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CLOUDBURST FLOODS IN UTAH 1850-1938

By

RALF R. WOOLLEY

With a chapter on physiographic features
By RAY E. MARSELL
and a
FOREWORD by NATHAN C. GROVER

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CLOUDBURST—a definition

The term "cloudburst" is commonly used to designate a torrential downpour of rain which by its spottiness and relatively high intensity suggests the bursting and discharge of a whole cloud at once. Cloudbursts are usually associated with thunderstorms; they may occur anywhere but generally over a relatively small area. They are common in the hilly and mountainous districts of the West, and the resulting floods pouring out from the small precipitous catchment basins are flashy and often destructive.

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FOREWORD

By NATHAN C. GROVER[1]

Cloudburst storms occur in many, if not all sections of the country. As the name indicates, such storms are characterized by intense precipitation that is generally of relatively short duration. On small drainage basins they cause record floods. Many such floods have been reported, but without information as to the amounts or intensities of the rainfall or the magnitudes of the resulting discharges of the streams draining the areas on which the rain falls. As the heavy precipitation falls within narrow boundaries and varies widely within short distances, no adequate records of its intensities or its total amounts are or can be made. The floods follow the storms with short-time warnings and subside almost as quickly as they rise; consequently no reliable records of discharge are generally obtainable. Few adequate reports on cloudburst floods have, therefore, been made, because the data that are essential for such reports cannot generally be made available.

Some sections of the country are more liable to cloudburst storms and floods than others. Among those that are especially liable are the western and southern fronts of the Wasatch Mountains of Utah. Here the conditions of topography and temperature appear to promote the formation of cloudburst storms, and the steepness of the slopes and their lack of sufficient vegetation to form a sod permit quick surface runoff and heavy erosion. There have, therefore, been many storms and floods of the cloudburst type in central and southern Utah, some of which antedate the known history of the region. They have been partly responsible for the carving of the mountains into peaks and valleys and for the debris fans that mark the passage of the streams from the mountains to the plains.

Mr. Woolley has compiled and studied the available information on cloudburst floods in Utah. As for other areas, specific data on intensities and amounts of precipitation and magnitudes of discharge are lacking. Such information has not generally been obtained and is not obtainable. He has been fortunate, however, in that graphic though fragmentary records of these floods over a period of nearly a century have been published in the newspapers of Utah. The Deseret News, especially in its more than

[1] Mr. Grover was formerly chief hydraulic engineer of the Geological Survey, U. S. Department of the Interior.

90 years of existence, has been an invaluable source of information. From the files of the newspapers Mr. Woolley has compiled the records written by eyewitnesses of many of these storms and floods. By means of this impressive array he shows the liability of the region to cloudburst floods and presents the results of a study of the relation of man's occupancy and use of the lands to the magnitude and devastating character of the floods.

Differences of opinion with respect to the relation of man's activities to the floods are made apparent by Mr. Woolley's observations, based on his studies and quotations made from published reports. One school of thought believes that man's activities have been one of the major causes, not perhaps of the storms to which the region is subject, but certainly of the devastating character of the resulting floods. This school holds that the reduction in vegetal cover caused by grazing, in a country that is so arid that even optimum conditions do not produce sods to check or prevent erosion, has been sufficient to permit destructive erosion in places where there would be none under natural conditions and to lead to quick runoff and, therefore, to such concentration of flood waters as to produce disastrous flood discharges and mud flows. Mr. Woolley does not agree with this school. He believes that the activities of man have had a minor rather than a major effect on the magnitude and effect of cloudburst floods, and he has presented facts to support his views. As in nearly all pioneer discussions involving new fields of thought the facts may not immediately be convincing to every one. They will, however, provoke thought and lead to valuable discussions of the problems related to the causes, effects, and possibilities of control of these floods.

Of the facts presented or of the thoroughness of their presentation there can be no doubt. There have been cloudburst storms in Utah and floods accompanied by mud flows ever since the earliest settlements were established and before man's activities could have borne any possible relation to storms, floods, or erosion. To be sure, more floods have been recorded in recent than in earlier years. Opinion differs, however, as to whether there have actually been more floods that have caused disaster, as some observers believe, or whether there have been no more or worse floods but more have been reported because there were more settlements and therefore more lives and property in jeopardy, as Mr. Woolley believes.

Mr. Woolley is a lifelong resident of Utah. His relatives and friends are among those who have suffered from the effects of cloudburst floods. He has studied closely over many years the facts and problems discussed in this paper. He has presented some of his information in another report which relates to a part of the State that is subject to cloudburst storms.[2] The bulk of his information with respect to cloudburst floods and to the effects of man's activties is, however, contained in the present report.

The problems related to the possibilities of controlling the floods of Utah do not fall within the scope of this report. In a few places levees have been built to confine the flood waters within predetermined channels across the debris fans. Such control may be effective until subsequent mud flows clog the channels. The Forest Service and the Soil Conservation Service have attempted to control floods at their sources by terracing, by contour storage, and by planting and stimulating the growth of vegetation. The success or failure of these efforts is still uncertain, as it has not been demonstrated that any of the projects has withstood a storm of the magnitude of those that produced the historical floods. In general, the topography is too steep to make feasible the construction of storage reservoirs for the control of cloudburst floods.

Mr. Woolley believes that cloudburst floods will continue to occur in Utah and that property and lives will continue to be lost, because the debris fans will be occupied by farms and homes, and such losses will be part of the price paid for the occupancy.

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[2] Woolley, R. R., Utilization of surface-water resources of Sevier Lake Basin, Utah: U. S. Geol. Survey Water Supply Paper 920 (in press).

CLOUDBURST FLOODS IN UTAH

By Ralf R. Woolley

ABSTRACT

Introduction.—Five years after the first settlement was made in Utah, at Salt Lake City in 1847, it became manifest to the settlers both there and at Manti that "cloudbursts" were of common occurrence in this region. Other settlements were made and gradually expanded on the steep alluvial fans of the mountain streams, and reports of cloudburst storms and their attendant floods became increasingly numerous as farms and homes were damaged by them.

In 1890 the theory was advanced that these floods occurred because the sheep and cattle had eaten off the vegetation in the hills, leaving nothing to hold the water back. This indictment of man's flocks and herds has become so common that during the past 20 years considerable study has been given to it. Most of the study, however, has been devoted to runoff from the catchment basins and factors involved in its control and little of it to an adequate scientific analysis of the relationship between physiographic and geologic features and the meteorologic phenomena involved in the storms.

Physiographic features.—Utah has an area of 84,916 square miles, of which 2,570 square miles is covered by lakes and rivers. Its altitude ranges from 13,498 feet in the northeast part to 2,500 feet in the southwest corner. The approximate mean altitude is 5,500 feet above sea level. Mountains and high plateaus occupy roughly the east half of the State and deserts the west half. Dark-colored soils characterize the mountain valleys and upland areas, where rainfall has been sufficient to cause a vigorous growth of grass and other shallow-rooted vegetation. Gray desert soils characterize the western desert areas, where rainfall is too scant to produce much vegetation. A little more than 14 percent of the State's area is included in national forests, about 4.3 percent in crop-farm land, and about 80 percent in grazing land.

Climate.—Climatically the State is divided by the Wasatch Mountains and high plateaus into two regions of approximately the same size. The seasonal distribution of temperature is about the same in both regions, but there are marked differences in the seasonal distribution of precipitation. Approximately 22 percent of the State has an average annual precipitation of 15 inches or more, about 30 percent has 10 to 15 inches, and 40 percent has 5 to 10 inches. The remaining 8 percent, comprising principally the Great Salt Lake Desert, receives less than 5 inches a year.

Cloudburst storms occur rather promiscuously throughout the State, being more frequent in the southern and eastern sections. The precipitation continues for 20 to 30 minutes on the average, though rarely it may continue for an hour or more. The extreme rates of rainfall in the mountains of Utah are not definitely known. In the afternoon of July 7, 1933, an unusual cloudburst at Bryce Canyon, in the High Plateaus (8,000 feet in altitude), yielded 0.9 inch of rain in 10 minutes.

Cloudburst floods.—Most of the cloudburst floods originate in areas below 8,000 feet in altitude. The most violent discharges originate in drainage areas of 10 square miles or less. Estimated flood discharges from many of the

smaller catchment basins range from 400 to 600 second-feet a square mile. Only a few communities in the State have not experienced cloudburst floods.

Present-day news reporting of these floods has a tendency to dramatize them, intensify the public interest in them, and develop a belief that such floods are much larger and occur oftener in the present than in previous times. Two 3-year periods are equally high in the maximum records of such floods since 1847, namely 1899-1901 and 1930-32.

Mudflows.—The mudflow is a manifestation of a cloudburst. It is a well-lubricated mass of alluvium that is spewed from the canyons in a fan-shaped deposit like a huge sheet of mortar or concrete. These flows make up the material in the innumerable alluvial fans that fringe the bases of the mountain ranges throughout the arid West. There are hundreds of such fans in Utah.

Historical floods.—More than 500 reports of outstanding cloudburst floods since 1847 indicate that at 112 different times farm crops, usually in small patches and varying in amounts, have been destroyed. Stretches of highway have been washed away or covered with mud and boulders and bridges destroyed about 140 different times; canals and diversion dams have been damaged more than 70 times; and railroad tracks have been washed out or covered up more than 60 times. Cities and towns have had streets flooded no less than 100 times, and homes have been either washed away or filled with a few feet of mud. Power plants and pipe lines have been damaged more than 25 times, and at least 26 persons have lost their lives by drowning.

Relation of cloudburst floods to settlement and land use.—The average density of population in Utah is little more than 6 people to the square mile. It varies from a minimum of 0.5 person to the square mile in Daggett, Grand, Kane, and San Juan Counties to a maximum of 257 persons to the square mile in Salt Lake County.

