

**WATER-RELATED GEOLOGIC PROBLEMS
OF 1983—UTAH OCCURRENCES BY COUNTY**

by
Bruce N. Kaliser

UTAH GEOLOGICAL AND MINERAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
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WATER-RELATED GEOLOGIC PROBLEMS OF 1983—UTAH OCCURRENCES BY COUNTY

By Bruce N. Kaliser

INTRODUCTION

Twenty-four counties in Utah were surveyed in 1983-84 to compile this summary of known geological events related to the 1983 wet year. It is hoped that this summary and the one by Davis (1989) will provide a data base that is 1) historically useful and 2) may be used in studies designed to mitigate similar occurrences.

Twenty-two of the twenty-four counties were included in the Presidential disaster declaration. One county included in that declaration, Garfield, in southeastern Utah, is omitted because of its inclusion in the report by Davis (1989). The three counties not included in the disaster declaration are Cache in northern Utah, and Iron and Washington counties in southwestern Utah. Under each county the sequence of types of events discussed or listed is as follows:

- (1) slope movements of all types.
- (2) ground-water changes, including elevation of shallow, unconfined water tables.
- (3) erosion and sedimentation effects.
- (4) foundation problems and other phenomena.

Descriptions are necessarily brief when that has been the sum total of information available. No attempt is made to speculate or elaborate upon mechanisms, processes, causes, longer range effects, etc., in this paper. Information that has been collected from all sources is presented. Though only reliable sources have been consulted in this compilation effort, quality of information does vary. No field verification has been done for this paper. Cost figures, too, have been accepted as acquired from other agency files, no independent substantiation having been possible, and reflect 1984 prices.

Beaver County

Landsliding was significant within the boundaries of the Fishlake National Forest: 78 individual slides and 28 landslide complexes were mapped in 1983 by the U.S. Forest Service within the county.

Landslide impact in Beaver Canyon was also significant. The Kent's Lake Road slide, NW¼, Sec. 25, T29S, R6W, occurred in late November of 1983, having crept for a period of weeks prior to failure. Three or four days prior to the failure residents marked 8"-wide cracks with rocks. The slide occupied about 1 acre, with a 10 to 20 foot high headwall scarp and did reach the stream but did not impound water. Engineering costs were estimated at \$13,000. Indirect costs included a 60-mile detour for summer cabin residents and possible cancellation of a \$15,000 timber sale. Near the slide there was a small slump (50' X 50') in May 1983. Other slides along State Highway 153 occurred also in March and April. It appears that there is some evidence that slopes may have begun to move in 1979, with more prominent movement in 1983.

Use of landslide material as fill near the Mahogany Camp-ground resulted in a mudflow onto the road below (1.5' to 2' thick) and into the stream.

High ground water presented problems in the towns of Beaver, Milford and Minersville. In late February ground water was seen to bubble up through asphalt in Milford for several days. East of Milford two or three farms near Five Mile Dam suffered crop loss due to surfacing ground water. Approximately 40 of 600 acres were harvested in 1983. Small ground holes with standing water in them were also reported near town.

Ground water was as shallow as 1' in Minersville where some porches and foundations were reported as having cracked from settlement problems. A coal delivery truck was reported to have sunk 18" while on a delivery in town. Septic tanks were affected by the high water table.

Beaver, which normally experiences a rising water table during the irrigation season, had an aggravated high-water table problem in 1983, with new trouble spots showing up, particularly on bench lands.

In Greenville the high water table prevented installations of a church sewage system in 1983.

River channel effects were noticeable on the Beaver River where coarse sedimentation caused the channel to widen, thereby inundating acreage that was previously dry. In all, some \$300,000 was spent to relieve problems on the Beaver River, from erosion and sedimentation. At Greenville, for example, in Sec. 35 and 36, T29S, R8W, bridge abutments were undermined with wingwalls destroyed, with a 45-foot section of road washed out. Elsewhere, power poles, water lines, penstock and diversion structures were damaged.

In the Escalante Desert, southwest of Milford, the writer has observed what appears to be surface evidence of hydro-compaction having occurred in sandy silt materials on the desert floor. No structures exist in the vicinity.

Box Elder County

Significant damage occurred to the Facer Creek and Willard Creek drainages from debris flows and debris floods. A debris flow on June 9 from Facer Creek covered State Highway 89 and inundated one home, barns, orchards, and farmlands. In addition to removal of debris, there were costs for restoration and enlargements of catch basins and piping to drain channels. Willard Creek required debris and coarse sediment removal from approximately 1,800' of channel which had been completely filled with 300,000 to 400,000 yds³; \$300,000 was spent on problems in these two drainages. Mountain Fuel Supply Corp. also has to provide replacement for its high-pressure natural gas line where it crosses Facer Creek on the benchland at elevation 4,900'. At that location, the channel was easily scoured in Lake Bonneville sediments

by the debris flows of late May 1983. Two small, shallow debris slides on steep slopes on the north side, in Sec. 18, T8N, R1W, caused the debris flows in Facer Creek.

Movement of a very large landslide area on the face of the mountain front south of Facer Creek, some 2/3 mile in length and 1/2 mile in width saw reinitiation of mass movement in the spring of 1983. The jeep trail up the mountain was rendered impassable in early June. One of the individual slides in the broad zone developed clear lateral shears prior to cessation of 1983 movement and demonstrated considerable linear extent. A Special Service District composed of the county and Willard City was created to construct a debris basin at a cost of \$250,000.

The Malad River bluffs in the Bear River City area experienced numerous bank slumps which reached into the river channel. Garland's culinary water line was broken (\$8,000 damage). Below Cutler Dam, the Hammond and West Canals were damaged in both the springs of 1982 and 1983; costs being in the neighborhood of \$150,000.

The lined canal of the Ogden River Water Users Association, east of Willard, suffered considerable damage, as it has historically. Cost to cover or pipe the susceptible stretch of canal has been estimated at \$350,000.

Ground discharges have impacted several communities in the county. The Garland Spring (SW 1/4 Sec. 4, T11N, R2W) overflowed the collection system. Deweyville, only 3,500' southwest of the spring, may have had its ground-water problems aggravated by this spring.

In Brigham City a new spring erupted near the Knob Spring development, resulting in overtopping of the spring box and turning out of all the flow. Another new spring above Beacher Ave. in the northeast portion of the city caused mud to mobilize across private land onto streets and into the storm sewer.

A new ground-water discharge which appeared about May 12, 1983, flooded the collection box for Mantua's spring (Sec. 23, T1W, R9N) with its 3000 gpm flow. The town was placed on a boil order for a week by health authorities concerned over the local situation.

Tremonton claimed water rights to a new spring, South Maple (NW 1/4, Sec. 4, T11N, R2W), spending \$23,000 to improve it for their culinary system.

Rising water tables affected communities and rural areas alike in Box Elder County. Impacted towns included Tremonton, Plymouth, Bear River City, Mantua, Garland, Deweyville, Bothwell, Portage, Brigham City, Honeyville, Harper, Corinne and Riverside.

In the town of Plymouth the problem was particularly severe with basements flooded, incessant pumping required, septic tanks failing and some residents forced to temporarily abandon their homes. The water table rose to within 4' of the surface, with 50 percent of the structures inundated in the town. Damage was estimated from \$150,000 to \$200,000 to homes, streets and a fire station; 29 homes were damaged, 2 evacuated. Drains were designed and installed at a cost of \$115,000.

Brigham City, county seat, had to also install a drain in its southwest portion, Lindsay Park Subdivision, at a cost of \$154,000. Damage occurred there to basement furnishings as well as to foundations of several homes. West of the Intermountain Indian School, the water table rose to within 18" of the surface in mid-May and created a problem for some 15 to 20 homes.

In Garland, the water table, in places, came to within 40' of the surface. Infiltration of the sewage system by ground water was extraordinary, amounting to 80-90 percent. Infiltration was later reduced to 12-18 percent upon improvement of the system at a cost of \$450,000. Prior to the improvement, the wastewater plant capacity had been exceeded. Street deterioration due to high ground water was also believed to be excessive in 1983, with emergency expenditure of \$14,000 required and an estimate of \$800,000 given to restore the entire street system.

Problems were minimal with the rising water table in Portage, and Bothwell had only locally perched conditions. In Harper, perched ground water came to within 18" of the surface, as it did also, locally, in Riverside. In Corinne, however, ponding occurred where the water table is normally 18" to 48" deep, causing basements on 15 to 30 homes to flood and septic tanks to fail. Streets were also affected in Corinne. Deweyville experienced a 15 percent failure rate of the town's individual homeowners' wastewater systems.

Honeyville experienced a perched water table as shallow as 18" to 48" deep, causing basements in 15 to 30 homes flood and part of town, for the first time in history. Some 12 homes had to pump their basements in 1983, none in 1982. The town street system was also impacted as the subgrade softened. \$83,000 was to be spent on a subsurface drainage system. Tremonton experienced significant ground-water infiltration into their sewage system in 1983. Septic tank failures occurred in the town vicinity.

The high water table has reduced yields on farmland in the vicinity of Honeyville, Deweyville, Tremonton, Bear River City, and Corinne, over an area of at least 800 acres. In the immediate vicinity of Honeyville the high water table in 1983 was cause for \$43,000 in agricultural loss claims to the U.S. Department of Agriculture. Applications for aid totaling \$20,000 were received by the USDA from farmers in the vicinity of Tremonton for installation of drain tile. Mantua's west side had aggravated water table problems. Some farms in the vicinity of Bear River City were unable to harvest in 1983 due to the wet conditions in the fields. At the northern town limit, one farmer applied for \$14,000 in USDA aid. Farmers also indicated that county roads west of town were too soft to travel on.

Ditches and settling ponds of the Blue Creek, Fisher Creek and Pine Canyon Irrigation Companies were affected by abnormal sedimentation rates in May and June of 1983. The latter system reported \$1,000 direct (dredging costs) and \$1,000 indirect damage to their system. Also, the North and Middle Canyon Irrigation Company, north of Portage, reported about \$2,000 damage to unlined canals from silting, and the Mantua Irrigation Company about \$500 for a similar problem.

Cache County

Landsliding was not widespread in Cache County in 1982 and 1983 but there were abnormally high numbers of occurrences.

Bordering on Porcupine Reservoir (Sec. 17 and 18, T9N R2E) there has been a large, sloping, valley-fill section sliding into the reservoir, upstream of the right abutment. Movement dimensions of the sliding area are 1/4 by 1/2 mile and the slumping appears to be retrogressive upslope.

In Smithfield (Sec. 17, T13N, R2E) a shallow debris slide bypassed campgrounds and missed the creek but did enter a residential backyard.

A slide along Nibley Road, east of Hyrum (Sec. 2, T10N, R1E) occurred late in the year, on November 4, 1983, and was peculiar for that reason. This 100' by 150' slope failure occurred in the backyard of a home. The deltaic sediments that failed on the steep river bluff surrounded the home. The failure was instantaneous and was clearly the result of extraordinary ground-water pressure adjacent to an old existing spring area in the lower portion of the old river bluff. A heavy concentration of organic material, exposed by the failure, indicated to the writer that the location has been a ground-water discharge point for a considerable period of recent geologic time (likely more than one thousand years). The tighter (less permeable) colluvial material on the slope formed a blanket which failed suddenly from the ground-water pressure. The resulting relatively coarse debris flow did not travel as far as the Blacksmith Fork drainage. A slide and debris flow, however, did enter and momentarily block the Blacksmith Fork River in June of 1983. Its location was in Sec. 9, T10N, R2E.

