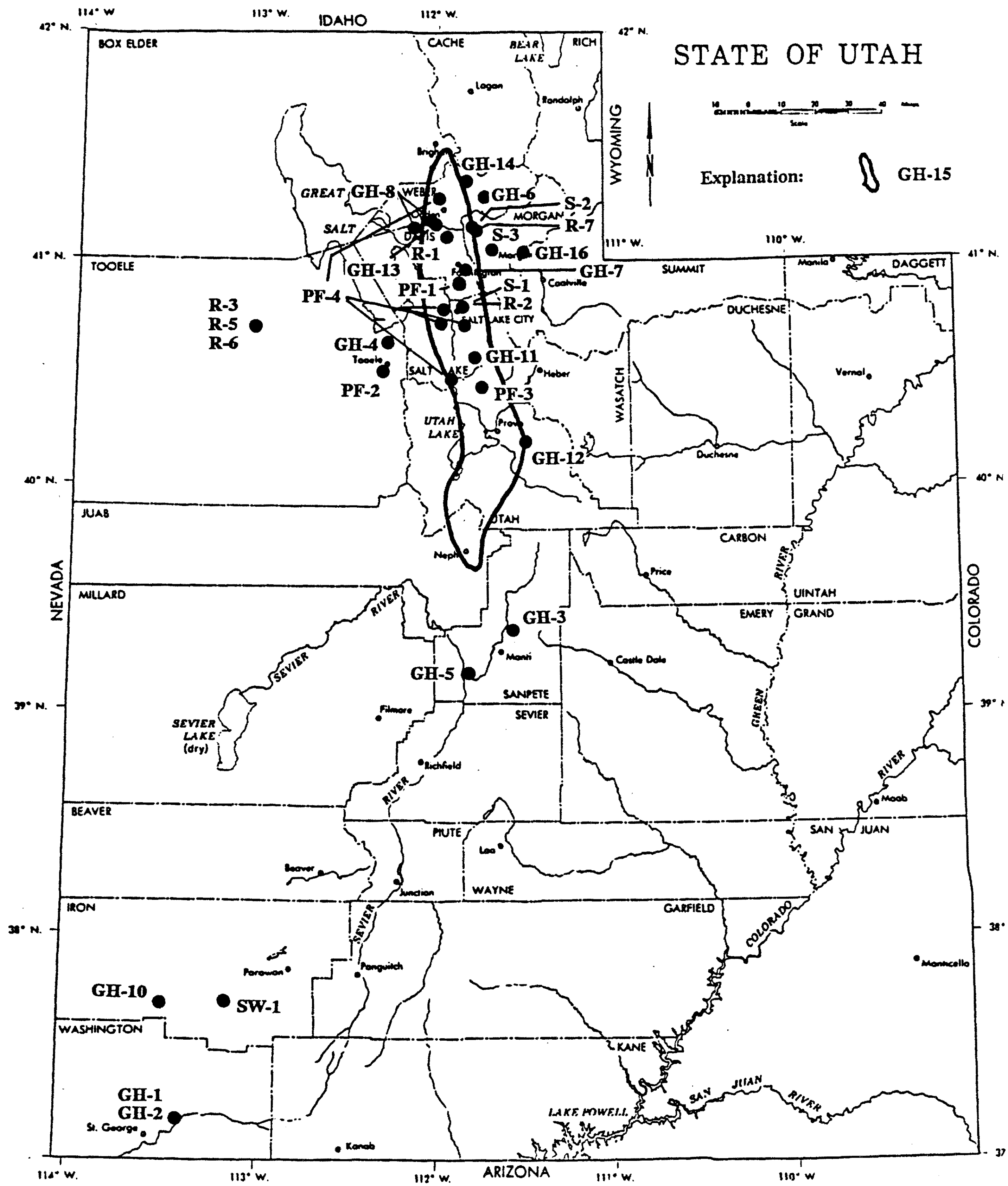

Figure 1. Location map. The scope of GH-9 and R-4 is statewide.

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Geologic Hazards (continued)

Geologic Hazards (continued)

Illustration

PUBLIC FACILITIES

Project: Preliminary Geologic Hazards Assessment of the Public Works Building Site and the Proposed City Hall/Police Station Site, City of Centerville, Davis County, Utah.			Requesting Agency: City of Centerville
By: Kimm M. Harty	Date: March 27, 1990	County: Davis	Job No.: 90-05 (PF-1)
USGS Quadrangle: Farmington (1295)			

INTRODUCTION AND SCOPE OF WORK

In response to a request from David A. Hales, City Administrator for the City of Centerville, the Utah Geological and Mineral Survey (UGMS) performed a preliminary geologic hazards assessment for a new public works building site and a proposed city hall/police station site. According to Mr. Hales, the public works building will be located at 1250 West, 750 North Street (fig. 1). Construction is to begin immediately, and the structure will be built in accordance with Uniform Building Code (UBC) seismic zone 4 specifications. Mr. Hales indicated the City Hall/Police Station will probably be built at 244 North Main Street (fig. 1). The scope of work consisted of a review of pertinent literature, including a geotechnical report on the public works building site (Northern Engineering and Testing, Inc., 1990), and a review of hydrologic and geologic hazards maps. No field work was undertaken for this project.

PUBLIC WORKS BUILDING

Flood hazards

The 1:24,000 scale topographic map indicates the site is at an elevation of approximately 4210 feet or less, which is several feet below the historical high level of Great Salt Lake. The geotechnical report by Northern Engineering and Testing, Inc. (1990) mentions a decision by Centerville City to bring in structural fill to raise the elevation of the site of the public works building for protection against fluctuating levels of Great Salt Lake. However, raising the site by three feet, as indicated in the report, may be inadequate. Raising the site by three feet would place the site only one foot or less above the 1986 historic high level of Great Salt Lake (almost 4212 feet). The UGMS generally advises against construction below 4217 feet, an elevation that represents the historic high lake level plus an additional five feet for wave action. An elevation of 4218 feet is the level adopted by Weber County as a "Beneficial Development Area" (BDA), below which development is restricted, and no development is permitted below 4215 feet in this county. Although the West Desert Pumping Project is designed to alleviate flooding of land surrounding Great Salt Lake, a rapid rise in the level of the lake, such as that realized during the early 1980s, could

Base map for USGS 7½ minute quadrangles, Farmington and Bountiful Peak.

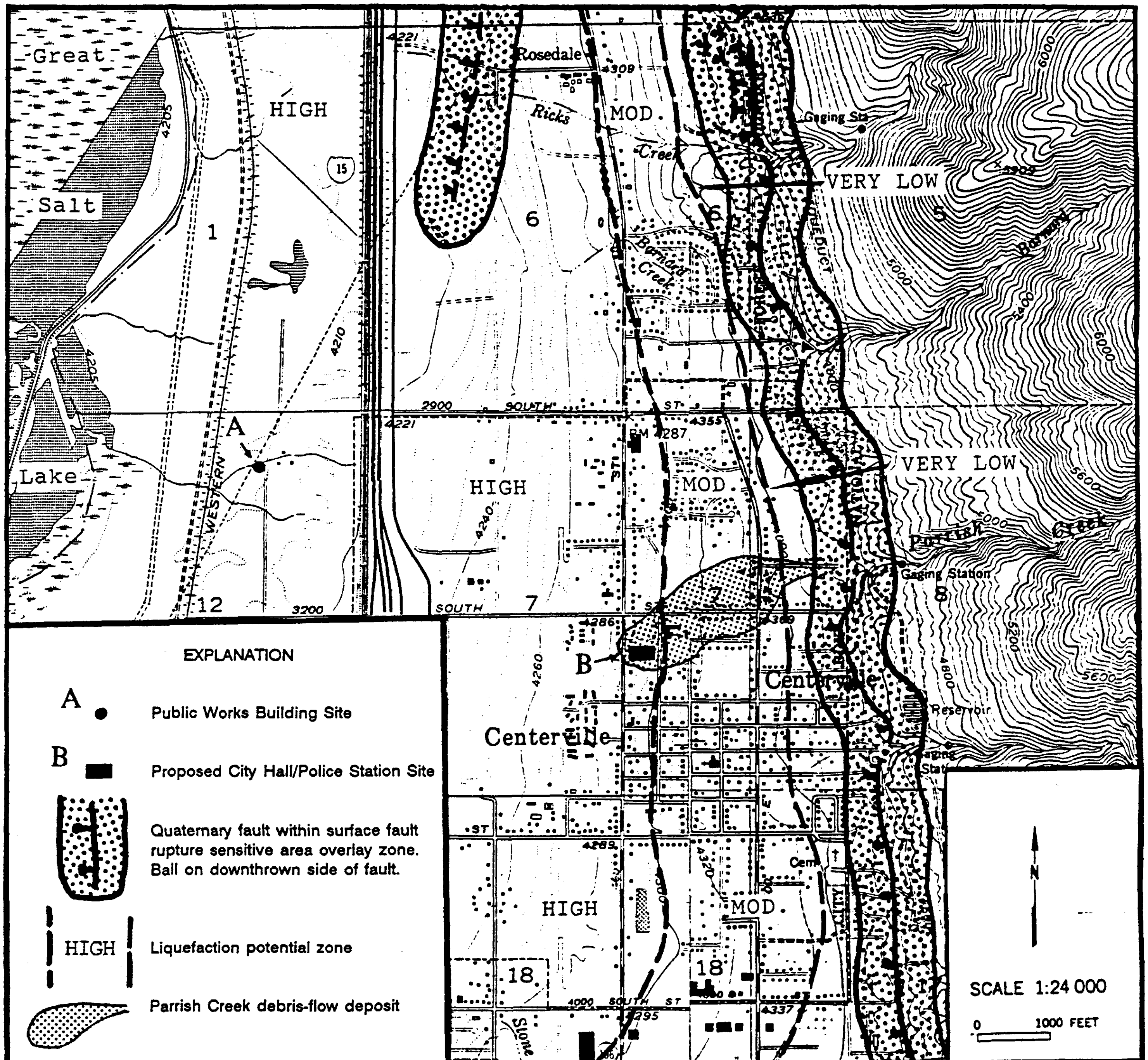

Figure 1. Topographic map of Centerville area showing building sites and various geologic hazards (after Anderson and others, 1982; Lowe, 1989a, b, c; Nelson and Personius, 1990).

PROPOSED CITY HALL/POLICE STATION SITE

Flood and Landslide Hazards

The proposed city hall/police station site is in flood-hazard zone B as depicted on flood insurance rate maps of Centerville (Federal Emergency Management Agency, 1982) (fig. 2). This zone represents the 500-year flood boundary of Parrish Creek. In addition, geologic hazards maps of Davis County indicate that the site is in a debris-flow hazard special study zone (Lowe, 1989b) (fig. 1). Specifically, the site is on the distal portion of the debris-flow deposit that flowed from Parrish Canyon in 1930. Neither of these maps considers the effects of a debris basin built in 1983 on Parrish Creek in reducing these hazards. Parrish Canyon currently has a debris basin at its mouth with a holding capacity of 40,000 cubic yards. It is estimated that approximately 508,000 cubic yards of material exited Parrish Canyon during a 1930 debris flow/flood (Williams and others, 1988), and there are varying opinions as to whether the debris basin is of sufficient size to handle future debris flows. If this site is chosen for construction of the building, it would be wise to contact Davis County Flood Control to discuss debris-flow and flood hazards and the adequacy of the Parrish Canyon debris basin.

Earthquake Hazards

The closest active fault is the Wasatch fault, about 1/2 mile east of the proposed site (fig. 1). The site is outside the surface-fault rupture sensitive area overlay zone outlined by Lowe (1989a, 1989c). However, as with the public works building, the city hall/police station must be constructed at least in accordance with standards for UBC seismic zone 3, and because it is an essential facility for emergency response, we recommend that zone 4 standards be followed for this building as well.

The proposed site is in a high liquefaction potential zone (Anderson and others, 1982), very close to the gradational border of the moderate hazard zone (fig. 1). To better assess the liquefaction potential at the site, a thorough soils foundation investigation by a qualified geotechnical firm should be performed prior to construction.

Problem Soils

The proposed site may be in an area of collapsible soils subject to hydrocompaction. Recent debris-flow deposits may contain numerous void spaces created upon rapid deposition and drying. These deposits generally consolidate with subsequent wetting over time, but this may take hundreds or thousands of years to occur naturally. Lawn watering or other water application activities can initiate this process, resulting in land subsidence. The soils foundation report should assess the potential for hydrocompaction of soils at the site.

exceed the ability of the pumps to counteract potential flooding.

Earthquake Hazards

The public works building site is not in a surface fault rupture zone as outlined by Lowe (1989a), and the closest active fault is about 3/4 of a mile northeast of the site (Lowe, 1989a) (fig. 1). However, all cities along the Wasatch Front are at risk from strong earthquake ground shaking, and the decision to construct the public works building in accordance with UBC seismic zone 4 specifications is a prudent one.

Other than by natural, climate-induced means, another mechanism of potential flooding from Great Salt Lake is by tectonic subsidence. Regional subsidence of the land surface can occur during large magnitude surface-faulting earthquakes. Such an earthquake on the Wasatch fault in this area could result in a drop in the land surface of 0-5 feet at this site (Keaton, 1987). This could cause rapid, permanent flooding at the site, the extent of which depends on the level of the lake at the time of the earthquake. Regional ground subsidence extending 10 and 11 miles from ruptured faults is known to have occurred during the 1959 Hebgen Lake, Montana and 1983 Borah Peak, Idaho earthquakes, respectively (Myers and Hamilton, 1964; Stein and Barientos, 1985). Earthquakes which may cause such subsidence at this locality occur on the average once every few thousand years, so there is a low probability that one will occur during the design life of the building. However, if it does occur, it is possible the site will be flooded.

The public works building is in a zone of high liquefaction potential (Anderson and others, 1982) (fig. 1). Soil liquefaction is a process in which sandy soils lose strength and behave like a liquid during earthquake ground shaking. Buildings constructed on these soils can sustain damage as the soils lose their ability to adequately support the structure. Areas that are most susceptible to soil liquefaction during earthquakes are those in which sandy soil layers and ground water are present within about 30 feet of the ground surface. Soil boring logs in the geotechnical report (Northern Engineering and Testing, Inc., 1990) indicate the presence of both of these conditions at the site. Liquefaction potential and possible remediation measures should be addressed as part of the soils foundation investigation.

Problem Soils

The geotechnical report (Northern Engineering and Testing, Inc., 1990) appears to adequately address other potential soil problems, such as removal of organic materials from the site. Organic-rich peat deposits are present in some areas surrounding Great Salt Lake, and they are usually unsuitable as foundation soils.

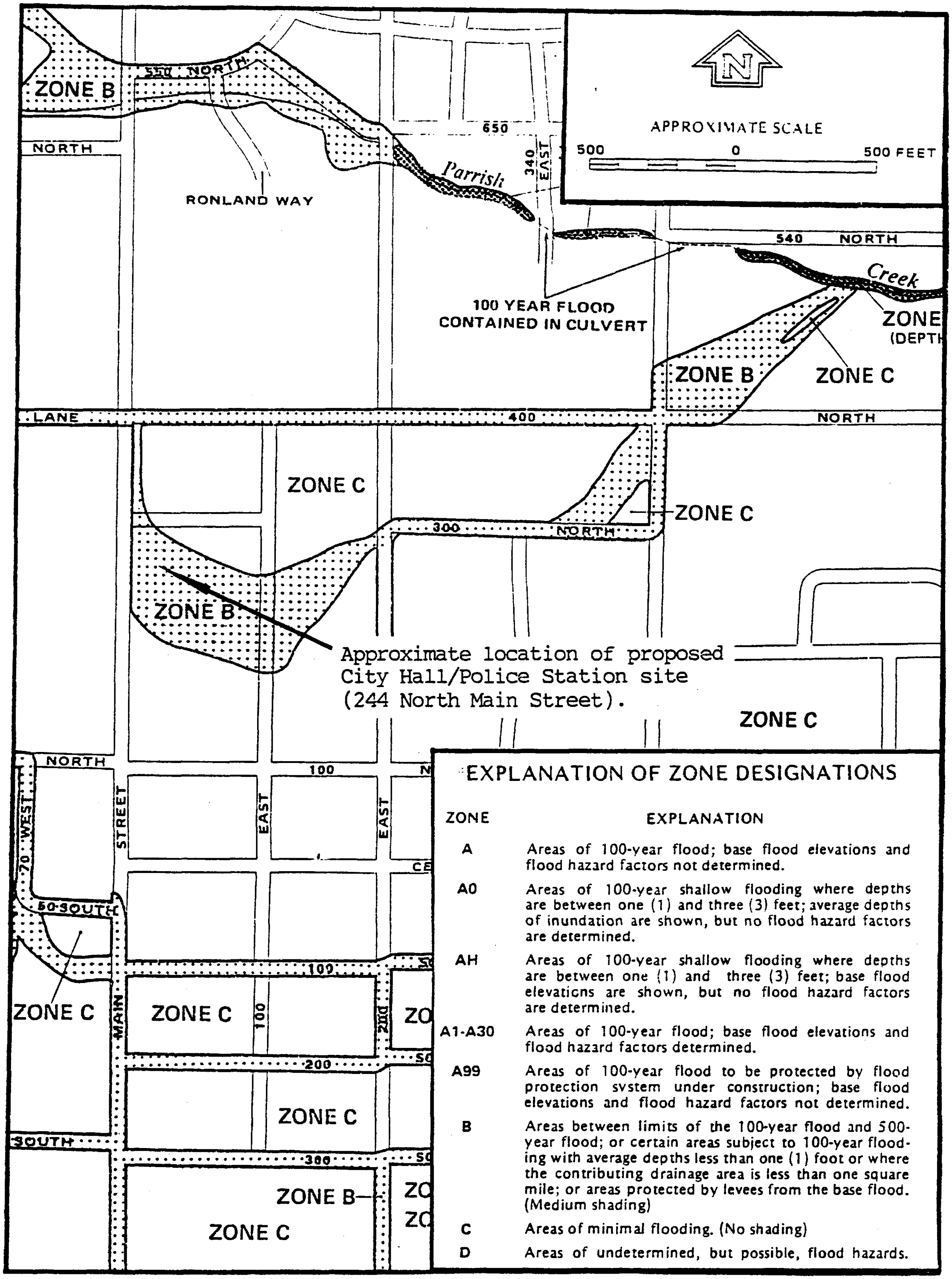

Figure 2. Flood insurance rate map for area near proposed City Hall/Police Station Site (modified from Federal Emergency Management Agency, 1982).

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Williams, S.R., Lowe, Mike, and Smith, S.W., 1989, The discrete debris-mud flow risk analysis method: Proceedings of the 1988 Conference of the Arid West Committee of the Association of State Floodplain Managers, Las Vegas, Nevada, October 19-21, 1988, p. 157-167.

Project:		Requesting Agency:	
Inspection of proposed site for gasoline storage and pumping station, Tooele County, Utah		Tooele County Dept. of Development Services	
By: Barry J. Solomon	Date: 3-26-90	County: Tooele	Job No.: (PF-2) 90-06
USGS Quadrangle: Tooele (1175)			

In response to a request from Rod Thompson, Manager, Engineering and Compliance Division, Tooele County Department of Development Services, an inspection was conducted of a proposed gasoline storage and pumping station site in the city of Tooele. The site will be used for the storage of motor vehicle fuel, and for the refueling of city, county, and school district motor vehicles.

The proposed facility lies in the southwestern corner of the city of Tooele, at the southwest corner of the intersection of State Route 36 and 900 South Street (attachment 1). The site is adjacent to a County maintenance yard on the west, an abandoned sand and gravel pit on the north, and vacant land along the Oquirrh Mountains range front to the south and east. The site was once quarried for gravel but is now abandoned, and the borrow pit has been partially filled with discarded construction material, soil, and refuse.

The geology of the proposed site has been mapped by Tooker (1980) and Solomon (in prep.). Gravel removed from the site was Quaternary-age Lake Bonneville beach deposits near the Bonneville shoreline. Small alluvial fans occur at the mouths of ephemeral drainages to the south and east, but they do not extend beneath Route 36 or encroach upon the proposed site. The mouth of Settlement Canyon lies about 2,000 ft northeast of the site, but debris and alluvium from the canyon is transported to the north and northwest away from the site; the mouth of the canyon is incised into the beach ridge on which the site is located, and the site is about 15 ft above the channel bottom. Ground water occurs under water-table conditions in the unconsolidated valley fill (Razem and Steiger, 1981), and depth to ground water is in excess of 175 ft at the proposed site. Recharge to this aquifer is from precipitation that falls directly on it, seepage from stream channels that cross it, seepage from irrigation and mine discharge, and subsurface flow from adjacent consolidated rocks. Lateral movement of water from the water-table aquifer contributes to recharge of artesian aquifers towards the center of the valley.

The proposed site lies within 500 ft of the Oquirrh Mountains range front. These mountains were uplifted by tectonic processes which continue to the present day. No known fault rupture of surficial material is present near Settlement Canyon, although the site does lie between two areas of suspected Quaternary faulting along the range front. The southern end of the Northern Oquirrh fault zone (Barnhard and Dodge, 1988) lies two miles north of the proposed site, and a suspected scarp on Quaternary unconsolidated sediments lies about five miles to the south near Stockton (Tooker and Roberts, 1988; Solomon, in prep.). The potential for surface rupture at the site during the life of the facility is minimal.

The principal geologic hazard at the site results from the material used to fill the abandoned gravel pits. Surface exposures and backhoe test pits excavated by the County show that the fill material is composed of poorly compacted soil and refuse. The refuse consists primarily of discarded construction material. Large fragments of concrete and asphalt up to two feet in diameter were observed, and a wooden timber several feet long was exposed in a test pit. Rags and metal fragments were also observed. Tests pits were up to 10-ft deep and did not intersect the bottom of the fill; observations in unfilled portions of adjacent pits suggest that the bottom of the fill is not much deeper, but an accurate depth cannot be determined without drilling or further trenching.

Fill material can pose three hazards to the proposed facility. First, a logistical problem is posed by the difficulty, and resultant expense, involved in the excavation of large blocks of concrete, asphalt, and other fragments in fill material. Second, and more importantly, the hummocky surface of the fill material suggests differential settlement of poorly compacted material; such settlement could pose a significant hazard to foundations of surface facilities. Differential settlement results from the long-term decomposition of organic material such as wood, from the low bearing strength of fresh material such as asphalt, and from the inability to compact soil around large clasts. Third, if fill is not totally excavated along routes of subsurface pipelines, settlement could result in damage to pipelines and storage tanks, spillage of fuel, and a resultant hazard of contamination or fire. Seepage of spilled fuel could recharge underlying aquifers and contaminate local water supplies.

The presence of artificial fill material at the site poses hazards to proposed facilities. To avoid potential settlement problems, the depth and distribution of the fill should be determined. Then, either remove the fill and place the facility on underlying native soil, or replace the fill with properly engineered fill. Contact Alex Pashley, Utah Department of Health, Bureau of Solid and Hazardous Waste (538-6170), to obtain information on the proper placement of underground storage tanks to minimize leakage and contamination of ground water.

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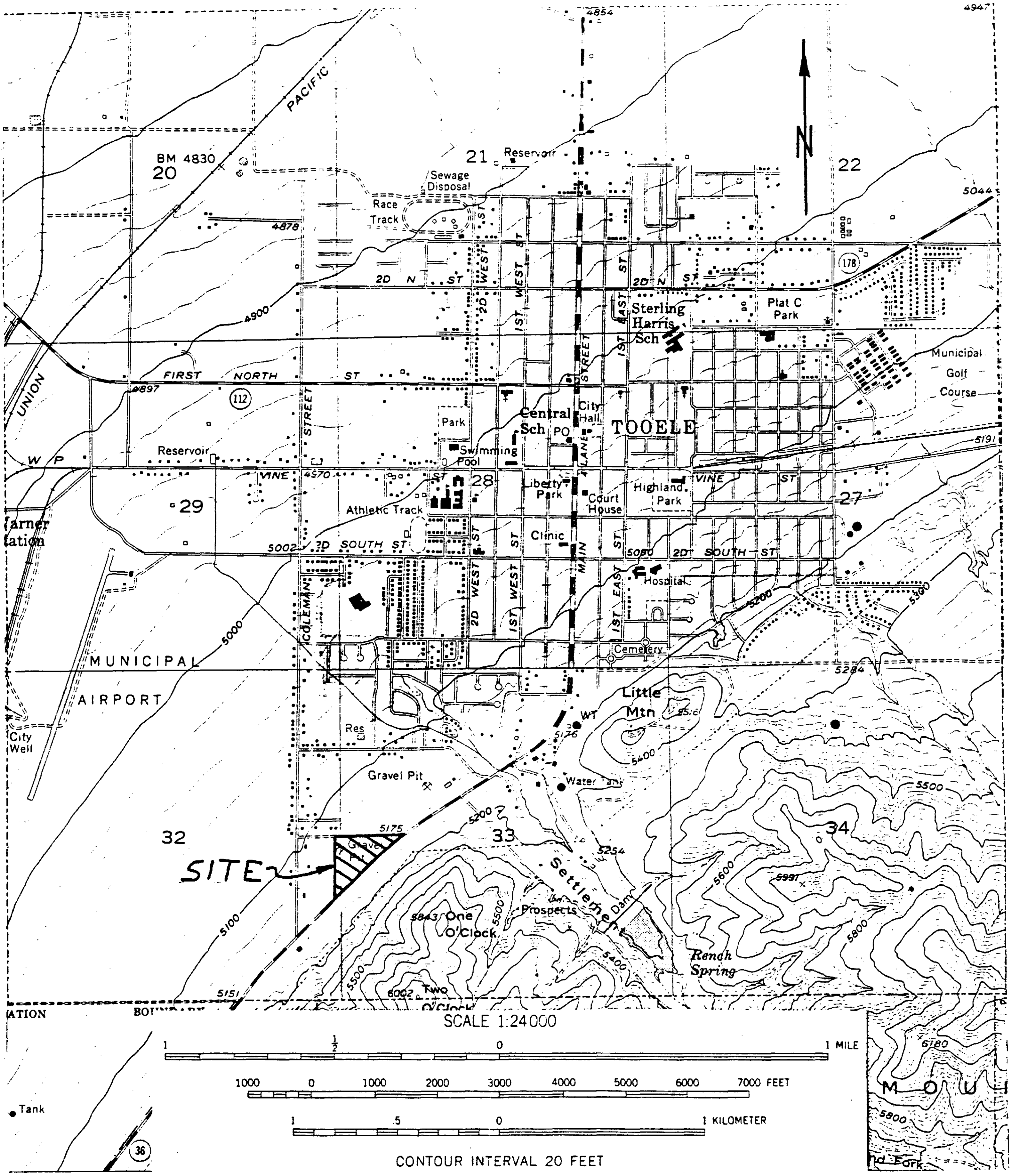

Attachment 1. Location of proposed site for gasoline storage and pumping station, Tooele, Tooele County, Utah.

Project: Geologic hazards investigation for a proposed Highland City office building site, Utah County, Utah			Requesting Agency: City of Highland
By: Susan Olig	Date: 3-12-90	County: Utah	Job No.: 90-07 (PF-3)
USGS Quadrangle: Lehi (1088)			

INTRODUCTION

This report presents the results of a geologic hazards investigation for the site of the new Highland City office building. It was requested by Jay Haws, Director of Operations, in a letter to the UGMS dated February 26, 1990. The site is at the northwest corner of the intersection of 10400 North and the Alpine Highway in Highland, Utah County. The purpose of the investigation was to identify potential geologic hazards at the site so that they could be considered by architects and engineers in site design and building construction. The scope of work included a review of existing literature, maps, and aerial photographs (scale ≈ 1:40,000), and a field inspection on March 5, 1990. No test pits were excavated and no laboratory soil tests were performed for this investigation, and it does not preclude the necessity for a standard soil investigation to provide engineering data for foundation design.

SETTING AND SITE DESCRIPTION

The city of Highland is in northern Utah County, north of American Fork and south of Alpine. The site in Highland is roughly two miles west-southwest of the mouth of American Fork Canyon (SW ¼, sec 36, T.4 S., R.1 E.; attachment 1). The topography is relatively flat with a regional slope between 1 and 2 percent (< 1 degree) to the southwest. The elevation at the north boundary of the site is 4885 feet, dropping to 4875 feet at it lowest point in the southeast corner. Fill that contains coarse rubble and debris has been placed in the southeast corner to raise the grade and attempt to level the site.

No buildings are present at the site except for the remains of a basement foundation for a small building (less than 2000 square feet) near the north boundary. Additionally, ditches follow the lot perimeter and a ditch runs north-south and roughly through the middle of the site. The ditches were dry at the time of inspection and are generally 2 feet wide and less than 2 feet deep. Ditches have culverts that cross under 10400 North and empty into a catch basin in a city park south of the street. Cottonwood trees that are 15 to 30 feet high are aligned along the ditches. Most of the ground surface is disturbed, with some patches of dried grass present.

GEOLOGY AND SOILS

Highland is located in northern Utah Valley, which is bounded on the north by the Traverse Mountains, on the east by the Wasatch Range, on the south by Utah Lake, and on the west by the Lake Mountains. Utah

Valley is a deep basin filled with unconsolidated sediments (Zoback, 1983). The upper layers of sediment are dominantly interbedded Quaternary-age alluvial and lacustrine (lake) deposits.

The site is roughly six miles from the northern edge of Utah Lake, a remnant of prehistoric (late Pleistocene) Lake Bonneville. It is on coarse-grained stream alluvium that was deposited below the Bonneville shoreline but above the uppermost Provo shoreline of Lake Bonneville (unit alp on attachment 2). This stream alluvium is dominantly reworked beach gravels of the Bonneville shoreline that were redeposited by the American Fork River on the fan-delta complex at the mouth of American Fork Canyon during the regression of Lake Bonneville to the Provo shoreline between 14,300 and 14,500 years ago (Machette, 1989). The present channel of the American Fork River is roughly 2000 feet to the east-southeast and is at an elevation more than 25 feet below the site. Younger post-Bonneville (Holocene to uppermost Pleistocene) deposits of this river (unit aly on attachment 2) are roughly 1000 feet east of the site.

Upper soil layers at the site range from silty sand to clayey sand with gravel. Much of the material is probably fill. Exposures in bluffs roughly 1000 feet to the east reveal that below this upper foot of soil lies silty to sandy gravel with cobbles and boulders, which extends at least 10 feet below the surface. The sediments are stratified, but overall are well-graded. Clasts are well-rounded and dominantly composed of quartzite or limestone.

These observations are consistent with the soil series mapped at the site by the Soil Conservation Service (SCS, 1972), which include Bingham gravelly loam and Sterling gravelly fine sandy loam. Both soils have a finer-grained topsoil (upper 1 to 2 feet), including gravelly sandy loam (SM; attachment 3) and gravelly sandy clay loam (SC), and an underlying coarser layer, including very gravelly sandy loam and sand (GW or GW-GM) and very gravelly sand (GP-GM or GM). Both soils are classified by the SCS (1972) as rapidly permeable, having a low shrink-swell potential, and imposing only slight limitations to foundations for low buildings.

Available information suggests that the depth to ground water is probably greater than 15 feet at the site, although the possibility of local perched ground water cannot be excluded without site-specific subsurface information. Hecker and others (1988) do not indicate shallow groundwater (less than 30 feet) at the site. No ponded water was observed at the surface during the field inspection. Depth to ground water was found to be greater than 50 feet in a boring located 2500 feet south of the site along the Alpine Highway at an elevation roughly 40 feet lower (Anderson and others, 1986). A spring occurs at the base of a bluff, 1200 feet to the east, at an elevation roughly 20 feet below the site.

GEOLOGIC HAZARDS

Attachment 4 is a summary checklist of geologic hazards for the site. All hazards that were considered are shown, and all those that are believed to exist at the site are discussed further below. Hazards which need to be considered in the soils foundation investigation for the site are also noted on attachment 4.

Earthquake Hazards

Utah Valley lies in the Intermountain seismic belt, a zone of shallow and diffuse seismicity that trends north-south through Utah (Smith and Sbar, 1974; Arabasz and others, 1987). Utah Valley is bounded on the east by the Provo segment of the Wasatch fault zone, a large normal fault that dips underneath the valley and is a source for large earthquakes. The main fault scarps are two miles east of the site (attachment 2) and geologic studies indicate that four large surface-faulting earthquakes (magnitude 7.0-7.5) have occurred along this portion of the fault in the last 8,000 years (Machette, 1989).

Machette (1989) also identified two short fault scarps northeast of the site that apparently offset latest Pleistocene (younger than 15,000 years) stream deposits (attachment 2). The west-facing scarp is roughly 4900 feet long and its south end is about 1950 feet from the site. A shorter (about 1300 feet long) east-facing scarp is over 2400 feet from the site. Both scarps strike south-southeast, away from the site. These smaller scarps are probably related to and formed during earthquakes on the Provo segment of the Wasatch fault zone.

Finally, there is a system of north-striking faults and folds underneath Utah Lake, which have had movement in the last 30,000 years (Hecker, in prep.). The north end of these structures is roughly 6 miles southwest of the site. Relatively little is known about the recent activity of these faults and folds and it is uncertain whether these structures are capable of independently generating earthquakes.

Ground Shaking

The greatest earthquake hazard present at the site is ground shaking resulting from either a moderate-sized earthquake, which could occur anywhere in the area, or from a large earthquake along a known fault, particularly the Provo or adjacent segments of the Wasatch fault zone. Seismic waves are generated at the earthquake source, travel through the earth, and cause ground shaking at the earth's surface. Ground shaking can cause damage or collapse of buildings not designed or constructed to resist the lateral forces of earthquakes. Three levels of design ground motions for the site are presented below, based on: 1) probable motions for the largest expected earthquake (most conservative option); 2) motions that have a low probability (10% chance) of being exceeded in 50 years; and, 3) the minimum design motions specified in the 1988 Uniform Building Code (UBC)(least conservative option):

1) Machette (1989) estimates that rupture of the Provo segment of the Wasatch fault would produce an earthquake of magnitude (M_s) 7.0 to 7.5 and this is a reasonable estimate for the largest expected earthquake near the site. Using Campbell's (1987) attenuation relation for ground motions in central Utah, an earthquake of this magnitude could produce peak horizontal ground accelerations between 0.4 and 0.8 g at the site (g is the acceleration of gravity, 32.2 ft/s^2). These large earthquakes are relatively infrequent, with an average recurrence interval of 2400 years (Machette, 1989).

2) Taking into account earthquakes from all possible sources in northern Utah, and their probability of occurrence, Youngs

and others (1987) estimated probabilistic values of ground accelerations for the Wasatch Front, including Utah Valley. For areas with firm sediments, such as the Highland site, they estimate peak horizontal ground accelerations that have a 10% chance of being exceeded in 50 years to be between 0.30 and 0.35 g. For areas underlain by rock they estimate peak accelerations between 0.36 and 0.42 g.

3) Seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed in each seismic zone. Highland is in seismic zone 3 of the 1988 UBC. Design and construction of the proposed city office building is required by state law to meet, as a minimum, the seismic design provisions specified for seismic zone 3 in this code.

These three options for design ground motions are presented because the proposed structure is a public building and UBC requirements for seismic zone 3 (option 3) may not be adequate to protect life safety in the event of a nearby large magnitude earthquake as specified in option 1. Although large events are rare, city officials should be aware of their possibility as the resulting ground shaking would be severe. Additionally, option 2 is based on a probabilistic evaluation of the hazard, which is similar to the basis for UBC requirements. However, the ground shaking values computed by Youngs and others (1987) suggest that the site should be classified in seismic zone 4 rather than in zone 3 as the 1988 UBC specifies.

<u>Tectonic subsidence</u>

Tectonic subsidence is the regional tilting of the earth's surface on the downthrown side of a fault during a large surface-faulting earthquake. It is a particular hazard to structures near lakes and in areas of shallow ground water because flooding may result. Keaton (1986) has modeled the tectonic subsidence that might be expected in Utah Valley for a large earthquake on the Provo segment of the Wasatch fault zone. The estimated subsidence at the Highland site is between 0 and 5 feet. Because the site is 400 feet above Utah Lake and is not in an area of shallow ground water, the potential for flooding due to tectonic subsidence is low. Although it is possible that tectonic subsidence may occur, its affect would be a regional drop of 0-5 feet of the site and surrounding area. The principal related hazard may be from local flooding due to a reduction in gradient in canals, sewers, or other gravity-flow structures.

<u>Other Earthquake Hazards</u>

Although there are active faults in the vicinity of the site, none are close enough to present a surface faulting hazard. The liquefaction potential at the site is very low because of the depth to ground water and the coarse sediments (Anderson and others, 1986). Similarly, it is unlikely that sensitive clays exist at the site.

<u>Slope Failure</u>

All slope failures, including earthquake-induced failures, have a low potential at the site because of the flat topography and the distance away from the Wasatch Range front. Bluffs along the American Fork River, 1000 feet to the east, are in relatively stable granular material and do not pose a hazard at the site. Also, studies mapping rock fall source areas (W. F. Case, UGMS, oral comm., March 8, 1990), landslides, and debris flows (Robison, 1988) in Utah County have not identified any of these hazards at the site.

Problem Soils and Subsidence

Differential settlement of non-engineered fill (uncompacted and unsorted fill containing oversized and possibly weak or degradable material) is the only potential hazard related to soils that was identified at the site. Coarse fill containing concrete blocks and probably other material has been placed at the site, particularly in the southeast corner. This material is probably not compacted and may be subject to differential settlement beneath a building if it is not properly compacted. The potential of all other problem soils or subsidence is low due to the types of sediments at the site, the flat topography, and the absence of any nearby mines. Owens and Rollins (in press) did not identify any collapsible soils at the site. Mulvey (in prep.) did not identify any occurrences of hydrocompaction, subsidence by dissolution or mine collapse, active dunes, or piping near the site.

Shallow Ground Water

All available evidence suggests that the regional water table is deep and the potential for shallow ground water at the site is low. However, localized shallow ground water may occur as a result of seepage from unlined ditches at the site, particularly if they carry water for any length of time.

Flooding

The potential of flooding at the site is low from all sources with the possible exception of the ditches. Although they were dry at the time of field inspection and some appeared to be abandoned, the culverts appear to be recently installed, suggesting that these ditches may carry water during some time of the year. The Flood Insurance Rate Map for the vicinity indicates that the site is above the 500-year flood boundary for the American Fork River and is in zone C, an area of minimal flooding (Federal Emergency Management Agency, 1982).

There are three small reservoirs with dams in American Fork Canyon: Silver Lake, Silver Lake Flat, and Tibble Fork Reservoir. All three of these dams are classified as high hazard by the U.S. Forest Service because they are upstream from populated areas (Harty and Christenson, 1988). A dam-failure inundation study estimates a flood level of 12 feet above the channel floor of the American Fork River for a point less than one mile upstream from the mouth of the canyon resulting from simultaneous failure of all three dams (W. Self, USFS, oral comm., March 3, 1990). Given the elevation of the Highland site, the distance to the American Fork River, and the width of the channel at this location, it is unlikely that the site would be flooded by the American Fork River due to dam failure.

Radon

A radon hazard may exist because unsaturated, permeable soils derived from some source rocks enriched in uranium occur at the site

(Sprinkel, 1988). However, it should be emphasized that actual levels have not been measured, and indoor concentrations of radon gas are dependent on the type of construction as well as geologic factors. American Fork Canyon is the primary source for sediments at the site and there are some exposures in the canyon of Manning Canyon Shale (Baker and Crittenden, 1961), a uranium-bearing shale and source of radon. Additionally, conditions are favorable at the site for the transport of radon gas as the soils are permeable and ground water, which inhibits radon movement, is deep.

CONCLUSIONS AND RECOMMENDATIONS

The hazard with the highest potential at the site is ground shaking from earthquakes. Information for three different earthquake-resistant design options is presented: 1) expected peak horizontal accelerations of 0.4 to 0.8 g for the largest expected earthquake near the site (M_s = 7.5 on the Provo segment of the Wasatch fault zone); 2) the peak horizontal accelerations (between 0.30 and 0.35 g) that have a 10% chance of being exceeded in 50 years; and, 3) the minimum design ground motions for seismic zone 3 as designated by the 1988 Uniform Building Code. Although the ground motions in the first option have a low probability of occurring, the city must be aware that such ground shaking from a large earthquake along the Wasatch fault zone would be quite strong and could occur at any time. The second option is more reasonable considering the type of facility that is proposed. The ground motions specified in option 2 suggest that the site should be in UBC seismic zone 4 and we recommend that this facility and any others built at the site be designed and constructed to meet the requirements for UBC seismic zone 4. At a minimum, the seismic provisions for seismic zone 3 of the 1988 UBC must be met.

Hazards identified as possibly present include tectonic subsidence from earthquakes, flooding from ditches, and radon. The amount of tectonic subsidence estimated for the site for a large earthquake along the Provo segment of the Wasatch fault zone is small (between 0 and 5 feet). The principal effect would be possible local flooding from canals or other gravity-flow structures which may experience a reduction in gradient. Thus, no mitigation measures are recommended for the site. Care needs to be taken in site design to accommodate existing drainage and divert ditches as necessary. Radon gas concentrations were not measured at the site, but the dry permeable soils, derived in part from the uranium-bearing Manning Canyon Shale in American Fork Canyon, suggest that radon could be a potential problem. Because radon concentrations are in part dependent on the type of construction and construction practices, it would be prudent to incorporate radon-resistant design into the structure (such as sealing the basement) and to measure indoor radon concentrations after construction is complete. The Utah Bureau of Radiation Control (Department of Health) provides guidelines for testing and mitigation.

A standard soil-foundation investigation is recommended to provide engineering data required to design the foundation. The potential for differential settlement of the non-engineered fill at the site should be evaluated in this investigation. The potential of all other earthquake, problem soil and subsidence, slope failure, shallow ground water, and flood hazards is low.

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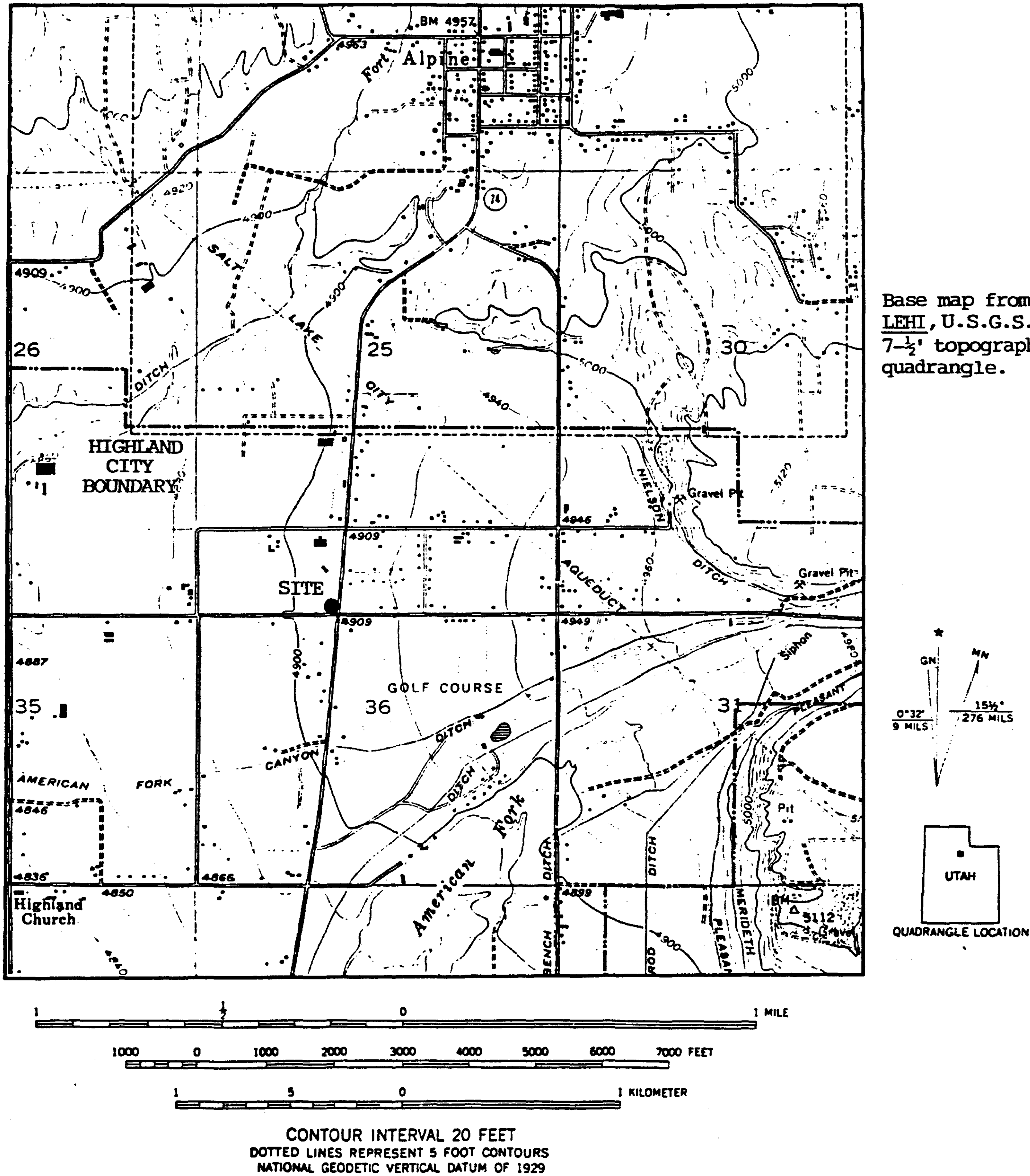
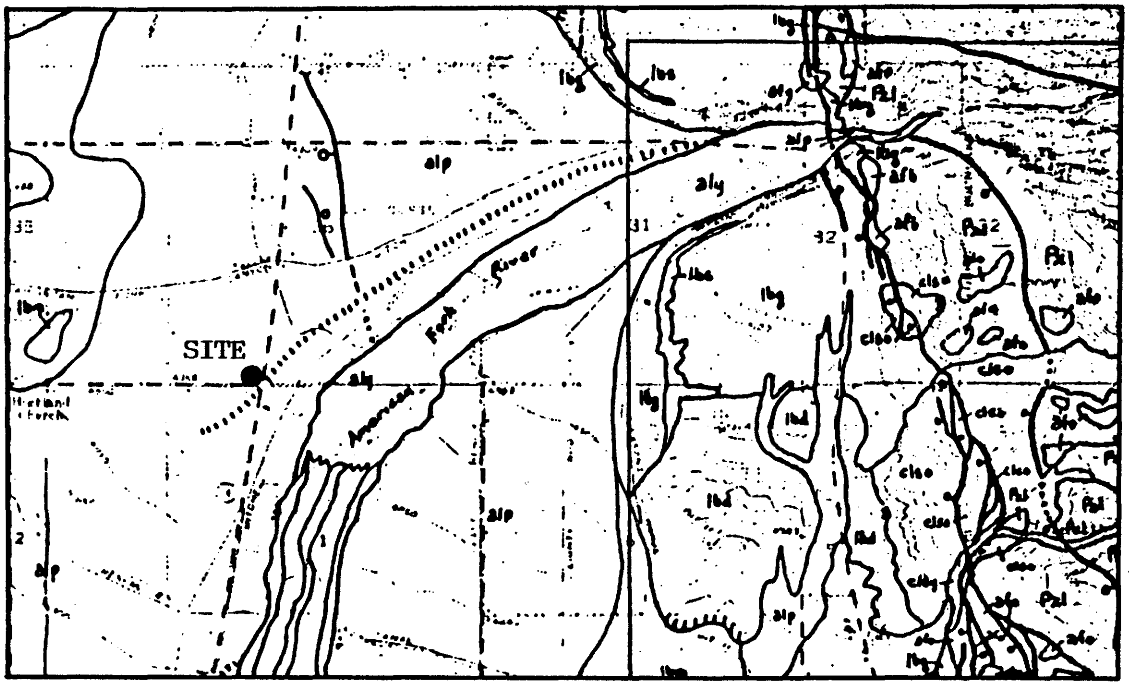
Job No. 90-07



Base map from LEHI, U.S.G.S. 7-½' topographic quadrangle.

Attachment 1. Location map showing proposed Highland City office building site.



0 1 MILES

0 1 KILOMETERS

Attachment 2. Surficial geologic map of the Highland site (modified from Machette, 1989).

LIST OF MAP UNITS

DEPOSITS OF THE BONNEVILLE (TRANSGRESSIVE) PHASE OF THE BONNEVILLE LAKE CYCLE (UPPER PLEISTOCENE)

lbd	Deltaic deposits
lbg	Lacustrine gravel
lbs	Lacustrine sand
lbm	Lacustrine silt and clay

DEPOSITS OF STREAM ALLUVIUM

aly	Younger stream alluvium, undivided (Holocene to uppermost Pleistocene)
alp	Stream alluvium related to the Provo phase of the Bonneville lake cycle (uppermost Pleistocene)

ALLUVIAL-FAN DEPOSITS

afy	Younger fan alluvium, undivided (Holocene to uppermost Pleistocene)
afb	Fan alluvium related to Bonneville phase of the Bonneville lake cycle (upper Pleistocene)
af4	Fan alluvium, unit 4 (upper to middle Pleistocene; pre-Bonneville lake cycle)
afo	Older fan alluvium, undivided (upper to middle Pleistocene; pre-Bonneville lake cycle)

COLLUVIAL DEPOSITS

clsy	Younger landslide deposits (Holocene to upper Pleistocene)
clso	Older landslide deposits (upper Pleistocene to upper Tertiary?)

BEDROCK

Pzl	Paleozoic sedimentary rocks, lower part (Lower Pennsylvanian, Mississippian, Devonian, and Cambrian)

SYMBOLS

Contact--Solid where well located or defined; dashed where approximately located; dotted where concealed

Gradational contact--Contact between two units that intertongue or between two differentiated units (such as al1 and al2) and its undifferentiated counterpart (aly)

(2)(4) AF

Normal fault--Bar and solid ball on down-dropped side along Wasatch fault zone; bar and hollow ball along other faults. Dashed where approximately located; dotted where concealed. Height of fault scarp and amount of offset of geomorphic surface (in parentheses) shown in meters.

Topographic escarpment--Escarpment along stream channels, terraces, and deltas; formed primarily by fluvial processes. Where escarpment coincides with the contact between map units, hachures face upslope; queried where position of escarpment is poorly located. Height of escarpment (in meters) shown in selected areas

N

Attachment 3.
Job No. 90-07

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Unified Soils Classification System (USCS)

ATTACHMENT 4.

SUMMARY OF GEOLOGIC HAZARDS
HIGHLAND CITY OFFICE BUILDING SITE

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

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

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

Project:			Requesting Agency:
Preliminary geologic hazard evaluation of proposed Disaster Field Offices along the central Wasatch Front, Utah			Utah State Division of Comprehensive Emergency Management
By: Susan Olig	Date: 4-16-91	County: Salt Lake, Utah Weber Counties	Job No.: 91-04 (PF-4)
USGS Quadrangle: Salt Lake City N. (BLM 1254); Salt Lake City S. (BLM 1213); Jordan Narrows (1131); Sugar House (1212); North Ogden (1370)			

PURPOSE AND SCOPE

This report summarizes a preliminary geologic hazard evaluation of five potential Disaster Field Office (DFO) sites being considered for emergency response facilities as part of the State's earthquake response plan with the Federal Emergency Management Agency. The evaluation was requested by John Rokich, Utah Division of Comprehensive Emergency Management, so that geologic hazards could be considered in the site selection process. The purpose of this study is to provide information for initial screening of the sites to compare their relative suitability with regards to geologic hazards. This reconnaissance evaluation was limited to review of existing information. I did not conduct any field investigations, and only hazards considered critical to emergency response facilities were evaluated. From this preliminary evaluation, Camp Williams is the most suitable site, and the State Fairgrounds and Ogden Defense Depot are the least suitable, from the standpoint of geologic hazards. To allow all potential hazards to be fully considered in the emergency response plan, I recommend that a more detailed hazard investigation of the final site(s) also be conducted.

GEOLOGIC HAZARD EVALUATION

All of the potential DFO sites are along the central Wasatch Front (attachment 1), where both historic and prehistoric earthquake activity is well-documented (for example, Arabasz and others, 1987; Machette and others, 1991). Attempting to assess differences in the recurrence of earthquakes at the different sites would be highly speculative with existing information, and for the purposes of this evaluation, all sites were considered to have an equal potential for earthquakes.

I evaluated earthquake, slope failure, and flooding hazards and rated each hazard as high, moderate, or low based on both the severity and likelihood of the hazard (table 1). Definitions for the specific hazards listed in table 1 can be found in attachment 2. Hazard ratings were somewhat subjective, but criteria were kept consistent between sites so that ratings give a good indication of the relative hazard at a site when compared to the other sites. Adequate information for a preliminary evaluation exists for most of the hazards, except for potential failure of sensitive clays. This hazard was evaluated based solely on geology, ground-water conditions, and similarities to sites studied by Parry (1974). Other instances where information was lacking are noted in the following sections, which also include a brief explanation for each hazard not rated as low.

Table 1. Preliminary evaluation of geologic hazards at proposed Disaster Field Office sites. Ratings are based on both relative severity and likelihood of hazard: H - high; M - moderate; L - low. *Based on little data.

SUMMARY OF GEOLOGIC HAZARDS CRITICAL TO EMERGENCY RESPONSE FACILITIES														
	Earthquake						Slope failure				Flooding			
Site	Ground shaking	Surface faulting	Tectonic subsidence	Liquefaction	Flooding	Sensitive clays*	Rock fall	Landslide	Debris flow	Avalanche	Streams	Alluvial fans	Lakes	Dam failure
Camp Williams	M	L	L	L	L	L	L	M	L	L	L*	L	L	L
Westminster College	H	M	L	L-M	M	L	L	L	L	L	M	L	L	L
Salt Lake Community College	H	L	M	M	L	M	L	L	L	L	L	L	L	L
Ogden Defense Depot	H	L	M-H	H	M	M	L	L	L	L	M*	L	L	M-H
State Fairground	H	L	M-H	H	M-H	M	L	L	L	L	L	L	M	L-M

Camp Williams

The earthquake ground-shaking hazard is moderate at Camp Williams and relatively lower than the other five sites. Although the potential for damaging ground motions is similar for all of the sites (Youngs and others, 1987), the expected severity is less at Camp Williams because of the site conditions (underlying firm Lake Bonneville gravels and sands, a shallow depth to bedrock, and a location outside of a basin where shaking can be amplified). Landslide hazards were also rated as moderate because of three historical slides on the west and southwest perimeter of the site (Harty, 1991). These slides are probably related to sloughing along the steep banks of the Jordan River and should be evaluated further if this site is selected.

Westminster College

The ground-shaking hazard is high and the surface-faulting hazard is moderate at Westminster College because of the proximity of the East Bench fault, roughly 800 feet northwest of the site (Personius and Scott, 1990). The East Bench fault is a splay of the Salt Lake City segment of the Wasatch fault zone. Theoretical and empirical studies suggest that complexities in how the rupture propagates can amplify ground shaking along the fault (Benz and Smith, 1988; Campbell, 1987). Anderson and others (1986) mapped the west part of Westminster College as having a moderate liquefaction potential and the east part of the campus as having a very low liquefaction potential. Because of steep slopes and the presence of springs along the East Bench fault (Van Horn and Fields, 1974), this area also has the potential for liquefaction-induced slope-failure. Because of the springs, I rated the flood hazard associated with earthquakes as moderate. The stream-flooding hazard is moderate because the southern end of the campus is in the 500-year flood plain of Emigration Creek (Van Horn and Fields, 1974). Although I rated landslide hazards as low, slopes directly to the northwest were mapped as less stable by Van Horn (1972), and failure on these slopes could affect access to this site.

Salt Lake Community College

The ground-shaking hazard is high at Salt Lake Community College because of the potential for amplified ground motions due to local site conditions (Hill and others, 1990; Tinsley, 1988). These conditions include soft Lake Bonneville clays and silts (Personius and Scott, 1990), and a location in the center of a deep basin. Estimates of tectonic subsidence at the College range from a 2- to 10-foot drop for a large earthquake along the Salt Lake City segment of the Wasatch fault zone, with a change in gradient of 0.4 feet/mile down to the east (Keaton, 1986). Anderson and others (1986) map the site as having a moderate liquefaction potential. I rated the hazard from sensitive clays as moderate because of the presence of lacustrine clays. However, the sensitivity of clays and the potential for ground failure at the site are unknown.

Ogden Defense Depot

The ground-shaking hazard is high at Ogden Defense Depot because of site conditions similar to those at Salt Lake Community College (soft sediments in a deep basin). Estimates of tectonic subsidence at the Depot range from a 3- to 15-foot drop for a large earthquake on the Weber segment of the Wasatch fault zone, with a change in gradient of 0.5 feet/mile down to the east (Keaton, 1986). The liquefaction hazard is high because the site is just south of a prehistoric lateral spread (M. V. Lowe, Utah Geological Survey, unpublished mapping), and Anderson and others (1990) map the area with a moderate-grading-to-high potential for liquefaction. Keaton (1986) identified the potential for ponding of shallow ground water associated with tectonic subsidence. I rated the hazard from sensitive clays as moderate because of the presence of Lake Bonneville clays in the northern part of the Depot (Davis, 1985). Although the flood insurance maps by FEMA do not cover the Depot, based on maps to the southeast and east, it appears that the southern part of the site is within the 500-year floodplain of Mill Creek. I rated the hazard from dam failure as moderate to high because the site is within the inundation zone from failure of Pineview Dam (U.S. Bureau of Reclamation, 1982). However, this rating does not indicate the likelihood of failure, but only the likelihood of flooding should the dam fail.

State Fairground

The ground-shaking hazard is high at the State Fairground because of site conditions similar to those at Salt Lake Community College. Estimates of tectonic subsidence at the Fairground range from a 3- to 15-foot drop (Keaton, 1986). Anderson and others (1986) mapped this area as having a high liquefaction potential. Flood hazards associated with earthquakes are moderate to high because Keaton (1986) identified the potential for ponding of shallow ground water and/or flooding from Great Salt Lake if the lake was at an elevation of around 4215 feet or higher, both a result of tectonic subsidence. The hazard from sensitive clays is moderate because of lacustrine clays underlying the east half of the site (Personius and Scott, 1990). However, fine-grained flood-plain deposits of the Jordan River underlie the west half of the site, and although these deposits contain clays, they were probably deposited in a freshwater environment and are less likely to be sensitive (Parry, 1974). Lake flooding hazards are moderate because of the proximity of Great Salt Lake and the site elevation is roughly 4220 feet, 8 feet above the historical maximum elevation of the lake. I rated the hazard from dam failure as low to moderate because the site is in the inundation zone for a worst-case scenario of all dams in Salt Lake County simultaneously failing while streams are at floodstage (Case, 1988).

SUMMARY AND RECOMMENDATION

Based on this review of existing information, Camp Williams has the least number of high and moderate hazard ratings and is the most suitable site from a geologic perspective. Westminster College and

Salt Lake Community College are comparable in their exposure to geologic hazards and are the next most suitable sites. Ogden Defense Depot and the State Fairground are the least suitable sites and have the largest number of high and moderate hazard ratings. I recommend that, whichever site is selected, a more detailed hazard investigation be done that includes a field investigation, interpretation of aerial photographs, and further evaluation of the hazards identified in this report.

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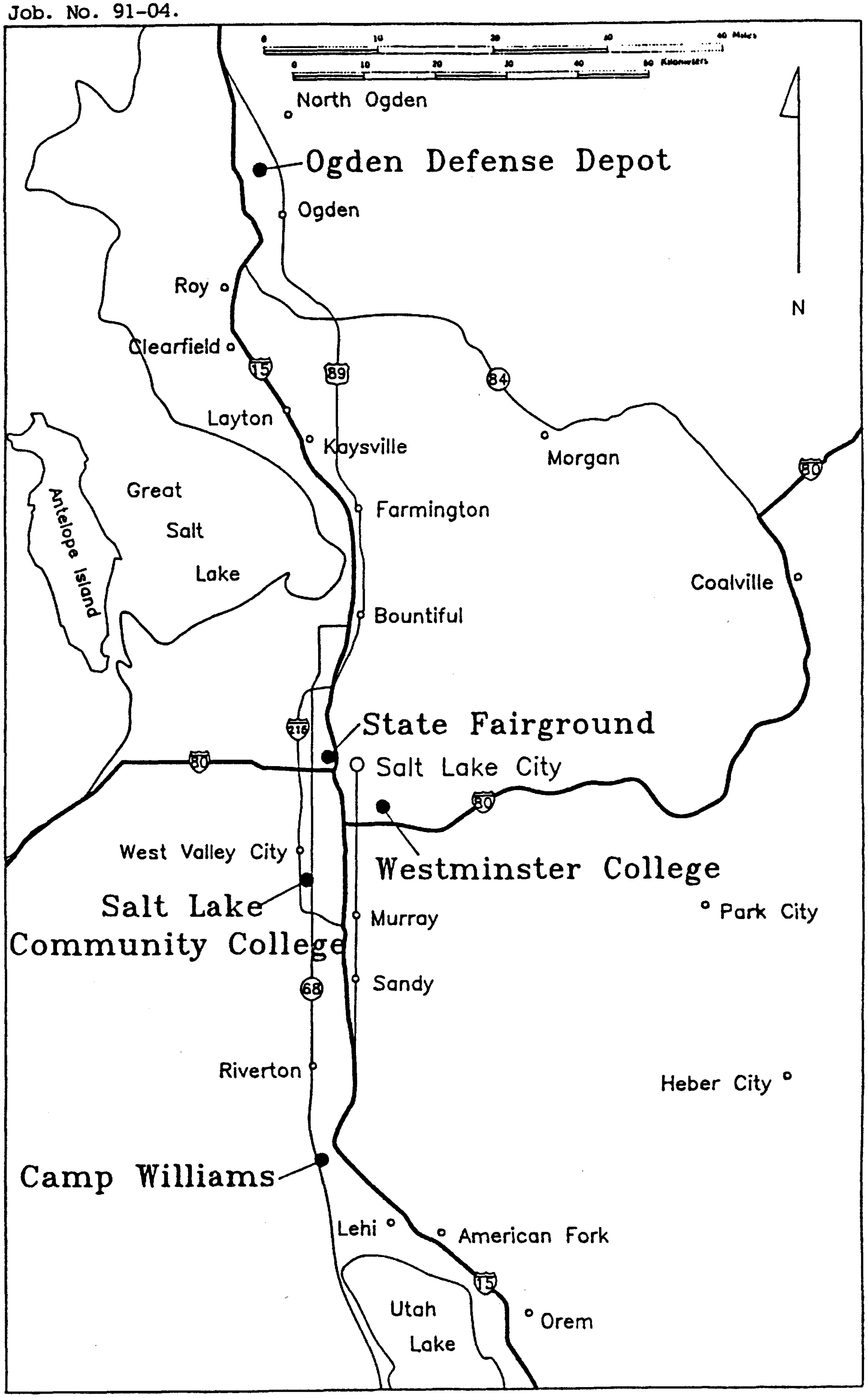
Attachment 1. Location map of potential Disaster Field Office sites. Job. No. 91-04.