Most of the present towns in Utah were established by 1880, and at that time the population of the State was 144,000. More than 230 towns in the State have experienced one or more cloudbursts. From 1880 to 1930 the population of the State increased 350 percent, the number of farms 290 percent, and the area included in farms 860 percent.

Practically all lands adjacent to water courses, and consequently those most subject to cloudburst floods, are now in farms. Although cloudburst floods are numerous and occur all over the State, less than 1 percent of the total area in farms has been devastated by them. In a few places homes and highly developed orchards, garden farms, and city lots have been obliterated. Such works as pipe lines, canals, power plants, railroads, and highways have been repeatedly damaged by floods and some projects have been abandoned, but ordinarily the damage is repaired after each flood, and the costs involved are considered a price paid for occupancy of the respective sites.

Economic importance of areas affected by cloudburst floods.—The actual value of physical property that has been rendered useless by cloudburst floods in the State would be exceedingly difficult to determine. It is apparent from available data that beyond an insignificant amount of improved farm land and a few small homes and small power plants there would be little if any monetary value involved. Records of the State Tax Commission fail to show a devaluating effect on property in any county or community because of damage from cloudburst floods. Apparently such damage is absorbed as a charge for occupancy of the areas involved.

AUTHORIZATION

In June 1938 the President approved an allocation of funds by the Public Works Administration to the Geological Survey for "surveys of floods and droughts, of run-off and its relation to rainfall, and of other factors affecting the variations of water supply, in order to make available information that is essential for the design and construction of projects relating to water utilization and control."

As one assignment under this allotment, studies were made of cloudburst floods in Utah, and the results of these studies constitute the basic data for this report.

ADMINISTRATION AND PERSONNEL

The work was performed in and from the Salt Lake City office of the division of water utilization of the water-resources branch of the Geological Survey under the general administrative supervision of Nathan C. Grover, chief hydraulic engineer, and with the advice and counsel of R. W. Davenport, chief of the division of water utilization.

The personnel and the periods worked up to the time the allotment was expended, September 1, 1939, were as follows:

Regular employees:

- Ralf R. Woolley, senior hydraulic engineer, part time.

Temporary employees:

- Dean F. Peterson, Jr., junior engineer, July 16 to September 21, 1938, and June 22 to August 31, 1939.
- James M. Fox, recorder and junior engineer, September 21, 1938, to August 31, 1939.
- Robert C. Dewey, recorder, August 5 to December 31, 1938.
- Lucius M. Hale, recorder, April 3 to May 20, 1939.
- Albert I. Gabardi, rodman, August 8 to October 1, 1938.
- J. William Hasler, rodman, August 8 to December 31, 1938.
- Owen D. Thomas, rodman, September 30 to December 31, 1938.
- Ruth H. Glissmeyer, junior clerk-typist, May 1 to July 31, 1939.

Detailed field studies and surveys were made from August 5 to December 31, 1938, of the Snowslide and Lost Canyon catchment basins tributary to Provo River, and of Parrish, Ford, Steed, and Davis Creeks, in Davis County, and channel cross sections were surveyed at several places along the Virgin River for use in studies of slope-discharge relationships.

The field work was begun under the direct supervision of Dean F. Peterson, Jr., and was continued from September until its conclusion under the direct supervision of James M. Fox. It included the topographic mapping of the area under study, by Dewey, Gabardi, Hasler, and Thomas and research on the physiographic evidences of past floods, the historical records of such events and recollections of eye witnesses and long-time residents, the character of materials in the alluvial fans, the character and extent of the soil and vegetative cover of the catchment basins, and the behavior of mudflows, by Peterson and Fox, assisted occasionally by Hasler. Volumetric estimates were made of alluvial fans and recent individual mudflows. Sieve analyses were made of alluvial deposits and the specific gravity of rock materials was determined. Weights of large boulders were determined from volumetric and specific gravity determinations.

The field work was necessarily limited by the time allotted for the project and the short season available. Two areas, one in Provo Canyon and the other along the Wasatch front in Davis County, were selected for study because of their widely different physiographic features, their records of cloudburst floods, and their easy accessibility. Field work was concluded December 31, 1938, owing to snow. In March 1939 volumetric estimates were made by Mr. Fox of the alluvial deposit from the flood of 1936 at Willard, in Box Elder County, and also of the total amount of material deposited behind the flood barriers constructed there in 1924. In April 1939 he conducted some field experiments in the artificial production of mudflows in miniature, and observed the mechanical characteristics of such flows.

From January 1 to August 31, inclusive, Fox devoted his time to assembling and abstracting reports on cloudburst floods, making meteorologic studies, assembling and reviewing all the available literature on mudflows and related phenomena, and assisting in preparing the text for this paper.

Mr. Hale did some drafting and computing work in connection with text figures.

Mr. Peterson devoted his time in 1939 to analyzing field data relative to the Snowslide and Lost Canyon areas and to the preparation of material for use in this report.

SCOPE OF REPORT

The area covered by this report was purposely limited to Utah primarily because the time and funds allotted for the project were insufficient to assemble and analyze the data for a larger area that might be comparable to those available for Utah. Furthermore, most of the data for Utah were readily assembled at Salt Lake City, and little field travel was necessary. An attempt is made in this report to present information on the physiography and climate of Utah in their natural relation to cloudburst floods and the general processes of degradation characteristic of the area.

It is obvious that a report of this kind for an area in which the local differences are so complex must be restricted to some extent in the amount of detail it gives, and for this reason no attempt is made to cover all the small individual drainage basins that have cloudburst floods. It is believed, however, that the material in this volume at least indicates the natural processes that produce these floods and that these processes are quite independent of man and his activities, although the results of the floods may be somewhat influenced by these activities.

COOPERATION AND BASIC DATA

The writer wishes to express appreciation to all who have cooperated with him in the preparation of this report. The generous contribution of information by those who may be considered experts in their field of work adds value to a work of this kind and is a source of confidence to its readers. Special acknowledgment is made to Mr. J. Cecil Alter, meteorologist, United States Weather Bureau, Salt Lake City, for his cordial and helpful cooperation, his constructive suggestions, and his critical review of the section on climate.

The basic data were obtained from all available sources. An effort has been made by the writer during his 28 years of intimate contact with the development of the State to accumulate all the information he could regarding its natural resources and especially that pertaining to the characteristics and utilization of the streams.

The historical data have been gathered by personal research and, for the later years, by the aid of the Utah Federal Writers project. Helpful suggestions and many photographs of flood damage were very graciously contributed by L. M. Winsor, district engineer, Division of Wild-life Refuges, United States Biological Survey. Flood data resulting from hearings conducted in Utah by the Corps of Engineers, United States Army, were made available for review by the writer at Los Angeles, and additional statistics on flood damage throughout the State were made available by Sumner G. Margetts, director, Utah State Planning Board.

PREVIOUS STUDIES

As population has increased and settlements have continually pushed man's activities farther and farther onto the natural flood plains of the mountain streams, reports of floods have become increasingly numerous, and damage to property from them has become correspondingly more frequent. This condition has given rise to the belief that floods are actually more numerous now than in times past and that man's coming and his activities have been the cause of it.

This belief has attracted a great many disciples and has become a popular dogma among them. It has tended to picture erosion—a normal geologic process that has contributed to the sculpturing of mountains, plateaus, plains, fertile valleys, canyons, and mesas since time began—as unduly dominant in the aspects of a horrible monster of destruction and a public enemy. There is a tendency to overlook proper distinction between the normal geologic process and what has been defined as "accelerated erosion," and to charge it all, including the alleged greater frequency of floods, to man's lack of wisdom in his use of the land.

In Utah the causes of these floods and measures of protection against them have become matters of serious concern to an increasing number of citizens. Different theories have been advanced as to their causes, among them that the climate is changing and that rainfall is in some way affected by the presence or absence of forests and other forms of vegetation. Capt. Thomas H. Bates wrote to the Utica, N. Y., Herald in the spring of 1875[3] giving as his opinion that the construction of railroads had been the chief means of inducing a greater spring and summer rainfall in Utah.

The Manti Sentinel,[4] in an account of a flood in Manti Creek on July 13, 1890, advanced the theory that "on account of the sheep and cattle having eaten off all vegetation in the hills near the town there is nothing to hold the water or in any way arrest its flow. The consequence is that a heavy rain instead of soaking into the ground rushes down the creek, flooding the country below and usually doing more harm than good." This indictment of man's flocks and herds has become so firmly established that the layman may be excused if he believes that sheep and cattle are the primary cause of floods. In a study made by Reynolds[5] in 1910 of the relation of grazing to floods in a district of the Wasatch Plateau in central Utah it is suggested that the partial denudation of the mountain slopes as the result of grazing between 1880 and 1902 was responsible for serious floods between 1888 and 1910. A later study by Forsling[6] states:

[3] According to the Deseret News, Salt Lake City, Utah, May 13, 1875.

[4] Published in Manti, Utah. Account republished in Deseret News, Salt Lake City, July 21, 1890.

[5] Reynolds, R. V. R., Grazing and floods—a study of conditions in the Manti National Forest, Utah: U. S. Forest Service Bull. 91, 1911.

[6] Forsling, C. L., a study of the influence of herbaceous plant cover on surface runoff and soil erosion in relation to grazing on the Wasatch Plateau in Utah: U. S. Dept. Agr. Tech. Bull. 220, p. 3, March 1931.

Grazing was greatly curtailed in the late nineties and has been carefully controlled since on the Manti Canyon watershed, one of the drainages concerned. In August, 1909, heavy rainstorms caused severe floods in the adjacent canyons to both the north and south of Manti Canyon, while the latter was not perceptibly affected. Manti Canyon had then had the benefit of several years' recovery from severe overgrazing, whereas the adjacent watersheds were still in bad condition. Since 1909 no flood of any consequence has occurred in Manti Canyon, although badly depleted portions of adjacent watersheds have had several bad floods.