A slide on College Hill in Logan (Sec. 35, T12N, R1E), below Utah State University campus, with approximate dimensions of 50' by 100' blocked the main concrete-lined Logan and Northern Irrigation Co. canal, causing the canal water to escape, damaging a culinary water line and flooding several residents. Damage was in excess of \$120,000. Indirect costs, from loss of crops, was estimated at \$75,000 to \$100,000. A second slide, about 1 block east of the first, also entered the canal, in December 1983. Historic debris slides in these Bonneville deltaic sediments in this vicinity have been rather common. Perched ground-water horizons are responsible, and failure is instantaneous and results in a debris flow. Heavy foliage on the slopes consume much of the moisture during the growing season.

The road up Millville Canyon, USFS #108, was displaced 4' vertically in a slump about 12' wide and 40' long, in Sec. 29, T11N, R2E. Another slide nearby, only slightly larger, stopped just short of the creek. In Providence Canyon (Sec. 17, T11N, R2E) a debris slide and flow occurred in mid-June. It did not block the creek.

A small slump occurred just to the edge of the road in Logan Canyon (Sec. 24, T14N, R3E). Small slumps occurred on rangeland near Richmond (Sec. 19, T14N, R2E) and a slump into the creek, with no blockage, occurred in 1982 at Red Banks Campground (Sec. 2, T14N, R3E). Also, in 1982 a small slump blocked the road in Sec. 4, T11N, R3E.

Shallow water table problems were aggravated in west Logan, Lewiston, Nibley, and Smithfield. Dry Lake in Sardine Canyon had considerable water in it 1983.

In the Cache National Forest, new springs were reported and road subgrades affected by high ground-water.

Erosion from Summit Creek flood stage on May 30, 1983 caused damage to outlet structures, creek bed and banks, and roads in the amount of about \$52,000.

In North Logan, cloudbursts on August 9 and 11, 1983 destroyed the culinary spring system from Birch Canyon. Damages amounted to \$134,000 plus pumping costs while the deep wells were in service.

Erosion around the main culinary water line at Second Dam in Logan caused \$25,000 damage. The city's DeWitte Spring was contaminated for the first time.

Hyde Park had one water line eroded but not broken. Clarkston, Newton and Trenton experienced washed out water lines.

Spring Creek Water Company had erosion damage to their unlined canals between May 30 and July 19, 1983, doing some \$5,000 damage. The Richmond Irrigation Company experienced diversion damage and flume, lined and unlined canal damage amounting to about \$20,000 along Cherry Creek, north of Richmond. Debris had to be removed from the Logan-Hyde Park, Smithfield Irrigation Company Canal, and canal bank erosion occurred to their unlined system.

Sedimentation of Logan River amounted to about 42,000 yd³ between the mouth of the canyon and Main Street, and 32,300 yd³ between Main Street and 600 West; cost to Logan City was \$110,000 for removal.

Siltation of Johnson Park Water Company pipes from Green Canyon in late August 1983 amounted to \$500 damage. Benson-Bear Lake Irrigation Company experienced sanding of channels also.

Carbon County

USFS Road #50247 along Mud Creek (Sec. 8 and 9, T14S, R7E) was damaged by 3 small landslide-caused debris floods, costing about \$33,000.

A landslide destabilized the ancient landslide that forms the left abutment of the Grassy Trail Dam, in Sec. 7, T14S, R14E. Inspection for the State Office of Dam Safety by the writer concluded that sliding was fortunately not deep seated, was largely in older slide material, and that only the glory hole spillway appeared to be in any jeopardy. The reservoir provides all of the culinary water for Sunnyside and East Carbon cities; both systems were therefore contaminated with the turbid waters. Costs were about \$32,000. Farther down canyon, ground cracks were seen to extend for a distance of approximately one mile on the same (east) side of the canyon.

Water Canyon, north Sunnyside (Sec. 4 and 9, T14S, R14E), experienced two rock slides onto the road.

In Woods Canyon, a landslide entered the stream channel which is tributary to Scofield reservoir, a culinary water source for Price, Helper, Wellington, Spring Glen and Carbonville (15,000 people total). According to a USFS report, the sediment imparted a high phosphate content to the water. Channel clearing costs were about \$2,000.

Eccles Canyon had four slides in Sec. 13 and 14, T13S, R6E which also contributed to the phosphate problem of the Price City municipal water system. The slides also plugged two mine site bypass culverts. Costs determined by the USFS include grass seeding, willow planting and fish habitat rehabilitation, for a total of about \$10,000.

Landsliding affected State Highway 33, north to the Duchesne County line, especially during the April 1983 period when this route served as a detour around Thistle. Multiple slumps from small to large in size threatened the road. A log of activity in mid-April, by the writer, records very wet conditions, 17 active slides in colluvium, 4 in old slides, and 5 in highway fills. Movement was in both disturbed and undisturbed zones in the vicinity of the road and some was only incipient (ground cracks only, with slide patterns). The county road up Nine Mile Canyon, through the Roan Cliffs, was also affected by multiple slumps.

Small landslides, occurring in the Manti-LaSal Forest, impacted the channels of Pontown Creek (4 acres), French Creek (30 acres) and Winter Quarters (32 acres). Bare soil on these three slide areas was to be seeded (total of 20 acres) at a cost of \$540. A slump on Upper Fish Creek, near Scofield Reservoir disturbed the road on May 29, 1983. Near Consumers (Sec. 18, T13S, R8E), a slide on the switchbacks occurred but did not close the road. A rockslide closed the road on August 18, 1983, along the Watis TV installation access road.

A slump bordering on Highway 6 displaced 250' of asphalt paved access road to the Price River Recreation Area (Sec. 16, T12S, R9E) in early May 1983; vertical displacement was 4'. Estimated cost for repair was \$50,000. Another slide area moved in Sec. 21, T12S, R9E, also causing road closure.

Soldier Canyon (Sec. 7, T13S, R12E) had a slump affect 100' of county road in June 1983 and on July 26 and August 17, 1983.

Ground water was not a significant problem in Carbon County. Helper experienced a high water table south of town. Homes on the west side of the highway had to pump basements for the first time. Through June and July 1983 nine pumps were required in one house with 4' of water in the basement. The water table in Wellington was higher than normal but no damage resulted.

Debris and sediment removal and channel work along 14 miles of the Price River, from Castle Gate to Wellington, cost the county about \$325,000 in 1983. The Price River Water Improvement District had 30' of sewer line wash out as a result of slide-caused flooding near Castle Gate; damage amounting to \$4,000. Other sewer line washouts occurred near Standardville and below Carbonville. Culinary water lines required repair above Carbonville, at Carbonville, south of Price, and above Wellington.

The Mancos Shale and its weathering products (i.e., residual soil and colluvium) pose considerable problems when subjected to a change in moisture content. Deteriorating shale above the unlined canal of the Carbonville Ditch Company loaded the canal in March, April, August and September, costing the company about \$5,000. Damage to homes and streets has largely been occurring over recent years in Price but was slightly aggravated in 1983.

Daggett County

Four miles of USFS road #015 (Lodgepole Creek Roads) in Sec. 16, T1N, R18E, near Dutch John, failed by landsliding, costing about \$6,000.

Damage to USFS Road #10096, Browne Lake Road, Sec. 31, T2N, R19E, Dutch John, was the likely result of high ground water. Cost was \$6,600.

Sheep Creek suffered from extensive erosion and sedimentation. The channel shifted in places where structures were affected. Rehabilitation for the Kokanee Salmon, spawning from Flaming Gorge Reservoir, is to be done at a cost of \$12,500. Other costs are about \$7,500 for hand labor on channel banks and blading. No slides were observed in the canyon in 1983; last reported movement was in 1965.

Davis County

Landsliding in the Davis County watersheds was considerable, in excess of 100 individual debris slides having been created in May and June of 1983. A minority of these debris

slides created havoc for several cities in the county as the debris flows and debris floods that resulted entered the urban environment.

The most famous of the events was the debris flow of Rudd Creek Canyon (figure 2), a half creek that had never previously even produced a clear-water flood. This 0.9 mi² drainage yielded approximately 105,000 yds³ of earth deposited over 17.9 acres on the alluvial fan in Farmington City (Davis County seat) (figures 1 and 2). Five times as much sediment was derived from channel scour as originated in the debris slide up the canyon. Damage in Farmington amounted to \$3,000,000 to residences; \$270,000 industrial; \$1,096,000 to public facilities and \$10,000 to commercial. Eight homes were destroyed and 35 damaged by the succession of debris flows from Rudd Canyon. Bountiful Water Subconservancy District service was disrupted for three weeks by damage to the aqueduct that transports irrigation water to the district. The Davis Aqueduct road was washed out and the 66" Davis Aqueduct itself was exposed and battered by successive flows that finally perforated it. Farmington City's water distribution system became contaminated, also.

In the town of Fruit Heights 75 residents were evacuated when it was feared that Baer Canyon would produce a debris flow that would threaten life. Water lines, culverts, and personal property in that community were subjected to damage from debris flood but nothing very serious resulted.

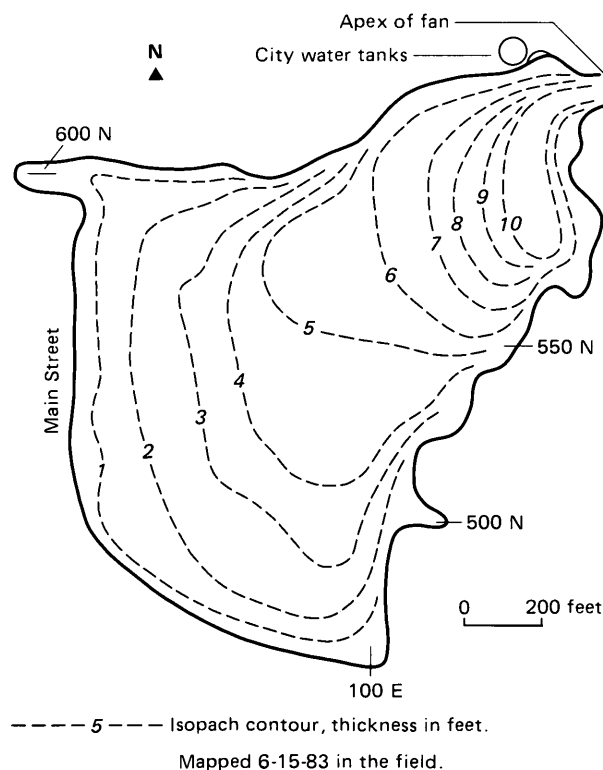


Figure 1. Isopach map of Spring, 1983 debris flow deposits on Rudd Creek alluvial fan, Farmington.