GLOSSARY OF GEOLOGIC HAZARDS TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Graben - A block of earth downdropped between two faults.

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

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

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

Hydrocompaction - see Collapsible soil.

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

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

Karst - See Soluble soil/rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Richter magnitude - see Magnitude

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

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

Sand dunes - See Active sand dunes.

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

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

Seismicity - Seismic or earthquake activity.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SCHOOLS

Project:			Requesting Agency:
Earthquake Hazards and Salt Lake City Schools, Salt Lake County			Salt Lake City Board of Education
By: Susan Olig	Date: 1-2-90	County: Salt Lake	Job No.: (S-1) 90-01
USGS Quadrangle: Salt Lake City North, Salt Lake City South, Sugar House, and Fort Douglas (BLM Nos. 1254, 1213, 1212, 1253)			

INTRODUCTION

In August of 1989 the Salt Lake City Board of Education established the Seismic Study Committee. The Committee's charge was to advise the Board on seismic hazard mitigation policies, with particular emphasis on responding to the seismic vulnerability assessment of the District's facilities that was conducted by Reaveley Engineers and Associates, Inc. The committee was comprised of 19 citizens with a variety of backgrounds. Genevieve Atwood and myself were requested to participate as members from the Utah Geological and Mineral Survey, providing technical support and contributing to the final report. The following is an overview of earthquake hazards in Salt Lake City that was included, with some minor modifications, as a section of the Committee's final report "Recommendations of the Seismic Study Committee to the Salt Lake City Board of Education". This review benefitted from comments and contributions by many of the committee members. In particular, Craig Nelson (Salt Lake County Planning) and William Gordon (Sergent, Hauskins & Beckwith) provided figures and tables.

EARTHQUAKE HAZARDS, SALT LAKE CITY

The earthquake threat in the Salt Lake Valley has long been recognized by geologists (Gilbert, 1928). The principal earthquake hazards include surface fault rupture, ground shaking, liquefaction, tectonic subsidence, and earthquake-induced rock falls, landslides, and seiches. Expected physical effects and different options for reducing these hazards are outlined in table 1. The available information on these hazards that is pertinent to Salt Lake City School District facilities is summarized in the following sections. The purpose of this report is to identify known and potential earthquake hazards. It does not preclude the necessity for comprehensive site investigations of potential geologic hazards at individual schools.

Surface Fault Rupture

Earthquakes in the Salt Lake City area are generated by displacements or ruptures along faults. Observations of historical earthquakes in the Great Basin indicate that large magnitude earthquakes (M_L greater than 6.3) have ruptured to the surface (Bucknam and others, 1980). Depending on the magnitude, these surface-faulting earthquakes have generated scarps as high as 20 feet. Additionally, multiple fault scarps can form and the associated zone of deformation can be wider than 1600 feet.

Two active fault zones are known to transect Salt Lake City: 1) the

Table 1. Principal Earthquake Hazards, Expected Effects, and Commonly-Applied Hazard Reduction Techniques

Hazard	Expected Effects	Commonly Used Hazard-Reduction Techniques. Other Mitigation Techniques May be Used Which are not Listed Here.
Surface Fault	Rupture	Rupture of ground with relative displacement of surface up to 15 feet along main trance of fault. Tilting the ground displacements may occur in a zone of deformation of to several hundred feet wide, chiefly on the downthrown side of the main fault trace.Avoid active traces by setting structure back a safe distance from fault.
Tectonic Subsidence	Regional tilting of valley floor toward fault causing flooding near lakes and in areas of shallow ground water. May cause loss of head in gravity-flow structures.	Increase tolerance for tilting in gravity-flow structures; design structures for releveling. Buffer zones or dikes around lakes or impounded water to limit flood hazard; prohibit basements in shallow ground-water areas.
Ground Shaking	Vertical and lateral movement of the ground as seismic waves pass. Amplitude and frequency of seismic waves variable, as are peak ground displacements, velocities, and accelerations depending on source, path, and size conditions.	All new buildings designed to meet or exceed Uniform Building Code Seismic Zone requirements (currently zones 3, 2B, and 1). Retrofit older buildings to strengthen structures so they meet current UBC require- ments. Site characterization studies for multi-story buildings to determine site response and design building to prevent destructive resonance. Tie down water heater and secure heavy objects inside the home.
Liquefaction	Saturated sandy soils may liquefy (become like quicksand) causing differential settlement, ground cracking, subsidence, lateral downslope movement of upper soil layers on gentle slopes, and flow failures (landslides) on steep slopes.	Improve soil-foundation conditions by removing susceptible soils, densification of soils through vibration or compaction, grouting, dewatering with drains or wells, and loading or buttressing to increase confining pressures. Structural solutions include use of end-bearing piles, caissons, or fully compensated mat foundations.

Table 1 Continued

Hazard	Expected Effects	Commonly Used Hazard-Reduction Techniques. Other Mitigation Techniques May be Used Which are not Listed Here.
Earthquake-Induced Rock Fall	Downslope movement of bedrock fragments and boulders causing damage due to impact.	Avoidance. Removal of potential rock-fall boulders, stabilization of sources of rock fall by bolting, cable lashing, burying, or grouting. Protecting structures with deflection berms, slope benches, or catch fences.
Earthquake-Induced Landslides	Downslope movement of earth material causing damage due to impact and/or burial below the landslide, differential displacement on minor scarps and movement in both vertical and horizontal directions within the central mass of the landslide, and loss of foundation support for structures straddling the main scarp at the top of the landslide.	Avoidance. Remove land-slide prone material. Stabilize slopes by dewatering, retaining structures at toe, piles driven through landslide into stable material, weighting, or buttressing slopes. Bridging.
Earthquake-Induced Seiches	Earthquake-generated water waves causing inundation around shores of lakes and reservoirs. Loss of life due to drowning. Damage due to flooding, erosion, and pressures exerted by waves.	Avoidance. Flood- proofing and strengthening to withstand wave surge. Diking. Elevate buildings.

Salt Lake City segment of the Wasatch fault zone; and, 2) the West Valley fault zone. Both fault zones have associated scarps that formed in the last 12,000 years (Scott and Shroba, 1985; Keaton and others, 1987). The relationship of fault scarps to Salt Lake City school buildings is shown on attachment 1. The Salt Lake City segment of the Wasatch fault zone generally bounds the east side of Salt Lake Valley and dips underneath the valley. The East Bench fault is a splay of the Salt Lake City segment that transects Salt Lake City, trending subparallel to 1300 East from roughly South Temple to south of 3300 south (attachment 1). The West Valley fault zone extends from the Salt Lake International Airport south to Taylorsville.

Large magnitude surface-faulting earthquakes have not occurred historically on the Salt Lake City segment of the Wasatch fault zone. However, geologic studies indicate they have occurred twice in the past 5,500 years, with the most recent event occurring shortly before 1600-1900 years ago (William Lund, Utah Geological and Mineral Survey, personal comm., 1989). Schwartz and Lund (1988) estimate an average recurrence interval of 4000 years for the Salt Lake City segment, but it is uncertain when the next surface-faulting earthquake will occur. The current state-of-knowledge cannot discount either the possibility of it occurring tomorrow or 500 years from tomorrow. Probability estimates range from 4 to 20 percent for a surface-faulting earthquake to occur anywhere along the <u>entire</u> Wasatch fault zone in the next 50 years (David Perkins, U. S. Geological Survey, personal comm., 1989). However, these estimates are model dependent and there is considerable uncertainty as to the appropriate model. Geologic studies indicate that two to five surface-faulting earthquakes have occurred in the last 13,000 years along the West Valley fault zone (Keaton and others, 1987). Presently, it is uncertain if these earthquakes were generated dependently or independently of the surface-faulting earthquakes along the Salt Lake City segment of the Wasatch fault zone. Because of the many uncertainties, it is prudent to assume that a large surface-faulting earthquake could occur at any time on either of these fault systems.

Foundations of buildings generally cannot withstand more than several feet of displacement without collapse (Youd, 1980). Fortunately, areas with fault rupture hazards are generally localized and can be identified and avoided. Salt Lake County has recently passed a natural hazards ordinance that provides a good example of how to do this. Special study areas for fault zones are identified (shown shaded on attachment 1) and a geologic study is required prior to issuance of building permits for new construction in these areas. The purpose of the geologic study is to more accurately locate faults on the site and determine appropriate distances to set structures back from the faults. Schools and other public buildings are currently exempt from this ordinance.

Ground Shaking

Ground shaking is the most extensive earthquake hazard and has the greatest potential to cause injuries, deaths, and damage to school buildings. Ground shaking is often measured in terms of either Modified Mercalli (MM) intensities or ground accelerations. The MM intensity scale is subjective and based on observations of damage and physical effects resulting from an earthquake. Ground accelerations are measured and recorded during an earthquake by special seismographs called accelerographs (see table 2 for the MM intensity scale and a rough

Table 2. Abridged Modified Mercalli Intensity Scale (Bolt, 1978)

Note: The mean maximum acceleration and velocity values for the wave motion are for firm ground, but vary greatly depending on the type of earthquake source.

INTENSITY VALUE AND DESCRIPTION		AVERAGE PEAK ACCELERATION (g IS GRAVITY = 980 CENTIMETERS PER SECOND SQUARED	AVERAGE PEAK VELOCITY (CENTIMETERS PER SECOND)
I.	Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale.)		
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale.)		
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale.)		
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale.)	0.015g-0.02g	1-2
V.	Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi Forel Scale.)	0.03g-0.04g	2-5

Table 2 (Continued)

INTENSITY VALUE AND DESCRIPTION	AVERAGE PEAK ACCELERATION (g IS GRAVITY = 980 CENTIMETERS PER SECOND SQUARED	AVERAGE PEAK VELOCITY (CENTIMETERS PER SECOND)
VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)	0.06g-0.07g	5-8
VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars. (VII Rossi-Forel Scale.)	0.10g-0.15g	8-12
VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (VIII+ to IX Rossi-Forel Scale.)	0.25g-0.30g	20-30
IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale.)	0.50g-0.55g	45-55

Table 2 (Continued)

INTENSITY VALUE AND DESCRIPTION	AVERAGE PEAK ACCELERATION (g IS GRAVITY = 980 CENTIMETERS PER SECOND SQUARED	AVERAGE PEAK VELOCITY (CENTIMETERS PER SECOND)
X. Some well build wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (X Rossi-Forel Scale.)	More than 0.60g	More than 60
XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.		
XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.		

approximation of the corresponding ranges of accelerations). The horizontal components of the ground motions usually cause the most damage as horizontal motions are typically larger than vertical motions and because man-made structures are built to withstand the vertical acceleration of gravity but are not necessarily built to withstand horizontal accelerations.

Intensities as large as VII have been reported in Salt Lake City for both the 1910 Salt Lake City earthquake (estimated M_L of $5\frac{1}{2}$) and the 1962 Magna earthquake (M_L=5.2) (Oaks, 1987; Hopper, 1988). Both earthquakes caused slight to moderate damage. Instrumentation was not in place to record ground accelerations during these earthquakes. In fact, ground accelerations caused by earthquakes have not yet been recorded in the Salt Lake Valley.

Estimated intensities for a large magnitude (M_s=7.5) earthquake on the Salt Lake City segment of the Wasatch fault zone range from VIII to greater than X in Salt Lake City (Algermissen and others, 1988). Estimated ranges of peak horizontal ground accelerations in Salt Lake City for such an event vary from 40% to 80% g (40 to 80 percent of the acceleration of gravity) (Campbell, 1987). The large variation in values is due in part to site-specific geologic and seismologic conditions. However, there are also large uncertainties because of a lack of strong ground shaking records for earthquakes in Utah. These estimated ground motions are very large and would cause extensive damage or collapse of many Salt Lake City schools.

Although large surface-faulting earthquakes are relatively infrequent in the Salt Lake Valley, ground shaking from more frequent moderate-sized earthquakes and from distant large earthquakes could also cause damage. Estimates for the rate of occurrence of moderate-sized earthquakes in just Salt Lake City have not been made. However, observations of historical seismicity along the entire Wasatch Front indicate an earthquake with a Richter magnitude of 5.5 or greater occurs on the average of once every 24 years (Arabasz and others, 1987). A rough estimate of the probability of such an event occurring in 100 years along the Wasatch Front is about 98%, while estimates for just the vicinity of Salt Lake City vary from 5 to 32%, depending on the size of the area chosen. The 5% estimate is for an area the size of Salt Lake Valley (roughly 1000 km^2 or 386 mi^2); the 32% estimate is for an area with a 50 km (31 mi) radius centered at Salt Lake City. These estimates are based on some simplifying assumptions with large uncertainties, including that the earthquakes are randomly distributed in time and that the most-likely rate of earthquake occurrence is uniformly distributed over the area.

Subsequent to the drafting of the Committee's report, recent observations of ground motions during the October 17, 1989 Loma Prieta, California, earthquake indicate that damaging ground motions occurred on soft sediments 100 km (62 mi) from the epicenter of the M_S7.1 earthquake. Since similar conditions are known to exist in Salt Lake Valley, a radius of 50 km (31 mi) may underestimate the area subject to damaging ground motions. Using an area defined by a 100 km (62 mi) radius results in a probability estimate of 79% for an earthquake with a Richter magnitude of 5.5 or greater to occur in 100 years.

To better account for some of the many factors that influence the ground-shaking hazard (such as the earthquake magnitude, the distance to the earthquake, and the different rates of recurrence for earthquakes with different magnitudes) it is useful to analyze the ground motions using a probabilistic approach. Recent studies indicate that peak horizontal accelerations between 30% and 35% g have a 10% chance of being exceeded in 50 years in the Salt Lake Valley (Youngs and others, 1987). These values are for firm sediments and are not site-specific. Accelerations that have a 10% probability of being exceeded in 50 years are typically used as the basis for minimum design requirements for most types of structures as specified in the Uniform Building Code. Accelerations of 30% g roughly correspond to a MM intensity of VIII, where "damage [is] slight in specially designed structures [but] considerable in ordinary substantial buildings, with partial collapse" (Bolt, 1978). There are two major components to reducing ground shaking hazards: 1) adequate earthquake-resistant design and building practices; and, 2) securing non-structural building components and contents.

Liquefaction

When water-saturated silts and sands are subjected to strong ground shaking they can become liquefied and temporarily behave like a viscous fluid. Liquefaction can result in large lateral displacements of the ground and loss of bearing strength of the soil, which can cause significant damage or collapse of structures. Anderson and others (1986) have mapped the liquefaction potential for Salt Lake County and their results for Salt Lake City, along with the location of Salt Lake City School District buildings, are shown in attachment 2. Many of these buildings are located in areas identified as having a high or moderate liquefaction potential. However, it should be noted that this map only shows general trends for planning purposes and is based on a probabilistic evaluation of ground motions that are necessary to cause liquefaction. Both the depth to ground water and the types of sediments present are quite variable in the Salt Lake Valley and site-specific variations of the liquefaction potential can be significant. More detailed geotechnical studies would be necessary to better assess the liquefaction hazard at individual sites.

Other Earthquake Hazards

Tectonic subsidence is the regional tilting of the earth's surface on the downthrown side of the fault during a large surface-faulting earthquake. Tectonic subsidence was observed for both the 1983 Borah Peak earthquake (M_S 7.3) in Idaho and the 1959 Hebgen Lake (M_S 7.5) earthquake in Montana. During the Hebgen Lake earthquake, an area of roughly 180 square miles was affected with a maximum vertical subsidence of 20 feet (Myers and Hamilton, 1964). Keaton (1986) modeled the tectonic subsidence that might be expected for a large earthquake on the Salt Lake City segment of the Wasatch fault zone. Results from his study indicate that Salt Lake City schools north of North Temple Street could be flooded by the Great Salt Lake as a result of tectonic subsidence. The actual area of inundation also depends on the level of the lake at the time of the earthquake. Although flooding could damage structures and their contents, it generally does not have the potential to cause severe failure or collapse of buildings. Therefore, tectonic subsidence does not pose the same degree of threat to life-safety as ground shaking, liquefaction, or surface fault rupture.

Earthquake-induced water waves (or seiches) in the Great Salt Lake have not been studied in enough detail to assess this hazard in Salt Lake City. However, it would be reasonable to expect that low-elevation areas, less than 4220 feet, close to the lakeshore would be most vulnerable. The severity of this hazard also depends on the elevation of the lake at the time of the earthquake.

Rock-fall hazards in the Salt Lake Valley have been identified by Case (1987). A review of his map with respect to existing school buildings indicates none of the sites are in known hazardous areas. A review of Keaton and other's (1987) seismic slope stability map for Salt Lake County shows all Salt Lake City schools are in areas mapped as having a low or very low potential for earthquake -induced landslides. However, a review of Nelson's (1987) landslide inventory map for Salt Lake County indicates that one school site is close to an area with a known landslide hazard. Ensign Elementary school (775 East 12th Avenue) lies very close to a deep-seated landslide in Lake Bonneville deposits (roughly located near 13th Avenue and M Street). A thorough investigation of slope-stability would be required to assess the landslide hazard at this site.

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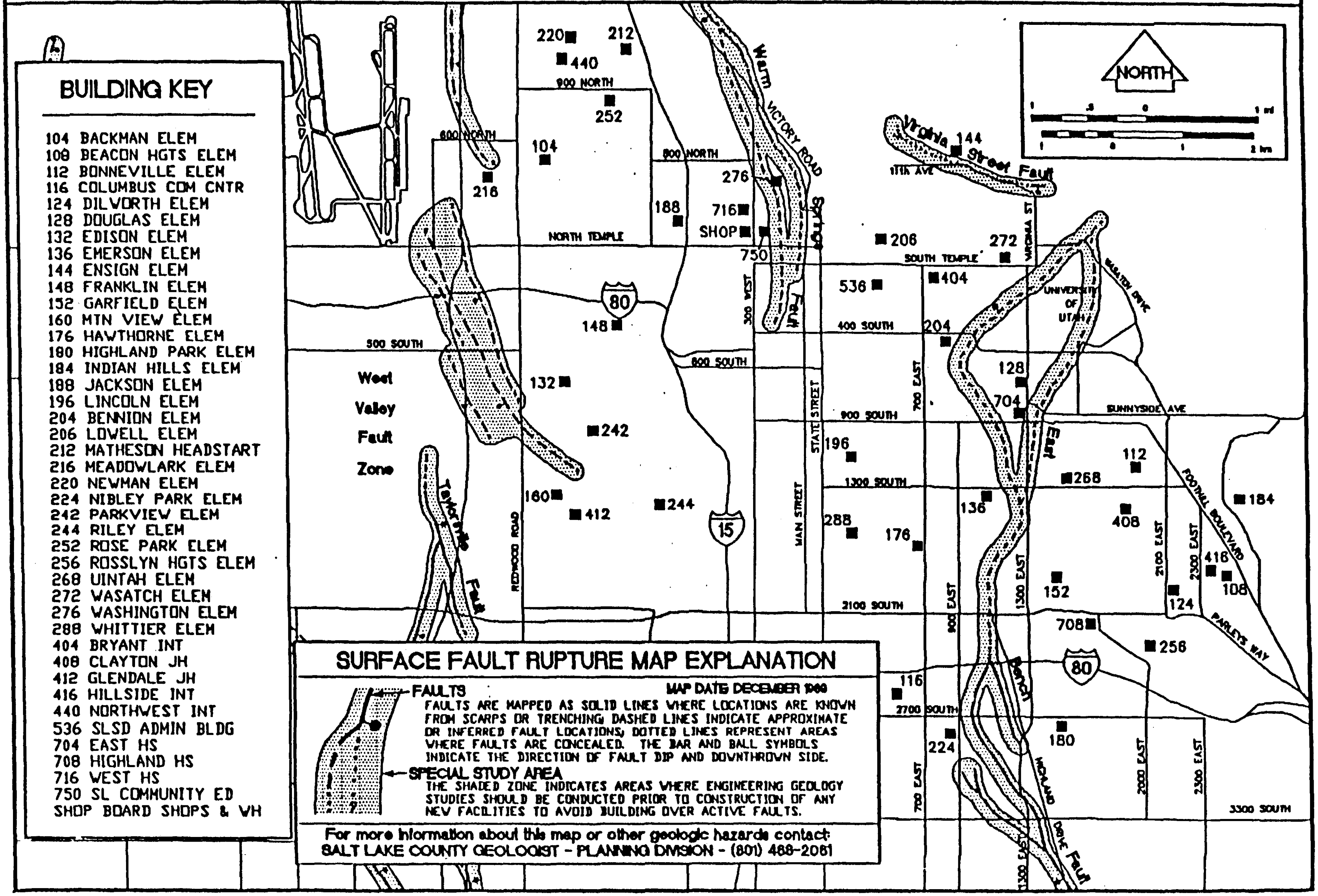
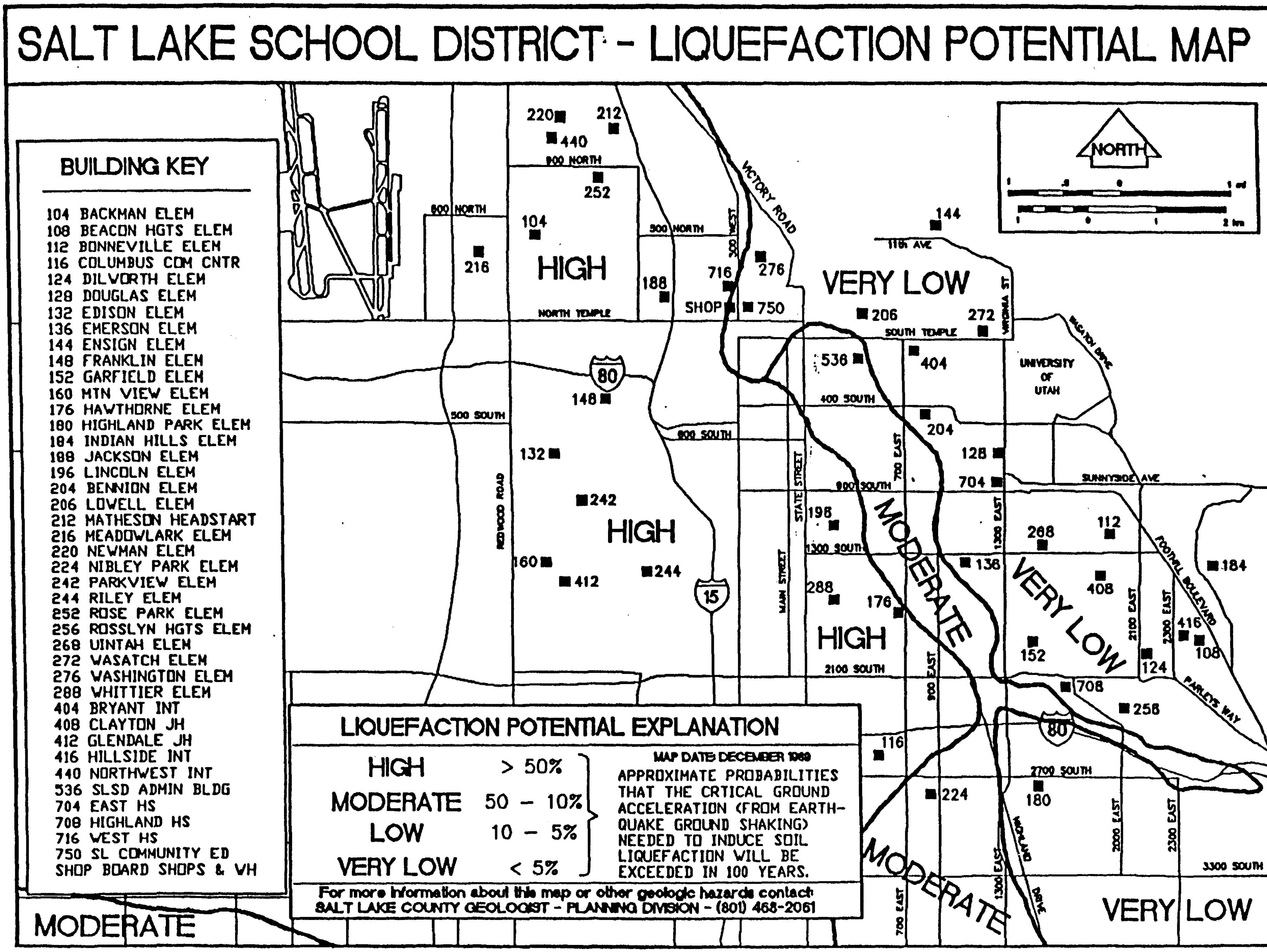
SALT LAKE SCHOOL DISTRICT - ACTIVE FAULT ZONE MAP



Attachment 1

Attachment 2



Project:	Requesting Agency:
Geologic hazards investigation of two prospective elementary school sites, Morgan County, Utah	Morgan County School District

By:	Date:	County:	Job No.:
Suzanne Hecker	6-27-90	Morgan	(S-2) 90-09

USGS Quadrangle:	
	Snow Basin (1344)

INTRODUCTION

This report describes the results of a geologic hazards investigation of two prospective elementary school sites in Mountain Green, Utah (attachment 1). One site is located on the west side of the Trappers Loop Road on the Warner family property (NW 1/4, sec. 25, T. 5 N., R. 1 E, SLBM). It will hereafter be referred to as the Trappers Loop site. The other site is a parcel owned by the Morgan County School District on the south side of State Highway 30 at approximately 4300 North (SE 1/4, sec. 25, T. 5 N., R. 1 E.), and will be referred to as the State Highway 30 site. This investigation was requested by Dr. J. Dale Christensen, Superintendent of the Morgan County School District (letter of 5/9/90). The scope of work for this study consisted of a literature review, examination of maps and aerial photographs (scale ~1:24,000), and a reconnaissance field inspection on May 23, 1990. Gary E. Christenson (Utah Geological and Mineral Survey) participated in the field inspection.

This report provides an assessment of geologic hazards which may affect each site, based on existing data and reconnaissance field work. It is meant to serve as a guide in selecting a site and in determining the need for detailed geotechnical work. This investigation does not preclude the necessity for a standard soil investigation to provide engineering data for foundation design.

SETTING AND SITE DESCRIPTION

Mountain Green lies north of the Weber River at the lower end of Morgan Valley (attachment 1). The Trappers Loop and State Highway 30 sites, with elevations of about 4890 and 4910 ft, respectively, are on similar low-gradient terrace surfaces approximately 30 ft above the surrounding valley floor. The terraces were originally a continuous surface, but they have subsequently been isolated by downcutting along Cottonwood Creek. The terrace surfaces have almost imperceptible 1 percent slopes to the northwest in the flow direction of the Weber River.

Both sites have a history of agricultural use and are covered with grassy vegetation. A concrete-lined irrigation ditch crosses the north end of the Trappers Loop site. North of State Highway 30 and the prospective school site, a residential area (Cottonwood Subdivision, attachment 1) has developed during the past 20 years on the terrace surface.

GEOLOGY AND SOILS

Morgan Valley is a deep sediment-filled basin in the northern Wasatch Range (Sullivan and others, 1988). Tuffaceous sandstones and conglomerates of the Norwood Tuff are extensively exposed on both sides of the valley (unit Tn on attachment 2). The upper layers of basin-fill sediment are young (Quaternary-age) deposits of dominantly alluvial and lacustrine (lake) origins. A large amount of deltaic material was deposited in the valley by tributaries to the Weber River during the highstand of ice-age Lake Bonneville, which flooded Morgan Valley and was about 300 ft deep at Mountain Green. The terrace surfaces beneath the Trappers Loop and Old Highway 30 sites are interpreted to be remnants of a river terrace (unit Qt on attachment 2) which formed when Lake Bonneville dropped below the level of the floor of Morgan Valley and stabilized at the Provo shoreline from about 14,500 to 13,500 years ago (Sullivan and others, 1988; Currey and others, 1984). The river alluvium consists mainly of sand and well-rounded gravel, much of which is probably reworked Lake Bonneville beach and deltaic deposits that were redeposited by the ancestral Weber River and Cottonwood Creek.

Surface materials and exposures along the margins of the terraces, including a gravel pit roughly 1000 ft east of the Trappers Loop site (attachment 1), indicate that the soil underlying the sites is sandy gravel with cobbles and boulders, capped by variable thicknesses of fine-grained sediments (mixtures of fine sand, silt, and clay). The upper, fine-grained soil layers are probably sheetflow, river over-bank, and/or windblown deposits. The coarse-grained deposits are stratified, generally well-graded, and probably have a river-channel origin. The clasts are well-rounded and have diverse lithologies.

The soil series mapped for the upper 5 to 6 feet by the U.S. Soil Conservation Service (SCS) (Carley and others, 1980) at the Trappers Loop and State Highway 30 sites are the Nebeker clay loam and the Parleys loam, respectively. Both are very deep and well-drained soils. The typical Nebeker clay loam profile in Morgan County has a clay loam topsoil (classified as CL to ML in the Unified Soil Classification System, see attachment 3) about 20 inches thick and a subsoil of clay overlying a sandy clay loam or clay loam (CL and CH) to a depth of 69 inches or more. In a typical Parleys loam profile, a 13-inch loam (CL to ML) topsoil overlies a 19-inch silty clay loam or clay loam (ML and CL) subsoil and a 28+-inch silty clay loam or loam (CL to ML) substratum.

The Nebeker soil is classified by the SCS as having slow permeability, moderate erosion hazard, and moderate (topsoil) to high (subsoil) shrink-swell potential. The Parleys soil has moderately slow permeability, moderate erosion hazard, and moderate shrink-swell potential. The Nebeker soil is rated as having severe limitations for building foundations due to its shrink-swell potential. The Parleys soil has moderate limitations due to its shrink-swell potential and low bearing strength.

Available information suggests the depth to ground water beneath the sites is greater than about 15 feet, although the possibility of local perched ground water cannot be excluded without site-specific subsurface information. A water-level contour map of Morgan County, reflecting conditions in the fall of 1980 (Gates and others, 1984), indicates that water-table depths at the Trappers Loop site and State Highway 30 site may have been roughly 30 feet and 50 feet, respectively. However, none of the control wells for the map were located at the sites. A spring is present at the base of the terrace scarp about 800 feet southeast of the State Highway 30 site, at an elevation roughly 30 feet below the site.

GEOLOGIC HAZARDS

Attachments 4 and 5 are summary checklists of the relative likelihood of various geologic hazards at the Trappers Loop site and the State Highway 30 site, respectively. All the hazards considered for this investigation are listed, and those which are believed to exist at the sites are discussed below. Hazards which need to be considered in the soils foundation investigation are also noted on attachments 4 and 5.

Earthquake Hazards

Morgan Valley lies within the Intermountain seismic belt, a zone of diffuse seismicity which trends north-south through the center of the state (Smith and Sbar, 1974; Arabasz and others, 1987). The valley is a structural and topographic basin within the tectonic transition zone between the Basin and Range Province to the west and the relatively stable Middle Rocky Mountains Province to the east.

Morgan Valley is bounded on the east by the Morgan fault, a large normal fault that dips beneath the valley and may be a source for large earthquakes (Sullivan and others, 1988). The Morgan fault is thought to have experienced recurrent large surface-faulting earthquakes (estimated maximum magnitude 6.75-7.0) during the late Quaternary (about the last 500,000 years), with an estimated average fault slip rate of 0.01-0.02 mm/yr. Limited data suggest that the average time interval between surface-faulting events (each with ground-surface displacements of 1.7-3.3 feet) is on the order of 25,000-100,000 years. The central section of the Morgan fault has evidence for a surface-faulting event sometime in the last 9,000 years (Sullivan and others, 1988). The town of Mountain Green is approximately 3.5 miles west of the north end of the fault.

The Wasatch fault zone, regarded as the eastern boundary of the Basin and Range Province, lies approximately 6 miles east of Mountain Green and has a westward dip. The Wasatch fault zone is significantly more active than other Quaternary faults in the region, with recurrence intervals for magnitude 7.0-7.5 earthquakes of 500 to 4000 years on individual segments of the fault (Machette and others, 1987).

Ground Shaking

The greatest earthquake hazard at the site is ground shaking resulting from either a moderate-sized earthquake, which could occur anywhere in the area, or from a large earthquake along a known fault, particularly the Morgan fault or one of the northern segments of the Wasatch fault zone. Seismic waves are generated at the earthquake source, travel through the earth, and cause ground shaking at the earth's surface. Ground shaking can cause damage or collapse of buildings not designed or constructed to resist the lateral forces of earthquakes.

Three options for design ground motions for the school sites are presented below, based on: 1) probable motions for the largest expected earthquake (most conservative option); 2) motions that have a low probability (10 percent chance) of being exceeded in 50 years; and, 3) the minimum design motions specified in the Uniform Building Code.

1) A reasonable estimate for the largest expected earthquake near Mountain Green is a magnitude (Ms) 6.75 to 7.0 event on the Morgan fault, as estimated by Sullivan and others (1988). Using Campbell's (1987) attenuation relation for ground motions in central Utah, an earthquake of this magnitude could produce peak horizontal ground accelerations of 0.23 to 0.35 g (g is the acceleration of gravity, 32.2 ft/s2) in Mountain Green, depending on assumptions of soil depths. Although a magnitude 7.0 to 7.5 earthquake on the Wasatch fault zone is much more likely, calculated ground-shaking values for such an event (0.20 to 0.30 g) are less than for the postulated Morgan fault earthquake due to the distance and dip direction of the Wasatch fault zone relative to Mountain Green.

2) Youngs and others (1987) used probabilities of earthquake occurrence from a variety of possible sources in northern Utah to estimate probabilistic values of ground accelerations for the Wasatch Front region, including Morgan Valley. For firm soil sites in the Mountain Green area, they estimate peak horizontal ground accelerations that have a 10 percent probability of being exceeded in 50 years to be slightly less than 0.25 g. For areas underlain by rock, the corresponding peak acceleration is slightly less than 0.30 g. However, these values do not reflect the occurrence of rare large earthquakes on faults within the Wasatch Range, such as the Morgan fault. Probabilistic ground-acceleration values for Mountain Green would likely be slightly higher if the relatively low, long-term rates of earthquake activity on these faults were incorporated into the analysis.

3) Mountain Green is in seismic zone 3 of the 1988 Uniform Building Code (UBC). Seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed in each seismic zone. State law requires that design and construction of the proposed school(s) must meet, as a minimum, the seismic design provisions specified in the code for seismic zone 3. Both sites are located on S1 soil types, as specified by the UBC.

The basis for the probabilistic evaluation of Youngs and others (1987) is similar to the basis for the UBC requirements, and the resulting ground shaking values (0.25 to 0.30 g) are in agreement with the seismic zone 3 specification for Mountain Green. Ground-motion values for the largest expected earthquake in Mountain Green are provided as a conservative option for design motions because the proposed structure is a school, which is regarded as a special-occupancy facility under the UBC. Nonetheless, these values (0.23 to 0.35 g) are not substantially greater than the probabilistic ground motions calculated by Youngs and others (1987) and the motions accounted for in the provisions for UBC seismic zone 3.

Other Earthquake Hazards

The Morgan fault is not close enough to Mountain Green to present a surface-faulting hazard or a significant tectonic-subsidence hazard at either site. The liquefaction potential is low based on the depth to ground water and the coarseness of the river-channel deposits at the sites.

Slope Failure Hazards

Slope failure hazards are unlikely to occur at either school site because of the flat topography of the terrace surfaces and the position of the surfaces with respect to the range front. Mapped landslides in the region (Kaliser, 1972; Resource Engineering, Inc., 1986; Harty, 1990; attachment 2) also indicate that there is a low potential for slope failure at the sites.

Problem Soils and Subsidence Hazards

Field evidence suggests that soil characteristics at the sites pose few problems for development. There were no indications that the fine-grained topsoil, which may vary in thickness from about 0 to 5 feet, is expansive. The coarseness of the deposits below the topsoil should provide good foundation material.

However, a possible erosion hazard does exist locally at the State Highway 30 site, where the southern boundary of the site follows the margin of the terrace surface. Small drainages have developed on the face of the terrace scarp, and small alluvial fans have been built on the flat valley floor at the base of the scarp. There is evidence that rapid mass movements (debris flows) have recently occurred in at least one of these drainages. Structures built near the edge of the terrace surface (within several tens of feet), especially adjacent to the drainage cuts, may be subject to erosion and a loss of foundation support during cloudburst storms or rapid runoff.

The SCS (Carley and others, 1980) rated the erosion hazard as moderate for the soils mapped at both school sites and rated the shrink-swell (expansive) potential as moderate for the soil at the State Highway 30 site and moderate to high for the soil at the Trappers Loop site. The shrink-swell properties of the soils may impose moderate (at the State Highway 30 site) to severe (at the Trappers Loop site) limitations for building foundations with shallow foundations. Low bearing strength for the soils at the State Highway 30 site also contributes to a moderate limitation for building site development. Combinations of shrink-swell potential, low strength, and frost action indicate severe limitations for the design and construction of local roads and streets at both sites.

However, it should be emphasized that these soil hazard ratings refer to "typical" soil conditions represented by the soil map units and should be used only to help make preliminary estimates pertinent to site construction. The available information may not adequately describe the soils actually present at either site. In addition, the evaluations pertain only to the upper 5 to 6 feet of soil and do not account for the coarse-grained deposits observed to underlie the terraces, which may impose far fewer limitations on foundation design and construction. The building inspector for Mountain Green reported no soil-related foundation problems for the Cottonwood Subdivision (oral communication, 6/6/90), which is located on the same terrace as, and just north of, the State Highway 30 site (attachment 1). Although the soils are erodible, load-bearing strength appears to be good.

Shallow Ground Water Hazards

Available evidence suggests that the water table is probably deeper than 15 feet, and the potential for shallow ground water at the sites is low. Although regarded as unlikely, if bedrock or impermeable layers of sediments are present at shallow depths, shallow perched water may occur locally beneath the sites, or may develop after construction as a result of lawn watering.

Flooding Hazards

The potential for flooding at the sites is low. The Flood Hazard Boundary Map for the vicinity indicates that both sites are above the "special flood hazard areas" (100-year flood plains) of nearby drainages (U.S. Department of Housing and Urban Development, 1978). A lined irrigation canal which crosses the north end of the Trappers Loop site is assumed to be designed for controlled discharge of water and is unlikely to present a flood hazard.

Mountain Green is located roughly 25 miles downstream from Echo Dam and 38 miles downstream from Wanship Dam on the Weber River. Dam-failure inundation studies by the U.S. Bureau of Reclamation (1983; 1985) identify the State Highway 30 site as within a potential flood hazard area, given the unlikely event of sudden failure of Echo Dam, either independent from or caused by failure of Wanship Dam. The Trappers Loop site lies beyond this potential dam-failure inundation area. Both school sites are outside the inundation area determined for failure of Lost Creek Dam, which is located on a tributary of the Weber River roughly 28 miles upstream from Mountain Green (U.S. Bureau of Reclamation, 1986). Similarly, based on an approximate inundation analysis (Case, 1986), neither site would be affected by flood waters from the sudden release of Wilkinson Reservoir, which is located on a small drainage less than a mile from the State Highway 30 site (attachment 1). An inundation study has not been done for Northwest Reservoir located above Cottonwood Creek slightly more than a mile upstream from both sites (attachment 1; Harty and Christenson, 1988).

Radon

The site areas may be susceptible to a radon hazard based on the generalized outcrop patterns of uranium-bearing rocks in the region (Sprinkel, 1988). Tertiary volcanic rocks (such as the Norwood Tuff, mapped in the vicinity of Mountain Green) have been associated with above average uranium concentrations and are considered to be radon sources (Sprinkel, 1988). Additionally, the unsaturated, permeable sediments beneath the school sites may provide favorable conditions for migration of radon gas to the surface. However, it should be emphasized that actual levels of radon have not been measured at the sites, and indoor concentrations of radon gas are dependent on the type of building construction as well as geologic factors.

CONCLUSIONS AND RECOMMENDATIONS

The Trappers Loop and State Highway 30 sites have similar geologic and hydrologic settings and may be equally suitable for construction of the proposed elementary school, depending upon the outcome of soil foundation studies. Potential hazards recognized at both sites include ground shaking from earthquakes, expansive and erodible soils, and radon. The State Highway 30 site is located within a potential dam-failure inundation zone.

The hazard with the highest potential at both sites is ground shaking from earthquakes. The results of an analysis (from Youngs and others, 1987) of the peak horizontal ground accelerations that have a 10% chance of being exceeded in 50 years at the sites (between 0.25 and 0.30 g) are consistent with the minimum design ground motions for seismic zone 3 as designated by the 1988 Uniform Building Code. Expected peak horizontal accelerations for the largest expected earthquake near the site (0.23 to 0.35 g for a Ms 7.0 on the Morgan fault) are not substantially greater than other, less conservative estimates for design ground motions.

Erosion may be a problem along the edges of the terrace surfaces, such as along the southern boundary of the State Highway 30 site, although this potential hazard can be easily avoided by locating structures away from the narrow (perhaps several tens of feet wide) strip of susceptible land. A soil survey study of Morgan County by the SCS (Carley and others, 1980) indicates that the upper 5 to 6 feet of fine-grained soil at both school sites may be expansive and/or erodible. These qualities, if present, could require special planning, design, and maintenance of buildings, roads, and sidewalks. Therefore, as indicated in attachments 4 and 5, a soil foundation investigation is recommended to provide site-specific soil information and the engineering data required to design foundations.

Radon gas concentrations were not measured in soils at the sites, but the presence of uranium-bearing sediments (the Norwood Tuff) in the vicinity, together with the dry, permeable soils at some depth below the sites, suggests that radon could be a potential problem. Because radon concentrations are in part dependent on the type of construction and construction practices, it would be prudent to incorporate radon-resistant design (such as sealed basements) and to measure indoor radon concentrations after construction is complete. The Utah Bureau of Radiation Control (Department of Health) provides guidelines for radon testing and mitigation.

The potential for flooding at the sites is low. However, the State Highway 30 site lies within a potential inundation area given the unlikely event of failure of the Echo Dam. A lined canal which crosses the north end of the Trappers Loop site should not pose a flooding hazard assuming that discharge is controlled. The potential for shallow ground water and all other flooding, earthquake, problem soil and subsidence, and slope failure hazards is considered to be low.

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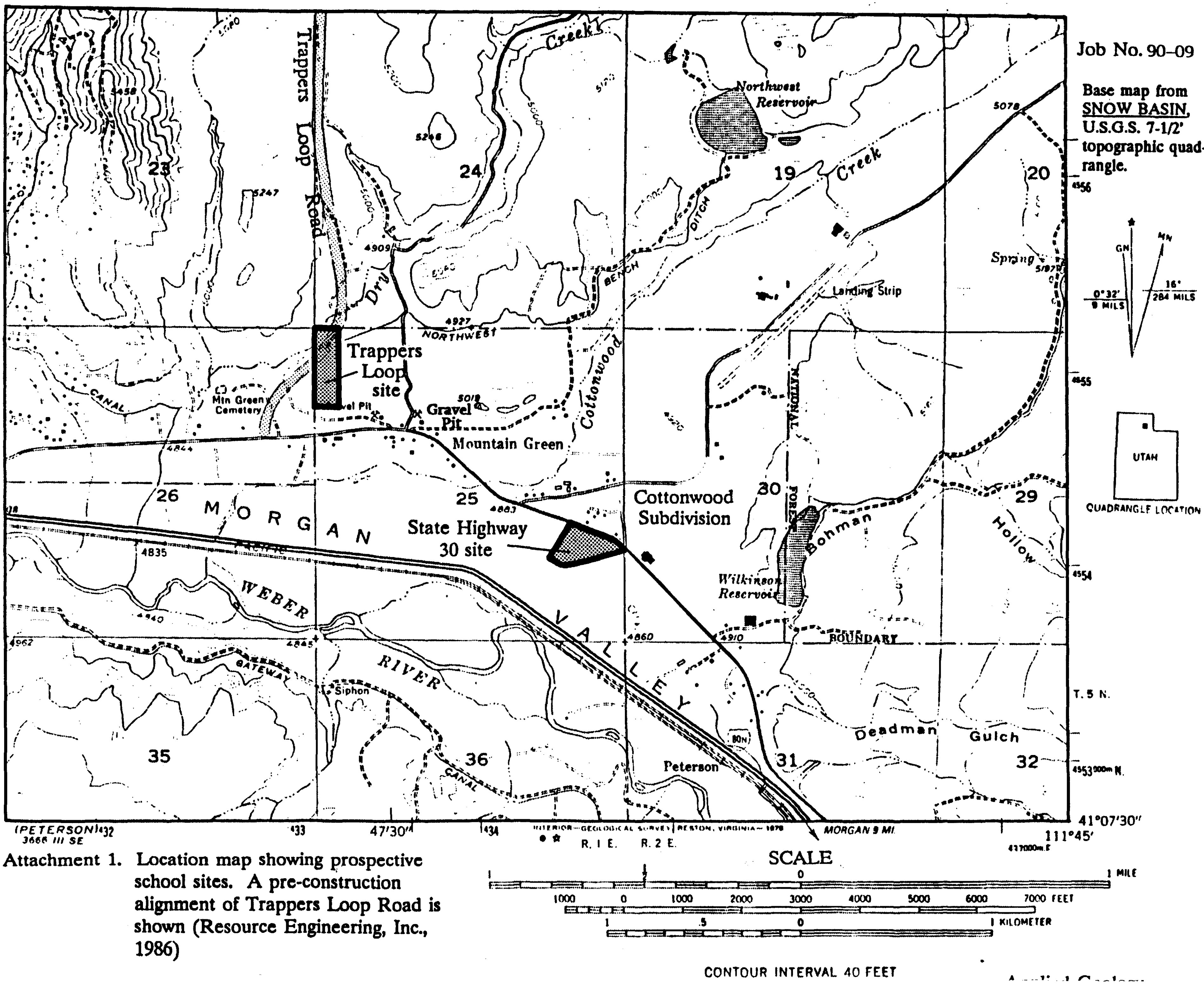
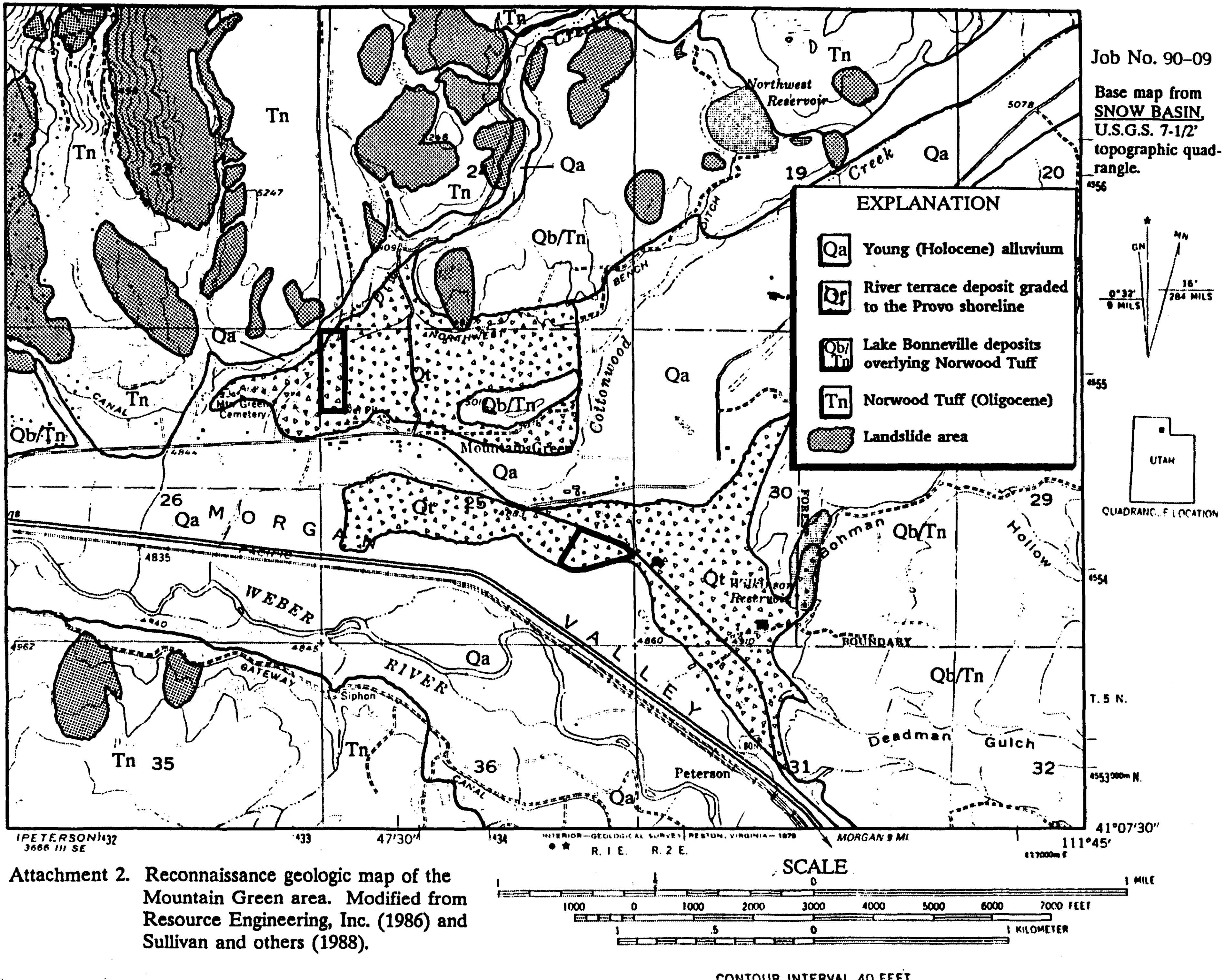


Attachment 1. Location map showing prospective school sites. A pre-construction alignment of Trappers Loop Road is shown (Resource Engineering, Inc., 1986)

Job No. 90-09

Base map from SNOW BASIN, U.S.G.S. 7-1/2' topographic quadrangle.



Attachment 2. Reconnaissance geologic map of the Mountain Green area. Modified from Resource Engineering, Inc. (1986) and Sullivan and others (1988).

Attachment 3.
Job No. 90-09

MAJOR DIVISIONS				GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS		GW	Well-graded gravels and gravel-sand mixtures, little or no fines
				GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES		GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS		SW	Well-graded sands and gravelly sands, little or no fines
				SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES		SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less			ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
				OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%			MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
				CH	Inorganic clays of high plasticity, fat clays
				OH	Organic clays of medium to high plasticity
Highly Organic Soils				PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Unified Soils Classification System (USCS)

ATTACHMENT 4.

SUMMARY OF GEOLOGIC HAZARDS
TRAPPERS LOOP SITE

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

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

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

ATTACMENT 5.

SUMMARY OF GEOLOGIC HAZARDS
STATE HIGHWAY 30 SITE

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

Project: Geologic hazards investigation for a prospective addition to a high school and possible seismic retrofit of a middle school, Morgan, Morgan County, Utah			Requesting Agency: Morgan County School District
By: Suzanne Hecker, Gary E. Christenson	Date: 7-3-90	County: Morgan	Job No.: (S-3) 90-10
USGS Quadrangle: Morgan (1318)			

INTRODUCTION

This report describes the results of a geologic hazards investigation of two school sites in Morgan, Utah. The Morgan County School District is considering the addition of a gymnasium and community activity center to the east side of the high school and a seismic retrofit of the middle school. The high school and middle school are about 300 yards apart, on the east and west sides, respectively, of 200 East Street in Morgan (W 1/2, sec. 36, T. 4 N., R. 2 E., SLBM; attachment 1). Because of their proximity, the school sites are generally subject to similar geologic hazards. However, each hazard may have different implications for the activities being considered. This investigation was requested by Dr. J. Dale Christensen, Superintendent of the Morgan County School District (letter of 5/9/90). The scope of work for this study consisted of a literature review, examination of maps and aerial photographs (scale ~1:24,000), and a reconnaissance field inspection on May 23, 1990.

This report provides an assessment of geologic hazards which may affect each site, based on existing data and reconnaissance field work. It is meant to serve as a guide for engineers, architects, and decisionmakers in taking appropriate action with respect to expanding the high school and upgrading the middle school, and also in site design and evaluation of the need for detailed geotechnical work at either site. This investigation does not preclude the necessity for a standard soil investigation to provide engineering data for foundation design or retrofit.

SETTING AND SITE DESCRIPTION

Morgan City is on the Weber River near its confluence with East Canyon Creek at the upper end of Morgan Valley (attachment 1). The school sites, with elevations of about 5065 to 5070 ft, are less than 10 feet above the Weber River on low-lying terrace surfaces south of the river. The terrace surfaces have gentle slopes (1 percent) to the west, in the direction of flow of the Weber River.

The site of the proposed addition east of the high school appears from older air photos to have had an history of agricultural use, but presently is part of the school grounds. The middle school is on a slightly higher terrace and consists of several buildings of differing heights and construction styles.

GEOLOGY AND SOILS

Morgan Valley is a deep sediment-filled basin in the northern Wasatch Range (Sullivan and others, 1988). Tuffaceous sandstone and conglomerate of the Norwood Tuff (Tn; attachment 2) and younger conglomerate (QTc) are exposed on the valley margins downstream from Morgan. Upstream from the city is conglomerate of the Wasatch Formation (Tw), exposed mainly south of the Weber River, and a series of older, faulted and folded bedrock units, comprised of sandstone, siltstone, limestone, dolomite, and quartzite exposed mainly north of the river (Mullens and Laraway, 1973; attachment 2). The upper layers of basin-fill sediment are young (Quaternary-age) deposits of dominantly alluvial and lacustrine (lake) origins. A large amount of deltaic material was deposited in the valley by the Weber River and its tributaries during the highstand of ice-age Lake Bonneville, which flooded Morgan Valley (Sullivan and others, 1988) and was about 150 ft deep at Morgan. The modern floor of Morgan Valley is underlain by Holocene alluvium (Qay). The terrace deposits beneath the school sites are Holocene channel and overbank deposits of the Weber River.

The topographic position of the sites and exposures in the river banks across from the high school indicate that the deposits beneath the sites are mainly coarse-grained (gravelly and cobbly), stratified, well-graded river alluvium. The clasts are well-rounded and of diverse lithologies. Fine-grained surface materials, seen at the high school, are probably flood overbank deposits, perhaps reworked by eolian processes.

The soil series mapped for the upper 5-6 ft by the U.S. Soil Conservation Service (SCS) (Carley and others, 1980) at the high school and middle school are the Steed cobbly loam and the Parlo loam, respectively. The parent material for both soils is alluvium derived mainly from sandstone, quartzite, and limestone. Both are very deep and well drained. The typical Steed cobbly loam profile in Morgan County has a cobbly loam surface layer (classified as GM-GC, GM, SM-SC, or SC in the Unified Soil Classification System; attachment 3) about 8 inches thick and an underlying layer of very gravelly sand (GP, GW) to a depth of 62 inches. In a typical Parlo loam profile, a 19-inch thick loam (CL-ML, CL) surface soil overlies a 12-inch thick loam (CL) subsoil and a very gravelly loamy sand (or sand; GP-GM, GM) substratum to a depth of 70 inches or more. The Steed soil is classified by the SCS as having moderate permeability, moderate erosion hazard, and low shrink-swell potential. The Parlo soil has moderately slow permeability, moderate erosion hazard, and moderate (surface soil) to low (substratum) shrink-swell potential.

Regional shallow ground-water maps indicate an average depth to water of less than 30 feet (Hecker and others, 1987). A water-level contour map of Morgan Valley, reflecting conditions in the fall of 1980 (Gates and others, 1984), indicates that water-table depths at the school sites were approximately 10 to 20 feet. A well about 0.5 mile upstream from the high school along the Weber River indicates an average depth to water of about 23 feet, with maximum seasonal fluctuations of about 10 feet (Gates and others, 1984). Ground water may be even more shallow (less the 10 feet) in low-lying areas close to the Weber River such as at the high school.

GEOLOGIC HAZARDS

Attachments 4 and 5 are summary checklists of the relative likelihood of various geologic hazards at the high school and middle school, respectively. All the hazards considered for this investigation are listed, and those which are believed to exist at the sites are discussed in more detail below. Hazards which should be considered in a soil foundation investigation prior to construction or retrofitting are also noted on attachments 4 and 5.

Earthquakes

Morgan Valley lies within the Intermountain seismic belt, a zone of diffuse seismicity which trends north-south through Utah (Smith and Sbar, 1974; Arabasz and others, 1987). The valley is a structural and topographic basin within the tectonic transition zone between the Basin and Range Province to the west and the relatively stable Middle Rocky Mountains Province to the east.

Morgan Valley is bounded on the east by the Morgan fault, a normal fault that dips beneath the valley and may be a source for large earthquakes (Sullivan and others, 1988). The Morgan fault is thought to have experienced recurrent large surface-faulting earthquakes (estimated maximum magnitude 6.75-7.0) during the late Quaternary (about the last 500,000 years), with an estimated average fault slip rate of 0.01-0.02 mm/yr. Limited data suggest that the average time interval between surface-faulting events (each with ground-surface displacements of 1.7-3.3 feet) is on the order of 25,000-100,000 years. The central section of the Morgan fault has evidence for a surface-faulting event sometime in the last 9,000 years (Sullivan and others, 1988). The fault projects along the east side of the city of Morgan, which is at the break between the central and southern sections (attachment 2).

The Wasatch fault zone, regarded as the eastern boundary of the Basin and Range Province, lies approximately 12 miles east of Morgan. The Wasatch fault zone is significantly more active than the Morgan fault and other Quaternary faults in the region, and has recurrence intervals for magnitude 7.0-7.5 earthquakes of 500 to 4000 years on individual segments of the fault (Machette and others, 1987).

Ground Shaking

The earthquake hazard present at the site with the greatest probability of occurrence is strong ground shaking resulting from either a moderate-size earthquake, which could occur anywhere in the area, or a large earthquake along a known fault, particularly the Morgan fault or one of the northern segments of the Wasatch fault zone. Ground shaking can cause damage or collapse of buildings not designed or constructed to resist the lateral forces of earthquakes.

Three options for design ground motions for the school sites are presented below, based on: 1) probable motions for the largest expected earthquake (most conservative option); 2) motions that have a low probability (10% chance) of being exceeded in 50 years; and, 3) the minimum design motions specified in the Uniform Building Code.

1) A reasonable estimate for the largest expected earthquake near Morgan is a magnitude (Ms) 6.75 to 7.0 event on the Morgan fault, as estimated by Sullivan and others (1988). Using Campbell's (1987) attenuation relation for ground motions in central Utah, an earthquake of this magnitude could produce peak horizontal ground accelerations of 0.35 to 0.52 g (g is the acceleration of gravity, 32.2 ft/sec2) in Morgan, depending on assumptions of soil depths. Although a magnitude 7.0 to 7.5 earthquake on the Wasatch fault zone is a much more likely event, ground-shaking values for such an event would be less than for the postulated Morgan fault earthquake due to the distance and dip direction of the Wasatch fault zone relative to Morgan.

2) Youngs and others (1987) used probabilities of earthquake occurrence from a variety of possible sources in northern Utah to estimate probabilistic values of ground accelerations for the Wasatch Front region, including Morgan Valley. For firm soil sites in the Morgan area, they estimate peak horizontal ground accelerations that have a 10% probability of being exceeded in 50 years to be about 0.23 g. For areas underlain at shallow depths by rock, which may include the Morgan school sites, the corresponding peak acceleration is about 0.27 g. However, these values do not reflect the occurrence of rare large earthquakes on faults within the Wasatch Range, such as the Morgan fault. Values for Morgan would likely be slightly higher if the relatively low, long-term rates of earthquake activity on these faults were incorporated into the analysis.

3) Morgan is in seismic zone 3 of the 1988 Uniform Building Code (UBC). Seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed in each seismic zone. State law requires that design and construction of the proposed school(s) must meet, as a minimum, the seismic design provisions specified in the code for seismic zone 3. Both sites are located on S1 soil types, as specified by the UBC.

The basis for the probabilistic evaluation of Youngs and others (1987) is similar to the basis for the UBC requirements, and the resulting ground shaking values are in agreement with the seismic zone 3 specification for Morgan. Ground-motion values for the largest expected earthquake in Morgan are provided as a conservative option for design motions because the structures are schools, which are regarded as critical facilities. The values (0.35 to 0.52 g) are substantially greater than the probabilistic ground motions calculated by Youngs and others (1987), and construction to UBC seismic zone 4 standards would be required to account for them.

<u>Surface Fault Rupture</u>

The southern section of the Morgan fault projects through Morgan in the vicinity of the high school (Sullivan and others, 1988; attachment 2). Because the fault is buried under young deposits, evidence for its exact location is obscured. Based on the projection of the fault from adjacent bedrock areas where it is exposed, the high school could be in or very near the rupture zone and the middle school may possibly be affected as well. Given the long estimated average recurrence of surface ruptures on the fault (25,000-100,000 years), surface fault rupture is a very low probability event. However, the time since the last event is not known, and it is possible that rupture could occur at any time. Evidence elsewhere along the Morgan fault indicates that the result of surface fault rupture could be offset of the ground surface 1.7-3.3 feet or more, with the east side up relative to the west side. Ground cracking and disturbance are likely in a zone perhaps several hundred feet wide along the surface trace.