The Manti Creek drainage basin is an excellent example of what geologists describe as "landslide" topography. Huge masses of the Wasatch Plateau, into which the basin is advancing, become unstable through natural weathering processes and slough off into the canyons, leaving almost vertical walls and piling from hundreds to thousands of tons of unconsolidated earth, rocks, and trees and other forms of vegetation in the bottom of the V-shaped canyons. These piles of debris are flushed out of the canyons by cloudburst and other heavy storms and are deposited over the alluvial fan of Manti Creek, upon which the town of Manti is situated. Beginning with the first record of a disastrous flood, in 1852, no less than 14 cloudburst floods have debouched from Manti Canyon. There have been intervals of 10, 15, 20, and 27 years without such floods being recorded, but sooner or later the storm strikes and a flood results. The most recent records show that a damaging cloudburst flood came from Manti Canyon in July 1934, when there were three crests, and that another came in July 1936.

To remove the destructive debris from mountain streams in the State a "barrier system of flood control" was developed by Winsor[7] in the early 1920's.

The first works of this type were built at Nephi in 1922. Other similar projects were built on many of the streams during subsequent years.

Soon after the cloudburst floods in Davis and Box Elder Counties on August 13, 1923, a study was made by the late Frederick J. Pack, professor of geology, University of Utah, of the flooded areas around the towns of Farmington and Willard. In the published report[8] of his study he says:

By far the outstanding feature of the entire flood is the enormous size of the boulders carried by it. Literally thousands of boulders, weighing five to ten tons each, are strewn along its path. Toward the apices of the cones the boulders become larger. At Willard and elsewhere fully a score of boulders have been measured, any one of which weighs 20 to 60 tons. The largest

[7] Winsor, L. M., The barrier system of flood control: Civil Engineering, vol. 8, No. 10, pp. 675-678, October 1938.

[8] Pack, F. J., Torrential potential of desert waters: Pan-Am. Geologist, vol. 41, pp. 349-356, 1923.

boulder found is situated near the apex of the fan at Willard. It weighs very close to a hundred tons and was carried for half a mile down a slope of approximately eight degrees inclination and then for nearly the same distance on a six-degree slope. It consists of quartzite and is roughly rectangular in form. Its dimensions, after due allowances were made for irregularities, were measured as follows: 14 feet from left to right, 7½ feet from bottom to top, 11 feet from front to back. Based on a specific gravity of 165 pounds per cubic foot, the mass weighs 190,575 pounds, or 95 tons.

In support of the theory that denudation of the watersheds caused the cloudburst floods of 1923 a paper was prepared by Paul and Baker.[9] Most of this pamphlet is devoted to a discussion of the relation of vegetative cover to the runoff from the watersheds. The authors conclude that such storms as described therein are not uncommon in the mountains, and therefore artificial denudation is the principal cause of the flood.

In recent years geologists have placed increasing emphasis on the potency of mudflows as geologic agents. Two mudflows in Utah, both incident to cloudburst floods, are described by Blackwelder.[10] In his conclusions he calls attention to the fact that runoff regimen is influenced by vegetative cover on watershed areas and that denudation may be artificial as a result of grazing or fire, or that there may be a natural scarcity of vegetation from insufficient moisture or poor soil, or both. He calls attention also to the meagerness of geologic investigation of the subject and points out that only six modern texts at that time devoted any attention to mudflows, and of these only two give so much as a paragraph.

In November 1930 some miscellaneous observations on floods and mudflows north of Salt Lake City were presented to the Utah Academy of Sciences, Arts and Letters and also to the Utah Society of Engineers by Crawford and Thackwell.[11] In discussing the causes of these devastating floods the authors contend that although overgrazing and fires are contributing factors to rapid runoff from floods their importance has been overstressed and that the primary factors lie in other unbalanced conditions in nature which are of sufficient importance of themselves to cause intermittent floods even if the contributing factors of overgrazing and forest fires did not exist.

It was on account of the recurrence and the destructive character of the floods that devastated property in Davis County and elsewhere in Utah that the late Gov. George H. Dern in 1930

[9] Paul, J. H., and Baker, F. S., The floods of 1923 in northern Utah: Utah Univ. Bull., vol. 15, No. 3, 1925.

[10] Blackwelder, Eliot, Mudflow as a geologic agent in semiarid mountains: Geol. Soc. America Bull., vol. 39, pp. 465-484, 1928.

[11] Crawford, A. L., and Thackwell, F. E., Some aspects of the mudflows north of Salt Lake City, Utah; Utah Acad. Sci., Arts and Letters Proc., vol. 8, pp. 97-105, 1931.

appointed a commission of citizens to study the origin and cause of floods in that county and other parts of the State and to ascertain whether flood prevention measures were feasible.

The report of this commission[12] is divided into three parts: Part 1, report of the committee on ways and means; part 2, preliminary report of the committee on flood control works; and part 3, report of the committee on causes and prevention measures. Part 3 forms the greater part of the combined report, and the conclusions of the committee as to "the causes of the many floods throughout the State in 1930" were as follows:

1. Uncommonly heavy rainfall.
2. Steep topography and geological conditions conducive to sudden runoff and to a large quantity of flood debris.
3. Scant vegetation on portions of the watersheds of the canyons which flooded, due in some cases to the natural barrenness or semi-barrenness of the land, but in many cases such as those in Davis County, to the depletion of the natural plant growth, by overgrazing, by fire, and to a small extent by overcutting of timber.

The committee also concluded that "had there been a mantle of vegetation practically equal to the original natural cover, the serious flooding in that section from the rains of 1930 would have been greatly diminished, if not prevented."

Under authority of Section 5574x, Chapter 37, Session Laws of Utah 1931, the State Land Board engaged the director of the Intermountain Forest and Range Experiment Station, U. S. Forest Service, with one member of his staff and two members of the staff of the Utah State Agricultural College, to make a flood survey in Utah.

The report of this survey was made to the State Land Board in January 1933, but it has not been published. Its conclusions are:

> Activities of man have been an important factor in the increase in floods and of soil erosion; * * * floods on the whole were not of such severity or of such great frequency until some time after settlement; * * * injudicious grazing is by far the most important factor [in bringing about] conditions favorable to the origin of floods.
>
> Of the 25 cases examined where floods have occurred in recent years *depleted condition of the plant cover* is considered to have played a material part in 23 cases, and in 16 of the 23 cases depletion of plant cover is considered to be the major factor giving rise to conditions favorable for flood runoff.

The report cites Manti Canyon as one of the canyons that was "once a repeated flooder" and states that it was in bad condition "when placed under national forest administration," but that under such administration no serious flood had occurred for many

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[12] Torrential floods in northern Utah 1930, in Report of special flood commission appointed by Gov. George H. Dern: Utah State Agr. Coll., Agr. Exper. Sta. Circ. 92, Jan. 1931

years at the time of the report (1933). That period seems short, however, for drawing significant conclusions.

Repeated emphasis of the theory that vegetative cover on watersheds "equal to the original natural cover" will greatly diminish or prevent floods gives rise to the question, What was the original cover? In an effort to answer this question research was made into the scores of authentic books of early explorers and pioneers in the West who have left written records of the general facts of climate and vegetation. The results of this study are recorded in a paper by Woolley and Alter.[13]

The historical accounts quoted in that paper date back to the year 1540, and they all indicate that "no extreme phase of the precipitation cycle, whether upward and comparatively wet, or downward and relative dry—nor the practices of man in substituting domestic livestock for wild game and diverting irrigation water onto two percent of the land—have ever been sufficient to produce a material change of a permanent character in the general aspect of the native vegetation."

Another flood study initiated in 1938 was the outgrowth of a request by the Corps of Engineers, United States Army to the Utah State Planning Board for information concerning floods in Utah. This request was "for location of floods, damage caused, estimated costs for control, the economic background, and data on precipitation, runoff, climate, etc., for each area." In response to this request an investigation was made of those streams in Utah that had produced damaging floods. Letters and reports from all parts of the State were received and filed by the Planning Board and made available to the Corps of Engineers. Flood control hearings were conducted by the War Department at Kanab, Price, Monticello, and Salt Lake City, at which all available information relative to floods was presented and filed for use in preparing flood-control plans.

The major studies that have been made thus far of cloudburst floods in Utah argue for the theory that man's activities are a primary cause of floods. Scientific study and analysis of the physiographic and geologic features and of the meteorologic phenomena involved in these storms have not received due consideration.

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[13] Woolley, R. R., and Alter, J. C., Precipitation and vegetation: Am. Geophys. Union Trans., pp. 604-607, 1938.

PHYSIOGRAPHIC FEATURES

By Ray E. Marsell[14]

BOUNDARIES AND AREA

When Utah was established as a territory in 1850 it was bounded on the west by the State of California, on the north by the Territory of Oregon, on the east by the summit of the Rocky Mountains, and on the south by the thirty-seventh parallel of latitude. The present western boundary was established in 1861, the eastern boundary in 1864, and the notch taken out of the northeast corner was increased to its present size in 1868.

The State comprises approximately 82,346 square miles of land and 2,570 square miles of water—a total area of 84,916 square miles. Its highest point is Kings Peak, with an altitude of 13,498 feet, in the Uinta Mountains in Duchesne County, in the northeastern part of the State; its lowest point is on Beaverdam Creek, where at an altitude of about 2,000 feet, the stream crosses the Washington County boundary, in the extreme southwestern corner of the State. The approximate mean altitude of the State is 5,500 feet.

The following table shows approximately the proportionate amounts of the area of the State at different altitudes.

