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**ABSTRACTS
OF SPECIALTY CONFERENCE PAPERS**

**DELINEATION OF LANDSLIDE,
FLASH FLOOD AND DEBRIS FLOW HAZARDS
IN UTAH**

June 14-15, 1984

**Utah State University
Logan, Utah**

ABSTRACTS
OF SPECIALTY CONFERENCE PAPERS

DELINEATION OF LANDSLIDE,
FLASH FLOOD AND DEBRIS FLOW HAZARDS
IN UTAH

June 14-15, 1984

Utah State University
Logan, Utah

June 14, 1984

10:30 a.m.

SYNOPSIS OF GEOLOGIC PHENOMENA: WET CYCLE OF 1981 TO PRESENT

Bruce N. Kaliser
Utah Geological and Mineral Survey

Study of the geologic events related to the wet cycle began in spring 1982 with a project being identified in the fall of that year. In May of 1982 a rapid earth flow occurred in granular materials on the benchland of Salt Lake County. It was the clear result of above normal runoff in a small intermittent drainage which provided high infiltration to the local perched groundwater regime. In the winter of 1982-83 aerial reconnaissance was undertaken which identified problems first with low benchland terrain, then at higher elevations. Video tape footage was taken of several of the problem areas in Utah, Salt Lake, Davis, and Weber Counties prior to the crisis period of late spring 1983. The great Thistle landslide started in early April 1983, and was followed by numerous smaller, shallow debris slides in May and June in northern and central Utah. Landslides of all types emerged in diverse geologic terrain.

Effects to Utah's population was significant from high groundwater. Flooding of basements, individual wastewater systems, municipal sewage systems and sanitary landfills resulted. Contamination of shallow aquifers was facilitated and crop yields were significantly reduced from root damage. Sedimentation was aggravated by the volumes of loose earth transported in debris flows and debris floods. Reservoir lifetimes have been reduced and carrying capacity of irrigation systems diminished. Erosion has weakened many types of facilities, particularly drainage structures, at considerable cost.

Moisture sensitive soils are grossly effected; some of these effects are either delayed or are not yet readily apparent.

Local ground collapse has occurred from piping, man-created underground voids and unengineered fill settlement.

An attempt is being made to put a cost estimate on damages from each of these phenomena.

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Session No. 1

11:00 a.m.

LANDSLIDE INSTRUMENTATION

M. K. McCarter
Mining Engrg. Dept., University of Utah
and
B. N. Kaliser
Utah Geological and Mineral Survey

Above normal precipitation and rapid snowmelt triggered numerous landslides in Utah during the spring of 1983. The most frequent occurrence involved shallow debris slides, but other forms of slope failures were also manifested.

It soon became evident that a monitoring capability would be highly desirable for the following reasons:

(1) Partially detached earth masses were left on steep mountain slopes which posed a continuous threat to communities on alluvial fans at the canyon mouths.

(2) The wet cycle did not appear to be over; thus the opportunity would continue for further events in which to acquire movement signatures.

(3) Much could potentially be learned about landslide mechanics from movement monitoring over a winter and spring period.

(4) Problems of a mechanical engineering nature with the devices could be identified over a potentially harsh winter with instrument installation at relatively high elevations.

(5) The flow of information to Wasatch Front communities could be sustained during potentially critical periods.

(6) Initial instrumentation could provide a necessary first step towards a warning system and appropriate response by emergency preparedness officials.

(7) An opportunity could be availed for state and local government - academic cooperation.

Landslides were prioritized in a technical session soon after landslide cessation in 1983 and two were chosen for extensometer and tiltmeter installations; later a third landslide was instrumented in benchland where a circular slide had severely damaged a number of homes. One of the two mountainside slides has been provided with telemetering to two Wasatch Front stations.

The system used for instrument site selection, array determination, station location, threshold identification and information dissemination is critical to success of this first attempt in Utah to instrument natural slopes.

Status: Instrumentation has been installed in three slide areas. Installation of a telemetering package is planned for March 1984. Threshold values are to be established for notification purposes. One of the 14 instrument packages has been damaged by snow loading.

*

Session No. 1

11:30 a.m.

MULTIVARIATE ANALYSIS OF LANDSLIDE-RELATED VARIABLES
IN DAVIS COUNTY, UTAH

Robert T. Pack
Civil and Environmental Engineering Department, Utah State University

During the spring snowmelt period of 1983, over 90 landslides occurred along the Wasatch Front between Kaysville on the north to Bountiful on the south. Watershed segments which produced landslides are compared to watershed segments in the same area which did not produce landslides to determine significant landslide-related variables. Variables employed in the analysis are limited to those which can be delineated from color and near-infrared aerial photography, topographic maps, geomorphologic maps, and geologic maps already available for the area. Principal component analysis is employed in examining the significance of, and relationship between variables. Discriminant analysis is then applied to the watershed segments to try and separate landslide areas from non-landslide areas. A discriminant function is produced which is able to classify watershed segments according to the probability it belongs to the landslide class. The

results of the analysis are presented along with inherent assumptions and limitations involved with inferential statistics.

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SYSTEM OPERATION FOR FLOOD DAMAGE MITIGATION

SESSION NO. 2

June 14, 1984

10:30 a.m.

FLOOD PREVENTION ON THE STRAWBERRY RIVER

Franklin E. Dimick

Utah Projects Office, U.S. Bureau of Reclamation, Provo, UT

Much of the attention of the news media during the spring floods of 1983 focused along the Wasatch Front. Other areas such as the Strawberry River received very little attention. This was due not only to the remoteness of the area but also because flood damage was held to a minimum with the use of storage reservoirs on the river system.

By coordinating the operation of four separate dams controlled by three different entities, the flood flow of the Strawberry River through the city of Duchesne, Utah, was held to a maximum of 1900 cfs. The uncontrolled flow would have been in excess of 4,000 cfs.

This effort required early planning, lifting of restrictions on Soldier Creek Dam, and 24 hour-a-day operation of Currant Creek Dam. The result was not only beneficial to the City of Duchesne but had an effect on the entire river system below Strawberry Dam, including the Colorado River.

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Session No. 2

11:00 a.m.

THE OPERATION OF MAJOR DAMS ON THE COLORADO RIVER SYSTEM THROUGH THE FLOOD OF 1983

John Newman

Water Operations Branch, Bureau of Reclamation, Salt Lake City, UT

Dams built on the mainstem of the Colorado River and its major tributaries were exposed to an extreme hydrologic event in 1983 which forced some structures to operate at or near their design limits. The volume of runoff realized in 1983 on the Colorado River was unprecedented in the past 65 years of recorded flows; however, it did not approach the magnitude of flood for which the major structures on the Colorado River were designed. A chronological day by day accounting of the flooding on the Colorado River itself and the human response to these rapidly changing conditions will be presented, with identification of the myriad of "overnight" structural modifications and unprecedented operational decisions that were required to ensure the safe operation of these structures through this event.

The major structures which will be discussed include: Fontenelle and Flaming Gorge Dams on the Green River in Utah and Wyoming; Blue Mesa, Morrow Point, and Crystal Dams on the Gunnison River in Colorado; Navajo Dam on the San Juan River in New Mexico; and Glen Canyon and Hoover Dams on the Colorado River mainstem. Actions taken at these major dams on the Colorado River were directed toward two major objectives. These were to ensure the structural safety of the spillways and other flow control structures and to limit downstream flooding as

much as possible. The objective of this paper will be to document the decision making which took place during the flooding on the Colorado River, and to provide some rationale as to why such decisions became necessary.

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Session No. 2

11:30 a.m.

FLOOD CONTROL

Lee J. McQuivey
Engineering Division Representative-Sacramento District,
Corps of Engineers

Flood Problems and Lessons Learned

Flood problems and flood awareness in Utah has increased as record setting precipitation and runoff has persisted since the fall of 1982. Serious flooding occurred in northern Utah in September 1982 as a result of runoff from rainfall. Snowmelt runoff in both 1983 and 1984 resulted in widespread flood problems and has vividly portrayed the associated problems of unstable soil conditions, landslides, debris flow, erosion, and deposition of sediment in valley channel reaches. From the flood experience many things have been learned to cope with floods and to reduce flood hazards. These include the need to preserve critical floodplains through zoning, regulation and restrictive development; to avoid placing restrictions across channels; to recognize that channel improvements and dams do not provide complete protection against flooding; that contingency flood control plans should be developed by communities and counties in advance of possible floods; that damages can be minimized through the use of available resources, personnel and volunteer assistance; and that assistance is available through State and Federal programs.

Flood Control

Responsibility for flood control is vested with the individual property owner affected but for extensive flood prone areas may best be resolved on a community, a county, a state, multiple state, federal, or even international basis. Solution of flood problems should begin at the lowest level of responsibility and normally includes problem identification, evaluation of potential structural and nonstructural management measures, and finally development and adoption of a flood control plan. Major efforts are underway by county governments to alleviate flood and related problems through special funding from increased taxes and bonding. The State legislature has appropriated nearly \$50 million during 1983 and 1984 to assist local interests in resolving flood related problems. The Federal government is involved in the Wasatch Front and Central Utah Special Flood Control Study and other ongoing investigations. Investigations normally include an evaluation of cost and benefits and require socio-economic and environmental assessments. Public involvement is an essential element with focus on involving all of those affected. Care must be taken to avoid transferring the problem to another area and to coordinate plans for improvements with all affected areas. Funding of protective measures should also be undertaken at the lowest level of government but should include participation from other beneficiaries in the area of impact.

Conclusions

Efforts are continuing to mitigate flood damages and to restore public facilities, to improve channel carrying capacities, and to alleviate other flood related problems. Effective flood control will require continued effort and support at all levels of government. All problems cannot be resolved by structural measures. Flood control is expected to include implementing practical and

affordable protective and corrective management measures to resolve the most serious problems, developing contingency plans to reduce damages in other areas, and adopting nonstructural floodproofing, flood insurance or "do nothing" measures in areas where protection cannot be economically justified.

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CURRENT EVENTS UPDATE

LUNCHEON

June 14, 1984

12:45 p.m.

Genevieve Atwood
Utah Geological and Mineral Survey

Abstract not provided.

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FLOOD HAZARDS

KEYNOTE

June 14, 1984

1:30 p.m.

FLOOD HAZARD MANAGEMENT - WHO HAS A RULER?

L. Douglas James
Utah Water Research Laboratory, Utah State University

Attractive building sites are causing residential development to move up the hillsides along Utah's Wasatch Front even as wet years remind us once again that rushing torrents laden with mud and debris do suddenly rage out of mountain canyons. In order to balance the advantages of these sites against the risk, developers and planners need quantitative information on the hazard. Engineers need design hydrographs to protect the development that occurs. Past flood hazard studies have not done the job because 1) sparse flow records do not support flood frequency analysis, 2) the amount of damages caused are more dependent on the sediment content than on the peak flow, 3) information is even more sparse for predicting sediment outflows, 4) design floods should be specified by both water and sediment hydrographs, 5) the capacity of a system to convey floods through urban areas depends on both water and sediment flows, and 6) water leaving the channel must be routed through the street network to establish flow depths and velocities on the floodplain. Antecedent conditions include soil moisture storage within the catchment and sediment storage within both the catchment and floodplain ponds and channels.