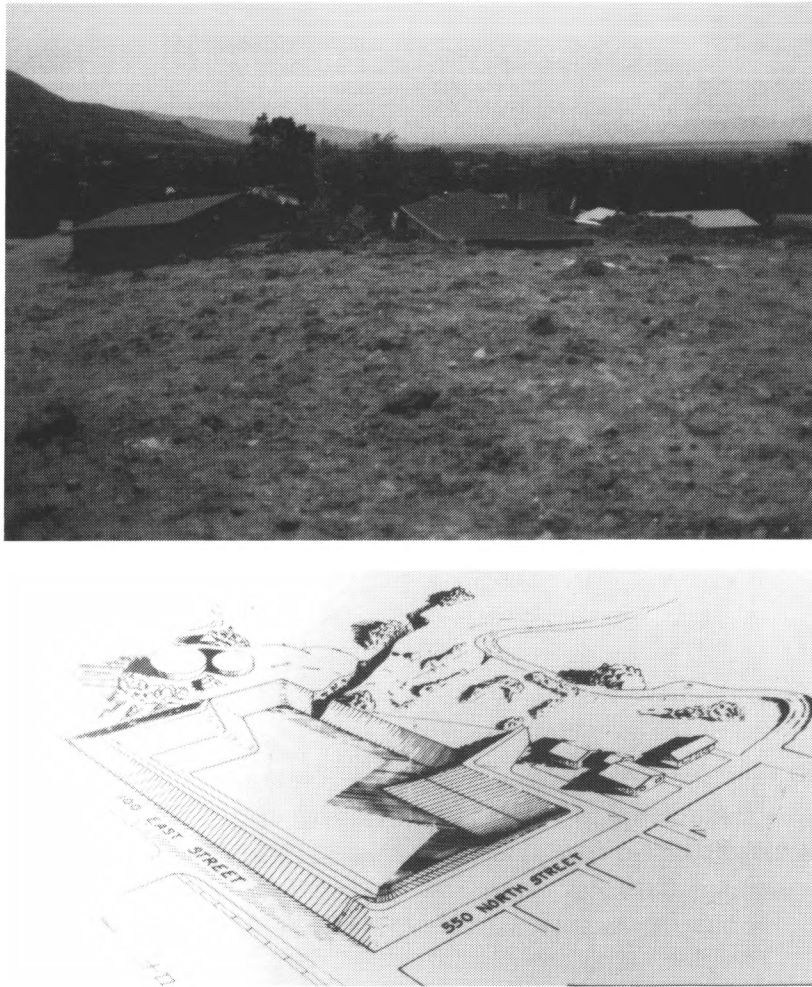


Figure 2. Rudd Creek, Farmington. Upper: Debris flow of May 30, 1983 engulfed residential neighborhood (photo by Dan Short). Lower: Debris basin design for the same site.

Bountiful City suffered over \$4,000,000 damage as two significant debris floods hit that city, from Stone and Barton Creeks. Half of the cost was to public facilities, including emergency work (\$2,120,000). An equal amount was lost to homeowners, with 2 homes destroyed, 25 damaged in the 25 to 50 thousand dollar range, and 325 others damaged to a lesser extent. A third canyon, Mill Creek, also contributed erosion and sedimentation damages. The map of the three drainages through the city of 34,000 people illustrates why the damage was so severe (figure 3a).

The debris slide in a northern tributary of Stone Creek swept down canyon as a debris flow but emerged from the canyon mouth as a debris flood (figure 3b). This, as was also true of other debris floods, could not be contained within the channel as modifications to the channel through the city had been performed by many entities over many years. Ground investigation during the summer of 1983 revealed that the channel of Barton Creek, in particular, is in a terribly disturbed state and a large area of shallow slumping has been destabilized on the south side of the drainage in the vicinity of the Brown tree farm.

Similarly, in Centerville, debris floods emerged from Centerville Canyon, affecting 2 homes and doing \$620,000 damage to public facilities.

Kaysville had roads and culverts plugged and Layton had \$100,000 damage to public facilities and damage to one home.

In all of Davis County there was over \$18,000,000 damages, the majority of which can be attributed to debris flows and debris floods. In October 1983 a \$12,000,000 flood bond was approved by the electorate in a special election. This money has been spent for debris basins and channel improvements.

In March and April, prior to the debris floods in Davis County, there were at least a dozen or more benchland failures, principally in North Salt Lake City, Layton, Bountiful, Kaysville, Farmington, and one in North Ogden, causing over \$200,000 in losses.

Ground water did rise in the county and springs flowed in greater abundance. A considerable acreage of ground was submerged east of I-15, from Chase Lane to Ricks Creek and at other localities, affecting the shallow, unconfined water table in the vicinity. At least one home, an old stone structure at the southern end of Farmington City, underwent additional settlement as a result of the high ground water (investigation by the writer).

The considerable erosion and sedimentation that occurred on the many drainages in Davis County were largely the result of the geologic instability in the canyons. Because of the likelihood of this problem remaining for some period of time in

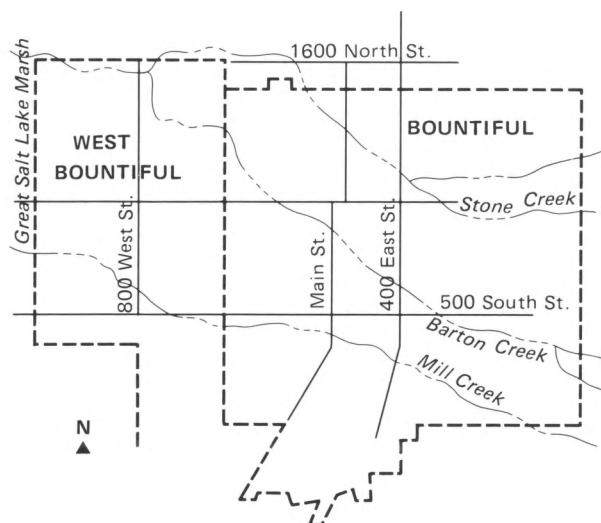


Figure 3. Drainage channels carrying debris flood loading in 1983 through cities of Bountiful and West Bountiful. Upper: Map of area. Lower: Stone Creek; collapse of embankment from debris floods (photo by Dan short).

subsequent spring seasons, FEMA funded watershed landslide-debris flow studies. This work was contracted to the U.S. Geological Survey, with engineering assistance from the Los Angeles Flood County Control District and the report of findings released to the public in the summer of 1983 (Wieczorik, 1983). The 19 canyons in the county have their headwaters mostly above elevation 8,200'. Canyon mouths are at the 5,000' elevation, and the creeks terminate in wetlands about elevation 4,200'.

Duchesne County

A number of small slides affected State Highway 33 at the south end of the county.

Slides in the Uinta Mountains were likely to have been more common than reports appear to indicate. Much of the county is primitive area and visitors are few. Three trails were closed by the USFS in the primitive area due to debris flows.

The Argyle area in Indian Canyon (mile post 166) experienced a landslide which continued to move slowly through the summer. Some 2' of settling occurred to the road surface over a distance of 300'.

High ground water and perched water tables offered more problems than normal in towns in the county. Duchesne, Roosevelt, Tabiona, Bluebell, Upalco, Altamont and vicinities were affected in 1983.

Starvation Reservoir experienced considerable sedimentation at its upper end over a distance of about one mile with deposits over 10' in thickness. Below the reservoir, erosion occurred at meanders. A new 6' to 8' incised channel was cut in the reservoir bottom upon exposure in the winter of 1983-84.

Approximately \$100,000 in farm claims to ASCS, from erosion and sedimentation in fields and ditches, are recorded for the county.

Damage to state and county roads was rather extensive where water entered the subgrade. Likewise, street damage in towns, especially Roosevelt, was considerably aggravated. In

the Golf Course Subdivision alone, damage to streets has been estimated at \$40,000.



Figure 4. Mill Creek, Bountiful: two types of slides. Upper: Shallow, transitional slides on south bank, high bench. Lower: Rotational slide—earth flow on north bank, high bench.

Emery County

Numerous landslides and debris flows occurred in Emery County in 1983, by far the greater number of which had little effect upon facilities.

Emery Canal Company's Brush Reservoir (Sec. 14, T20S, R4E) with a capacity of 140 acre feet, was grossly impacted by being in the midst of a landslide zone. Gates that had been purchased for installation in the spring of 1983 were never installed due to the magnitude of the impact. Cost to replace this storage facility was estimated to be on the order of \$500,000. A number of debris slides and debris flows occurred in the vicinity of Electric Lake Reservoir, Sec. 11, T14S, R6E, also.

A potentially very significant slide was the reactivated ancient earth flow of the south side of Seeley Creek, west of Joes Valley Reservoir, which threatened to dam the creek. This slide, though in Sanpete County, would have its greatest impact in Emery County, downstream.

Three landslides in the upper drainage of Crandall Canyon (Sec. 1, T16S, R6E), caused debris flows and floods, plugging the major culvert. Huntington Canyon, Left Fork, had slides that impacted State Highway 31 (Sec. 5, T15S, R7E), Huntington Campground and its water supply, USFS Trail #F15131 and the channel of Huntington Creek. Damage assessment was \$310,000 including rehabilitation suitable for fish habitat.

Four landslides occurred in the vicinity of Monument Peak (Sec. 11 and 24, T14S, R6E, and Sec. 7 and 19, T4S, R7E). About 300' of USFS road #50018 was lost. The right-of-way of a natural gas transmission line was damaged in Sec. 17, T14S, R7E. In Intex Canyon landslides partially covered USFS road #50012, doing \$2,000 worth of damage. In Nuck-Woodward Canyon a landslide buried 150' of road #50110 and debris floods washed out three culverts and other portions of the road; damage was \$11,000.

Shallow ground water in Emery and Huntington softened streets. Problems of seasonally high water table due to irrigation are normally such that 1983 proved no worse for the most part.

Huntington Creek lost its hydraulic capacity due to siltation in the spring. Restoration of its cross section would cost an estimated \$300,000. Bridge damage along the drainage totaled about \$700,000.

Erosion of a meander on the Green River, above the town of Green River, has the city concerned that in a subsequent runoff period the meander may be altogether cut off. The resulting gradient change, then, might be expected to continue down river, possibly changing the river's course through the town.

Huntington City had about 200' of its culinary water line exposed through erosion in Tie Fork Canyon (Sec. 3 and 4, T16S, R7E). The city also had some erosion of its sewer lagoon.

Millers Flat Canyon had one major and one minor culvert wash out with damage to the USFS road in the amount of about \$25,000.

Farmers' claims for ditch sedimentation and regrading of fields amounted to \$12,000.



Figure 5. Barton Creek, Bountiful. Upper: Channel realignment; Lower: Encroachment on channel by new home (photo by Dan Short).



Iron County

A slide in Parowan Canyon has been creeping for some 20 years, even damming the stream in the past. The slide is beyond the Dry Lakes turnoff, about 7 miles upstream from Parowan, in Sec. 14, T35S, R9W. It is believed that this slide moved more than normal in 1983. The slide was likely initiated when Highway U-143 and Parowan Creek were realigned.

At Cedar Breaks, on the Panguitch Lake Road, Sec. 26, T26S, R8W, a road cut that has been frequently active in the past has moved again.

In Yankee Meadow, on the Sidney Valley Road (Sec. 31 and 32, T35S, R8W), high ground-water pressure caused a landslide. The USFS has estimated \$2,000 to stabilize the cut and remove the debris about, ½ acre being involved. The road was closed throughout the summer.

Up Cedar Canyon, at Zions View, Sec. 27, T37S, R9W, about 100' of Highway U-14 was lost in a landslide. It is interesting to note, however, that other troublesome slides in Cedar Canyon in recent years, such as at MacFarlane Mine and near Pink Cliffs, remained stable in 1983.

The closure of U-14 and the county road between Panguitch and Panguitch Lake, due to landslides, impacted Cedar Breaks National Monument by forcing opening of the road through the monument earlier than normal, based on depth of snowpack, causing an extra expenditure of \$8,000.

In places on Highway U-143, in Cedar Breaks National Monument, Wasatch Formation mudstones under the road-base have retained moisture and caused road deterioration.

Parts of Cedar City that have experienced hydrocompaction problems in the past decade are believed to have seen some aggravation of the problem in 1983. Areas affected were, more specifically, the north I-15 interchange, I-15 south of Cedar City and a subdivision in the southeastern part of the city.

Juab County

Fourteen landslides disrupted access to both Chicken and Pigeon Creeks, east of Levan. Levan City faced \$314,000 in damages. Levan City's culinary water system was affected by a shift in the channel of Chicken Creek. Erosion of Chicken and Pigeon Creeks during the period May 15 to June 25, 1983, did some \$400,000 of direct and \$100,000 of indirect damages according to the Levan Irrigation Company. Damage was done to lined and unlined canals and diversion structures. USFS roads #50146 and #50101 each had damage of about \$5,000.