Tectonic Subsidence

Tectonic subsidence is the permanent change in ground surface elevation which may accompany surface faulting as one side of the fault drops in relation to the other. It would be particularly hazardous for structures on the downdropped (in this case, the west) side because flooding could result as water from the Weber River floods into the newly formed low-lying areas. If the Morgan fault were to rupture with 1.7-3.3 feet of downdropping of the west side, flooding of unknown extent possible affecting the schools could occur. Such subsidence would have the same recurrence and probability as surface fault rupture on the Morgan fault (once every 25,000-100,000 years), so it also is a very low probability event.

Liquefaction Potential

There is a potential for liquefaction at both sites because of the presence of shallow ground water, alluvial deposits perhaps containing poorly graded sandy layers, and the possibility of strong earthquake ground shaking sufficient to cause liquefaction (Mabey and Youd, 1989). However, because the actual depth to water and soil type (and density) have not been determined, the liquefaction potential is not known.

Slope Failure

Slope failure hazards are low at both school sites because of the flat topography of the terrace surfaces and the position of the sites with respect to the range front. The lack of mapped landslides nearby (Kaliser, 1972; Mullens and Laraway, 1973; Harty, 1990; attachment 2) also indicates that there is a low potential for slope failure at the sites. Possible erosion and shallow slumping may occur along the Weber River if it is allowed to undercut its banks, but this can be controlled with riprap and should not affect the schools.

Problem Soils and Subsidence

Soils in the area are coarse-grained and granular (sand, gravel, and cobbles) with relatively few fines except in uppermost horizons (Carley and others, 1980). The soils have low (high school) and low to moderate (middle school) shrink-swell potential, and moderate erosion hazard. No damage due to shrink-swell of soils was apparent at the middle school, and because soil becomes more coarse grained with lower clay content at depth, it is unlikely that the soil at foundation depths is expansive. Because of the gentle slopes, erosion should not be a problem except along river banks or during floods.

Shallow Ground Water

Shallow ground water is likely present at both sites, and may flood basements or any below-ground facilities. Seasonal fluctuations appear to be about 10 feet or less as indicated in a well upstream, but will vary with irrigation, precipitation, and river level.

Flooding

The high school is above the 100-year flood level, but within the 500-year flood level of the Weber River. The 100-year flood boundary is along the east side of the site (FEMA, 1987). Thus, structures placed east of the high school would likely be in the 100-year flood plain. Although upstream dams reduce flood hazards, the effects of the dams have been considered in the development of the flood hazard boundary maps (FEMA, 1987; James Harvey, oral commun., June 29, 1990). The middle school is above the 500-year flood level and is not in a flood hazard area.

Morgan is located downstream from both Echo and Wanship Dams on the Weber River and Lost Creek Dam on Lost Creek, an upstream tributary of the Weber River (Harty and Christenson, 1988). Dam failure inundation studies by the U.S. Bureau of Reclamation (1983, 1985, 1986) indicate that both schools could potentially be flooded by a sudden failure of any of the three dams. In the case of Wanship Dam, a failure must also cause failure of Echo Dam downstream in order to flood Morgan.

Radon

The generalized radon hazard map of Utah (Sprinkel, 1988) indicates a potential hazard in the Morgan area. The alluvium at the school sites is derived principally from rocks upstream on the Weber River which in general are not uranium-bearing. However, the local volcanic rocks (chiefly the Tertiary Norwood Tuff) have been associated with above-average uranium concentrations and are considered to be radon sources (Sprinkel, 1988). The permeable sediments beneath the school sites may provide favorable conditions for migration of radon gas to the surface, although the shallow ground water in general restricts movement of radon gas though the soil. Measurements in two homes in the Morgan area for the Utah indoor radon survey indicated levels of 2.2 and 5.7 pCi/l (Sprinkel and Solomon, 1990). A level of 4 pCi/l is considered by the Environmental Protection Agency (EPA) and the Utah Bureau of Radiation Control to indicate a potential hazard, and they recommend further testing for levels above 4 pCi/l. Actual levels of radon were not measured at the sites, and indoor concentrations of radon gas are dependent on the type of building construction as well as geologic factors.

CONCLUSIONS AND RECOMMENDATIONS

The high school and middle school sites have similar geologic and hydrologic settings and, except for flood hazards, are subject to similar hazards. Potential hazards recognized at both sites include strong ground shaking from earthquakes, surface fault rupture, tectonic subsidence, liquefaction, flooding from dam failures, shallow ground water, and radon.

The hazard with the highest potential at both sites is strong ground shaking from earthquakes. The results of an analysis (Youngs and others, 1987) of the peak horizontal ground accelerations that have a 10% chance of being exceeded in 50 years at the sites (0.23 and 0.27 g for firm soil and rock, respectively) are consistent with the minimum design ground motions for seismic zone 3 as designated by the 1988 Uniform Building Code. Expected peak horizontal accelerations for the largest expected earthquake near the site (0.35 to 0.52 g for a Ms 7.0 earthquake on the Morgan fault) are substantially greater and would require construction to UBC seismic zone 4 standards.

Two of the hazards identified as possibly present (surface fault rupture and tectonic subsidence) have a very low probability of occurrence but would have serious consequences should they occur. The average time between surface-faulting events on the Morgan fault is very long (25,000 to 100,000 years), but such an event could cause serious damage to buildings and threaten life safety from strong ground shaking, ground rupture through foundations, and flooding. The exact location of the fault and likely rupture zone is not known so a hazard may exist at both sites. From the best available evidence, however, the fault is projected just east of the high school, so the hazard is greatest in the area of the proposed addition. Liquefaction is also a potential hazard at both sites.

Flooding is another hazard that is greatest for buildings east of the high school, although the present buildings at both sites are above the 100-year flood level of the Weber River. Failure of Lost Creek or Echo Dams, or Wanship Dam assuming Echo also fails, could flood both sites.

Radon gas concentrations were not measured at the sites, but the presence of uranium-bearing sediments (the Norwood Tuff) in the vicinity suggests that radon could be a potential problem and measurements elsewhere in Morgan indicate a potential hazard. Because radon concentrations are in part dependent on the type of construction and construction practices, it would be prudent to measure indoor radon concentrations in present buildings to determine if a hazard exists. If so, radon-resistant construction should be incorporated into any new construction. The Utah Bureau of Radiation Control (Department of Health) and EPA provide guidelines for radon testing and mitigation.

Soil and slope failure hazards at both sites are low. As indicated in attachment 4, however, a soil foundation investigation is recommended at the high school to provide site-specific soils information and the engineering data required to design foundations if it is decided to proceed with for the addition. The investigation should address liquefaction potential and shallow ground water as well. If a decision is made to retrofit the middle school, a part of the planning should include an evaluation of liquefaction potential (attachment 5).

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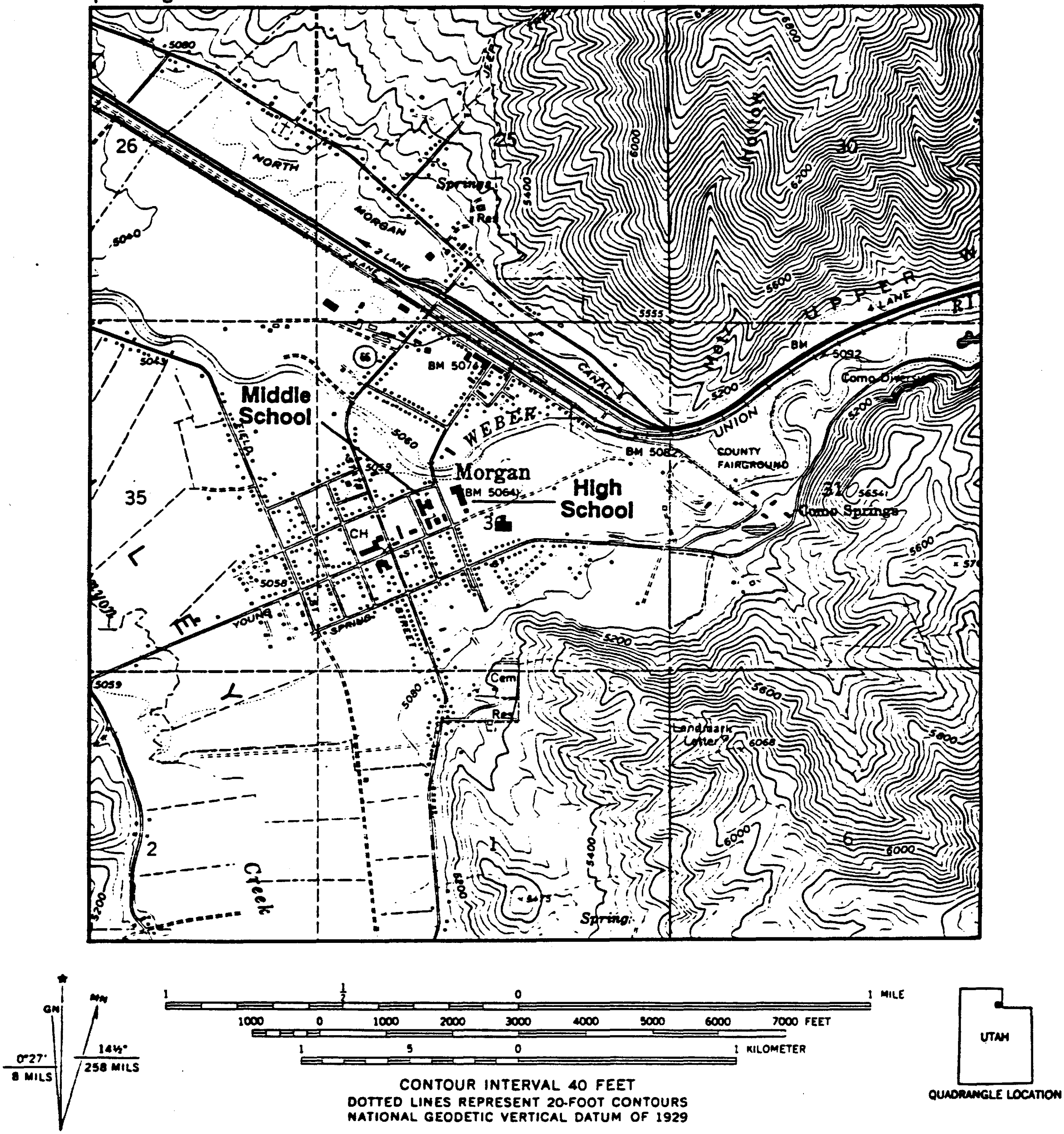
Base Map from
MORGAN, U.S.G.S
7-1/2' topographic
quadrangle.

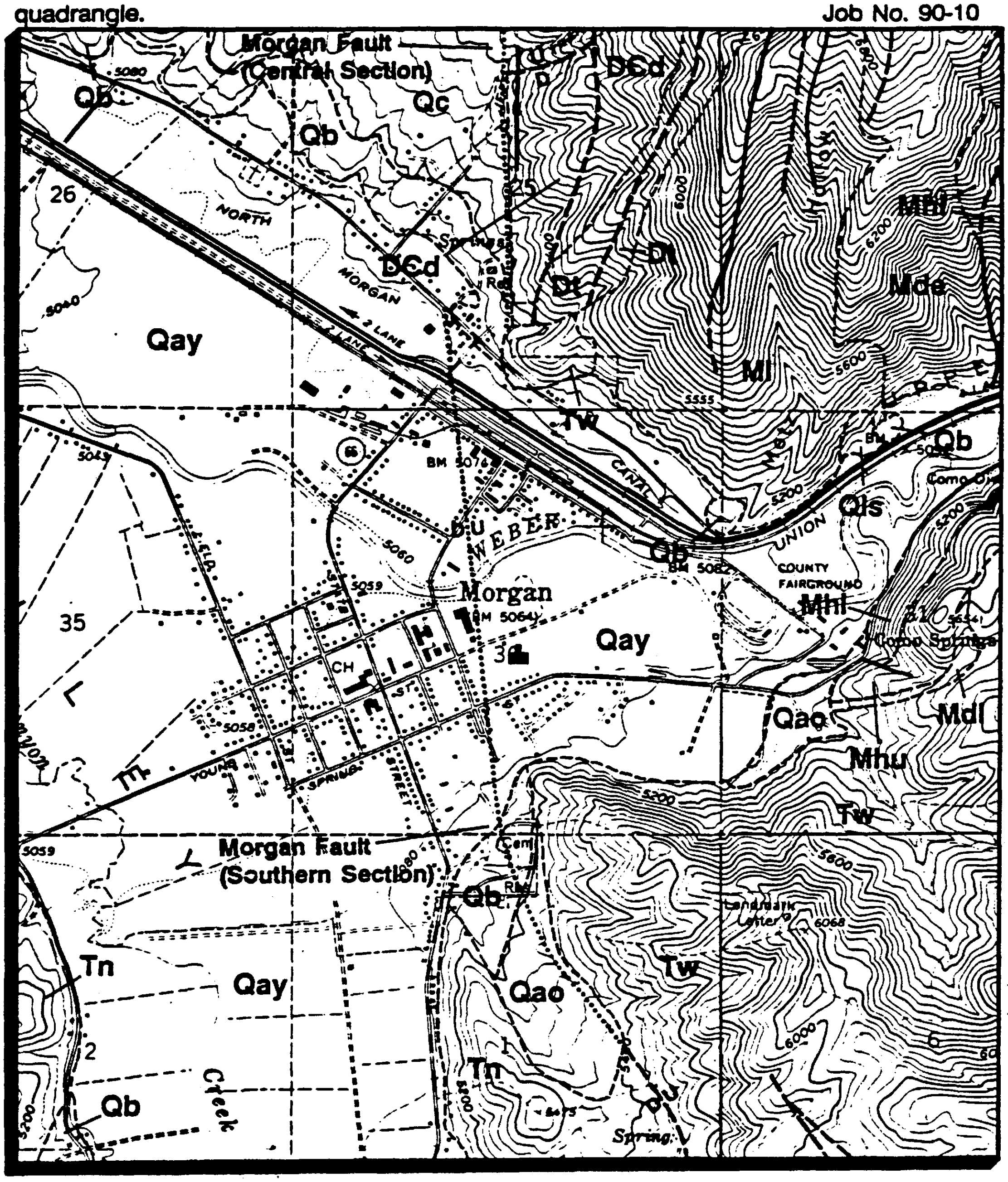
Job No. 90-10



Attachment 1. Location map showing the High School and Middle School in Morgan. The site for the prospective gymnasium and community center is on the east side of the High School.

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

Job No. 90-10



Qay Qc Qls
Qay, *younger alluvium*
Qc, *colluvium*
Qls, *landslide deposits*

Qao
Older alluvium

Qb
Bonneville Formation

Tn
Norwood Tuff

Tw
Wasatch Formation

Mdu Mdl
Doughnut Formation
Mdu, *upper member*
Mdl, *lower member*

Mhu Mhl
Humbug Formation
Mhu, *upper member*
Mhl, *lower member*

Mde
Deseret Limestone

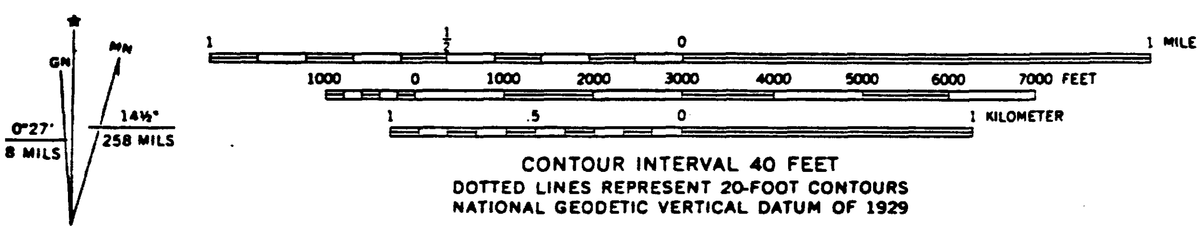
Ml
Lodgepole Limestone

Dt
Three Forks Formation

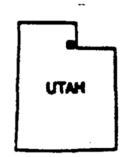
DЄd
Dolomite

U
D
Fault
Dashed where approximately loc
dotted where concealed or infer
U, *upthrown side;* D, *downthrow side*

Contact
Dashed where approximately loc



CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION

Attachment 2. Geologic map of the Morgan area. Modified from Mullens and Laraway (1973) and Sullivan and others (1988).

Attachment 3.
Job No. 90-10

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

* Based on the material passing the 3-in. (75-mm) sieve.

Unified Soils Classification System (USCS)

SUMMARY OF GEOLOGIC HAZARDS
Morgan High School SITE

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

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

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

SUMMARY OF GEOLOGIC HAZARDS
Morgan Middle School SITE

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

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

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

SOLID WASTE DISPOSAL

Project: Proposed Lindsay Hill Mine solid waste disposal site			Requesting Agency: Southwest District Health Department
By: Mike Lowe	Date: 3-23-90	County: Iron	Job No.: (SW-1) 90-04
USGS Quadrangle: Cedar City (239)			

The purpose of this investigation was to make a preliminary evaluation of the potential for ground-water contamination by a proposed solid waste landfill in the abandoned Lindsay Hill Mine, approximately 10 miles west of Cedar City (fig. 1). The investigation was limited to determining if the rock in the open-pit mine is fractured, and if a liner is needed to protect ground water. The scope of this investigation consisted of a literature review and one-hour field investigation of the site on March 9, 1990. Roads providing access into the pit are not maintained, and the field investigation was restricted to viewing the pit from the north rim. Pit walls were visible from the rim, but the bottom was predominantly covered with slope wash and rubble. Bill Dawson (Southwest District Health Department), York Jones (Cedar City resident and employee of Utah International, the former mine owners), and Bill Lund and Susan Olig (UGMS) were present during the field inspection.

The general pit dimensions of the Lindsay Hill Mine are 800 feet by 900 feet by 400 feet deep (Jones, 1989). The walls of the open-pit consist, from west to east, of Tertiary-age quartz monzonite porphyry, replacement deposits of iron ore (mostly hematite with lesser magnetite), the Co-op Creek Member (limestone) of the Jurassic-age Carmel Formation (the Homestake Limestone Member of Mackin and others, 1976), and the Crystal Creek Member (siltstone, sandstone, and shale) of the Carmel Formation (the Entrada Formation of Mackin, 1947; the Banded Member of the Carmel Formation of Mackin and others, 1976) (Hintze, 1988) (fig. 2). The quartz monzonite makes up most of the west wall of the pit. The bottom of the pit and the lower portion of the east wall consist of the Co-op Creek Limestone Member of the Carmel Formation and the remnants of the ore body in the limestone. The Crystal Creek member of the Carmel Formation occurs in the upper portion of the east wall. Both members of the Carmel Formation dip approximately 30 degrees to the east.

All rock units exposed in the open-pit mine are extensively fractured. The spacing and orientation of the fractures is variable. Open east-dipping fractures or bedding planes in the limestone unit could be seen on the south wall. In the vicinity of the Lindsay Hill Mine, the western portion of the Co-op Creek Member is brecciated (Mackin, 1947). Most of the fractures in the monzonite, the only unit which could be viewed at close range, appeared to be more tightly closed than those in the limestone. Origins for the fractures include regional folding, faulting, and emplacement of the Granite Mountain pluton (Mackin, 1947). Mackin and others (1976) map faults along the northwest and southeast margins of the ore body that was mined in the pit.

The fractures in the walls, and presumably the bottom, of the pit

Job No. 90-04
Applied Geology Program

Base map from Cedar City NW, U.S.G.S. 7-½' topographic quadrangle.

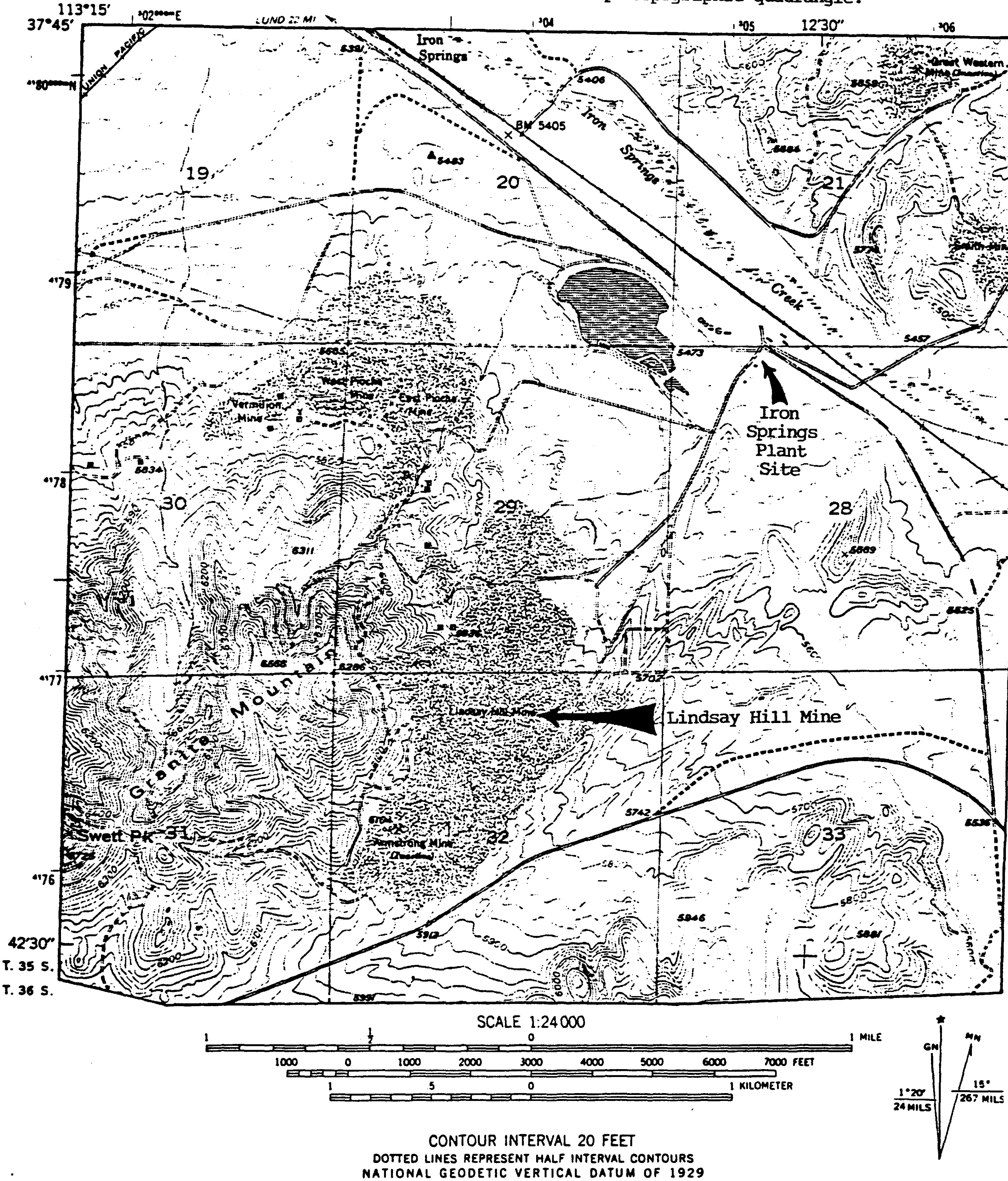


Figure 1. Location map for Lindsay Hill Mine.

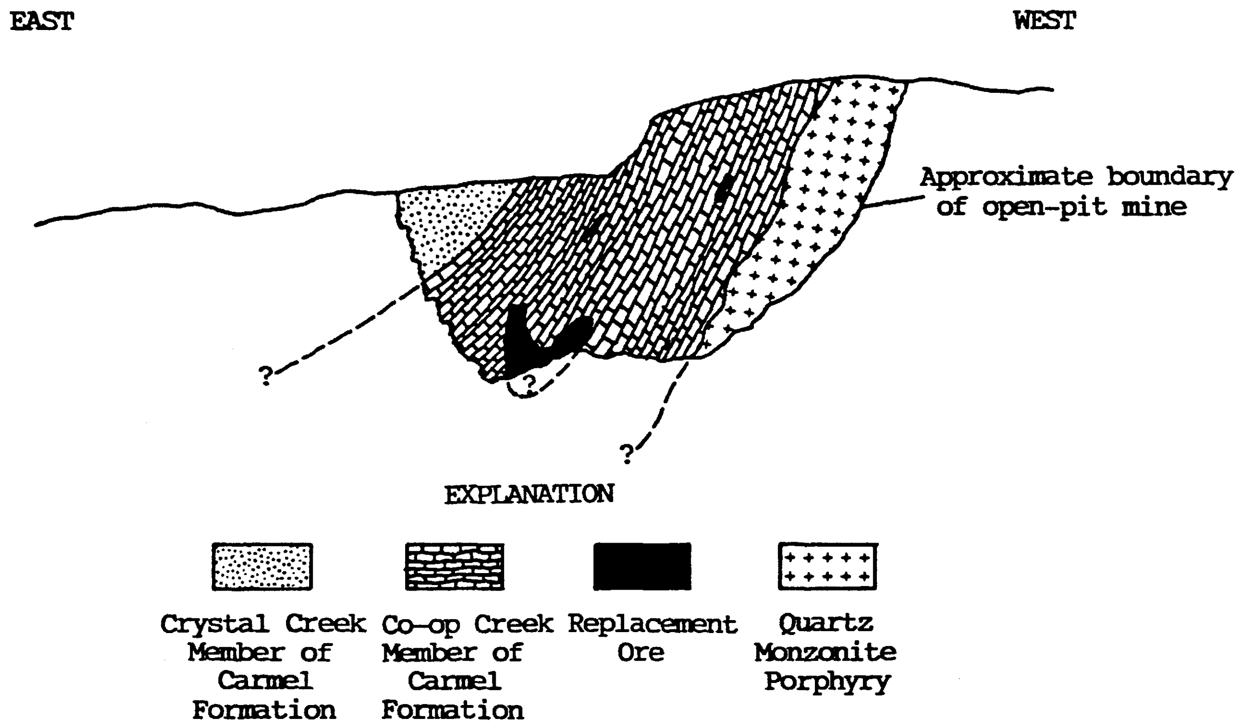


Figure 2. Diagrammatic map showing geologic units exposed in south wall of Lindsay Hill Mine.

could conduct water laterally and vertically away from the pit. Little is known of the aquifer characteristics of the rock units exposed in the pit, however, none of these units are reported to yield water in the Cedar Valley area (Bjorklund and others, 1978). No water was present in the pit and there was no evidence of ground-water seepage at the time of the investigation, indicating either that the floor is permeable or evaporation rates are higher than ground-water seepage, if any, and precipitation. The field investigation was conducted in the winter when precipitation is high and evaporation low. In any case, the possibility that water entering the pit, or leachate formed if solid waste is disposed in the pit, could infiltrate into and contaminate ground water in potential rock aquifers beneath the pit cannot be precluded.

The degree to which the contamination of ground water in bedrock aquifers is of concern with respect to using the pit as a landfill is a function of local ground-water conditions and the potential for contamination of adjacent alluvial aquifers. Regional ground-water maps (Bjorklund and others, 1978) indicate that primary recharge to Cedar Valley occurs from the east, and that ground-water flow is generally to the northwest across Cedar Valley and into Escalante Valley through Iron Springs Gap north of the Lindsay Mine. The mine is located in the Granite Mountain uplands to the west and south of alluvial aquifers in Cedar Valley and Iron Springs Gap. The amount of recharge to alluvial aquifers occurring from the mine is unknown, but is probably not great compared to that coming from the east. No evidence of springs in the Lindsay Hill Mine were noted during the field inspection. "The water table at the Iron Springs Plant Site is about 5,440, and the Pit elevation is 5,850 down to 5,450" (Jones, 1989). The Iron Springs Plant Site is about one mile northeast of the pit and close to Iron Springs Creek, which has an elevation of 5,420 feet in the vicinity of the plant. Iron Springs Creek is a gaining stream primarily fed by ground water from western Cedar Valley; the stream is thus a good indicator of the depth to shallow ground water in the alluvial aquifer because the stream originates from springs located where the water table intercepts the ground surface. This information indicates that the elevation of the water table in the vicinity of the pit is not significantly higher, and may be lower, than in western Cedar Valley or at the Iron Springs Plant Site. Because the depth to ground water at the pit and degree of interconnection between bedrock and alluvial aquifers in the area are not known, the direction (and rate) of ground-water flow and potential for contamination of nearby aquifers are not known.

Other areas of concern regarding use of the pit for a landfill that were noted during the field inspection included problems presented by the steep walls of the pit and evidence for surface drainage into the pit. Because the walls of the pit are near vertical, lining would be difficult. These steep walls also present a hazard to pit operators and users from rock falls, and access roads to the pit would likely be treacherous. Rills due to erosion from surface-water flow were noted on the south wall of the pit, and this flow had caused deposition of several small alluvial fans in the pit. The probable source of the water is runoff during rainstorms from Granite Mountain to the west. In order to help keep water out of landfill, drainage diversion would need to be provided.

In conclusion, the bedrock walls of the Lindsay Hill Mine pit are extensively fractured, and it is likely that rock in the bottom of the pit is similarly fractured. These fractures could conduct leachate, if formed, into ground water in bedrock aquifers beneath the pit. To help protect the potential aquifers, it would be prudent to line the pit if it is to be used as a solid waste disposal site. The threat posed to adjacent alluvial aquifers by any contaminated ground water beneath the pit is not known. A thorough hydrogeologic study would be required to answer this question.

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GEOLOGIC HAZARDS

Project:	Requesting Agency:
Inspection of new Quail Creek dike cutoff trench	Division of Water Rights, Office of Dam Safety

By:	Date:	County:	Job No.:
William Lund Suzanne Hecker	2-1-90	Washington	(GH-1) 90-02

USGS Quadrangle:
St. George NE (78)

At the request of the Utah Division of Water Rights, Office of Dam Safety, we (WRL & SH) made an inspection of the geology exposed in the cutoff trench excavated for the new Quail Creek dike in Washington County. We were accompanied on the inspection by Chad Gourley, a geologist in the Office of Dam Safety.

The cutoff trench is approximately 2100 feet long and 80 feet deep at its deepest point. The upper part of the excavation descends by a series of benches to a floor into which a slot trench is being excavated with a trenching machine. The slot trench is about 32 inches wide and up to 28 feet deep with vertical walls. Due to unforseen construction delays, the westernmost five to six hundred feet of the slot trench had not been excavated at the time of our inspection. In addition, heavy equipment and crews using high-pressure air and water hoses to clean the trench walls prevented access to the lowest part of approximately the eastern half of the cutoff trench. We were able to access the slot trench near station 11+00 and spoke with two geologists employed by Morrison-Knudson Engineers, Inc. (the design engineers) who were making a log of the trench wall. We also had access to the upper, benched portion of the excavation. The inspection took about three hours to complete.

The Quail Creek dike cutoff trench extends in an approximately east-west direction across the east flank of the north-south trending Virgin anticline. Rocks exposed in the trench belong to the Shnabkaib member of the Triassic Moenkopi Formation. The results of a detailed petrographic study made of the rocks in the foundation area of the dike are presented in Appendix C of the Independent Review Team's report on the "Investigation of the Cause of the Quail Creek Dike Failure" (available in the UGMS library). However, in general the rocks consist of thin to medium bedded, gypsiferous shale, mudstone, siltstone, and dolomite. The gypsum is present both as fillings along bedding planes and joints, and as microcrystalline cement within the rocks. The bedding strikes roughly north-south (normal to the trend of the dike), and dips to the east at low to moderate angles. The angle of dip progressively increases toward the left (east) abutment of the dike.

The following geologic features of possible concern to the construction of the Quail Creek dike were noted during the inspection:

1. Open joints, some up to several tens of feet long and locally more than an inch wide. One joint was probed to a depth of about 20 inches. The majority of open joints were observed between about stations 3+00 and 6+00, which is roughly the area where the original dike breached.

2. Numerous closed joints throughout the trench that are commonly filled with gypsum.

3. Many bedding planes along which beds of gypsum, up to and inch or more thick, had accumulated. Near the ground surface, some bedding planes are open or only partially filled with gypsum.

4. Several small normal-slip faults (down-to-the-east) in the western and central parts of the trench. Zones of intense rock fracturing associated with these faults range from a few inches to several feet wide. The zones of fractured rock are commonly weathered, and quite soft and punky.

5. Areas of soft (punky or clayey) rock, usually localized along faults, cracks, joints, or bedding planes. These areas of soft rock were found at all levels within the cutoff trench, and appear to be the result of dissolution of gypsum cement within the rock.

6. Small, localized water seeps, usually along bedding planes.

7. Small, localized petroleum seeps along bedding planes in the slot trench near station 11+00. A strong odor of H_2S gas pervaded the slot trench in the vicinity of the petroleum seeps. Thin, discontinuous stringers of a soft, yellow mineral (elemental sulphur?) were noted in the walls of the slot trench near the petroleum seeps.

8. A thin, red, highly fractured and possibly porous siltstone bed that extends from the ground surface near station 4+50 to the bottom of the trench near station 3+25.

The failure of the first Quail Creek dike has been attributed to seepage and piping beneath and through the original structure. That seepage was most likely localized along open joints and bedding planes. As noted above, similar features were recognized in the present cutoff trench. The petroleum seeps, H_2S gas, and possible elemental sulphur are conditions not previously noted in excavations at the site. The potential reactivity of these materials with the cement used to fill the slot trench and construct the dike needs to be considered.

It is our opinion following the inspection of the cutoff trench that the geologic features listed above, while not necessarily barriers to construction of the new Quail Creek dike, must be carefully considered in the final design of the structure and appropriately mitigated to prevent future problems. We realize that the schedule for constructing the dike is tight, but we believe it would be beneficial to have an official inspection of the completed and cleaned cutoff trench made by all parties involved in the design, construction, and final approval of the new Quail Creek dike. That inspection could best be led by the Morrison-Knudson geologists who logged the trench and are the most familiar with its geology. Further, we believe it would be particularly appropriate to have the members of the Independent Review Team present at that inspection so they can evaluate the foundation geology for themselves and provide input to the final design process.

Project: Second UGMS inspection of the new Quail Creek Dike cutoff trench			Requesting Agency: Division of Water Rights, Office of Dam Safety
By: William Lund, Susan Olig, Mike Lowe	Date: 3-14-90	County: Washington	Job No.: (GH-2) 90-03
USGS Quadrangle: St. George NE (78)			

At the invitation of the Utah Division of Water Rights, Office of Dam Safety, a second inspection was made on March 10, 1990 of the geology exposed in the cutoff trench excavated for the new Quail Creek Dike in Washington County. The first inspection was made by William Lund and Suzanne Hecker on January 31, 1990, prior to the cleaning of the trench walls and during a phase of construction that limited access to many areas of the cutoff excavation (see memo of February 1, 1990 to MLA). At the time of the second inspection, both the up- and downstream faces of the cutoff trench had been cleaned, as had the ground surface beneath the footprint of the dam on the downstream side of the excavation. The entire cutoff trench was accessible except for the slot trench in the bottom of the excavation, which had been filled with concrete since the time of the first inspection. We were accompanied during the inspection by Rick Hall and Chad Gorley of the Office of Dam Safety, and by Chuck Payton and Eric Rennat, geologists for Morrison-Knudson Engineers, Inc. (the design engineers) who were in the process of mapping the cutoff trench at the time of our visit.

The cleaning of the cutoff trench walls provided a much clearer view of those features identified during the first inspection (open and closed joints, faults and shears, zones of soft rock, water seeps, secondary gypsum along joints and bedding planes, and stringers of elemental sulphur) as being of concern to the construction of a water-retention facility at the Quail Creek site (see memo of January 31, 1990). The oil seeps previously observed in the slot trench (now filled with concrete) were no longer visible, but H_2S gas could still be smelled in some areas of the excavation and could be seen bubbling up through puddles of water in the bottom of the cutoff trench. The H_2S gas was noted primarily in an area of the trench (about station 4+50) where a spring in the bottom of the excavation was flowing at an estimated rate of 5 to 10 gpm. It is our understanding that an attempt was made to grout the spring, but without success.

A second spring discharging about 2 gpm was discovered issuing from an open joint at station 5+00 in the south (downstream) wall of the cutoff trench about 20 feet above the floor of the excavation. According to Mr. Payton, the spring was not there two days earlier when that area of the trench was mapped. The Washington Water Conservancy District is filling Quail Creek Reservoir to the extent permitted by the dike construction in order to store water for the upcoming irrigation season. Because of the topography in the reservoir basin, the water in the reservoir was not yet approaching the construction site on the day of our inspection, but the level of the water in the reservoir was about 20 feet above the bottom of the cutoff trench (C. Payton, oral communication). Mr. Payton attributed the appearance of the new spring to the rising level of the reservoir. Since no other source of water exists on the downstream side of the cutoff trench, Mr. Payton's explanation seems reasonable. For the water to appear high on the south trench wall, it would be necessary for a flow path (open joint or bedding plane) to extend from the reservoir (several hundred yards distant) to beneath the cutoff trench, and presumably below the concrete-filled slot trench, along which the water migrates until a pathway (an open joint or shear) to the surface is encountered. The water then rises under the pressure of the reservoir head until it daylights in the cutoff trench.

A second observation of significance during this inspection was the discovery by workmen of a large solution channel in the north (upstream) wall of the cutoff trench. The channel was at about station 7+50 and approximately 20 feet below the top of the trench. It was a foot or more in diameter and extended 40 feet horizontally toward the reservoir. The channel appears to be localized along the intersection of two large joints. We believe it is important to note that the large spring in the bottom of the cutoff trench, the small spring on the south wall of the trench, and the solution channel in the north wall all occur in relatively close proximity to one another (within a few hundred feet) in the general area where the original dike failed. This is also the area of the cutoff trench where the largest and most continuous open joints were observed.

Two high-angle reverse faults, both dipping to the east, were clearly exposed by the cleaning in the north wall of the trench at about stations 10+50 and 11+00. West of the faults, the rock exposed in the trench walls was highly deformed, exhibiting numerous small anticlines, synclines, normal and reverse faults, and steeply dipping beds. The trench is shallow in this area (4 to 6 feet) and the final height of the dike will be less than 10 feet. Therefore, the deformation in this part of the trench is probably of little consequence to the stability of the structure, but Mr. Payton indicated that the original dike did leak in this area.

Probably the single most striking feature revealed by the cleaning of the trench walls was the large amount of secondary gypsum present along bedding planes and joints in the rock exposed in the cutoff trench. These layers are continuous and often closely spaced. Gypsum was particularly abundant at the east end of the trench from about stations 1+00 to 4+00, but was evident throughout the excavation. In many areas, layers of gypsum along bedding planes are up to an inch thick. It is understood that the high percentage of gypsum in the rock at the Quail Creek site has been recognized and efforts are being made to accommodate it in the design of the dike. Nevertheless, the shear volume of this potentially soluble and easily erodible mineral in the foundation of the dike is cause for great concern, especially considering the recent appearance of the spring in the cutoff trench wall before any water has been impounded directly behind the dike.

The results of the second inspection of the Quail Creek Dike cutoff trench show that open, continuous conduits (joints, shears, and bedding planes) exist in and beneath the dike foundation, and that it is possible, even with a concrete-filled slot trench, for water from the reservoir to find its way directly to the dike foundation. It is considered probable that other, as yet undetected, conduits will also convey water to and beneath the dike foundation once the dike is complete and water is impounded behind it. For that reason, we recommended that consideration be given to a grouting program on the upstream side of the cutoff trench prior to construction of the dike to seal as many potential conduits as possible. Isolating the gypsum-rich foundation rocks from flowing water would reduce the amount of dissolution and erosion that could take place. Grouting prior to the dike construction would allow better access to the dike foundation, both for the grouting and for packer tests to evaluate the effectiveness of the program. The geologic logs of the trench walls prepared by the Morrison-Knudson geologists could be used to identify critical areas along the dike alignment requiring special attention during the grouting program; although the vicinity of the two springs and the zone of open joints at the east end of the cutoff trench are clearly two areas of particular concern.

Project:			Requesting Agency:
Geologic hazards investigation of a proposed 1.5-2.0 million-gallon water tank site, Ephraim Canyon, Sanpete County, Utah			City of Ephraim
By: Kimm M. Harty	Date: 6-26-90	County: Sanpete	Job No.: (GH-3) 90-08
USGS Quadrangle: Ephraim (759), Danish Knoll (758)			

INTRODUCTION

At the request of Alan Grindstaff, City Administrator for Ephraim City, the Utah Geological and Mineral Survey performed a geologic hazards investigation of a proposed site for a buried 1.5-2.0 million-gallon concrete water tank to be constructed in Ephraim Canyon. The primary use of the water tank will be for storage of culinary water; a secondary use will be for hydro-electric power generation. The proposed site is in the southern half of section 17, T. 17 S., R.4 E., Salt Lake Baseline and Meridian, and is approximately 3 miles up Ephraim Canyon (attachment 1). The site is accessible via State Road 29, the main road through the canyon. The scope of work included a review of pertinent maps and literature, and a field reconnaissance on June 4, 1990. Alan Grindstaff was present during the field inspection. No subsurface excavation was performed for this investigation and it does not preclude the necessity for a standard soil investigation to provide engineering data for foundation design. For maximum efficiency, economy, and safety, this report should be made available to engineers involved in site design and construction.

SETTING AND SITE DESCRIPTION

The proposed water tank site is on U.S. Forest Service land, on a flat-topped bedrock ridge trending roughly north-south into Ephraim Canyon (attachment 1). The site is nearly 700 feet above Cottonwood Creek, the main drainage in Ephraim Canyon. The surface of the ridge dips northward toward Cottonwood Creek, with slopes atop the ridge ranging from nearly flat to about 26 percent (14 degrees). The site is at approximately 8240 feet elevation, and is within a few hundred feet of a buried, 12-inch diameter aqueduct that currently supplies the city of Ephraim with culinary water (attachment 1). Most of the ridge surface is covered by vegetation (grasses) and forest (pine, aspen trees). However, a large portion of the ground surface north of the aqueduct is only sparsely vegetated following construction of a water collection box in 1984.

GEOLOGY

A detailed geologic map of Ephraim Canyon shows the ridge to be mainly Cretaceous-Tertiary-age North Horn Formation (Baum and Fleming, 1989) (attachment 2). In this area, the North Horn Formation consists of cemented sandstone, mudstone, and shale. The upper contact of the North Horn Formation is gradational with the overlying Tertiary-age Flagstaff Limestone, composed of limestone interbedded with claystone. The top of the ridge is weathered bedrock mantle and colluvium likely derived from the North Horn Formation. The material is primarily derived from the North Horn Formation. The material is primarily weathered gray shale containing numerous angular cobble-sized clasts. The surface of the disturbed area shows a pattern of polygonal desiccation cracks, characteristic of materials with a high clay content. Baum and Fleming (1989) show the surface of the ridge to be covered by "Qc", a generally poorly sorted, unstratified, and unconsolidated mixture of boulder, cobble, and pebble-sized sandstone and limestone clasts in a matrix of sandy or silty clay (attachment 2). This unit ranges in thickness from about 3 to 30 feet (Baum and Fleming, 1989), but its thickness on the ridge is unknown.

Ephraim Canyon is cut by a series of north-trending normal faults and bedding dips toward the west (attachment 2; Baum and Fleming, 1989). The dip of bedding at the proposed site could not be determined due to the lack of outcrops. However, it is likely that the bedrock here also dips about 15-20 degrees toward the west.

Depth to ground water at the proposed site is unknown, but the static water table is likely deep beneath the ridge, and is below the foundation level of the proposed water tank. Perched water may exist at the site. No seeps or springs were observed in the ridge vicinity, and none are shown on topographic maps of the area.

GEOLOGIC HAZARDS

Attachment 3 is a summary checklist of potential geologic hazards at the site. All hazards that were considered are shown, and all those that are believed to exist at or near the site are discussed further below. Hazards that need to be considered in the soils foundation investigation for the site are also noted on attachment 3.

Earthquake Hazards

Like many cities in Utah, the Ephraim area lies along the Intermountain seismic belt (ISB), a generally north-south trending zone of active seismicity that traverses the central part of the state. Associated with the ISB have been a number of moderate-sized earthquakes (magnitudes 4.0 - 6.0 in the Ephraim region in historical time (1850-present) (Arabasz and others, 1979). The closest large earthquake (magnitude about 6.5) occurred approximately 50 miles to the southwest, in the Richfield area in 1901.

There are no known active faults (those which have ruptured the surface within the last 2 million years) in Ephraim Canyon. However, several potentially active fault zones which could be source areas for future earthquake activity have been identified within 20 miles of the water tank site. The closest is the Snow Lake fault zone atop the Wasatch Plateau about 4 miles east of the water tank site (attachment 4). Although this fault has not been studied in detail, topographic and morphologic evidence suggest this fault may have experienced movement in Holocene time (within the last 10,000 years) (Foley and others, 1986, in Hecker, 1990). Farther east, about 10 miles from the water tank site, the Joes Valley fault zone trends north-south through the Wasatch Plateau (attachment 4). This fault zone has been studied by the Bureau of Reclamation (Foley and others, 1986), who estimates that several of the faults within the zone may have ruptured in Holocene time. Foley and others (1986) suggest this fault zone could be associated with earthquakes as large as magnitude 7.5, which are believed to occur about once every 10,000-20,000 years on many of the faults in the Joes Valley fault zone (Foley and others, 1986, in Hecker, 1990). About 10 miles west of the water tank site, the Gunnison fault trends north-south along the base of the San Pitch Mountains (attachment 4). Like the Snow Lake and Joes Valley fault zones, Holocene movement is also suspected on this fault (Hecker, 1990). The southernmost segment of the Wasatch fault zone is about 17 miles west-southwest of the water tank site (attachment 4). This fault segment is believed to be capable of generating earthquakes up to magnitude 7.5, and probably last moved about 10,000-15,000 years ago (Machette and others, 1987).

Ground Shaking

The greatest earthquake hazard at the site is ground shaking resulting from either a moderate-sized earthquake, which could occur anywhere in the area, or from a large earthquake along a known fault. Seismic waves are generated at the earthquake source, travel through the earth, and cause ground shaking at the earth's surface. Ground shaking from a large earthquake in the Ephraim vicinity could damage the tank or rupture associated waterline connections. Two levels of design ground motions for the site are outlined below based on: 1) probabilistic motions that have a 1 in 10 chance of being exceeded in a 250-year period (most conservative), 2) the minimum design motions specified in the 1988 Uniform Building Code (UBC) (least conservative). Under level 1 at the proposed site, a peak ground acceleration on rock of 0.5 g has a 1 in 10 chance of being exceeded in a 250-year period (NEHRP, 1988). This figure approximates the probable maximum acceleration that the site may experience. Under level 2, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. These standards are based on design ground motions with a 1 in 10 chance of being exceeded in 50 years. The proposed water tank site is approximately on the gradational boundary between Uniform Building Code (UBC) seismic zones 2B and 3. For zone 2B, a Z factor of 0.2 is required in design calculations. This effectively corresponds to a peak ground acceleration of 0.2 g. For seismic zone 3, the Z-factor value is 0.3, effectively corresponding to a peak ground acceleration on rock of 0.3 g. The site is on rock and has an S-1 soil type as specified in the UBC (1988 edition). This factor takes into account the effects of soils on ground motions caused by earthquakes.

Other Earthquake Hazards

Although there are four known potentially active faults within 20 miles of the proposed site, none is close enough to present a surface faulting hazard. The hazard from tectonic subsidence is very low. The liquefaction hazard at the site is likely very low due to the near-surface presence of bedrock in the area, and the probable lack of ground water near the surface. Slope stability is addressed in the following section of this report.

Slope Failures

Landslides (for example, slumps and earth flows) and debris flows are the most commonly occurring geologic hazards in Ephraim Canyon. During the "wet years" of 1982-1986, numerous landslides and debris flows caused extensive damage to the main canyon road, aqueducts, hydroelectric plant, and various other structures in Ephraim Canyon (Lund, 1986; Baum and Fleming, 1989). Throughout the Wasatch Plateau area of central Utah, landslides are common in the North Horn Formation, which is very prone to sliding because it weathers rapidly, has a high clay content, is only semi-unconsolidated, and has a relatively low shear strength. Landslides commonly occur at the contact between the North Horn and overlying formations, but also within the formation itself. Debris flows generally form on steep slopes in surficial colluvium or weathered rock. The North Horn Formation occurs throughout Ephraim Canyon, and it is estimated that about 60 percent of the canyon is covered with landslide and debris-flow deposits (Baum and Fleming, 1989). It is also suspected that the Flagstaff and Colton Formations, both of which contain claystone layers, also fail and produce landslides in Ephraim Canyon.

Attachment 2 shows the distribution of landslides and debris flows in the vicinity of the proposed water tank site. Slope-failure deposits of varying ages surround the ridge on its west, north, and east sides. Deposits labeled Ql_2 or Qd_2 are landslides and debris flows that occurred between 1983-1986, during the wet years (Baum and Fleming, 1989) (attachment 2). Those labeled Ql_1 are older landslide deposits. The east flank of the ridge is bordered by an older, large landslide that is about 1 1/2 miles in length, with an average slope of 13 percent. The age of this slide is not known. Like many large landslides in Utah, it may have initially moved thousands of years ago, during the late Pleistocene or early Holocene. However, its hummocky appearance and numerous ponds suggest the slide may have been active more recently. The closest, most recently active landslides are at the west base of the ridge (attachment 2). A recent debris-flow deposit can be seen on the ridge slope near the aqueduct. It formed on a 60 percent slope about 200 feet below the elevation of the ridge top, in the North Horn Formation. A recent slump deposit, formed on an older landslide, can be seen to the north of this debris-flow deposit. Approximately 1 1/4 miles west of the proposed water tank site is the Majors Flat landslide (not shown on map) that in 1984 ruptured the aqueduct.

The landslides surrounding the ridge slopes could experience rejuvenated movement in the future. The inherently weak, clay-rich geologic formations in the area are highly susceptible to landslides, especially during periods of increased precipitation. Strong earthquake ground shaking could also initiate landslides in Ephraim Canyon. Additionally, the steep slopes (up to 90 percent in some areas) below the ridge are especially conducive to the continued production of debris flows. Baum and Fleming (1989) report that some of the "Qc" (colluvium, slope wash, etc.) on the map (attachment 2) may actually be landslide deposits. Most of the ridge surface is designated as "Qc", but no landslides were noted on this surface during the investigation.

Problem Soil

Alternating wetting and drying of soil containing a high percentage of clay, especially sodium-rich clay, can cause soil to expand and contract. Volumetric changes associated with expansive soil can cause foundations to shift or crack. High clay content soil is present at the proposed water tank site, and may be found at the foundation level of the tank. As most of the area is forested, infiltration capacity of the soil is generally good. However, erosion could occur at the water tank site if surface runoff from State Road 29 is allowed to drain downslope toward the water tank site. Erosion could occur in areas where construction of the water tank necessitates removal of vegetation.

Flooding

Flood hazards at the proposed site are low. There are no stream channels on the ridge surface. There is a lake about 1/2 mile south-southwest of the proposed site, at the Lake Hill Campground (attachments 1 and 2). Although this lake is upslope of the site, and is also on the same ridge, any floodwaters from the lake would drain off the ridge in a northwesterly direction, in the area immediately adjacent to the lake. The site could experience minor flooding from surface runoff during intense rainstorms.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the site which would make the site unsuitable for construction of the water tank. However, some hazards exist which could affect the water tank or associated workings in the future. These hazards are summarized below, and on attachment 3.

The hazard with the greatest potential of occurring at the site is earthquake ground shaking. Information for two earthquake-resistant design options is presented: 1) probabilistic peak horizontal ground acceleration of about 0.5 g that has a 10 percent chance of exceedence in 250 years, and 2) the minimum design ground motions for seismic zones 2B and 3 as designated by the UBC. Although the ground motions in the first option have a low probability of occurring, the city must be aware that such ground shaking from a large earthquake could occur at any time. Under option 2, the Ephraim area is on the boundary between UBC seismic zones 2B and 3, and it is recommended that at least ground motion-levels expected for seismic zone 3 be used in the design of the structure. The hazards from fault rupture, tectonic subsidence, and liquefaction at the proposed water tank site are low.

Landslides and debris flows probably will not affect the water tank, but may affect water lines. The site itself is on a relatively flat, stable surface away from the ridge slopes. However, lines which transport water to and from the tank traverse known landslides as well as the steep ridge slopes, and have ruptured in the past due to landslide movement. According to Alan Grindstaff, nearly 100 percent of the aqueduct route is inspected yearly for leaks or other problems. It is recommended that the water tank and associated connection routes also be inspected regularly, to guard against leaks that could cause slope instability on the ridge.

A standard soil foundation investigation is recommended to provide engineering data required to design the water tank foundation. Expansive soils may exist at the site, and the presence or absence of these soils should be assessed in the soil foundation report. Potential erosion can be avoided by ensuring that runoff from State Road 29 is directed away from the water tank. After completion of the water tank, re-establishing vegetation at the site, as coordinated with the U.S. Forest Service, is also recommended to lessen the potential for erosion. The depth to ground water is unknown, although it is believed to be considerably deeper than the foundation of the water tank. It is possible however, that perched ground water could exist beneath the site. The presence or absence of shallow perched ground water at the site should be considered in the soil foundation report.

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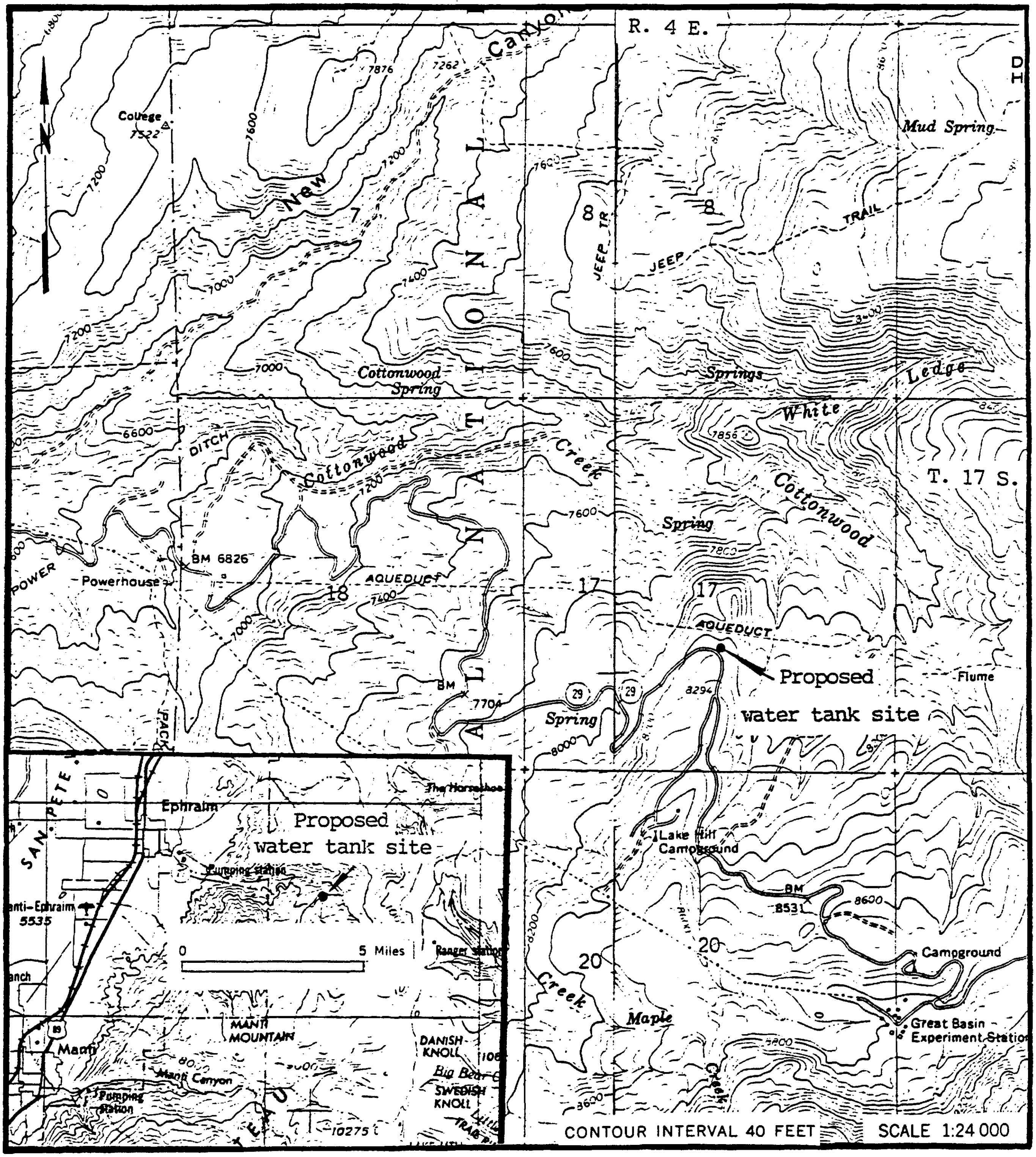
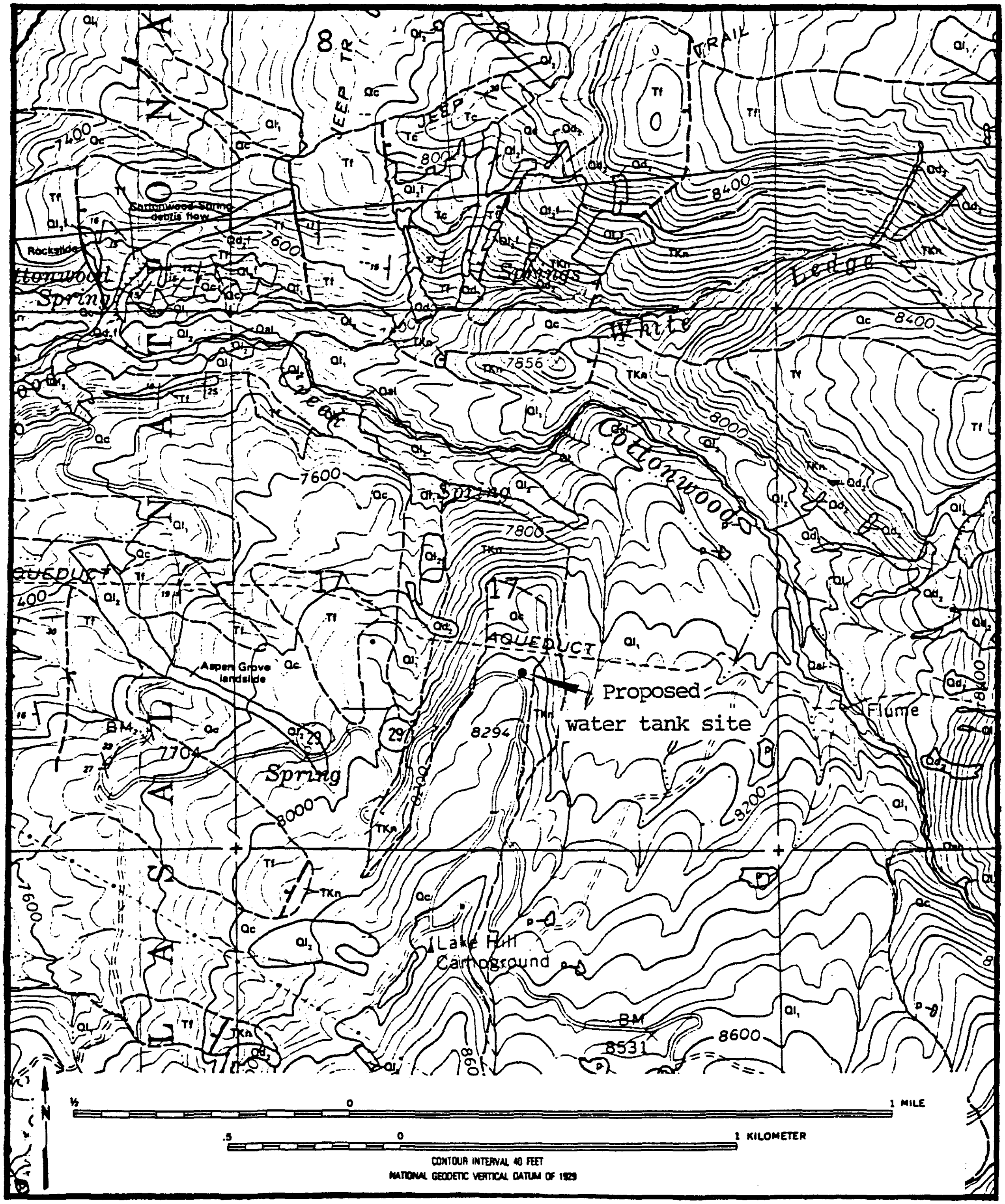
Attachment No. 1, Job No. 90-08



Map showing location of proposed water tank site.
(Base map from USGS 7 1/2-minute topographic maps Ephraim and Danish Knoll)



Geologic map showing proposed water tank site (Baum and Fleming, 1989).
See explanation, next page.

Explanation to accompany attachment 2.