A simulation modeling approach is offered for assessing the risk in this complex situation. The model outlined will estimate water and sediment hydrographs emerging from mountain canyons and route them through channels and debris basins and then through urban street and storm sewer networks. Multiple hydrograph generations and routings can be used to assess the cost effectiveness of alternative designs and the risks to specific properties.

The processes incorporated into the model are 1) snowpack accumulation and melt, 2) cloudburst runoff, 3) loosening of mountainside sediments by wet soil conditions, 4) erosion from the land surface and in gulleys, 5) routing the water and sediment runoff from subcatchments to the mouth of the canyon, 6) storage of water and sediment in debris basins and ponded areas above culverts, 7) floodplain channel and culvert blockage by sedimentation, and 8) flow through the streets. Concepts, equations, and model structure are presented for each process. Simulated results are compared with recorded data for known floods. The simulated flow through the streets can then be used to estimate depths and velocities and consequently flooded areas and the danger to safety.

The complex simulation model is a measuring device, a ruler in space age clothing. It is used to organize data on interactive soil water stability relationships in catchments and on floodplains and sediment water relationships in alluvial channels to simulate the flooding that would result from given combinations of antecedent and storm weather conditions. Large numbers of sequences can be generated, and the resulting water and sediment flood hydrographs and flooding can be compared.

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DEBRIS FLOWS - IDENTIFICATION AND RUNOUT

SESSION NO. 3A

June 14, 1984

2:10 p.m.

IDENTIFICATION OF DEBRIS FLOW AND DEBRIS FLOOD POTENTIAL ALONG THE
WASATCH FRONT BETWEEN SALT LAKE CITY AND WILLARD, UTAH

Gerald F. Wieczorek, Stephen Ellen, Elliott W. Lips, and Susan H. Cannon
U.S. Geological Survey
and
Dan N. Short
Los Angeles County Flood Control District

In late May and early June of 1983, rapid melting of an exceptionally heavy snowpack in the Wasatch Range triggered numerous debris flows from hillsides, some of which traveled down the main stream channels and beyond the mouths of the canyons; others, diluted by extremely high runoff in the channels contributed large quantities of debris to flooding. Reconnaissance along the Wasatch Front in mid-June revealed many hillsides with freshly-developed scarps and cracks having small offset. These areas of incipient, partly-detached landsliding could mobilize into debris flows from future episodes of rapid melting of snowpack similar to that which occurred in the spring of 1983 or from intense rainfall during summer convective storms. Evidence of historic and prehistoric debris flows were used in concert with an empirical model of debris-flow runout from partly-detached landslides to develop a technique for rating the potential for debris flow and debris flood from canyons along the Wasatch Front between Salt Lake City and Willard, Utah.

We evaluated the potential for a debris flow from a partly-detached landslide to reach the canyon mouth by estimating its potential travel distance through comparison to debris flows that reached canyon mouths in this area during the spring of 1983. Observation and theoretical considerations indicate that for channels of more-or-less similar cross-section, and for materials of similar properties, the ability of a given debris flow to sustain movement depends upon its volume and the gradient of the channel. We used the estimated volume (15,500 m³) of the main debris-flow scar in Ward Canyon as a standard of comparison for major-size canyons and used a volume of 3,600 m³ of the debris-flow scar in Hornet Creek as a standard for smaller canyons that are locally called half-canyons. In drainages with volumes of partly-detached landslides exceeding these standards, the potential for debris flow reaching beyond the canyon mouth was rated as very high. Where volumes of partly-detached landslides were less than these standards, the potential for debris flood was rated very high because of the likely contribution of large quantities of sediment to the bedload of the stream during periods of flooding.

Mapping of prehistoric debris flow and alluvial fan deposits as well as documentation of debris flows and debris floods in this area has existed long before the conditions brought by rapid snowmelt in the spring of 1983. Where more than one historic or prehistoric debris flow was recognized beyond the canyon mouth, the drainage was rated as having a high potential for recurrent debris flow. In a similar manner we evaluated potential for recurrent debris

flood where alluvial fans at canyon mouths suggest a succession of past debris floods. We assigned relative potential for debris flow as very high, high, moderate or low and for debris flood as very high, high or low in 22 major canyons and numerous half-canyons, between Salt Lake City and Willard.

Based on the experience of the Los Angeles County Flood Control District with hydrologic design of debris basins and with design of other mitigative measures we made recommendations for the areas beyond the mouths of canyons for those drainages with a very high potential for either debris flow or debris flood. As a consequence of these recommendations, the Federal Emergency Management Agency, in cooperation with the state and local governments (as of November 1983) has constructed a debris basin below Rudd Canyon, has funded three other debris basins and has discussed as many as 16 other potential debris basins.

*

Session No. 3A

2:40 p.m.

FACTORS INFLUENCING DEBRIS-FLOW RUNOUT

Elliott W. Lips, Gerald F. Wieczorek, and H. Brad Boschetto
U.S. Geological Survey, Menlo Park, CA

Of the thousands of debris flows that occurred in the spring of 1983 in Utah some traveled only a few tens of meters down the hillsides, while others traveled several kilometers before coming to rest on alluvial plains beyond the mouths of canyons. Since the identification of runout distance is necessary in evaluating the potential hazard of a debris flow, an explanation for this wide range of distances is essential for the evaluation. Previous investigators have identified at least four primary factors that effect the distance a debris flow will travel: 1) volume of material in the flow, 2) gradient of the path down which the flow travels, 3) geometry of the channel in which the flow is confined, and 4) composition of the material making up the flow; however, no method exists for relating these factors to runout distance.

We have developed a method of quantifying the relationships between those parameters that were observed to have the greatest effect on debris-flow runout. This method is based on data collected during detailed investigations of eight debris flow deposits located in Sanpete County (Birch Springs and Crooked Creek near Fountain Green, two unnamed creeks near Lower Gooseberry Reservoir, South Fork of North Creek near Mount Pleasant, and Little Clear Creek near Indianola), in Utah County (Pole Canyon near Santaquin) and in Davis County (Ward Canyon above Bountiful). At these sites we took measurements and made calculations for volume of material from the source area, gradients and cross-sections of the channel, width and depth of deposit and length traveled. Samples were taken along the flow path and analyzed for grain size. While at these sites we also mapped distinctive features of the flows on enlargements of recent aerial photographs which we later used for control on stereo pairs in the PG-2 plotter to produce topographic maps of the debris-flow sites. Analyzing this data we developed an empirical model that considers the length of runout to be a simple function of several easily measureable variables. Although we view this model as valid for the sites we investigated, we realize the need to test it on a larger statistical sample before widespread application. By determining the volume of material likely to mobilize, gradient and geometry of the channel, and grain size of the material, the length of debris-flow runout could be determined for other canyons.

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June 14, 1984

3:30 p.m.

RUDD CREEK DEBRIS FLOW

Bruce C. Vandre
USDA-Forest Service, Ogden, UT

By studying the past we hope to learn for the future. However, we need to recognize that past natural events may significantly change the conditions affecting future events. Although conditions may suggest that events will change, the difficult question becomes - Will the threat of consequences significantly change?

During the spring of 1983 a debris flow initiated in the upper portions of Rudd Creek and its effects terminated at an elevation approximately 2800 feet below in the City of Farmington causing extensive property damage. Photogrammetric maps of the channel area, before and after the debris flow, were prepared and compared for geotechnical evaluation. The map changes were interpreted in the light of site inspections, geotechnical concepts, and published knowledge regarding debris flows.

This paper presents the geotechnical study findings and interpretations, discusses the site changes which may affect future events, discusses the major uncertainties, and compares the Rudd Creek Canyon characteristics with other canyons in the vicinity.

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Session No. 3B

4:00 p.m.

COMPOSITION AND DYNAMICS OF RUDD CANYON MUDFLOWS, JUNE 4-5, 1983

Thomas C. Pierson
U.S. Geological Survey, Vancouver, WA

A series of mudflows, occurring during the period of rapid spring snowmelt in 1983, caused catastrophic property damage on the debris fan at the mouth of Rudd Canyon in Farmington, Utah. The third and fourth largest flows to come down out of the small, steep Rudd Creek watershed arrived, respectively, at 10:30 a.m. on June 5 and at 7:15 p.m. on June 4. These flows, triggered by slope failures of saturated soil masses high in the basin, were observed, sampled, and photographed with movie and time-lapse cameras, in the channelized reach immediately upstream of the canyon mouth.

Both surface velocity and horizontal velocity distribution were recorded over the duration of the flows. Preliminary analysis suggests peak velocities ranged between 1 and 3 m/s, which is roughly 2 to 3 times slower than the coarser, less viscous debris flows of similar magnitude and slope measured at Mount St. Helens. The June 4 flow had a peak depth of 1.4 m and a peak width of 4.0 m. The larger June 5 flow reached a peak depth of 2.2 m and a peak width of 4.7 m, and at peak flow the energy slope was 0.11 m/m.

Both flows contained less than 50% gravel during peak flow, and silt and clay contents ranged between 10 and 20%. Maximum sediment concentration of the June 4 flow was 83 wt%. The June 5 flow had a slurry temperature of 12.5°C and its maximum sediment concentration was 88 wt. %. Slurries were densest at or near peak flow and resembled flowing wet cement. Both flows became gradually more dilute during flow recession, changing from mudflow to hyperconcentrated streamflow within 30 minutes of flow-front arrival. A sample of the still-fluid June 5 deposit, collected 4 hours after deposition, had an entrained air content of 1.0%.

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DEBRIS FLOWS IN THE OREGON COAST RANGE: PREDICTING BEHAVIOR
AND RISK TO FISH HABITAT

Lee Benda

Pacific NW Forest and Range Experiment Station, Corvallis, OR

Debris flows, common erosion events in forested steepplands of the Oregon Coast Range, affect forest management, water quality, and fish habitat. I am studying the behavior of these events in Knowles Creek, a 5th order tributary of the Siuslaw River. The results of the study will be used to predict the risk debris flows present to coho salmon and steelhead trout resources downstream. Debris flows in the basin initiate in high gradient areas and transport 2,000-10,000 m³ of inorganic and organic material into lower gradient areas of the channel network where anadromous fish reside. Lengths and volumes of debris flows seem to be governed by specific physical features of the watershed. Channel gradient and geometry, controlled primarily by drainage pattern and location within basin, affect transport, scour, and deposition of debris flows. Long high volume flows (\bar{x} = 1000 m) usually initiate on major drainage divides and pass from 2nd to 3rd order streams in the absence of significant deflection at tributary junctions. Shorter small volume debris flows (\bar{x} = 550 m) usually originate on interflaves and other areas of the basin where reduced gradients and increased deflection occur at tributary junctions. Instream deposits of organic and inorganic debris, and sedimentation, were found to have the greatest effects on fish habitat. The stability of debris flow deposits, and their spatial and temporal effects on fish habitat, were a function of initial volume, location within the basin, composition, and flood frequency. Stream energy, based on drainage area, is a major factor controlling stability of the deposits. Coupling knowledge of debris flow behavior in Knowles Basin with knowledge of the distribution and abundance of fish generated a method for predicting risk to fish habitat from debris flows originating at any point in the basin. Such knowledge will aid land-use-planning and forest management in the region.