Two slides occurred in the upper reach of Four Mile Canyon; removal of one cost \$5,000.

Deep Creek Canyon had two slides of no real consequence.

Three small slides exposed some 19 acres of soil in Sutton Canyon.

A landslide slump in Gardner Canyon, north of Nephi, (Sec. 21, T12S, R1E), 330' X 1,100', took out a culinary water line to four homes and partially blocked the creek.

A small slide occurred in the I-15 road cut in the massive ancient landslide mass just south of the Utah County line; no damage resulted.

In Nephi Canyon (Sec. 5, T13S, R2E) a small slide passed by the KOA Campground, doing no damage. The operators kept

a portion of their campground area vacated for the duration of the season as a precautionary measure.

On Currant Creek, Goshen Canyon, near the Utah County line, a landslide entered the unlined canal in March 1983. Subsequent erosion in May undercut the cement siphon pipe. Cost to the Currant Creek Irrigation Company was \$2,100.

The west and southwest portions of Levan had aggravated shallow ground water problems.

Callao and Trout Creek have experienced high ground water since 1982.

Nephi has had homes in the south and southwest parts of town with basement seepage problems.

In the Mona area the Erma Newton home experienced the emergence of a new spring, in a location where older residents have no recollection of ever seeing one.

Partown (T13S, R18W) installed an underground sprinkler system in 1982, finding the water table deeper than 8'. In 1983, the water table engulfed the system at 3' to 4' depths.

The Deep Canyon Irrigation Company, south of Levan, reported the erosion of 2,500 linear feet of pipeline, 500 linear feet of ditch lining and three irrigation structures, totaling \$125,000 of direct costs plus \$75,000 in crop loss.

The Callao Irrigation Company reported \$1,000 direct damage, \$8,000 indirect from erosion of Basin Creek, Toms Creek and Indian Farm Creek.

The Don E. Jones farm near Nephi reported to the USDA \$60,000 losses from sand and debris deposition.

Nephi City suffered extensive damage to public facilities from erosion and sedimentation by Salt Creek; damage of \$603,000. Both Bradley and Marsh springs were washed out. Levan, too, had erosive damage to their springs.

Juab County encumbered costs of \$1,200,000 in debris removal, culvert and bridge replacement, channel cleaning and road clearance.

Approximately 1' of settlement has been reported as occurring to I-15.



Figure 6. Barton Creek, Bountiful. Upper: Debris flood damage; Lower: Constriction of channel (photo by Dan Short).

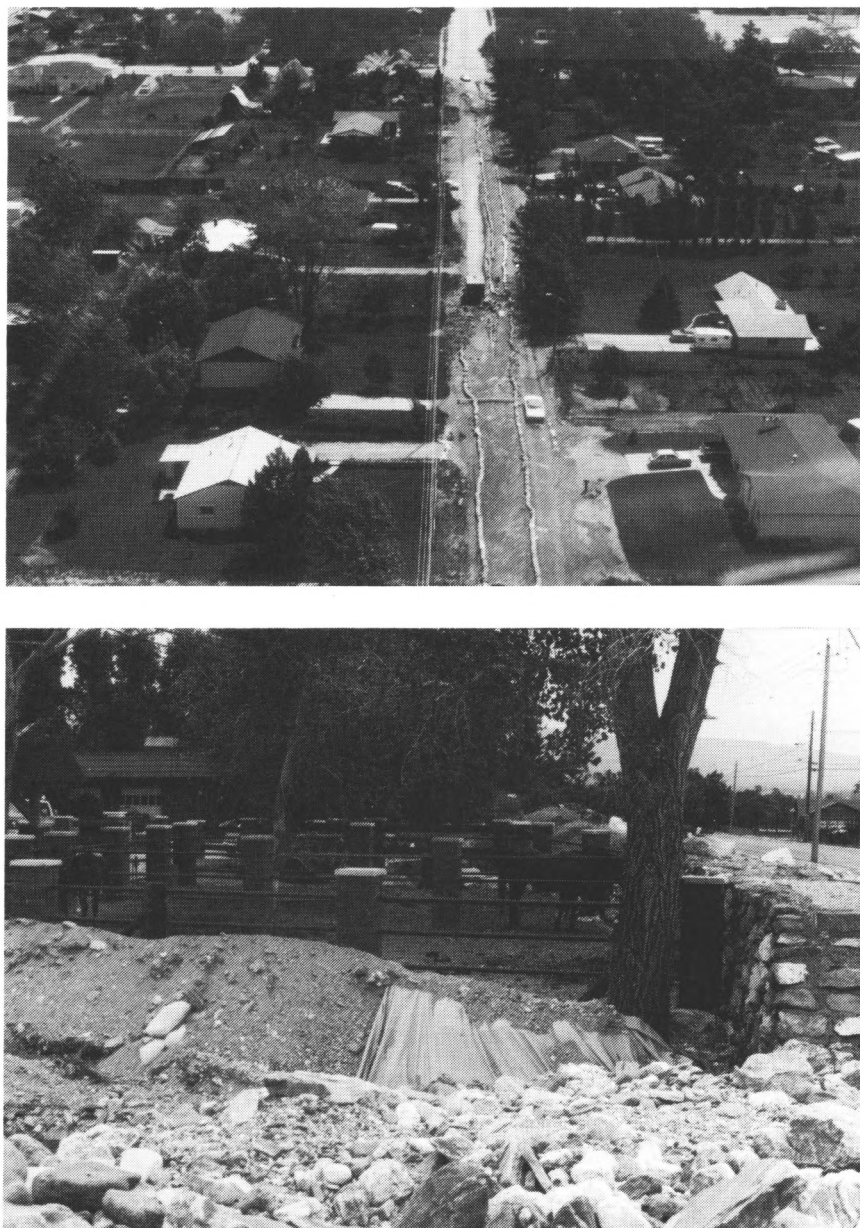


Figure 7. Upper: Bernard Creek, Centerville: South Fork street diversion; Lower: Ricks Creek debris basin with stable within; structure dates from 1930s (photo by Dan Short).

Millard County

In Pharo Canyon, Sec. 10, 11, and 12, T21S, R2½W, some 25 slides were reported, approximately three of which were large, in June. No improvements were damaged, however.

Near Fillmore, in North Fork Canyon, some slides and cracks were reported, with no stream blockage.

In Pine Follow, Sec. 24, T24S, R4, ½W, a slump about 200' long crossed a cattle trail in May.

In Spring Canyon a slide crossed a trail in Sec. 7, T24S, R4W, and another like situation occurred in Sec. 18, T24S, R4W.

In the South Fork of Chokecherry Creek, a slide on Shingle

Mountain, Sec. 5, T 22S, R3W, blocked the road in May. Dimensions were approximately 2,000' X 500'. In Section 3 another slide of similar dimensions cut a secondary, non-culinary, water line to a residential development.

Shallow, high ground water has caused septic tank problems in the Delta, Hinkley, and Deseret area.

In Scipio, the western part of town has had to pump greater quantities of ground water than normal from basements. In the eastern part of town problems have occurred for the first time. Cattle sank up to their bellies due to a water table elevated to a 1' depth.

Excessive discharges have created problems with the collection system for Oak City's culinary spring. Likewise, Kanosh had problems with its upper spring. Streets in Kanosh, Fillmore and Hinkley have deteriorated at a higher than normal rate in 1983.

New springs and increased flows of existing springs are reported by the USFS in the Pahvant and Canyon Mountain ranges.

Oak Creek suffered severe erosion, removing 10 sections of 10" pipe at a cost of \$20,000 in late May 1983 and damaging unlined canals to the worst extent in history. Debris flows and debris floods may have been responsible. Some 370 yds³ of debris was left on Oak City streets, costing \$1,100 to remove.

Erosion by Corn Creek in Kanosh did \$13,000 damage to a culinary water line, irrigation canal, poser poles, road and parking lot. Sediment amounting to 388,000 yds³, 2' to 16' deep, over 44 acres, cost \$486,000 to remove. The Corn Creek Irrigation Company debris basin was filled by June 30. The upper spring for Kanosh was also affected. Along Corn Creek there was loss of camping units in the Adelaide Campground, with damage estimated by the USFS at \$50,000.

Oak Creek washed out a Fillmore City spring, road and campground. Debris flows and debris floods likely were responsible.

Erosion endangered Watercress Spring in Sec. 36, T12S, R4W. Contamination problems that resulted required Fillmore City to install a chlorinator at a cost of \$22,000. Repairs cost \$40,000 and well pumping added \$72,000 of excess costs between May 1983 and the end of the year.

The USDA county ASCS office reports \$446,000 in Emergency Conservation Program claims for debris removal, land leveling, structure, and fencing.

Surface bodies of water developed: (1) along the Old Sevier River drainage, in T18S, T19S, and T20S, R8W, R9W, and R10W, beginning in June and comprising some 1,000 acres, with the highway affected; (2) in T24S, R11W, comprising about 30 to 40 acres; and (3) west of Lynndyl in T14S and T15S, R8W.

The break of the DMAD dam and its repercussions are not addressed herein.

Figure 8. Davis County watershed Left: Appearance of watershed immediately following a debris slide; right: Extensometer installation in Rudd Creek Canyon.





Figure 9. Slump taking out Hwy. 65 in East Canyon. Slide occurs in transition zone from cut to fill section of road. Note heavy tree growth, requiring relatively abundant water, directly upslope. Also note fracture with some vertical displacement indicating potential for considerable enlargement.

Morgan County

Landsliding in Morgan County in 1983 occurred mostly where it has been a troublesome problem in recent times, in the Mountain Green area, to the north, and along the Weber Basin Canal, to the south of the Weber River. Both areas experienced aggravated movements. Terrain consists largely of prehistoric landslides that have been reactivated in recent years by activities of man.

Nine miles north of I-80, on State Highway 65, a large slump resulted in closure of the road (figure 9).

Erosion by the Weber River washed out the main sewer, from the pump station to the lagoons, for the city of Morgan. Cost to repair was \$29,000. Erosion of the Lost Creek Bridge abutment, 1 1/2 miles north of Croydon, caused \$5,000 damage and erosion of the East Canyon Creek. Richville Lane Bridge had \$2,300 damage. Damage to prime farm land and homes was estimated at \$1,000,000.

Piute County

Slope failures in Piute County appeared to have been confined to the National Forest lands where 65 individual slides over 1 acre in size and 29 slide complexes were identified (but not confirmed as 1983 movements). Manning Meadows Road (USFS #40083), Sec. 13, T27S, R2W, was displaced by a .25 mile wide slump.

In Circleville, some fifteen basements flooded in the north side of town, with from 6" to 6' of water. Inundation of cesspools by the ground water resulted in contamination of shallow ground water. The normally high water table in Antimony, Kingston, Circleville and Junction was aggravated

somewhat. Fields of crops could not be harvested because of very shallow ground water. Marshy meadows were too wet for livestock. Greenwich appears to have been affected by a high water table for the first time.

Box Creek Reservoir (upper) spilled and in the process deposited thousands of cubic yards of sediment, up to 9' in thickness. Thompsonville irrigation pond became silted with 80,000 yds³ in the one season. Additional land also silted as did a sprinkler irrigation line.

Angle also experienced silted fields. The road was affected at Junction, and at Marysville the Pink Creek channel became 40 to 60 percent filled with sediment (\$20,000 spent to remove). Bullion Creek did some \$6,200 damage. Total erosion damage to public facilities (road, culvert, bridges, water line) amounted to \$72,500. Like damage in the unincorporated county cost Piute County about \$100,000. Considerable damage occurred at Circleville to a diversion structure, bridge, and some homes. Circleville encumbered costs in excess of \$163,000; Kingston had a bridge wash out from scoured abutments at a cost of \$8,500.