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Ql_2 **1983–1986 landslide deposits, undivided**—Brown, reddish-brown, and gray, unconsolidated, unsorted debris: boulder-, cobble-, and pebble-sized clasts of limestone and sandstone, supported by a matrix of sandy clay. Deposits made by earthflows, slumps, and similar landslides that occurred in pre-1983 landslide debris sometime between 1983 and 1986. Surfaces of deposits cracked and deformed. Heads of landslides slope gently, bodies slope parallel to neighboring ground, and toes slope more steeply than neighboring ground. Thickness as much as 30 m

Ql_2f **1983–1986 landslide deposits, first-time failures**—Deposits made by rockslides and earthflows that occurred in previously unfailed materials between 1983 and 1986. Gray or reddish-brown porous rubble consisting of blocks and cobble- and pebble-sized clasts mixed with clay. Upper parts of deposits clast supported, lower parts matrix supported. Earthflow deposits resemble those of Ql_2 in lithology, color, and texture. Thickness as much as 15 m. Locally includes areas of bedrock exposed in headscarps of rockslides

Qd_2 **1983–1986 debris flow deposits**—Brown, unconsolidated, unsorted, unstratified debris; angular boulder-, cobble-, and pebble-sized clasts of limestone and sandstone in matrix of sandy or silty clay. Deposits left by debris flows that were active between 1983 and 1986. Deposits form long, narrow strips in and adjacent to gullies on steep slopes. Thickness as much as 3 m

Qd_2f **1983–1986 debris flow deposits, first-time failures**—Brown, unconsolidated, unstratified, unsorted debris; angular boulder-, cobble-, and pebble-sized clasts of limestone and sandstone in matrix of sandy clay or silty clay. Primarily matrix supported. Unit was deposited by debris flows during 1983–1986. Flows mobilized from bedrock or weathered bedrock that had not previously failed and moved downslope. Thickness less than 10 m

Qal **Alluvium**—Brown, sorted, stratified, unconsolidated deposits of clay, silt, sand, pebbles, cobbles, and boulders. Alluvium occurs in and adjacent to channels of Ephraim Creek and its tributaries. Upper few decimeters of terrace deposits commonly weathered to dark brown. Thickness as much as 5 m

Qc **Colluvium, residuum, and slope wash, undifferentiated**—Poorly sorted, unstratified or locally stratified, unconsolidated deposits of boulder-, cobble-, and pebble-sized clasts of limestone and sandstone in a gray or brown matrix of sandy or silty clay. Upper few decimeters commonly brown or dark brown topsoil. Material derived from local bedrock and transported downslope by gravity or sheet flow. Includes talus deposit (SE1/4 sec. 9, T. 17 S., R. 4 E.) at base of White Ledge, fan- and cone-shaped deposits at base of steep slopes, and sheetlike deposits that mantle gentle to steep slopes. Deposits typically from 1 to 10 m thick. Locally includes area of bedrock and alluvium

Ql_1 **Pre–1983 landslide deposits**—Unsorted, unstratified, unconsolidated debris; boulder-, cobble-, and pebble-sized clasts of sandstone and limestone supported by a brown or gray matrix of sandy clay. Dark brown soil, from 50 to 100 cm thick, developed on this unit. Toes, benches, ridges, closed depressions, and other morphologic features, characteristic of landsliding, are subdued on these deposits. Thickness as much as 50(?) m

Qd_1 **Pre–1983 debris or mud-flow deposits**—Gray or brown, weathered, crudely stratified debris. Angular boulder-, cobble- and pebble-sized clasts of limestone or sandstone supported by matrix of silty clay or clay. Deposits result from single debris-flow events, occur in and near channels, and have subdued levees and tongue-like terminations. Dark brown soil, from 10 to 40 cm thick, is developed on these deposits. Thickness less than 2 m

TERTIARY AND CRETACEOUS UNITS

Tc **Colton Formation (Eocene)**—Green, variegated, and brown claystones interbedded with gray limestones and fine- to medium-grained yellow or brown sandstones. Conformable with and interfingers with underlying Flagstaff Limestone. Only lower 20–30 m exposed in study area. (Spieker, 1946; Bonar, 1948; Zawiskie and others, 1982)

Tf **Flagstaff Limestone (Eocene and Paleocene)**—White, gray, ~~and light-brown~~ limestones interbedded with gray, green, and black claystones. Conformably and gradationally overlies North Horn Formation. Lower 80–90 m (Ferron Mountain Member): gray, bluish-gray, and light-brown carbonate rocks interbedded with dark-gray, massive or laminated, from 0.05- to 2.4-m-thick claystones. Carbonate beds, from 0.1 to 1.9 m thick, fine grained or micritic. Mud cracks filled with dark micrite common. Gastropods and pelecypods common in fine-grained, sparry carbonate beds. Middle 132–142 m (Cove Mountain Member): white, pale gray, and pale yellowish-brown, micritic, massive carbonates in beds from 0.1 to 8.0 m thick; white or gray, limy, medium-grained sandstones; gypsum nodules in gray, green, red, or orange claystone beds. Cove Mountain Member consists of, from bottom to top: 20 m of green and gray claystones containing abundant gypsum nodules; 15 m of thick, resistant, massive limestone with solution cavities; from 20 to 25 m of red and gray claystones interbedded with limestones and lenticular, limy sandstones; and from 72 to 87 m of alternating white, massive or laminated limestones; fissile, black or green claystones; and beds of chert nodules. The Cove Mountain Member does not contain fossil mollusks. Upper 50 m (Musinia Peak Member): olive-green or light-brown claystones; laminated and massive, gray and light-gray, cherty, fossiliferous limestones; brown chert nodules; silicified, fossiliferous limestones. Mollusk fossils abundant. Total thickness of Flagstaff Limestone in Ephraim Canyon is about 275 m (Spieker, 1946; Bonar, 1948; LaRocque, 1960; Stanley and Collinson, 1979)

TKn **North Horn Formation (Paleocene and Upper Cretaceous)**—Orange to buff sandstones and variegated mudstones. Only upper 250 m exposed in Ephraim Canyon. Upper 150 m: evenly bedded, red, orange, brown, gray, green, purple, or variegated mudstones; thick, evenly bedded yellow, orange, or gray, well-cemented, fine- to coarse-grained, massive sandstones; and (uncommon) gray fossiliferous limestones. Lower 100 m: irregularly bedded, red, orange, brown, gray, green, purple, or variegated mudstones; yellow, orange, or gray, well-cemented, crossbedded, lenticular sandstones; green, fine-grained sandstones and nodular green siltstones (Bonar, 1948)

Contact—Dashed where approximately located; hachured where separate debris flow or landslide deposits, belonging to a single map unit, are in contact

Fault—Dashed where approximately located. Bar and ball on downthrown side

Strike and dip of beds

Seep or spring

Pond

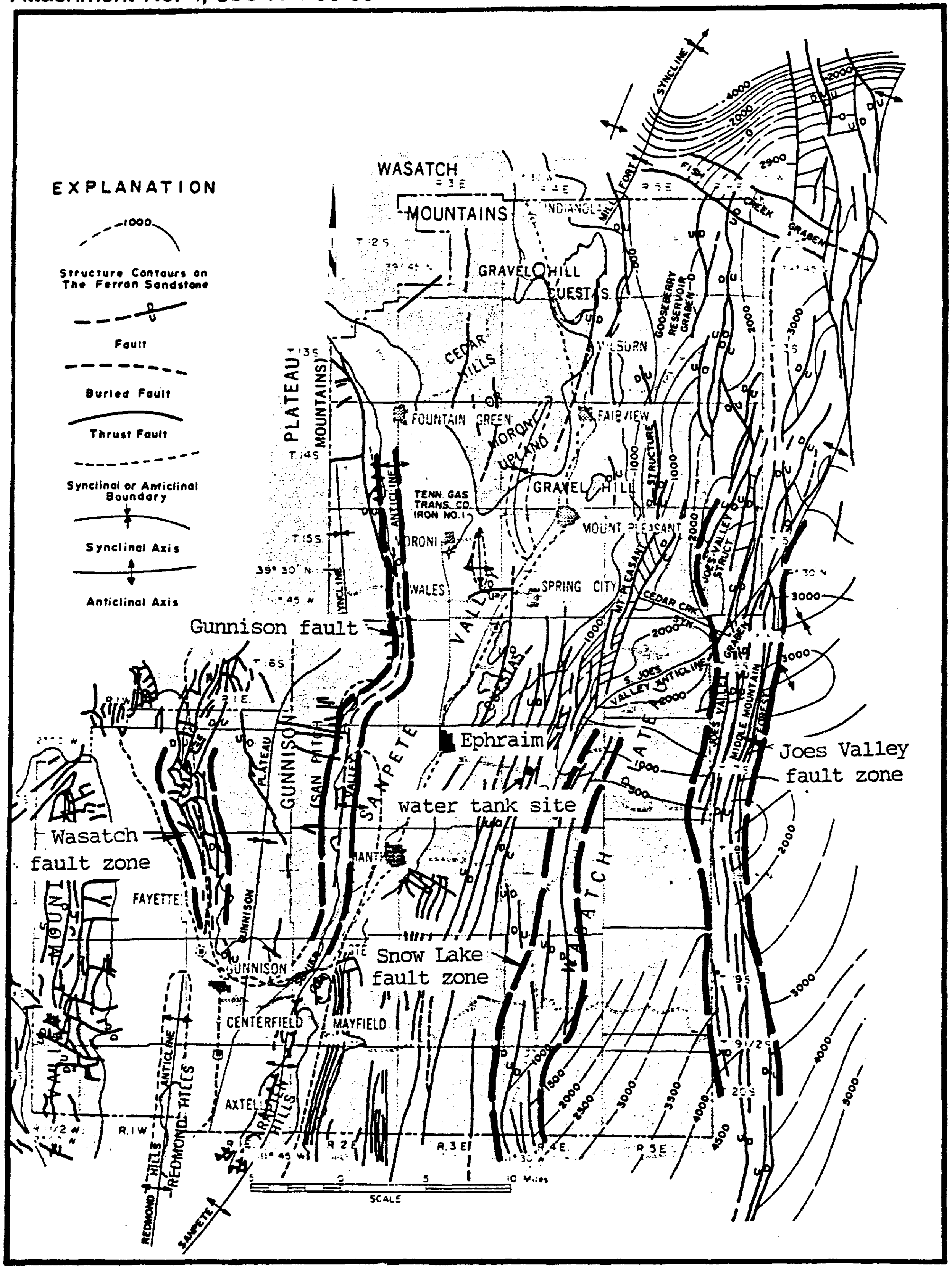
Wetland

SUMMARY OF GEOLOGIC HAZARDS
Ephraim Canyon Water Tank SITE

	Hazard Rating* Probable	Possible	Unlikely	Further Study Recommended**
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction			X	
Slope failure			X	
Flooding (seiche)			X	
Sensitive clays			X	
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive		X		S
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion		X		
Active sand dunes			X	
Mine Subsidence			X	
Shallow ground water perched			X	S
Flooding				
Streams			X	
Alluvial fans			X	
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon		Not Applicable		

*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.



Regional map of the Sanpete Valley showing structural features. Suspected active faults are outlined by thick dashed lines (Modified from Pratt and Callaghan, 1970).

Project: Potential geologic hazards at the proposed Erda Valley Ranchettes Subdivision, Tooele County, Utah			Requesting Agency: Tooele County Department of Development Services
By: Bill D. Black	Date: 10-05-90	County: Tooele	Job No.: (GH-4)90-13
USGS Quadrangle: Tooele (1175)			

PURPOSE AND SCOPE

In response to a request by Rod Thompson, Manager, Engineering and Compliance Division, Tooele County Department of Developmental Services, a geologic hazards review of a proposed Erda Valley Ranchettes Subdivision, NE1/4, sec. 27, T. 2 S., R. 4 W., SLBM, Tooele County, Utah, was undertaken. The proposed Erda Valley Ranchettes Subdivision is approximately 1 mile northeast of the town of Erda near the north end of Tooele Valley (attachment 1). The purpose of this review was to identify potential hazards at the subdivision which should be considered by Tooele County and the developer prior to construction. The investigation included examination of geologic reports and preliminary geologic hazards maps being prepared by the Utah Geological and Mineral Survey. Only available literature was utilized, no field reconnaissance was undertaken.

GEOLOGY AND GEOLOGIC HAZARDS

The subdivision slopes gently to the west at a gradient of approximately 2 percent and is underlain by a sequence of reworked pre-Lake Bonneville alluvial-fan deposits. The bulk of this material consists of thin layers of silty, clayey gravel derived from mixed-rock sources (U.S. Soil Conservation Service, unpublished data). Permeability through the soil is moderately slow. Potential geologic hazards include flooding due to shallow ground water and surface runoff, expansive clays, and earthquake ground-shaking.

Ground water in the subdivision occurs in unconsolidated sediments in both confined and unconfined aquifers. A shallow water table in the unconfined aquifer may cause basement flooding, as has occurred in Erda (Lund, 1986; Case, 1987). Although no water-well data is available to indicate the depth to ground water in the unconfined aquifer, it is possible that the water table is locally shallow. Water-well data for wells in the deep (>100 feet) confined aquifer indicate depths to the potentiometric surface of from 20 feet in the western end of the subdivision to 60 feet at the eastern end. Seasonal fluctuations in the deep confined aquifer of up to 12 feet have been recorded in nearby wells (Razem and Steiger, 1981). Because the unconfined aquifer is recharged principally by upward leakage from the confined aquifer, it is possible that the water table may roughly coincide with the potentiometric surface and be locally shallow, particularly in the western end of the subdivision. Because we are now in a drought period, present levels will not indicate the highest possible level. The water table during the mid-1980s wet period was likely much higher that at present.

The potential for flooding due to runoff could also be a hazard in the subdivision. In 1984, the Erda area experienced floodwater inundation and sediment deposition due to runoff from Middle and Pass Canyons that damaged roads, homes, and farmland (K.M. Harty, Utah Geological and Mineral Survey, oral commun., 1990). Runoff from Middle and Pass Canyons may also cause damage at the subdivision.

Expansive clays cause differential settlement or heave with changes in the moisture content of a soil, and may result in cracking and failure of foundations. Changes in soil moisture commonly accompany development and cause susceptible soils to shrink and swell. Soils at the subdivision have a moderate shrink-swell potential (Soil Conservation Service, unpublished data). When recognized early in the planning process, the effects of expansive clays can be minimized by using proper foundation design and site drainage.

The Erda Valley Ranchettes Subdivision is in Uniform Building Code (UBC) seismic zone 3, the zone of greatest hazard in Utah. The nearest active fault is the Oquirrh marginal fault, an active segment of the Oquirrh Mountains fault zone which lies along the eastern edge of Tooele Valley and is 2 miles southeast of the subdivision. This fault is believed to be capable of producing earthquakes up to magnitude 7 to 7-1/4 (Youngs and others, 1987). The subdivision area could also be shaken by large earthquakes on the nearby Wasatch and other faults in northern Utah, and by moderate earthquakes anywhere in the region.

WASTEWATER DISPOSAL

Limitations for the use of septic tank soil absorption fields in the subdivision are considered to be severe due to the low permeability of the soil (U.S. Soil Conservation Service, unpublished data). Soils in the subdivision are dominantly clayey with moderate shrink-swell potential, and percolation rates may be insufficient to meet county requirements. Percolation tests run in such soils need to allow saturation prior to measurement because permeability decreases as soils become saturated and swell.

CONCLUSIONS AND RECOMMENDATIONS

The potential for flooding due to shallow ground water may present a hazard in the subdivision if basements are planned. There is also a potential hazard from cloudburst or snowmelt floods from Middle and Pass Canyons. Shrinking and swelling of expansive clays in the soil could cause problems if not considered in foundation design and site drainage, and may also limit the use of soil absorption systems for wastewater disposal.

I recommend that a private consultant be retained to perform a standard soil foundation investigation prior to construction to define soil and ground-water conditions and provide data needed to design foundations. Shallow exploratory borings or monitoring wells will be needed to fully assess the potential for shallow ground-water hazards. Potential flooding from surface runoff should also be considered. Buildings must be constructed to conform to UBC seismic zone 3 requirements. Suitability for septic tank soil absorption fields should be evaluated on a site-by-site basis, with consideration given to swelling soils when performing percolation tests.

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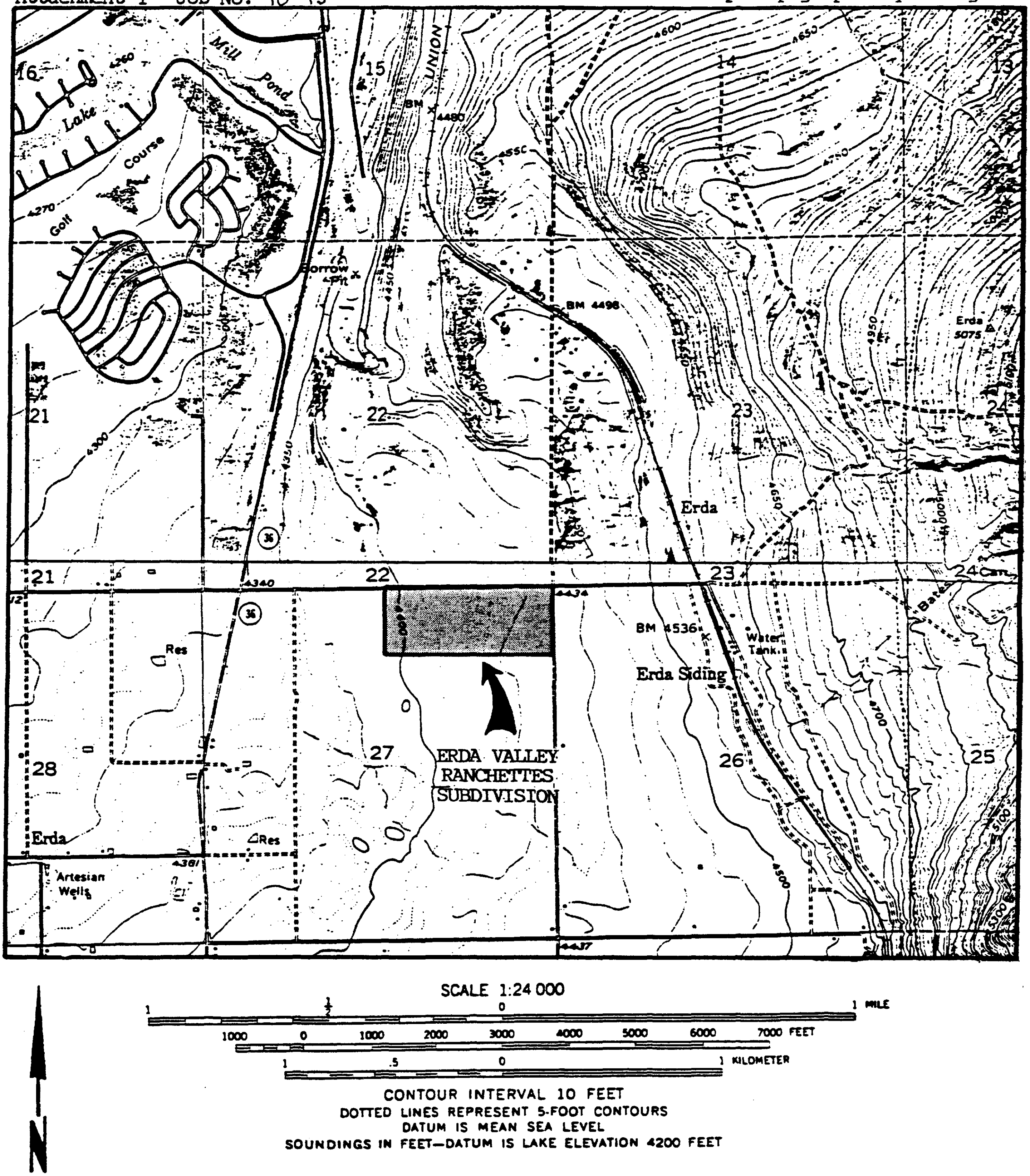
Base Map from TOOELE and MILLS JUNCTION, U.S.G.S. 7-½' topographic quadrangles.

Attachment 1 Job No. 90-13



Attachment 1. Location map.

Project:	Requesting Agency:
Geologic hazards investigation of a proposed 500,000-gallon water tank site, Gunnison City, Sanpete County, Utah	Gunnison City

By:	Date:	County:	Job No.:
Bill D. Black William E. Mulvey	02-28-91	Sanpete County	91-02(GH-5)

USGS Quadrangle: Gunnison (720)

PURPOSE AND SCOPE

The Utah Geological and Mineral Survey conducted a geologic hazards investigation of a proposed site for a 500,000-gallon water tank in Sanpete County, Utah. The investigation was requested by Bruce A. Blackham, Mayor of Gunnison City. The proposed water tank is to be constructed approximately 1 mile northwest of Gunnison City, in the NW1/4, SW1/4, sec. 8, T. 19 S., R. 1 E., SLBM (attachment 1). The purpose of this investigation was to identify potential geologic hazards at the water-tank site which should be considered by Gunnison City prior to construction. This report should be made available to the project engineers to ensure proper site design and construction. The scope of work included examination of pertinent maps and literature, and a field reconnaissance on January 29, 1991. Mark Pickett of Gunnison City, and Timothy Jones of Jones & Demille Engineering were present during the field inspection.

SETTING AND SITE DESCRIPTION

The proposed water tank site is on a ridge-top trending roughly north-south on the western edge of Gunnison Valley (attachment 1). The site is at approximately 5360 feet elevation and is about 1200 feet south of State Highway 28, one of the major roads leading into Gunnison City. Although snow-covered at the time of the investigation, most of the ridge surface appeared to be vegetated with grasses and sagebrush.

GEOLOGY

A detailed geologic map of the Gunnison area shows deposits which are Tertiary and Quaternary age (attachment 2) (Mattox, 1989). The water tank site is underlain by Tertiary-age rock of the Green River Formation. In the Gunnison area, this formation is divided into a lower mudstone member and an upper carbonate member. Pale olive to light greenish-gray calcareous mudstones dominate the mudstone member while the carbonate member consists of limestone, dolomitic limestone, chert, and volcanic tuff (Mattox, 1989). At the water-tank site, bedrock of the lower mudstone member of the Green River Formation dips gently to the southeast at approximately 5 degrees (Mattox, 1989). Test pits excavated by the Gunnison City Public Works Department prior to this investigation show the bedrock to be shallow (1-3 feet) and highly fractured.

Depth to the water table at the proposed site is unknown, but the water table is probably below the foundation level of the proposed tank. However, perched water may exist locally.

GEOLOGIC HAZARDS

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

Earthquake Hazards

The Intermountain seismic belt (ISB) is a generally north-south trending zone of seismic activity that bisects the state. Associated with the ISB are a number of earthquakes in the Gunnison area. The largest nearby earthquakes include a magnitude $6^1/_2$ earthquake in the Richfield area during 1901, and two magnitude 6 earthquakes near Elsinore in 1921 (Arabasz and others, 1979). From 1962 to 1986, four earthquakes of magnitude 4.0 or greater occurred in the Gunnison area: a magnitude 4.4 earthquake in Juab Valley in 1963, a magnitude 4.4 earthquake near Elsinore in 1972, a magnitude 4.0 earthquake near Annabella in 1982, and a magnitude 4.4 earthquake centered 11 miles to the northwest of Gunnison in 1986 (Arabasz and others, 1979).

There are four potentially active fault zones identified within 30 miles of the water tank site which could be sources for future earthquakes. These include the southernmost segment of the Wasatch fault, which is about 4 miles northwest of the site near Fayette, and the Gunnison fault, which extends from Fountain Green along the west side of Sanpete Valley south to Gunnison Reservoir (Hecker, in prep.). The most recent movement on the Fayette segment of the Wasatch fault occurred 10-15,000 years ago (Machette and others, 1987). Although this segment is thought to be older and less active than the central segments of the Wasatch fault, the Fayette segment is capable of generating earthquakes of magnitudes up to 7.5 (Machette and others, 1987). No detailed studies have been made on the Gunnison fault, although there is evidence of movement during Holocene time (10,000 years ago to present) (Hecker, in prep.). Two other nearby faults, the Sevier fault, which extends from Annabella south to Panguitch and into Arizona, and the Elsinore fault, which extends from Vermillion along the west side of Sevier Valley south to Elsinore, are not thought to have been active during the last 10,000 years. However, both have been active in Quaternary time (last 1.6 million years) and are potential sources of large earthquakes.

Ground Shaking

The greatest earthquake hazard at the site is ground shaking resulting from a moderate-sized earthquake, which could occur anywhere in the area, or a large earthquake centered on a known fault. Seismic waves are generated at an earthquake source and travel through the earth, resulting in ground shaking at the earth's surface. Ground shaking at the water tank site could damage the tank or rupture waterline connections. Three levels of design ground motions are outlined below based on: 1) probabilistic motions that have a 1 in 10 chance of being exceeded in a 50-year period, 2) probabilistic motions that have a 1 in 10 chance of being exceeded in a 250-year period, and 3) the minimum design motions specified in the 1988 Uniform Building Code (UBC). Under level 1 at the proposed site, a peak ground acceleration of 0.15 - 0.2 g has a 1 in 10 chance of being exceeded in a 50-year period (Algermissen and others, 1990). Under level 2, a peak ground acceleration of 0.4 - 0.6 g has a 1 in 10 chance of being exceeded in a 250-year period (Algermissen and others, 1990). Under level 3, the seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The proposed water tank site lies within Uniform Building Code (UBC) seismic zone 3. For zone 3, a Z-factor of 0.3 is required in design calculations, which effectively corresponds to a peak acceleration on rock of 0.3 g. Because the site is on bedrock, it is an S-1 soil type as specified in the UBC (1988 edition). This factor takes into account the effects of soils on earthquake ground motions.

Other Earthquake Hazards

Although there are four known potentially active faults within 30 miles of the proposed site, none is close enough to present a hazard from surface fault rupture. The hazard from tectonic subsidence is low. The hazard from liquefaction is low due to the presence of bedrock and the probable lack of ground water at or near the surface. Seismic slope stability is discussed below.

Slope Failures

The hazard from slope failure is low. Because the water tank site is on a ridge-top, the hazard from rock fall is low. The Green River Formation is a competent unit and there are no mapped landslides and debris flows in this unit in the vicinity of the water-tank site (Harty, in press) (Mattox, 1989). The hazard from earthquake-induced slope failures is low due to the competency of the rock.

Problem Soils

The hazard from problem soils such as expansive clay, collapsible soil, and soluble soil/rock is low. Soils at the site are mainly sandy and contain little clay. The foundation of the water tank will be in bedrock and thus has a low potential for geologic hazards from problem soils. There are no documented occurrences of problem soil in the area (Mulvey, in prep.).

Other Hazards

Because ground water at the site is probably deep, the hazard from shallow ground water is low, although local perched zones may be found. Because of the ridge-top location, flood hazards are also low. Radon hazards are generally not a consideration for municipal water systems because sufficient aeration occurs in the system to dissipate any radon gas in the water.

CONCLUSIONS AND RECOMMENDATIONS

No geologic hazards are present at the site which would make it unsuitable for a water tank. Only earthquake ground shaking is likely to affect the tank in the future. Information on three earthquake-resistant design options is presented: 1) probabilistic peak horizontal ground acceleration of 0.15 - 0.2 g that has a 10 percent chance of being exceeded in a 50-year period, 2) probabilistic peak horizontal ground acceleration of 0.4 - 0.6 g that has a 10 percent chance of being exceeded in a 250-year period, and 3) the minimum design ground motions for seismic zone 3 as designated by the UBC. Although ground motions in the second option have a low chance of occurring, the city should be aware that such ground motion from a large earthquake could occur at any time. It is recommended that at a minimum, ground-motion levels expected for seismic zone 3 be used in design of the tank (option 3 above). The hazards from surface fault rupture, tectonic subsidence, and liquefaction are low. The hazards from slope failure, problem soil, shallow ground water, and flooding also are low. A standard geotechnical investigation is recommended to provide data required to design the water-tank foundation.

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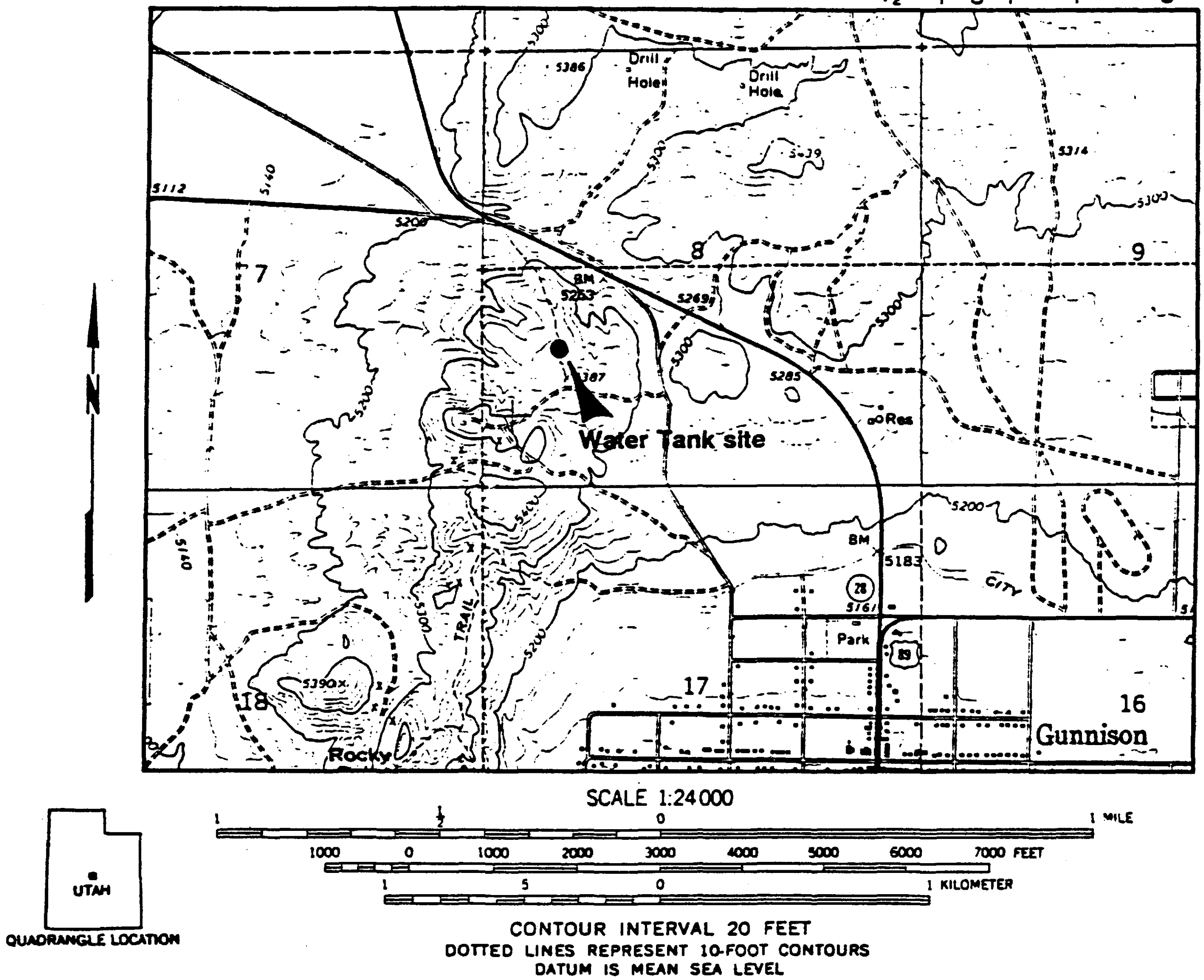
Mattox, S.R., 1989, Geologic map of the Gunnison Quadrangle: Utah Geological and Mineral Survey Open-File Report 146, scale 1:24,000.

Mulvey, W.E., in prep., Soil and rock causing engineering geologic problems in Utah: Utah Geological and Mineral Survey Map, scale 1:750,000.

Job no. 91-02

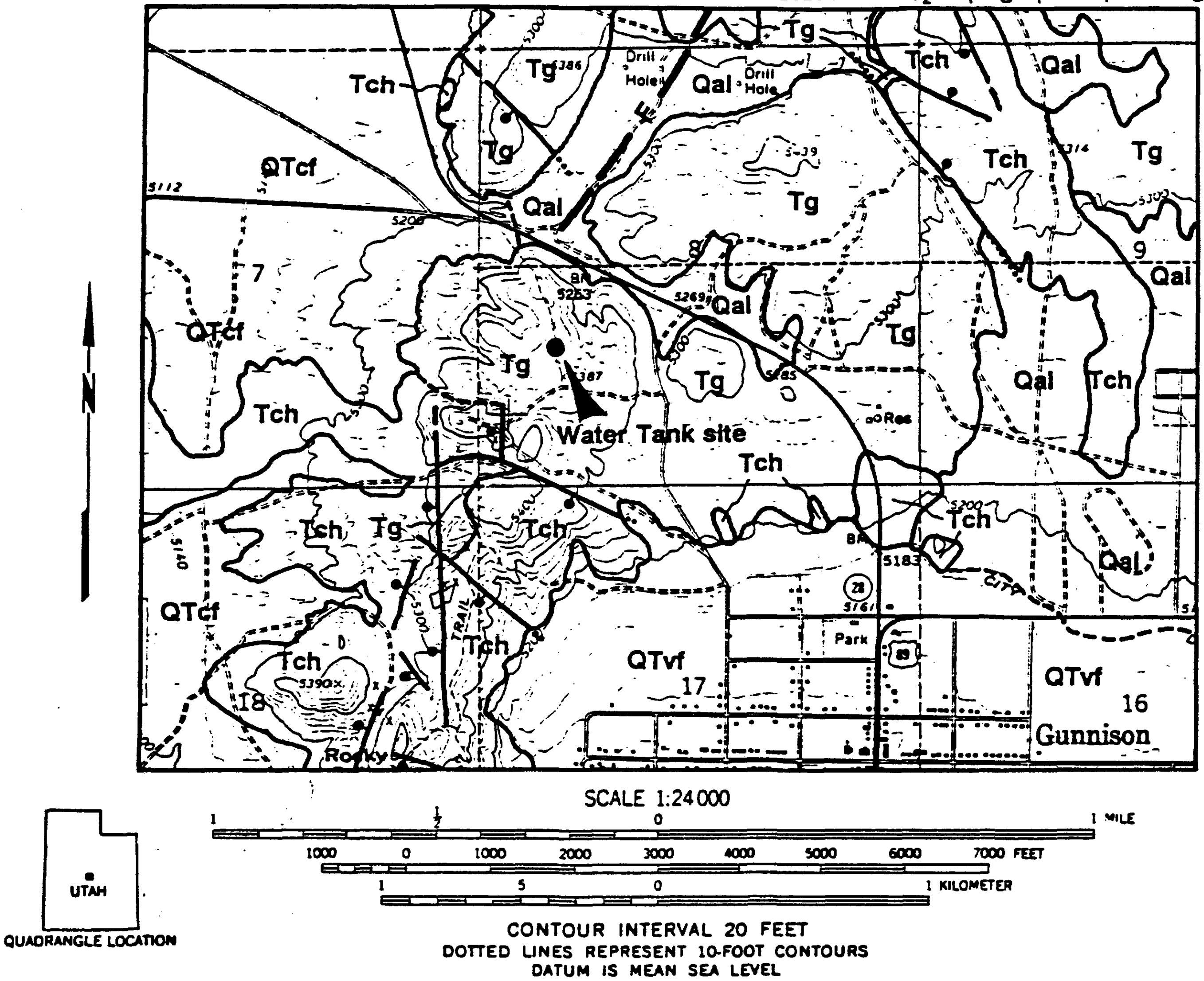
Base map from GUNNISON,
U.S.G.S. 7-$^{1}/_{2}$' topographic quadrangle.



Attachment 1. Map showing location of water-tank site.

Job no. 91-02

Base map from GUNNISON,
U.S.G.S. 7-1/2' topographic quadrangle.



QUATERNARY

Qal	*Slopewash and fluvial deposits.*
QTvf	*Valley-fill deposits.*
QTcf	*Older alluvial fans coalesced along the margin of the plateau.*

TERTIARY

Tch	*Crazy Hollow Formation - Pebbly conglomerate, sandstone, and reddish mudstone.*
Tg	*Green River Formation.* *Upper - limestone, dolomitic limestone, chert, and volcanic tuff.* *Lower - pale-olive to greenish-gray calcareous mudstone.*

Contact - Dashed where inferred.

Bedrock Fault - Dashed where inferred, dotted where concealed. Bar and ball on downthrown side.

F *Fracture*

Attachment 2. Geologic map (modified from Mattox, 1989).

SUMMARY OF GEOLOGIC HAZARDS
Gunnison Water Tank SITE

	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				
Collapsible			•	
Soluble (karst)			•	
Expansive			•	
Organic			•	
Piping			•	
Non-engineered fill			•	
Erosion			•	
Active sand dunes			•	
Mine subsidence			•	
Shallow ground water			•	
Flooding				
Streams			•	
Alluvial fans			•	
Lakes			•	
Dam failure			•	
Canals/ditches			•	
Radon	NOT	APPLI	CABLE	

*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.

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).

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.

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.

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

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

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

Richter magnitude - see Magnitude

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

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

Sand dunes - See Active sand dunes.

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

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

Seismicity - Seismic or earthquake activity.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Project: Preliminary geologic evaluation of an earth slump in the Green Hill Country Estates Subdivision in Ogden Valley, Weber County, Utah.			Requesting Agency: Weber County Engineering Department
By: K.M. Harty Mike Lowe	Date: 3-21-91	County: Weber County	Job No.: (GH-6) 91-03
USGS Quadrangle: Browns Hole (1368)			

INTRODUCTION AND BACKGROUND

On March 8 1991, the Utah Geological and Mineral Survey investigated an earth slump that had occurred a few days earlier in Ogden Valley, Weber County, Utah. The purpose of the investigation was to evaluate the hazard potential of the landslide, which occurred on private property at 9110 East 650 North in the Green Hill Country Estates Subdivision (sec. 9, T. 6 N. R. 2 E., Salt Lake Baseline and Meridian) (attachment 1). The investigation was requested by Mr. Curtis Christensen, Weber County Engineering Department, and consisted of a field reconnaissance, map and literature review, and air-photo analysis. Present during the evaluation was Scott Callaghan, owner of the property containing the landslide.

According to Mr. Callaghan, land above a cut slope behind his house began moving 2-3 days prior to March 8, 1991. Mr. Callaghan informed us that about 2 weeks prior to March 8th, the previous owner of the property had a bulldozer clear a path behind the Callaghan house to provide access for a moving van. Mr. Callaghan said that to create the wider path, the bulldozer removed the lower portion of the slope.

SITE DESCRIPTION

The landslide is classified as an earth slump (attachment 2), and covers 0.11 acres (0.045 ha) of land on the north side of Kelley Canyon (attachment 1). The slump is oriented S 33^{o} W, is 90 feet (27.4 m) long, and ranges between 24 feet (7.3 m) wide at the head and 69 feet (21 m) wide at the toe (attachments 2 and 3). The slump occurred on an 11-degree (20-percent) slope, in clay-rich colluvium and weathered arkose and argillite of the Precambrian-age Maple Canyon Formation (Crittenden, 1972). The slump has a stepped appearance due to numerous minor scarps. The main and minor scarps are relatively low, generally less than about 2 feet (0.6 m) high, and the rupture surface is likely shallow. The earth slump appeared to have moved about 5-10 feet downslope. The hillside above the slump is covered with native grasses and sage brush, and forms a shallow topographic basin bounded by gently-sloping bedrock ridges. Although there is no defined channel in this basin, drainage is toward Mr. Callaghan's property in the lowest part of the basin.

Mr. Callaghan informed us that there had been previous movement of this landslide in the recent past, prior to his ownership of the property. The earlier landslide occurred sometime after a visit to the site by M. Lowe in 1987. Evidence of this landslide was seen in the form of a 5- to 10-foot- (1.5-3-m-) wide arcuate zone of barren soil bordering the perimeter of the current failure (attachment 3). It appeared that the former landslide may have partly detached from the hillside, and that material from the failure had been recompacted into the slide margins (main and lateral scarp areas). The contact between the main scarp of the older failure and the fill was still clearly visible during the investigation.

At the time of our visit, the toe of the slump was about 15 feet (4.6 m) behind the house. The slump was issuing water from the lateral scarps, an indication of a build-up of positive pore-water pressure along the rupture surface. Water from the landslide had ponded between the toe of the landslide and the house, and Mr. Callaghan was excavating small ditches along both sides of his house to drain the pond and lateral scarps (attachment 3). Water was flowing from a number of areas on and near the property that were not obviously linked with either the earth slump or these drainage ditches. Water was flowing onto the Callaghan driveway from beneath a retaining wall at the southeast corner of the house (attachment 3). Mr. Callaghan mentioned that this had been occurring at least since he took ownership of the house 5 days prior to our visit, 2-3 days prior to movement of the landslide. During the investigation, water was also observed flowing down a drainage ditch adjacent to Mr. Callaghan's neighbor's driveway, which crosses Mr. Callaghan's property (attachment 3). This water was seeping into the ditch from the base of a slope above the driveway (attachment 3).

Visual inspection of the foundation of Mr. Callaghan's house showed no apparent disturbance, but sealed and unsealed cracks were observed in the garage and basement floors. A sealed crack in the basement floor runs the length of the house, and is oriented parallel to the contour of the slope (attachment 3). Outside, two fresh, connecting ground cracks were seen about 20 feet away from the northwest side of the house (attachment 3). The longest of these cracks was approximately 2.5 feet (0.76 m), and was oriented parallel to the contour of the slope.

DISCUSSION AND RECOMMENDATIONS

Geologic maps and air photos indicate that hillslopes near the Green Hill Country Estates Subdivision have experienced landslides in the past. Several late Pleistocene-Holocene-age (about 15,000-10,000 years ago) landslides have been identified on slopes to the northwest and southeast of Maple and Kelley Canyons (attachment 1) (Crittenden, 1972; Lowe, in preparation). Most of these landslides occurred in the Maple Canyon Formation, the same formation underlying the earth slump on the Callaghan property. No landslides have been mapped in the immediate vicinity of the Callaghan property, and none were observed on aerial photographs. However, subdued hummocky topography along the north side of the creek in Kelley Canyon east of the Callaghan property, and subdued yet distinct slope changes observed above the Callaghan earth slump both in the field and on the air photos, indicate that this area may have experienced landslides in Holocene or earlier times.

The most recent slope failure on the Callaghan property was likely related to a combination of factors, including geology, topography, ground-water hydrology, and man-made slope modifications. Geologic materials with high clay contents are generally susceptible to landsliding. The mostly arkosic bedrock in the area contains up to 40 percent potassium feldspar (Crittenden, 1972), which weathers to clay. The colluvium and weathered bedrock observed in the earth slump and in a 10-foot- (3-m-) high cut slope behind Mr. Callaghan's neighbor's house contain abundant clay. It is likely that the earth slump failed at the contact between the surficial colluvium/weathered bedrock, and the underlying, more indurated bedrock. The slope likely experienced a build-up of positive pore-water pressures at this interface. The ground-water recharge area above the landslide is limited, and the water flowing from the earth slump was likely derived from the recent snowmelt. However, there is the possibility that a deep bedrock aquifer may be delivering water to the slope surface. The shallow topographic basin upslope of the earth slump channels runoff from rainstorms and snowmelt toward the Callaghan property. Ground water is also directed toward the property. It is probable that a build-up of positive pore-water pressure within weak geologic material greatly reduced the slope's resistance to shearing. Further reduction in slope stability was likely caused by excavation of the backyard cut slope, which may have reactivated the slope failure.

Due to the topographic and hydrologic conditions at the site, it is probable that the hillslope behind the Callaghan house will continue to experience stability problems unless steps are taken to modify these conditions. In the short term, the earth slump could experience additional movement, particularly if ground water continues to saturate the site. It is unlikely, however, that the earth slump will mobilize into a fast-flowing earth flow because of the cohesive nature of the slump material, and the relatively low slope. Because the rupture surface appears to be shallow, it is doubtful that the earth slump will move an appreciable distance. However, a seasonal build-up of pore-water pressure during spring snowmelt or after significant rainstorms could result in rejuvenated movement of the earth slump and/or new failures in adjacent areas.

We advised Mr. Callaghan that a permanent drain system may be needed to de-water the slope and that he should immediately consult a private geotechnical engineer or engineering geologist to further assess slope conditions. We also told Mr. Callaghan that property downslope from the earth slump may also be subject to instability problems. Cracks in the garage and basement floors, the fresh earth cracks northwest of the house, water flowing from the base of the retaining wall, and water flowing from the slope adjacent to the neighbor's driveway suggest that slopes below the elevation of the earth slump are potentially unstable and may require stabilization. We advised Mr. Callaghan to have a consultant examine these areas as well.

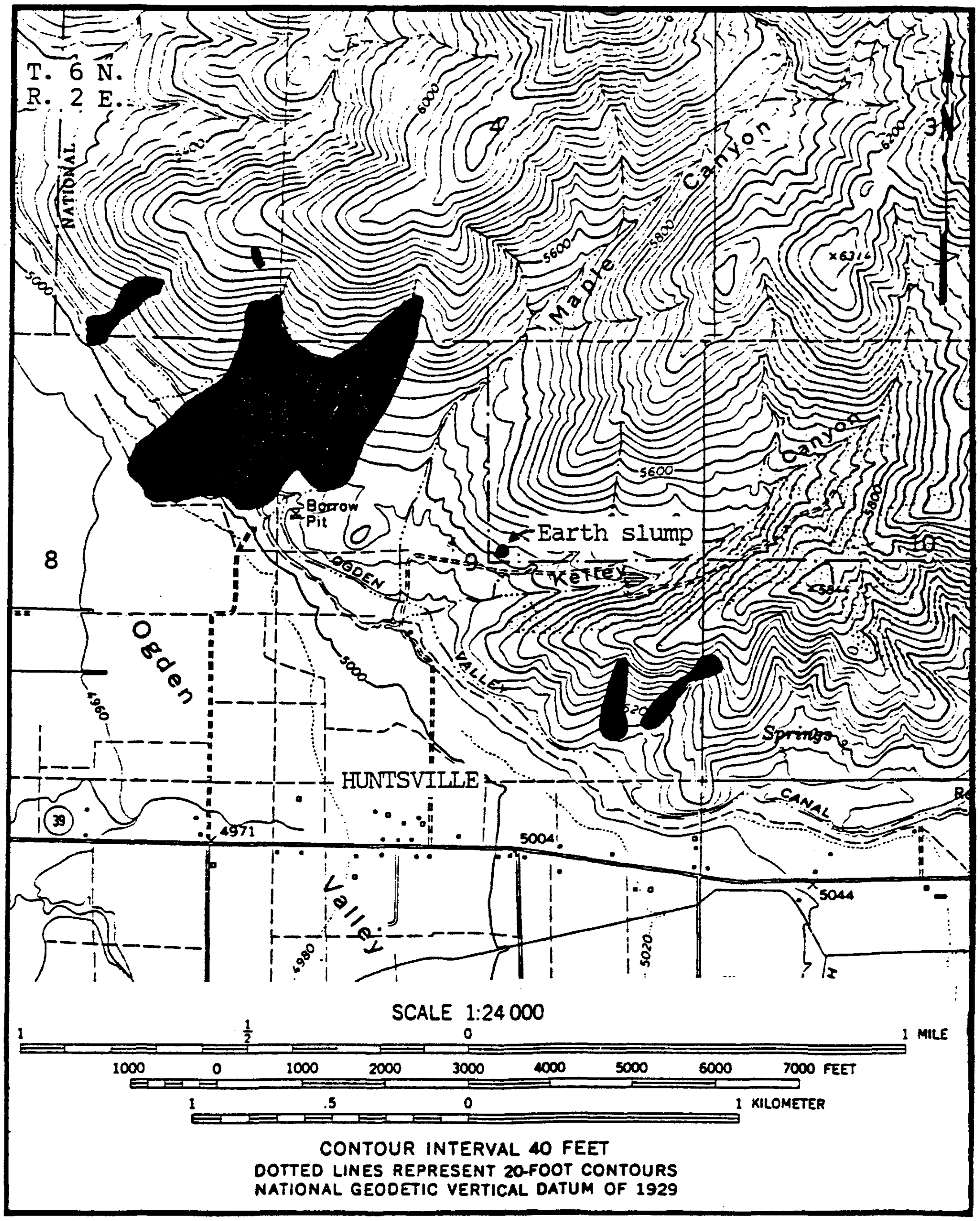
CITED REFERENCES

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

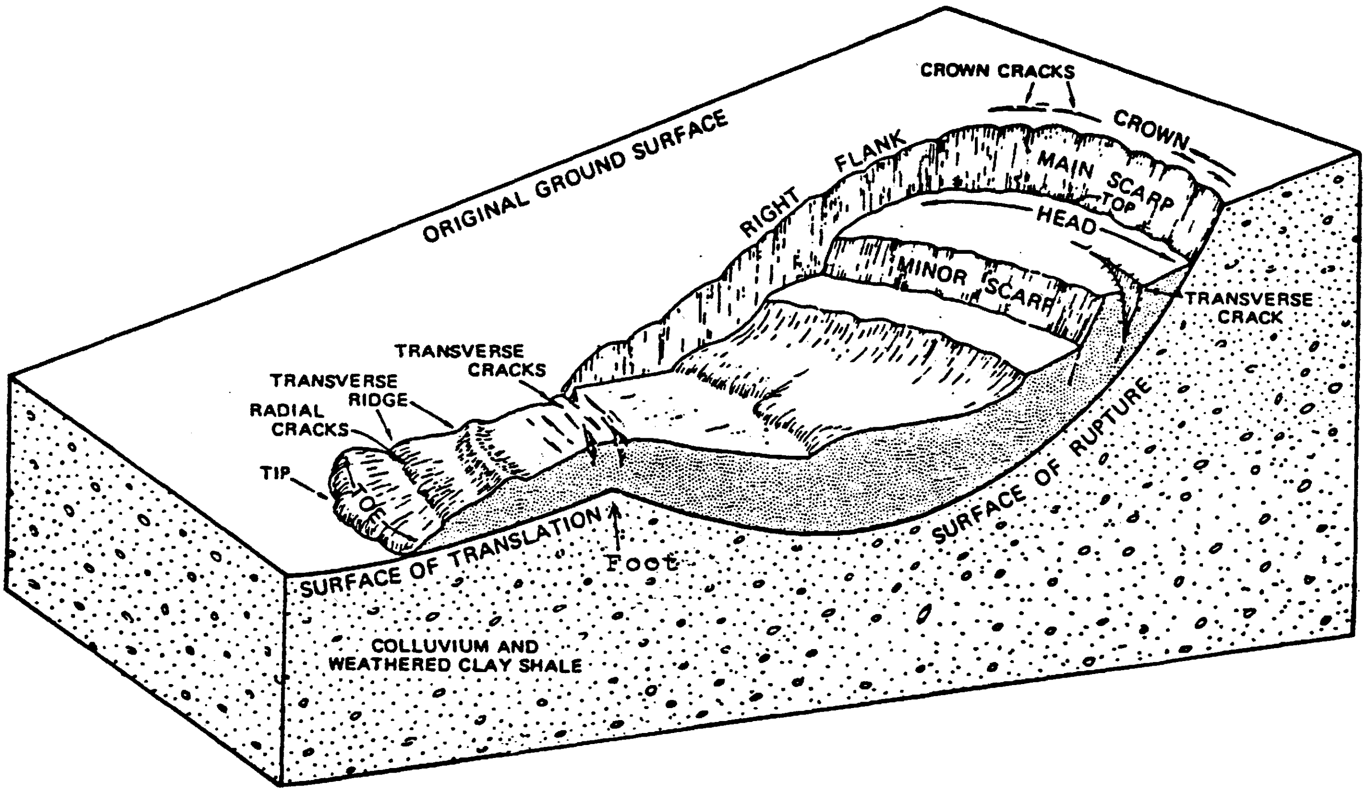
Lowe, Mike, in preparation, Surficial geology of Ogden Valley: Utah Geological and Mineral Survey Open-File Report, 69 p., scale 1:24,000.

Varnes, D.J., 1978, Slope movement types and processes, in Schuster, R.L., and Krizek, R.J., eds., Landslides - analysis and control: National Academy of Sciences Transportation and Research Board, Report 176, p. 11-33.

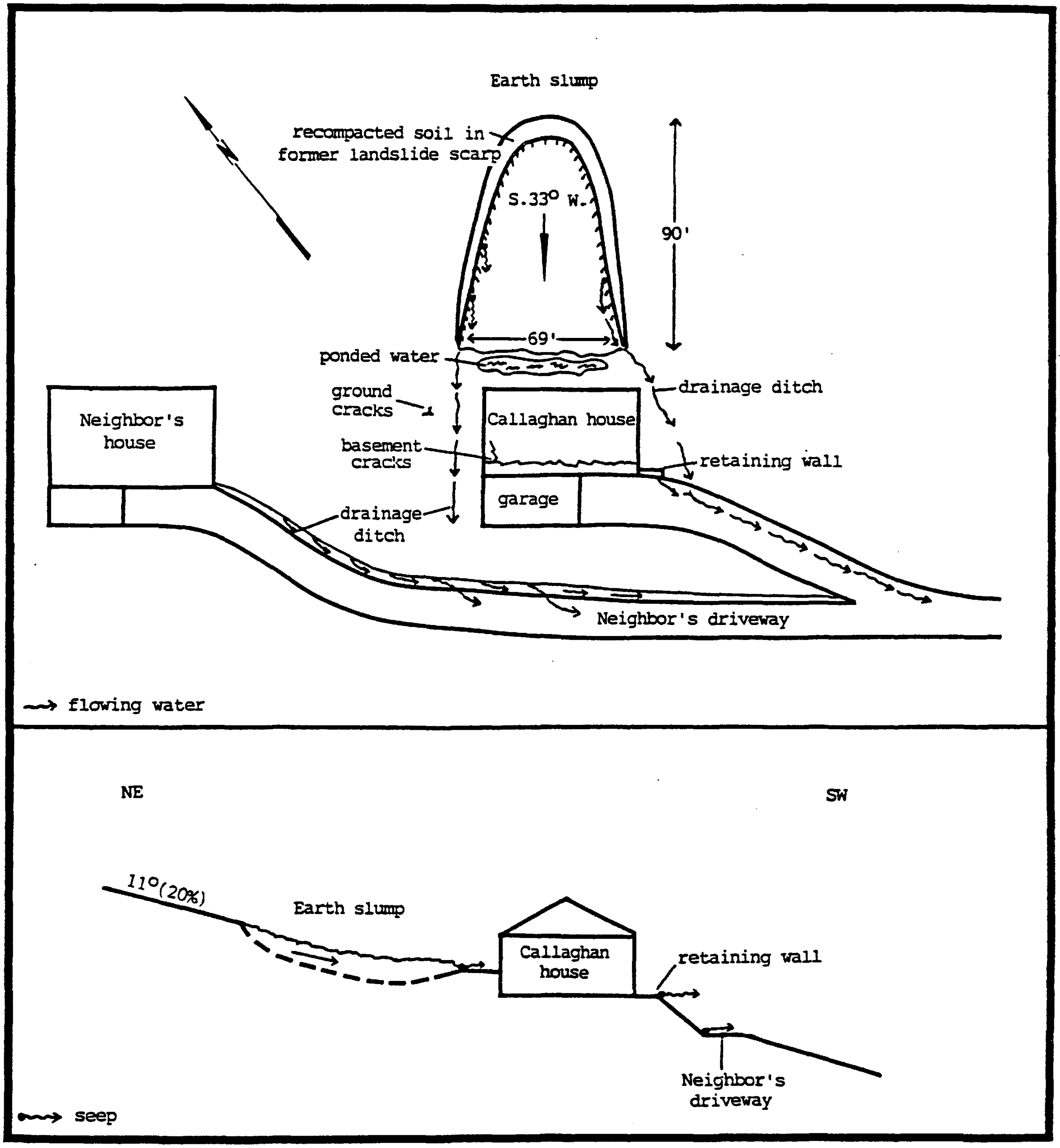
Base map from USGS 7½-minute topographic quadrangle, Browns Hole, Utah



Topographic map showing March 1991 earth slump (●) and late Pleistocene-Holocene landslides (▬) (Landslide compiled from Crittenden, 1972; Lowe, in preparation).



Typical slump (modified from Varnes, 1978).



Earth slump and surrounding features (not to scale). Upper sketch: Planimetric view of earth slump. Lower sketch: Cross-sectional view of hillslope showing relative levels of water seepage.

Project:			Requesting Agency:
Potential debris-flow volumes reaching the valley floor from the Lone Pine Canyon drainage basin, Centerville, Utah			Mr. Fred Campbell, P.E. Centerville City Engineer
By: W.E. Mulvey Mike Lowe	Date: 4-23-91	County: Davis County	Job No.: 91-05 (GH-7)
USGS Quadrangle: Farmington (1255) Bountiful Peak (1294)			

INTRODUCTION

On March 25, 1991, the Utah Geological and Mineral Survey conducted a geologic investigation of Lone Pine Canyon northeast of Centerville, Davis County, Utah (attachment 1). The purpose of the investigation was to assess debris-flow potential in the canyon, and provide Centerville City with estimates of potential debris- flow volumes. These volumes will help determine the design of a debris basin to be constructed at the mouth of the drainage. This investigation estimates sediment volumes only, and does not preclude the necessity for hydrologic and engineering studies prior to designing hazard-reduction structures. The investigation was requested by Mr. Fred Campbell, Centerville City Engineer, and consisted of a field reconnaissance of the lower canyon, map and literature review, air photo analysis, and comparative analysis of sediment yield potential for debris flows using the Pacific Inter-Agency Committee (PSIAC) and Davis County Flood Control. Scott Williams of Davis County Flood Control reviewed the report.

BACKGROUND

Previous estimates of debris-flow potential in Lone Pine Canyon vary greatly. In 1988, FEMA contracted the U.S. Army Corps of Engineers to develop a model to assess alluvial-fan flooding and debris-flow movement on alluvial fans in Davis County. Data from the 1983-84 debris-flow events along the Wasatch Front (Wieczorek and others, 1983) were used to calculate debris-flow volumes. The model predicted a debris flow of 81,000 yd^3 could be generated from Lone Pine Canyon (U.S. Army Corps of Engineers, 1988). The landslide-generated debris flows in 1983-84 are considered by some investigators to have been a unique Holocene (last 10,000 years) occurrence (Mathewson, 1989). If that is the case, the events of 1983-84 could be assumed to be the worst case scenario for landslide-initiated debris flows. Because of this, and the fact that no debris flows have occurred in Lone Pine Canyon during historical time (that is, it is a pristine canyon), the U.S. Army Corps of Engineers calculation may be a maximum event. The fact that debris flows in Lone Pine Canyon did not occur in 1983-84 may indicate that the potential for landslide-initiated events is low. Wieczorek and others (1983) used geomorphic evidence estimate to debris flow and flood potential in Lone Pine Canyon, which they named Halfway Canyon. They determined that the drainage had a moderate potential for debris flows, and a high potential for debris floods, but gave no volumes for these events.

INFLUENCE OF GEOLOGY AND TOPOGRAPHY ON SEDIMENT YIELD

Geology and topography in Lone Pine Canyon affect debris-flow potential, and may reduce the volume of material reaching the mouth of the drainage.

Geology

Bedrock in Lone Pine Canyon consists primarily of schist and gneiss of the Archean-age Farmington Canyon Complex (Bryant, 1984). These rocks are resistant to erosion but poorly exposed in the drainage basin. Where exposed, the rocks form knobs and small cliffs. However, bedrock in most of the drainage basin is highly fractured, because it is part of a pre-Bonneville-age landslide (attachment 2). The slide initiated at about 6400 feet (Nelson and Personius, 1990) and extended to the valley floor prior to formation of the Bonneville shoreline. Because of the slide, bedrock permeability may be increased in the drainage basin. Increased bedrock permeability may have allowed higher infiltration rates and localized relief of artesian pressure in the bedrock aquifer during the wet-cycle years (1983-1984), reducing the potential for landsliding which was responsible for debris flows in adjacent drainages during that period.

Surficial deposits consist of colluvial, alluvial-fan, debris-flow, and Lake Bonneville sediments. Colluvium covers slopes above the Bonneville shoreline. An alluvial fan consisting of alluvium and debris-flow deposits mantles the Bonneville shoreline bench (attachment 2). The fan consists of boulders, cobbles, gravels and sands eroded from the Farmington Canyon Complex. The fan surface slopes up to about 30 percent to the west. Below the Bonneville shoreline bench, deposits in slopes are coarse-grained lacustrine gravels and sands, which become finer grained toward the valley floor. These deposits are most likely thin and depth to bedrock is shallow. Channels cut into these Lake Bonneville deposits carry water from canyon mouths to the valley floor. Several coalescing alluvial fans with apices at channel mouths are found on the valley floor (attachment 2). These alluvial-fan deposits do not necessarily delineate the area of modern debris-flow and alluvial-fan flood hazard because of modification of the site due to excavation of the gravel pit.

Topography

The topographic bench formed by the Bonneville shoreline may affect the volume and travel path of debris flows in Lone Pine Canyon, prior to the flows reaching the valley floor. Above the shoreline bench, the majority of the canyon consists of heavily-vegetated slopes of 30 percent or steeper. Channel configuration above the bench consists of a relatively straight, single main channel. Between 5800 and 6000 feet, channel gradient decreases due to slumps in the pre-Bonneville landslide. Immediately above the shoreline bench, resistant bedrock outcrops force the channel into an abrupt right-angle turn to the south and another to the west. These bends in the channel, combined with the abrupt decrease in stream-channel gradient and channel confinement at the shoreline bench, result in a reduction of stream velocity and flow depth, and deposition of channel debris on the shoreline bench. Evidence for this is the alluvial fan on the bench which overlies shoreline deposits (attachment 2). Abandoned channels on the fan indicate that debris flows and floods can shift channel location. Numerous incised channels cut into the west-facing slope of the shoreline bench are further evidence for this. The slope steepens again to greater than 30 percent and most channels empty into to the gravel pit on the valley floor.

Because the main channel on the Bonneville bench fan can change position with each flood event, any of the several channels leading to the gravel pit could one day be the main channel.
From accounts of flooding in 1983, the channel near the Centerville City pump house apparently carried most of the runoff from Lone Pine Canyon.