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HAZARD MITIGATION - NONSTRUCTURAL MEASURES I

SESSION NO. 4A

June 14, 1984

2:10 p.m.

EFFECTIVENESS OF WARNING SYSTEMS WITH DAM FAILURES IN UTAH

W. Graham

U.S. Bureau of Reclamation, Denver, CO

Dam failures have claimed the lives of about 300 people in the United States in the last 20 years. In Utah, two people have died from dam failures during this same period. The effectiveness of a dam failure warning system is dependent upon the success of the various warning system components. The components of a dam failure warning system can be defined as follows: 1) means for predicting or detecting dam failure, 2) criteria for deciding to warn the population at risk, 3) dissemination of dam failure flood warnings, and 4) appropriate response among the population at risk. Large losses of life can occur when there are faults in any of the first three components. The most tragic failures, however, occur when the first component is unsuccessful, i.e., when the failure is not predicted or goes undetected. Adequate surveillance or monitoring of dams appears to be the key element in avoiding large human losses from dam failure.

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HAZARD MITIGATION - UPGRADING THE "STANDARD OF CARE"

Michael F. Richman
 Van Cott, Bagley, Cornwall & McCarthy, Salt Lake City, UT

1. STANDARD OF CARE - DEFINITION
 - a. Same Locality
 - b. Similar Locality
2. GOVERNMENTS ROLE IN ESTABLISHING "STANDARD OF CARE"
 - a. Reporting Requirements
 - b. Code Control
 - c. Enforcement
 - d. Requisite Expertise
3. SOILS PROFESSIONALS RESPONSIBILITY IN ESTABLISHING "STANDARD OF CARE"
 - a. Compliance with Governmental Strictures
 - b. Utilization of "State of Art" Techniques
 - c. Policing the Profession
4. PROPOSALS FOR UPGRADING THE STANDARD
 - a. Statewide Adoption of UBC § 70
 - b. Statewide Adoption of CDMG NOTE #44
 - c. Professionalizing Governmental Authority
 - d. Registration of Soils Professionals
5. ANTICIPATED BENEFITS
 - a. Reduction in Disaster Related Damage
 - b. Reduction in Cost to Taxpayers for Natural Hazards

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SPECIAL PROBLEMS IN FLOOD HAZARD DELINEATION

SESSION NO. 4B

June 14, 1984

3:30 p.m.

PERIODIC SURGES IN EPHEMERAL FLOODS

Richard J. Heggen
 Department of Civil Engineering, The University of Mexico

Periodic surges, also known as roll, slug, or intermittent waves, have been noted in ephemeral discharge. Such surges may arise from a rapid increase in discharge, or may develop in response to fluid instabilities in steep channels at a steady mean discharge. Periodic surges initiate as small undulations; with growth they become traveling hydraulic jumps.

Periodic surges in flash floods may cause brief but significant spikes in the discharge hydrograph. Associated with the surges are impulses which may substantially exceed the forces associated with steady mean discharge. Surge impulses may affect debris flow, channel stability, and the stability of hydraulic structures.

The analytic fundatmentals of surge hydraulics are identified. Using a case study, criteria for surge formation are identified. Surge form and translation are evaluated. The hydraulic consequences of surges in an ephemeral channel are discussed.

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FREQUENCY ANALYSIS OF THE 1983 WASATCH FRONT FLOODS

Randall P. Julander and Richard H. Hawkins
Watershed Science Unit, Utah State University

The flooding along Utah's Wasatch Front is considered for 15 stations. An unusual combination of antecedent conditions, weather, and geology provoked particularly destructive late season snowmelt flooding and debris movement. Standard Log-Pearson III methods were applied to one-day peaks on existing and extrapolated data for a common time base. In addition, a number of associated watershed and climatic variables were studied as possible causative factors. Based on the analysis, several of the flood peaks were estimated to be of a return period on the order of thousands of years.

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ADDITIONAL STUDY IS NEEDED TO DETERMINE FREQUENCY
OF PEAK FLOWS IN UTAH

Blakemore E. Thomas
U.S. Geological Survey, Salt Lake City, UT

A commonly used approach to define flood-frequency relations for gaging-station records is to use the method of moments recommended by the U.S. Water Resources Council (Guidelines for determining flood flow frequency, U.S. Water Resources Council Bulletin 17B, 1981, 28 p., 14 appendixes). This approach assumes that the annual peak flows fit a log Pearson Type-III statistical-frequency distribution. Using three moments (mean, standard deviation, and skew), the magnitude and frequency of annual peak flows can be estimated. A problem in Utah and other western states is that the annual peak flows at a particular gaging station can result from snowmelt, rainfall, or a combination of both. Using the method of moments, the relation determined for an array of annual peaks from a mixed population usually does not adequately fit the larger peak flows. The U.S. Geological Survey recently has completed investigations in Colorado and Idaho on the flood-frequency analysis of streams with a mixed population of peak flows.

Another method used to analyze gaging-station records with a mixed population of peak flows is to determine the rainfall and snowmelt peaks for each year and do a separate flood-frequency analysis for each array of peaks. The two probability relations then can be combined where the joint or composite probability is equal to the sum of the individual probabilities minus the cross product of the individual probabilities. The composite relation usually will fit the larger peak flows better than a relation based on the array of peaks with a mixed population. For any flood-frequency analysis, the U.S. Water Resources Council (1981) recommends using a combination of the skew coefficient for the gaging station and a regional skew. A regional skew map was prepared for Utah by the U.S. Water Resources Council (1981); however, it was developed primarily for large drainages with snowmelt floods. To use the composite method, regional skew coefficients are needed for peak flows resulting from snowmelt and rainfall. Therefore, a regional skew map is needed for peak flows resulting from rainfall.

Examples of streams in Utah that have flood-frequency relations for mixed snowmelt-rainfall floods will be given. Graphs of the different frequency relations show that significantly different estimates of the larger peak flows can result from using a mixed-population relation as compared to a composite

relation. Streams with a mixed population of floods usually are in a transition zone between high mountains and lower plateaus or valleys. The transition zone in Utah generally is between 6,000 to 8,000 feet; but it varies throughout the state, therefore, the altitudes need to be defined better in order to determine when to use the composite flood-frequency analysis.

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THISTLE LANDSLIDE SESSION

June 14, 1984

7:30 p.m.

THE THISTLE LANDSLIDE

Genevieve Atwood and Bruce N. Kaliser
Utah Geological and Mineral Survey

Movement of the Thistle landslide on the west side of the Spanish Fork Canyon, 0.5 mile downstream from Thistle, has been documented over a period of many years. Relatively minor movements of the toe of the slide had affected the railroad tracks which were on the west side of the canyon. Evidence of headward regressive movement had been reported. The slide had been mapped as 8000 feet long, 900 feet wide at the toe where it is confined between ridges of Jurassic sandstone. Volume was estimated at 25 million cubic yards. The primary geologic unit involved is the North Horn Formation of Cretaceous-Tertiary age. In April 1983, a major part of the slide began to move into the Spanish Fork Canyon elevating both the railroad tracks and the highway on the opposite side of the canyon. After attempts to maintain road and rail traffic through the canyon failed, an attempt was made to keep a channel open for the Spanish Fork River. When this proved impossible, emphasis was placed on controlling the lake that was developing behind the slide. The filling rate was calculated and construction was started on an overflow tunnel through the Jurassic sandstone on the east side of the canyon 170 feet above the river bed. The main mass of the landslide continued to move rapidly, greater than 70 feet of measured lateral movement per day. This mass movement and stabilization efforts which included the transfer of material from the lower foot onto the tow resulted in an engineered "dam" 200 feet high. Earth was moved on the surface of the slide to maintain access to the tunnel portals and prevent overtopping by the lake waters. After major movement of the slide had stopped, the downstream face of the slide was engineered to provide greater stability. Subsequently a drain tunnel was constructed and the lake drained. In addition to the transcontinental rail and highway traffic disrupted by the slide, the lake flooded the community and railyards at Thistle and the highway and railroad into south central Utah. The costs of relocating the highway and railroad, attempting to stabilize the slide, and draining the lake will total well in excess of \$100 million. The railroad to central Utah has not been reopened. The economic loss to the railroad and to the economy of Utah was large. Further movement of portions of the Thistle landslide is likely in the near future, entirely probable in the long-term future, and inevitable in the geologic future.

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Evening Session

7:50 p.m.

ROLE OF THE STATE ENGINEER'S OFFICE AND FLOOD CONSIDERATIONS FOR SPANISH FORK

Dee C. Hansen
Utah Division of Water Rights, Salt Lake City, UT

Abstract not provided.

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Evening Session

8:10 p.m.

THISTLE LANDSLIDE EMERGENCY RAILROAD RELOCATION
THISTLE, UTAH

D. E. Hiltz
Shannon and Wilson, Inc., Spokane, WA

On April 14, 1983, a huge landslide slowly moved 80 to 90 million cubic yards of soil and rock into the Spanish Fork Canyon in central Utah, destroying the Denver & Rio Grande Western Railroad mainline tracks and U.S. Highways 6/89. The slide formed a 220-foot-high dam and the resulting lake which eventually submerged the town of Thistle, threatened the stability of the dam, and jeopardized the town of Spanish Fork.

Shannon and Wilson, Inc., designed and supervised construction of an emergency spillway to prevent overtopping of the dam. By predicting the eventual height of the still-growing dam and by estimating how fast the water would rise behind the dam, Shannon & Wilson, Inc., was able to locate the spillway to minimize the amount of water impounded behind the dam, while still allowing sufficient time for construction before the lake level reached the intake. Round-the-clock construction of the combination rock tunnel and steel pipeline began on April 25 and was completed 20 days later, just three days before the water reached the inlet. The location of the emergency spillway also determined the maximum lake level, thus allowing rail line relocation to begin. Shannon & Wilson, Inc., evaluated the local geology and determined the alignment, support requirements, and construction method for the 3,000-foot-long twin tunnel. The first tunnel was completed on July 3. Rail service was restored on July 4, 1983, completing in just 81 days a project which, under normal circumstances, would have taken more than a year to design and construct.

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Evening Session

8:30 p.m.

RAPID DESIGN AND CONSTRUCTION OF US 650 ON BILLY'S MOUNTAIN

W. Hurley
Utah Department of Transportation, Salt Lake City, UT

Abstract not provided.

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Evening Session

8:50 p.m.

THE EMERGENCY DRAINING OF THISTLE LAKE

Robert L. Morgan, John A. Bischoff, Randall J. Essex,
and S. Thomas Freeman
Woodward-Clyde Consultants, Santa Ana, CA

Beginning in April 1983 the State of Utah Department of Public Safety and the Division of Water Rights, Woodward-Clyde Consultants, and Morrison & Knudsen, undertook an around-the-clock design and construction effort to drain the 53-meter-deep lake that was impounded behind the Thistle landslide after it blocked the Spanish Fork River.

The landslide, which began to move on April 10, 1983, and continued through May 1983, is considered the sixth largest landslide recorded in U.S. history and is, by far, the most costly geologic event ever to have occurred in Utah. The landslide and lake severed major transportation arteries and entirely inundated the community of Thistle. The landslide is an ancient slide mass consisting of debris primarily from the Cretaceous/Tertiary North Horn Formation.