Approximate amount of land at various altitudes in Utah

Altitude above sea level (feet)	Great Basin		Colorado River Basin		Entire State	
	Area in square miles	Percent of basin	Area in square miles	Percent of basin	Area in square miles	Percent of State
2,000– 3,000			258	0.6	258	0.3
3,000– 4,000			1,579	4.1	1,579	1.9
4,000– 5,000	18,284	39.5	6,825	17.8	25,109	29.6
5,000– 6,000	11,803	25.5	11,324	29.4	23,127	27.2
6,000– 7,000	6,943	15.0	7,924	20.5	14,867	17.5
7,000– 8,000	4,814	10.4	4,685	12.1	9,499	11.2
8,000– 9,000	2,870	6.2	2,912	7.5	5,782	6.8
9,000–10,000	1,157	2.5	1,816	4.7	2,973	3.5
10,000–11,000	370	.8	869	2.2	1,239	1.4
11,000–12,000	44	.095	374	.9	418	.5
12,000–13,000	3	.005	61	} .2	64	} .1
13,000–14,000			1		1	
Total	46,288	100	38,628	100	84,916	100

PROVINCES

GENERAL DESCRIPTION

According to the classification of the physical divisions of the United States prepared by N. M. Fenneman[15] in cooperation with the Physiographic Committee of the Federal Geological Survey,

[14] Assistant professor of geology, University of Utah.

[15] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, pp. 19-98, pl. 1, 1917.

Utah includes parts of three major physiographic provinces. The western third of the State includes part of the Basin and Range province, and the remaining two-thirds includes parts of the Middle Rocky Mountains province and the Colorado Plateaus province.

The area in Utah that lies within the Basin and Range province is a part of the Great Basin section of that province. It is an arid to desert region almost entirely without external drainage and consists of isolated mountain ranges and broad intervening valleys many of which are fringed by alluvial fans made up of the material eroded by floods from the steep slopes of the uplands.

The northeastern part of the State, in the Middle Rocky Mountains province, includes the north-south trending Wasatch Range and the east-west trending Uinta Mountains. (See pl. 1.) The Wasatch Range has two northern branches, the Bear River Range and the Bear River Plateau,[16] which are separated from the Wasatch Front Range by Cache Valley—a broad intermont depression—and from each other by the valley of Bear Lake, which extends northward into Idaho.

The east-central and southeastern parts of the State are included in the following subdivisions of the Colorado Plateaus province: (1) The High Plateaus of Utah, a broad strip of high block plateaus, in part lava-capped, that makes up the western part of the province in Utah; (2) the Uinta Basin, a dissected plateau of strong relief that embraces the northern part; and (3) the Canyon Lands, a region of intricately and deeply trenched plateaus bisected by the Colorado River.

DRAINAGE

The principal drainage of the State is either westerly to Great Salt Lake and Sevier Lake, in the Great Basin, or easterly to Green River and Colorado River, in the Plateaus province. The divide between the drainage of the Colorado River and the Great Basin lies mostly within the Colorado Plateaus province (see pl. 1), although a part of the Great Basin in southwestern Utah is drained by a tributary of the Colorado River. About half of the State drains to the Great Basin, the other half to the sea.

TOPOGRAPHY

In general the State consists of two highly contrasted areas, one, the Great Basin area, low in average altitude, and the other, including parts of the Colorado Plateau and Rocky Mountains, high in altitude. The two areas are separated along a north-south line by a prominent escarpment that faces west and constitutes

[16] Mansfield, G. R., Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, p. 29, and pl. 15, 1927.

the western margin of the Wasatch Range in the north and the western edge of the Colorado Plateaus province in the center. This abrupt slope, which separates the eastern highland from the western lowland, is one of the most conspicuous topographic features in the State, especially as viewed from the west. At intervals of a few miles this barrier is cut by short, deep steep-walled canyons that debouch at the western foot of the escarpment, dividing the upland into parallel east-west trending ridges that give a notched or crenulated character to the western margin of the upland. Floods are characteristic of these canyons, and the material carried down by the canyon-cutting process forms an alluvial fan at each canyon mouth.

The escarpment is due in part to dislocation of the earth's crust along two major zones of fracture and movement. The Wasatch fault zone coincides with the base of the scarp for a distance of about 150 miles in its northern section. The Hurricane fault zone, which lies within the plateaus south of Cedar City, follows the escarpment for an unknown distance to the north, possibly to a point 20 or 30 miles south of Beaver. Toward the middle of the scarp, between Levan and a point several miles south of Beaver, the slopes are more gentle and very irregular. Here evidence of faulting is obscure. There are no great continuing faults but only occasional faults and parts of the front where the beds are warped downward into the Great Basin. Apparently the division of the State into two general physiographic regions has been brought about by repeated movements along the front, both by warping and faulting. The cumulative effect has been to raise the eastern part of the State along this zone from 3,000 to 6,000 feet above the western part. Evidence of geologically recent movement along the Wasatch fault zone is conspicuous (see pl. 2) and has been ably described by Gilbert[17] and others.

Renewed uplift, at intervals, of the upland or eastern part of the State has increased stream gradients in those parts of the channels immediately upstream from the faults along its western margin. Thus the valleys that cross the scarp tend to keep their sharp V-shape right down to the fault zone at the foot of the escarpment. This steepening of the stream gradients also results in maintaining steep valley slopes, which accelerate runoff and greatly increase the capacity of running water to transport debris.

Streams having the Pacific Ocean as their base level have cut much deeper channels than the streams draining to the relatively high base level of Great Salt Lake (altitude 4,200 feet) and Sevier

[17] Gilbert, G. K., Studies of Basin Range structure: U. S. Geol. Survey Prof. Paper 153, 1928.

Lake, the common base levels for streams in that part of the Great Basin that lies in Utah.

The relatively greater altitude of the Rocky Mountains and Plateaus provinces along their western boundary is of significance in that it forces the moisture-laden air coming from the west to rise into cooler regions and drop much of the precipitation that makes permanent runoff from that area, in contrast to the intermittent runoff from the Great Basin province to the west.

All three provinces display characteristics of late youth to early maturity in topographic development; the upland surfaces in all three are generally rough and rugged, with very strong relief. The flood plains of the major streams in the Rocky Mountains and Plateaus provinces are narrow or practically nonexistent; only where they enter the Great Basin do they attain considerable width.[18]

About half of the Great Basin province consists of isolated but roughly parallel north-south trending mountain ranges, whereas most of the northern third of the eastern upland is mountainous in the extreme (containing the Wasatch and Uinta Mountains), and even the remaining two-thirds is so generally trenched by deep and steep-walled gorges that it has a mountainous aspect.

In all three provinces slopes are predominant; flat areas are limited in extent and confined mainly to the central floors of the intermontane basins, particularly the floor of Pleistocene Lake Bonneville, in the western part of the State, and to a few "stripped" plains and plateau surfaces in the Plateaus part. In the Great Basin, however, alluvial slopes of 10° or less are extensive. Probably in no State west of the Rocky Mountains are plains so restricted in extent as in Utah. The steep gradients of the smaller streams, their confinement in narrow canyons, and their abrupt change of gradient when they spread upon the alluvial fan at the bases of the slopes are major factors in the destructiveness of cloudburst floods, as these fans are choice agricultural spots and are thickly settled.

COLORADO PLATEAUS PROVINCE

The Colorado Plateaus province as a whole has the simplest geologic structure and topographic expression of the three provinces in Utah. It is distinguished, first, by relatively high altitude, second, by the nearly horizontal position of much of the great thickness of sedimentary rocks of which it is chiefly composed, and, third, by its myriads of labyrinthine, steep-walled canyons.

[18] Callaghan, Eugene, Geologic features [of Sevier Lake Basin], in Woolley, R. R., Utilization of surface-water resources of Sevier Lake Basin, Utah: U. S. Geol. Survey Water-Supply Paper 920 (in preparation).

A. WASATCH RANGE EAST OF SPRINGVILLE.

Shows an unglaciated and maturely dissected part of the western margin of the range. Note the roughly triangular, gully-scarred fault-facets (A) steeply notched on their lower margins by wave-cut cliffs alined along an ancient beach of Lake Bonneville. A recent fault scarp associated with the Wasatch fault zone appears as a dark shadow at left of beach. Note accordant summit levels of the range in the background where it merges with the Uinta Mountains on the horizon. View looking northeastward. Air photo by R. E. Marsell.

B. WASATCH RANGE SOUTHEAST OF SALT LAKE CITY.

Shows horseshoe-shaped glacial moraine 700 feet high at mouth of Bell Canyon (lower left of center). Note sharply truncated ends of ridges, these triangular fault-facets being faintly notched by a shore terrace of Lake Bonneville in lower right corner of photograph. Recent fault scarp, plainly shown below (west of) these facets, has dislocated the moraines at A. View looking northeastward. Air photo by R. E. Marsell.

Its surface, except for valley bottoms or canyons, ranges from 5,000 to more than 11,000 feet in altitude. Owing to the generally arid climate and approximate flatness of the strata, the hard layers, where exposed by drainage channels, form ragged lines of cliffs that retreat from the drainage lines as the softer rocks beneath are eroded away. The hard and soft layers are frequently repeated, so that the surface over much of the province consists of a succession of platforms or benches separated by steep slopes or cliffs. There are hundreds of such lines of retreating escarpments or cliffs with highly crenulate or fringelike margins, often set one above the other like steps, with broad platforms between them. The most prominent of these erosional escarpments, consisting of several rows of closely spaced cliffs (see pl. 3, *A*), forms the southern margin of the Uinta Basin section and the eastern margin of the High Plateaus section. These two border areas of the province are higher in general than the central or Canyon Lands area (see pl. 3, *B*). Possibly in no other landscape are the substance and structure so plainly revealed as in the Plateaus province. The angular profiles suggest classical architectural forms, so much so that Dutton,[19] impressed by this resemblance, described them in architectural terms.