EVALUATION OF SEDIMENT YIELD POTENTIAL USING PSIAC

The Sediment Yield Rating Model designed by the Pacific Southwest Inter-Agency Committee (PSIAC) (1968) has been used to determine sediment yield for debris flows in Salt Lake and Utah Counties following wild fires (Nelson and Rasely, 1990; Robison, 1990). The model requires values be assigned to nine parameters affecting sediment yield: geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and transport (attachment 3). These values are then used to estimate average sediment yield in acre-feet per square mile per year for the entire drainage basin.

The model has some limitations. It was designed for use in a drainage basin of 10 square miles or larger, and may be less accurate in smaller drainage basins. Also, PSIAC estimates an average annual sediment yield. Large, long duration and high intensity cloudburst storms, or greater than average annual precipitation may produce sediment yields that exceed the average annual sediment yield. Lastly, the model may underestimate the amount of material contributed to a debris flow from channel scour. In Robison's (1990) investigation of debris flows in Mapleton, Utah, PSIAC underestimated the volume of material deposited in the debris-flow events. PSIAC calculations for post-fire conditions indicated 4700 yd^3 of sediment available for transport. U.S. Forest Service calculations based on measurement of the debris-flow deposits estimate that 15,000 yd^3 of material were deposited during two rain-storm events. Robison (1990) estimates the volume of material was between 5000 and 7000 yd^3. We therefore suggest that PSIAC calculations be used only as an estimate of sediment derived from the watershed. The disparity between PSIAC calculations and actual debris amounts in Mapleton may be due to the large amount of material contributed by channel scour where the channel crossed the Bonneville shoreline. A similar situation exists in Lone Pine Canyon.

We used PSIAC to estimate the potential sediment yield due to storm runoff from the Lone Pine Canyon watershed both under present conditions and following a complete burn, which is considered the worst case for PSIAC. The data sheet used to perform PSIAC calculations is included in attachment 3, and a description of PSIAC ratings for each factor are given below.

Surface geology

Geology is rated from 0 (most competent) to 10 (least competent) based on the erosion resistance or competency of the bedrock. The Lone Pine drainage is underlain by Archean-age Farmington Canyon Complex. Very little bedrock is exposed in the drainage basin, but where exposed, outcrops consist of hard, ledge-forming rocks. However, much of the drainage basin is underlain by a large pre-Lake Bonneville landslide and the bedrock is highly fractured. Lacustrine gravel and sand deposits mantling slopes below the Bonneville bench are erosion prone and may contribute material to the channel. The presence of fractured bedrock and erodible Lake Bonneville deposits in the drainage basin resulted in assigning a 3 for both pre- and post-fire conditions.

Soils

Soils are rated from 0 (least erodible) to 10 (most erodible). Soils in the Lone Pine Canyon drainage basin consist primarily of gravelly sand which received a rating of 5 for both pre- and post-fire conditions. Although the deposits contain a high percentage of rock fragments, which help armor the deposits against erosion, they are made up predominately of easily-eroded single-grain sands.

Climate

Climate is rated from 0 (least severe) to 10 (most severe) based primarily on the duration and intensity of storms. Storms along the Wasatch Front are generally of moderate duration and intensity, but very intense cloudburst storms may occur. A rating of 7 was used for both pre- and post-fire conditions.

Runoff

Runoff is rated from 0 (least) to 10 (most) based on peak flow volume and flow per unit area. Because of the low percentage of bedrock exposed, high percentage of vegetation, and reduction in slope at the Bonneville bench, the drainage basin received a rating of 2 for pre-fire conditions. We assigned a rating of 10 to the drainage basin for post-fire conditions because damage to the vegetation promotes runoff rather than infiltration.

Topography

Topography is rated from 0 (least) to 20 (most) based on steepness and relief. Most slopes in the drainage basin are above 30 percent, however, slopes along the Bonneville bench are 30 percent or less. This break in slope slows stream transport of material down the drainage, resulting in the deposition of a small alluvial fan on the Bonneville bench. Above the bench, slopes disturbed by pre-Bonneville landsliding have a stepped topography. Because of this, the drainage basin received a pre-fire and post-fire ratings of 15.

Ground cover

Percent of drainage basin covered with vegetation, rock fragments, and litter is used to rate ground cover between 10 (little protection) and -10 (well protected). The majority of the drainage is covered with vegetation and litter, except the part below the Bonneville bench. Vegetation here is restricted to the floor and sides of the drainage, with grasses and sagebrush covering adjacent slopes. Rock fragments are common throughout the drainage basin. Because of these conditions, the drainage received a pre-fire rating of -8. Because of the destruction of vegetation and litter during a fire, the drainage basin received a post-fire rating of 8.

Land Use

Land use is rated between 10 (worst) and -10 (best) based on the percent of the drainage basin cultivated, intensively grazed, or recently logged or burned. Most of the drainage is pristine except for the part from the Bonneville bench to the gravel pit. This area is disturbed by roads and construction, giving a rating of -8 for pre-fire conditions. The drainage basin received a post-fire rating of 10, because of the destruction of vegetative cover.

Upland Erosion

Upland erosion is rated between 25 (most) and 0 (least) based on the percentage of the drainage basin characterized by rill, gully, or landslide erosion. The main channel has few side channels to contribute debris along its course, and the main channel is relatively uncluttered with debris. However, deposits below the Bonneville bench show signs of recent erosion in channels. Because of this erosion, the pre-fire rating is 5. Forest Service data collected following cloudburst-initiated debris flows from denuded Davis County watersheds in the 1930's show that upland erosion could be severe following a wildfire (Croft, 1967). For this reason post-fire conditions received a rating of 25.

Channel-Erosion and Sediment Transport

Channel depth, eroding banks, and degree of armoring by bedrock, boulders, and vegetation provide a means of rating channel erosion and sediment transport between 25 (most) and 0 (least).
Upper reaches of the channel are pristine with little channel erosion, but below the Bonneville bench, channels show recent erosion and are not well vegetated. Also, small landslides were identified in the upper reaches of the channel. Because of this, the pre-fire rating is 7. Because the channel contains some debris and vegetative litter that could be mobilized during the higher stream flows that would occur following a wildfire, the drainage basin received a post-fire rating of 20.

Sediment Yield

The Lone Pine Canyon drainage received a total pre-fire Sediment Yield Factor Rating of 28. This corresponds to an estimated pre-fire sediment yield of 0.23 acre-feet per square mile per year. The drainage basin has an area of approximately 0.78 square miles (U.S. Army Corps of Engineers, 1988), giving a pre-fire sediment yield of approximately 0.18 acre-feet (371 cubic yards) per year. The post-fire sediment yield (Sediment Yield Factor Rating 103) was estimated to be 2.4 acre-feet (5050 cubic yards) per year. Post-fire calculations assume a 100-percent burn of the drainage basin, a worst case scenario for PSIAC.

DAVIS COUNTY FLOOD CONTROL MODEL

Using data collected from historical debris flows in Davis County, it was determined that, in pristine perennial drainages with average main-channel slopes greater than 20 percent, an average of 11 to 12 cubic yards (yd^3) of material per foot of channel was contributed to a debris flow regardless of triggering mechanism (Williams and Lowe, 1990; Williams and others, 1989). This model does not include material from the triggering event. Therefore, channel conditions are the most important factor which must be evaluated when applying the Davis County Flood Control model. During the 1983 Rudd Canyon debris-flow event, 80 percent of the debris reaching the mouth of the canyon was contributed by the stream channel (Weiczorek, 1983). Other Davis County streams, which had produced channel-scouring debris-flow events in the 1930's, produced much less debris per foot of channel during the 1983 events. This is because the rate of sediment accumulation in stream channels is slow, and 40-50 years was insufficient time to return the scoured channels to pristine condition. Thus, the 11 to 12 yd^3 per foot of channel cannot be used in non-pristine channels. Lone Pine Canyon is a pristine drainage with an average main channel slope greater than 20 percent. Using the Davis County Flood Control model, we determined that the 1.2 mile (6336 feet) pristine channel of Lone Pine Canyon could produce between 69,696 yds^3 (11 yds^3 per foot of channel) and 76,032 yd^3 (12 yds^3 per foot of channel) of debris during a maximum debris-flow event (recurrence interval unknown) involving the entire canyon. Because Lone Pine Canyon is an ephemeral stream drainage, this event is most likely during the spring snowmelt when the greatest thickness of channel alluvium is saturated and is most likely to be mobilized. The alluvium would dry out during the summer and fall, and channel conditions would no longer be similar to those found in the perennial streams which were used to produce the Davis County Flood Control model.

Lone Pine Canyon is dissimilar to channels used to develop the Davis County Flood Control model in another way. Side-channel slopes in Lone Pine Canyon are not as steep or high, and this may reduce the amount of debris that has accumulated in the channel. Thick channel fills were not evident on air photos, but no field investigations were performed in the upper canyon area.

CONCLUSIONS AND RECOMMENDATIONS

Potential sediment yields (rounded to the nearest 100 yd^3) from Lone Pine Canyon are listed in table 1.

Table 1. Estimates of potential sediment yield from Lone Pine Canyon.

Method	Sediment yield	
PSIAC (Average annual)		
Pre-burn pristine	400 yd^3	
Post-burn	5100 yd^3	
Davis County Flood Control	(Maximum event, entire canyon)	Addition of PSIAC
11 yd^3 per foot of channel	69,700 yd^3	74,800 yd^3
12 yd^3 per foot of channel	76,000 yd^3	81,100 yd^3

Sediment yield determined using PSIAC may underestimate average annual sediment volumes, as the model may not include all of the material scoured from the channel (Robison, 1990) and because estimates are average annual sediment yields. Sediment yields from high intensity cloudburst storms or above average precipitation may exceed PSIAC calculations. The Davis County Flood Control model may overestimate maximum debris-flow volumes in Lone Pine Canyon, because: 1) deposition of some debris will occur on the bench formed by the Bonneville shoreline before reaching the valley floor, 2) channel sediments may be less saturated and less likely to mobilize than those in perennial drainages, and 3) the amount of channel debris available for transport is probably less than that for other pristine channels used to develop the model. Even if considerable material is deposited on the Bonneville bench fan (item 1 above), water from the flow could continue as a debris-flood down channels in the Bonneville gravels and sands to the valley floor. It is likely that Bonneville sediments would then be eroded and incorporated into the flow. We believe that the section of the channel below the Bonneville shoreline will probably contribute more sediment per unit length than sections above the shoreline in the upper canyon.

Because of the numerous channels in the Bonneville sediments at the canyon mouth, and the potential for any of these channels to become the main channel during a debris flow event, it is important that Centerville City either place the debris basin to trap debris from all channels, or take steps to confine and direct flows where desired.

The landslide-generated debris flows in 1983-84 are considered by some investigators to have been a unique Holocene occurrence (Mathewson, 1989). These events are assumed to be a worst case scenario for landslide-induced debris flows. Because landsliding and debris flows did not occur in Lone Pine Canyon during the 1983-84 wet-cycle, the potential for landslide-induced debris flows may be low.

It is important to note that this evaluation considers only debris volume and not water volume. Fire damage will increase runoff significantly. The hydrology of the drainage basin should be evaluated for post-fire conditions to determine potential flood volumes. This is necessary to design the debris basin to pass flood waters, and assess the potential for flooding in downstream developed areas.

In a small, ephemeral drainage such as Lone Pine Canyon, it is difficult to make and accurate assessment of potential debris volumes, as is shown by the range of volumes in table 1. We do not believe these calculated volumes to be any more than general approximations, of limited reliability. In order to get a more reliable estimate of debris-flow volume, further study to assess the amount of material present in the channel is necessary. We did not investigate conditions along the entire length of the channel, and therefore, do not have measurements of thickness of material in the channel. In a pristine channel, such measurements can be very difficult to obtain because exposures are generally absent. Drilling and geophysical studies may be required. However, with-out these data, it is difficult to evaluate the relative reliability of the methods used for estimating debris-flow volumes.

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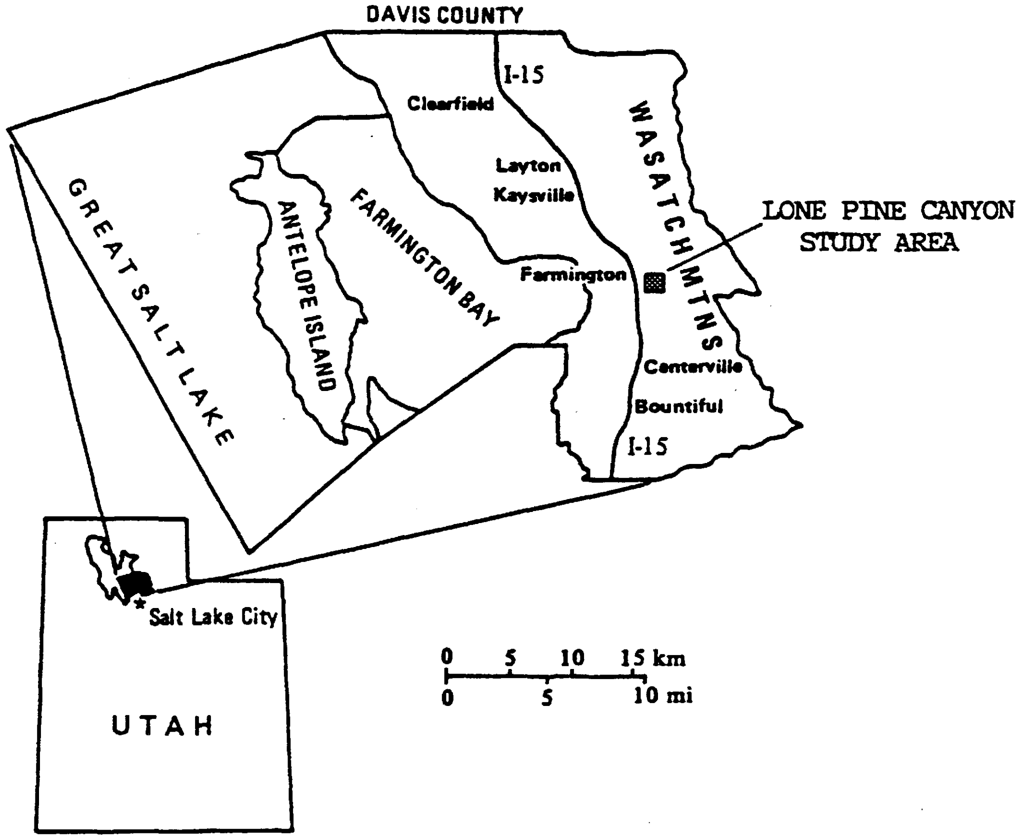
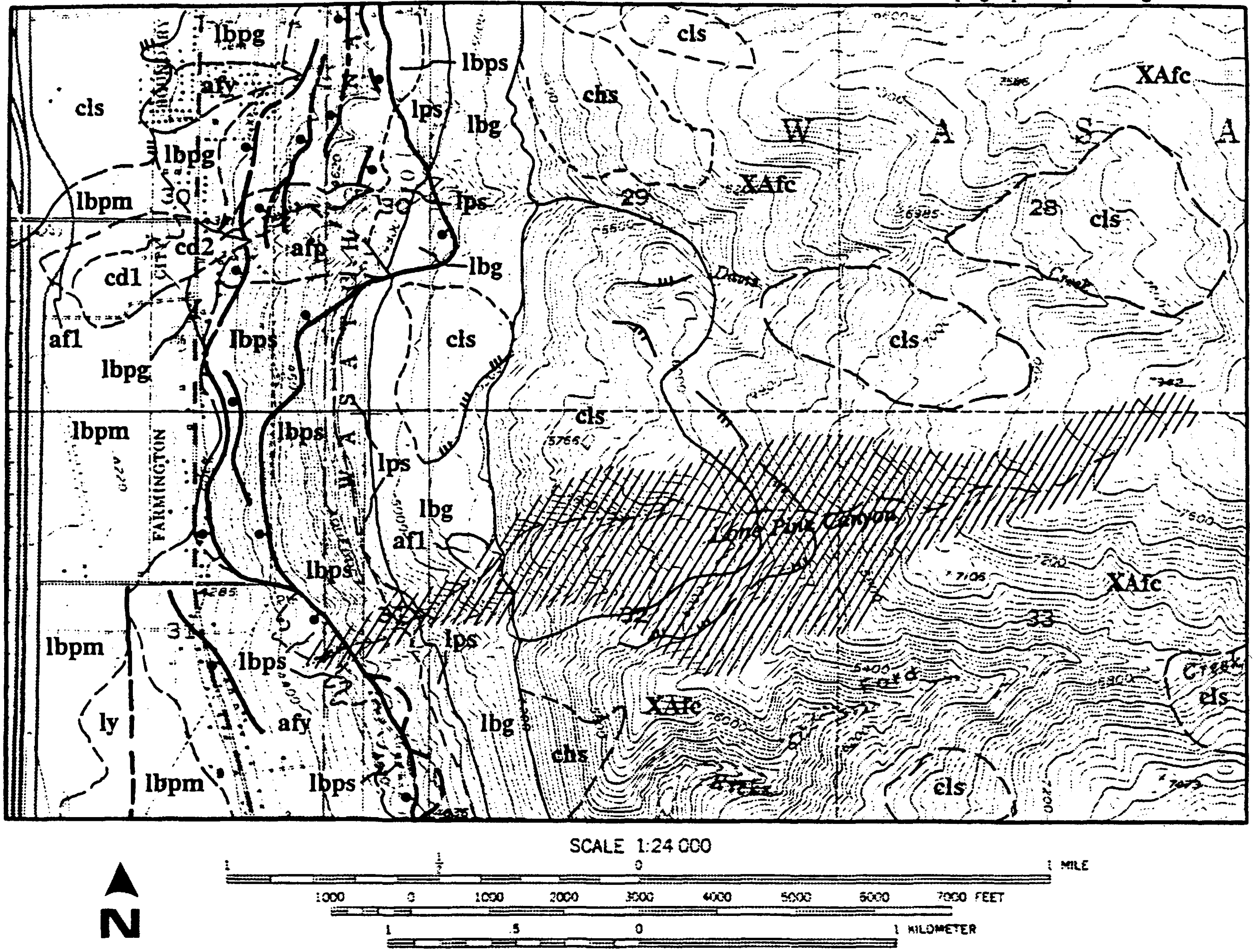
Attachment 1



Attachment 1. Location of Lone Pine Canyon study area.

Attachment 2

Base map from Bountiful Peak and Farmington U.S.G.S. 7-1/2' topographic quadrangles.



EXPLANATION

LACUSTRINE DEPOSITS

- **ly** Young lacustrine and marsh deposits
- **lps** Lacustrine sands related to regressive phase
- **lbg** Lacustrine sands and gravels related to transgressive phase
- **lbpg** Lacustrine sand and gravel, undivided
- **lbps** Lacustrine sand, undivided
- **lbpm** Lacustrine silt and clay, undivided

ALLUVIAL-FAN DEPOSITS

- **afl** Fan alluvium 1 (upper Holocene)
- **afy** Younger fan alluvium, undivided (Holocene to upper Pleistocene)
- **afp** Fan alluvium related to regressive phase of the Bonneville Lake cycle (upper Pleistocene)

COLLUVIAL DEPOSITS

- **cd1** Debris-flow deposits 1 (upper Holocene)
- **cd2** Debris-flow deposits 2 (Holocene to upper Pleistocene)
- **chs** Hillslope colluvium (Holocene to upper Pleistocene)
- **cls** Landslide deposits (Holocene to middle Pleistocene)

BEDROCK

- **XAfc** Farmington Canyon Complex (Early Proterozoic and Archean)

SYMBOLS

- Contact - Dashed where approximately located
- Normal Fault - Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side.
- Landslide escarpment
- Lone Pine Canyon drainage

Attachment 2. Geologic map of Lone Pine Canyon area (modified from Nelson and Personius, 1990).

Attachment 3

Lone Pine Canyon Watershed Utah State Pristine Condition

North Channel Subwatershed Name Mulvey, Lowe

.78 mi^2 ~~acres~~

PSIAC - 1968

Date 3-25-91

SEDIMENT YIELD FACTOR RATING

	SURFACE GEOLOGY (a)	SOILS (b)	CLIMATE (c)	RUNOFF (d)	TOPOGRAPHY (e)
	(10) a. Marine shales and related mudstones and siltstones	(10) a. Fine textured; easily dispersed; saline-alkaline; high shrink-swell characteristics b. Single grain silts and fine sands	(10) a. Storms of several days' duration with short periods of intense rainfall b. Frequent intense convective storms c. Freeze-thaw occurrence	(10) a. High peak flows per unit area b. Large volume of flow per unit area	(20) a. Steep upland slopes (in excess of 30%) b. High relief; little or no floodplain development
	(5) a. Rocks of medium hardness b. Moderately weathered c. Moderately fractured	(5) a. Medium textured soil b. Occasional rock fragments c. Caliche layers	(5) a. Storms of moderate duration and intensity b. Infrequent convective storms	(5) a. Moderate peak flows per unit area b. Moderate volume of flow per unit area	(10) a. Moderate upland slopes (less than 20%) b. Moderate fan or floodplain development
	(0) a. Massive, hard formations	(0) a. High percentage of rock fragments b. Aggregated clays c. High in organic matter	(0) a. Humid climate with rainfall of low intensity b. Precipitation in form of snow c. Arid climate, low intensity storms d. Arid climate; rare convective storms	(0) a. Low peak flows per unit area b. Low volume of runoff per unit area c. Rare runoff events	(0) a. Gentle upland slopes (less than 5%) b. Extensive alluvial plains
Factor value	Pre/Post fire 3	Pre/Post fire 5	7	Pre fire 2 Post fire 10	Pre/Post fire 15

	GROUND COVER (f)	LAND USE (g)	UPLAND EROSION (h)	CHANNEL EROSION AND SEDIMENT TRANSPORT (i)
	(10) Ground cover does not exceed 20% a. Vegetation sparse; little or no litter b. No rock in surface soil	(10) a. More than 50% cultivated b. Almost all of area intensively grazed c. All of area recently burned	(25) a. More than 50% of the area characterized by rill and gully or landslide erosion	(25) a. Eroding banks continuously or at frequent intervals with large depths and long flow duration b. Active headcuts and degradation in tributary channels
	(0) Cover not exceeding 40% a. Noticeable litter b. If trees present understory not well developed	(0) a. Less than 25% cultivated b. 50% or less recently logged c. Less than 50% intensively grazed d. Ordinary road and other construction	(10) a. About 25% of the area characterized by rill and gully or landslide erosion b. Wind erosion with deposition in stream channels	(10) a. Moderate flow depths, medium flow duration with occasionally eroding banks or bed
	(−10) a. Area completely protected by vegetation, rock fragments, litter b. Little opportunity for rainfall to reach erodible material	(−10) a. No cultivation b. No recent logging c. Low intensity grazing	(0) a. No apparent signs of erosion	(0) a. Wide shallow channels with flat gradients and short flow duration b. Channels in massive rock, large boulders, or well vegetated c. Artificially controlled channels
Factor value	Pre fire -8 Post fire 8	Pre fire -8 Post fire 10	Pre fire 5 Post fire 25	Pre fire 7 Post fire 20

Subtotal (a) – (g)	Pre fire =16 Post fire =58	Subtotal (h) – (i)	Pre fire =12 Post fire =45	TOTAL RATING – – – = – – . – ac.ft./sq. mi./yr.

(Instructions on reverse)

Pre fire rating = 28
Post fire rating = 103

SHEET 1 OF 1

GENERAL INSTRUCTIONS

District Office prepares one copy for District file.

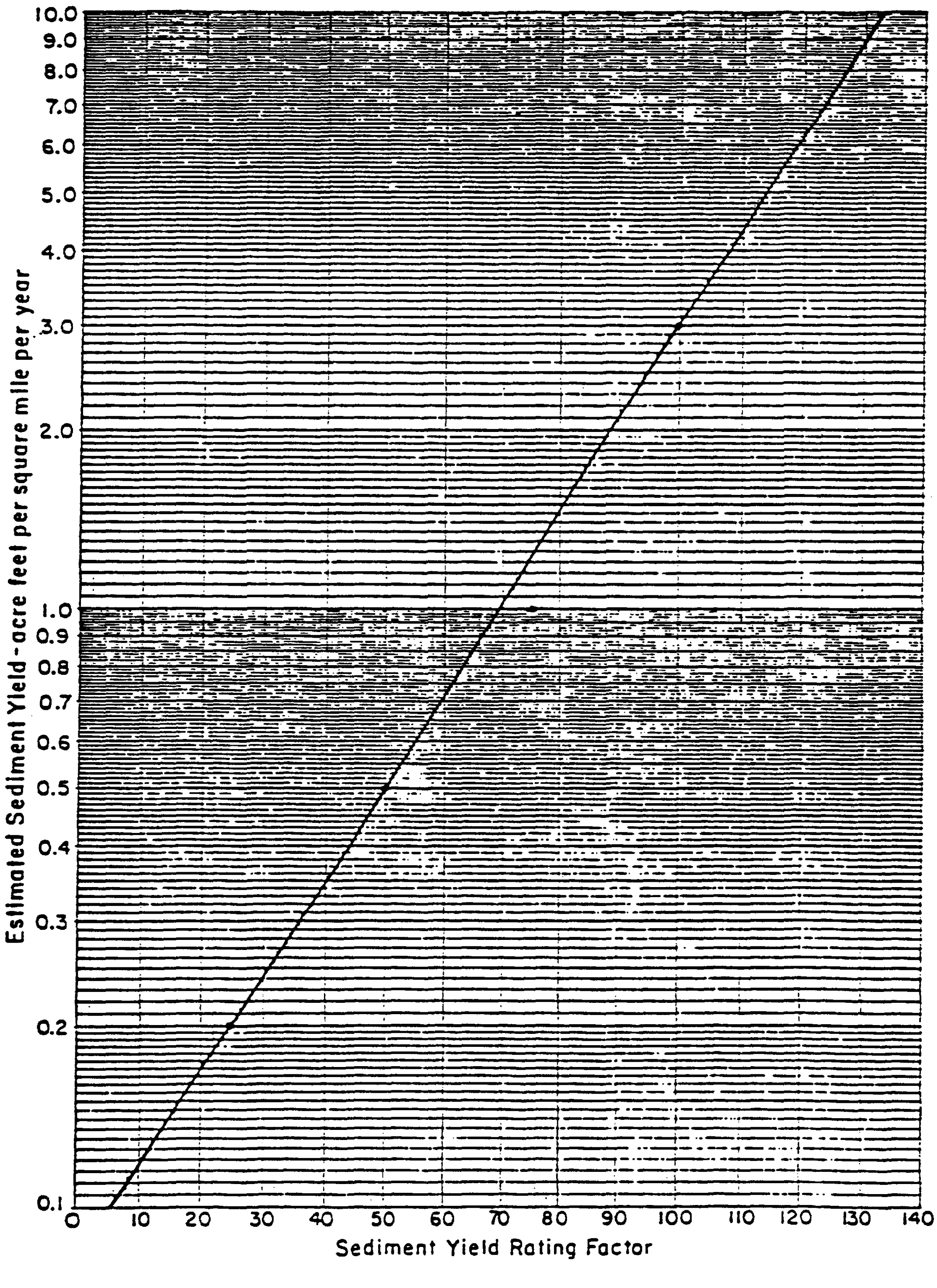
SPECIFIC INSTRUCTIONS

(Items not listed are self-explanatory)

Numbers indicate values assigned appropriate characteristics. Letters a, b, c, and d refer to independent characteristics to which full value may be assigned.

Interpolation between the sediment yield levels may be made. High values for columns (a) through (g) should correspond to high values for (h) and (i). If they do not, factors (a) through (g) should be reevaluated. If they do not correspond, then a special erosion condition exists.

Convert *Total Rating* to sediment yield by use of graph.



Project: Geologic-hazards investigation of three proposed water-tank sites, Weber and Davis Counties, Utah			Requesting Agency: Hooper Water Improvement District
By: Bill D. Black Gary E. Christenson	Date: 05-24-91	County: Weber, Davis	Job No.: 91-06 (GH-8)
USGS Quadrangle: Roy (1346)			

PURPOSE AND SCOPE

The Utah Geological Survey conducted a geologic hazards investigation of three potential sites for a two-million-gallon water tank in Weber and Davis Counties, Utah (attachment 1). Dan Trease, Chairman, Hooper Water Improvement District, requested the investigation. The purpose of this investigation was to identify potential geologic hazards at the water-tank sites for the Hooper Water Improvement District to use in choosing a site, and to provide information on hazards to be considered prior to construction at the chosen site. This report should be made available to the project engineer to ensure proper site design and construction with regard to geologic hazards. The scope of work included a literature and map review, and a field inspection of the sites on May 13, 1991. Charles T. Farley of the Hooper Water Improvement District was present during the field inspection.

SETTING AND SITE DESCRIPTION

The first site (North Bench site) is northwest of the City of Roy, in the NE1/4, NW1/4, sec.11, T.5 N., R.2 W, SLBM (attachment 1). It is at an elevation of approximately 4365 feet and is near the base of a bench on a slope which trends northeast. The proposed water tank site is west of an existing tank constructed in 1967. The site will be leveled and the tank anchored to a concrete pad in the same fashion as the existing tank.

The second site (South Bench site) is approximately one mile to the southwest of the North Bench site in a similar setting, in the SE1/4, SE1/4, sec.10, T. 5 N., R. 2 W., SLBM (attachment 1). The South Bench site is at an elevation of approximately 4385 feet and is near the base of a slope which trends north in this area. Like the North Bench site, the proposed water tank site is near an existing tank and will be of similar construction.

The third site (Howard Slough site) is in the NE1/4, SE1/4, sec.30, T. 5 N., R. 2 W., SLBM (attachment 1). The Howard Slough site is at an elevation of 4240 feet, in a low swampy area which trends roughly from the south to the northeast. Unlike the North Bench and South Bench sites, the proposed tank at the Howard Slough site will be made of rubber and buried.

GEOLOGY AND SOILS

Surficial deposits at all three sites are of Quaternary age (attachment 2) (Davis, 1985). All sites are underlain by a sequence of Lake Bonneville deposits, which consist chiefly of well-sorted sand, containing silt and clay. The bench at the North Bench and South Bench sites is a part of a delta deposited by the Weber River in Pleistocene Lake Bonneville. As the lake receded, the Weber River cut down into the delta, leaving the bench over 200 feet above the present river level. The Howard Slough site is underlain by Bonneville recessional shoreline and deep-lake deposits, with modern organic (swamp) deposits at the surface. No test pits were dug at the sites during the field inspection; mud pits dug by the Hooper Water Improvement District at the Howard Slough site for drilling of the well were still open but flooded.

At the North Bench and South Bench sites, the soil consists of loamy fine sand of the Layton series, which exhibits rapid permeability, low shrink-swell capacity, high shear strength, slight compressibility, and good compaction (Erickson and Wilson, 1968). In the Unified Soil Classification System (USCS), The Layton soil is a silty sand (SM). Depth to ground water at the North Bench site is probably greater than 10 feet; depth to ground water at the South Bench site is less than 10 feet (Charles T. Farley, oral commun., 1991), possibly due to ponding behind the railroad grade.

At the Howard Slough site, the soil consists of an alkaline silt loam or clay loam of the Leland series, which exhibits low permeability, moderate shrink-swell capacity, moderate shear strength, medium compressibility, and good to poor compaction (Erickson and Wilson, 1968). In the USCS, the Leland soil is a silt or clay (ML or CL-ML). Ground water is at or near the surface.

GEOLOGIC HAZARDS

Attachments 3a, 3b, and 3c are summary checklists of potential geologic hazards at the three sites. All hazards considered are shown and discussed below. A glossary of geologic hazards terminology is included (attachment 4) to aid in explanation of any unfamiliar terms.

Earthquake Hazards

All three sites are in an active earthquake zone called the Intermountain seismic belt, which extends from northwestern Montana to southwestern Utah (Smith and Sbar, 1974). In the Weber County area, the largest magnitude earthquake during historical time occurred in 1914 near Ogden and was an estimated Richter magnitude 5.5 (Arabasz and others, 1987). Numerous smaller earthquakes have occurred in Weber and Davis Counties within the last 120 years. Most of these earthquakes cannot be attributed to known faults, although faults capable of generating earthquakes are present in this part of northern Utah.

The Weber segment of the Wasatch fault, which trends north-south along the base of the Wasatch Range from North Ogden south to Bountiful, is the fault of most concern because of its recency of movement, potential for generating large earthquakes, and close proximity (roughly 9 miles to the east). The Wasatch fault is capable of generating earthquakes of magnitudes up to 7.5 (Machette and others, 1991). Stratigraphic and geomorphic evidence suggests that the most recent event on this segment occurred within the past 200-800 years (Machette and others, 1991).

Ground Shaking

A major hazard at all three sites is ground shaking resulting from either a moderate-sized earthquake, which could occur anywhere in the area, or a large earthquake centered on the Wasatch fault. Seismic waves are generated from an earthquake source at depth and travel through the earth, resulting in ground shaking at the earth's surface. Sensitive clays and loose, saturated sands (discussed below) are particularly susceptible to ground shaking. Ground shaking at the water-tank sites could damage the tank and/or rupture waterline connections.

There are three levels of design ground motions: 1) probabilistic motions that have a 1 in 10 chance of being exceeded in a 50-year period, 2) probabilistic motions that have a 1 in 10 chance of being exceeded in a 250-year period, and 3) the minimum design motions specified in the 1988 Uniform Building Code (UBC). A peak ground acceleration in firm soil of 0.25 - 0.3 g has a 1 in 10 chance of being exceeded in a 50-year period (Youngs and others, 1987). A peak ground acceleration of 0.5 - 0.6 g has a 1 in 10 chance of being exceeded in a 250-year period (Youngs and others, 1987). The seismic provisions of the UBC specify minimum earthquake-resistant design and construction standards to be followed for each seismic zone in Utah. The proposed water tank sites area currently in Uniform Building Code (UBC) seismic zone 3, although and amendment to the UBC to upgrade the Wasatch Front area to seismic zone 4 is being considered. For zone 3, design calculations require a Z-factor of 0.3, which effectively corresponds to a peak acceleration on rock of 0.3 g; design calculations require a z-factor of 0.4 for zone 4, which effectively corresponds to 0.4g. Because soil profiles at the sites are not well known, an S-3 soil type is specified by the UBC (1988 edition). This factor takes into account the effects of soil on earthquake ground motions.

Liquefaction

Liquefaction is a phenonemon that occurs when loose, saturated, fine-sand deposits are subjected to earthquake shaking, causing loss of shear strength (Anderson and others, 1982). Four types of ground failure are commonly associated with liquefaction (Anderson and others, 1982; Tinsley and others, 1985): 1) flow landslides (slopes greater than 5 percent), 2) lateral-spread landslides (slopes from 0.5 to 5 percent), 3) ground oscillation (slopes less than about 0.5 percent, liquefaction at depth), and 4) bearing-capacity failures (slopes less than 0.5 percent). Buried tanks could float to the surface if these soils were to liquefy, possibly damaging the tank or rupturing waterline connections.

The liquefaction potential at all three sites is high (Anderson and others 1982, 1990). As the depth to ground water increases, greater levels of ground shaking are required to cause liquefaction-induced ground failure (Keaton and Jalbert, 1991). Thus, the potential for such ground failure is greatest at the Howard Slough and South Bench sites where ground water is shallow, and least at the North Bench site. At the North Bench and South Bench sites, slopes are greater than 5% and liquefaction-induced ground failure may result in downslope movement. The Howard Slough site is flat, and liquefaction is likely to cause settlement but probably not lateral displacement.

Other Earthquake Hazards

There are no mapped faults which present a hazard from surface fault rupture in the vicinity of any of the three sites. Because of the distance of the sites from the Wasatch fault zone, the hazard from tectonic subsidence is low. The hazard from earthquake-induced slope failure is discussed below.

Slope Failures

The hazard from non-earthquake-induced slope failure and rock fall is low. The hazard from non-liquefaction-related earthquake-induced slope failures is probably also low at the North Bench and South Bench sites because of sandy soils and gentle slopes, and is low at the Howard Slough site due to the lack of any appreciable slopes. No existing slope failures have been mapped in the area.

Problem Soils

At the North Bench and South Bench sites the hazard from problem soils is low (Erickson and Wilson, 1968). Soils at the these two sites are sandy and contain little or no clay. The foundation of the water tank at these sites will be anchored on a concrete slab and existing water tanks at the two sites have no visible foundation problems.

At the Howard Slough site there is a possible hazard from expansive clays, sensitive clays, and compressible organic soils (Erickson and Wilson, 1968). Expansive clays cause differential settlement or heave with changes in the moisture content of a soil, and may result in cracking of foundations. The soil at the Howard Slough site has a moderate shrink-swell potential (Erickson and Wilson, 1968). Sensitive clays may occur at the site and can experience a loss of strength when disturbed during ground shaking. Compressible organic soils may also occur at this site and can cause differential settlement. Although the effects of these problems soils may be significantly reduced because of the rubberized design of the tank proposed at this site, these types of soils may still damage waterlines and waterline connections.

Shallow Ground Water

Shallow ground water may reduce the bearing capacity of soils and may cause buoyancy problems for buried tanks. At the North Bench site, ground water is well below the foundation of the tank. However, the extent of water-table fluctuations is not known, so it is still considered a potential problem. At the South Bench site, the depth to ground water is less than 10 feet and should be considered in foundation design. At the Howard Slough site, ground water is at or near the surface, and buoyancy of the rubberized tank and possible damage to the waterline connections may be a problem.

Other Hazards

The hazard from flooding is low at all three water tank sites (Federal Emergency Management Agency, 1982). Radon hazards are generally not a consideration for municipal water systems because sufficient aeration occurs in the system to dissipate any radon gas in the water.

CONCLUSIONS AND RECOMMENDATIONS

From a geologic-hazards standpoint, a water tank could be built safely at any of the three sites. However, in the order of suitability (from most to least suitable) and need for engineered hazard-reduction measures, the sites are: 1) North Bench, 2) South Bench, and 3) Howard Slough. The difference between the North Bench and South Bench sites is slight.

Earthquake ground shaking may affect all three sites. Information on three earthquake-resistant design options is presented: 1) probabilistic peak horizontal ground acceleration of 0.25 - 0.30 g that has a 10 percent chance of being exceeded in a 50-year period, 2) probabilistic peak horizontal ground acceleration of 0.5 - 0.6 g that has a 10 percent chance of being exceeded in a 250-year period, and 3) the minimum design ground motions for seismic zone 3 and zone 4 as designated by the UBC. Although ground motions in the second option have a low chance of occurring, the water improvement district should be aware that such ground motion from a large earthquake could occur at any time. Because we support the amendment that the Wasatch Front area be upgraded to seismic zone 4, we recommend that ground-motion levels expected for seismic zone 4 be used in design of the tank.

The hazards from surface fault rupture and tectonic subsidence at all three sites are low. The hazards from slope failure, rockfall, and flooding also are low.

Liquefaction potential at all three sites is high; site-specific studies to evaluate liquefaction and resulting ground-failure potential and recommend hazard reduction measures should be performed prior to final site design. At the North Bench, and particularly the South Bench site, shallow ground water may occur and require special design measures. At the Howard Slough site, shallow ground water and possibly expansive/sensitive clays and compressible organic soils may require special design measures. We recommend a standard soil foundation investigation to provide data required to design the water-tank foundation and address liquefaction, problem soil, and/or shallow ground-water hazards as shown in attachments 3a, 3b, and 3c. This report should be made available to the project engineers to ensure proper site selection, design and construction.

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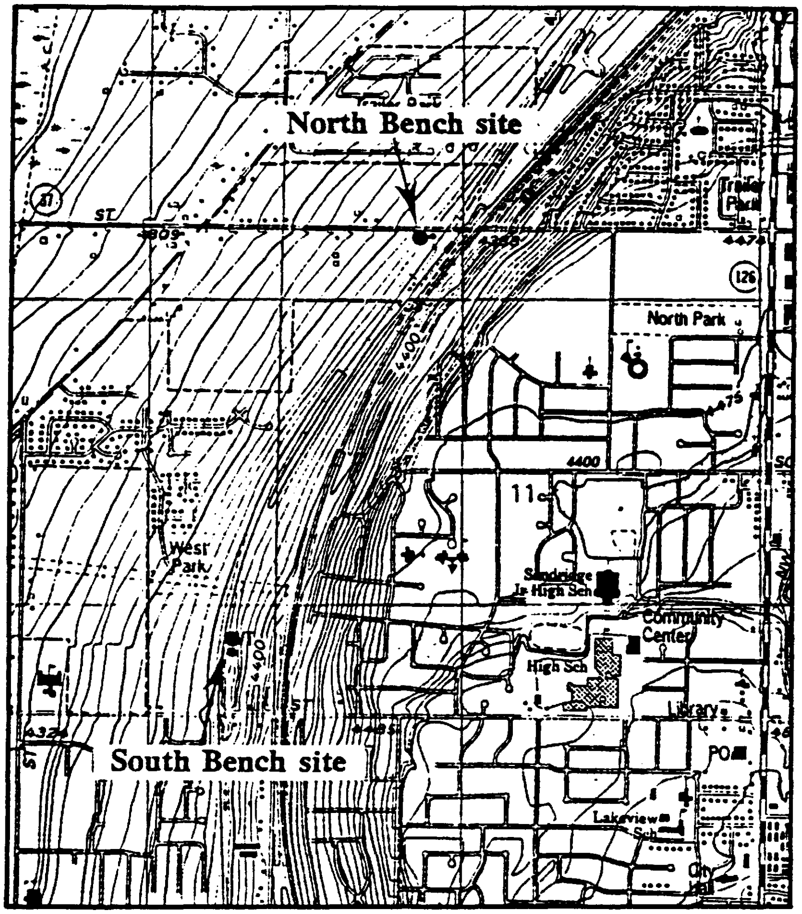
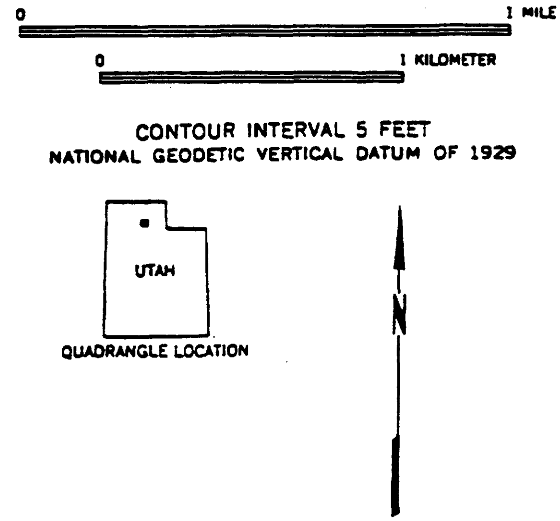
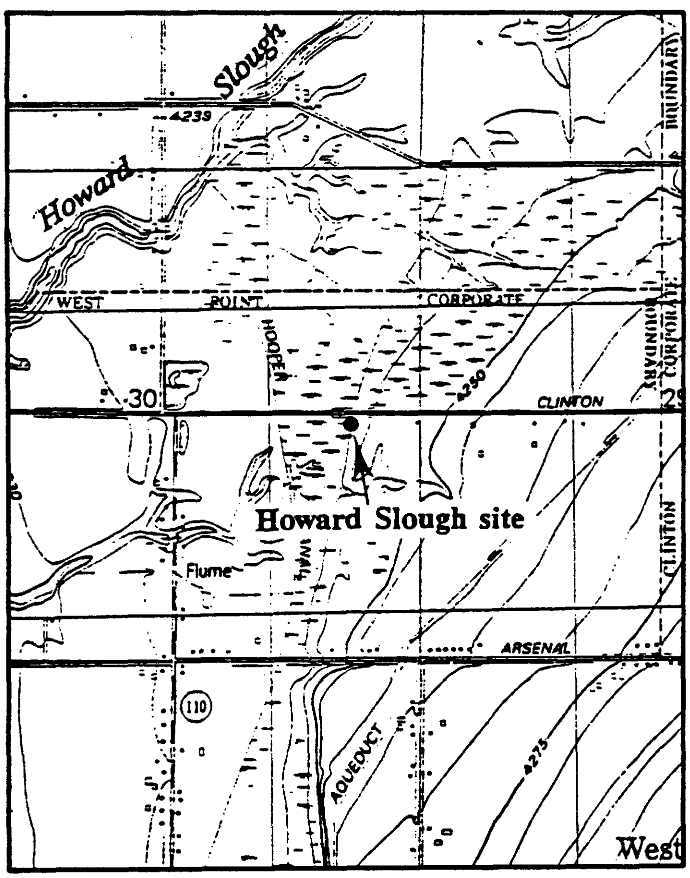
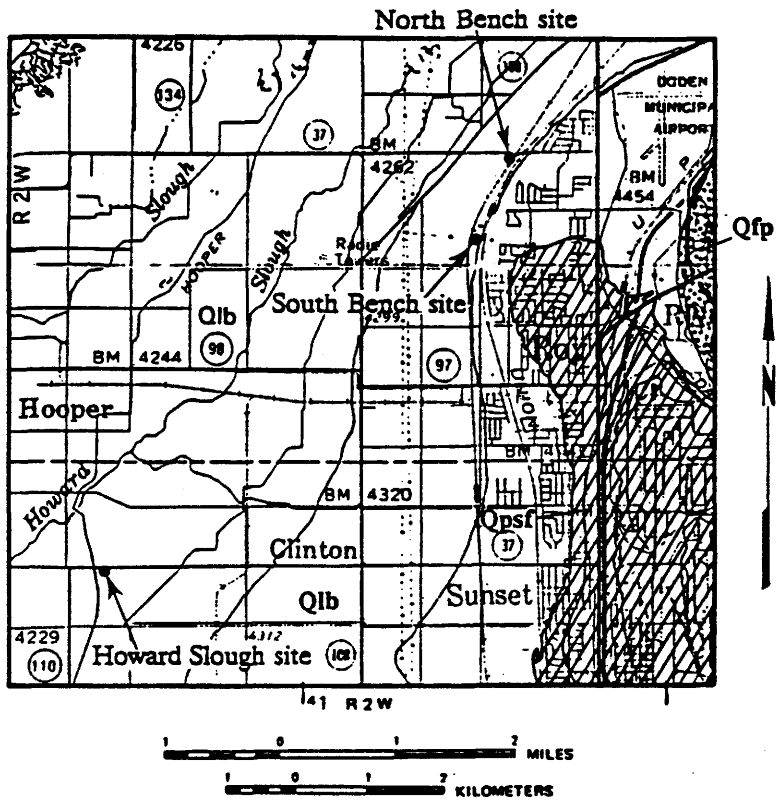


Base Map from ROY, U.S.G.S.
7-1/2' topographic quadrangle.





Attachment 1. Maps showing water tank sites.



Qfp — Floodplains. *Floodplains adjacent to existing streams; mostly silt and sand deposits.*

Qlb — Provo Formation and Younger Lake Bottom Sediments. *Clays, silts, sands, and locally, offshore sand-bars.*

Qpsf — Provo Formation and Younger Shore Facies. *Chiefly sand and gravel in beach deposits, bars, spits, and deltas.*

Attachment 2. Geologic map (after Davis, 1985).

SUMMARY OF GEOLOGIC HAZARDS
Hooper North Bench SITE

	Hazard Rating*			Further Study Recommended**
	Prob-able	Pos-sible	Un-likely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction		X		S
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow ground water		X		S
Flooding				
Streams			X	
Alluvial fans			X	
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon	Not evaluated			

*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
Hooper South Bench SITE

	Hazard Rating*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction	X			S
Slope failure			X	
Flooding			X	
Sensitive clays			X	
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive			X	
Organic			X	
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow ground water	X			S
Flooding				
Streams			X	
Alluvial fans			X	
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon	Not evaluated			

*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
Hooper Howard Slough SITE

	Hazard Rating*			Further Study Recommended**
	Probable	Possible	Unlikely	
Earthquake				
Ground shaking	X			
Surface faulting			X	
Tectonic subsidence			X	
Liquefaction	X			S
Slope failure			X	
Flooding			X	
Sensitive clays		X		S
Slope failure				
Rock fall			X	
Landslide			X	
Debris flow			X	
Avalanche			X	
Problem soils/subsidence				
Collapsible			X	
Soluble (karst)			X	
Expansive		X		S
Organic		X		S
Piping			X	
Non-engineered fill			X	
Erosion			X	
Active sand dunes			X	
Mine subsidence			X	
Shallow ground water	X			S
Flooding				
Streams			X	
Alluvial fans			X	
Lakes			X	
Dam failure			X	
Canals/ditches			X	
Radon		Not evaluated		

*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.

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).

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.

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.

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

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

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

Richter magnitude - see Magnitude

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

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

Sand dunes - See Active sand dunes.

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

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

Seismicity - Seismic or earthquake activity.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Project: Preliminary assessment of geologic hazards at telecommunication facilities and microwave towers throughout Utah			Requesting Agency: Utah State Division of Information Emergency Management
By: Susan Olig	Date: 5-28-91	County: Statewide	Job No.: (GH-9) 91-07
USGS Quadrangle: Statewide			

PURPOSE AND SCOPE

This report summarizes a preliminary geologic hazard assessment of sites occupied by microwave towers, state-owned or leased telecommunications facilities, and U.S. West facilities throughout the state of Utah. The assessment was requested by Paul Forsythe, Division of Information Technology Services (ITS), so that geologic hazards, which could affect the performance of these critical facilities, could be considered in their long-term management. The purpose of this study is to highlight where geologic hazards exist or may exist within the system, and to help ITS assess its vulnerability and determine where further investigation is needed. This reconnaissance assessment was limited to review of existing information, and only catastrophic hazards affecting emergency response were assessed, including earthquake, slope-failure, and flood hazards. We did not conduct any field investigations. We strongly recommend that detailed site investigations be conducted prior to construction of a new facility or significant modification of an existing facility so that geologic hazards can be adequately considered in site-specific design.

GEOLOGIC HAZARD ASSESSMENT

We divided the sites into two categories for assessment purposes, U.S. West and state-operated telecommunication facilities, and microwave towers. The U.S. West and state-operated facilities are all located in valleys or alluvial basins where there is considerable variation in the hazards present at each site. For convenience, we've tabulated the hazard information for these sites. In contrast, all of the microwave towers are located near or on the tops of peaks. In regard to hazards, these sites are very similar to one another and a table delineating specific hazards at each site would be repetitive. Therefore, we discuss the hazards at these sites as a group and point out differences where appropriate.

U.S. West and State-Operated Facilities

Tables 1 and 2 list the specific earthquake, slope-failure, and flood hazards that were assessed for the state-operated and U.S. West facilities, respectively. Attachment 1 is a glossary explaining these hazards and other terms. Sites were assessed as Y if information indicates the hazard is present, N if information indicates the hazard is not present, or P if existing information is incomplete or equivocal and the hazard may be present.

Earthquake hazards are the most common hazards for all the state-operated facilities (table 1). All of these facilities are along the central Wasatch Front, where both historic and prehistoric earthquake activity is well-documented (for example, Arabasz and others, 1987; Machette and others, 1991), and all the sites are subject to potentially damaging ground motions from earthquakes. The Wasatch Front is within the Intermountain seismic belt, a north-south trending belt of shallow seismicity that extends from Montana, south through Idaho and central Utah, and into northern Arizona (Smith and Sbar, 1974). Many sites are underlain by water-saturated silts and sands and these sites are also subject to liquefaction (for example Anderson and others, 1986; 1990). Earthquake-related flooding caused by regional tilting of the ground surface, principally during large earthquakes, is also possible at many sites (Keaton, 1986). Failure of sensitive clays is caused by ground shaking during earthquakes and although sensitive clays have been identified along the Wasatch Front (Parry, 1974), very little is known about their distribution. Only one facility, Perpetual Storage Inc. in Little Cottonwood Canyon, is subject to slope-failure hazards. Only a few sites are subject to flooding from streams or dam failure. It should be noted that assessment of flooding from dam failure only reflects the results from dam-failure inundation studies and does <u>not</u> reflect the likelihood of dam failure or the structural integrity of the dam.

The U.S. West facilities along the Wasatch Front are similar, in regards to geologic hazards (table 2), to the state-operated facilities previously discussed. In general, outside of the Wasatch Front there is less available information about geologic hazards; thus, the greater number of P or equivocal hazard ratings. U.S. West facilities within the Intermountain seismic belt are subject to earthquake hazards such as ground shaking (for example, Cedar City, Kanab, Richfield, and Price), whereas facilities outside the Intermountain seismic belt are generally not subject to earthquake hazards (for example, Roosevelt, Vernal, and Green River). Besides earthquake hazards, the most common potential hazards are flooding from streams, alluvial fans, and dam failure. Potential slope-failure hazards are rare (for example, Wendover).

<u>Microwave Towers</u>

Because microwave towers are generally located on or near mountain peaks (P. Forsythe, oral commun., 1991), these sites are inherently subject to few geologic hazards. The only earthquake hazard likely to exist at these sites is ground shaking, and attachment 2 shows the locations of microwave towers relative to the ground-shaking hazard in the state. This map shows contours of ground accelerations (in units of percent gravity or g) with a 10 percent probability of being exceeded in 50 years (Algermissen and others, 1990). Microwave towers within the 10 percent g contour are more likely to experience damaging ground motions, and towers within the 20 percent g contour are in the area with the greatest ground shaking hazard. Although damaging ground motions are less likely in the area outside the 10 percent g contour, such motions are still possible, particularly for sites near the boundary, such as Frisco Peak, Tabby Mountain, and Cedar Mountain. It should be noted that numerous studies indicate that ground motions can be amplified on peaks (for example, Davis and West, 1973; Kawase and

Table 1. Preliminary assessment of geologic hazards at larger state-owned or leased telecommunication offices. Assessment was based solely on existing information: N - no evidence for potential hazard; Y - evidence indicates potential hazard exists; P - evidence is equivocal or incomplete, hazard may exist.

SUMMARY OF GEOLOGIC HAZARDS CRITICAL TO EMERGENCY RESPONSE FACILITIES													
	Earthquake					Slope failure				Flooding			
Site	Ground Shaking	Surface faulting	Lique-Faction	Flooding	Sensi-tive clays	Rock fall	Land-slide	Debris flow	Aval-anche	Streams	Alluvial fans	Lakes	Dam Failure
State Office Building	Y	N	N	N	N	N	N	N	N	N	N	N	N
Computer Center	Y	N	N	N	N	N	N	N	N	N	N	N	N
Capitol Building	Y	N	N	N	N	N	N	N	N	N	N	N	N
Calvin Rampton 4500 S. 2700 W.	Y	Y	Y	N	P	N	N	N	N	N	N	N	N
Triad Center 355 N. North Temple	Y	N	Y	Y	P	N	N	N	N	N	N	N	P
Human Services 120 N. 200 W.	Y	Y	N	Y	P	N	N	N	N	N	N	N	N
Health 288 N. 1460 W.	Y	N	Y	Y	P	N	N	N	N	N	N	N	P
Corrections 6100 S. 500 E.	Y	N	Y	Y	P	N	N	N	N	N	N	N	N
Courts 230 S. 500 E.	Y	N	Y	N	P	N	N	N	N	N	N	N	N
Agriculture 350 N. Redwood Road	Y	N	Y	Y	P	N	N	N	N	Y	N	P	P
Provo Regional Center 150 E. Center St., #2100	Y	N	Y	Y	P	N	N	N	N	N	N	N	N
Ogden Regional Center 2540 Washington Blvd.	Y	N	Y	Y	P	N	N	N	N	Y	N	N	Y
Perpetual Storage Inc. 6279 E. Little Cottonwood Canyon Rd.	Y	N	N	N	N	P	P	P	Y	P	P	N	P

Table 2. Preliminary evaluation of geologic hazards at U.S. West facilities. Assessment was based solely on existing information : N - no evidence for potential hazard; Y - evidence indicates potential hazard exists; P - evidence is equivocal or incomplete, hazard may exist.

SUMMARY OF GEOLOGIC HAZARDS CRITICAL TO EMERGENCY RESPONSE FACILITIES													
	Earthquake					Slope failure				Flooding			
Site	Ground Shaking	Surface faulting	Lique-Faction	Flooding	Sensi-tive clays	Rock fall	Land-slide	Debris flow	Aval-anche	Streams	Alluvial fans	Lakes	Dam Failure
Bountiful - 45 W. 2nd S.	Y	N	N	N	P	N	N	N	N	P	N	N	N
Cedar City - 41 N. Main	Y	N	N	N	N	N	N	N	N	P	N	N	N
Clearfield - 363 N. Main	Y	N	N	N	P	N	N	N	N	N	N	N	N
Draper - 11351 S. 10th St.	Y	N	N	N	N	N	N	N	N	N	N	N	N
Farmington - 50 N. 1st E.	Y	N	Y	N	P	N	N	N	N	N	P	N	N
Green River - 245 N. Cherry	N	N	N	N	N	N	N	N	N	P	P	N	N
Heber City - 145 W. Center	Y	N	N	N	N	N	N	N	N	N	N	N	P
Holladay - 2335 E. 4800 S.	Y	N	N	N	P	N	N	N	N	N	N	N	N
Kanab - 23 S. 100 E.	Y	N	P	N	N	N	N	N	N	P	P	N	N
Kearns - 2780 S. 4015 W.	Y	N	N	N	P	N	N	N	N	N	N	N	N
Kaysville & Layton - 360 S. Fort Lane	Y	N	Y	Y	P	N	N	N	N	N	N	N	P
Logan - 10 S. 1st. E.	Y	N	N	P	P	N	N	N	N	N	N	N	P
Magna - 2680 S. 940 W.	Y	N	Y	N	P	N	N	N	N	N	N	N	N
Midvale - 55 E. 7800 S.	Y	N	Y	N	P	N	N	N	N	N	N	N	N

Aki, 1990) and accelerations mapped on attachment 2 do not take this into account. Thus, actual values could be higher. Unfortunately, these effects are very site- and earthquake-specific and difficult to predict. However, the problem of ground shaking might not be as severe as it first appears; it is possible that for many towers, the necessary lateral resistance to wind would be greater than lateral forces necessary for earthquake design. A qualified structural engineer would need to evaluate this possibility.

Because of the relatively high topographic position of the microwave towers, flood hazards are not expected at these sites. The potential for slope-failure hazards is generally low, particularly if the towers are at the locally highest elevation (that is, directly on a peak); they would not be subject to rock falls, debris flows, or avalanches. However, towers located below peaks could be subject to these hazards, and field inspection of these sites would be necessary to assess these hazards. Eight microwave towers are potentially subject to deep-seated landslides, including Bald Mesa, Teasdale Peak, Frisco Peak, Cedar Mountain, Levan Peak, Oquirrh Mountain, Lewis Peak, and Logan Peak (Harty, 1991).

SUMMARY

Tables 1 and 2 summarize results from this preliminary assessment of geologic hazards at state-operated and U.S. West telecommunications facilities. In general, sites within the Intermountain seismic belt, and particularly along the Wasatch Front, are subject to more hazards than sites located elsewhere in the state. Earthquake hazards, particularly ground shaking and liquefaction, are the most common hazards. Flood hazards from streams are the next most common hazard, whereas only a few sites are subject to slope-failure hazards.

In contrast, microwave towers are subject to fewer geologic hazards because of their general locations on peaks. Ground shaking is the greatest and most common hazard, particularly within the area of the Intermountain seismic belt (attachment 2). Most sites do not have potential slope-failure hazards but some towers need to be evaluated on a site-specific basis. These include towers below the locally highest elevation, which could be subject to rock falls, debris flows, or avalanches, and towers that could be subject to deep-seated landslides (Bald Mesa, Teasdale Peak, Frisco Peak, Cedar Mountain, Levan Peak, Oquirrh Mountain, Lewis Peak, and Logan Peak).

This preliminary assessment was based solely on published information and we strongly recommend that prior to construction of new facilities or modification of existing facilities that a detailed site investigation, including a field inspection, be conducted so that geologic hazards can adequately be considered in design. Site-specific evaluations will be needed to further assess hazards at those sties where hazards are rated as Y or P in tables 1 and 2 and for certain microwave towers as discussed in the previous section.

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GLOSSARY OF GEOLOGIC HAZARDS TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Graben - A block of earth downdropped between two faults.

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

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

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

Hydrocompaction - see Collapsible soil.

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

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

Karst - See Soluble soil/rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Richter magnitude - see Magnitude

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

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

Sand dunes - See Active sand dunes.

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

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

Seismicity - Seismic or earthquake activity.