Because the 58 m-high dam formed by the slide possessed unknown physical characteristics and engineering properties, its stability was and is of major concern. The City of Spanish Fork is located in the flood plain just 18 km downstream from the slide. A rapid breach of the dam would flood significant portions of that city. For this reason, the decision was made to drain the lake as quickly as possible and to permanently divert the river around the slide mass through a diversion tunnel.

The emergency nature of the work required that the geotechnical investigations and tunnel design had to be completed rapidly, and concurrently with construction. Following the geotechnical investigations, and after construction of the drainage tunnel began, several alternative lake tapping schemes were developed. Based on cost estimates and total drainage times, the drainage scheme described below was selected and constructed.

The drainage scheme involved the excavation and construction of a 685 m-long, 3.5 m x 4 m diameter concrete-lined, horseshoe shaped tunnel. The tunnel was driven at streambed level throughout the canyon wall forming the east abutment of the landslide. The tunnel was excavated through the massive bedded but jointed Navajo sandstone using drill and blast techniques. Steel sets, with some local reaches of rock bolts, were used for tunnel support. A 60 m deep, 5 m diameter vertical shaft was excavated by a Robbins raise bore machine at a location about 300 m upstream of the dam near the edge of the reservoir and connected with the upstream end of the drainage tunnel. The lake water was drained by benching downward in successive 6 m lifts and excavating a channel "slot" in the canyon wall of Navajo sandstone between the shaft and the reservoir. Two knife gate valves 120 cm and 150 cm in diameter were installed in a tunnel bulkhead just downstream of the tunnel/shaft intersection to control the water discharge.

Design and construction of the tunnel, shaft, and other facilities were completed in less than four months. Drainage was initiated on October 1, 1983, with discharge flows through the drainage tunnel controlled between approximately 800 to 1200 cfs. Drainage of the lake was completed at the end of January 1984.

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HAZARD MITIGATION

KEYNOTE

June 15, 1984

8:30 a.m.

HAZARD MITIGATION THROUGH COMPREHENSIVE EMERGENCY MANAGEMENT

W. Dewsnup
Utah Comprehensive Emergency Management Office, Salt Lake City, UT

Abstract not provided.

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June 15, 1984

9:10 a.m.

UTAH'S LANDSLIDES OF 1983 AS A MAGNITUDE-FREQUENCY
EVENT WITH A FINITE RETURN PROBABILITYAndrew E. Godfrey
Fishlake National Forest, Richfield, UT

Landslides are traditionally viewed as individual events occurring in a closed system and the landslide activity on the Wasatch Plateau in central Utah during 1983 is viewed as an extraordinary event expected only in exceptionally wet years. An alternative approach is to adapt the fluvial hydrologist's magnitude and frequency calculations for flood events to the prediction of landslide probabilities. This paper explores a possible method for calculating landslide magnitude and frequency across the entire Wasatch Plateau. To do this, the more traditional closed system approach is replaced by one in which hillsides subject to potential landsliding are viewed as open systems.

Preliminary results from this study indicate that mass movements in the most unstable areas of the Wasatch Plateau, such as those underlain by the North Horn Formation, can occur with equal probability in any given year. However, the total land area involved is only a small percentage of the entire Wasatch Plateau. Examples of these landslides are the one in Bulger Canyon (1971) which involved 10 acres and the one above Manti (1974) involving about 300 acres. In contrast, the wet year of 1983 produced a higher percentage of area involved in mass movement on the Wasatch Plateau, about 6,500 acres. In addition, the 1983 slides occurred in areas of lower landslide susceptibility than the areas involved in drier years.

When viewed as magnitude-frequency events, the effects of mass movements in shaping landforms can be placed in proper perspective. Although the locations of specific slides cannot be predicted, since statistical analysis results in the loss of a degree of spatial resolution, these magnitude-frequency data, combined with traditional landslide hazard studies, can enhance predictions of hazards to man-made structures.

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Session No. 5A

9:40 a.m.

SOIL SLUMPS AND DEBRIS FLOWS: PREDICTION AND PROTECTION

Robert A. Hollingsworth
Kovacs-Byer and Associates, Inc., Studio City, CA

Debris flows generated by shallow soil slumps present a significant hazard to the residents of hillside areas. Soil slumps are mass failures of the residual soil or colluvium overlying the bedrock on natural slopes. These failures occur exclusively during periods of heavy rainfall. Once the failure has initiated, deformation of the mass changes the soil from a rigid body to a viscous fluid which can move downslope at speeds reaching that of an avalanche.

A method for predicting the potential for soil slumps occurring at individual sites was developed in 1981 for the Santa Monica Mountains of Southern California. This method was based on field observations of failures which occurred during the heavy rains of February 1980. Numeric values of 0 to 4 are assigned to three factors for each site: the soil type, the slope gradient, and the influence of concentrated drainage. The sum of these factors yields a

practical guideline for evaluation of the potential for soil slumps occurring at individual sites.

The San Francisco Bay area was visited in October 1982 to determine whether the prediction method devised for the Santa Monica Mountains was applicable to other areas. The results of the tests and analyses indicate that with a slight modification in the soil factor, the method is applicable. The method, with minor modifications, should also be applicable to other areas. Regional maps of soil type, slope gradient, and drainage factors can be developed for an area and overlain to evaluate the areas most susceptible to failure.

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RAIN, FIRE, AND DEBRIS

SESSION NO. 5B

June 15, 1984

10:30 a.m.

OBSERVATIONS ON SLOPE FAILURES ASSOCIATED WITH THE RAINSTORMS OF
1978, 1980 and 1983 IN SOUTHERN CALIFORNIA

P. M. Merifield
Lamar-Merifield Geologists, Inc., Santa Monica, CA

Widespread damage from slope failures resulted from rainstorms during February and March 1978. Two periods of rainfall culminating in the intense storms of February 9-10 and March 3-4, 1978, brought over 8 inches to some locations in less than 24 hours. Six storms during 9 days in February 1980 brought over 20 inches of rain to mountain and foothill areas. Most of the damage and fatalities were due to debris flows and debris flooding; ten people perished in debris flooding of the small community of Hidden Springs in the San Gabriel Mountains. Much of the flood damage in mountain and foothill areas was associated with burned watersheds, which produced an order of magnitude more debris than unburned areas, causing some recently constructed debris basins to overflow. Both man-made and natural unburned slopes suffered damaging slope failures. Debris flows were largely restricted to slopes vegetated with grasses or other ground cover lacking deep root systems. In general, unburned slopes with deep-rooted vegetation were not characterized by debris flows, debris flooding and other shallow slope failures.

The winter of 1982-1983 also brought greater than normal precipitation to southern California. But rainfall was distributed over the season, and short-duration, high-intensity storms comparable to 1978 and 1980 were lacking. Debris flows and debris flooding were not prevalent, but 1983 was characterized by deep-seated landslides; unusually high ground-water levels were a major contributing factor.

Recommended mitigative measures include regional studies by state and local governments to identify hazardous areas, site-specific investigations by private consultants when properties change hands, and increased efforts to educate the public about landslide and flood hazards.

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Session No. 5B

11:00 a.m.

RELATIONSHIP OF FIRE/FLOOD TO DEBRIS FLOWS

Gerard Shuirman, James E. Slosson, and Delmar Yoakum
Slosson and Associates, Van Nuys, CA

The erosion rate of a watershed can be dramatically increased due to the fire/flood sequence that often plagues California and other semi-arid to arid

areas subject to brush fires and seasonal rainfall. As a result, fire-affected areas will suffer more extensive damages related to debris flows. Case histories in southern California have shown that erosion may be increased by a factor approaching fifty for the first year following a significant burn. High temperature wild fires: 1) change the physical properties of the soil profile causing concentration of coarse-grained particles in the top few inches of the soil profile; 2) develop a wax-like aliphatic hydrocarbon water-repellent zone of 1 to 3 inches below the surface which inhibits infiltration of rainfall; 3) loosen the outer few inches of the soil profile allowing gravity-related dry ravel and rapid erosion from flow water during periods of high intensity rainfall; and 4) destroy the litter and brush which act as a series of natural micro debris basins.

During the torrential rains of 1978 and 1980, the bulking factor for some burned southern California watershed streams ranged from 200% to 500%. Coefficient of runoff for these same burned watersheds appears to have reached approximately 100% for the 15 to 60 minute period of rainfall. This sudden surge of sediment-laden flow was then superimposed upon nearly full bank flow creating the "flash floods" and "debris flows" which caused death and destruction.

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Session No. 5B

11:30 a.m.

THE OPHIR CREEK DEBRIS FLOOD OF MAY 30, 1983--
A REAL TEST OF GEOHYDROLOGIC HAZARD MAPPING

Patrick A. Glancy
U.S. Geological Survey, Carson City, NV

During the early 1970's, the U.S. Geological Survey, in cooperation with the Nevada Bureau of Mines and Geology, initiated a project of environmental and geologic mapping of 7-1/2-minute topographic quadrangles in Nevada. Part of this project involved the delineation of geohydrologic hazards including those related to water-borne flood debris. Flood-magnitude and flood-frequency relations were determined using basin characteristics, streamflow measurements, channel geometry, and available streamflow records for nearby streams. These relations were in turn used to estimate the magnitude of the 100-year flood. (The 100-year recurrence-interval flood is the one most commonly used by local planners for flood-hazard prediction and planning.) Onsite field assessment of debris hazards was related to specific characteristics of the drainage basin and to topography of probable depositional areas. Debris-hazard areas were generally delineated as severe (many large boulders), moderate (a few boulders, but most fine-grained sediment), or light (almost all fine-grained sediment).

The Washoe City Quadrangle, along the east front of the Sierra Nevada between Reno and Carson City, was the first quadrangle mapped. Flood and related debris-flow hazards along Ophir Creek, a drainage basin of about 4 square miles, were evaluated as part of this effort. A peak flow of 2,000 cubic feet per second for the 100-year flood was estimated for the creek near its canyon mouth, less than 1/2 mile above an already existing real-estate development. The map also delineated debris-hazard areas downstream from the flow-estimate site, in the area where housing developments would most likely increase in the future.

No flooding occurred for about a decade after the mapping. But about noon on May 30, 1983--a clear hot day following several days of intensive melting of a record snowpack--a mass of rock and finer grained sediment with associated vegetal cover and snowpack, of 40- to 50-acre extent, moved quickly down the steep southeast face of Slide Mountain. Some of this mass slide into Upper Price Lake, a small 4- to 5-acre pond on upper Ophir Creek. The rapid debris movement into the lake displaced the lake contents and those of a much smaller, adjacent downstream pond, and swept the cumulative contents (20-30 acre-feet),

down the steep canyon of Ophir Creek (25-percent grade). This flood wave gouged debris from the canyon floor and walls, and increased in momentum as it gained mass downstream. After 8 to 9 minutes of travel time at an average velocity of 18 to 20 miles per hour (25-30 ft/sec), the mass arrived at the site of the flow estimate of a decade earlier. The approximately 30-foot-high flood wave of fluid debris is estimated to have had a flow rate of about 50,000 cubic feet per second--25 times greater than the previously estimated magnitude of a 100-year flood. Downstream, the mass killed one person, injured several others, destroyed or severely damaged five homes, buried a highway to a maximum depth of 9 feet, and damaged or destroyed considerable other property (including several vehicles and some livestock). Heaviest damage was caused by debris that included numerous boulders having diameters as great as 12 feet.