Approximately 4,000 acres of private agricultural land was affected by sedimentation in the county.

USFS road #40072 in Sec. 12 and 13, T29S, R2W and Sec. 17 and 18, T29S, R2W were heavily impacted.

A 1.5' diameter sink hole showed up at a residence in Circleville in July 1983. Water was found at a depth of 1' in the hole.

Rich County

High ground-water problems in Randolph amounted to public expenditures of \$24,000. In addition, there were septic tank failures. There were shallow ground water problems in Laketown, Garden City, Woodruff and elsewhere on the west side of Bear Lake.

Erosion threatened public and private property by runoff in Woodruff Creek and the Bear River. The Bear River removed 3,600' of road embankment in three locations. Woodruff Creek undercut the bridge abutments one mile below Woodruff Reservoir; damage was \$12,000.



Figure 10. Salt Lake city; streets as conduits
(photo by Division of Comprehensive Emergency Management).

Salt Lake County

Landslides in Salt Lake County were for the most part small with only a very small percentage of them being damaging.

Small failures of colluvium on steep slopes along Emigration Canyon closed the road several times. A failure of mostly highway fill occurred near Little Mountain. The greatest problem occurred near the mouth of the canyon where relatively large masses of moving fill broke a sewer line and threatened to move into the creek channel. The head of one of these masses

removed landscaping from a condominium complex and affected landscaping close to the foundation on one side.

In a residential neighborhood to the south of Emigration Canyon, two small debris flows were triggered by both melting snow and rain, involving Navajo Sandstone colluvium on the mountain front. One of these occurred in the backyard of a residence and the other flowed through several yards, having detached from a pioneer road cut a short distance to the north.



Figure 11. Salt Lake City; improvised drainage (photo by Division of Comprehensive Management).



Several slides caused small debris flows in Red Butte Canyon, one of which reached the reservoir. Some of the damage that was caused by the flooding in Red Butte, Emigration and City Creeks undoubtedly resulted from debris floods that evolved from relatively short travel distance debris flows. Red Butte experienced \$234,000 damage due to erosion and

progressive culvert failure. Red Butte reservoir, water supply for Fort Douglas, was impacted. Emigration Creek experienced \$3,630,000 damage and City Creek cost \$5,900,000 for replacement of the channel and structures. The subsurface conduit from City Creek plugged with debris and overtopped. Deltaic gravels in the lower reaches of the drainage eroded and furnished the coarse clasts that so successfully plugged everything through the city. Several small slumps occurred in *in situ* and road fill material along the road behind the State Capitol. The old landslide slump that moves every few years, on the west side just south of the city watershed gate, moved in a somewhat greater increment.

Sliding in Parleys Canyon mostly occurred in the Lambs Canyon tributary. In the latter the \$495,000 of damage was largely attributable to debris floods.

Many remote slides occurred in mountainous terrain, largely from Ankarah Formation colluvial cover which everywhere appears reddish.

The water table in the center of the valley rose over one foot over a fair sized area, particularly around Rose Park.

West Valley City had extensive street damage and greater expenditures from high ground water than elsewhere. A subdivision at 5200 West 4300 South with 10-year-old homes had some 20 basements with water. In the Chesterfield part of the city, the city has had a permanent pump installation to help de-water a 3 to 4 block area since 1982; costing about \$40,000 a year.

Clogging of conduits caused extensive damage in Salt Lake City, in the City Creek drainage. Public access to the downtown area, in particular, was severely hampered for nearly one month while the streets were used as drainage channels (figures 10, 11, 12). The vicinity of Canyon Road, North Temple, and 1300 South was most critical, with public property taking the brunt of the damage.

Channel bank erosion was rather extensive on Big and Little Cottonwood Creeks and on the Jordan River; \$4,000,000 on the former two drainages and \$1,300,000 on the Jordan, exclusive of flood fight costs. Several dozen unstable banks were identified along Jordan River canals at the south end of the valley which proved a nuisance since these canals were relied

upon to take the peak runoff from the river channel. The channel of the Jordan River has shifted up to a few hundred feet. A significant problem that this has created is that many properties along the river have legal descriptions written using the river bank as one boundary.

Corner Canyon in the southeast corner of the county had its

The west side drainages of Rose Creek, Midas Creek, Bingham Creek, and Coon Creek experienced only minor channel bank erosion and sediment; total damage to all four being \$27,000.

Numerous "sink holes" appeared throughout the city, none of which were natural or geological but instead are the result of

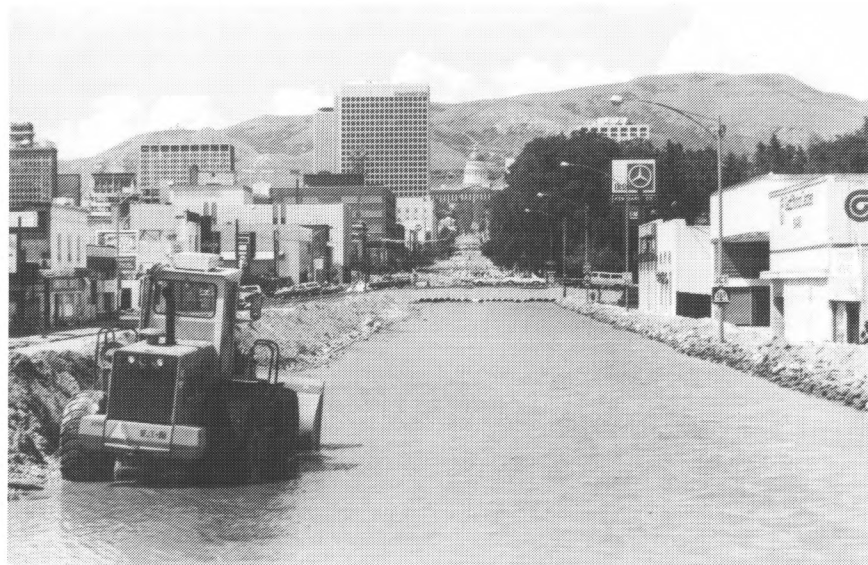


Figure 12. Salt Lake City (photo by Division of Comprehensive Emergency Management).

alignment changed with the installation of Fort Street (800 East 13600 South). The resulting decrease in the channel gradient formed a site for sediment deposition.

High sediment loading of the Bell Canyon water system, serving Draper and Salt Lake County, impacted the treatment plant.

underground openings created historically by man (figure 13a). These features result from saturation of the soil mantle. The extra weight of the soil does not allow a subsurface void such as an old root cellar, hand-dug well, or cesspool to be bridged. Most interesting of these features were two vertical-walled collapse chimneys which appeared in the same sloping-

ground yard on the high bench in the King Hills Subdivision. The cause of these ground failures was believed to be the presence of a pioneer exploration adit constructed through alluvium to reach a frontal fault in bedrock. Old aerial photographs were consulted by the writer and William Gordon, Dames and Moore, to confirm this hypothesis.

Some piping of fine lacustrine sands and silts was observed along I-15, southeast of Salt Lake City (figure 13b).



Figure 13. Salt Lake County, hydrogeologic effects; Upper: Collapse feature; Lower: Piping in interstate embankment.



Sanpete County

Landsliding impacted Sanpete County to a very major extent. In fact, the state's attention was drawn to these events on many occasions in May and June. On May 22 a debris flow swept down Twelvemile Canyon from the immense South Fork landslide and reached as far downstream as the Pinchot Campground before transforming into a debris flood. A landslide in Fairview Canyon threatened to dam on May 30, requiring the evacuation of the town and the closing of Highway U-31. On June 1, nine more canyons were significantly affected in the Sanpete Ranger District. On June 2, the 100-acre landslide in the White Ledge Fork of Ephraim Creek severed a power line. On the third, further landsliding and debris flow activity ensued. June 5 saw aggravation of the Twin Lake slide in Twelvemile Canyon. On that date two opposing slides at Beaver Creek, in Twelvemile Canyon, were constricting the channel of Twelvemile Creek and threatening a blockage. Maple Canyon landslide in Ephraim Canyon impacted Ephraim City's water line on June 9. On June 10 the Twin Creek spillway was purposefully breached in a controlled fashion because of the landslide threat. And on June 16 many new slides were found throughout the county's watersheds.

The majority of the landslides occurred on the west side of the Wasatch Plateau where the monocline causes the strata to dip to the west at an increasingly greater angle towards the west. On the north end, east of Indianola, the South Fork of Thistle Creek had four slides in Sec. 8, T12S, R5E. Dry Creek, east of Milburn had debris flow-caused channel damage which removed 3,000' of newly placed 12" pipe. Oak Creek had nine areas of movement, in Sec. 16, 19, 20 and 21, T13S, R5E. Cottonwood Creek, east of Fairview was seriously impacted (figure 14). Six bad slide areas occurred in Sec. 23, 27, 31, 33, 34 and 35, T13S, R5E. Movement affected the town's spring and transmission line, requiring the town to pump water from a well. Birch Creek, to the south, experienced a slide that briefly caused channel damage which removed 3,000' of newly placed 12" pipe. Oak Creek had nine areas of movement, in Sec. 16, 19, 20 and 21, T13S, R5E. Cottonwood Creek blocked the creek and then broke, in May. Birch Creek Irrigation Co. lost all of their structures. Oak Creek, east of Spring City, had a slide area on the north side, in Sec. 6, T16S, R5E, that caused the irrigation system to be turned off. Ephraim canyon had multiple slides, including a complex slide in Sec. 4, 5, 8, 9, T17S, R4E; a slide crossing the Larsen Ditch, in Sec. 9 and 10, T17S, R4E; and slides south of Cottonwood Creek, in Sec. 13, T17S, R3E, and Sec. 17 and 18, T17S, R4E, and one crossing a jeep trail in Sec. 30, same township. Ephraim City's new water line telescoped 33'. A slide in Manti Canyon caused a city water line break near the north limit of Sec. 14, T18S, R3E. Other big slide areas occur east and west of the last slide, in the same township. Manti City cleared 60,000 yds³ from the debris basin, which also suffered spillway damage. The city's upper power plant was closed, requiring the purchase of electricity from Utah Power and Light. A giardia water-borne disease outbreak complicated the landslide impact on Manti City. Expenses of the city amounted to something over \$84,000. Sixmile Canyon, east of Sterling, saw movement of the Forbush Cove slide on the south side near the mouth, a slide on the north side in Sec. 27 and 34, T18S, R3E, and two in Sec. 4, T19S, R3E. Some 12 ancient landslides became reactivated in Twelvemile Canyon, east of Mayfield, from Twin Lake east to the immense slide in the upper reach of South Fork. Mayfield's upper spring was affected and contaminated.

On the east side of the plateau, there was sliding on the north side of Rolfson Canyon, in Sec. 29 and 32, T14S, R6E. In the Seely Creek drainage a slide on the south side occurred above Joes Valley Reservoir, just below the confluence with Olsen Creek, in Sec. 3, T18S, R5E. Another, in Beck Creek, occurred in Sec. 30, T17S, R5E. Farther south, in the Ferron Creek drainage, three slides occurred in Sec. 7, T19S, R5E, and two in Sec. 1, T19S, R5E. In the North Fork of the Muddy Creek drainage, between Spinners and Brush Reservoirs, a significant slide occupies the majority of Sec. 11, T20S, R4E.

In the southern portion of the San Pitch Mountains, in the county, the following slides were documented.

Upper reach of Hells Kitchen Canyon, Sec. 15, T17S, R1E.