As the name of the province implies, there is not just one plateau but many. Fenneman,[20] in discussing them, in part, says:

"The constituent plateaus, more or less sharply separated and receiving local names, are numbered by the dozen. Some rise, tablelike, above their neighbors on all sides; others abut, steplike or terracelike, against their higher neighbors; a few are basinlike, limited on all sides by infacing cliffs. They differ also in the degree of dissection by streams, ranging from widespread flats or rolling lava plains to deeply and maturely dissected mountains of erosion. As a consequence of differing altitudes and stages in the erosion cycle, the several plateaus differ greatly in temperature, rainfall, and vegetation. At one extreme are hot wind-swept deserts; at the other are cool, lake-dotted, dense forests; between these are open forests, park and grass lands."

The margins of the various plateaus in some places are simple cliffs, in others they are modified fault scarps, and in a few they are monoclines of vast proportions, where the flat-lying strata have been bent upward in a broad sweeping curve, to flatten out again on the plateau top. The same layer that floors one platform may also floor a neighboring one several thousand feet higher in the plateau. In places the flexed strata are sheared and the monoclinal margin passes into a faulted margin, and vice versa.

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[19] Dutton, C. E., Report on the geology of the high plateaus of Utah: U. S. Geog. and Geol. Survey Rocky Mountain region (Powell), 1880.

[20] Fenneman, N. M., Physiography of western United States, p. 276, McGraw-Hill Book Co., 1931.

The fact that the cliffs of the retreating escarpment are of unusual height is due to the great thickness and massive character of the many hard sandstone layers in the plateau country. This is well illustrated by the broad terraces south of the southern margin of the High Plateau district, particularly by the wall that is formed by a single layer of brightly colored sandstone 2,000 feet thick in which Zion Canyon is so spectacularly cut. The topmost layers of the southern part of the High Plateaus are commonly soft Eocene deposits, whose composition and structure are particularly favorable to the formation of cliffs. The intricacy of dissection of these cliffs is extraordinarily well shown in Cedar Breaks National Monument and Bryce Canyon National Park.

An exceptional feature that lends variety to the typical landscape of the Plateaus province is the presence within it of several scattered groups of laccolithic mountains, where intrusion of igneous rocks has domed or otherwise disturbed the sedimentary layers. Erosion has since stripped the sedimentary rocks from the tops of many of the laccoliths, exposing their igneous cores. Noteworthy examples are the Henry Mountains, the Abajo or Blue Mountains, and the La Sal Mountains (pl. 4), the last attaining an elevation of more than 13,000 feet. Their isolation, and the abruptness with which they rise from the level plateau surfaces, lend to these mountains a peculiar grandeur.

BASIN AND RANGE PROVINCE

Ranking almost equally with the Colorado Plateaus province in size but lacking its physiographic simplicity is the lowland in the western part of Utah. This is a part of the Great Basin section of the Basin and Range province and includes about 40 percent of the State's area. The name "Great Basin" was first applied to the area by Capt. John C. Frémont, who was the first to recognize the nature of its interior drainage while crossing the region in his expeditions of 1843 and 1845.

Topographically, the province is distinguished by its succession of subparallel mountain ranges and intervening desert plains. In general, each mountain range is isolated from its neighbors and is 40 to 80 miles long, the shorter ranges predominating. One or both margins of a range may rise abruptly from the adjoining plain and display a general straightness of base that is quite independent of rock composition and the usual complex structure within the range, a typical feature of many of the mountain ranges of the province and one that suggests their probable fault-block origin. The crest lines of the ranges, although jagged in detail, are surprisingly uniform and even, lacking the sharp high peaks and broad saddles that produce the familiar notched and segmented appearance of a typical mountain range. Although, from a topographic standpoint, the region fails to display in its surface forms the simple, geometric aspect of the Plateaus province, there is at least a suggestion of orderliness in the rude parallelism of the ranges.

The stage of topographic development of the basin ranges, although still a subject of considerable discussion,[21] appears to be that of early maturity for the ranges in Utah; block mountains in an advanced stage of their first cycle of erosion probably predominate, but there are a few ranges in whose formation faulting is not regarded as an essential factor.[22]

The steep slopes that so generally prevail in the basin ranges do not disappear altogether at their bases, for the margins of the intervening basins commonly have steep slopes. Frequently only a relatively narrow central strip is flat, bordered by piedmont plains of coalescing alluvial fans that range in inclination from 3° to as much as 10° as they approach the mountains. In contrast with the loftier and more humid sections of Utah that drain to the sea, the waste of the mountains in the Great Basin tends to accumulate in fan-shaped alluvial deposits at the foot of the ranges instead of being carried out of the region by perennial streams. In many places, as a general result of the arid climate and steep mountain fronts, the sloping margin of the basin is formed of a series of these confluent alluvial fans.[23] In other places the sloping plain is a "pediment,"[24] or rock platform, but thinly veneered with rock waste.

The center of the intermontane basin is usually occupied by a barren mud flat, the "playa," which may be the site of an ephemeral lake, where the mud-laden flood waters from the melting snows of spring or from the infrequent but torrential cloudburst storms of summer accumulate and evaporate in the dry desert air. The so-called "alkali flat" is a playa coated with white efflorescent salts, formed by the active discharge of ground water by evaporation. The name "salina" is often given to such a playa. One of these salt beds in western Utah, called the Bonneville Flats because of its remarkable flatness and the hardness of its surface when dry, is an internationally known speed course where the world's automobile speed records have been made.

It is evident that many of the playas—and the basins themselves—are the sites of former lakes, whose disappearance is so

[21] Fenneman, N. M., op. cit., p. 333.

[22] Marsell, R. E., Salient geological features of the Traverse Mountains, Utah; Utah Acad. Sci., Arts and Letters Proc., vol. 8, pp. 106-110,, 1931.

[23] Blackwelder, Eliot, Desert plains: Jour. Geology, vol. 39, No. 2, p. 136, 1931.

[24] Bryan, Kirk, Erosion and sedimentation in the Papago country, Ariz., with a sketch of the geology: U. S. Geol. Survey Bull. 730, p. 54, 1922.

recent, geologically, that their beaches, sea cliffs, and shore-line embankments are preserved around the margins of the basins. Most of that part of the Great Basin that lies in western Utah was formerly occupied by Lake Bonneville, the largest of these ancient lakes.[25] Great Salt Lake, Utah Lake, and Sevier Lake occupy the lowest parts of the former lake bottom. Lake Bonneville, at its highest level, was as large as Lake Michigan and deeper than Lake Superior. The prominant terrace marking its highest shore line, known as the Bonneville level, is about 1,000 feet above Great Salt Lake and nearly a mile above sea level. Since the waters of this great prehistoric lake lapped well up on the flanks of the Wasatch Range and the basin ranges to the west, the shore lines and deltas are conspicuous features which, with the relatively smooth surface of the old lake bottom, stand out in marked contrast with the rugged surfaces of the surrounding mountains.

MIDDLE ROCKY MOUNTAINS PROVINCE

That part of the Middle Rocky Mountains province within Utah is the smallest in area, the highest in general altitude, and the most complex, topographically, of the three provinces that make up the State. Its major physical divisions, as previously noted, are the Wasatch and the Uinta Mountains.

The principal streams that rise within the State rise in this area. The larger part of the population of the State is huddled along its western border near Salt Lake City, where the clear mountain streams enter the Great Basin.

When viewed from the air, the province has the aspect of a vast tableland, maturely dissected but still preserving something of its tabular form. Although the Uinta Mountains are somewhat higher than the Wasatch Range, the deepest canyons are found in the latter, several of them rivaling the Yosemite in depth and grandeur. The greater relief of the Wasatch region is accounted for by the nearness to base level of its westward flowing streams and the abruptness of the escarpment that forms the western margin of the range.

Glacial erosion has contributed greatly to the steepening of the canyon walls and has produced large cliff-rimmed basins at their heads. Glaciers also occupied parts of the loftiest of the High Plateaus and the summits of a few of the higher basin ranges, but their effects on the topography are much more conspicuous in the mountain province. In fact, the crest of the Uinta Mountains was completely buried under an ice cap, from which rivers

[25] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, 1890.

of ice descended[26] at both margins of the range. Erosion of the canyon walls by the ice masses has not only steepened them but has removed most of the soil and rock mantle, exposing bare rock surfaces that greatly increase the rate of runoff during the torrential downpours of cloudburst storms. The longest glacier in the Wasatch Range, in Little Cottonwood Canyon (see pl. 5), attained a length of 14 miles with a minimum depth of ice, near its end, of 1,500 feet. The Uinta glaciers were nearly twice as long and much thicker.

The Wasatch Range extends southward from near the Idaho line to Salt Creek Canyon, where it joins the High Plateaus of Utah near Nephi, in the center of the State. From Salt Lake City northward the range consists of a single high ridge, scored by short, exceedingly steep ravines that descend both westward to the Great Basin and eastward to a chain of mountain valleys, called by Gilbert[27] "back valleys," which, from north to south, are Cache Valley, Ogden Valley, and Weber, or Morgan, Valley. The altitude of the northern Wasatch, as this part of the range is called, is somewhat less than 10,000 feet, whereas the central part, facing Jordan Valley, culminates in Mount Timpanogos, 12,008 feet high. The physiographic character of the range also changes in the central part. The range expands into a series of parallel east-west ridges whose highest peaks lie close to the western margin of the range, giving the central mass an asymmetrical profile. The hydrographic divide here does not coincide with the crest line as it does farther north. In the extreme southern part of the range, its form returns to that of a single high ridge, culminating in Mt. Nebo, 11,887 feet high.

Like many of the basin ranges, which it resembles in many respects, the Wasatch Range consists of complexly folded and faulted rocks, displaying a wide range in composition and age. Folding of the sedimentary layers, which constitute the bulk of the range, was followed by intrusion and partial burial by igneous rocks. The present range represents the re-elevated core of the ancient range, and its topography reflects more than a single cycle of erosion.[28]

The Uinta Mountains are the largest east-west mountain mass in the Western Hemisphere. Their length is about 150 miles and their width 30 to 40 miles. Much of the crestal region is above 12,000 feet in altitude. In its structure the range is much simpler

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[26] Atwood, W. W., Glaciation of the Uinta and Wasatch Mountains: U. S. Geol. Survey Prof. Paper 61, 1909.