The disaster has allowed comparisons between the predicted and actual consequences of flooding and related debris movements. Consequences of the rapid release of a relatively small quantity of impounded water also improved both the general knowledge of flash flooding and the understanding of hazards resulting from failure of small dams.

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HAZARD MITIGATION - NONSTRUCTURAL MEASURES II

SESSION NO. 6A

June 15, 1984

9:10 a.m.

THE GEOLOGIC-HAZARD OVERLAY ZONE: A POTENTIALLY USEFUL TOOL FOR
LAND-USE MANAGEMENT IN HAZARDOUS AREAS

James McCalpin
Department of Geology, Utah State University

Land use management in private lands subject to potentially devastating geologic hazards is fraught with problems. State-level government agencies can delineate areas of high risk, describe the potential hazards, and suggest mitigating measures, but are not empowered with land-use control. Local governments (county, city) do have land use controls, but do not have the scientific expertise necessary to identify and manage hazard areas. A solution to this dilemma has been successfully implemented for about 8 years in a county in the Colorado Front Range Urban Corridor, which has many characteristics similar to counties along the Wasatch Front. In the Jefferson County, Colorado, system, a special Geologic-Hazard (G-H) Overlay Zone was created which overlies pre-existing zone districts in areas identified to be potentially hazardous. The restrictions of the Overlay Zone are in addition to those of the underlying zone district. Prohibited uses within the G-H Zone include buildings intended for human occupancy, and any land use which significantly increases the danger from the geologic hazard. Certain provisional uses may be authorized by county technical personnel, such as roads, fills, utilities, or structures for livestock or storage. Zone boundaries are determined based on published geologic mapping and expert witness testimony, and are adopted within a county-initiated rezoning process. Full disclosure is obtained because the zoning category appears on all property deeds and on maps on file in the respective Planning Departments. The zone may be altered or removed during an application to rezone, if the applicant can supply positive verification that: 1) the hazard as mapped does not actually exist, or 2) the hazard has been successfully mitigated by some remedial measure. The advantages of the G-H Overlay Zone system are: 1) it can utilize federal and state level geologic expertise while maintaining actual land-use regulation within local governments, and 2) zones may be modified once approved, but the burden of proof is placed on potential developers to prove the absence of hazard.

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GEOLOGICAL HAZARDS MAPPING AND RECOMMENDATIONS TO REVISE THE HILLSIDE
ORDINANCES IN PROVO, UTAH

C. Charles Payton and Dale B. Truesdell
International Engineering Company, Inc., San Francisco, CA

In recent years the City of Provo, located on the Wasatch Front, has experienced increasing pressure to allow development of attractive "view lots" on the high elevation benches and hillsides of its "East Bench." Although the area is desirable and picturesque, large parts of the East Bench consist of soil and rock in a naturally fragile state of stability underlain by multiple branches of the Wasatch Fault. In the past, development was planned and designed utilizing inadequate guidelines for foothill development in a geologically hazardous environment.

The wet springs of 1983 and 1984 activated a variety of instability problems including landslides and subsidence that damaged homes, apartments, and other buildings, broke utility lines, and closed streets. The previous hillside ordinance regulations did not adequately consider the implications of geological hazards such as shallow water table, soil conditions, landslide areas, faults, or alluvial fans.

The purpose of this study was to produce geological hazard maps of the East Bench of Provo which would be useful as a basis for revising the existing subdivision regulations on hillside development.

The geological hazards were divided into the following map categories:

- A. No known hazard
- B. shallow water table
expansive soils
- C. collapsible soils
potential landslide
secondary fault
- D. alluvial fan (potential debris flow or flash flood areas)
active landslide
primary Wasatch Fault

Flash flood zones were not part of this study.

The geological hazard categories were ranked in groups from A to D in order of increased potential risk to lives and property and the corresponding difficulty and expense in mitigating that risk.

Revisions to the existing City of Provo subdivision ordinance were proposed to reduce or avoid geological hazards. The revisions were based on new regulations requiring specific geotechnical investigations by qualified professionals for each hazard category. The investigations are to be performed by a qualified engineering geologist, geotechnical engineer, or civil engineer. These investigators must certify that the design of the development incorporates their conclusions and recommendations.

It was recommended that human dwellings should not be constructed over the trace of a secondary fault or within a 50-foot setback from a primary Wasatch Fault. Essential or critical structures, such as high-rise buildings, hospitals, and schools may be subject to a wider setback at the discretion of the City of Provo.

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June 15, 1984

10:30 a.m.

URBAN LANDSCAPING FOR MITIGATION OF FLOOD DAMAGES

Abbas A. Fiuzat
Department of Civil Engineering, Colorado State University
and
Yung Hai Chen
Simons, Li and Associates, Inc., Fort Collins, CO

This paper reports the results of one phase of a comprehensive study of flood hydraulics and flood hazard mitigation on alluvial fans. The conceptual model of an urban development on an alluvial fan was constructed and subjected to various levels of flooding. Among the factors studied were: design of streets to act as flood drainage channels; design of protective flood dikes; construction of elevated buildings on piers; incorporation of drop structures among individual house lots; efficiency of flood interceptor channels; concentration of buildings and/or streets; and other factors. Relative effectiveness of different flood damage mitigation methods are given; design criteria for certain flood damage prevention structures are presented; safety factors for floodproofing structures are discussed and recommendations for proper urban landscaping to minimize flood damage are presented.

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Session No. 6B

11:00 a.m.

LANDSLIDE AND DEBRIS FLOW HAZARD MITIGATION MEASURES
FOR EXISTING DEVELOPMENT

Allen E. Chin
South Pacific Division, U.S. Army Corps of Engineers

The landslide and mudflow disasters in the state of Utah in 1983 showed the vulnerability of communities to natural hazards of this type. There were numerous landslides that caused damage and disrupted transportation. The most devastating slide occurred at Spanish Fork and created a large lake. There were also numerous debris flows and mudflows that caused devastating damages. Probably the most severely damaged areas were developments in Farmington and Bountiful.

Although the state of the art of flood hazard mitigation is well developed and flood plain management has been extensively implemented in many communities, the state of the art of regulating and mitigating the unique hazards of soil instability is not as well developed or extensively implemented. But there are opportunities to mitigate the hazards of landslide and mudflow prone areas in Utah. Structural mitigation measures might include dams, debris basins, and other retention or diversion structures. Nonstructural mitigation measures may include zoning and grading ordinances, public information and warning, slide control for existing development and protecting existing structures against mudflow.

This paper will discuss the different hazard mitigation measures available for landslide and mudflow control. But it will emphasize nonstructural hazard mitigation measures. Generally, hazard mitigation can be categorized into two areas; measures for fairly undeveloped areas and measures for developed areas. Nonstructural hazard mitigation for undeveloped areas normally consists of zoning and regulatory controls to restrict future development to uses compatible with the risk. While hazard mitigation for existing development includes remedial

measures for landslide control on hillside areas and diversion/deflection devices for protecting buildings in mudflow areas.

The Corps of Engineers and other authors have developed techniques for mitigating hazards to existing development. Examples of mitigation measures developed in a recent Corps landslide study will be illustrated. Public information/education brochures on landslide and debris flow mitigation techniques will also be shown because it is important to inform property owners what is involved in mitigating these hazards. Selection of mitigation measures should consider economic and engineering feasibility, legal and regulatory conformity, and environmental acceptability. In summary, this paper will present techniques for mitigating landslide and mudflow hazards in developed areas and provide illustrations of measures that may work.

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Session No. 6B

11:30 a.m.

ALTERNATE DRAINAGE AND RECHARGE OF SURFACE DEPRESSIONS
AND UNDERGROUND AQUIFERS IN UPPER BASINS: AN
ALTERNATIVE IN WATER MANAGEMENT AND LEVEL
CONTROL FOR TERMINAL LAKES

S. A. Jenab, C. G. Clyde, J. C. Batty, J. P. Riley, and J. M. Bagley
Utah Water Research Laboratory, Utah State University

Terminal lakes accumulate all the runoff and salts from their drainage basins. During wet cycles, excess flood waters end up in terminal lakes. Consequently, the lake water level rises and inundates the near-shore areas. In dry years, there is no excess water to run into the lake and the lake water level declines.

Municipalities and industries around a lake are especially vulnerable to extreme fluctuations of lake water levels.

Draining wetlands and shallow groundwater aquifers provides:

- a. water for irrigation,
- b. underground storage space for recharging in wet years,
- c. water for preventing extreme declines of terminal lake water level in dry years,
- d. additional hydropower as the water flows downstream.

Recharging the surface depressions and shallow aquifers provides:

- a. replenishment of the depleted underground water storage,
- b. control of rapid rise of terminal lake levels and the associated inundation of the near shore areas,
- c. moderation of flood damages along rivers.

Alternating drainage and recharge of wetlands and groundwater aquifers in the upper basin helps control the fluctuation of terminal lake water levels, reduces flood hazards to cities, industries, and agricultural lands, and conserves water for municipal and irrigation purposes.

Recorded water levels in the Great Salt Lake in Utah have fluctuated between extremes of 4211.50 in 1875 and 4191.35 feet in 1961. These levels represent 13.6 million acre-feet of water more and 8.0 million acre-feet less than the historical average lake volume at a level of 4201.1 feet. If the lake level is to be controlled between 4202.0 and 4195.0, a total of 12.6 million acre-feet of water would have to be stored elsewhere during the high runoff series of years such as 1875. In the drier years such as 1961, 2.4 million acre-feet of water would have to be released to the lake to hold the level at 4195.0 feet.

In the Upper Bear River Basin, many aquifers offer promising storage-recharge possibilities. In Cache Valley, the aquifers have nearly 40 million acre-feet of storage capacity, and reduction of 100 feet in the groundwater elevation would provide 2 million acre-feet of storage. In the Upper Bear River Basin, the top 100 feet of saturated deposits in the valley groundwater reservoirs contain 12 million acre-feet of water which could be withdrawn by wells and drains.

The alternate draining and recharging of wetlands, surface reservoirs and groundwater reservoirs offer a long term alternative for controlling terminal lake levels which has much merit, and should be thoroughly studied.

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CURRENT EVENTS UPDATE

LUNCHEON

June 15, 1984

12:45 p.m.

L. Tempest
Utah Comprehensive Emergency Management Office, Salt Lake City, UT

Abstract not provided.

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EMERGENCY PREPAREDNESS/RESPONSE

KEYNOTE

June 15, 1984

1:30 p.m.

THE FLOOD OF 1983: SALT LAKE CITY'S EMERGENCY
PREPAREDNESS AND RESPONSE

Albert E. Haines
Chief Administrative Officer, Salt Lake City Corporation

Prior to the Flood of 1983, Salt Lake City had a proposed Emergency Management Plan addressing only floods. The plan consisted of four basic parts: (1) an emergency board and the board's responsibilities; (2) identified internal and external logistical resources; (3) a basic flood control plan; and (4) the definition of the different phases of an emergency. The plan had not been tested until the Flood of 1983. Just prior to Memorial Day the emergency board was activated and a command center established.