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

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

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

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

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

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

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

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

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

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

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

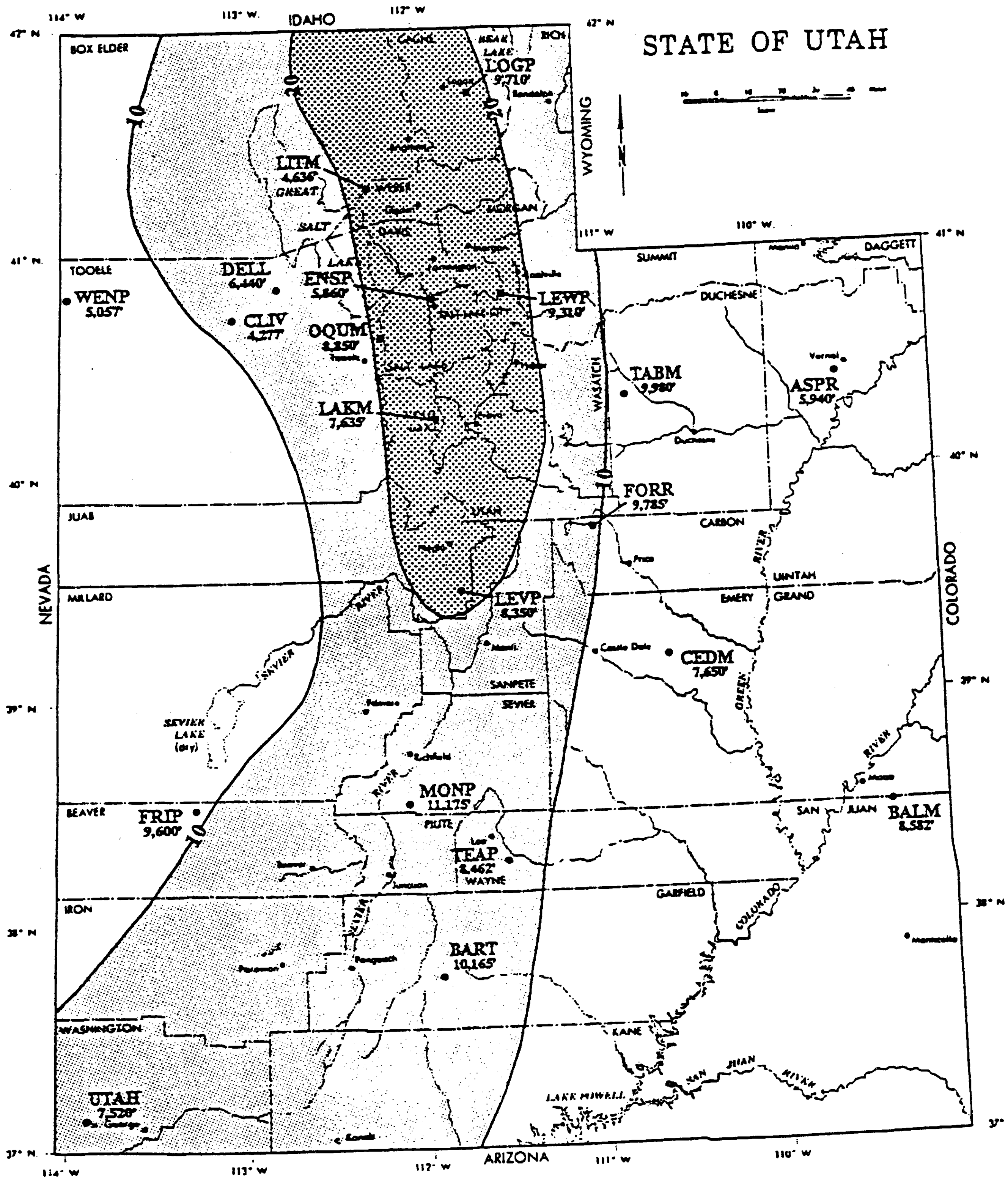
Unconfined aquifer - An aquifer without a low-permeability overlying bed such that water in the aquifer is not under pressure.

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

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

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

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



Attachment 2. Locations of microwave towers relative to the earthquake ground shaking hazard in Utah. Shaded areas have a greater potential for experiencing damaging ground motions. Darker shading shows the area with the greatest hazard. Contours are accelerations on rock (in percent g) with a 10 percent probability of being exceeded in 50 years (from Allgermissen and others, 1990).

Project: Reconnaissance investigation of active ground cracks north of Newcastle, Iron County, Utah			Requesting Agency: National Earthquake Information Center, USGS
By: Gary E. Christenson	Date: 6-12-91	County: Iron County	Job No.: (GH-10) 91-08
USGS Quadrangle: Newcastle (242)			

INTRODUCTION

On April 30, 1991, an investigation was performed of ground cracks approximately 5 miles north of Newcastle in the Escalante Desert (SW1/4 sec. 23 and NW1/4 sec. 26, T. 35 N., R. 15 W., SLBM; attachment 1). The cracks were brought to our attention in a letter (dated March 27, 1991) from a Beryl resident (Evan Hansen) to the National Earthquake Information Center in Golden, Colorado, forwarded to us by Anthony J. Crone of the U.S. Geological Survey. The purpose of the investigation was to determine the origin of the cracks, which has direct implications with respect to their hazard potential.

The Utah Geological Survey (UGS) recently completed several geologic studies in the Newcastle area, and this investigation was performed in part because the cracks may have implications for those studies. The UGS investigated the geothermal resources in the Newcastle area under contract to the U.S. Department of Energy (Blackett and others, 1990), and also worked in cooperation with the U.S. Geological Survey to produce a geologic map of the Newcastle quadrangle (Siders and others, 1990) and a map of Quaternary faults in the Cedar City 1°X2° quadrangle (Anderson and Christenson, 1989). These studies involved specific investigations of the ground-water system, geology, and tectonics of the area.

The scope of additional work for this study of ground cracks was a field reconnaissance on April 30, 1991 in one area of cracks (attachment 1). I was accompanied on the investigation by Mr. Hansen and Robert M. Robison of Sergent, Hauskins, and Beckwith, geotechnical consultant for the Kern River Pipeline which passes east of the area of cracks. Kimm M. Harty and Robert Blackett, UGS, reviewed this report. A glossary of geologic hazards terms is included in attachment 2.

DESCRIPTION

Mr. Hansen first noticed the ground cracks in 1975 or 1976. He remembers a period of increased activity in 1978, but they were less active from 1982 until 1990. He believes they are now undergoing another period of increased activity. It is not known whether this "increased activity" noted by Mr. Hansen relates to opening of cracks, or merely increased erosion along existing cracks. During a previous period of "activity," Mr. Hansen measured a 4-inch increase in distance between stakes placed on either side of a crack, indicating that this "activity" is due, at least in part, to opening of cracks. During the field reconnaissance on April 30, we made a measurement between stakes placed earlier this year and found no change. The most recent crack activity roughly coincides with a period of below-normal precipitation which began in 1988. The years prior to 1978 were also dry, although 1978 was wetter than normal (Office of the Utah State Climatologist, unpublished data). Mr. Hansen has noticed other areas of cracks in the southern Escalante Desert, including some just 2 miles to the south of these cracks and others 2 miles west of Newcastle.

Ground cracks investigated for this study are in an area of sagebrush and grass which is used for cattle grazing. No fresh, uneroded cracks were observed. All cracks have been eroded or degraded by surface-water flow, piping, and grazing animals. Crack width varies, depending on the extent of erosion, piping, and collapse. Many cracks consist of a series of connected, shallow, elongate closed depressions, up to a foot deep and several feet wide, which channelize flow and locally direct water into the subsurface. Open voids along cracks extend several feet below the bottoms of some of these depressions. Shallow modern drainages through the area are likely developed along cracks. Some cracks are associated with what appear to be broader areas of localized subsidence, although topographic surveys would be needed to confirm this. No evidence of vertical offset across the cracks was observed, however, erosion may mask small offsets on the order of several inches or less.

Crack lengths vary from several tens of feet up to about a hundred feet. The dominant trend of the cracks is N-S to NNE, parallel to modern drainage. The dominance of this trend is due in part to original crack orientation and in part to preferential erosion along drainages. East-west-trending cracks are less common, and are generally shorter than N-S-trending cracks. Cracks are widely and irregularly spaced. We observed approximately a dozen cracks of varying lengths in an area of roughly 0.1 square miles (attachments 1 and 3).

GEOLOGIC SETTING

Surficial soil in the area of ground cracks is sandy, silty clay (CL) and clayey silt (ML). Mud cracks are common at the surface, and the soil is mostly dry except in some closed depressions along cracks. These silty and clayey soil types are highly erodible and subject to piping. The U.S. Soil Conservation Service (Ulrich, 1952) maps the upper 5 feet of soil as Antelope Springs silt loam.

The area of cracks is in the distal part of a young (Holocene and Upper Pleistocene) alluvial fan deposited by Pinto Creek (Siders and others, 1990). It is on the east edge of that fan where the main channel of Pinto Creek flowed prior to diversion upstream by man (attachment 3). Modern runoff and sheetwash is locally channelized because the area remains topographically low. The contact between alluvial-fan deposits from the Antelope Range to the east and the Pinto Creek alluvial fan is along the east edge of the area of cracks (attachment 3). Slopes are steeper and soils correspondingly coarser grained to the east on the Antelope Range alluvial fans.

The Antelope Range fault follows the west-facing range front and is a basin-and-range normal fault with evidence for recurrent Quaternary movement (Shubat and Siders, 1988; Siders and others, 1990). The most recent event was probably during middle to late Pleistocene time, and no definitive evidence for Holocene activity has been identified (Anderson and Christenson, 1989). The dominant trend of the cracks roughly parallels (1) the Antelope Range fault, (2) the geologic contact between alluvial fans from the Antelope Range and Pinto Creek, and (3) modern drainage (attachment 3).

GROUND WATER

The principal ground-water aquifer in the Escalante Desert is the Quaternary-age unconsolidated and semiconsolidated gravel, sand, silt, and clay which fills the valley (Mower, 1982; Klauk and Gourley, 1983). Mower (1982) reports that the aquifer ranges in thickness from zero near the edge of the valley to more than 1000 feet in the center. Gravity surveys south of Newcastle suggest that the unconsolidated and semiconsolidated basin-fill deposits between Newcastle and Beryl Junction may be as much as a mile thick (Blackett and others, 1990). Bedrock aquifers bound and underlie the principal aquifer. Recharge to the principal aquifer is by subsurface flow from bedrock and inflow from stream channels and irrigation (Mower, 1982). The aquifer contains silt and clay beds, but none are of sufficient extent to preclude vertical movement of water (Mower, 1982), and thus the aquifer is unconfined.

Prior to the beginning of large-scale pumping for irrigation, flow of ground water in the principal aquifer was to the north toward the Milford area (Mower, 1982; Klauk and Gourley, 1983). Pumping in the southern Escalante Desert has altered the flow of ground water by creating a large cone of depression centered near Beryl Junction. Water-level declines from 1937 to 1978 of more than 60 feet have been documented in the area of maximum water-level decline south of Beryl Junction (Mower, 1982). The northernmost effects of this cone of depression extend 10 miles north of Beryl Junction, and ground-water flow in this area is now from north to south. In the area of ground cracks north of Newcastle, about 30 feet of decline occurred during the period from 1937 to 1978 (Mower, 1982).

ORIGIN OF THE GROUND CRACKS

Possible origins for the ground cracks can be grouped into two categories: (1) subsidence resulting from soil/water interaction, and/or (2) active tectonics. Under (1) above, cracks may be caused by (a) subsidence due to ground-water withdrawal from shrinking of expansive clays upon drying and/or consolidation accompanying removal of pore water, (b) hydrocompaction in collapsible soil, (c) natural differential settlement or consolidation of basin-fill deposits, and/or (d) dissolution of soluble materials with subsequent subsidence/collapse. Possible tectonic origins include (a) surface fault rupture associated with the Antelope Range fault or buried faults in the Escalante Valley, (b) liquefaction, or (c) aseismic spreading and tensional cracking.

Soil/Water Interaction

Ground-Water Withdrawal

Polygonal ground cracks in clayey soil have been reported southwest of Milford, where they have been attributed to drying, contraction, and subsidence accompanying lowering of the water table due to pumping (Mower and Cordova, 1974). Maximum drop in the water table in the Milford area from 1950 to 1972 was about 30 feet, and subsidence of 4 inches has been documented at one well head (Mower and Cordova, 1974). About 2 miles east of Newcastle, where maximum water-table declines in the Escalante Desert are recorded, other large-scale polygonal cracks are visible on 1967 air photos in an area of clayey soil and restricted drainage.

Two wells are near the area of cracks (attachments 1 and 3). A stock-watering well is at the west edge of the area (well #1), and an irrigation well is about 2000 feet further west (well #2) (Mower, 1981, 1982). The depth to water measured at well #2 was about 32 feet in 1949, dropping to 66 feet in 1980 (Mower, 1981). This is a large-discharge well with a measured discharge in 1977 of 790 gal/min (Mower, 1981). The greatest rate of decline occurred in the years prior to 1977, when the depth to water was greatest (78 feet) (Mower, 1981). The driller's log for well #2 indicates that the upper 74 feet is almost entirely clay, and the interval of water-table fluctuation is "heavy clay" (Mower, 1981), a term generally used by drillers to indicate highly plastic clay. High plasticity clays are generally expansive and shrink as moisture content is reduced, such as would occur during a decline in the water table. In other nearby wells, more sand and gravel are reported (Mower, 1981). These observations are all consistent with an origin for the cracks related to shrinking of expansive clays accompanying water-table declines due to pumping. Also, activity on the cracks roughly coincides with periods of below-normal precipitation, presumably when the water table is lowest and declines from pumping are greatest.

No attempt was made to identify and analyze existing geodetic survey data or investigate wells for evidence of regional subsidence and its relation to water-table declines. Survey data may exist along roads and railroads in the Escalante Desert, but it is unlikely that a survey of sufficient accuracy (1st Order) to detect small (less than 1 foot) elevation changes has ever been performed near the area of cracks. There is no reported evidence at well heads for subsidence (Woody Sandberg, U.S. Geological Survey Water Resources Division, oral commun., May 28, 1991), although detailed investigations have not been performed.

Hydrocompaction

Hydrocompaction in collapsible soil has caused subsidence and ground cracks in other parts of southwestern Utah, particularly near Richfield and Cedar City. Although grain sizes (clayey silt) of alluvial-fan deposits in the area of cracks north of Newcastle are typical of collapsible soil elsewhere, the depositional environment (stream-flow deposits in the distal part of an alluvial fan) is not. Surficial materials may, however, include a significant eolian component, and Holocene eolian silts are commonly subject to hydrocompaction. Localized hydrocompaction in collapsible soil commonly results in vertical offset across cracks, and this was not apparent here. However, the cracking at the surface could be the result of hydrocompaction in deeper layers which causes only tension cracks at the surface. Localized depressions and broad swales typical of areas of hydrocompaction appear to be present, although cracks do not circumscribe these depressions as commonly occurs in hydrocompaction. Thus, the evidence for hydrocompaction as an origin for the cracks is not strong, but it cannot be ruled out.

Natural Differential Settlement

In the Las Vegas Valley, so-called "compaction fault" scarps in basin-fill sediments have been attributed to differential consolidation of underlying sediments having dissimilar grain-size and compressibility characteristics (Werle and Stilley, 1991). Although there are no scarps associated with the ground cracks north of Newcastle, the possibility that they may originate from differential settlement of the underlying basin fill should be considered.

The cracks occur at the edge of the thick Escalante Desert basin fill, which in this area is at least more than 257 feet thick (depth of well #2), and is likely much thicker. Proceeding west from the Antelope Range, the thickness and compressibility of basin-fill deposits increases as grain size decreases. An abrupt change in thickness and grain size occurs near the area of cracks at the contact between fine-grained silt and clay of the Pinto Creek alluvial fan, and sand and gravel of the Antelope Range alluvial fans (attachment 3). This area may thus act as a hinge-line for any natural differential settlement that may occur.

If natural differential settlement were occurring, however, it is likely that it would be a progressive process through time, and that evidence for prehistoric settlement such as the "compaction fault" scarps in the Las Vegas Valley would be present. Because only modern ground cracks are evident, it is unlikely that long-term natural settlement is taking place. However, because the area of cracks is near the edge of saturated basin-fill deposits in an area of probable abrupt change in thickness and coarseness of deposits, any settlement caused by modern water-table declines may hinge here.

Dissolution of Soluble Materials

Surface subsidence and cracking may accompany dissolution of soluble materials such as halite (salt), gypsum, and calcium/ magnesium carbonates (pedogenic caliche, limestone, dolomite). Bedrock in mountains which drain into this part of the Escalante Desert, and clasts in alluvium derived from these mountains, are chiefly volcanic in origin and contain few soluble minerals. A Pleistocene-age gypsum bed up to 10 ft thick is present on the floor of the Escalante Desert about 4.5 mi west of the area of cracks (Siders and others, 1990). Eroded polygonal cracks generally less than 2 ft long, probably caused by contraction accompanying desiccation, are common in the gypsum bed where it is exposed at the surface. The bed grades laterally into similar-age alluvial-fan deposits which contain a 3-5 ft thick pedogenic carbonate horizon (Siders and others, 1990). No cracks are present in these carbonate-rich deposits.

Although sedimentary environments conducive to deposition of soluble materials may have existed in the past in the Escalante Desert, no halite, gypsum, or carbonate "hardpans" are reported in logs of wells in the area of cracks (Mower, 1981). The modern soil is relatively young and contains little carbonate.

Active Tectonism

Historical seismicity in the Escalante Desert is scattered and of small to moderate magnitude (University of Utah Seismograph Stations unpublished data, in Anderson and Christenson, 1989). The largest earthquake in the area was the 1901 Pine Valley earthquake (estimated magnitude 6.3) about 25 miles to the south. Several magnitude 5 earthquakes occurred in Cedar City in 1942, about 25 miles to the east. No significant earthquakes have occurred during the time immediately preceding recognition of the cracks around 1975, and none has occurred since. The vicinity of the cracks is characterized by a lack of significant earthquakes throughout historical time. However, because of the sparse population prior to placement of seismographs in the area, and the few instruments in this part of the University of Utah seismograph network, the historical record is probably not complete.

There is little evidence for Holocene-age activity on any faults in the Escalante Desert (Anderson and Christenson, 1989). The only Quaternary fault mapped in the area is the Antelope Range fault (attachment 2). The most recent surface faulting on this fault is conservatively estimated to have been in middle to late Pleistocene time (10,000 to 750.000 years ago) (Anderson and Christenson, 1989). The dominant orientation of ground cracks is parallel to the trace of the Antelope Range fault. The fault is about 3/4 mile east of the cracks, putting the cracks outside what would normally be considered the zone of deformation and surface faulting. There is no evidence for deformation in the area between the cracks and the fault. No earthquakes large enough to cause surface faulting (magnitude about 6.5 or larger) have been reported in the area of cracks in historical time, and thus it is unlikely that the cracks are a result of surface faulting on the Antelope Range fault or an unidentified buried fault at the site.

In general, liquefaction only occurs in earthquakes of magnitude 5 and larger. The lack of such earthquakes nearby, the depth to ground water of greater than 30 feet, and the presence of fine-grained basin fill generally not susceptible to liquefaction, indicate that liquefaction is an unlikely cause of the cracks.

Active aseismic extension, proposed as a possible cause of the cracks by Mr. Hansen, is difficult to evaluate. In general, repeated geodetic measurements or gravity surveys are needed to identify modern tectonic activity (Thatcher, 1986). Such data are not available in the Newcastle area. Geomorphic studies can yield indications of active tectonic processes over a longer term, but appropriate datums such as paleolake shorelines are not present in the Escalante Desert. However, detailed evaluation of the drainage and geomorphology of the generally flat valley floor (for example, the distribution of modern closed depressions, drainage channel profiles, and drainage patterns) may be used to search for evidence of recent tectonism. Such geomorphic studies detect only relative vertical movements, however, and do not detect horizontal movements except as they may be reflected in subsidence (extension) or uplift (compression). Any vertical movements detected by these geomorphic studies may have the same uncertainty in origin as do the cracks.

CONCLUSIONS

Without further study, it is difficult to determine the origin of the ground cracks. The most likely cause is believed to be contraction and subsidence accompanying drying and consolidation of clayey basin-fill deposits due to lowering of the water table. In the area of cracks, the entire thickness of soil in the interval of recent water-level decline (32-66 feet) is noted on driller's logs as "heavy clay." The cracks are localized because of this clay, and also because of the valley-margin position where changes in basin geometry, thickness and grain size of deposits, and thickness of saturated basin fill are greatest and most abrupt. Activity on the cracks also seems to coincide with periods of below-normal precipitation, presumably when the water table is lowest and declines from pumping are greatest. Hydrocompaction of collapsible soil may play a role in the development of the cracks, but dissolution of soluble material, surface faulting, and liquefaction probably do not. Active aseismic extension is considered unlikely, but cannot be excluded as a possible origin without geodetic measurements of modern regional horizontal strain.

For a definitive evaluation of ground crack origins, it may be necessary to (1) map the areal distribution and extent of cracks in the Escalante Desert and evaluate their relation to subsurface geology, pumping centers, and depth to water, (2) perform soil tests to identify collapsible and expansive soils, (3) excavate trenches to investigate depth and width of primary cracks, and (4) perform studies to identify regional subsidence. Geophysical (gravity, seismic) and topographic surveys in areas of cracks may help to better define the depth to ground water and bedrock, and extent of subsidence accompanying cracking. Microseismic, gravity, and geodetic monitoring, and geomorphic analysis of late Quaternary deposits, may also be helpful in evaluating possible origins.

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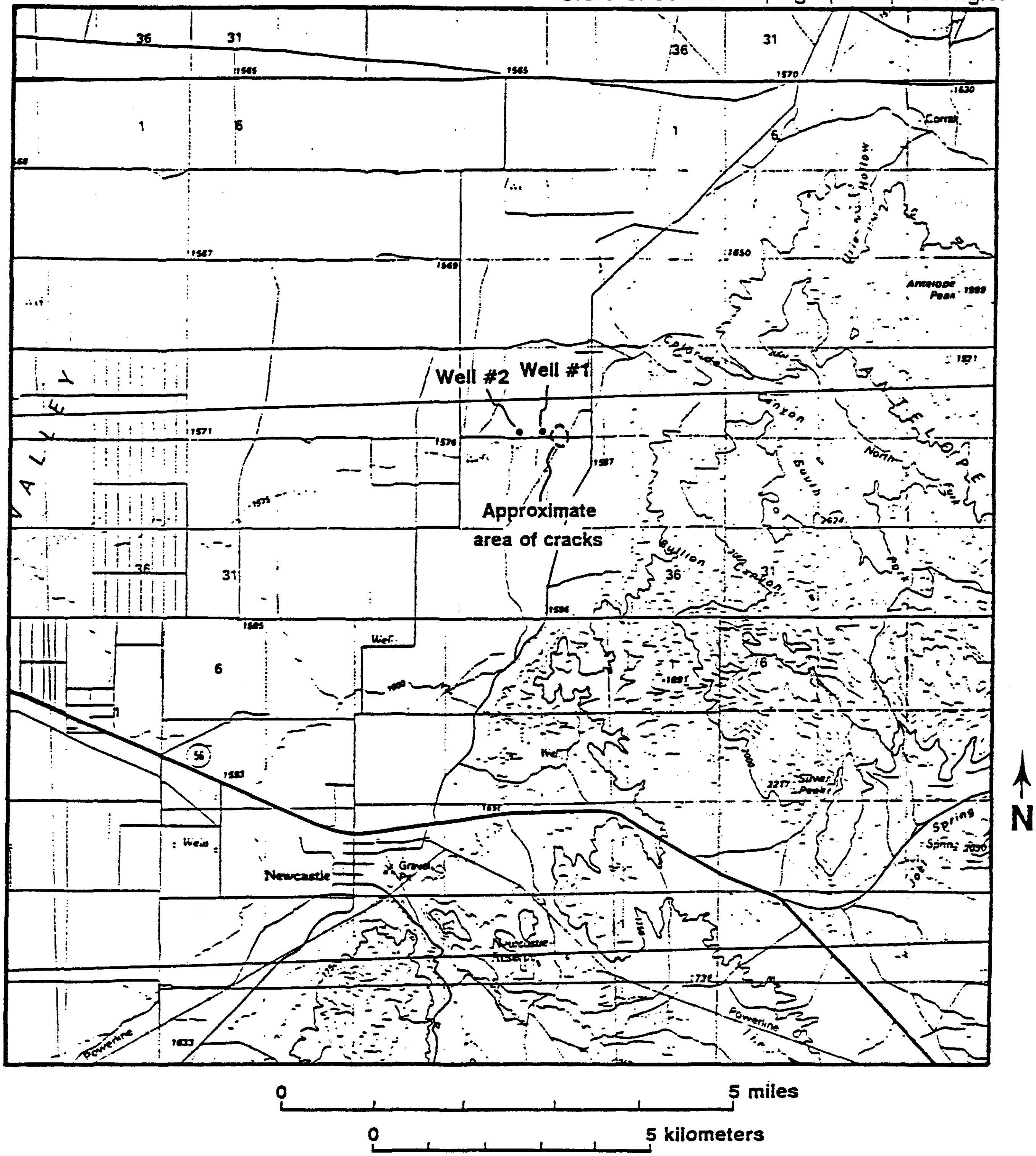
Attachment 1
Job No.

Base Map from CEDAR CITY,
U.S.G.S. 30'x 60' topographic quadrangle.



Attachment 1. Location map.

GLOSSARY OF GEOLOGIC HAZARDS TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Graben - A block of earth downdropped between two faults.

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

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

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

Hydrocompaction - see Collapsible soil.

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

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

Karst - See Soluble soil/rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Richter magnitude - see Magnitude

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

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

Sand dunes - See Active sand dunes.

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

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

Seismicity - Seismic or earthquake activity.

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

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

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

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

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

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

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

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

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

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

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

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

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

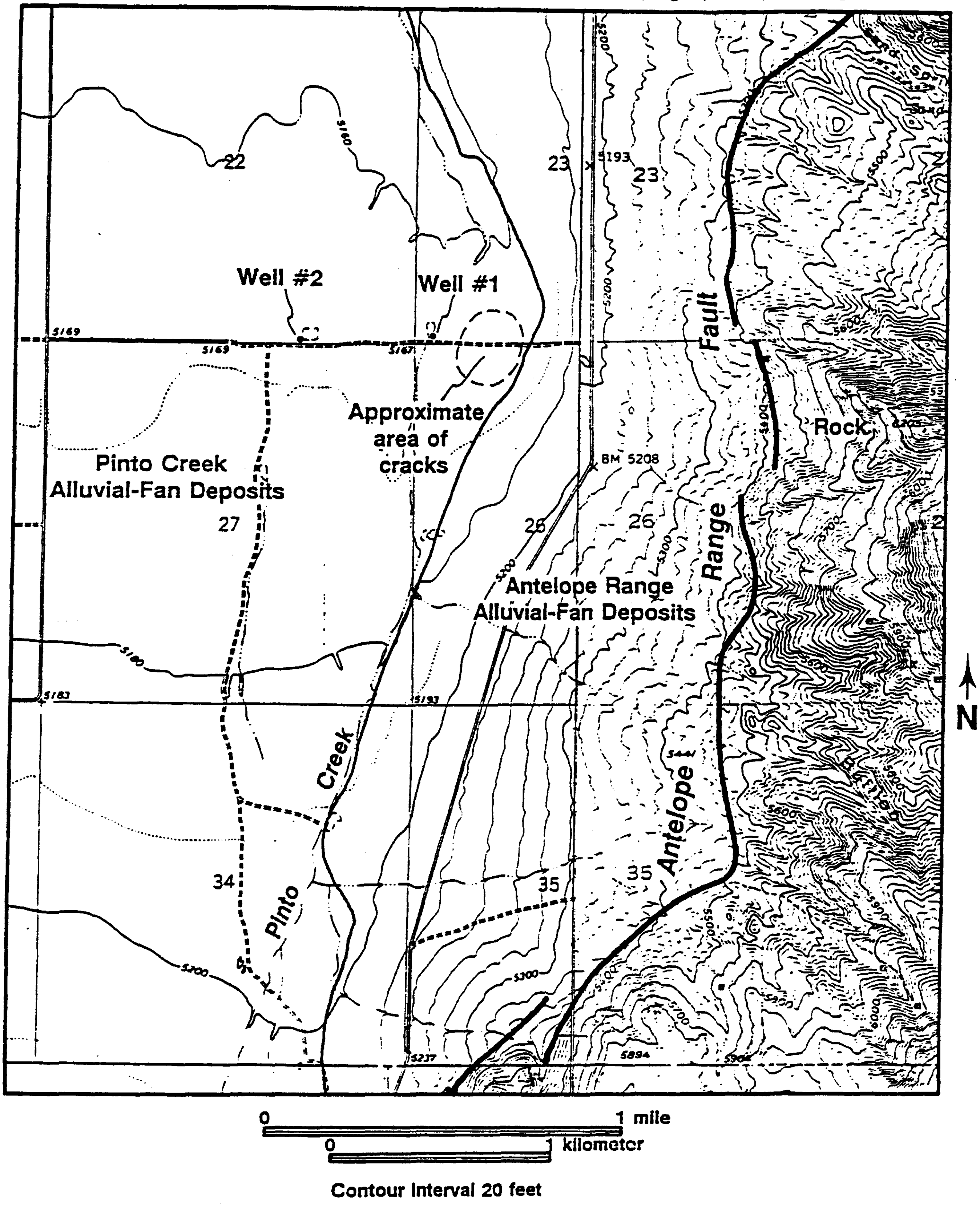
Water table - The upper boundary of the zone of saturation in an unconfined aquifer.

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

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

Attachment 3
Job No.

Base Map from SILVER PEAK and NEWCASTLE, U.S.G.S. 7-1/2' topographic quadrangles.



Attachment 3. Generalized geology in the area of cracks (modified from Shubat and Siders, 1988, and Siders and others, 1990).

Project: Geologic investigation for fault-related causes of seepage problems at Lower Bells Canyon Reservoir, Salt Lake County			Requesting Agency: Mr. Richard B. Hall Dam Safety Section Div. of Water Rights
By: William E. Mulvey	Date: 7-11-91	County: Salt Lake County	Job No.: (GH-11) 91-10
USGS Quadrangle: Draper (BLM 1171)			

INTRODUCTION

On Wednesday June 26, 1991, the Utah Division of Water Rights Dam Safety Section was notified that the downstream face of the dam at Lower Bells Canyon Reservoir was leaking a significant volume of water. Because of the reservoir's location, in a graben formed by the Wasatch fault, the Utah Geological Survey (UGS) visited the site to help ascertain if movement or differential subsidence along the fault could have contributed to seepage problems at of the dam.

The reservoir is located in the NE 1/4 sec.14, T. 3 S., R. 1 E., Salt Lake Baseline and Meridian, in Salt Lake County. UGS personnel visited the site on three separate occasions, June 27, 28, and July 1, 1991. W.E. Mulvey and B.D. Black visited the site on June 27; W.E. Mulvey, B.D. Black, and G.E. Christenson on June 28; and W.E. Mulvey on July 1. The UGS investigation involved field reconnaissance of fault scarps in the vicinity of the reservoir, borrow areas, and a traverse of the lake's shore, looking for evidence of ground cracking or disturbance.

GEOLOGY

Deposits at the site are Quaternary in age, consisting of lateral moraines and outwash from glaciers occupying Bells Canyon during the late Pleistocene (23,000 to 14,500 years ago) (attachment 1) (Personius and Scott, 1990). Material in the moraines is coarse grained, ranging from sands to gravels, with numerous cobbles and boulders. Outwash sediments are also coarse-grained, but contain fewer boulders, and lenses of silt are common (Personius and Scott, 1990). The lateral moraines served as borrow areas for construction of the dam.

There is no bedrock exposed at the reservoir, however, east of the site, quartz monzonite of the Oligocene-age Little Cottonwood Stock forms cliffs along the sides of upper Bells Canyon. The quartz monzonite is the source for the glacial sediments found in lower Bells Canyon.

FAULTING

The Salt Lake City segment of the Wasatch fault offsets lateral moraines and forms a broad zone of deformation at the mouth of Bells Canyon. The reservoir is located in a graben formed during multiple faulting events, the most recent of which was 1100 - 1860 years ago (Schwartz and Lund, 1988). The main Wasatch fault and four antithetic faults are mapped in the vicinity of the reservoir (attachment 1).

Net tectonic displacement for the last 19,000 years on the fault at the reservoir (measured on the crest of the left lateral moraine) is 47.5 feet (14.5 m). Recurrence intervals for the Slat Lake City segment are estimated to be 4000 +/- 1000 years, with average surface displacement being 13-16 feet (4-4.5 m) per event (Schwartz and Lund, 1988). One quarter of a mile south of Bells Canyon, evidence for surface displacements of this magnitude were observed in trenches across the Wasatch fault at Dry Creek Canyon.

LOCAL SEISMICITY DURING THE PERIOD JUNE 1 -26, 1991

Records from the University of Utah Seismograph Stations shows a total of 10 small earthquakes within a 50 kilometer (31 mile) radius of the dam during the period June 1 to 26, 1991 (attachment 2) (Sue Nava, University of Utah Seismograph Stations, written commun., 1991). The closest earthquake to the dam was a magnitude 1.0, which occurred 10 miles to the north near the center of Salt Lake City on June 26.

CONCLUSIONS

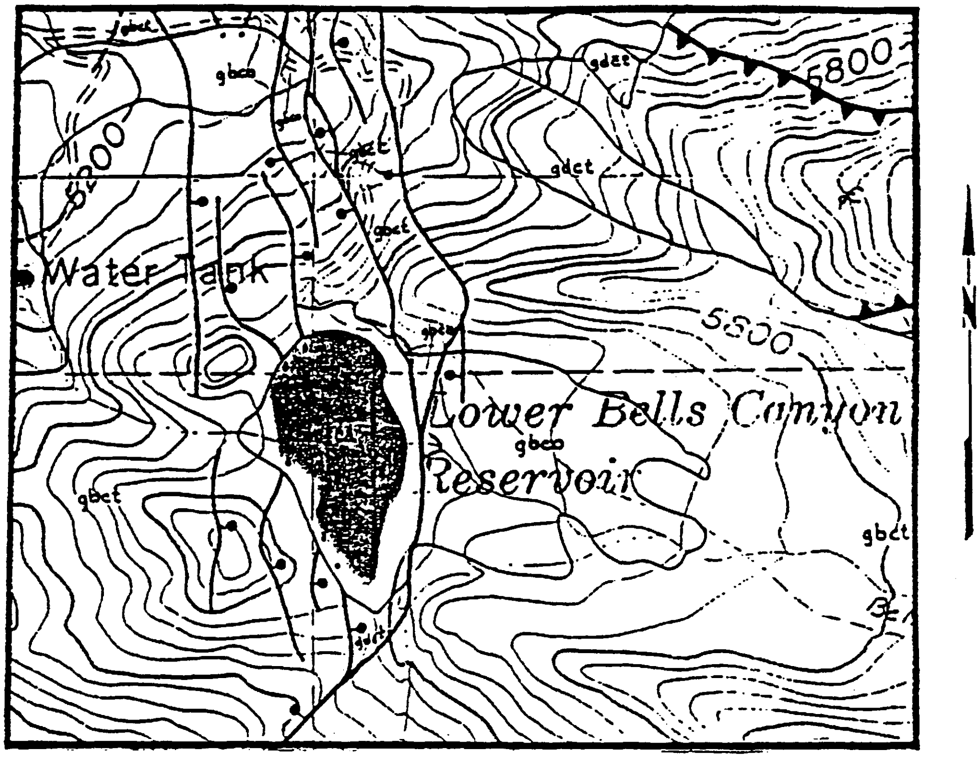
A field check of fault traces at the reservoir showed no evidence of recent surface displacement or fresh ground cracks. The University of Utah Seismograph Stations reported no earthquakes occurring during this period (June 1 - 26) that were centered near the reservoir, or were large enough to damage it. Therefore, earthquake activity or modern displacement along faults probably did not contribute to problems at the Lower Bells Canyon dam. However, the possibility that existing faults in the foundation may have in some way contributed to seepage through the dam has not been precluded. Also, the potential for faulting must be considered in planning for the long-term future of the dam and reservoir.

REFERENCES CITED

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

Schwartz, D.P., and Lund, W.R., 1988, Paleoseismicity and earthquake recurrence at Little Cottonwood Canyon, Wasatch fault zone, Utah, in Machette, M.N., ed., In the Footsteps of G.K. Gilbert -- Lake Bonneville and Neotectonics of the Eastern Basin and Range Province: Utah Geological and Mineral Survey Miscellaneous Publication 88-1, p. 82-85.

Attachment 1



SCALE 1:10,000

0 ½ 1 MILE

0 .5 1 KILOMETER

CONTOUR INTERVAL 10 AND 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

gbco **Outwash of Bells Canyon age (upper Pleistocene)**—Clast-supported cobble and pebble gravel, locally bouldery, in a minor matrix of sand and silt; poorly to moderately sorted; clasts subangular to round. Thin to thick, parallel bedding and crossbedding. Deposits grade into alluvial gravel graded to Provo shoreline (alp) below Big and Little Cottonwood Canyons. Exposed thickness 1-40 m

gbct **Till of Bells Canyon age (upper Pleistocene)**—Matrix-supported boulder, cobble, and pebble gravel in sandy silt to silty sand matrix; very poorly sorted; clasts subangular to subround; massive. Forms large moraines at mouths of Little Cottonwood and Bells Canyons and smaller moraines in cirque valleys in Wasatch Mountains. Exposed thickness 1-10 m

gdct **Till of Dry Creek age (middle Pleistocene)**—Matrix-supported boulder, cobble, and pebble gravel in sandy silt to silty sand matrix; very poorly sorted; clasts subangular to subround; massive. Surface of deposit contains abundant grus derived from weathering of quartz monzonite (Ti) boulders. Exposed near mouths of Little Cottonwood and Bells Canyons. Soil profile: A-Bt(moderate-strong)-Cox-Ca. Exposed thickness 1-8 m

p€ **Precambrian metamorphic rocks (Proterozoic and Archean)**—Consists of low- to high-grade metamorphic rocks

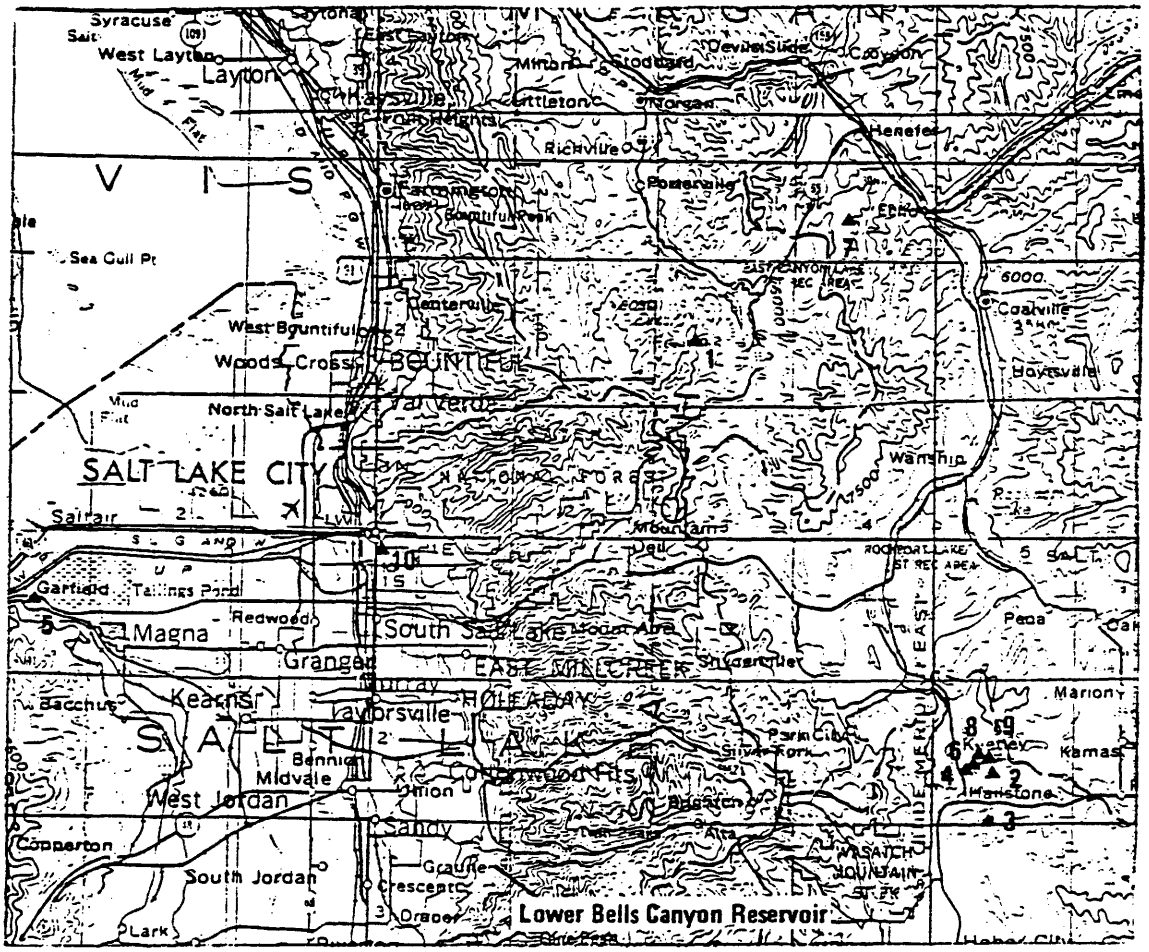
Contact—Dashed where approximately located; dash-dot lines are contacts between geomorphic features in a map unit

DC-1 12(9) **Normal fault**—Bar and solid ball on downdropped side along Wasatch and other active fault zones; bar and hollow ball along other faults in bedrock. Dashed where approximately located, dotted where concealed, and queried where origin is uncertain. Height of fault scarp and amount of geomorphic surface offset (in parentheses) shown in meters. Trench locations shown with cross bar: DC-1-4, Dry Creek trenches; LC1-4, Little Cottonwood trenches

Thrust fault—Sawteeth on overriding plate or block (mapped in bedrock only); dashed where approximately located, dotted where concealed

Attachment 1. Geology of Lower Bells Canyon Reservoir area. From Presonius and Scott, 1990.

Attachment 2



Scale 1:500,000

1 inch equals approximately 8 miles

Map No.	Date	Lat-N	Long-W	Magnitude
1	6-4	40-53.18	111-40.84	1.0
2	6-5	40-37.35	111-25.20	1.2
3	6-10	40-35.53	111-25.29	1.1
4	6-14	40-37.32	111-26.50	1.6
5	6-17	40-43.25	112-10.88	1.0
6	6.18	40-37.74	111-26.07	1.5
7	6-19	40-57.29	111-33.54	1.5
8	6-21	40-37.41	111-26.00	1.3
9	6-26	40-37.78	111-25.46	0.8
10	6-26	40-45.32	111-56.87	1.0

Attachment 2. Earthquakes (▲) between June 1-26,1991, within 50 km (31 miles) of Lower Bells Canyon Reservoir. From University of Utah Seismograph Stations.

Project: Investigation of a rock fall in Hobble Creek Canyon, Utah County, Utah.			Requesting Agency: Utah County Office of Emergency Services
By: Kimm M. Harty	Date: 8-7-91	County: Utah County	Job No.: (GH-12) 91-11
USGS Quadrangle: Granger Mountain (1045)			

On August 4, 1991, the Utah Geological Survey (UGS) investigated a rock fall that occurred in the Left Fork of Hobble Creek Canyon in Utah County. The rock fall caused extensive damage to a private residence at 1910 S. Holiday Hills Road in the Holiday Hills Subdivision (sec. 21, T. 7 S. R. 4 E., Salt Lake Baseline and Meridian) (attachment 1). The purpose of the investigation was to assess the possibility of additional rock falls occurring in the area, and to advise local officials of current hazard conditions. The evaluation was requested by Dick Casto, Director of Emergency Services for Utah County through Wes Dewsnup of the Utah Division of Comprehensive Emergency Management. The evaluation consisted of a field reconnaissance, and map and literature review. Present during the field reconnaissance were Gary Christenson of the UGS; William Casper, owner of the damaged home; and Mr. Casto.

At approximately 5:30 a.m. on August 4, 1991, two large rock-fall clasts struck and damaged the main house and attached guest house. According to Mr. Casper, two smaller clasts also entered the attic of the main house through the roof. Only the two largest clasts were examined during the investigation. The largest of these was approximately 7 x 5 x 4 feet. This clast entered through the guest house roof, plunged through the second floor into the first floor, and then out the back (west) wall of the structure. This clast came to rest at ground level below a deck connecting the guest house and main house. The other large clast was 7 x 4 x 4 feet, and entered the two-story main house at ground level, coming to rest in a ground-floor utility room. Both clasts were quartzite boulders of the Wallsburg Ridge Member of the Upper Pennsylvanian-age Oquirrh Formation (Baker, 1976). Quartzite of the Wallsburg Ridge Member is widely exposed in a band of outcrops across the upper mountain slopes east of Hobble Creek above the Holiday Hills Subdivision.

We traced the lower few hundred feet of the rock-fall travel path on foot and examined the rock-fall source area and upper travel path with binoculars. It appeared that the source of the rock fall was a large bedrock outcrop approximately 1300 feet upslope from the Casper residence, at an elevation of about 6280 feet (attachment 1). One or more boulders dislodged from the outcrop and moved down the steep, 70 percent slope in a series of bounces and rolls. We observed parallel scar tracks within at least the lower 500 feet of the slope, indicating that either a number of boulders fell from the source area, or that a single, large boulder had fractured into smaller clasts during travel. The pattern of ground cratering, disturbed ground, and damaged trees and vegetation within about 500 feet of the Casper residence suggested that rock-fall boulders moved downslope mainly by bouncing. Much of the slope behind the Casper residence is mantled by colluvium and cobble-size talus. Combined with steep slopes, this relatively hard mantle probably allowed the rock-fall boulders to maintain rather than dissipate energy when striking the slope, and also likely enhanced movement by bouncing. Mountain slopes east of the subdivision are heavily covered with scrub oak, but vegetation apparently did not significantly retard movement of larger rock-fall clasts. Sheared tree limbs immediately behind the Casper residence indicated that some rock-fall clasts bounced approximately 25-30 feet above the ground surface before impacting the roofs of the main and guest houses.

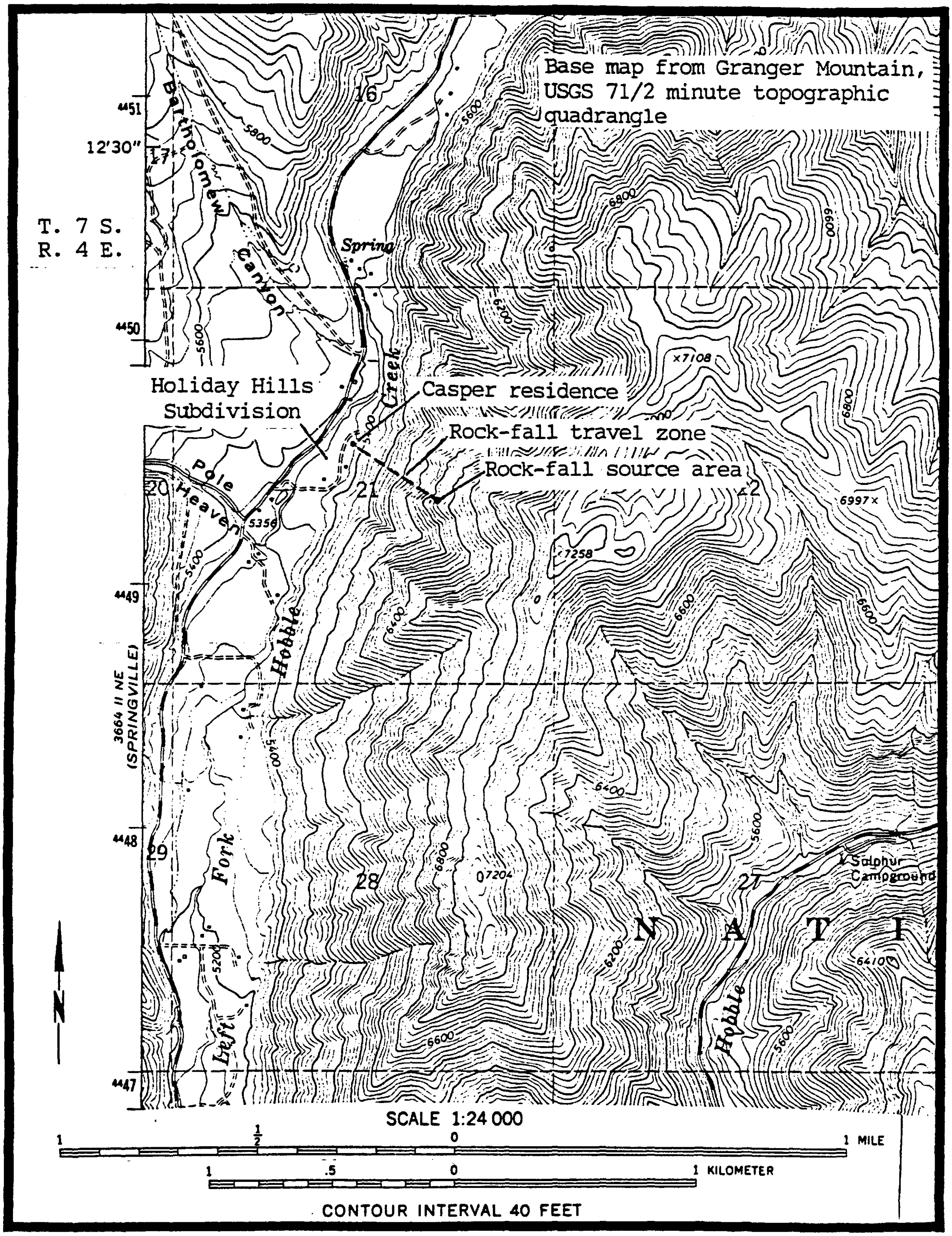
The rock fall was likely triggered by infiltrating precipitation from an intense thunderstorm that occurred during the evening of August 3rd. Dick Casto reported that this rainstorm had ceased at about 8:00 p.m on the evening before the early morning rock fall. According to Mr. Casto, representatives from the Utah County Sheriff's Department arrived at the Casper residence shortly after the rock-fall event, and reported that a few smaller rock falls continued to occur on the slope. They reported, however, that none of the rocks made it down to the subdivision.

We observed large rock-fall clasts scattered throughout the subdivision, indicating that much of the subdivision, particularly homes nearest the base of the slope, is in a rock-fall hazard area. We advised Mr. Casper and Mr. Casto that the hazard after this rock fall was probably no greater or less than before, and that rock falls could occur at any time and impact structures in the subdivision. Residents need to be aware of the hazard, and concern should be heightened during and immediately after rainstorms and earthquakes. To determine the relative hazard at different lots and the feasibility of hazard-reduction measures, we recommend that a more detailed rock-fall hazard analysis be performed for the subdivision by a qualified geotechnical firm, and that this information be disclosed to all current and future property owners in the subdivision.

CITED REFERENCE

Baker, A. A., 1976, Geologic map of the west half of the Strawberry quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-931, scale 1:63,360.

Attachment No. 1, Job No. 91-11



Topographic map showing August 4, 1991 rock fall, Left Fork of Hobble Creek Canyon.

Project:			Requesting Agency:
Investigation of seeps and landslide potential in South Weber near 5939 S. Weber Dr., Weber and Davis Counties, Utah			- None - Emergency Response
By: Bill D. Black, Mike Lowe	Date: 09-06-91	County: Weber, Davis	Job No.: (GH-13) 91-12
USGS Quadrangle: Ogden (1345)			

INTRODUCTION

The Utah Geological Survey conducted an investigation of a new seep near 5939 South Weber Drive along the bluff on the south side of the Weber River, Weber and Davis Counties, Utah (attachment 1). The seep was brought to our attention by Brad Holbrook, a local homeowner. The purpose of this investigation was to identify the source of the seep and evaluate the potential for reactivation of a nearby 1983 landslide (LSa307, attachment 2). The scope of work included a field inspection of the area on September 6, 1991, and a literature and map review. Two recent landslides in the canal service road southeast of the seep noted during the field inspection were also investigated. Floyd Baham, manager of the Davis and Weber Counties Canal Company, was present during the field inspection.

GENERAL GEOLOGY AND PAST LANDSLIDING

The 1983 landslide is on the southern boundary of the City of Riverdale, in sec. 19, T. 5 N., R. 1 W., SLBM (attachment 1). The bluff on which the landslide occurs is in an area referred to as the South Weber Landslide Complex (Pashley and Wiggins, 1972). The 1983 landslide is a rotational slump about 800 feet wide in gravel and clayey deltaic sediments deposited by the Weber River as it flowed into Pleistocene Lake Bonneville. Downcutting by the river into the delta following the recession of Lake Bonneville created the steep slopes bordering the river along which many landslides occur (attachment 2).

The 1983 landslide occurred primarily as a result of changes in ground-water conditions due to precipitation, irrigation, or leakage from the Davis-Weber Canal (Lowe, 1985) (attachment 2). According to Bruce Kaliser (letter to Riverdale City Council dated June 28, 1983), active landsliding was affecting seven homes on the landslide.

RECENT SEEPS AND LANDSLIDING

The recent seep is located in the City of South Weber, in the NE1/4, SW1/4, sec. 19, T. 5 N., R. 1 W., SLBM (attachment 1). The seep is approximately 400 feet downslope from the Davis-Weber Canal, above the eastern margin of a 1983 landslide (attachment 2). The sudden appearance of the seep, which was wet but not flowing at the time of the field inspection, is possibly linked to continuing degradation of the canal. An inspection of the canal directly upslope from the seep showed damage in the lining.

The Davis-Weber Canal, which was constructed over 100 years ago, flows west from the mouth of Weber Canyon along the bluff above the landslide. The canal is cement-lined through the area, but the lining is cracked and deteriorating in many places. In two locations southeast of the seep and 1983 landslide, the damage to the lining of the canal and subsequent leakage of water into slopes has apparently caused landsliding along a service road that parallels the canal.

Although the contribution of water from the canal to the seeps and landslides cannot be accurately differentiated from other potential sources of ground water (precipitation, irrigation, water from Hill Air Force Base), evidence indicates that canal leakage is a major contributor. Monitoring wells installed by Hill Air Force Base show increases in the water table that correspond to the start of flow through the canal (Floyd Baham, oral commun., Sept. 6, 1991), and temporary repairs of the canal lining appear to have stopped the two landslides in the canal service road. Two tests for determining the contribution of water leaking from the canal are: 1) placing dye in the canal and monitoring dye and discharge in relation to canal flow at springs and seeps below the canal, such as the flowing spring above the home at 5925 South Weber Drive, or 2) placing a known quantity of water in the damaged sections of the canal and measuring the loss of water (Lowe, 1985). The Davis and Weber Counties Canal Company has temporarily patched the two damaged sections and plans to discontinue use of the canal for this year on October 1, 1991. Although the canal company plans to repair the two damaged sections, it is not known whether they have any plans for repairing the rest of the canal.

LANDSLIDE POTENTIAL

The new seep above South Weber Drive does not appear to indicate imminent reactivation of the 1983 landslide, and the landslide exhibited no evidence of new cracks or movement in the main scarp at the time of the field inspection. However, this does not preclude movement of the landslide in the future or landsliding at some other location along the South Weber Landslide Complex, which could threaten homes in the area.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, water leaking from damaged sections of the canal appears to be responsible for landsliding at two locations along the canal service road east of the new seep, but cannot be directly linked to the recent appearance of the seep. Dye or other tests would be required to definitively evaluate the role of canal leakage in seeps and landslides in the area. The seep does not appear to indicate an increased potential for reactivation of the 1983 landslide at this time, but water from canal leakage or other sources may be infiltrating into the landslide complex and could eventually cause reactivation of the landslide or additional landsliding at some other location.

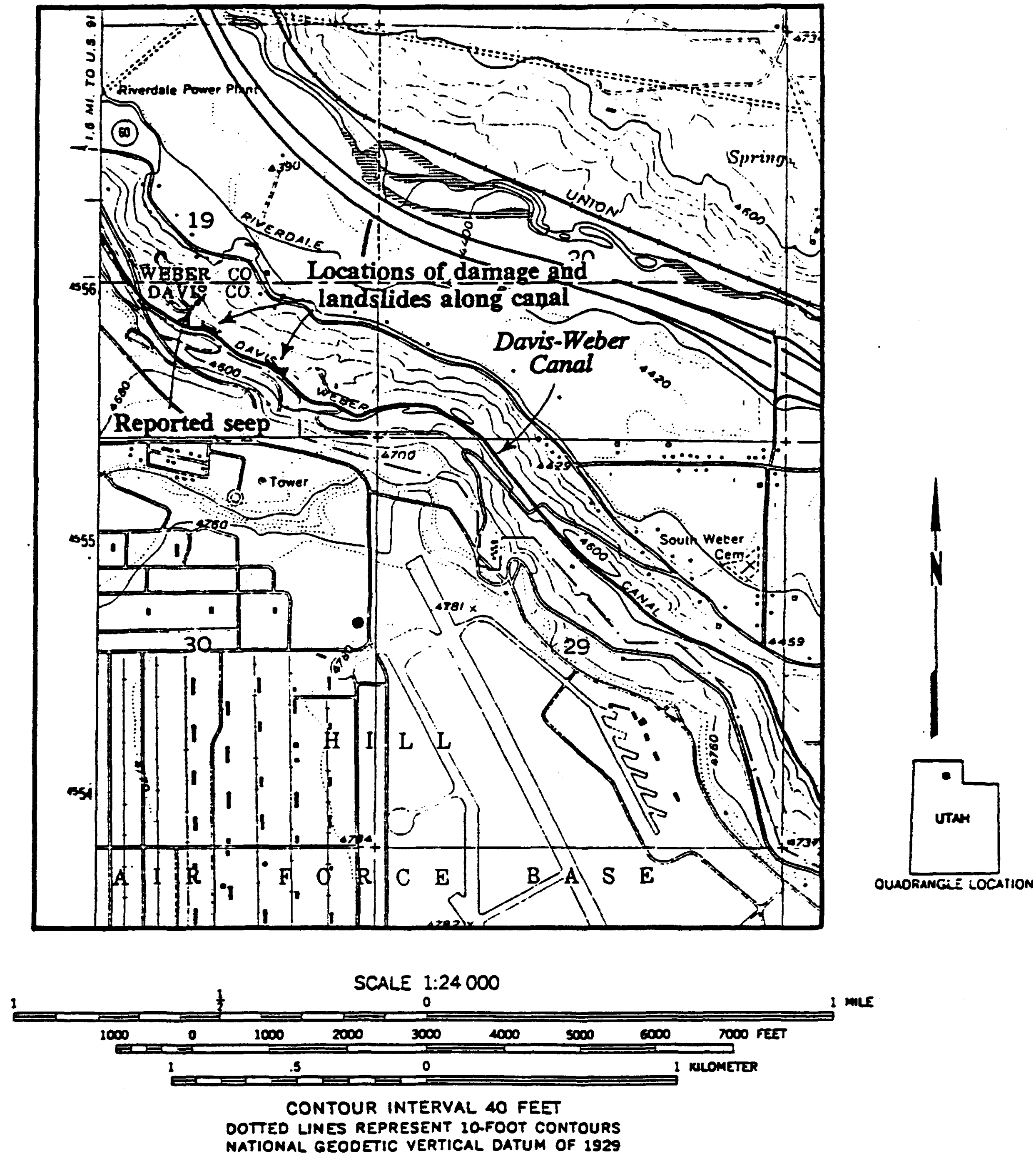
It is recommended the canal be inspected and any damage repaired, and that systematic monitoring of the canal lining be performed to reduce the possibility of leakage and infiltration of water into the landslide. The seeps and landslide should also be monitored for any change in flow or evidence of movement.

REFERENCES

Lowe, Mike, 1988, Investigation of landslide at approximately 5931 South Weber Drive, Riverdale, Utah, in Black, B.D., comp., Technical reports of the Wasatch Front County Geologists, June 1985 to June 1988: Utah Geological and Mineral Survey Report of Investigation 218, p. 80-82.

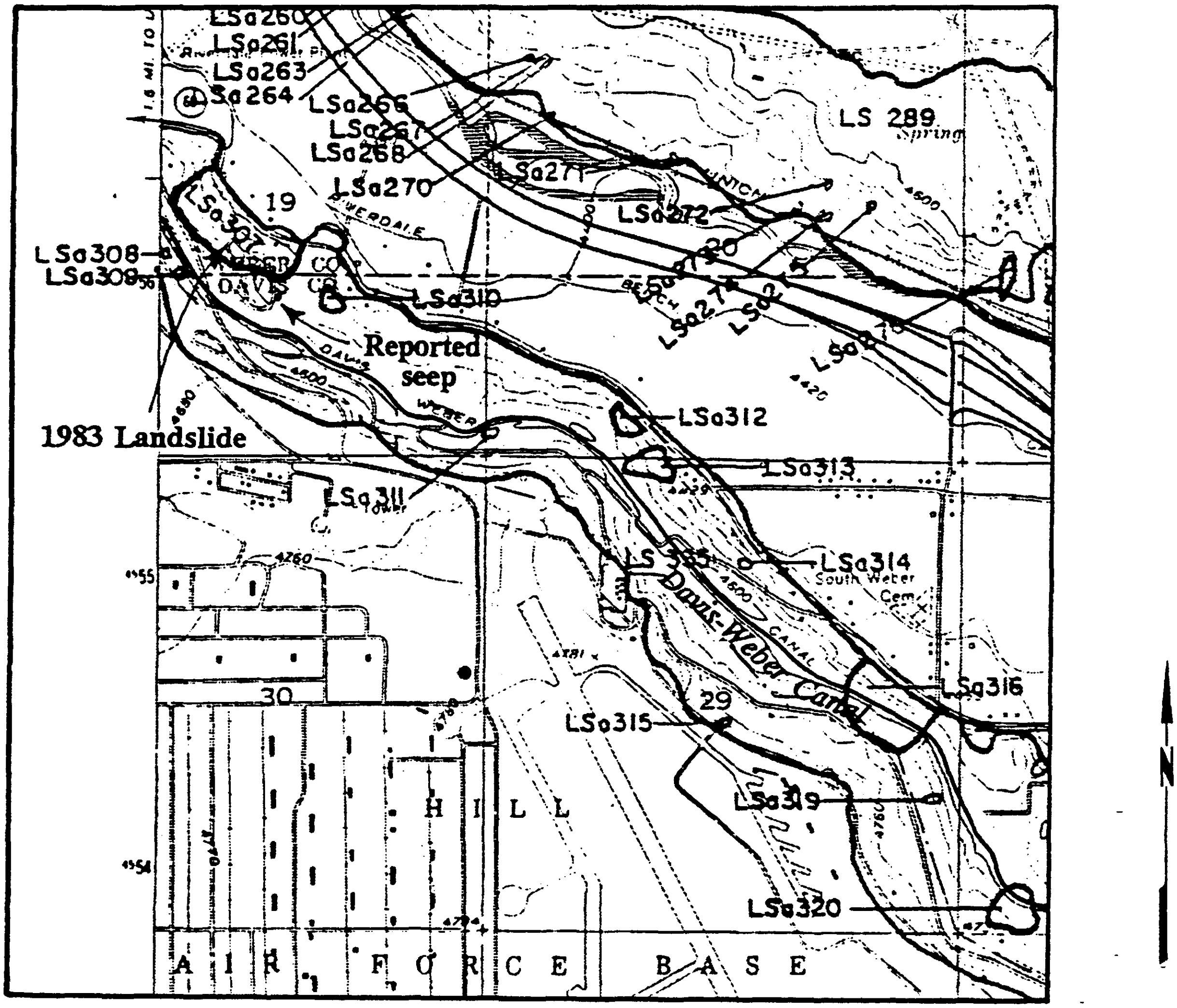
Pashley, E.F, Jr., and Wiggins, R.A., 1972, Landslides of the northern Wasatch Front, in Hilpert, S.L., ed., Environmental Geology of the Wasatch Front: Utah Geological Association Publication 1, p. K1-K16.