[27] Gilbert, G. K., Studies of Basin Range structure: U. S. Geol. Survey Prof. Paper 153, pp. 53-54, 1928.

[28] Eardley, A. J., Strong relief before block faulting in the vicinity of the Wasatch Mountains, Utah: Jour. Geology, vol. 41, No. 3, pp. 243-267, 1933.

than the neighboring Wasatch and more closely resembles the structure of the Plateaus province, for it consists of a broad, nearly horizontal platform, elevated between steep monoclinal margins. In form the range consists of a narrow, discontinuous crestal ridge from which fairly evenly spaced canyons, greatly enlarged by glacial action, descend on both sides. The range drains in part to the Great Basin and in part to the Green River of the Colorado River system.

SOILS

Because of the great importance of soil in the study of land use and the significance of its structural characteristics in relation to its receptibility of plant roots, its amenability to cultivation, and its susceptibility to blowing by wind or erosion by water, it seems desirable in this report to set forth some of the fundamental characteristics of the soils of Utah as they are related to local variations in climate, relief, vegetation, and other factors.

Before the development of the modern concept of soils and before there had been accumulated any body of soil science, classifications were made on the basis of the nature of the parent material, but now according to the principle of geographics[29] two general forces are considered to be in operation during the genesis of a soil, (1) the destructional forces of weathering, both physical and chemical, and (2) the constructional biological forces.

Rainfall, temperature, and humidity as components of climate obviously influence the amounts of the chemical elements and compounds in the soil through their influence upon vegetation and upon the weathering processes that produce the parent material from which the soil is developed. The whole process of soil genesis is one of evolution. The material of which the soil is composed is largely accumulated through the processes of weathering, and wind, moving water, ice, and temperature changes are important factors in the disintegration of the parent rock masses. Transportation of the weathered material may be by wind, as is true of sand dunes, by water, as illustrated by alluvial fans and flood plains, and by ice, as shown by glacial deposits.

Following or even coincident with accumulation of parent material, living matter begins the constructional processes of soil development. Wherever rainfall is adequate and properly distributed throughout the frost-free period vegetation appears, but the relationship between soil and plant life is so interdependent that it is not always possible to point to either as the cause of the other; they evolve together.

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[29] Kellogg, C. E., Development and significance of the great soil groups of the United States: U. S. Dept. Agr. Misc. Pub. 229, 1936.

In the development of soils from unconsolidated rocks a certain amount of erosion is necessary for the genesis and maintenance of a fertile soil, but excess erosion leads to the thinner, less fertile types that are found on hilly land where the relief is conducive to increased removal of material and increased runoff of water, leaving less moisture for the growth of plants and consequently slowing down the soil-forming processes.

In many places within a general region soils are so influenced by local conditions of relief and parent material as to be wholly unfit for crops. Soils on steep hillsides that are thin and subject to excessive erosion when cultivated and stony and very sandy soils are examples of such unfit lands. In regions with large areas of rugged mountains, broad deserts, and high plateaus, such as are found in Utah, soils areally are dominated in their genesis by the local factors of relief and parent material.

Although detailed soil surveys have been made of only a fractional part of the total area of Utah, accumulated results of the soil surveys of the United States by the Department of Agriculture, begun in 1899, have provided sufficient data for Dr. Marbut,[30] of the Bureau of Chemistry and Soils, to prepare a report, with map, which has been drawn upon liberally for the following discussion of soils in Utah.

Occurring mainly in the valleys of Utah is a soil series that has been mapped as the Hyrum. It is a series that was established in Cache Valley and consists of dark-colored soils developed from water-laid material deposited in ancient Lake Bonneville. These soils occur around the rim of the valley basin in localities where, because of their nearness to high mountains, the rainfall has been sufficient during the progress of soil development to cause a vigorous growth of grass and other shallow-rooted vegetation.

In the Uinta Basin, in northeastern Utah, soils with the general characteristics of the Hyrum occur around the basin edges and lighter-colored soils occur in the interior. Dark-colored soils are also found in the relatively smooth areas on the higher levels in the Uinta Mountain region.

The soils along the top of the Tavaputs Plateau, which is bounded on the south by the Book Cliffs and extends westward in a very narrow belt from some 20 miles east of Grand Junction, Colo., to Price, Utah, are dark colored and covered with brush. North of this belt the soils are light in color. In the Monticello region, in southeastern Utah, are areas of dark soils used for production of dry-farm wheat. The rainfall in this region is heavy

[30] Marbut, C. F., Soils of the United States: U. S. Dept. Agr. Atlas of Am. Agr., pt. 3, 1935.

enough to have developed sufficient vegetative cover throughout the period of soil development to give the soils a dark color.

The Gray Desert soils occupy the Great Basin area of the State, extending from the foot of the Wasatch Range westward. Except for the small areas where irrigation is possible, these soils are practically nonagricultural. The series of isolated, short, north-south mountain ranges that are a prominent topographic feature of this region are either entirely bare or have a very thin cover of brush, except in some of the highest, where some open forests are found. The ranges are separated by long, gently sloping alluvial fans spreading outward from the mountains, the fans from adjacent parallel ranges meeting along the axial line of the lowland belt between the mountains. In places where the fans do not actually meet they are separated by a flat area, known as a playa, that is usually subject to flooding. The playas, however, constitute a very small and unimportant part of the whole region.

Most of the soils of the region lie on the alluvial fans and playas and are developing from the same kind of materials as those that formed the fans and playas. In this process of development the deposition of material does not take place over the whole surface of the fan at any one time. The streams that bring the material from the mountains during the desert thunderstorms shift their courses from time to time and eventually distribute the material over the whole fan. In some part of every fan, therefore, the material is now accumulating or has accumulated so recently that mature soils have not developed. In other parts of the fans the accumulation took place a long time ago. These conditions are characteristic of the hundreds of fans that are now being built throughout the State by "cloudburst" floods.

The low areas that include Great Salt Lake and the now dry Sevier Lake consist of fine-grained lake-laid deposits that have accumulated through the ages. They are more or less salty because of the concentration of mineral salts left by evaporation, the only way for the water to leave the basins.

NATURAL VEGETATION

Vegetation is a very important factor in the economic value of land, and its intimate relationships with rainfall, temperature, and soils are relevant to any study of the economic importance of areas affected by cloudburst floods.

The natural vegetation of Utah, according to Shantz and Zon,[31] comprises alpine meadows in a few small areas in the tops of the Uinta Mountains and on the High Plateaus, in the south-

[31] Shantz, H. L., and Zon, Raphael, Natural vegetation: U. S. Dept. Agr. Atlas of American Agriculture, 1924.

A. BOOK CLIFFS EROSIONAL ESCARPMENT—BOUNDARY BETWEEN THE CANYON LANDS AND UINTA BASIN DIVISIONS OF THE COLORADO PLATEAUS PROVINCE.

B. A TYPICAL LANDSCAPE IN THE CANYON LANDS.

San Rafael district of the Canyon Lands section of the Colorado Plateaus province. Note labyrinth of cliff-walled gorges separated by flat-topped benches or pinnacle-capped ridges, with isolated buttes and mesas. Book Cliffs erosional escarpment dimly visible on the horizon. View looking southeastward. Air photo by R. E. Marsell.

central part of the State; spruce and fir (Northern Coniferous Forest) in some small scattered areas fringing the alpine meadows; yellow pine and Douglas fir extending in a rather wide belt along the Wasatch Mountains and southward nearly to the south end of the State; piñion and juniper in extensive areas flanking the pine-fir areas; lodgepole pine on the Uinta Mountain slopes; and sagebrush, the predominant vegetation, which covers nearly all the undeveloped remainder of the State, with the exception of the Great Salt Lake Desert and some small areas in the Sevier Lake Basin, which support salt desert shrubs. The perennial vegetation that gives character to the desert area of the State consists principally of shrubs that are protected against excessive transpiration by their small size, small leaves, and wide spacing, which enables them to conserve the scanty supply of moisture and continue their growth through rainless periods.

The character of the vegetation is an index to the amount of water available for growth. Precipitation ranges from 5 to 10 inches but seldom more than 10, and drought may occur at almost any time. Although the plants are well adapted to extreme drought, they may be killed by prolonged dry periods. The appearance of the vegetation is monotonous, and one is impressed by the great expanse of a single plant species.

Grasslands are not extensive in Utah. They characterize areas in which trees have failed to develop, either because of unfavorable soil conditions, poor drainage, intense cold and wind, deficient moisture supply, or repeated fires. Usually they are well supplied with water in the surface soils during the growth period and do not depend upon stored soil moisture. Grasses are, therefore, characteristic of regions of summer rainfall. Bunch grass is not uncommon on the foothills and in the mountain valleys where rainfall ranges from 10 to 25 inches. It develops where the moisture supply is insufficient for a dense stand of grasses. Isolated spots of dense stands of grasses are found in the alpine-meadow areas and in the vicinity of springs, where water is plentiful and close to the surface.

Sagebrush occupies most of the higher land, which is free from alkali, well drained, and moistened by natural rainfall or by flood waters to a depth of 4 to 18 feet. It is best developed where the rainfall is from 10 to 15 inches. It is characteristic of the alluvial fans and plateaus ranging principally from 4,000 to 7,000 feet in altitude. A good even stand of large sagebrush indicates land upon which crops can be grown successfully by dry-farm methods. Most of the land under irrigation throughout the State was originally covered with sagebrush.

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LAND CLASSIFICATION

A broad regional picture of the use and value of land in Utah is presented in a report by Deeds and Falck.[32] The classification of the lands is based upon the climatic, physiographic, and soil factors as they are reflected in the natural vegetation. Farming land is shown on the classification map (pl. 6) as three types of cultivated crop land—irrigated land (about 1,300,000 acres), grain-crop land (466,000 acres), and forage crop land (315,000 acres). The total crop land amounts to about 5 percent of the area of the State exclusive of national forests and reservations.