The emergency board with advice from the Public Works Department considered the alternatives for handling the anticipated volumes of water. It was decided that the water from Red Butte and Emigration Canyons could be handled using the City's storm drain system. However, the volume of water in Mountain Dell Reservoir was determined to exceed the capacity of the storm drain system. Primarily the 1300 South conduit was not large enough to accommodate the anticipated flow. It was decided to dike 1300 South and run the excess volume of water on top of the street. In three days, working around the clock, 1300 South was bermed from State Street to the Jordan River.

The City planned on handling the flow of City Creek as it usually did, down the North Temple underground conduit. However, City Creek surprised the city crews by peaking with larger water volume than was predicted. The tremendous flow washed out creek banks and uprooted trees. The debris quickly blocked the

North Temple storm drain. The City improvised by calling on volunteers and diverting the water from City Creek down State Street to 400 South and into the storm drain system. It became quickly apparent that the storm drain system at 400 South was not adequate to handle the volume; consequently, the City improvised once more by continuing the "State Street River" from 400 South to 800 South down State Street. This also required the construction of two four-lane, temporary bridges over 500 and 600 South. These two streets are the two main access streets to and from Interstate 15.

While all of the other flooding activities were going on within the city limits, water flows from Big Cottonwood Canyon were threatening the City's water treatment plant. The City sent crews to sandbag and dig channels in order to divert water away from the plant. Otherwise, drinking water to many county and city residents would have adversely been affected.

A number of lessons were learned from the flood experiences: 1) Communications quickly became a critical problem; 2) Command Center physical facilities needed to be changed; 3) Chain of command needed to be less cumbersome; 4) Logistical support and management of volunteers needed to be better organized; 5) Financial documentation and intergovernmental relations were critical because of the need to document the cost of fighting the floods and proving to county, state and federal agencies the legitimacy of such flood fighting expenses.

From these lessons learned, a new Emergency Management Plan was developed, adopted, and implemented. The plan had several significant changes: 1) The Emergency Board was restructured. 2) Intergovernmental relations and volunteers are now being handled by the Mayor's Office. 3) For logistic support the Personnel Department is responsible to see that city employees and volunteers are fed during the emergency period. The Finance and Administrative Services Department will handle purchasing, pre-contracting for services, financial documentation, and city equipment maintenance. 4) For communication support the Police Department is responsible at the stationary command center and the Fire Department is responsible to provide a mobile command center. 5) An on-site or incident commander is designated at each major problem area. 6) The Command Center was restructured to separate the decision makers and support staff.

The experiences of the 1983 flood have made the handling of the 1984 flood effort much more manageable. The new Emergency Management Plan when tested proved workable.

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DAM EROSION AND SEDIMENT FLOW

SESSION NO. 7A

June 15, 1984

2:10 p.m.

A BREACH EROSION MODEL FOR EARTHEN DAMS

D. L. Fread

Hydrologic Research Laboratory, National Weather Service, NOAA

A physically based mathematical model to predict the discharge hydrograph emanating from a breached earthen dam is presented. The earthen dam may be man-made or naturally formed by a landslide. The model is developed by coupling the conservation of mass of the reservoir inflow, spillway outflow, and breach outflow with the sediment transport capacity of the unsteady uniform flow along an erosion-formed breach channel. The bottom slope of the breach channel is assumed to be essentially that of the downstream face of the dam. The growth of the breach channel is dependent on the dam's soil properties (D_{50} size, unit weight, friction angle, cohesive strength, and flow resistance factor), and an empirical factor which accounts for the effects of a grass cover. The model

considers the possible existence of the following complexities: 1) core material having properties which differ from those of the downstream face of the dam; 2) the necessity of forming an eroded ditch along the downstream face of the dam prior to the actual breach formation by the overtopping waters; 3) enlargement of the breach through the mechanism of one or more sudden structural collapses due to the hydrostatic pressure force exceeding the resisting shear and cohesive forces; 4) enlargement of the breach width by slope stability theory; and 5) initiation of the breach via piping with subsequent progression to a free surface breach flow. The outflow hydrograph is obtained through a time-stepping iterative solution that requires only a few seconds for computation on a mainframe computer. The model is not subject to numerical stability or convergence difficulties.

The model's predictions are compared with observations of a breached landslide-formed dam in Peru and a piping failure in the man-made Teton Dam in Idaho. Also, the model has been used to predict possible downstream flooding from a potential breach of the landslide blockage of Spirit Lake in the aftermath of the eruption of Mt. St. Helens in Washington. Model sensitivity to numerical parameters is minimal; however, it is sensitive to the soil cohesion and the empirical grass cover factor when simulating man-made dams and to the soil cohesion and flow resistance factor when simulating landslide-formed dams.

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Session No. 7A

2:40 p.m.

PHYSICAL PROPERTIES AND MECHANICS OF HYPERCONCENTRATED SEDIMENT FLOWS

J. S. O'Brien and P. Y. Julien
Dept. of Civil Engineering, Colorado State University

The authors advance a better understanding of hyperconcentrated sediment flows, commonly referred to as debris flows or mudflows, with a fundamental investigation of the nature of fluid motion. In these flows of large concentrations of sediment, the predominant processes of energy dissipation are related to the viscous, turbulent, dispersive and yield stresses. The relative magnitude of these components largely depend on the fluid properties and whether the flow matrix consists of cohesive or noncohesive sediment. Based on experimental data, the following relationships are provided: 1) stress versus rate of strain, 2) viscosity versus sediment concentration, and 3) yield strength versus sediment concentration. These results expand our knowledge of the physical properties of hyperconcentrated flows.

The authors also review the application of fluid principles to these flows. The fundamentals of fluid mechanics are outlined for the case of hyperconcentrated flows on steep slopes with emphasis on the physical properties of non-Newtonian fluids. A theoretically sound and simplified methodology prescribe the engineering analysis for these hazard flows.

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DEBRIS FLOW THEORY

SESSION NO. 7B

June 15, 1984

3:30 p.m.

MECHANISMS ASSOCIATED WITH UTAH'S 1983 SLIDES AND DEBRIS FLOWS

Roland W. Jeppson
Civil and Environmental Engineering, Utah State University

Climatic and physical factors that contributed to the widespread mountain slides, debris flows and debris floods during the spring of 1983 are studied and

analyzed. Analyses of precipitation data throughout the entire State of Utah, as well as stations within individual climatic zones lead to the conclusion that on a month by month basis the amount of precipitation prior to and associated with the 1983 extensive flooding is only moderately above normal, and statistically not unusual. The rarity of the event is the persistency of month after month of above normal precipitation for nearly a 3-year period of time.

The rapid melting of an unusually large snowpack due to abrupt increases in temperature from unseasonably cool to moderately above normal is believed to have saturated soils in many mountain swales that during other wet water years remained largely unsaturated, and consequently retained their stability on steep slopes with the aid of negative soil water pressures. The mechanics of the reduction in stability as these usually unsaturated soils are subjected to seepage forces that must be resisted for failure not to occur are examined.

The debris flow that took place at the end of May 1983 that deposited 90,000 cubic yards of material over a several square block area of Farmington is simulated by numerically solving the Saint-Venant equations of motion and continuity. This computer simulation is based upon relationships associated with the mechanics of debris flows that appear to describe their pertinent physical flow properties. This simulation is based on the fact that the largest fraction of the volumetric flow at the mouth of Rudd Creek came from channel scour rather than the debris slide that initiated the debris flow.

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Session No. 7B

4:00 p.m.

ANALYSIS PROCEDURES FOR DEBRIS FLOW MOVEMENT

Jey K. Jeyapalan
Dept. of Civil and Environmental Engineering,
University of Wisconsin

While the art of calculating the factor of safety of a slope against sliding and the science of measuring shear strength properties of various types of geological materials are supported by extensive research and practice, very little progress has taken place for predicting the characteristics of debris movement. This paper will review a few procedures for characterizing the rheological behavior of debris and for classifying the flow into various types of segments. Different types of analyses procedures and associated mechanics of debris movement will also be discussed in this paper. Suitable laboratory procedures for measuring material parameters will be presented. A few case histories will be used to illustrate some of the salient features of the phenomenon of debris movement. In addition, a movie of debris flow in motion will be shown as part of this presentation.

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Session No. 7B

4:30 p.m.

HYDRAULIC CONCEPTS IN DEBRIS FLOW SIMULATION

Cheng-lung Chen
U.S. Geological Survey, Gulf Coast Hydroscience Center, NSTL, MS

One-dimensional debris flow (or mudflow) simulation is based on a general viscoplastic fluid model and the basic concepts of open-channel hydraulics. previously developed uniform mudflow formula is applicable to wide channels only.

Extending this formula to a more general case of one-dimensional debris flow in a channel with section of arbitrary geometric shape requires that it be semi-empirically reformulated by replacing the flow depth by the hydraulic radius. Among the rheological parameters yet to be redefined in terms of the hydraulic radius are the yield-stress index (i.e., the relative strength of the yield stress against the bed shear), the Hedström number, and the Bingham (or yield) number. A combination of the Darcy-Weisbach equation with this semi-empirically reformulated uniform mudflow formula further enables one to express the Darcy-Weisbach resistance coefficient in terms of the generalized Reynolds number and the redefined yield-stress index (or alternatively Hedström or Bingham number). In practice, however, generalized Manning's n reformulated by varying it with the rheological parameters and the hydraulic radius is more useful in a full range of laminar and turbulent mudflow. Unlike in wide channels, the momentum and energy correction factors for nonuniform distribution of mudflow velocities over an arbitrary channel section cannot be theoretically evaluated; they are only estimated through velocity measurements in the laboratory or field. The form of the one-dimensional model for mudflow is found to be identical to that for clear-water flow; therefore, the clear-water model can be applied to the mudflow simulation by using the empirically determined momentum (or energy) correction factor and resistance coefficient for mudflows. Experience in modeling debris flows following the May 18, 1980 eruption of Mount St. Helens shows the practical usefulness of this semi-empirically reformulated uniform mudflow formula.

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LEARNING FROM THE PAST: DEVELOPING INCREASED PREPAREDNESS

SESSION NO. 8A

June 15, 1984

2:10 p.m.

AN OVERVIEW OF DISASTER RESPONSE, RECOVERY, AND PREPAREDNESS:
LANDSLIDE AND FLOOD DISASTERS IN CALIFORNIA AND UTAH,
1978-84, AND IMPLICATIONS FOR THE FUTURE

William M. Brown III
U.S. Geological Survey, Menlo Park, CA

California and Utah were beset by a series of natural disasters originating from severe winter storms in 1978, 1980, 1982, 1983, and 1984. These storms produced, at different times and places, high-intensity rainfall, large volumes of stream runoff, heavy snowfall, and large ocean waves. The consequences of these events were widespread debris flows and avalanches, deep-seated landslides, riverine and coastal flooding, and coastal erosion. The magnitude of these processes generally was considered to be very rare in most affected areas to the extent that some of the American West's largest communities were ill-prepared for what occurred, despite decades of meteorological observations and the building of immense storm-defense systems. Whereas the death toll from the storms was almost miraculously low, direct property damage exceeded \$1.5 billion, and costs continued to accumulate during the storms' aftereffects, many of which persist in 1984.