Head of Axhandle Canyon, Sec. 22, T17S, R1E.

Sec. 24, T17S, R1E.

Maple Canyon drainage, south side, four slides in Sec. 3 and 4, T15S, R2E, and Sec. 34, T14S, R2E.

Head of Tidds Canyon; three slides, Sec. 9, 15 and 16, T14S, R2E.

Fountain Green Pole Canyon; Sec. 4, 9 and 10, T14S, R2E.

Log Hollow; large slide in Sec. 33, T13S, R2E.

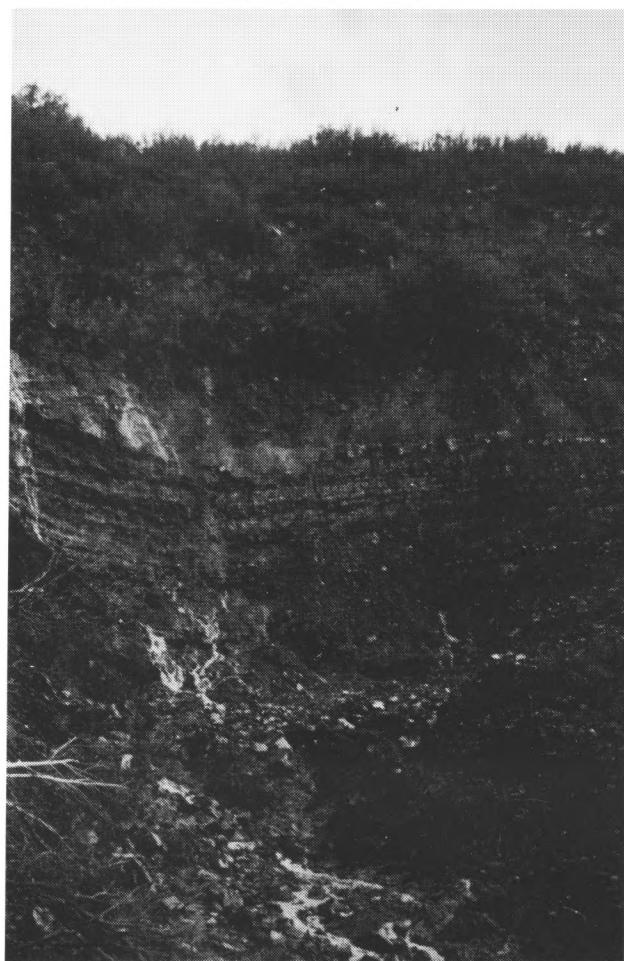


Figure 14. Scarp of debris slide in Cottonwood Canyon, east of Fairview. Note that bedrock comprises headwall scarp and that there is prolific issuance of ground-water, both from colluvium contact and from bedrock.

Ground-water problems were common in towns in the county. The worst situation existed in Fountain Green where most basements were pumped. A drain, constructed at a cost of \$106,000, yielded $\frac{1}{2}$ second foot of ground-water. In Mt. Pleasant, an area of the town between 200 S. and 900 S. and 100 E. and 500 W. was seriously impacted by a rising water table. Parts of Sterling, Fayette, Ephraim and Fairview were also affected by shallow ground-water conditions.

Water systems were affected in Fairview, Mayfield, Monroe, Mt. Pleasant and Gunnison. In Fairview and Mayfield transmission lines from springs were washed out in the canyons. Monroe's spring source became somewhat turbid and Mr. Pleasant experienced contamination of its reservoir with muddy water. Gunnison's spring is discussed below.

Submerged acreage was a serious problem in the county. An estimate has been made that about 16,000 acres were inundated, most of which was farmland. Northwest of Manti a lake about 3 miles long, 2 miles wide and 4' to 5' deep was created. Northwest of Ephraim some 5,000 to 6,000 acres of cropland were affected. Several hundred additional acres of marsh formed at Sterling.

The San Pitch River was responsible for considerable erosion and sedimentation. At Gunnison, because of its leaving its banks, a sewer line was washed out, resulting in raw sewage reaching the river. Silting by the river affected that town's culinary water spring, as well. Some 500 acres were affected by sediment deposition by the San Pitch.

Westward-flowing drainage from the Wasatch Plateau, tributaries of the San Pitch River, suffered significant repercussions from the historically unprecedented snowmelt runoff. Following review of the damage in 1983 the U.S. Army Corps of Engineers, based upon 50-year-frequency discharge rates, recommended improvement plans. Costs for each of these are:

Cottonwood Creek at Fairview	\$118,000
Birch Creek	\$49,000
Pleasant Creek at Mt. Pleasant	\$400,000
Cottonwood Creek at Ephraim	\$703,000
Manti Creek at Manti	\$312,000
Sixmile Creek at Sterling	\$131,000
Twelvemile Creek at Mayfield	\$767,000

Costs of damage throughout Sanpete County in 1983 totaled \$18,776,000; \$15,068,000 in the public sector, \$3,233,000 in agricultural damages (includes \$1,241,000 from loss of pasture and cropland and 1983 harvest due to breaching of Gunnison Reservoir), and \$475,000 in other, private economy losses.

Perhaps the major cost in the county will be watershed rehabilitation. This cost alone is sure to exceed \$1,000,000.

Sevier County

Landslides were in abundance in the high elevations of Sevier County. The USFS reports 127 individual slides and 56 slide complexes, distributed among the ranger districts as follows:

Ranger District	Slides	Slide Complexes
Beaver	25	2
Monroe Mt.	15	5
Richfield	72	25
Loa	0	18
Fillmore	15	6

A number of slides occurred in Salina Canyon, including two rock falls, in Sec. 20, T22S, R3E, and Sec. 34, T21S, R1E. A slide in Sec. 20, T22S, R3E, on the south side of the canyon, diverted the creek and caused road damage. Between Salina and Fremont Junction there were about 30 slides. Earth movement generally kept the turbidity in Salina Creek high all summer in 1983. The City of Salina's culinary water system, sewage plant and pressurized irrigation system suffered major damage from floods. Significant slides are listed below:

- Oak Ridge (Sec. 3 & 10, T23S, R2E): affected ½ mile of Road #40032.
- Monroe Canyon (Sec. 14, T26S, R3W): affected 1 mile section of Road #400778-1.
- Clear Creek (Sec. 3, 9, 16, & 21, T24S, R4E): affected 3 mile section of Road #40016.
- Gates Lake (Sec. 3, T24S, R2E): affected 2 mile section of Road #40040.
- Maple Spring Canyon (Sec. 21, T22S, R2E): affected about 200 acres and destroyed power lines. Occurred May 27, 1983.
- Willow Creek (Sec. 2, 3, 4, 5, 11, & 12, T21S, R2E): the slump on Anthony Flat moved from May 20 to June 10 affecting a 5 mile section of the road.
- Conservation Spring (Sec. 9 & 16, T21S, R3E): slump zone.
- Gooseberry (Sec. 14, 15, & 16, T23S, R2E): affected 2 miles of Road #40640, between May 20 and June 10; slump zone.
- Hoodo Creek: slump zone
- Sheep Creek: slump zone.
- Brown's Hole Road (Sec. 12 & 13, T23S, R2E): affected 1.5 mile section of Road #40038.
- Monroe Mt. Road (Sec. 13, T26S, R2W): road closed summer, 1983; 35'-40' vertical displacement.
- Water Hollow (Sec. 1, 11, 12 & 14, T22S, R2E): affected 5 mile section of Road #4004.

East of Richfield, along Glenwood Road, water has come up into basements and septic systems. Concerns were high in Venice that their well might have become contaminated by individual waste disposal systems but testing by Health District authorities did not confirm such problems. Northeast and east of Aurora the rising water table affected crop yields. Also east and west of Venice farmland had been similarly affected. Alfalfa yields were down about 50 percent. The Frank A. Cowley farm, for example, took a \$5,300 crop loss on 25.5 acres. Leveling and removal of sediment cost another \$1,850 on that farm. Gary C. Cowley reported \$20,000 in crop loss and another \$3,000 damage. He indicates that the 1922 flooding did no such erosion nor was the water table as high.

Rapid runoff caused erosion and sedimentation damage in many communities throughout Sevier County. These were: Monroe-\$73,000. An irrigation structure owned and operated by Monroe City was damaged along with water lines and the

city power plant penstock; Elsinore-\$10,000, culinary water lines; Aurora-\$8,500, culinary spring construction; Salina-\$58,000; Richfield-\$4,200; Sigurd-\$5,000; Redmond-\$3,100; Joseph-\$24,000; and \$305,000 in the unincorporated areas.

Damage was also suffered by the Annabella Irrigation Co. when a section of river bank collapsed above the diversion with the result that 600' of highlines canal washed out along with a hydrologic recording station; \$25,000 damage. Spring Hill Irrigation Co. suffered \$14,000 damage and the South Bend Canal Co. lost a diversion structure and several hundred feet of unlined canal. Clear Creek Irrigation Co. spent \$2,000 to dredge canals and Sevier Valley Canal Co. had their worst sedimentation season ever, with \$15,000 plus in direct damages. This latter system is particularly susceptible inasmuch as it runs along the base of the Pavant Range. Cedar Ridge Irrigation Co., west of Sigurd, experienced coarse sedimentation (gravel) in their canals, costing \$15,000 to clear.

Richfield Cottonwood Irrigation Co. spent \$2,200 in 1983 to dredge their unlined ditches of sediment deposited in May and June. This sum can be contrasted with that spent in previous years in order to grasp the magnitude of the sedimentation problem in the wet cycle. In 1979, \$600 was spent; \$133 in 1980; \$112 in 1981, and \$1,100 in 1982. Farther into the cycle, in 1983, the expenditure required was twice 1982's and some 3½ to 20 times above normal years.

Crop loss occurred from flood plain deposition of the Sevier River between Austin and Prattsville.

Water tables also caused damage at higher elevations. At Sevenmile Valley in the Loa Ranger District, Fishlake National Forest (NW¼, Sec. 2, T25S, R2E), for example, the road remained in unsatisfactory condition through the year, despite drainage expenditures of over \$1,000.

On the west side of Richfield (Sec. 23 and 26, T23S, R3W) ground cracks have been reported, the definitive cause of which has not yet been determined. Inspection by the writer in 1985 has provided strong indications, however, that hydro-compaction is responsible. Alluvium of historic age as revealed by buried rubbish, is the affected substratum. The role of a high water table is still uncertain, although it may be responsible for runway distress at the airport.

Summit County

Chalk Creek was the focus of the greater landslide problems in Summit County. Four slides have affected the road. Remedial work also was required on the river channel at two of the slides and at one a canal inlet was relocated. Total damage from these four slides amounted to direct costs of \$170,400. Locations of the slides are in Sec. 3, T2N, R7E; Sec. 12, T2N, R5E and Sec. 5 and 8, T2N, R6E. Two slides at South Fork were caused by river erosion and resulted in failure of the road.

Forest Road #059, in Sec. 26, T2N, R10E slid over an area of 2 acres in April 1983. Also occurring in the Wasatch National Forest was a slump across Soapstone Road in both 1982 and 1983 and a slump across Spring Canyon Road in 1983.

Sliding affecting private facilities included reinitiation of a small slide affecting a ditch of the West Hoystville Irrigation Company, in the SE¼, Sec. 32, T2N, R5E and a slide on Upper Evergreen Road, in the residential community of Summit Park.

Cost of landslide damage in Summit County was reported as \$177,000.

Sedimentation blocked manholes in the town of Kamas, causing sewage to back up into homes. Estimated damage was \$4,100. Erosion in Kamas did damage to a road culvert amounting to \$3,000. Muddy water is reported to have entered the Kamas water system.