Base map from <u>OGDEN,</u>
U.S.G.S topographic quadrangle



Attachment 1. Location map.

Base map from <u>OGDEN,</u>
U.S.G.S topographic quadrangle



SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

LS = deep landslides, chiefly slumps and earthflows
LSa = active (historical) landslides
123 = inventory number for slope failure

Attachment 2. Section of slope failure inventory map - Ogden Quadrangle (Weber County Planning Commision, unpublished map).

Project: Cameron Cove Subdivision debris flow, North Ogden, Utah.			Requesting Agency: Emergency Response
By: W.E. Mulvey Mike Lowe	Date: 9-18-91	County: Weber County	Job No.: (GH-14) 91-13
USGS Quadrangle: North Ogden (BLM 1370)			

INTRODUCTION

On Monday, September 9, 1991, William E. Mulvey and Mike Lowe of the Utah Geological Survey visited the site of a debris flow which occurred around 8:00 p.m. on the night of September 7, 1991. The debris flow originated from an unnamed canyon in the Wasatch Range northeast of the Cameron Cove Subdivision in North Ogden, Utah (attachment 1). The purpose of the visit was to determine the source and cause of the debris flow, and the extent to which slopes damaged by an August, 1990, fire contributed sediment to the debris flow. Scope of work for the investigation included walking the drainage to the source area, mapping and measuring the deposit, and a review of pertinent literature and air photos of the slide area.

DESCRIPTION OF THE EVENT

On September 7, 1991, over a 24-hour period, rainfall in the North Ogden area ranged from 2.5 to 8.4 inches (Brenda Graham, National Weather Service, oral commun., September 23, 1991). This set a new state record for a 24-hour period, and was estimated to be equivalent to a 1000-year storm (Mark Eubank, WeatherBank Inc., oral commun., September 11, 1991). Runoff from the storm was concentrated in channels on bedrock cliffs at the head of the unnamed canyon. During heavy rains, these channels often form waterfalls, cascading several hundred feet to talus slopes below (Bruce Dursteler, Mayor, North Ogden, personal communication, September 9, 1991). The concentration of heavy runoff apparently mobilized talus and debris along seasonal tributary channels at the base of the cliffs. As the tributary flows moved down the canyon and were combined with the main channel, additional material scoured from the channel was incorporated into the debris flow. The flow exited the canyon mouth and traveled down an alluvial fan for a distance of 1300 feet, where the debris damaged several houses in the Cameron Cove Subdivision (attachment 1). Flood waters associated with the storm and debris flow also caused widespread damage in the subdivision.

GEOLOGY

The canyon is predominately underlain by the Lower Cambrian Tintic Quartzite. The Tintic Quartzite is a buff to rusty weathering, cliff-forming orthoquartzite (Crittenden and Sorenson, 1985). The only other bedrock present in the canyon is an erosional remnant of the Cambrian Maxfield Limestone. The Maxfield Limestone is a dark-blue-gray, light-gray weathering, cliff-forming limestone or dolomite (Crittenden and Sorenson, 1985). The canyon has several tributary drainage channels in its upper reaches, with the northern- and southern-most forks being best developed. The confluence of these channels is at approximately 5800-feet elevation (attachment 1). Slopes above the confluence of the tributary channels in the upper canyon are covered by talus and colluvium. Above the talus and colluvial slopes, the Tintic Quartzite forms 800-foot cliffs which reach the top of the ridgeline at 7680 feet.

At the mouth of the canyon a well-developed alluvial fan is present. The fan is active, being influenced by faulting events on the Wasatch fault. Levees at the canyon mouth, and bar and swale topography on the lower fan surface are evidence of active alluvial fan-building processes.

SOURCES OF DEBRIS

Examination of the main and tributary channels indicated that material in channels from the base of the cliffs to the mouth of the canyon had been incorporated into the debris flow. Depth of scour in the main channel averaged 5 to 6 feet, and in places as much as 17 feet (Dr. D.M. Vaughn, Dept. of Geography, Weber State University, oral commun., September 25, 1991). Much debris remains in the channel, primarily behind large boulders which act as natural dams. In general, the drainage-basin slopes did not appear to have contributed much material to the flow. However, on slopes below the cliffs but above 5800 feet there was evidence of contribution from slope-wash erosion of drainage-basin soils. Grasses were absent in these areas, cobbles were left standing on pedestals of soil, and small rills were present. This is the only place damaged by the July 30 - August 3, 1990 wild fire (Lowe and Harty, 1990) that appears to have contributed sediment to the debris flow. Sediment contribution from the 1990 burned area was low because of the rapid revegetation of oakbrush, woody plants, and grasses.

Our observations in the channel indicate that much debris is still contained in and along the channel itself. Several natural dams composed of large boulders have considerable amounts of debris behind them. In many places along the channel, side-slopes have been destabilized by scour and undercutting of the channel banks. The volume of debris still in the channel is at this time undetermined, and accurate estimates of its volume may be difficult.

ESTIMATES OF DEBRIS-FLOW VOLUME

We measured width and length of the debris-flow deposit from the mouth of the canyon to within 40 feet of the rear of the damaged homes. We could not get closer to the homes due to removal of debris by heavy equipment. Above the homes, depths were estimated and widths were measured at approximately 165-foot intervals (attachment 2) and used to estimate the volume of material present. The volume of material in each interval was calculated using the area of a trapezoid (width measurements were used as the top and bottom, length measurement as the height) multiplied by the estimated thickness for every measured interval. The volume was estimated at 13,218 cubic yards. The estimate does not include debris around homes and removed from the streets. The volume of material from around the houses and in the streets was estimated by North Ogden offical s to be 22,800 tons (Dennis Shoup, North Ogden City Manager, oral commun., September 24, 1991).

This estimate was based on the number of truck loads of material (1900) with an average weight (12 tons per truck) of material carried by each truck. This is equivalent to 12,510 cubic yards of material. When combined with our estimate of material above the houses, the estimated total volume of the debris flow is 25,728 cubic yards.

The potential sediment contribution from slope wash in the drainage was calculated following the fire by Lowe and Harty (1990) using the Pacific Southwest Inter-Agency Committee (PSIAC) 1968 Sediment Yield Rating Model. Lowe and Harty (1990) estimated that the average-annual post-fire sediment yield from slopes in this drainage was approximately 0.24 acre-feet per year, or 387 cubic yards. Although the sediment yield from a storm of this magnitude may be greater, if this is correct it indicates that a small percentage of the total volume of debris (25,728 cubic yards) was derived from the slopes. The majority of material involved in this debris flow was therefore apparently derived from scour of channels and talus on slopes immediately below the cliffs. This result was confirmed by field observations of channel scour and slope wash.

CONCLUSIONS

Heavy rainfall, steep topography (specifically the cliffs at the canyon's head), and an abundance of available channel debris and talus combined to cause the 1991 Cameron Cove Subdivision debris flow. The cliffs acted as an impermeable surface, concentrating runoff and directing it onto talus and colluvium below the cliffs. Talus and colluvium was mobilized and channeled into the north and south forks of the canyon, and several minor channels in between. The channels subsequently began to erode and contribute material. We estimate this channel scouring began at the base of the cliffs in the tributaries and continued to the mouth of the canyon. Upon leaving the confining walls of the canyon and spreading onto the lower-gradient alluvial fan at the canyon mouth, deposition of the coarser material occurred.

At present, stream channels in the unnamed canyon still contain debris that could be mobilized and incorporated into another debris flow. However, intense thunderstorms which initiated this debris flow will become less common with cooler temperatures and the beginning of autumn. This change in weather conditions will reduce the potential for another large debris flow from the canyon this year. The hazard for subsequent years continues, however. Levees from prehistoric debris flows were observed on the alluvial fan at the mouth of the canyon. The active alluvial fan at the canyon mouth indicates that the recent large debris flow was not a geologically unusual event for this canyon, but instead is part of the alluvial-fan-building process. Debris flows will likely occur again on this fan. Houses remain at risk and a long-term, permanent solution to the problem should be pursued.

REFERENCES CITED

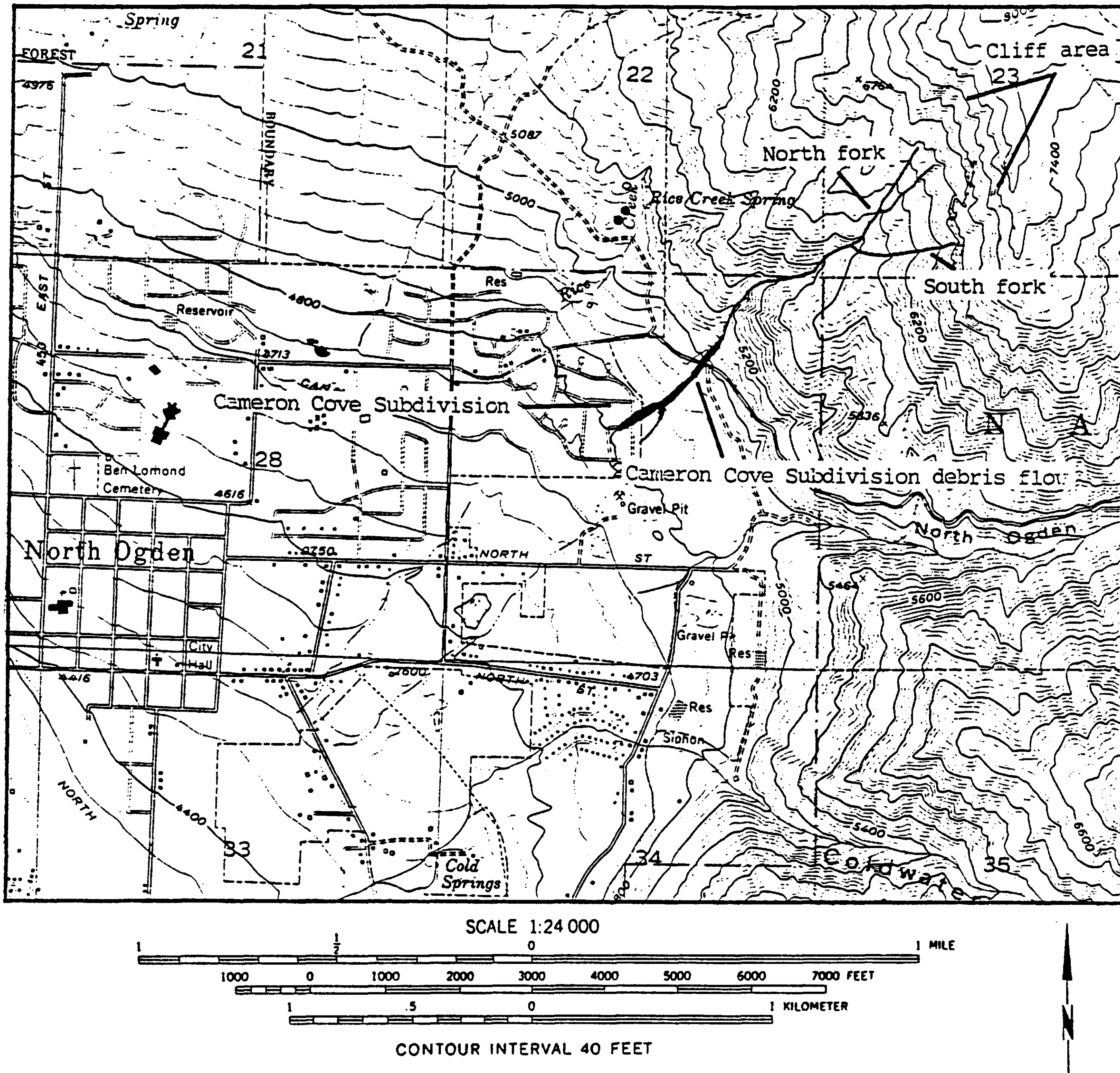
Crittenden, M.D., Jr., and Sorensen, M.L., 1985, Geologic map of the North Ogden quadrangle and part of the Ogden and Plain City quadrangles, Box Elder and Weber Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1606, scale 1:24,000.

Lowe, Mike, Harty, K.M., and Rasely, R. C., 1990, Reconnaissance of area burned by a wild fire north east of North Ogden and evaluation of potential sediment yield: Utah Geological Survey Technical Memordandum, 6 p.

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

Attachment 1

Base map from USGS North Ogden Quadrangle.



Attachment 1. Cameron Cove Subdivision debris flow, North Ogden City.

Attachment 2

Segment of debris flow	Width					
	Top a(ft)	Bottom b(ft)	Length(height) h(ft)	Depth d(ft)	Volume (yd^3)	
Stations						
1-2	56	82	118	2.25	679	
2-3	82	69	165	2.75	1269	
3-4	69	80	30	3.00	248	- Ogden Divide Highway
4-5	80	66	165	2.50	1115	
5-6	66	84	165	1.75	802	
6-7	84	101	165	2.25	1272	
7-8	101	160	165	2.75	2193	
8-9	160	119	165	3.00	2558	
9-10	119	150	165	3.75	3058	
				Total	13,218	
Volume of debris hauled from the site (Dennis Shupe, North Ogden City Administrator, oral commun., September 24, 1991)				---	12,510	
				Total	25,728	

Calculation of volume of material from the Cameron Cove, North Ogden, Utah, debris flow September 7, 1991. Ten width measurements and nine length measurements were taken along the slide path. Using the formula for the area of a trapezoid (volume $yd^3 = \frac{\frac{1}{2}(a.b)(h)(d)}{27}$) the slide was divided into nine trapezoids, their area determined and combined with depth estimates to calculate the volume of the debris flow.

Project:			Requesting Agency:
Probabilistic Ground Motions Along the Central Wasatch Front: Implications for a Seismic Zone Change			Uniform Building Code Commission, Utah Div. of Occupational and Professional Licensing
By: Susan Olig	Date: 10-3-91	County: Box Elder, Weber, Morgan Davis, Salt Lake, Utah, and Juab	Job No.: (GH-15) 91-14
USGS Quadrangle:			

INTRODUCTION

The following report summarizes technical information relevant to evaluating present Uniform Building Code (UBC) seismic zone designations along the Wasatch Front in Utah. It was included as an appendix to a code change submittal and was requested by Carl Eriksson, Chairman of the Structural Advisory Committee to the UBC Commission. The UBC Commission administers the UBC throughout Utah and is presently considering the 1991 edition for adoption. However, the portion of the seismic zone map covering Utah is the same in the 1988 and 1991 editions. As a result of recent information about the ground shaking hazard along the Wasatch Front, the Commission has considered changing the seismic zone from 3 to 4 along the central Wasatch Front. After reviews by advisory committees and much deliberation, the Commission held a public forum on June 26, 1991 to discuss and recieve public comment on whether to submit a code change to the International Conference of Building Officials (ICBO). After the forum, the Commission voted 5 to 1 to submit the proposed zone change to ICBO. The reason for the proposed change, as stated in the code change submittal, follows:

> "Under the auspices of the National Earthquake Hazard Reduction Program (NEHRP), extensive research on earthquake sources and hazards along the Wasatch Front was conducted in the past ten years. Much of the knowledge gained was incorporated into a 1987 probabilistic ground-shaking analysis that indicates larger peak ground accelerations than were mapped in previous studies that were the basis for the 1988 Seismic Zone Map. These new estimates of accelerations, with a 10 percent probability of being exceeded in 50 years, range from 0.3 g to 0.4 g along the central Wasatch Front. By definition (SEAOC Blue Book), this meets the criteria for seismic zone 4."

The appendix, as summitted with the proposed code change, follows.

Appendix - Supporting Technical Information for Proposed Seismic Zone Amendment

On the 1988 UBC seismic zone map for Utah, all of the central Wasatch Front is in seismic zone 3 (figure 1). Table 1 outlines the criteria used by the Structural Engineers Association of California (SEAOC) to initially develop the 1988 seismic zone map for ICBO (SEAOC, 1988 or "Blue Book"; S. M. Dowty, ICBO, written commun., 1989).

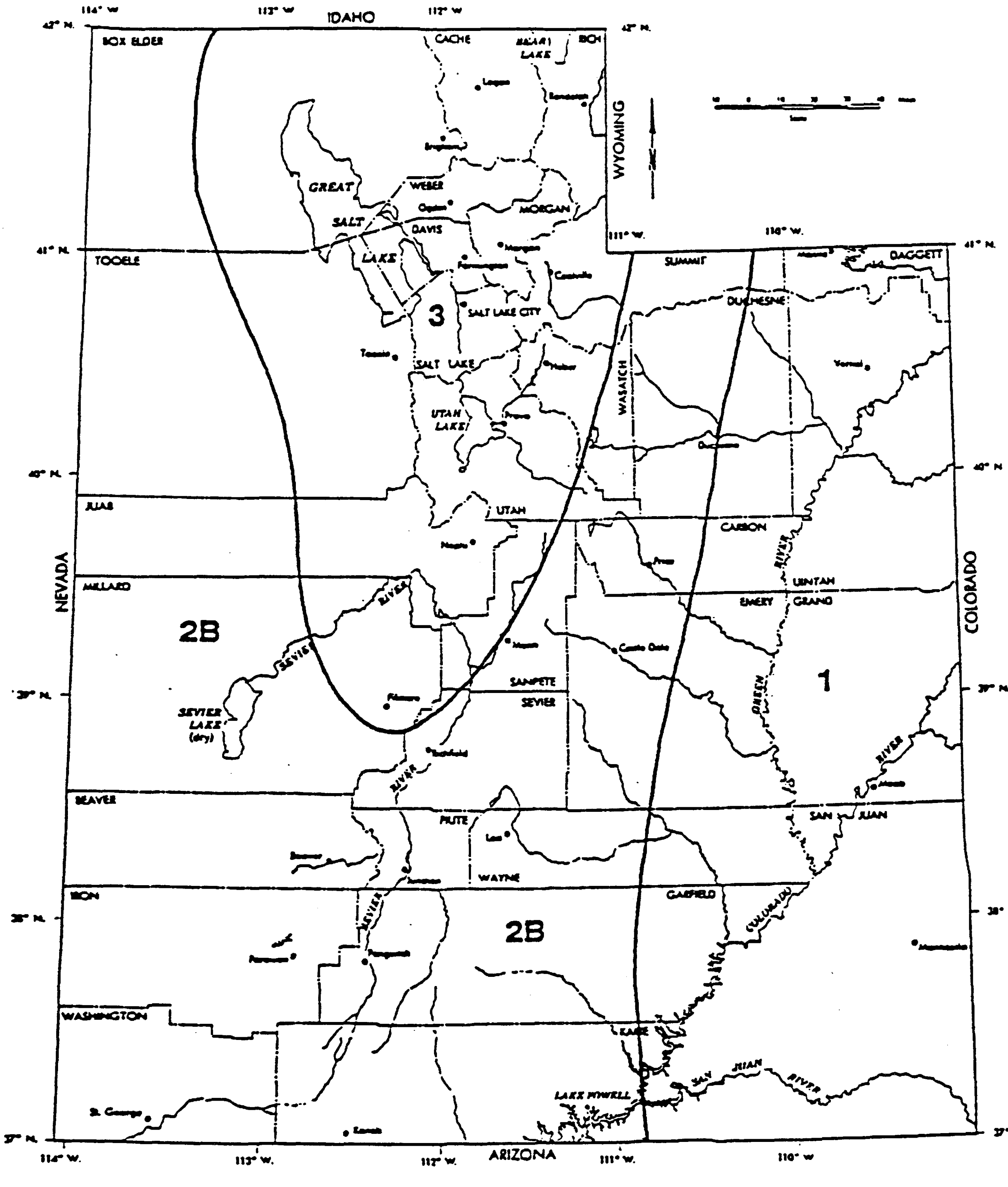


Figure 1. The 1988 UBC seismic zone map for Utah.

Table 1. Criteria Used by the Structural Engineers Association of California (SEAOC) to initially develop the 1988 UBC seismic zone map of the United States.

Effective Peak Acceleration (EPA) on Rock with a 10% Probability of Being Exceeded in 50 Years[1]	Seismic Zone	Z Factor
EPA $\leq$ 0.075	1	0.075
0.075 < EPA $\leq$ 0.20	2B	0.20
0.20 < EPA $\leq$ 0.30	3	0.30
EPA > 0.30	4	0.40

[1]In units of gravity (g)

Youngs and others (1987) performed a relatively detailed probabilistic ground-shaking analysis of the Wasatch Front that was funded by the U. S. Geological Survey under the National Earthquake Hazards Reduction Program. As part of their study, they estimated and mapped (approximate scale 1:1,600,000) peak horizontal ground accelerations with a 10 percent probability of being exceeded in 50 years (figure 2). Their results indicate a large area along the central Wasatch Front (essentially from Nephi to Brigham City) with accelerations on rock that are greater than 0.3 g, and values of 0.4 g and greater for the Salt Lake City-Ogden area. These estimates are much higher than previous estimates of 0.2 to 0.28 g for the central Wasatch Front in a national study (approximate scale 1:7,500,000) by Algermissen and others (1982).

Youngs and others (1987) also estimated spectral accelerations with a 10 percent probability of being exceeded in 50 years, and effective peak accelerations (EPA), as specified by the SEAOC criteria, can be estimated using their results. EPA is defined in the Applied Technology Council's 1978 provisions (section C1.4.1) as:

$$\text{EPA} = \frac{\text{Average spectral acceleration (for period band 0.1–0.5 seconds)}}{2.5}$$

Using this definition and Youngs and others'(1987) average spectrum for rock sites along the Wasatch Front (figure 3), EPA's with a 10 percent probability of being exceeded in 50 years were estimated (table 2). Estimates of EPA are less than peak horizontal ground accelerations shown in figure 2, but differences are small (less than 10 percent). Indeed, estimates of EPA for most of the central Wasatch Front, including Ogden, Salt Lake City and Provo, exceed 0.3 g.

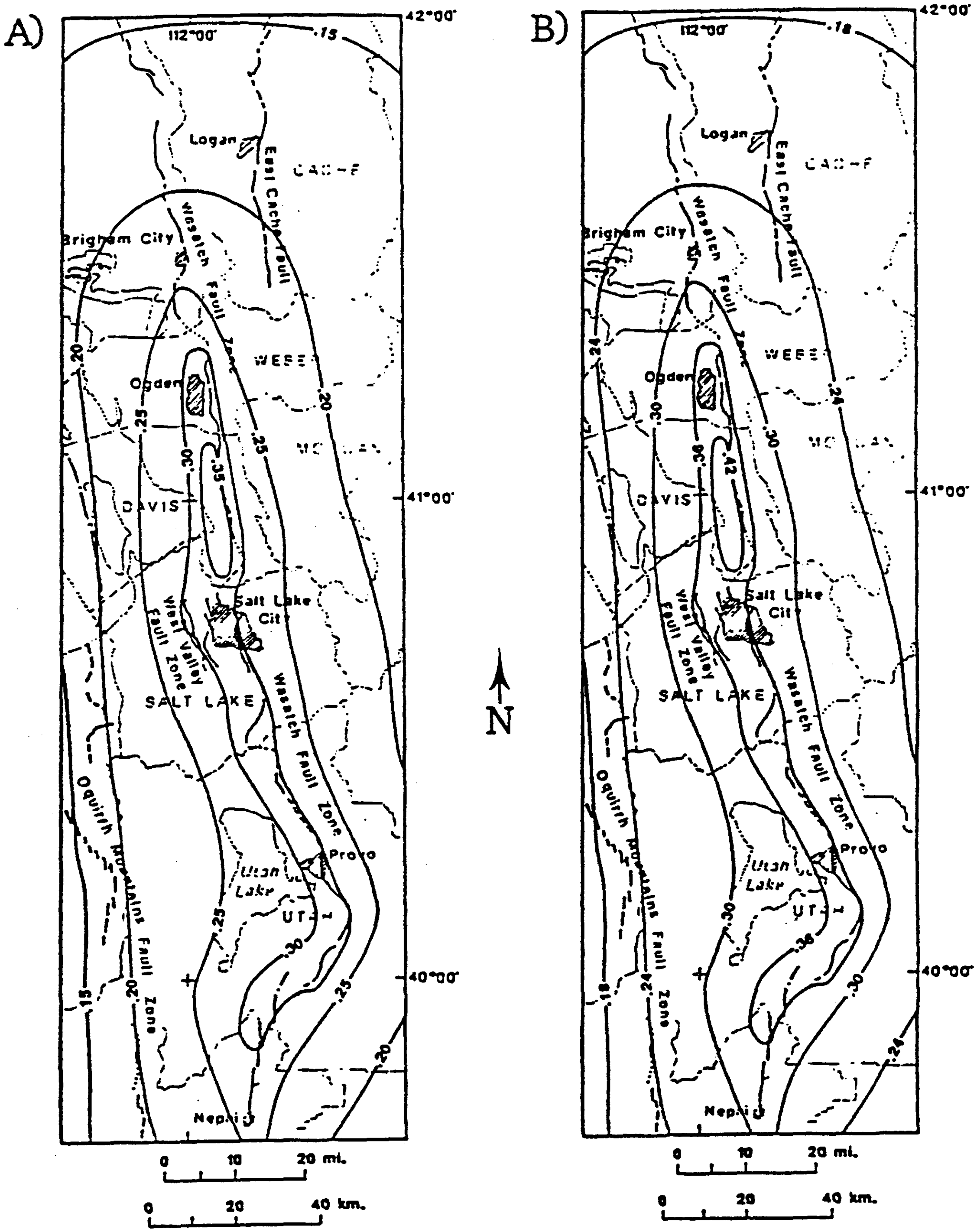


Figure 2. Map of peak horizontal ground accelerations on firm sediments (a), and on rock (b), with a 10 percent probability of being exceeded in 50 years along the Wasatch Front, Utah. Modified from Youngs and others (1987, p. M-88).

Table 2. Estimates of effective peak accelerations corresponding to peak ground accelerations on rock along the Wasatch Front, Utah. Estimates were made using the spectrum in figure 3.

Peak Ground Accelerations (g)	Effective Peak Accelerations (g)
0.30	0.28
0.36	0.33
0.42	0.39

Applying the SEAOC criteria for determining seismic zones to the map in figure 2b indicates a change from seismic zone 3 to zone 4 is warranted along the central Wasatch Front. Figure 4 shows the proposed change; the proposed map is the same as the 1988 seismic zone map outside of the Wasatch Front. The only change is a seismic zone 4 along the central Wasatch Front, where peak horizontal ground accelerations of 0.30 g and greater were mapped by Youngs and others (1987).

U.S. Geological Survey experts recently published a map of peak horizontal accelerations on rock with a 10 percent probability of being exceeded in 50 years for the United States (Algermissen and others, 1990) that indicates values of 0.2 to 0.29 g for the central Wasatch Front, values much smaller than those mapped by Youngs and others (1987). Because of this difference, it is important to try to ascertain why Youngs and others (1987) estimated larger values. The 1990 study of Algermissen and others is an update of their 1982 study, incorporating uncertainty in attenuation relations and fault length. Seismic sources in Utah, and their characterization, were essentially unchanged from the 1982 study (S. T. Algermissen, U.S. Geological Survey, oral commun., 1990).

Comparison of the two studies reveals that attenuation relations, minimum and maximum magnitudes, fault segmentation models, or models of earthquake occurrence are not responsible for the higher estimates of Youngs and others (1987). The use of paleoseismic data by Youngs and others (1987) to characterize the recurrence of large (surface-faulting) earthquakes is in part responsible for their higher acceleration estimates. For example, Youngs and others (1987) estimate an average recurrence interval for M_s 7.0 and greater events on the entire Wasatch fault zone of 330 years. This is a combined value for both their segmented (weighted 0.8) and unsegmented (weighted 0.2) fault models. In contrast, Algermissen and others (1982) used an average recurrence interval of about 720 years based on extrapolating historical data. This value was calculated using the recurrence data presented in their table 1 (p.78) for seismic source no. 040, and Gutenberg and

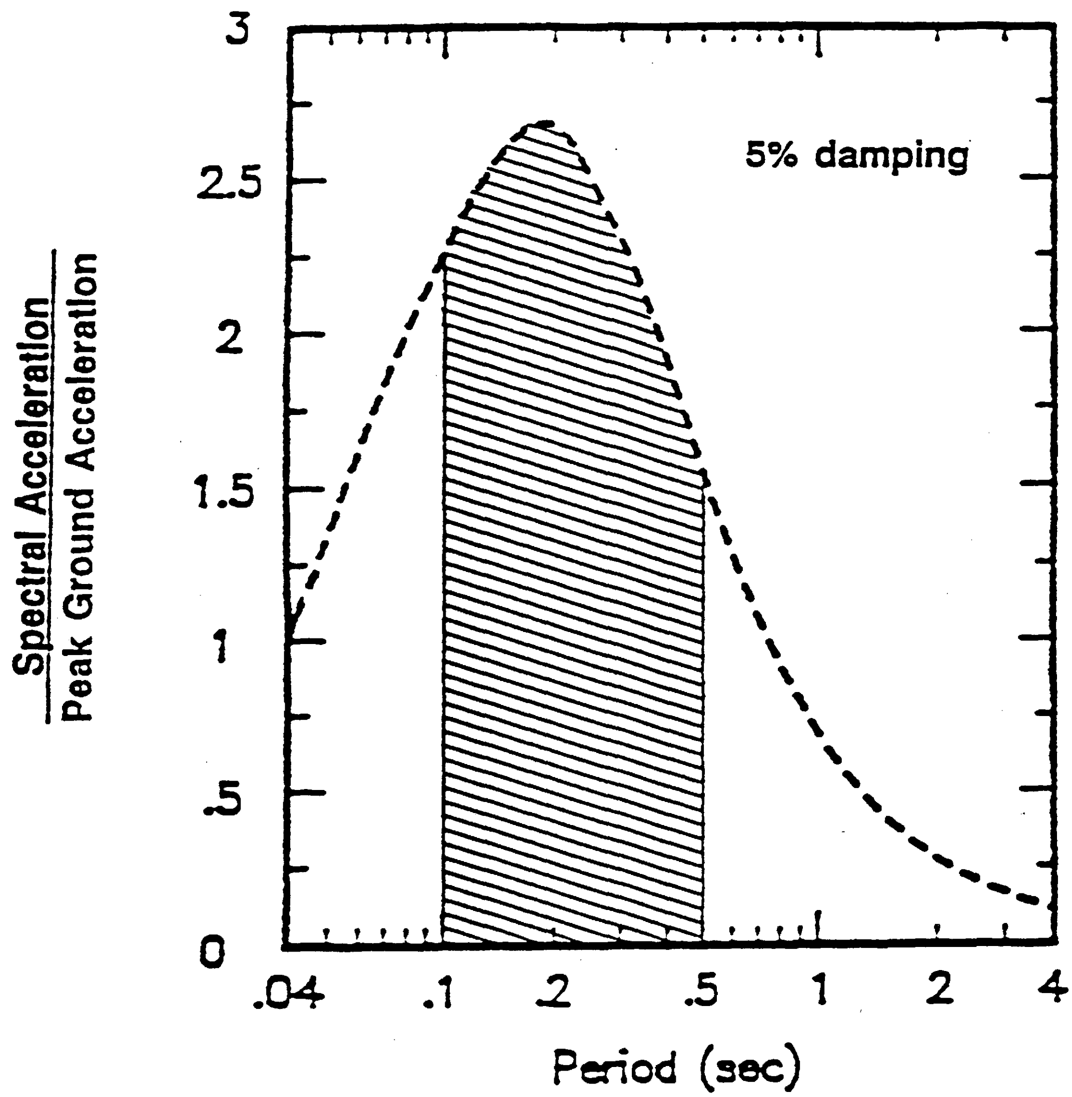


Figure 3. Normalized average spectrum for the Wasatch Front, Utah, with a 10 percent probability of being exceeded in 50 years, from Youngs and others (1987). Effective peak accelerations in table 2 were estimated by finding the average response within the 0.1 to 0.5 second period band (shown by hatching), scaling by the appropriate peak ground acceleration, and dividing by 2.5.

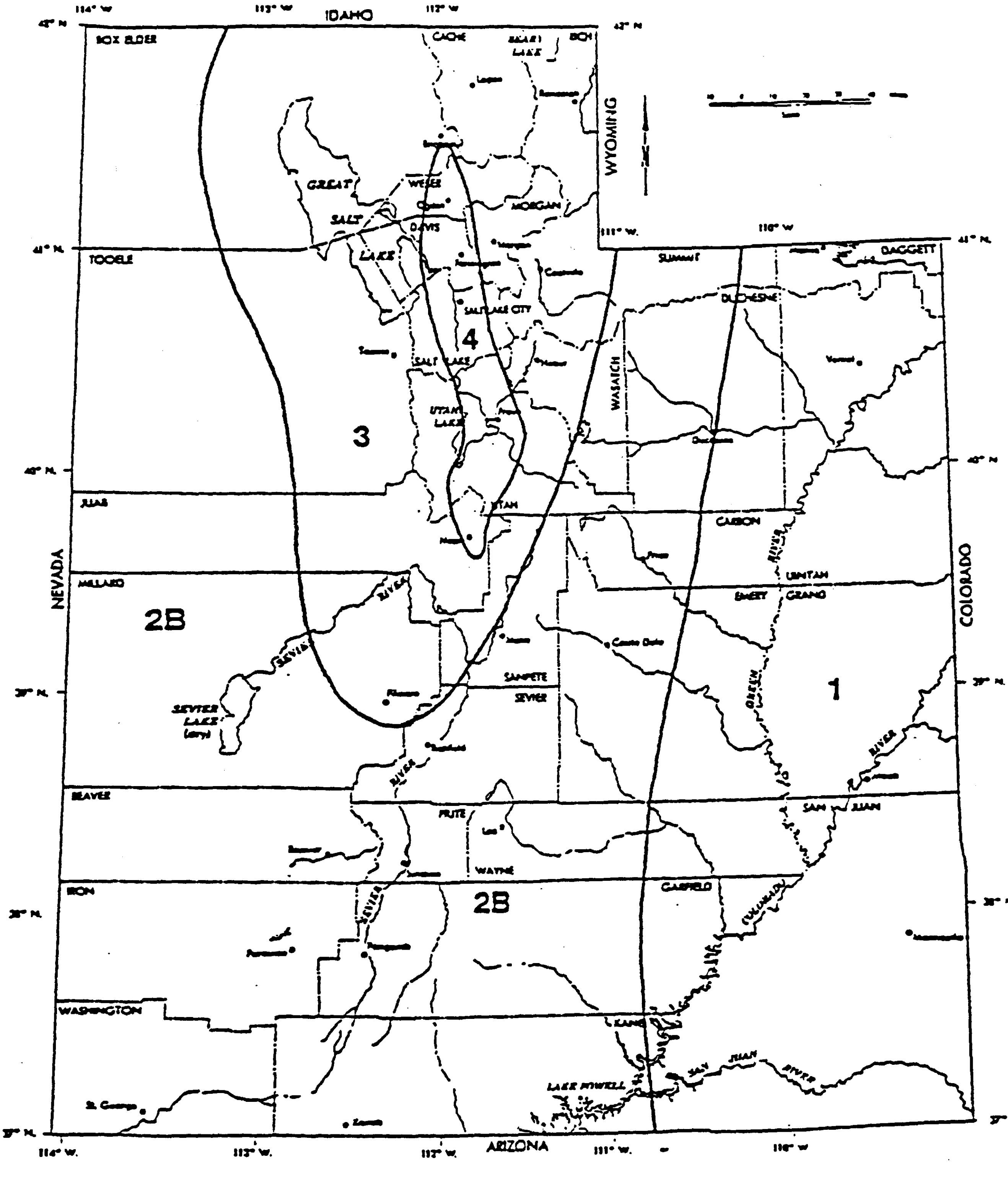


Figure 4. Proposed UBC seismic zone map for Utah.

Richter's 1942 magnitude-intensity relation. This recurrence interval is roughly twice that indicated by recent paleoseismic data of 220 to 455 years (Machette and others, 1991). It should be noted that this recurrence interval is still longer than the recurrence intervals for many faults in California, and, therefore, some opponents of this amendment believe that the Wasatch Front should not be in the same seismic zone as these more seismically active areas in California, regardless of the SEAOC criteria.

Differences in defining earthquake sources and incorporating uncertainty in the analyses also probably contributed to the larger estimates of Youngs and others (1987), but specific contributions are difficult to ascertain. A considerable amount of information about potential sources for large earthquakes along the Wasatch Front has been collected since 1982 as a result of the research focus of the National Earthquake Hazards Reduction Program (for example, Machette and others, 1987, 1989; Machette, 1988; McCalpin and others, 1987), and much, but not all, of this information was available and incorporated into Youngs and others' (1987) analysis. Their more detailed modeling of sources for large earthquakes and their use of more recent information about these sources were significant factors resulting in the higher acceleration estimates of Youngs and others (1987).

It should be noted that some engineers in Utah believe that present ductility requirements for seismic zone 3 are adequate to account for the larger values mapped by Youngs and others (1987), and that increasing elastic design values to a zone 4 is not necessary. However, not all engineers agree, and in fact, Bertero (in press) reports that "... the rationale for and reliability of the values recommended for the Rw factor can be questioned in view of recent research results. The UBC-recommended values appear to be too high, particularly for short-period buildings which are designed to just satisfy the minimum strength required by the UBC provisions." The UBC Commission of Utah is not prepared to reevaluate Rw values for the purposes of analyzing the zone 3 versus zone 4 issue along the Wasatch Front, and therefore, this is one of the reasons that this amendment is being submitted to ICBO for review.

Finally, it is recognized that this amendment does not address some other very important earthquake design issues in Utah that may also increase force levels, such as the amplification of ground motions by soft sediments within basins. However, it is believed that this issue is best considered separately and that more information is needed before it can be resolved. Nor does this amendment deal with determining what is an acceptable level of risk or appropriate exceedence probability level in Utah. However, information on how the ground-shaking hazard varies at different probability levels does need to be considered in evaluating this amendment (figure 5). Because of the long recurrence of large earthquakes, estimated accelerations for a 50-year exposure time increase rapidly as probabilities of being exceeded drop below 10 percent. Consequently, lowering probability levels for design below the present 10 percent, by even a few percent, would

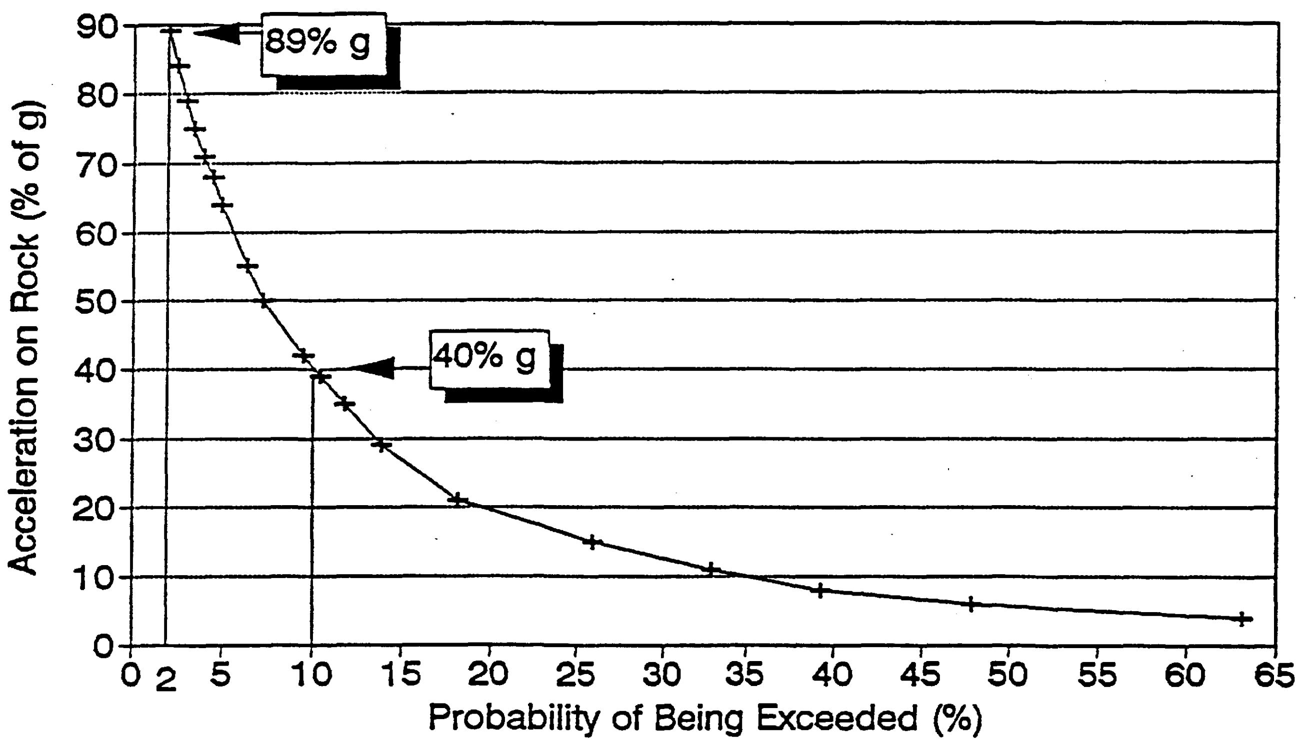


Figure 5. Peak horizontal ground accelerations on rock (in percent of g) with various probabilities of being exceeded during 50 years in Salt Lake City, Utah. Values were calculated using hazard curves of Youngs and others (1987) and assuming a Poisson model for earthquake occurrence.

noticeably increase design ground motions in Utah. This becomes particularly relevant if the seismic zonation criteria used to develop the 1988 map are reevaluated. For example, the following recommendations were made by the Zone Criteria Subcommittee of the Structural Engineers Association of Northern California in 1982:

> "Although the statement of intent given for the SEAOC recommendations implies that zonation should be based on what is in some sense the 'worst possible' event, the committee proposes to use the 2000-year earthquake rather [than] the maximum possible earthquake in developing the zonation map... The choice of 2000 years is based on what the committee considers appropriate relative to other risks that the public accepts in regard to life safety." (Matthiesen and others, 1982)

A 2000-year event roughly corresponds to between a 2 and 3 percent probability of being exceeded in 50 years, much lower than the probability level actually used to develop the 1988 seismic zone map. Indeed, estimates of accelerations along the Wasatch Front for these exceedence probabilities are double those for the current exceedence probability of 10 percent (see figure 5). Given this information, it seems unlikely that reevaluating the seismic zonation criteria (at least from a probability viewpoint) would result in the central Wasatch Front not meeting zone 4 criteria.

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Project: Investigation of a sinkhole 2.5 miles west-northwest of Henefer, Utah			Requesting Agency: Emergency Response
By: Susan Olig	Date: 10-8-91	County: Summit	Job No.: (GH-16) 91-15
USGS Quadrangle: Devils Slide (BLM #1317)			

INTRODUCTION

Edward Kimball, Codes and Environmental Affairs Supervisor with Questar Pipeline, contacted the Utah Geological Survey (UGS) to inform us of a sinkhole developing along their Mainline No. 3 pipeline that carries natural gas from Coalville to their Sunset Station. Because the pipeline is significant to the safety and well-being of Utah citizens and because sinkholes have not been previously identified in the area, the problem is of interest to the UGS. The scope of this investigation included a review of the geologic map of the Devils Slide Quadrangle, mineral occurrence files, and 1:20,000 scale 1967 aerial photographs, and a field reconnaissance of the sinkhole and immediate vicinity. On October 4, 1991, I accompanied Mr. Kimball in a field inspection of the feature. At the site, we also met with Joseph Kippen, the landowner, and Terry Glover, Bob Ramsey, and Larry Bodyfelt, all with Questar Pipeline. This report is intended to document the occurrence for scientific purposes and assist future investigations should the sinkhole keep enlarging and eventually threaten the pipeline.

SITE AND SINKHOLE DESCRIPTION

The sinkhole developed in an unnamed ephemeral drainage just south of Roberts Hollow and 0.2 miles east of the boundary between Summit and Morgan Counties (sec. 1, T. 3 N., R. 3 E.; attachment 1). It is roughly 100 feet north of a west-northwest trending channel and is about 75 feet above the channel on a ridge and at an approximate elevation of 6880 feet. Vegetation above and below the pipeline is dominated by scrub oak and is moderate to dense. Vegetation along the channel is dense and dominated by aspen, willow, and oak. The pipeline route was successfully reseeded with grass. There is a small debris basin along the channel, roughly 500 feet east and downstream of the sinkhole. Although there is a small, collapsed, copper adit roughly 1.1 miles to the west of the sinkhole, there is no subsurface mining within the immediate area (within 1 mile of the sinkhole) (Mullens and Laraway, 1964; Utah Mineral Occurrence System files, UGS).

The sinkhole is developed in the Echo Canyon Conglomerate (Mullens and Laraway, 1964), an Upper Cretaceous boulder conglomerate with rounded limestone and sandstone clasts in a siltstone matrix. The percentage of matrix, degree of induration, and erodibility is variable. Beds are relatively flat-lying and undeformed. The Echo Canyon Conglomerate is over

500 feet thick in the area.

The sinkhole was roughly 15 feet long, 4-8 feet wide, and 30-33 feet deep. It was "kidney-shaped" in plan-view and elongated trending southwest, with the northeast end under the pipeline and the southwest end extending toward the drainage. The pipeline is approximately 18 inches in diameter and buried one to two feet below the surface. It presently spans the hole at its narrowest width (less than 5 feet). The walls of the hole were near vertical, with some overhanging ledges, and clearly exposed the Echo Canyon Conglomerate. The bottom of the hole sloped to the southwest, was covered with material sloughed from the walls (silt, cobbles, and boulders), and was completely dry. Surface water was not observed anywhere at the site, including along the channel, the pipeline, or in the debris basin. Reconnaissance of the slope immediately below the sinkhole and the channel as far as 1500 feet to the east (downstream) did not reveal any recent deposits that were obviously related to evacuation of material from the sinkhole. According to Bob Ramsey, the first report of the sinkhole was by a local sheepherder in July 1991 and at that time the hole was much smaller (roughly 10 feet deep and 5 feet in diameter).

PRELIMINARY INTERPRETATIONS OF ORIGIN

The most probable cause of the sinkhole appears to be piping. The lack of subsurface mining in the immediate area precludes collapse of excavations as a probable cause for the sinkhole. There are exposures of Twin Creek limestone roughly one half mile north of the sinkhole and solution subsidence (collapse of Echo Canyon Conglomerate deposits due to dissolution of underlying limestone) cannot be completely dismissed. However, the minimum depth of the limestone is over 500 feet. It is unlikely that dissolution at this depth would result in such a deep, steep-sided, well-defined sinkhole at the ground surface. Additionally, the lack of other karst features or topography in the area suggest that collapse due to dissolution of underlying limestone is not the most likely cause.

Piping occurs when a permeable, weakly consolidated or unconsolidated layer becomes saturated and preferentially conducts subsurface water. Greater ground-water velocities can actually transport fine-grained material to a local free face that intersects the permeable layer. According to Costa and Baker (1981), mudstone and siltstone are materials subject to piping and piping is a common process in the headward erosion of gullies in semi-arid climates. The most probable origin of the sinkhole is that a permeable, less-indurated layer within the Echo Canyon Conglomerate allowed piping of matrix material to the "free face" formed by the slope along the ephemeral drainage that is south of the sinkhole.

It should be noted that surface runoff concentration is a key component in piping and there was no obvious evidence of surface runoff concentration into the sinkhole. However, it is possible that surface runoff and shallow, subsurface, underflow concentrates along the pipeline corridor and are intercepted by the loose disturbed fill along the pipeline. It then travels downslope along the pipeline until it intersects a more permeable zone or layer in the Echo Canyon Conglomerate. Concentrated flow then may move vertically downward and horizontally along bedding, carrying away fine-grained fractions and causing piping and collapse. Observations of the sinkhole during a large enough rainstorm could clarify this possibility if water was observed to be flowing from the base of the pipeline fill along the uphill (west) side of the sinkhole. A problem with the piping interpretation is that there was no obvious evidence of either an exit hole, "pipe", or material removed from the sinkhole by piping, on the slope below the pipeline along the drainage. However, only fine-grained material (silt) would be transported and the deposit could have been washed away or obscured by vegetation and the bouldery surface of the slope. Also, much of the material may be washed vertically down into deeper, more permeable beds, rather than laterally out to the slope. The enlargement of the hole since July also supports piping as the cause of the sinkhole as piping is a self-enhancing process.

Further investigation is necessary to try and identify possible areas of runoff concentration, the depth and extent of possible piping, where exactly the material is going, and the source of water. Answers to these questions are critical to more definitively identify the origin of the sinkhole and decide on appropriate mitigation measures.

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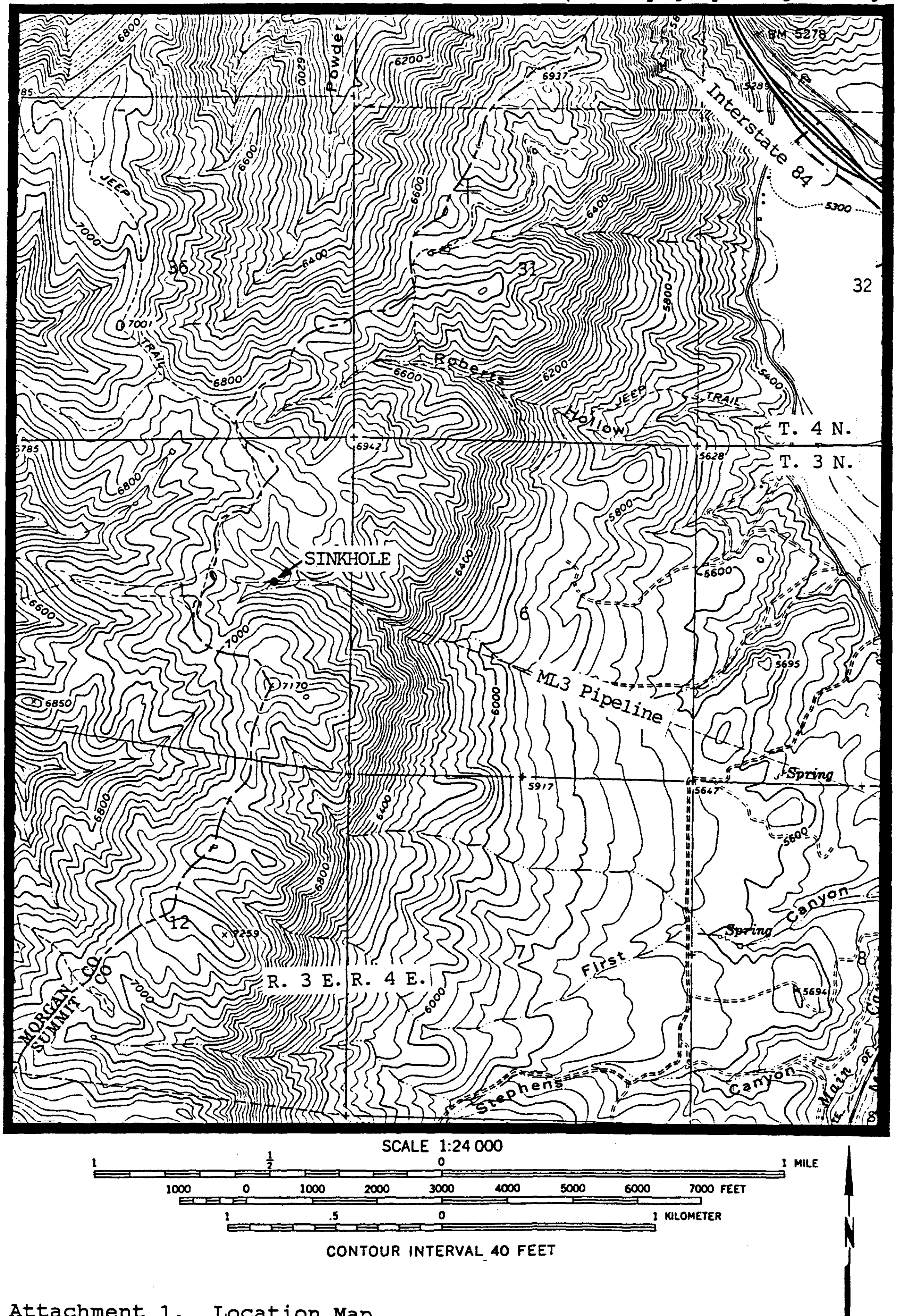
Attachment 1, Job No. 91-15   Base map from Devils Slide, U.S.G.S. 7-1/2' topographic quadrangle



Attachment 1. Location Map

REVIEWS

Project: Review of "Geotechnical Investigation, Dawson Hollow Estates Subdivision, Layton, Utah."			Requesting Agency: Layton City Community Development
By: Mike Lowe	Date: 7-31-90	County: Davis	Job No.: (R-1) 90-11
USGS Quadrangle: Kaysville (1320)			

INTRODUCTION

The purpose of this report is to review the engineering geology aspects of a geotechnical report (Bingham Engineering, 1990) for the proposed Dawson Hollow Estates Subdivision located in the NW 1/4 sec. 14, T.4 N., R. 1 W., SLBM, in eastern Layton City, Utah, and to comment on the feasibility of extending Country Oaks Drive. Engineering aspects of the report should be reviewed by a geotechnical engineer. The review was requested by Scott Carter, Layton City Community Development, and the scope of investigation included a literature review, an examination of aerial photographs (1985, 1:24,000 scale), and a brief field inspection on July 27, 1990.

The Bingham Engineering (1990) report identifies flooding, shallow ground water, earthquake ground shaking, liquefaction, and slope failure as the principal geologic hazards which could occur at the site. This appears to be a complete and accurate listing of the hazards present, although recommendations regarding mitigation are sometimes unclear or lacking. Each is addressed separately below:

Flooding: A 100-year flood plain has been identified from Federal Emergency Management Agency maps along both the Middle and South Forks of Kays Creek (Bingham Engineering, 1990). The report does not show which lots are affected, or recommend mitigation measures. The boundaries of the 100-year flood plain should be shown on the Plot Plan and Federal Emergency Management Agency guidelines followed for portions of the proposed subdivision which are within those boundaries.

Shallow ground water: Shallow ground water was encountered at depths ranging from 3.1 to 9.4 feet in some of the boreholes along the Middle and South Forks of Kays Creek; area and foundation subdrains have been proposed to mitigate the problem (Bingham Engineering, 1990). The layout of the proposed subdrains has not been included in the report, and potential effect on stream flow in the Middle and South Forks of Kays Creek has not been evaluated. This information must be provided before a proper review of the proposed mitigation method can be accomplished.

Earthquake ground shaking: The site is in Uniform Building Code (UBC) seismic zone 3; the Bingham Engineering (1990) report recommends that as a <u>minimum</u> construction should incorporate earthquake-resistant design required for UBC seismic zone 3, which is consistent with present building practices.

Liquefaction: Regional maps (Anderson and others, 1982) denote the liquefaction potential to be "moderate" in the ridge area and "high" in bottoms of the drainages. Although soil and ground-water data were collected from borings, the Bingham Engineering (1990) report does not evaluate the liquefaction potential at the site-specific level or recommend mitigation measures. The Davis County Planning Commission (Lowe and others, 1990) does not require site-specific investigations of liquefaction potential for residential subdivisions in the unincorporated area, but does recommend that appropriate disclosure be required. I am not aware of Layton City's policies regarding liquefaction hazards, but I support Davis County's policy and recommend disclosure as a minimum for the proposed Dawson Hollow Estates Subdivision unless site-specific studies are performed and show that the hazard does not exist.

Slope stability: The eastern portion of the proposed subdivision where slopes exceed 30 percent are in areas where landslide-hazard special studies are recommended (Landslide-Hazard Map, Kaysville Quadrangle, Davis County Planning Commission, 1989a). Bingham Engineering (1990) did not identify any existing landslides within the boundaries of the proposed subdivision, although slope failures were identified in the site vicinity, including an area south of the South Fork of Kays Creek. Slope failures have also occurred south of the Middle Fork of Kays Creek (Dames and Moore, 1982; Lowe, 1988), immediately northeast of the proposed subdivision site. These slope failures are shown on the Slope-Failure Inventory Map for the Kaysville Quadrangle (Davis County Planning Commission, 1989b).

Soils in slopes in the proposed subdivision are similar to those that have failed nearby, although slopes are generally not as steep. Based on the Plot Plan provided by Bingham Engineering (1990), however, slopes in some areas within the proposed subdivision may exceed 40 percent (the western portion of the area labeled "Rear Lots are Not Buildable", for example). Slope stability is highly dependent on ground-water conditions, and because of the present drought borehole data may not reflect long-term ground-water conditions at the site. Also, the proposed development itself may have an effect on ground-water conditions and the potential for slope failure.

The potential for new slope failures in landslide-hazard areas shown on the Landslide-Hazard Map for the Kaysville Quadrangle (Davis County Planning Commission, 1989a) is not addressed in the report, except to indicate that no failures exist at present. If homes are planned in these areas, I recommend that slope stability analyses be performed to address the potential for landsliding under static, development-induced, and earthquake-induced conditions as well as all likely ground-water conditions (Lowe and others, 1990, Robison and Lowe, 1990), and appropriate actions taken. The potential for damage to structures on relatively flat ground above and below the slopes should also be considered. Landslide material was deposited approximately 100 feet from the base of the slope during the 1986 slope failure which occurred on the south side of the Middle Fork of Kays Creek to the east of the proposed subdivision site.

Recommendations for excavations and cut slopes provided in the report should be reviewed by a geotechnical engineer as should plans for any engineered retaining structures for cut slopes.

Plans for the engineering and construction of the extension of Country Oaks Drive westward down the ridge were not provided in the Bingham Engineering (1990) report. Most of this extension of Country Oaks Drive will be down the top of the ridge. This is probably the most stable portion of the hill and construction probably will not produce cuts requiring retaining walls. As the road turns north, down the hill toward the Middle Fork of Kays Creek, cuts and fills may be required. The entire length of the extension of Country Oaks Drive should be provided with a means of keeping water off the ridge slopes. Plans for how this road will be constructed should be provided to the Layton City Engineer for review prior to approval of the proposed subdivision.

In conclusion, most of the geologic hazards which may potentially occur within the boundaries of the proposed subdivision have been identified, but recommendations regarding mitigation are sometimes unclear or lacking. The boundaries of the 100-year flood plain, as identified on Federal Emergency Management Agency maps, should be shown on the Plot Plan. The layout of the proposed subdrains and an evaluation of their potential impact on stream flow should be provided. Liquefaction hazards may exist at the site, and handling of this hazard depends on Layton City's policy regarding liquefaction hazards in residential subdivisions. I recommend that the liquefaction hazard either be assessed at a site-specific level and, if necessary, mitigation measures taken, or disclosure required. It is recommended that the potential for slope failure be further evaluated for areas where slope-stability studies are recommended on the Landslide-Hazard Map, Kaysville Quadrangle (Davis County Planning Commission, 1989a), to determine if mitigative measures are necessary. Engineering aspects of the proposed subdivision, including grading plans and specifications for cuts and fills, should be reviewed by a geotechnical engineer. Signatures of engineering geologists (including statement of qualifications) and Registered Professional Engineers (including P. E. licence number) responsible for the investigation should be included in the report.

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Davis County Planning Commission, 1989a, Landslide-Hazard Map, Kaysville Quadrangle: Unpublished Davis County Planning Commission Map, scale 1:24,000.

Davis County Planning Commission, 1989b, Slope-Failure Inventory Map, Kaysville Quadrangle: Unpublished Davis County Planning Commission Map, scale 1:24,000.

Lowe, Mike, 1988, Country Oaks Drive landslide: Utah Geological and Mineral Survey Report of Investigation 218, p. 7-8.

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Robison, R, M., and Lowe, Mike, 1990, Landslide hazards: a guide for land-use planning, Davis County, Utah: U. S. Geological Survey Open-File Report 90-225, p. HH-1-26.

Project:			Requesting Agency:
Review of "Final Report for: Geoseismic Studies - West, East, and Highland High Schools, Salt Lake City, Utah"			Salt Lake City School District
By: Suzanne Hecker	Date: 9-12-90	County: Salt Lake	Job No.: (R-2) 90-12
USGS Quadrangle: Sugar House (1212), Fort Douglas (1253), Salt Lake City North (1254)			

In response to a request from Steve Harman, Salt Lake City School District, the Utah Geological and Mineral Survey (UGMS) has reviewed portions of the "Final Report for: Geoseismic Studies - West, East, and Highland High Schools, Salt Lake City, Utah" by Sergent, Hauskins and Beckwith Consulting Geotechnical Engineers (dated August 6, 1990; SHB Job No. E90-2070). The report addresses active faulting and related deformation, liquefaction potential, ground response, and soil bearing strength at each of the three school sites. The scope of this review is limited to the work done to assess the potential for faulting at the sites. In this regard, I evaluated the data and resulting conclusions drawn from four drill holes at each site and from a series of trenches at the East High School site.