This paper will review the 1978-84 sequence of federally declared storm disasters in California and Utah, notable successes and failures in dealing with them, and the recent and proposed evolution of preparedness for future, similar events. Specifically, structural, monitoring, and warning systems will be appraised, and disaster-prone areas will be identified. The relations among population, development, geographic area, and storm-disaster occurrence will be reviewed. Similarities and differences as to storm impacts in different regions will be discussed with a view toward speeding up information transfer and making best use of other communities' experiences.

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COMMUNITY "HELPING THY NEIGHBOR" PLAN

David L. Scott, M.D.
Pediatrics, University of Utah, and
Davis County Emergency Service

The purpose of the plan is to coordinate and communicate a plan for disaster response in a community, before, during and after a disaster.

The plan provides an organization whereby any individual can communicate his or her needs to the community by passing through at most 3-4 levels in the chain and receive assurance that the community is well enough organized to meet family and individual needs.

The plan considers most disaster situations and has provided an organized response that is preplanned, rehearsed and understood by everyone prior to any conceivable situation. This plan includes means for dealing with evacuation, mass feeding, aged and handicapped, medical needs, crisis intervention and multiple casualties. Strong links have been developed with the county program to provide the plan with cohesiveness and a strong base.

The plan recognizes that perhaps the most important element is a quick, organized response. A well organized communications system, which is being implemented, is a necessity.

Included with this abstract is a 20 page insert which is part of the heart of the program in that it contains the information the family will use to respond to a disaster situation. It requires families to form into neighborhood groups which are also grouped into areas. Areas are then grouped into districts. A community, depending on its size, will have from one to many districts. Bountiful, for example, has 11 districts. The insert has been distributed to every family in Davis County in the back of the South Davis Telephone Directory or the North Davis Telephone Directory which will be distributed in August.

The presentation of the program includes also a 10 minute video-taped dramatized description of how the program works. This tape is intended to be the first of many such video presentations designed to help implement one aspect or another of the program.

The program is exciting in its simplicity and yet far-reaching effect. It is presently being used as Davis County communities deal with the pressures of the spring rapid water runoff.

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DIFFERENT PERSPECTIVES CREATE DIFFERENT RESPONSES

SESSION NO. 8B

June 15, 1984

3:30 p.m.

IMPACTS OF THE WEBER BASIN RESERVOIR SYSTEM UPON
THE OGDEN AND WEBER RIVER DRAINAGES DURING THE
SPRING RUN-OFF AND FLOODS OF 1983

Mark D. Anderson
Weber Basin Water Conservancy District

Weber Basin Water Conservancy District (District) dictates water releases for flood control purposes as follows:

Ogden River drainage - Pineview and Causey Reservoirs;
Weber River drainage - East Canyon, Lost Creek and Wanship Reservoirs;
Willard Bay - for lower Weber flood control.

The main function of these reservoirs is to provide irrigation and culinary water, and reclamation benefits to the people and communities within the boundaries of the District.

Through efficient operation of the reservoirs, it was possible to reduce the peak runoff and effectively reduce damage to the river drainages and communities.

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Session No. 8B

4:00 p.m.

RESPONDING TO THE FURY OF THE COLORADO RIVER--
A PUBLIC AFFAIRS PERSPECTIVE

Kathy Wood Loveless
U.S. Bureau of Reclamation, Salt Lake City, UT

Objective

In meeting the challenges of any natural disaster, one of the most important tasks is disseminating timely, accurate, and relevant information to the public and media. The objective of this paper is to document and analyze how that task was handled in 1983 when the Colorado River Basin received 210 percent of normal flows, resulting in: 1) unique operating procedures at many dams; 2) flooding downstream to numerous residents and businesses; 3) rumors that ran the full gamut from reasonable to ridiculous; 4) over \$30 million worth of damage to the Glen Canyon Spillways alone; 5) a public and media awareness that was not only national, but international in scope; and 6) a series of hearings and investigations by the U.S. Congress and the Government Accounting Office that revealed some areas requiring change while confirming the validity of others.

Summary

The natural phenomena that resulted in the Colorado River Basin's receiving 14.6 million acre-feet when just prior to the runoff period it was expected to receive only 6.7 million has been well documented elsewhere. This paper attempts to explore the human response to that record runoff. As soon as the sudden above-average temperatures of June began to melt the heavy snowpack of April and May, runoff into Lake Powell began to rise so quickly that its full elevation of 3,700 feet was quickly reached. To minimize damage to the spillways from high flows, 8-foot high metal flashboards were added to the top of the spillway gates. These flashboards allowed Lake Powell to hold an additional 1.5 million acre-feet. Notifying concessionaires around the reservoir, as well as recreationists, that the reservoir could rise 8 feet above its "full" level and still not seriously threaten their livelihood required immediate action to reassure them. Other related issues had to be addressed, such as the impact 8 additional feet of water would have on the delicate Rainbow Bridge, having previously been embroiled in litigation.

This action concerned Reclamation because it did not want to set a precedent of operating reservoirs with the use of flashboards. Additionally, spillways were being used at dams throughout the West where they had rarely, if ever, been used before. In western Colorado, Crystal and Morrow Point were used while only the outlet tubes of Blue Mesa were used. Special concern surrounded the operation of Fontenelle Dam in southwest Wyoming, which was seeping water and had been drawn down for monitoring.

Rumors that flashed throughout the West ranged from the Bureau of Reclamation's supposed decision to blow up Glen Canyon Dam, as was reported in the Los Angeles Times; to the Red Cross Chapter Chairman of Sweetwater County, Wyo., telling residents of Green River, Wyo., that they had 72 hours to evacuate because he "knew" Fontenelle Dam was failing; to radio reports in western Colorado that a "6-foot-wall of water" was coming over the Crystal spillway (6 cubic feet-per-second of water was being released). The handling of these kinds of rumors was a special challenge because: a) people for some perverse reason during unusual times want to believe the worst is happening, and b) there is always the suspicion of a "government coverup" of what is really happening.

Reporters from all major newspapers, the three television networks, principal news magazines in the United States, and many media outlets from England, Australia, and other countries either called or visited the Reclamation's Salt Lake City Public Affairs Office to obtain information in covering the event. Managing the flow of information required constant updating by operating officials, use of the latest code-a-phone radio actuality equipment, toll-free telephone numbers, and a staff of writers and documentary photographers.

Finally, following the crisis period, Congressman Morris Udall called for a series of hearings to focus on what had occurred, including how officials responded and what the public's views were. Meetings of the Seven Basin State Governors to review the "operating criteria" (a series of stipulations on how the federal system of dams and reservoirs should be operated) of the river ensued. The Government Accounting Office conducted its investigation. In short, the findings of all were that the Bureau of Reclamation had operated the system of dams according to law, regulation, and prudent judgment; but perhaps some alterations should be made in the operating criteria. Additionally, it was suggested that the various data collecting agencies of the Colorado River Forecasting Service needed more funds and personnel to improve snowpack data collection methods.

Upon conclusion of the flooding emergency, the Upper Colorado Regional Public Affairs Office produced two videotapes that have since received wide circulation and acclaim. The first, "1983: The Record Water Year," outlined the flooding as it affected Utah and the Upper Colorado River Basin. The second, "The Spillways of Glen Canyon," details the damage and repair of the huge spillways, and is updated periodically as the repair work nears completion.

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Session No. 8B

4:30 p.m.

LOCAL FLOOD FIGHT AND CLEANUP RESPONSE

Charles H. Call, Jr. (and other city staff)
Salt Lake City Corporation

This paper discusses Salt Lake City's response to the Flood of 1983. Management of flood fighting and cleanup is discussed. This includes communication, responsibilities, coordination, decisive response, responding to the total problem, applying same level of effort to cleanup process, etc. Both the good and bad aspects of Salt Lake City's 1983 response to flooding will be discussed in an effort to help tailor an efficient plan. Salt Lake City's current Emergency Flood Control Plan will be discussed.

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POSTER SESSION ABSTRACTS

June 14 and 15, 1984

APPLICATIONS OF INFRARED AND OBLIQUE AERIAL PHOTOGRAPHY
FOR DETECTION AND DELINEATION OF GEOLOGIC HAZARDS

Woodrow L. Higdon
Geo-Tech Imagery Int., San Clemente, CA

Photography as a technical tool has been around for many years, but has never been specifically used as an investigative tool by geologist trained in professional photography. The application of specialized techniques, films, and knowledge can significantly improve detection and delineation capabilities for various types of geologic hazards. The effective application requires multiple professional skills in an individual rather than several individuals as the situation presently exists. The end result is ground and aerial photography in black and white, color, and infrared that is specifically generated for existing or suspected geologic conditions. The directions and angles of views are determined by a pre-shooting geologic review of available information on the area, and an on site visual analysis during field shooting. The ability to understand and evaluate geologic data, and to recognize geologic features in the field is essential to the generation of useful and informative imagery. Professional photographic skills applied by geotechnical professionals can significantly improve these areas of information, as well as other areas of information in land use projects.

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DRAINING HILLSLOPES AS A PREVENTIVE MEASURE FOR LOCAL LANDSLIDES

S. A. Jenab and C. G. Clyde
Utah Water Research Laboratory, Utah State University

Landslides are rare but hazardous events of nature. Each year they cause much damage, and force many people from their homes throughout the world. Recent slides in Ecuador, South America, and Thistle, Utah, are examples of such events.

One type of landslide may occur where layered subsurface strata near steep hillside topography causes a perched water table to develop from accumulation of groundwater above layers of low permeability. In recent years in Cache Valley, Utah, landslide events of this type have occurred which have endangered canals, highways, farmland, etc.

Water affects the hillslope landslide problem in several different ways:

- a. By increasing the weight of the overlying material and thus increasing the driving force.
- b. By decreasing the cohesion and the shearing strength of the material.
- c. By eroding of hillside material by the outflowing groundwater above the low permeability layer.

Excessive groundwater seems to be a main cause of many slides occurring in Utah and other locations. If excess water could be drained from the critical seepage area of these hillslopes, the driving force would be decreased, the shearing strength of the soil mass would be increased, the hillside erosion would be reduced and often the slides would be prevented.

In this paper, some theoretical drainage approaches will be made to determine the extent of the necessary dewatering zone, the rates of discharge, and the size and arrangement of drain pipes for effective hillside drainage. Suggestions will be made for the measures needed to prevent such localized hillslope landslides.

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DECISION ANALYSIS IN EVALUATING NATURAL HAZARDS

Brent D. Taylor
U.S. Bureau of Reclamation, Upper Colorado Region

Many federal, state, and local governmental agencies, along with private companies, and individuals continually make decisions involving human safety, economic liability and environmental concerns, in the face of uncertainties as to future natural events, such as landslides and other ground failure hazards, floods, and debris flows, and earthquakes, etc. In these decisions, with economic limitations on each of the different levels of Government and the potentially large cost of many mitigation measures for natural hazards, it is important that costs and benefits be evaluated as precisely as possible for alternative courses of action. There are three basic approaches for decision making on these kinds of problems. One of these approaches includes a risk based evaluation. Risk analysis can be used to evaluate public safety, and environmental concerns, etc., as well as economic damage costs and benefits, and where this approach can be used, it offers significant advantages over the other two more traditional approaches. The three basic decision making approaches are identified and discussed with examples illustrating their interrelationships and individual applications for different natural hazard situations.