Irrigated areas embrace tillable areas on which crops are grown with the aid of water additional to that derived from natural rainfall and for which a water supply is available. Dry-farming land embraces tillable areas having a growing season, normal rainfall, and suitable soil for the successful production of hardy grain crops. The forage-crop land embraces tillable areas having less favorable growing conditions than farming land but suitable for the production of grain hay in most years.

Other lands of the State chiefly valuable for agricultural utility are classified as grazing lands. These have been subdivided into seven types of the seven readily distinguished types of forage growth that occur in a characteristic succession from the highest to the lowest altitudes. In order of occurrence from high to low they are the subalpine, mountain brush, sagebrush, woodland, shadscale, greasewood, and creosote types. (See pl. 6.)

The subalpine lands embrace an area of about 1,792,000 acres in the high mountains and plateaus, in which rainfall exceeds 18 inches, the growing season is short, and the summer temperature is moderate, so that there is little loss of moisture through evaporation. Timber is ordinarily found in the zone of these lands, but there are many open parks having no timber and areas in which timber forms only a scattered stand.

The mountain brush lands constitute about 2,293,000 acres in a zone that is next lower in altitude than the subalpine type. The plant growth represents a transition between the high-mountain vegetation and that of the foothills. The precipitation is less than in the subalpine zone, the growing season is longer, and the summers are warmer. Practically all the areas of this type can be used during early summer and fall, but during midsummer parts cannot be grazed because of lack of water for stock or the drying up of feed.

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[32] Deeds, John F., and Falck, Depue, Land-classification report for Utah [mimeographed], U. S. Geol. Survey, 1932.

The woodlands embrace an area of about 14,651,000 acres and occupy a zone between the mountain lands that receive a relatively high rainfall and the hot, semidesert regions that have a relatively low rainfall. They are found mainly in rocky or dry gravelly foothills or areas of shallow soil where the annual rainfall ranges from about 10 to 15 inches and the maximum temperature ranges from 90 to 95 degrees. The most conspicuous vegetation is piñion or juniper or an association of both, which are used to some extent by local ranchers for fence posts and firewood. Many species of shrubs and grasses are not uncommon in this zone, and open patches of sagebrush occur where the better soil conditions prevail.

Sagebrush land includes about 6,051,000 acres of the State's area. It is usually well-drained and has fertile soil free from alkali. This zone has an annual rainfall of 8 to 16 inches. A good undergrowth of grasses fringes the upper part of the belt where favorable soil conditions and adequate rainfall are found. On lands poorly supplied with soil moisture because of low rainfall or on dry, shallow, or porous soils the sagebrush is small.

Shadscale lands comprise about 11,818,000 acres in the State. On these the soil moisture is less than the minimum required for sagebrush growth. Land of this type is to be found in the arid valleys and benchlands where the annual rainfall is less than 8 inches. Shadscale is the most abundant species of vegetation and grows mainly on a shallow, heavy soil with more or less alkali in the subsoil.

Greasewood lands embrace an area of 5,121,000 acres in which the soil moisture is generally fair to good but in which poor drainage has resulted in an accumulation of akali and a vegetative growth limited to alkali-resisting plants.

Creosote bush lands indicate extremely arid conditions. They include an area of about 81,000 acres along the lower Virgin River Valley. This type is characterized by a shallow coarse-textured soil free from alkali. Rainfall is approximately 8 inches a year and summer temperatures reach an extreme of more than 100° F.

The percentage of the State included in each land type is as follows:

Land types in Utah

	Percentage of State area
National forests	14.2
Other reserved lands	1.9
Irrigated land	2.9
Grain-crop or dry-farm land	.8
Forage-crop land	.6
Grazing land:	
Subalpine	3.4
Mountain brush	4.4
Woodland	28.0
Sagebrush	11.4
Shadscale	22.3
Greasewood	9.6
Creosote	.5
	100.0

It will be noted from the table that approximately 80 percent of the State's area is comprised of the seven types of grazing lands. If the national forests and other reserved lands are excluded from the remaining 20 percent, a little less than 5 percent of the entire State is included in towns and improved farms. These facts are important with respect to the distribution of reported cloudburst floods and their relative economic aspects. It is also highly important that the facts relative to types of land, soils, rainfall, and natural vegetation be given proper and serious consideration in all plans for the development of vegetative cover and its probable relation to such floods.

CLIMATE

GENERAL DISCUSSION

Utah is broadly classified as being in the temperate zone. Its climate is essentially semiarid, with somewhat different characteristics in the two major east and west sections resulting physiographically from the barrier formed by the Wasatch Mountains and High Plateaus, which extend diagonally southwestward across the State. The seasonal temperature distribution is about the same in both sections but there are marked differences in the seasonal distribution of precipitation.

The average altitude of the State is approximately 5,500 feet above sea level, with a low of 2,500 feet where Beaverdam Creek crosses the boundary in the southwest corner, and a high of 13,498 feet at Kings Peak, in the Uinta Mountains in the northeastern part of the State.

With variations in altitude there are wide variations in temperature and precipitation. The maximum temperature on record is 116° F., the minimum, —50° F. The distribution of precipitation over the State with relation to areas and altitudes is shown in figure 1.

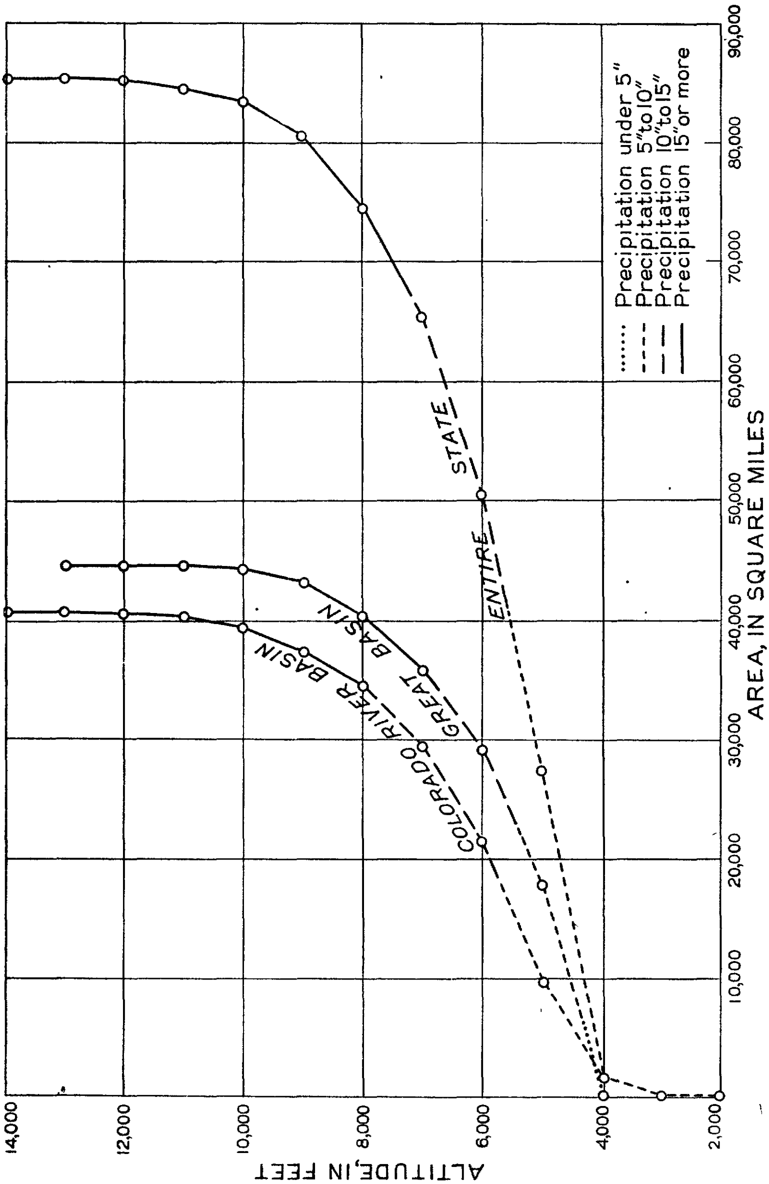

FIGURE 1.—Distribution of precipitation in Utah with relation to areas and altitudes.

Approximately 22 percent of the State, in or near the mountains and upland areas, has an average annual precipitation of 15 inches or more. About 30 percent receives 10 to 15 inches annually, and 40 percent from 5 to 10 inches. The remaining 8 percent, comprising principally the Great Salt Lake Desert, receives less than 5 inches a year.

The greater part of the State's population is concentrated in the habitable areas of highest precipitation. These areas are the valleys along the stream courses and the fertile fans built up by the streams as they emerge from their canyons. This characteristic of population development is quite natural if it is realized that irrigation is essential to all successful agriculture in the State, because the mean State-wide annual precipitation is about 12 inches, and this is not sufficient to support more than a scanty vegetation.

Some salient aspects of Utah's climate are shown in figure 2, covering the 48-year period from 1891 to 1938, inclusive.

It is interesting to note that for southern and eastern Utah prepared from records of the United States Weather Bureau July and August are the wettest months of the year, whereas June, July, and August are the driest in the northern and western parts. June has less precipitation than any other month. The aridity of the climate is indicated by the average number of days in each month on which 0.01 inch or more of precipitation was recorded. Precipitation of consequence is reported on an average of 59 days a year for the State as a whole.

METEOROLOGY

GENERAL STATEMENT

The principal sources of moisture for the State's rainfall are the Atlantic and Pacific Oceans. The air masses originating over the Atlantic Ocean and Caribbean Sea travel westward in a wide swing across the Gulf of Mexico and the Rio Grande Valley. Those from the Pacific Ocean travel eastward. From both air masses the mountain ranges and highlands "wring out" considerable water, and the desert areas at the lower altitudes remain relatively dry as compared to the upland areas. Thus in all parts of the State topographic obstructions materially influence the precipitation process. Conditions favorable for precipitation may exist for two or three days, for a week, or rarely for as long as two weeks, but on the average they may be expected to occur slightly oftener than twice a month over the intermontane West.