Field investigations, particularly trenching, are difficult in areas with driveways and buried utilities, such as at the East High School site. Because of such constraints, it is sometimes not possible to obtain conclusive results. My principal concern with the reviewed report is that it does not identify uncertainties associated with the study results. Sergent, Hauskins and Beckwith (SHB) present firm conclusions which may not be warranted given the scope and physical constraints of their investigation. My specific comments are listed below:

1) The trench logs from the East High School site do not include enough information from which to trace the continuity of sedimentary layers. The marker beds referred to in the report, which were used to interpolate between trenches and to identify deformation, should have been logged to support the conclusion that deposits are not significantly deformed. Also, by not illustrating the geometry of, and the net deformation across, the "semi-warping" in Trench 3 (Figures 5F and G), I am not able to evaluate the conclusion that "this semi-warping is not indicative of the zone of deformation associated with active fault zones" (p.20).

2) Evidently, SHB interpreted sedimentary layers to be continuous between trenches 2 and 3 by projecting beds at an assumed average dip of 4° across the 60+ ft between trenches (Figure 5E). However, an identical alignment of bedding in the trenches could result from beds which dip an average of 3° and have 1 ft of vertical offset within the unexposed interval --or a 2 ft offset across beds which dip 2°. Earthquake-related deformation in the sections between trenches cannot be completely excluded, and this should have been made clear in the report. Geologists at UGMS have observed faulted, thin-bedded Lake Bonneville sediments which show virtually no deformation or change in dip near or between faults.

3) The report states (p. 18) that based on the lack of bedding distortion in exploration borings at the Highland and East High School sites, "it is concluded that the sites are not within zones of fault deformation or have the soils experienced deformation as the result of liquefaction." Such statements seem more conclusive than can be justified by SHB's exploration program. Much of the deformation related to faulting or liquefaction may be subtle or localized and is unlikely to be detected from a series of 4-inch bore holes spaced hundreds of feet apart. In any case, liquefaction potential is better addressed through geotechnical evaluation of present soil and ground-water conditions, as was done elsewhere in the report, and faults are better studied through geologic mapping and trenching. However, as shown in Figure 1 of the report, the Highland and West High School sites lie outside the surface fault rupture special study areas defined by Nelson (1990). Thus, barring other evidence for possible faulting, further study of this hazard is not required at these sites.

I recognize the difficulty in doing fault investigations under the conditions which exist at the school sites, and I am reassured to learn that SHB found no obvious evidence for deformation. However, given the scope of work and results presented in the report, the conclusion that "...the sites are not within zones of fault deformation..."(p. 18) seems too strong. The statement may be true, but the uncertainties need to be made clear. I am concerned that the marker beds used to interpret stratigraphic continuity between trenches are not shown on the trench logs, and I believe that the possibility for deformation within the unexcavated areas between trenches cannot be ruled out.

REFERENCES

Nelson, C.V., 1990, Surface fault rupture and liquefaction potential special study areas: Salt Lake County Public Works - Planning Division unpublished map, scale 1:48,000.

Project:			Requesting Agency:
Review of a License Application for Radioactive Materials, License Amendment #UT 2300249, Envirocare of Utah, Inc.			Utah Division of Environmental Health, Bureau of Radiation Control
By: Barry J. Solomon	Date: 11-16-90	County: Tooele	Job No.: (R-3) 90-14
USGS Quadrangle: Aragonite (1222)			

The license amendment is to permit the disposal of additional types of low-level radioactive waste adjacent to the South Clive site, Utah. This site is the location of the disposal cell used in the Vitro Remedial Action project. The site is about 80 miles west of Salt Lake City, Utah, and lies within the Great Salt Lake Desert. The material will be disposed in an earthen embankment, compacted in place, and covered with barriers.

This review concentrates upon those portions of the amendment which discuss the geology and seismology of the proposed project, but other aspects of the amendment were reviewed and appropriate comments made where significant deficiencies were noted. This review was conducted in accordance with NUREG-1200, Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility, U.S. Nuclear Regulatory Commission, January, 1987. References to specific sections of NUREG-1200 are not provided for every review comment, but all comments are in response to NRC requirements in the Standard Review Plan.

General Comments

1) The applicant relies heavily upon data generated for the adjacent Vitro Remedial Action project. For regional interpretations this may be acceptable, but for site-specific interpretations data generated from a nearby site is not interchangeable. The use of off-site data may lead to an inappropriate design. Since no design verification activities were conducted as a part of this project, as they should have been, crucial errors in facility design may have been made.

2) The applicant appears to have followed NUREG-1199, Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facilty, in the preparation of this amendment. NUREG-1199 requests that specific information be adequately cross-referenced in various sections of the amendment to provide a coherent presentation of technical data, and to insure that such data is available to the reviewer so that interpretations can be validated. Cross-referencing in this amendment was inadequate and hindered the timely review of the document.

3) Although this review was technical rather than editorial in nature, it must be noted that the amendment is replete with editorial mistakes. Most were insignificant errors such as misspellings and transpositions of letters, but some errors made

the content incomprehensible. One paragraph is poorly written and may be misinterpreted (see comment below for Section 5.2, p. 5-4).

4) The term "etc." is repeatedly used, and when used is imprecise and nonspecific. The use of "etc." is inappropriate for the proposed facility.

Specific Comments

CHAPTER 1:

P. 1-12, Sec. 1.2.4.7, par. 4 - The discussion of the level of Great Salt Lake correctly concludes that any rise of the lake will be unlikely to affect the proposed site. The significance of the 4217-ft elevation should be discussed in more detail, however, and more information given regarding historical and Holocene lake levels and how they relate to possible flooding.

Figure 1.1 - This figure should show Wendover, Utah, and West Wendover, Nevada, since these communities are closer to the site than Salt Lake City.

CHAPTER 2:

P. 2-1, Sec. 2.1.1 - A topographic map at the appropriate scale should be included to show topography of the region surrounding the site.

P. 2-2, Sec. 2.1.1, par. 3 - The maximum expected accelerations in bedrock, given here and elsewhere, are not specified to be either probabilistic or deterministic. If probabilistic, the parameters related to this estimate should be given (250 year exposure time with a 90% probability of not being exceeded?); if deterministic, determined from what possible event (the Maximum Credible Earthquake?). Give a reference for this data, also.

P. 2-3, Sec. 2.1.2, par. 2 - The first sentence "projects" population increases for Tooele County up to 1985, followed by a decline in the growth rate. These "projections" are now out of date and should be replaced with 1990's projections.

P. 2-5 and 2-6, Sec. 2.3.1 - This section is incomplete, does not adequately describe regional and site geologic conditions, and is not the result of a thorough literature search, adequate reconnaissance, and site characterization.

There is no discussion of regional geomorphology or physiography, and the discussion of regional stratigraphy and geochronology is entirely inadequate. Most of the surficial unconsolidated material in northwest Utah was deposited in Lake Bonneville, yet no mention of the lake is made (see also the comment on Sec. 2.5.2, below). There are no isopach maps of the thickness of unconsolidated material, and there is no contour map showing depth to bedrock or the basin configuration. The latter would seem to be essential to adequately describe regional structure and its effects upon the ground-water regime.

There is no discussion of mineralogy, organic materials within sediments, degree of cementation, or zones of alteration. The possible presence at the site of the White Marl (a widely distributed, deep-water Lake Bonneville unit) and oolitic sands, is of concern. When classified according to the Unified Soil Classification System, marl is usually reported as a low plasticity silt (ML) or clay (CL); such material, as well as sands, are noted in borehole logs of Appendix R. However, because of their high calcium carbonate content, both the White Marl and oolitic sands may be susceptible to dissolution when brought into contact with low to moderately acidic solutions, and if dissolved could pose a threat to the integrity of the facility due to possible settlement and subsidence. If White Marl sediments are compacted to form the liner for the disposal cells, acidic leachate may have a detrimental affect upon the cell liners. See related comments for p. 2-21 thgrough 2-24.

Tectonic structures are discussed in Section 2.5.3 and in Appendix K, but no map is presented which locates significant regional features such as faults described in Sections 2.3.1 or 2.5.3. Appendix K was written for another project and does not ever describe where the Clive site lies in relation to the other study, nor is the location of the Clive site shown on any of the maps of this appendix. Appendix H also discusses regional seismicity, but the site is not adequately located on maps.

The only reference of supporting documents is Dames & Moore (1982), yet there is no complete citation in the text, nor is there any list of references, either at the end of this report, or in Appendix H.

The last paragraph of this section (p. 2-6) summarizes the liquefaction potential study of Appendix J. As presented, the data does not support the conclusion that "significant liquefaction due to an MCE event is improbable." Boring logs (Appendix R) show saturated, poorly graded sands at shallow depths (20 to 30 ft according to the applicant on p. 2-6). The poor quality of reproduction of logs in Appendix R precludes reading of blow counts, but the applicant states that "SPT blow count values for sands lying below the water table less than 10." This seems quite low and, combined with a shallow water table and poor grading of sands, would seem to indicate that a significant liquefaction potential exists, particularly with MCE accelerations of 0.37g. To say that the embankment is unsaturated (Appendix J, p. C-2, conclusion C), and that this is a factor which will contribute to a negligeble liquefaction potential, is misleading. Saturated sands lie <u>below</u> the embankment at depths of less than 30 ft, and it is these soils which will contribute to the liquefaction potential. Contrary to what the applicant states on p. 3-9 (see comment below for that page), the applicant did not monitor ground water levels during the high stand of Great Salt Lake, and has not taken into account the potential for a rise in ground-water levels to affect the liquefaction potential. Regardless of this it is generally accepted that, contrary to what the applicant states on p. 2-6, overburden pressure is not too large at depths of 20-30 ft to preclude the possibility of liquefaction, particularly if the applicant considers the depth of the excavation and the density of overlying waste material. Replacement of overburden with lower-density waste will increase the liquefaction potential of underlying saturated sands. In spite of the above discussion, perhaps the most damaging argument against the applicant's conclusions is that the applicant's argument is based upon off-site borehole data. It is the reviewers experience that sand bodies within lakebeds of the site vicinity are often discontinuous or lenticular. The applicant cannot adequately describe the liquefaction or settlement potential of the site without site-specific borehole data. On-site borings are needed, and geophysical methods are available to determine the continuity of unconsolidated strata.

P. 2-6, Sec. 2.3.2, and p. 2-7, Sec. 2.3.2.1 - NUREG-1199 requests that the applicant provide a list of all historical earthquakes with a magnitude of 3 or more, or with a Modified Mercalli (MM) intensity of IV or more, within 200 miles of the site. The LA contains lists for a 50-km (31-mi) radius in Appendix H, and a 200-km (124-mi) radius in Appendix K. Table 2.2 (incorrectly referred to as table 2.3 in the text) lists earthquakes in the "Utah Region," but does not define what area this term covers, and only lists earthquakes with a magnitude of 5.5 or greater or a MM intensity of VII or greater. To comply with NUREG-1199, the list should include epicenter coordinates, depth of focus, origin time, intensity, and magnitude. Earthquake-induced hazards within the 200-mi radius must also be identified.

The applicant's estimates of the Maximum Credible and Design Earthquakes are incomplete without consideration of floating earthquakes. This topic is discussed in Appendix K, Sec. 2.3.5., where the threshold of surface faulting in Utah is estimated to be from magnitude 6.0 to 6.5. The conclusion of Appendix K (p. 65) that ".....the probability of earthquake-induced ground deformation at the proposed SSC sites is very small," however, is only applicable to the Superconducting Supercollider project, and is not necessarily applicable to the Envirocare project. The above conclusion was based upon a project with a large areal extent and for earthquakes within 50 km of the center of the site. For the Envirocare project, the potential for deformation must be calculated for a magnitude 6.5 earthquake located directly beneath the site. Moreover, such a potential event must be considered in design accelerations, which will impact all aspects of site design, including liquefaction potential, settlement, subsidence, and related design parameters.

P. 2-6, 2-7, and 2-8, Sec. 2.3.2 - Neither Appendix H or Appendix K calculate ground velocities (NUREG-1200, Sec. 4.3.5). Ground velocities should be calculated, and the resultant figures should be interpreted in the light of a detailed description of the materials at the site. This interpretation must indicate the potential for amplification of vibratory ground motion in the unconsolidated material, and should be presented in the form of a probabilistic seismic hazard estimate with a 250-yr exposure period.

Although a probabilistic estimate is provided for ground acceleration in Appendix K, a 50-yr exposure period is used. Given the extended length of the postclosure period during which the integrity of the facility must be maintained, a 250-yr exposure period is more appropriate. The estimates that are provided in the amendment are inconsistent; the maximum acceleration at the site is noted as 0.37g on p. 2-2 and as 0.31g on p. 2-8.

No isoseismal maps are presented for the data in Table H-6, and it is not readily apparent from the table which fault is the source for the calculated maximum acceleration. For the maximum historical earthquakes associated with tectonic provinces within a 200-mile radius of the site, isoseismal maps should be presented for the earthquakes having a magnitude greater than or equal to 3 (NUREG-1200, Sec. 4.3.4).

P. 2-8, Sec. 2.3.2.2 - Is the design earthquake (NUREG-1200, Sec. 4.3.6) the same as the MCE? If not, the analysis and data required for the MCE must be repeated for the design earthquake.

There is no indication that the applicant conducted any detailed investigation for potential Quaternary faulting on site. At a minimum, this should include air photo analysis and regional mapping independent of past work for other, nearby projects.

P. 2-12, Sec. 2.4.2.1 - Depth to the water table is noted from 25 to 35 ft here, but from 20 to 30 ft on p. 2-6.

P. 2-15, Sec. 2.5.2 - This section misses entirely the point of discussing the geology of the site and region. The facility will be constructed in unconsolidated material deposited by Pleistocene Lake Bonneville, yet no mention is made of lake beds or even of unconsolidated material, only of bedrock in mountain ranges of the region.

P. 2-16, Sec. 2.5.3 - See comments above on seismicity.

P. 2-17 and 2-18, Sec. 2.5.5 - All samples referred to in this section were collected offsite. There is sufficient variability in these sediments to justify site-specific collection and analysis. Much raw data is presented from nearby wells, but most of the data is not interpreted (just presented as lists of numbers), and no discussion is presented on the application of the data in facility design, either here or in Chapter 3.

There is no discussion of the criteria used to determine that the samples were properly taken in accordance with Regulatory Guide 1.132 and tested in sufficient number to define all the soil and rock parameters needed for characterizing the site in accordance with Regulatory Guide 1.138. Test methods are not referenced.

P. 2-18, Sec. 2.5.5, par. 4 - A persistent "compressible stratum of low plasticity silty clay" is noted at depths of from 25 to 35 ft, but no mention is made of the potential effect of this instability (settlement) on the facility, nor has this unit been sampled and tested for accurate evaluation. Appendix L is insufficiently detailed to determine if this layer was taken into account in the analysis for settlement and cover cracking. Appendix L refers to a section 2.0, Material Properties, which is not included with this amendment.

P. 2-17 through 2-20, Sec. 2.5.5 and 2.5.6 - Much analytical data is referred to in these sections and in Tables 2.7 through 2.15, but there are no interpretations or conclusions drawn from the data, either here or in Chapter 3 (Design and Construction). How was this data used; what does it mean? What are the recommended design parameters, and how was the data used to support them?

P. 2-19, Sec. 2.5.6, Par. 1 - "No remolded strength or consolidation data are available for the proposed borrow area soils." This would appear to be necessary data.

P. 2-19, Sec. 2.5.6, Par. 2 - "Grain size distribution and the results of Atterberg limits tests were previously presented in Section 7.0." Section 7 of this report discusses occupational radiation protection, and is not previous to sec. 2.5.6. Does this refer to the data in Tables 2.8 to 2.18? This data was not determined from samples in the proposed borrow area either (see comment above).

P. 2-20, Sec. 2.6.1, Par. 1 - "Four soil profiles across the site were constructed from well logs." These profiles were constructed across the Vitro site, not across the subject site. There is sufficient variability to suggest the need for data on the subject site rather than from nearby areas.

P. 2-21, Sec. 2.6.1.1 - There is no information, either here or in Chapter 9 (Quality Assurance), on sampling procedures, sample preservation, storage, analytical procedures, QA, or QC related to the collection and analysis of ground-water samples.

P. 2-21 to 2-23, Sec. 2.6.2 - This text is inappropriate and unresponsive to NRC requirements. Rather than chemical characterization of soils and geochemical modeling, the applicant has provided a summary of the physical soil characteristics. See comments regarding dissolution of carbonate for p. 2-5, 2-6, and 2-24.

P. 2-23 to 2-25, Sec. 2.8.1, 2.8.1.1, and 2.8.1.2 - These sections are misplaced. "Soils" are not biotic features, and should therefore not be a subheading under Section 2.8, Biotic Features. Rather, this discussion should appear in Sec. 2.6.2, Site Soil Characteristics, to partially satisfy what is required there. Sections 2.8.1.3 (Vegetation), 2.8.1.4 (Terrestrial Wildlife), 2.8.1.5 (Aquatic Biota), and 2.8.1.6 (Endangered and Threatened Species) should be renumbered; they are not appropriate subheadings of Section 2.8.1 (Soils).

P. 2-24, Sec. 2.8.1.2 - Reference is repeatedly made to Table 2.21. There is no such table; I assume reference should be made to Table 2.20. Table 2.20, though, contains no data on solubility or ion exchange, and the deepest sample is only 51 inches. The applicant apparently has written this section with only a concern on how soils will affect revegetation. Soil chemistry should be studied, however, with an eye toward possible settlement from soluble minerals and geochemical interaction with ground water and leachate. Since the excavation will reach a depth of at least 8 ft, and since potential interactions between soil and fluids will extend even deeper, analysis of samples to only 51 inches in inadequate.

P. 2-27, Sec. 2.9, and Sec. 4.5.4.4 (Soil) and 4.5.4.7 (Water) - The organizational structure, technical qualifications, training program, and QA program related to soil and water monitoring programs are not described. The instrumentation and methods to be used are not indicated; this should include the type and frequency of analyses, minimum detectable amounts, and lower limits of detection for each constituent. The applicant should also indicate a statistical basis for comparing baseline, operational, and post-closure data.

P. 2-27, Sec. 2.9.2 - A reference is made to Section 4 for details of site characterization monitoring. Section 4.5.4.7 says that locations of ground-water monitoring wells are shown in Table 4.7. This table lists well numbers, but does not describe locations, and locations are not shown on Fig. 4.5 or on any other figure. Table 4.7 does not even indicate the depths of zones to be tested in soil or water, and therefore no evaluation is possible of the efficacy of the proposed program.

Figures 2.1, 2.7, 2.13, and 2.15 - Units of measurement in these figures are inconsistent and confusing. Fig. 2.1 has a horizontal scale in feet, but contours are in meters, with no labeling of the contour interval. Figs. 2.7 and 2.13 have contours in feet, while neither the contour interval nor units of measurement are given for Fig. 2.15.

Figure 2.6 - There is no Figure 2.6, although there are Figs. 2.5 and 2.7.

Figures 2.7 and 2.13 - The location of the Vitro embankment does not agree on these two figures (in Fig. 2.13, I assume that what is labeled as "disposal embankment area" is actually the Vitro embankment, and not the Envirocare embankment, based upon shape). In Fig. 2.7, the embankment is east of borehole SC-1; in Fig. 2-13, it is north of SC-1. Also, this is an amendment for the Envirocare embankment; it, rather than the Vitro embankment, should be shown on Fig. 2.13.

Figures 2.14 and 2.15 - Neither of these figures show the location of the proposed facility. This is a particular problem in Figure 2.15 because there are no other reference features (such as boreholes or test pits) on the map.

Table 2.9 - The location of some test pits in this table are not

shown on Fig. 2.14 or on any other figure.

CHAPTER 3:

P. 3-3 through 3-8, Sec. 3.1.1 - There is no mention of a buffer zone. The applicant should submit information on measures that provide adequate site dimensions to carry out environmental monitoring activities and to take mitigative measures, if needed.

P. 3-8, Sec. 3.2 - "Maximum Credible Precipitation (PMP)" should be Probable Maximum Precipitation (PMP) and Maximum Credible Earthquake (MCE). This section should also discuss the volume and effects of anticipated voids in relation to structural stability of the facility, and the relationship between the geochemical environment and anticipated degradation. Material to be disposed includes building debris, scrap metal, glass, and masonry rubble, and could have a significant effect upon the performance of the facility.

P. 3-9, Sec. 3.3.1.2, Par. 3 - The measurement of ground water levels during the period September 1982 through January 1984 does not, as the applicant says, indicate the position of the water table during the highest recorded levels for Great Salt Lake. The recent high for the lake was reached in 1986, and again in 1987. Also, Table 3.1 shows that ground-water measurements were begun in September 1981, not 1982.

CHAPTER 4:

General comment - This chapter does not describe a program of physical surveillance of monitoring stations, site facilities, and site environs to confirm the operational status of monitoring equipment and instrumentation, to verify the integrity of trench covers, and to detect evidence of erosion and subsidence.

P. 4-9, Sec. 4.3 - This section does not describe a buffer zone whose configuration includes consideration of site geology, topography, soil and rock characteristics, direction of groundwater flow, and sufficient space to conduct mitigative measures if needed.

P. 4-17, Sec. 4.5.2.6, Par. 2 - When refering to the 1988 Environmental Report, reference should be made to Appendix S.

P. 4-21 to 4-23, Sec. 4.5.4.4 and 4.5.4.7 - The sections on operational testing of soils and water only describe tests for radiological constituents. Such testing should also be done for Eh, pH, TOC, ionic contaminants, and other non-radiological parameters (NUREG-1200, Sec. 4.4). See also comments for p. 2-27.

P. 4-23, Sec. 4.5.4.7, Par. 3 - This section describes a study completed to define and characterize the aquifer below the proposed disposal site. "The study is provided in the RCRA Part B Plan Approval Application." If these are the results which are in Sec. 2.4.2, that section should be referenced; if not, the results should be included in this amendment.

CHAPTER 5:

P. 5-1 and 5-2, Sec. 5.1.2 - See earlier comments on liquefaction (not "liquification") potential and on the highest recorded levels of Great Salt Lake. Since, as was noted for p. 3-9, ground-water monitoring was not conducted during the high-stand of Great Salt Lake, the statement made here that ground water would not encroach into the embankment is unsubstantiated.

P. 5-1 through 5-4, Sec. 5.1.2 - No geotechnical monitoring program for the potential effects of settlement and infiltration is presented, nor are remedial actions proposed. Monitoring data must be used to verify the predicted performance of the excavations and remedial actions. The monitoring program should extend through the initial five years of the observation and surveillance period to ensure that the data collected are representative of a successfully closed disposal facility. The monitoring program must specify settlement and infiltration action levels. The visual inspection noted on p. 5-8 is not sufficient to satisfy this requirement.

P. 5-4, Sec. 5.2, Par. 1 - "At the termination of disposal activities.....the entire facility and all equipment.....will be contaminated and brought to radiation....." This paragraph is poorly written. Although it presumably is meant to say that contaminated facilities and equipment will be cleaned up, it can be interpreted to indicate that equipment will be brought up to contaminated levels allowed in the referenced document.

CHAPTER 6:

General Comment - There is no scenario that takes into account the significant transient population on Interstate 80, which is only about 4 miles north of the site.

P. 6-11, Sec. 6.1.5 - This section says that a study was conducted by Rogers and Associates, but does not say what the results were, nor is the study included as an Appendix to this amendment. The amendment should be self-contained; reviewers and other interested parties should not have to search elsewhere for such significant information.

Ultimately, the Bureau of Radiation Control did provide me with Appendices B and C of the Rogers and Associates report. The report states on p. B-2, Sec. B.1, par. 1, "If sufficient water were to percolate into the disposal units and accumulate, the water could eventually overflow the units and be released onto the ground surface (the bathtub effect). This overflowing water could contaminate the ground surface and cause radiological exposures to site intruders." The report continues on p. B-8, last paragraph, ".....it appears unlikely that water would accumulate in the disposal units at the Clive facility. The conclusion that water will probably not accumulate in the Clive disposal units is based on the premise that saturated hydraulic conductivities of soils under all of the existing and proposed disposal units are similar to the values assumed in the analyses described above." This final sentence indicates that even Rogers and Associates realize that no accurate conclusions can be drawn without site-specific data. The study by Rogers and Associates was not conducted on the subject property.

P. 6-12 and 6-13, Sec. 6.3 - See earlier comments related to surface drainage, erosion, slope stability, settlement, and subsidence.

P. 6-13, Sec. 6.3.3 - Neither sections 5.1.2, 6.3.3, or Appendix L discuss the potential for settlement and/or subsidence caused by dynamic loading during a design-basis seismic event; only settlement due to compression and consolidation of the reworked Vitro tailings and undisturbed foundation soils due to the placement of the tailings embankment was analyzed. This is insufficient to analyze the long-term stability of the embankment.

Of more significance, though, is the application of any analysis in Appendix L to the potential for settlement and cover cracking at the Envirocare embankment. Appendix L was conducted for the Vitro embankment; material properties for Vitro tailings may be significantly different from waste in the Envirocare project. To say, as in the cover sheet for Appendix L, that ".....Envirocare Embankment is exactly the same as the Vitro Embankment as far as all data is concerned in these calculations" is not true.

CHAPTER 8:

P. 8-8 through 8-12, Sec. 8.2, and table on p. 8-7 - The organizational structure of the applicant seems overly vague as it relates to QA, and is not responsive to NRC requirements. Of particular concern is that, from the table on p.8-7, there does not appear to be consistent and sufficient separation between the reporting responsibility and authority of the functional areas of radiation protection, QA, and training and the site operations. This separation is essential to ensure independence from operating pressures. See comments below for Chapter 9.

CHAPTER 9:

General Comment - There is no procedure stated for design verification activities (design review, alternate calculations, or testing) or other design controls. This is a crucial element of a QA program (NUREG 1200, p.9.1-14, sec. 5.4).

P. 9-2, Sec. 9.1.1 and 9.1.2 - Section 9.1.1 says that the Project Engineer is in charge of all QA, Section 9.1.2 says that the Engineer's Assistant coordinates all quality assurance and quality control activities, but the table on p.8-7 says that the Project Manager is responsible for QA; this is confusing and indicates a lack of independence. Actually, what the applicant describes here and on following pages is the organization which will <u>conduct</u> quality-related activities. This does not cover, however, a QA organization which will have an independent managerial position and staff to <u>oversee and audit</u> quality-related activities. The person responsible for QA must have no other duties or responsibilities unrelated to QA that would divert his/her full attention from QA matters (NUREG 1200, p.9.1-8, Sec. 2.1d).

P. 9-3, Sec. 9.1.4 - To whom will this outside QA auditor be responsible to within Envirocare - the Project Manager, Project Engineer, Engineer's Assistant, or a QA Manager? This answer is finally provided on p.9-22 - the President of Envirocare - but should be included in Sec. 9.1.4 also.

P. 9-22 through 9-25, Sec. 9.7 - This section is titled "Radiological Quality Assurance Audits" and sounds as though the QA audits are only for radiological aspects of the project. This should not be so. All quality related items must be independently audited, including design, engineering, procurement, manufacturing, construction, inspection, testing, instrumentation, and control. The purpose of an audit is to verify compliance with <u>all</u> aspects of the QA program, not just radiological aspects.

Project:			Requesting Agency:
Review of a Portion of R447-25 of the Utah Administrative Code, License Requirements for Land Disposal of Radioactive Waste-General Provisions			Utah Division of Environmental Health, Bureau of Radiation Control
By: Barry J. Solomon	Date: 12-03-90	County: Statewide	Job No.: (R-4) 90-15
USGS Quadrangle:			

In response to a request from Larry Anderson, Director, Bureau of Radiation Control, a review was conducted of the siting criteria contained within R447-25 of the Utah Administrative Code, "License Requirements for Land Disposal of Radioactive Waste-General Provisions." The review concentrated upon geotechnical aspects of the siting criteria. Specific comments on sections of the provisions are given below:

1) As currently written, R447-25-3C.1.e. addresses some possible causes of subsidence, but has significant omissions. This item should also refer to facilities located "within areas underlain by," rather than simply "within," underground mines, salt domes, and salt beds. Expand the definition of this section to include location of facilities within other subsidence- and collapse-prone areas: (1) areas subject to the lowering or collapse of the land surface either locally or regionally, such as areas of extensive withdrawal of water, gas, or oil; (2) areas underlain by weak and unstable soils, such as soils that lose their ability to support foundations as a result of hydrocompaction, expansion, or shrinkage; and (3) karst terrains, which are areas where solution cavities and caverns develop in limestone, gypsum, or dolomitic materials. This section, however, should not place a blanket prohibition upon siting within subsidence- or collapse-prone areas. Rather, siting and design studies should be required to demonstrate the structural stability of proposed facilities. Engineering measures may be incorporated into the design of units to mitigate potential adverse impacts on facilities that may result from destabilizing events. The recommended requirement should read, "Treatment and land disposal facilities may not be located within the following areas, unless adverse impacts can reasonably be mitigated: a. areas underlain by underground mines, salt domes, and salt beds; b. areas subject to subsidence or collapse due to fluid withdrawal; c. areas underlain by weak and unstable soils; d. karst terrains."

2) Modify the wording of R447-25-3C.1.g. to reflect a more flexible attitude, as noted above, toward siting within areas susceptible to mass movement. The recommended requirement should read, "Treatment and land disposal facilities may not be located within areas likely to be impacted by landslide, mud flow, or other earth movement, unless adverse impacts can reasonably be mitigated."

3) Add to R447-25-3C.1. an item prohibiting the location of a facility in an area where natural resources, if exploited, may result in inadvertent intrusion into the disposal site after removal of active institutional control. The siting criteria must

also prohibit location of facilities in areas where the exploitation of natural resources during construction, operation, and closure, or after closure, will compromise the site. The recommended requirement should read, "Treatment and disposal facilities may not be located within areas where the exploitation of natural resources will result in inadvertent intrusion into the site, or will compromise the site integrity."

4) Add to R447-25-3C.1. an item prohibiting the location of a facility in an area where Holocene volcanic activity has occurred. Volcanic activity has occurred in southwestern Utah as recently as 600 years ago and, if volcanism were to be renewed there, nearby disposal sites might not meet their performance objectives during operational and post-closure periods. The recommended requirement should read, "Treatment and land disposal facilities may not be located within areas where Holocene volcanic activity has occurred."

5) Insert, before R447-25-3D, a requirement that facilities, including liners, leachate collection systems, and surface water control systems, be built to resist an appropriate level of earthquake-induced horizontal acceleration at the site. For this type of facility, such a level should be at least the acceleration with a 90-percent probability of nonexceedence in 250 years. This is the level proposed by the U.S. Environmental Protection Agency for Municipal Solid Waste Landfills. Whereas R447-25-3.C.1.d. protects against damage and loss of life in earthquakes as the result of surface displacement along faults, it does not address the potential effects of ground shaking, or of secondary effects of the shaking such as ground or facility failure. Types of failure that may result from ground motion are: (1) damage to structures and contents directly from ground shaking; and (2) failure of unit components due to soil liquefaction, liquefaction-induced settlement and landsliding, and soil slope failure in foundations and embankments. By minimizing the risk of failure, the potential for exposure of radioactive waste to the atmosphere will be reduced, as will the possible contamination of runoff and ground water. The recommended requirement should read, "Treatment and land disposal facilities must be designed to resist the earthquake-induced horizontal acceleration with a 90-percent probability of not being exceeded at the site in 250 years."

6) Sumner Newman and Bob Lowe of the Bureau of Drinking Water and Sanitation are developing new Wellhead Protection Program regulations. Check with them to assure compliance of R447-25-3E and F with new or proposed regulations.

Project:			Requesting Agency:
Review of comment responses to Notice of Deficiency #5, Radioactive Materials License Amendment #UT 2300249, Envirocare of Utah, Inc.			Utah Division of Environmental Health, Bureau of Radiation Control
By: Barry J. Solomon	Date: 12-13-90	County: Tooele	Job No.: (R-5) 90-16
USGS Quadrangle: Aragonite (1222)			

The license amendment is to permit the disposal of additional types of low-level radioactive waste adjacent to the South Clive site, Utah. This review is only of comment responses in Notice of Deficiency #5 which discuss the geology and seismology of the proposed project. The initial review of the License Amendment was completed on November 16, 1990, and appears as UGMS Technical Report No. 90-14. Review comments assume incorporation of satisfactory responses into the final license amendment, which must still be reviewed.

General Comments

UGMS-1. Appendix Y does contribute additional site-specific information that was not included with the original license amendment. Specifically, a log for well GW-2 on the east edge of the RCRA landfill cell is present. I also requested, and received from Envirocare, well logs for two more holes (I-3 and III-1, fig. 8, App. Y) drilled near the perimeter of the RCRA landfill cell; data from these wells were used by Dr. T. L. Youd in Appendix DD. These data, however, are still insufficient to answer site-specific questions on liquefaction, settlement, and compaction (see specific responses, below). Envirocare has advised me that from 3 to 5 additional wells will be drilled in 1991, and data from these wells should be sufficient to answer relevant questions. Envirocare must pay close attention, though, to quality control. Careful characterization of samples, sampling techniques, and test methods is required for accurate interpretations. As Dr. Youd has indicated in Appendix DD of the comment response document, careful QC might have resulted in a more satisfactory estimation of the potential for liquefaction and settlement.

UGMS-2 Envirocare's response is satisfactory.

UGMS-3 Envirocare's response is satisfactory.

UGMS-4 Envirocare's response is satisfactory.

Specific Comments

CHAPTER 1:

UGMS-5 Envirocare's response is satisfactory.

UGMS-6 Envirocare's response is satisfactory.

CHAPTER 2:

UGMS-7 Envirocare's response is satisfactory.

UGMS-8 Envirocare's response is satisfactory.

UGMS-9 Envirocare's response is satisfactory.

UGMS-10 Envirocare's response is satisfactory, with the following exceptions:

1) Appendix CC of the comment response document states that there will be no infiltration into the embankment only if a flexible membrane liner is used above the radon barrier. If the Bureau of Water Pollution Control concurs with the conclusions of Appendix CC, and if such a liner is used, then the presence of the White Marl and oolitic sands is not of concern in regard to interaction between leachate and soil. However, the possibility of dissolution of carbonate in foundation soils by ground water has not been explored, and remains a potential cause of subsidence beneath the site; and

2) Whereas Dr. Youd states in Appendix DD that "Liquefaction at the substantial depths indicated would not likely cause an instability problem for an embankment constructed on the site," he adds several caveats. Significant among them are the potential for a rise in ground-water levels to saturate sands at shallow depths, and the lack of quality control which may have introduced error into the estimation of liquefaction potential. If the Bureau of Water Pollution Control determines that there is no significant potential for a rise in the ground water to the level of shallower sands, I will conclude that liquefaction at shallower depths is of no concern. The lack of QC can be remedied by implementing proper procedures during the drilling of additional holes in 1991. With proper QC procedures, data generated from these additional site-specific holes should be sufficient to accurately determine the liquefaction potential of the site.

UGMS-11 Envirocare's response regarding the list of historical earthquakes is satisfactory.

I have also reconsidered my comment regarding "floating earthquakes" and associated ground accelerations. Figure 4.10, Appendix K, of the License Amendment does take into consideration the impact of floating earthquakes in the region of the site. The value of 0.37 g originally used by Envirocare as the design acceleration falls within the range of probabilistic values with a 10% exceedance probability for a 250-year exposure period (a return period of 2,373 years) calculated for a point locality at the center of the proposed supercollider site (which is equivalent to the Envirocare point locality). The calculations in Appendix BB (which uses a design acceleration of 0.37 g) are, therefore, sufficient to indicate stability of the embankment. Section F of Appendix BB, however, states that for several design scenarios the factor of safety falls below a value of 1.0, which is inadequate. By reducing the design acceleration, the factor of safety is elevated above 1.0, but there is no justification to reduce the design acceleration. The only design scenarios in Appendix BB under which the proposed containment structure will be stable incorporate a textured synthetic membrane in slope armor applications. If the applicant intends to use such a feature, it should be specifically stated so.

Dr. Youd, in Appendix DD, has estimated horizontal ground acceleration at the site due to a floating earthquake to be 0.5 g, significantly higher than the value used in Appendix BB for calculation of slope stability. This (0.5 g), however, is a deterministic acceleration which is the maximum expected value not considering its probability of occurrence. As noted above, the appropriate probabilistic value is less (0.37 g), and is more appropriate to the facility considering the expected duration of operational and post-closure monitoring periods. Appendix DD, therefore, overestimates the liquefaction potential. This is a moot point, however, since Dr. Youd concludes (and I concur) that "Liquefaction at the substantial depths indicated would not likely cause an instability problem for an embankment constructed on the site." Of more importance, though, are other questions that Dr. Youd raised regarding quality control and ground-water levels (see the responses for UGMS-10 and -34). Moreover, more site-specific information is still needed. The applicant must prove that shallow, saturated, liquefiable sands do not occur on the site to be developed, and that shallow, potentially liquefiable unsaturated sands are unlikely to be saturated by a rise in the ground-water level; this cannot be done without data from the south and west edge of the site. These questions may more properly be addressed during Envirocare's proposed 1991 field program.

UGMS-12 Envirocare's response is satisfactory.

UGMS-13 Envirocare's response is satisfactory.

UGMS-14 Envirocare's response is satisfactory.

UGMS-15 Envirocare's response is satisfactory.

UGMS-16 Envirocare's response is satisfactory.

UGMS-17 Appendix AA of the comment response document contains monitoring data from Vitro, but is relevant only to the problem of short-term settlement, and is not site-specific. Appendix L of the License Amendment only deals with settlement due to compaction caused by overlying material. The appropriate site-specific data can be collected during the proposed 1991 field program, and should be applied to the determination of settlement potential as a result of the design-basis seismic event.

UGMS-18 Envirocare's response is satisfactory.

UGMS-19 Envirocare's response is satisfactory.

UGMS-20 Envirocare's response is satisfactory.

UGMS-21 Site-specific soil profiles may be constructed following the drilling of boreholes proposed by Envirocare for 1991. These profiles are necessary to establish the continuity, or lack of continuity, of strata and associated properties beneath the site.

UGMS-22 No response was given by the applicant. Appropriate QA and QC procedures should be stated in the License Amendment and careful procedures should be implemented prior to the start of field work in 1991 to prevent questions such as arose in Appendix DD (see UGMS-1 above).

UGMS-23 The response refers to an additional section (Physical and Chemical Properties of Soils), but this was not attached. Even if there will be no infiltration into the embankment, chemical characterization of foundation soils still must be undertaken to determine if soluble minerals within the soil will interact with ground water beneath the site to cause settlement. The potential for a rise in the ground-water level should be taken into consideration.

UGMS-24 Envirocare's response is satisfactory.

UGMS-25 Soil chemistry should be studied even in the absence of leachate to determine the potential for settlement of foundation soils due to interaction between soluble minerals and ground water (see UGMS-23).

UGMS-26 No response was given by the applicant. A response is required to insure accurate data collection and analysis (see UGMS-1).

UGMS-27 Envirocare's response is satisfactory.

UGMS-28 Envirocare's response is satisfactory.

UGMS-29 Envirocare's response is satisfactory.

UGMS-30 Envirocare's response is satisfactory.

UGMS-31 Envirocare's response is satisfactory.

CHAPTER 3:

UGMS-32 Envirocare's response is satisfactory.

UGMS-33 Envirocare's response is satisfactory.

UGMS-34 Neither Table 3.1 nor Envirocare's Hydrogeologic Study (Appendix CC) show ground-water elevations for the period from February, 1984 through September, 1989. These data could be important to estimate the potential rise in ground-water levels and the resultant effects upon liquefaction potential and soil-ground water interactions. The applicant must postulate, and justify, the potential for a rise in the ground-water level.

CHAPTER 4:

UGMS-35 Envirocare's response is satisfactory.

UGMS-36 Envirocare's response is satisfactory.

UGMS-37 Envirocare's response is satisfactory.

UGMS-38 Envirocare's response is satisfactory.

UGMS-39 Envirocare's response is satisfactory.

CHAPTER 5:

UGMS-40 See the response for comment UGMS-34.

UGMS-41 Envirocare's response is satisfactory.

UGMS-42 Envirocare's response is satisfactory.

CHAPTER 6:

UGMS-43 No response was given by the applicant, however I have reconsidered the question and no longer think it relevant to siting. The potential impact on transient population is not mentioned in NUREG-1200.

UGMS-44 Appendix CC indicates that there will be no infiltration into the embankment only if a flexible membrane liner is used. If such a conclusion is confirmed by the Bureau of Water Pollution Control, and if this design is used in the facility, then Envirocare's response is satisfactory.

UGMS-45 See earlier comments on slope stability, settlement, and subsidence (UGMS-1, 10, 11, 17, 23, and 25).

UGMS-46 Appendix DD (not BB) concludes that settlement in foundation soils due to a design-basis seismic event will be from 0.9 to 1.1 ft. This is a significant amount, and does not even take into account settlement of disposal material due to seismic loading (Appendix L calculates settlement under static conditions only). This amount, though, may be overestimated because of the design acceleration used (see UGMS-11, above). Dr. Youd indicates the possibility that rigorous QC procedures applied to sample collection and analysis could reduce the uncertainty of his analysis; such results could even be more favorable to the applicant. Because the applicant will be conducting a field program in 1991, the settlement analysis should be repeated with site-specific data collected under more stringent QC procedures. A value of 0.37 g should be used in the new analysis (see comment UGMS-11), and seismic loading should be applied to both the foundation soils and disposal material.

Also, I am still not convinced of the applicability of a settlement study conducted on Vitro disposal material to the Envirocare disposal material. The applicant should document the similarity of physical characteristics between the two materials.

CHAPTER 8:

UGMS-47 Envirocare's response is satisfactory.

CHAPTER 9:

UGMS-48 The fact that the conclusions of Appendix DD were qualified with reference made to the need for careful quality control in future activities, indicates that past QC efforts were not adequate. The applicant should improve upon such efforts for the upcoming field work.

UGMS-49 Envirocare's response is satisfactory.

UGMS-50 Envirocare's response is satisfactory.

UGMS-51 Envirocare's response is satisfactory.

Project:			Requesting Agency:
Safety Evaluation Report for Radioactive Materials License Amendment #UT 2300249, Envirocare of Utah, Inc.			Utah Division of Environmental Health, Bureau of Radiation Control
By: Barry J. Solomon	Date: 1-10-91	County: Tooele	Job No.: (R-6) 91-01
USGS Quadrangle: Aragonite (1222)			

This report provides input to be included in the Safety Evaluation Report (SER) for the proposed Envirocare facility. The SER will be compiled by the Utah Bureau of Radiation Control (UBRC). The evaluation findings in this input are based upon a review of only the geotechnical portions of the subject license amendment (LA), as well as responses made by the applicant to questions raised in reviews of the geotechnical portions. The license amendment was submitted to the UBRC on April 24, 1989, and was transmitted to the Utah Geological and Mineral Survey (UGMS) for review on October 9, 1990; the initial review of the geotechnical portions of the LA was submitted to the UBRC on November 16, 1990 (UGMS Technical Report No. 90-14); review comment responses were provided on December 11, 1990 (Envirocare response to UBRC Notice of Deficiency #5); comments on the Envirocare response were provided on December 13, 1990 (UGMS Technical Report No. 90-16); and responses to the second round of comments were provided on December 21, 1990 (Envirocare response to second round of UBRC Notice of Deficiency #5). Questions on the second round responses were transmitted by phone conversation to Envirocare on January 4, 1991, and final satisfactory responses were issued by Envirocare on January 10, 1991.

The evaluation findings contained herein apply only to the eastern portion of the facility originally proposed in the LA, and do not apply to the remainder of the facility as originally proposed, or to any future modifications which may be suggested. The eastern portion of the facility is depicted in fig. 5 (p. 9) of Appendix Y, which was submitted by Envirocare in their December 11 response to Notice of Deficiency #5. This portion of the facility is labeled the RCRA Landfill Cell in Appendix Y.

The detailed evaluation findings which appear below are grouped according to the LA chapter to which they apply. The evaluation was conducted according to the Standard Review Plans (SRP) contained within NUREG-1200 (U.S. Nuclear Regulatory Commission, 1988, Standard review plan for the review of a license application for a low-level radioactive waste disposal facility). The findings are based upon content and format requirements of NUREG-1199 (U.S. Nuclear Regulatory Commission, 1987, Standard format and content of a license application for a low-level radioactive waste disposal facility) and of Chapter R447-25 of the Utah Administrative Code (License Requirements for Land Disposal of Radioactive Waste). It is the finding of this evaluation that the applicant has followed applicable guidelines contained within NUREG-1199 and conforms to geotechnical requirements contained within R447-25.

Evaluation Findings
Chapter 1 - General Information

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

Chapter 2 - Site Characteristics
Section 2.3 - Geology and Seismology
Section 2.3.1 - Geological Site Characterization

The geologic site characterization for the Envirocare low-level waste disposal facility has been reviewed according to SRP 2.3.1. The geology and seismology of the proposed site have been adequately characterized, modeled, and analyzed to ensure that the long-term performance objectives of R447-25-19 through 22 are met as required in R447-25-23(1)(a). The tectonic and geologic processes and seismic activity do not occur with such frequency and to such an extent that they significantly affect the ability of the disposal site to meet R447-25-19 through 22 as required in R447-25-23(1)(h) and (i).

Section 2.3.2 - Seismic Investigation

The information on the seismic investigation for the Envirocare low-level waste disposal facility has been reviewed according to SRP 2.3.2. As a result of this review, the following conclusions are reached:

(1) The seismologic information provided by the applicant is adequate, and no capable faults exist at the site that would adversely affect the safety of the site.

(2) The design-basis earthquake is adequately defined, and the potential for amplification is addressed.

(3) Adequate geophysical investigations have been carried out to characterize the site.

The applicant has met performance objectives in R447-25-19 through 22 and the technical requirements for land disposal facilities in R447-25-23(1)(h) and (i).

Section 2.5 - Geotechnical Characteristics

The geotechnical characteristics of the Envirocare low-level waste disposal facility have been reviewed according to SRP 2.5. The objectives of the review were to ensure that: (1) the scope of the geotechnical and geophysical field investigations and laboratory and field testing are adequate; (2) the interpretations of the data to develop typical soil layering, typical cross-sections, and design parameters used in the design are reasonable and conservative; and (3) the geotechnical characterization of the site meets the guidance and acceptance criteria in SRP 2.5.

The following information was determined during this review:

(1) The geologic characterization of the site addresses the potential for surface or subsurface subsidence at the site, the instability of soil because of mineralogy, and the history of deposition and erosion of soil deposits.

(2) The design-basis seismic event is adequately defined by parameters such as magnitude and acceleration.

(3) The geotechnical and geophysical investigations conducted to characterize the site and borrow materials are adequate in scope.

(4) The static and dynamic engineering properties of various materials used in the analysis and design of the facility are based on adequate field and laboratory testing and a reasonable and conservative interpretation of the test data.

(5) The ground-water conditions such as the position of the ground-water table, the extent of its fluctuation, and the presence of artesian conditions have been defined on the basis of adequate investigation.

(6) The selection of the properties of fill borrow material was based on an adequate exploration and testing program.

(7) Site stratigraphy and design parameters used in the design are a reasonable and conservative interpretation of the data.

The geotechnical site characterizations in the LA provide the basic data needed to determine if the disposal facility meets the performance objectives stipulated in the regulations, thereby satisfying the requirements of R447-25-7(1), R447-25-11(6), and R447-25-23(1).

<u>Section 2.7 - Natural Resources</u>
<u>Section 2.7.1 - Geologic Resources</u>

The information on known geologic resources near the Envirocare low-level waste disposal facility has been reviewed according to SRP 2.7.1. The applicant has correctly and adequately identified known occurrences of sand and gravel near the proposed waste disposal facility. The applicant has shown that the deposits are at a location so that future exploitation of those deposits is unlikely and will not result in the failure of the proposed facility's performance objectives under R447-25-19 through 22 as required in R447-25-23(1)(c). No other known geologic resources occur in the proposed disposal area or region and attempts at future resource exploitation are unlikely.

<u>Chapter 3 - Design and Construction</u>

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

Chapter 4 - Facility Operations

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

Chapter 5 - Site Closure and Institutional Controls
Section 5.1 - Site Stabilization
Section 5.1.2 - Geotechnical Stability

The geotechnical stability aspects of the proposed site closure plan for the Envirocare low-level waste disposal facility have been reviewed according to SRP 5.1.2. The objectives of the review were to ensure that: (1) the overall site grading plan provides for adequate cover on all the disposal unit excavation caps and for appropriate grading to direct the flow of surface water away from the excavations, taking into consideration the anticipated long-term settlement and/or subsidence at the site; (2) all the natural and artificial slopes of dikes and ditches at the disposal site will be stable in the long term and the disposal site will require minimal care and maintenance during the institutional control period; (3) the monitoring programs to evaluate the performance of the disposal excavations are adequate in scope so that the needed data can be collected; and (4) the applicant has committed to use all the data collected during the operational phase of the facility to revise and/or improve the final site closure plan that will be submitted before site closure.

The information in the LA has been reviewed to determine if:

(1) The applicant has adequately described how the excavation will be backfilled, how the excavation cap will be constructed, and how the performance of the excavation will be monitored.

(2) The applicant has committed to analyze the monitoring program data, either to validate the predicted performance of the excavation cap or to change, if necessary, the design and/or construction procedures to enhance the performance of the backfill and cap.

(3) The applicant's proposal for final grading of the site provides for a cover of adequate thickness on all excavations and appropriate grading to direct the flow of surface water away from the excavations.

(4) All artificial and natural slopes of the dikes and ditches within the disposal site will be stable in the long term.

(5) The long-term monitoring program to evaluate the performance of the geotechnical aspects of the disposal site is adequate in scope and presented in appropriate detail.

(6) The applicant has committed to use the data and experience gained during the operational phase and to revise and/or improve the site closure plan that will be submitted for review during the final stage of the operational phase.

The information on the geotechnical stability aspects of the site closure plan in the LA is adequate to satisfy the objectives of this review. On the basis of information provided for this review, there is reasonable assurance that the disposal facility, if closed according to the site closure plan, will satisfy the long-term performance objectives of R447-25-7(7), R447-25-11(6), R447-25-22, and R447-25-25(1)(j).

The geotechnical stability aspects of the site closure plan in the LA meet all applicable regulations and are acceptable.

Chapter 6 - Safety Assessment
Section 6.3 - Long-Term Stability
Section 6.3.2 - Stability of Slopes

The long-term stability of the slopes at the Envirocare low-level waste disposal facility has been reviewed according to SRP 6.3.2. The objectives of the review were to ensure that: (1) critical slopes at the disposal site have been identified for evaluation, (2) the information on the geotechnical characterization of the slope area and borrow material is adequate, (3) slope characteristics have been described in appropriate detail, (4) the design and analysis of slope stability were presented in appropriate detail, (5) there are provisions for quality control during construction, and (6) information in the LA meets SRP 6.3.2.

The information in the LA has been reviewed to determine if:

(1) The applicant has identified both engineered and natural slopes at, or in, the general vicinity of the disposal facility that should satisfy the long-term stability requirement of the regulations.

(2) The information in Section 2.5 is adequate to enable the reviewer to independently judge the applicant's interpretation of the stratigraphy and design parameters used in the slope stability analyses.

(3) The applicant's description of the slope characteristics, cross-sections, the soil and foundation conditions at the slope, the summary and description of both the static and dynamic properties of the soil, and the phreatic surface and seepage forces used in the analysis are a reasonable and conservative interpretation of the available data.

(4) In the static and dynamic analyses performed by the applicant, reasonable and conservative design assumptions were used and uncertainties were considered with regard to the shape of the slope, the boundaries of several types of soil within the slope, forces acting on the slope, pore-water pressure within

the slope, failure surface corresponding to the lowest factor of safety, the effect of assumptions inherent in the method of analyses, and adverse environmental conditions.

(5) The applicant has definite plans for applicable quality control actions pertaining to both the selection and excavation of borrow materials and the compaction phase of earthwork.

The information on both short-term and long-term slope stability in the LA is adequate to satisfy the objectives of this review. On the basis of data and analyses provided for this review, the applicant has proven that the factors of safety against short-term and long-term failure of engineered slopes and natural slopes at the site are greater than the acceptable minimum of 1.30 for short-term and 1.50 for long-term static stability and greater than 1.0 for dynamic stability for both cases. Therefore, there is reasonable assurance that the slopes at the disposal facility are stable in the long term and that the slope stability requirements of R447-25-8(4), R447-25-11(6), R447-25-22, R447-25-23(1)(i), R447-25-24(1)(a), and R447-25-24(1)(b) are met.

On the basis of this review, it has been determined that the long-term slope stability aspects of the LA meet all the requirements of the applicable regulations.

<u>Section 6.3.3 - Settlement and Subsidence</u>

The long-term settlement and/or subsidence aspects for the Envirocare low-level waste disposal facility were reviewed according to SRP 6.3.3. The objective of the review was to ensure that: (1) information on the site characteristics, construction of the facility, waste disposal operations, and disposal excavation caps is adequate; (2) the areas that are potentially susceptible to long-term settlement have been identified and their modeling (characterization of the problem) is reasonable and conservative; (3) the uncertainties have been considered and addressed appropriately in the settlement analyses; (4) the applicant has committed to perform remedial actions if long-term settlement should be a potential problem; and (5) the information presented meets the guidance and acceptance criteria in SRP 6.3.3.

The information in the LA has been reviewed to determine if:

(1) The information on site characteristics, the excavation and backfilling of disposal excavations during the operations phase, and disposal excavation cap design and construction was adequate to justify the applicant's interpretation of stratigraphy, the typical section of disposal excavations, and the parameters used in the settlement analyses.

(2) Both the general areas within the disposal site and the excavation cover areas that are potentially susceptible to long-term settlement are identified, and the applicant's description of the typical sections, the long-term condition

of the backfill and buried waste within the excavation, the parameters used in estimating the settlement, and the assumptions on ground-water conditions were a reasonable and conservative interpretation of the available data.

(3) The uncertainties such as severe events or conditions resulting in settlement, the extent and boundaries of the various materials within the sections being analyzed, and the effect of assumptions inherent in the method of analysis were considered by the applicant in the settlement analyses.

(4) The applicant had provided definite proposals for remedial actions if excessive settlement and/or settlement-induced cracks should occur in the disposal excavation cover, and evaluated the scope and feasibility of such proposals.

The information on long-term settlement and its safety implications is adequate to satisfy the objectives of this review. On the basis of the review of information provided by the applicant and the commitment for remedial action during the operational phase and initial 5 years or longer, if necessary, of the institutional control phase, the applicant has satisfactorily demonstrated that the potential for long-term settlement and/or cracking of the disposal excavation cover is minimal and thereby the settlement and/or subsidence aspects of R447-25-8(4), R447-25-11(6), R447-25-22, R447-25-24(1)(a), and R447-25-24(1)(b) are satisfied.

On the basis of this review it has been determined that the adverse effect of long-term settlement and/or subsidence on the performance of the disposal facility is minimal. The information on the settlement and/or subsidence aspects meets all the applicable regulations, contingent on the commitment by the applicant to perform remedial actions, if necessary, to mitigate the adverse effects of settlement and/or subsidence on the performance of the disposal facility.

<u>Chapter 7 - Occupational Radiation Protection</u>

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

<u>Chapter 8 - Conduct of Operations</u>

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

<u>Chapter 9 - Quality Assurance</u>

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

<u>Chapter 10 - Trust Agreement</u>

The emphasis of this chapter is not geotechnical. No evaluation findings are provided.

Project: Review of Schick International's geologic hazards investigation for Peterson Pipeline Associations water storage tank and pipeline, Morgan County, Utah			Requesting Agency: Mr. R. Stephen Young, Morgan County Planner/ Building Inspector
By: W.E. Mulvey	Date: 6-21-91	County: Morgan County	Job No.: (R-7) 91-09
USGS Quadrangle: Peterson (1319)			

At the request of Mr. R. Stephen Young, Morgan County Planner and Building Inspector, the Utah Geological Survey reviewed the Schick International geologic hazards report for the Peterson Pipeline Association's proposed water storage tank and pipeline. The tank and pipeline are located south of the town of Peterson in sec. 6, T. 4 N., R. 2 E., Salt Lake Baseline and Meridian, in Morgan County.

The Schick International report adequately discusses all potential geologic hazards at the site (faulting, earthquake-ground shaking, landslides, ground-water and foundation conditions), and can be used as a planning document for design of structures, with the following comments.

The ground-shaking value listed in the report (0.2 g) is incorrect for both zone 3 and 4. Design requirements for ground-shaking must be corrected to comply with the UBC seismic zone used; if zone 3 is used, the value is 0.3 g, if zone 4 is used, the value is 0.4 g. The soil foundation report should address problems associated with grading, trenching, and road construction which may increase the potential for damage from landsliding and expansive clays.

GROUND SHAKING

The ground-shaking value (0.2 g) listed in the report for UBC seismic zone 4 is incorrect. Values for zones 3 and 4 are 0.3 g and 0.4 g respectively (S.S. Olig, Utah Geological Survey, oral commun., June, 1991). We agree that the tank should be designed to UBC seismic zone 3 specifications at a minimum, and the correct information should be conveyed to the project engineer for incorporation into design specifications.

LANDSLIDING

Landslides are common in the Norwood Tuff and Lake Bonneville deposits in Morgan Valley and the surrounding region (Sullivan and others, 1986). The Schick International report recognizes this, and states that most slides in the vicinity of the tank are surficial, occurring in interbedded sands and clays in Lake Bonneville deposits, and will not affect the site. This is probably a correct assessment of the landslide potential in the area of the tank and pipeline under present conditions. However, when grading the site and building access roads for use during and after construction, proper drainage must be maintained to prevent ponding, saturation of sediments, and possible landslides.

EXPANSIVE SOIL AND ROCK

Weathered Norwood Tuff contains expansive clays that have severely damaged structures in the town of Mountain Green in Morgan Valley (Mulvey, in press). Clays in Lake Bonneville deposits at the water-tank site and through which the pipeline passes are most likely derived from the Norwood Tuff. In areas where wetting and drying of the clays can take place, such as the seep adjacent to the Gateway Canal, these clays could damage the pipeline. The soil foundation report for the project should consider expansive clays, and if found, recommend measures to mitigate their potential for damage.

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

APPENDIX

1990-1991 Publications of the Applied Program

Bulletin

Lund, W.R., editor, with contributions by W.F. Case, Suzanne Hecker, K.M. Harty, W.R. Lund, R.H. Klauk, H.E. Gill, W.E. Mulvey, B.D. Black, G.E. Christenson, C.V. Nelson, D.A. Sprinkel, J.W. Gwynn, B.T. Tripp, Genevieve Atwood and D.R. Mabey, 1990, Engineering geology of the Salt Lake City metropolitan area, Utah: Utah Geological and Mineral Survey Bulletin 126, 66 p.

Maps

Harty, K.M., 1991, Landslide map of Utah: Utah Geological and Mineral Survey Map 133, 28 p., 2 sheets, scale 1:500,000.

Special Studies

Lund, W.R., Schwartz, D.P., Mulvey, W.E., Budding, K.E., and Black, B.D., 1991, Fault behavior and earthquake recurrence on the Provo segment of the Wasatch fault zone at Mapleton, Utah County, Utah (Volume 1, Paleoseismology of Utah): Utah Geological and Mineral Survey Special Studies 75, 41 p.

Mulvey, W.E., and Lund, W.R., 1990, Geologic evaluation of wastewater disposal in rock, Duchesne County, Utah: Utah Geological and Mineral Survey Special Studies 72, 21 p., 3 pl., scale 1:100,000.

Solomon, B.J., and Klauk, R.H., 1989, Regional assessment of geologic conditions for sanitary landfills in Sevier County, Utah: Utah Geological and Mineral Survey Special Studies 71, 15 p., 4 pl.

Circular

Sprinkel, D.A., and Solomon, B.J., 1990, Radon hazards in Utah: Utah Geological and Mineral Survey Circular 81, 24 p.

Report of Investigation

Black, B.D., compiler, 1990, Technical reports for 1988-1989, Applied Geology Program: Utah Geological and Mineral Survey Report of Investigation 220, 159 p.

Open-File Reports

Eldredge, S.N., and Mulvey, W.E., 1991, Places with hazards; a teacher's handbook on natural hazards in Utah for secondary earth science classes geologic hazards lecture set--Part C, Problem soil and rock in Utah: Utah Geological Survey Open-File Report 211C, 21 p. Part II - slide set for 211-C; 14 slides, 3 p.

Sprinkel, D.A., and Solomon, B.J., 1991, Places with hazards; a teacher's handbook on natural hazards in Utah for secondary earth science classes geologic hazards lecture set--Part D, The radon hazard in Utah: Utah Geological Survey Open-File Report 211-D, 32 p. Part II - slide set for 211-D; 20 slides, 4 p.

Sprinkel, D.A., and Solomon, B.J., 1990, Utah indoor radon data: Utah Geological and Mineral Survey Open-File Report 175-DF, 1 diskette, 1.2 Meg.

Lowe, Mike, in cooperation with R.M. Robison, C.V. Nelson, G.E. Christenson, 1990, Geologic hazards and land-use planning--Background, explanation, and guidelines for development in Weber County in designated geologic hazards special study areas: Utah Geological Survey Open-File Report 197, 65 p.

Lowe, Mike, in cooperation with R.M. Robison, C.V. Nelson, G.E. Christenson, 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, 63 p.

Survey Notes

Christenson, G.E., 1989, The October 17, 1989 Ms7.1 earthquake near San Francisco: Survey Notes, v. 23, no. 4, p. 9-10.

Christenson, G.E., 1991, Earthquake hazards of Utah: Survey Notes, v. 24, no. 3, p. 3-10.

Christenson, G.E., 1991, Earthquake legislation: Survey Notes, v. 24, no. 3, p. 26.

Harty, K.M., 1989, Landslide mapping, hazards, and historical landslides in Utah: Survey Notes, v. 23, no. 4, p. 2-8.

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Solomon, B.J., 1989, Geology and sanitary landfills in Sevier County, Utah: Survey Notes, v. 23, no. 4, p. 17-18.

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v. 6, no. 3-4
v. 7, no. 1
v. 7, no. 2
v. 7, no. 3