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MULTI-HAZARD MAPPING AND DEVELOPMENT CONTROL

Merrill K. Ridd
Center for Remote Sensing and Cartography,
University of Utah Research Institute

OBJECTIVE

The objective of this paper is to present an approach to the identification and mapping of multiple hazards in sensitive landscapes, and to provide technical/legal guidelines for development to minimize hazard susceptibility.

APPROACH

This will be a summary of a case study in Davis County. The investigation was performed by a team of 18 geotechnical/biophysical specialists, each investigating their "domain" and integrating their efforts to effect a comprehensive framework for analysis of complex landscape where multiple hazards interact. The study was performed under the auspices of the Davis County Planning Commission and funded by the Four Corners Regional Commission, NASA, and various state agencies.

The investigation was designed to (1) maximize the use of existing data, augmenting it with new data as time and funds permit, (2) integrate that data into a logical analytical scheme, (3) present the data in a form that is meaningful and useful to non-technical planning professionals and officials, and (4) provide guidelines for development through a model ordinance outline.

The investigation results in a mapping of geomorphic process-form units, which become the frame of reference for statements of hydrologic, seismic, soil engineering, and other dynamic factors affecting landform stability. Ratings of hazard susceptibility for each factor are associated with each land unit. Mitigating measures and ordinance guidelines are then linked to the geomorphic units.

The value of the paper in a conference such as this is, hopefully, to provide a broad view of the several hazards that interact at the sensitive piedmont environment along the Wasatch, and to illustrate on a land unit-by-unit basis how there might be developed a mechanism to analyze and avoid or minimize hazard threats.

The paper will be illustrated with 35mm slides and maps.

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AERIAL RECONNAISSANCE OF HAZARDS AND IMPACTS

Merrill K. Ridd
Center for Remote Sensing and Cartography,
University of Utah Research Institute

The objective of this paper is to illustrate the utility and application of the EPA ENVIROPOD aerial camera system in identifying hazards and mapping impacts of events.

During the past year the Center for Remote Sensing and Cartography has been operating under a memorandum of understanding with the Environmental Protection Agency (EPA) and the State of Utah, to test the effectiveness of the ENVIROPOD in monitoring environmental conditions and changes. With the outset of landsliding and flooding throughout the state, an ample number of targets arose. Some 22 missions were flown for a variety of purposes: flood mapping along the Weber, Ogden, Jordan, and Sevier Rivers; debris flow detection and mapping along the Wasatch piedmont; high water mapping around Great Salt Lake, Utah Lake, and Bear Lake; dike damage detection along causeways and waterfowl areas in Great Salt Lake; and landslide pattern detection at Thistle and elsewhere in the state.

The paper will describe the aerial camera operating system and demonstrate its flexibility and utility in responding to emergency needs. A variety of applications, as indicated above, will be presented. Factors of film type (natural color and color infrared), flying height and scale, flight planning, indexing, and interpretation will be illustrated. The remarkable detail that is detectable from the very high quality film will be emphasized, as will the flexibility of placing the camera in the optimal position with regard to viewing angle, time of day, and exposure conditions.

Access to the system has been fortuitous for the State of Utah during the 1983 season, and promises to be of equal or greater value during the 1984 season. In addition to the above applications pertinent to the purposes of the Specialty Conference, a further application has been suggested by the USU landslide study team in a possible pre-snowmelt detection of ground failure in canyon environments. Such detection may provide a kind of "early warning system," and is certainly worth pursuing as an ideal application of the ENVIROPOD system.

The paper will be illustrated with 35 mm slides, overhead transparencies, and handouts.

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PROTECTIVE DEVICES FOR MITIGATING DEBRIS-FLOW DAMAGE

Robert A. Hollingsworth
Kovacs-Byer and Associates, Inc.

Debris flows generated by soil slumps present a hazard to developments in hillside areas. Where structures are located below natural slopes, protective devices should be incorporated into the design.

Determination of the type and location of protective devices for a particular site should consider the site constraints, including the topography, depth to bedrock, location and direction of concentrated flow, and expected volume of debris. Where adequate area is available to contain the expected debris, retaining devices such as debris basins, retaining walls with freeboard, and slough walls may be utilized. Other situations require the use of self-cleaning protective devices such as deflection walls to direct debris around structures.

Sidehill drains and debris fences can be used in conjunction with other devices. Sidehill drains are placed upslope of other devices to intercept and channel sheet flow runoff and erosion debris. Debris fences are commonly used in canyons to retard the rate of the debris flow, retain a portion of the debris and break up the flowing mass, thereby allowing the escape of any air trapped under the flow.

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ROLE OF TECHNICAL PEOPLE/COMMITTEES DURING CRISIS PERIODS OF GEOLOGIC HAZARD EVENTS

Bruce N. Kaliser
Utah Geological and Mineral Survey

The Utah Geological and Mineral Survey has provided on-site assistance to political subdivisions throughout the state before, during, and after the occurrence of geologic hazard events. 1983 was no exception except that the phenomena were so large in magnitude and impact that two Technical Committees were established: one for the Thistle Landslide, in April, and one for the Davis County debris flow and debris flood events, in May and June. Individuals were sought with expertise in complementary fields, normally from the public sector where their availability could be sustained. Priorities were reestablished on a daily or twice-daily basis. A Technical Committee spokesperson addressed elected officials following each Technical Committee meeting. At the pleasure of the committee of elected officials, the media and the public was addressed by the spokesperson. In open meetings the public was given the opportunity to query any matter on their minds. In this manner the geologic phenomena were explained and removed from the realm of the mysterious.

Assistance insued through the disaster recovery phase with additional expertise being brought in as well. Needs in the engineering and nonengineering spheres were identified and explored with city, county, and state emergency preparedness and recovery officials.

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MINIMIZING THE DAMAGE OF GEOLOGIC HAZARDS THROUGH
LEGISLATION AT THE STATE LEVEL

Jennifer L. Falk
Utah Geological and Mineral Survey

The havoc of last spring's floods and mudslides, together with the October earthquake that shook Salt Lake Valley, have sensitized many Utah residents to the problems presented by geologic hazards. It is thus an auspicious time for taking constructive measures to prevent and minimize the damage they cause. One way to do this is through legislation at the state level.

Usually, legislation concerning geologic hazards is passed in response to a crisis. Due to the lack of time for careful planning and analysis, it often becomes apparent later that the legislation is flawed. Utah now has the opportunity to consider its legislative alternatives and can pass measures best suited to the state and its residents.

The purpose of this paper is to evaluate these choices and their legal implications. California and Colorado face geologic hazards akin to those in Utah. The paper will discuss existing laws in these states and their suitability for Utah, including the circumstances leading to their formulation, cost, mechanism, enforcement, and effectiveness. In addition, the history of the attitude in Utah toward such legislation will be discussed. Specific attention will be paid to the bill recently put before the Utah legislature, and the lessons learned in drafting it and working for its passage.

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475 LANDSLIDES IN THE CITY OF PACIFICA, CALIFORNIA

Vincent N. Pascucci
Howard-Donley Associates, Inc., Redwood City, CA

Heavy rains triggered over 475 landslides in the City of Pacifica, California, in early January 1982. A number of landslides occurred where dense residential development existed at the base of steep natural hillsides. The city retained our geotechnical services in response to the emergency needs of the citizens. At many sites landslides had partially inundated homes with debris. One slide had completely destroyed several houses and buried three children.

It was necessary to identify potential landslide risk areas. Air photo interpretation, topographic maps and air reconnaissance were used to plot areas of potential high landslide risks onto orthophoto maps to develop temporary landslide hazard maps.

Majority of slope failures were shallow and occurred on natural topographic swales with slope angles ranging from 1:1 to 2:1 (horizontal to vertical). Nine slope failures were studied in detail. The failure prone colluvium and residual soil overlies various types of bedrock including Juro Cretaceous Franciscan greywacke, altered volcanic rock (greenstone) and Paleocene sandstone and shale (turbidite sequence). Colluvial and residual soils involved in failure were essentially cohesionless clayey, silty sand with a trace of gravel. Geometry of most of the slope failures was controlled by tension cracks and soil-bedrock contact. A majority of the slope failures were classified as complex landslides and resulted in debris/earth flows. Samples were collected from representative soil horizons and tested for soil properties and strength characteristics. Representative soils involved in debris/earth flows had cohesion values less than 400 psf (19 kPa) and average angle of internal friction of 35 degrees.

The engineering properties were utilized to back calculate the factor of safety against sliding before failure. Total saturation and reduced cohesion because of tension cracks was sufficient to cause a reduction in the factor of safety to within 10 percent of 1.0. Mitigation measures were constructed at three slope failures. Initial repair consisted of constructing retaining walls, drainage systems, impact walls and revegetation. Future mitigation measures included timber cribwalls, baffles to retard soil flow, and containment walls.

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FLASH FLOOD DAMAGES ON THE SANTA CRUZ RIVER

H. S. Oey
Department of Civil Engineering, University of Texas
and
Othon Medina
El Paso Natural Gas Company

In the fall of 1977 heavy rains caused big flash floods in Southern Arizona rivers, in particular the Santa Cruz River. The flash floods caused extensive changes in flow regimes and created peculiar meandering behaviors. An underground pipeline crossing across the Santa Cruz River was exposed due to scour and rendered undesirable necessitating the construction of an above ground crossing in the form of a pipeline bridge. Examination of the river bottom at the crossing site was conducted thoroughly to study the scour pattern. The study revealed that fresh leaves and tree branches were found at depths of up to 17 ft. This prompted us to speculate that during the flood scouring occurred to a depth of 17 ft. or more. This paper also discusses the practical problems involved in trying to find an economical solution.

Analysis of the river behavior and the flood characteristics is presented along with the design philosophy of the pipeline bridge piers taking into account the scouring problems. Innovative construction methods had to be employed. Measures to solve the meandering problems are discussed. Finally, a closing discussion is presented on how the bridge successfully withstood the historically tremendous flood of the fall of 1983, but a new unanticipated problem surfaced because of farmer's measures along the river which alter the stream's behavior.

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REGIONAL INSIGHTS IN DETERMINING EXTREME FLOOD MAGNITUDES

Randall V. Peterson
U.S. Bureau of Reclamation, Upper Colorado Region

Most flood mitigating efforts center around choosing a return period level of protection, determining the flood magnitude associated with this return period, and constructing or zoning to accommodate this flood flow. Of these three steps, the most nebulous is the determination of the flood magnitude of specific frequency floods, particularly for rare events. There are diversities of opinion in determining these extreme frequency flood flows chiefly due to data sparsity and interpretation. From a regionalized analysis of flood runoff, greater insight can be gained regarding the flood potential of a drainage area. The difficulties of predicting extreme frequency flood magnitudes is discussed and a procedure is proposed for a regional relationship for estimating snowmelt and thunderstorm flood magnitudes for specific drainages.

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