Coalville experienced erosion problems in the amount of about \$20,000. This included removing debris and sediment from the wastewater treatment plant, from a city park and city streets.

At Echo Dam some rip rap and embankment earth required replacement, at a cost of \$3,100.

Bridge abutment damage at Oakley amounted to about \$4,000. Another bridge requiring repairs was on Border Station Road, in the amount of \$8,700. Beaver Creek damaged a culvert (\$9,300) and the South Fork of Chalk Creek eroded the road, doing damage in the amount of \$10,300. Damage of \$7,500 was done to Wooden Shoe Road (Sec. 29, T1S, R8E).

The Henefer Irrigation Co. dam, 2 miles south of Henefer, was eroded as the course of the drainage actually changed somewhat. Damage was approximately \$1,000.

The Daly No. 2 mine shaft collapsed at the ground surface on August 4. It is likely that infiltration through the cover of fill weakened support of the turn-of-the-century structure.

Tooele County

A debris slide in Settlement Canyon occurred in August which meant that it was attributable to a rainfall event rather than snowmelt. Since very few debris flows were rainfall triggered in 1983, this event is significant and requires further investigation. The flow blocked the county road and hit the creek, with evidence of it reaching 6' to 8' in height.

Soldier Canyon, east of the town of Stockton, experienced four major cloudbursts between July 31 and August 19, 1983. At least one of these events produced either a debris flow or a debris flood. It washed out 4 sections a main culinary water line and access road. Damage amounted to \$32,000 for the town of Stockton. The Soldier's Creek Water Co. has estimated their damage at \$60,000 direct, \$200,000 indirect cost.

A number of new springs have arisen in Settlement Canyon. One of these is believed to have been responsible for an outbreak of 1300 documented cases of Giardiasis in mid-June in southwestern Tooele City. Some springs are believed to have disappeared in the canyon, possibly due to landsliding.

Johnson Pass springs are believed to have run about 150 percent of normal in 1983.

Cooley Canyon, near Grantsville, has a spring that last flowed in 1972 and resumed in 1983. In 1972, the road subsided slightly but it subsided significantly more in 1983 (2.5').

Flowing wells that normally begin to flow in March began to flow after the heavy September 1982 precipitation and continued into October. Since then they have started flowing earlier in the year.

Skull and Rush Valleys have both had high water tables in 1983. State Highway 199 in Rush Valley has had water problems between Highway 36 and the bench. Meredith Sod Farm lost about 50 acres of sod because of the wet ground. Farmland was also inundated by expansion of Rush Lake which local residents believe was last a large water body some 50 or 60 years ago, at which time it occupied about 100 acres. The lake occupied some 2,000 acres in 1983.

Skull Valley, on the road from Timpie to Dugway, was softened sufficiently that two heavy transport carriers were affected; one having sunk, into the asphalt and the other having rolled.

Ground water entering basements was a problem in Burmester, Grantsville and Erda. Highway ramps at Lake Point and Mills Junction, on I-80, were softened.

Problems with erosion occurred in Settlement, South Willow, Ophir (water transmission line washed out; \$25,000 damage), Middle (\$1,000 damage to 4" PVC water line) and Soldier Canyons. Tooele County was given \$359,000 for erosion and sedimentation related recovery work.

Uintah County

Dry Fork is utilized as a municipal watershed because its flow enters sink holes feeding the Ashley spring culinary water source. The upper sink hole was blocked by flood debris and water was diverted into the lower sink hole. A large slump-earthflow-type landslide threatened the lower sink hole, however. The slump was about 100 acres in size and released debris flows down the Dry Fork drainage. It also threatened to dam the creek. Because the city of Vernal's drinking water comes from Ashley Spring, which demonstrated high turbidity, residents were required to boil their water for a period of two weeks in June 1983. About \$10,000 was spent to take immediate measures to safeguard the water supply.

Slump failures on the Red Cloud loop road in Brown's Canyon have been estimated to cost \$112,000 to reestablish the road. The failures occurred both above and below the road (Sec. 14, T2S, R19E). USFS road #10018 in Sec. 23, T2S, R19E was affected when a culvert became plugged by a debris flow out of a side canyon. Sink Ridge Trail, USFS #1032, had slope failures along it for a distance of 2 miles; \$15,000 cost.

A debris flow covered Whiterocks Road (Sec. 23, T3N, R1W), affecting 1/8 mile of road and costing \$7,000.

State Road 264, near Jensen (NW, NE 1/4 Sec. 28, T5S, R23E), moved towards the Green River. South of Jensen (Sec. 21 and 28, T5S, R23E) about 1/4 acre of land was creeping.

Old Diamond Mountain Road (NE, NE 1/4, Sec. 34, T2S, R23E) has moved with a 1.75 acre area which slumped.

In the northern part of the county (Sec. 31 and 32, T1N, R22E) a small slide came down onto the state road in mid-June.

Emergence of new springs under USFS Road #10018, Red Cloud loop in Dry Fork Canyon (Sec. 14, T2S, R19E), for a distance of about 300 feet, incurred costs of \$26,000 for emergency repairs and \$80,000 additional for longer term correction of the problem. Flow of the springs was 20 cfs in mid-June 1983; no discharge was known prior to then.

In the south part of Maesser ground-water at very shallow depth resulted in the deterioration of roads.

Erosion took considerable land along Ashley Creek in June 1983. Expenditure to remove sediment and debris was \$139,000. The Uintah River took out the USGS stream gage and changed channel courses between June 1 and July 1, 1983 across the Uintah-Ouray Indian Reservation. Work to prevent damage from occurring cost \$10,000/day for 15 days (\$150,000), plus \$25,000 heavy equipment repair.

Campground road and culvert damage in the national forest occurred at Paradise Park and East Park in the amount of \$9,400.

Throughout the unincorporated part of the county damage to bridges and culverts amounted to \$350,000. In Vernal, Ashley Creek eroded a culinary water line, culverts, etc., with a damage assessment of \$17,000. Dry Creek in Vernal caused abutment erosion costing \$6,500.

Ashley Creek in Maesser eroded the water system costing \$21,000.

Erosion by the Green River broke through the protective dikes of the Ouray National Wildlife Refuge in five locations. Some 6,200 acres of refuge land was inundated; dike damage amounted to \$300,000.

The county roads department reported that road damage was the worst ever in 1983. One can speculate that a higher moisture content in the subbase was the likely factor which aggravated the frost heaving problem in the Uintah basin.

Utah County

Slide movements began on the benchland (below 5200' elevation) in February. A rotational slide came down onto 1500 East street in Provo, blocking the street and threatening to continue to move farther west into the subdivision. The toe of this slide did continue to creep westward throughout the spring, but stopped short of one single-family dwelling. This slide clearly illustrated a feature of benchland slides in Utah County which became increasingly more evident in 1983: the movement of Quaternary sediments (lake Bonneville age and post Bonneville), riding on a block of intact Mississippian or Mississippian/Pennsylvanian shale that became displaced in the Quaternary or earlier through normal faulting in the Wasatch fault zone or through massive landsliding. Seven additional benchland slumps were spotted from the air on March 21, 1983, and the number increased through the spring between the communities of Highland, on the north, and Provo, on the south. Some residential neighborhoods became affected, with streets, retaining walls, utilities and homes damaged.

Movement of the more than 28 million yd³ ancient Thistle landslide likely was reinitiated by April 10 (Kaiser and Fleming, 1983). By April 14 the toe experienced sufficient vertical uplift to have disrupted three major traffic arteries: U.S. 89, U.S. 6 and the Denver and Rio Grande Western Railroad line. Mapping of the slide vicinity has since been done by the U.S. Geological Survey (Witkind and Page, 1983).

The geotechnical issues are briefly enumerated here:

1. Thickness of the landslide mass.
2. History of past movements.
3. Variation of material properties within the landslide mass.
4. Pore water pressure distribution within the landslide mass.
5. Distribution of fill materials within the landslide mass.
6. Paleogeography of the landslide basin.
7. Irregularities of relief and geologic structure (discontinuities of the right abutment (comprised of Navajo Sandstone hogback).
8. Present factor of safety against reinitiation of partial or total mass movement.
9. Presence of voids within the landslide mass and the effect that future movements could have upon these.

10. Foundation material of the landslide-dam, both within the Spanish Fork Canyon section and below the long sinuous mass at higher elevation to the west. a question of the significance of a local structure called the Thistle Canyon fault and its relationship to a possible diapir has been raised (Witkind, 1986; Willis, 1987).

In addition to these questions, the tunneling, rock cuts, soil fills and terrain modification by man that has been necessitated for the restoration of the arteries and lifelines has opened a succession of other geotechnical questions in the landslide vicinity. Of these, the high rock cuts for the highway across Billie's Mountain (U.S. 6) have been the most problematic up to the present time.

Damages of \$337,000,000 have been documented from the Thistle Landslide alone, including \$139,000,000 to railroad facilities and loss of revenues to the Denver & Rio Grande Western and the Utah Railway systems, \$122,000,000 in mine loss revenue due to four mines having to close down, \$46,000,000 to the Utah Dept. of Transportation and the Federal Highway Administration, almost \$17,000,000 to public facilities, almost \$3,000,000 for disaster relief from government agencies, including individual family grants, and over \$1,000,000 to electric and telephone facilities. The town of Thistle was totally inundated by the reservoir that backed up behind the landslide dam. Losses in Thistle included 17 homes valued at \$1,390,000 and railroad facilities. A 120-mile road detour to Price, Utah had the effect of escalating delivery costs to the eastern part of the state. Unemployment was given a boost and retail sales dropped. Not included in the \$337,000,000 cost are such indirect costs as (1) travel cost increases, (2) loss of trade, (3) tax revenue losses, (4) tourist revenue losses, and (5) litigation expenses.

Debris flows were initiated in the mountainous terrain at the end of May. Dozens of debris flows, triggered by debris slides, occurred between Alpine on the north and Payson Canyon in the south, with most damage occurring in American Fork Canyon. A small slide came through the USFS Little Mill Campground over the Memorial Day weekend and temporarily blocked the campground road. At about the same time two flows blocked the highway just above the USFS Gray Cliffs picnic area. On May 31 it became necessary for the State Dept. of Transportation to close the canyon road, Highway 92, at the mouth of the canyon. On June 2, at 10:30 a.m., another debris flow impacted the canyon, coming out of Tank Canyon. It deposited about 1,400 yds³ along a 700' section of the highway. A greater volume of material is believed to have gone into the American Fork River. This flow left marks 40' above the channel on the rock face on the south side of the river, opposite the mouth of Tank Canyon. Erosion of the channel of the American Fork River ensued and within 20 minutes pavement fell into the river just above Swinging Bridge picnic area within the Timpanogos Cave National Monument, more than 2 miles downstream from the slide. A large section of highway was lost approximately ½ mile below the confluence.

Further upstream, above Tibble Fork reservoir, a very large landslide slump occurred in the area known as Van's Dugway. This slide threatened to block the drainage, thus posing a threat to the integrity of the reservoir. Movement of the toe proved to be slow, however, with the river able to erode it at an equivalent rate. This slide was also regarded as a threat to the National Monument by the U.S. Park Service and resulted in closure of the Park to all visitors for a period of two weeks.

(May 30 through June 14). A 34' bridge of prestressed concrete was displaced in the Monument and water and sewer lines affected, also. Undercutting of a considerable length of retaining rock wall occurred through the Monument site.

Cattle Creek, 1 mile below the Monument, had a debris flow out of it on June 10 at 1:00 a.m., blocking one lane of the highway for approximately 60'. A second larger debris flow followed at 3:00 a.m. and was diverted by debris from the first flow into the river, temporarily blocking the box culvert under the highway. The 12' rise in the channel came to within 1½ feet of the road surface.

The earth slide at Silver Lake Flat, over 1,000,000 yds³, had been creeping for a period of perhaps as long as 12 months prior to May 1983.

The state DOT district geologist reported on a rock slide in the road cut immediately east of Thistle, in the hogback of Jurassic Twin Creek Limestone, on March 2. He also observed deterioration of the high cut ½ mile north of Covered Bridge, in Spanish Fork Canyon. This road cut is in ancient landslide mass.

In Payson Canyon there were several areas of landsliding (figure 15). At the Right Fork (Sec. 11, T10S, R2E), sliding occurred into the creek. At Red Lake, deep cracks appeared in early June, just off of the four-wheel-drive road. Slippage occurred at the Wimmer Ranger Creek switchbacks. There were serious slide repercussions to the Strawberry Highline Canal. In early June, in Sec. 29, T9S, R2E, soil slid out from under the canal, over an area of about 10 acres. This canal functions normally as the emergency runoff canal for diverting water away from town, but it was lost in 1983.

A slide of about 2 acres in area jeopardized the city's culinary water line in Sec. 21, T9S, R2E. Two in Bennie Creek, the larger about 3 acres in size and the smaller affecting a trail, less than .5 acre, also occurred.

On August 18 a small debris flow crossed the road west of the mouth of Hobble Creek. The source slide was in a high road cut, but surprisingly consisted of coarse Bonneville-age,

deltaic sediments. A perched water table was seen to be draining immediately following the episode. This event followed 1" of rain in ¾ hour, with 2½" of additional rain during the previous 4 days. It is quite significant that other bench failures of granular materials were very rare. With the rise of Utah Lake, entirely within the county, the shallow, unconfined water table rose, too, with widespread occurrences of basement flooding (figure 16).

Spring damage occurred to Santaquin and Mapleton city springs, and transmission lines were damaged in the Goshen and Pleasant Grove systems.

In Nephi, Juab County, the water table in the alluvium of Peteetneet Creek flooded basements and increased sewer system infiltration by some 25 to 30 percent. High ground-water pressures caused sink hole activity in the fall of the year in the vicinity of Salem ponds. The late timing was undoubtedly due to the distance from the recharge zone which occurs to the east.

Wasatch County

The earliest landslide in Wasatch County was probably that on U.S. 40 near Keetley, (NE ¼, Sec. 18, T3S, R5E) a slump which involved mostly but not entirely highway embankment fill. This failure closed the road for several days and slowed traffic by way of a detour for the entire time. Slide length was 259'; width, 220'. Original fill slope was 30°. Crown to the overall post-failure slope was 15°. The slide came to rest only 118' from the Ross Creek drainage.

A ¼ mile-square slump was first noticed in late October by hunters in Sec. 7, T3S, R5E, immediately south of Jordanelle. At that time the county requested an evaluation by the writer which disclosed a heaving of the Provo River bed which has resulted in displacement of the channel slightly towards the east. A flume crosses the slide and a natural gas line is in close proximity, but neither was affected.



Figure 15. Payson Canyon landslide. From both road deformation and misalignment of center stripe, creep is evident on this 10-year-old landslide (slump) toe. This historic slide moved no more than this in 1983.

Near Wallsburg (SW, SW, Sec. 33, T5S, R5E) a 150' X 150' slide affected an irrigation ditch in May of 1983.

Four slides are known on Snake Creek. Northwest of Midway in Sec. 17, T3S, R4E, a slide was initiated in the fall of 1982. The slide is linear, about 200' wide by 200' long and enters the creek. Another slide, in Sec. 20, blocked the road for a day, for a width of about 50'. The third is at Epperson Spring, Sec. 21, where emergence of a new spring caused the slide on May 27, 1983, and also interfered with the existing spring which is a water source for the Wasatch Mountain State Park. The fourth area is in Sec. 17 and is in the vicinity of another spring, above a summer home development. Initial movement was prior to 1983; in 1983 there was greater movement and some effect upon the road.

The Center Creek drainage, Sec. 28, 29, 32, and 33, T4S, R6E, has had three slides; these being isolated, however, they are not affecting any facility.

Two small slides that occurred in Pine Creek, Sec. 30, T1S, R10W, have affected USFS Road #083, constructed about two years ago.

High ground water has aggravated problems in the Heber-Midway area, particularly north of Highway 113. The high water table in many places in the county reduced hay yields but no pastureland was lost. In Wallsburg, some basements were flooded. Heber City, with its drainage system, has had few problems in recent time but in 1983 the upper east end of town

had wet basements. Ground-water infiltration into the sewage system was a considerable problem until slip liners were installed on the lines. Road deterioration in Heber City was reported to have accelerated by a factor of two, also.

Erosion-caused damage to the Oak Haven Upper Culinary Water System on May 28, 1983, in the South Fork of Lime Canyon (Sec. 29 and 30, T3S, R4E), amounted to \$15,000. Early June deposition in the Wasatch Canal, north and east of Heber City, was the worst of any previous year, about \$10,000. Heber City had road erosion damage of \$49,000 and Wasatch County, \$242,000.

Washington County

About 5,000 to 6,000 yds³ of material have been creeping along the shoulder of State Highway 27, at Harrisburg Junction (Sec. 33, T41S R14W). This slide first moved upon creation of the roadcut 22 years ago. I-15 also has about a 10,000 yd³ earth movement in the same vicinity.

Further movement has occurred, resulting in ground cracks on the road, south of Leeds, (Sec. 12, 13, 14, T41S, R14W).

Rock falls were believed to have occurred during 1983 in Rockville, Springdale, and Zion National Park, Shuntavi Butte (Sec. 3, T39S, R12W). The latter occurred on July 13.

Figure 16. Embankment construction to protect I-15 from rising waters of Utah Lake (photo by Division of Comprehensive Emergency Management).



Runoff erosion and sedimentation problems in Washington County were not great. The Hall and Grafton Ditch Co. reported \$2,000 damage at Rockville. The USFS (Dixie National Forest) reported bank erosion at the Pine Valley campground and the erosion of fish structures, installed in 1982, by high 1983 runoff (\$500 damage).

Flash flooding was far more severe, apparently, in Washington County in 1983. Springdale had 3" of rain in 1 ½ hours on September 26; damage of \$1,200,000 resulted in the town. The main road, post office and residences had to be dug out from under 2' to 4' of mud and debris. Springdale Consolidated Irrigation Co. reported damage of \$150,000, two thirds of which was direct damage.

Weber County

North Ogden City experienced a debris flood out of Cold Water Canyon in June 1983 which resulted from a debris slide of a few thousand cubic yards in a steep tributary on the south side of the canyon. The city's water transmission line was threatened at the time.

Cost's included \$82,000 to replace two undersized culverts, and \$370,000 to construct a debris basin (figure 17).

Also, at the canyon mouth, on the south side, a landslide developed in early June as a result of the undermining of the steep colluvial slope by the scouring done by the debris flow. While still in flood stage, the stream was able to adjust slightly to the north as the landslide toe encroached.

Valley Drive, just west of the mouth of Ogden Canyon, was closed on more than one occasion by reinitiation of sliding of the ancient landslide debris bordering the road on the south side. April 9 was the date of one such blockage. Seven distinct toe failures occurred in all, along Valley Drive, but the one farthest east was judged to be the most serious because of a linear slide mass having developed behind the toe, upslope to the south. Springs discharging from 1 to 10 gpm were seen to emerge from four of the landslide toes.

To the south, along the bounding headwall of the ancient landslide area there was a greater than normal annual increment of movement. This area, inasmuch as it borders on ten residential properties on 1950 South and Buchanon Street, is checked every year by the writer. Along this ancient scarp a maximum 3' of new displacement of a thin slice of sediments was observed in the spring of 1983. Elsewhere along the old scarp the new displacements were less. The 3' scarplet was about one third the distance from the crown to the toe of the slope but elsewhere, east and west, this changed as well.

Near the eastern limit of this same ancient landslide complex some additional movement occurred on a portion of the mass which threatens a city water line.

On the opposite side of the river bluffs, to the north, there was also very significant landsliding, affecting facilities for hydropower generation, irrigation, and two residential lots (figure 17). The latter location, affecting the two lots, was further west, detached from the eastern slide area and much earlier in genesis. One home appears to have been threatened from further movement. Factors relevant to the slide here include earlier minor displacements of the slope materials, either by landsliding or tectonic; presence of open joints in the

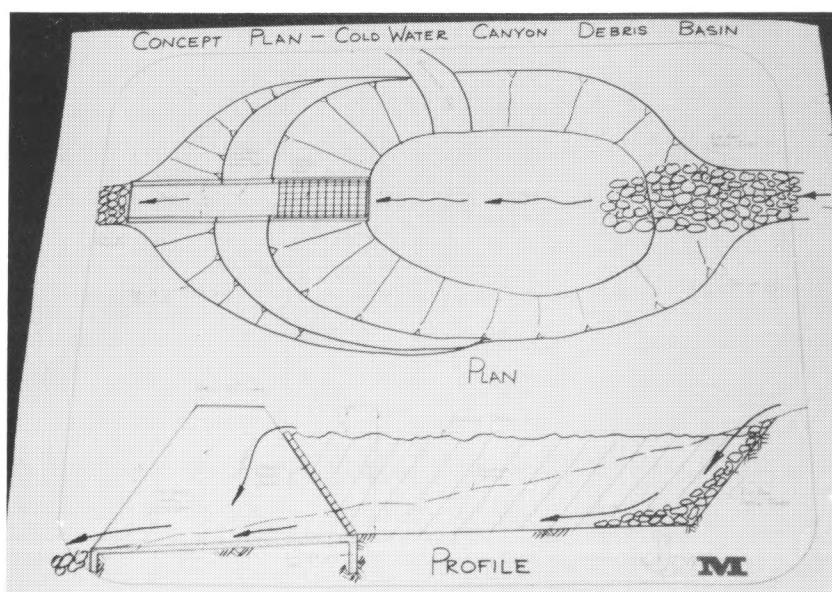


Figure 17. Weber County. Upper: Slide along Ogden River bluff has removed the yards of two homes; Lower: Debris basin design for Cold-water Canyon, North Ogden City.

sediments; perched water table; filling of a gulley at time of subdivision activity; and house and lot drainage in the two backyards. At the time of the main slide, the material flowed rapidly down slope, demolishing a barn and entering a canal. Several horses had only been removed from the barn the day prior to the event.

Within the city limits of Riverdale, along the south bluff, a large ancient earth slump entirely in Bonneville-age sediments became differentially reactivated. Most active region along the tow was the eastern portion but the head moved significantly towards the west. Movement appears to be little more than creep, with movement believed to have been occurring from February through August. Over \$200,000 damage was done to several single family residences, at both the head and tow regions.

Ground water, perched in the benchland, showed up at a couple of new locations, but likely was present in far greater

extent than recognized. Washington Terrace, seepage appeared in the vicinity of St. Benedict's Hospital. At 34th and Polk Streets, in Ogden, perched ground water was pumped from two basements in older homes for the first time. Having been built in a low relief draw (i.e., gentle swale) it is evident that alluvium, rather than lacustrine sediments, was carrying the ground water. Being west of the mountain front by $\frac{3}{4}$ mile, there was a delay between peak runoff and when the problem showed up.

Data from the minutes of the Weber County Emergency Board (9/28/83) show damage from erosion and sedimentation was done to 1,000 acres of cropland, 500 acres of pastureland, and 7 acres of residential property; all together sustaining \$860,000 damage. Facilities added \$128,000 more to the damage assessment of just under \$1,000,000. To the public sector, damage came to well over \$2,000,000.

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