Storm-producing conditions not uncommonly prevail over large areas involving parts of several States, but precipitation may be

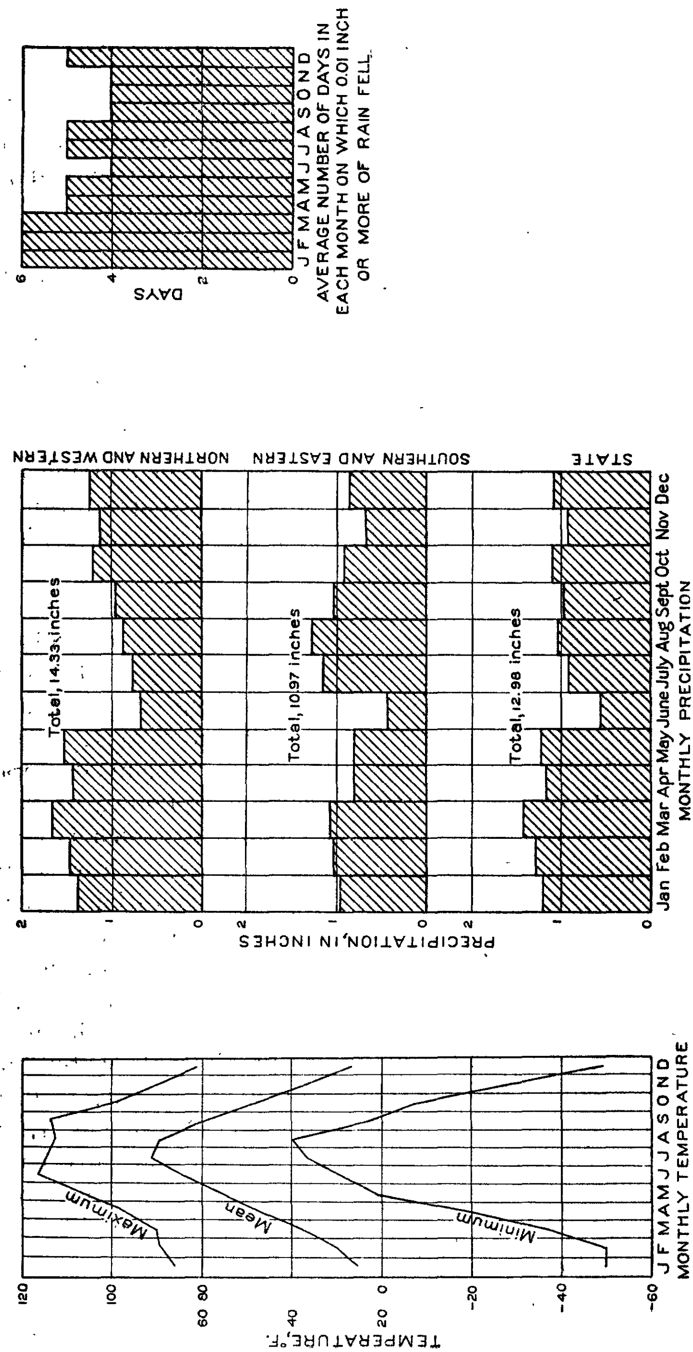

FIGURE 2.—Climatological charts for Utah showing average temperature and precipitation, 1891-1938.

"spotty." For example, widespread and relatively heavy rains over Arizona and New Mexico are often accompanied or followed by appreciable precipitation in the southern part of Utah and only a trace, or none at all, over the northern part. Moisture content of the air is highly important in its relation to precipitation. Storm periods of similar barometric and thermal conditions may yield only a trace of moisture or a copious downpour, depending on the initial quantity of moisture in the air mass.

STORM COURSES

Throughout the winter season over the entire State of Utah all storms enter the State from southwest to northwest traveling eastward. Most of the summer rains occur in thunderstorms or as thundershowers, and the moist air masses connected with these storms enter the State from the direction of the Gulf of Mexico. Thus, the southern and eastern parts of Utah, because of topographic characteristics that favor continued lifting of the warm, moist air masses, receive more summer precipitation than the northern and western parts, beyond the Wasatch divide.

STORM TYPES

This report is chiefly concerned with the heavy summer rains in Utah, Apparently these are of two distinct types: (1) The steady or cyclonic storms, which are not very frequent and may result in a large total precipitation but are spread over a protracted period and have relatively small intensities; and (2) thunderstorms, which generally include the violent downpours of brief duration and high intensity commonly known as "cloudbursts." Of these two types the cyclonic storm, which is characterized by rather intensive low-pressure areas, is less common in the summer. On the other hand, summer conditions over the arid West often produce wide areas of uniform atmospheric pressure with a pronounced northward flow of warm, moist air of tropical origin from the Atlantic and Caribbean regions. The moisture content of the air in this warm current, which not only is of direct influence on the amount of precipitable water but is also of indirect influence on the stability of the air, is largely dependent on the position of the high-level anticyclone. Then if convection by any means is initiated when the moisture content is high a cloudburst storm may result. Such storms may be expected during periods of high temperature when conditions are most conducive to convection.

CYCLONIC STORMS

The cyclonic type of storm is shown by the weather maps in plate 7, and an analysis of such a storm within the period September 21-25, 1930, inclusive, is shown by the charts in figure 3.

A. MOUNT ELLEN, HENRY MOUNTAINS.

Shows northernmost of the isolated laccolithic mountain groups along the western margin of the Canyon Lands. Note typical badland topography developed on the soft mudstones and shales of the Moenkopi formation. Bench in middle distance is capped by resistant Shinarump sandstone. Photo by J. E. Broaddus.

B. LA SAL MOUNTAINS.

Highest of the isolated laccolithic mountain groups in the Colorado Plateaus province, eastern Utah. Photo by J. E. Broaddus.

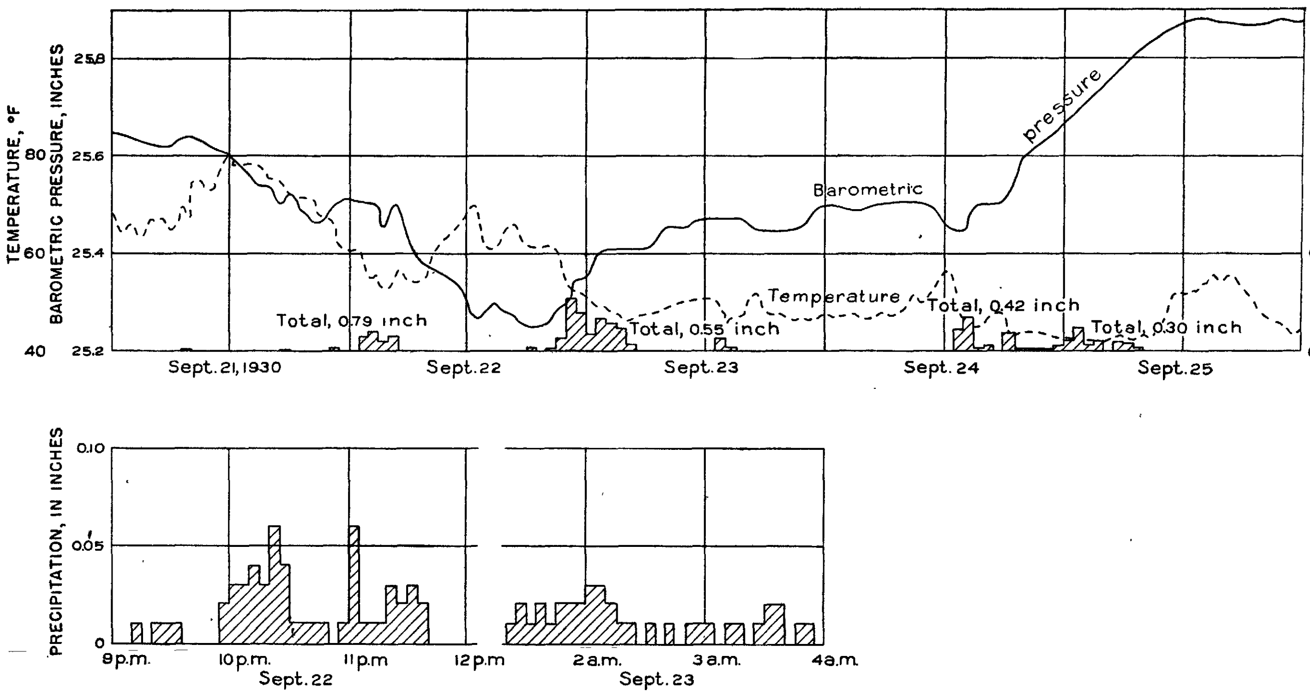

FIGURE 3.—Characteristics of cyclonic storm of September 22-23, 1930. Lower chart shows intensities for heaviest part of storm, between 9 p. m., September 22, and 4 a. m. September 23. During the remainder of the 2-day period, 5-minute intensities exceeded 0.03 inch only once. From records of United States Weather Bureau.

Although more than 1 inch of rain fell in a 6-hour to 8-hour period on September 22 to 23 and varying amounts in other periods, no heavy damaging runoff resulted. In storms of this kind, if a relatively heavy fall occurs in the mountains for any great length of time, high-water stages are built up in the streams leaving the larger drainage basins. Smaller streams, however, having a much greater channel capacity per square mile of drainage area, require the concentrated violence of a cloudburst to produce a dangerously high runoff.

THUNDERSTORMS

The convective form of thunderstorm is much more prevalent in Utah than the general air-mass form. The sharp topographic features and widely varying thermal conditions are conducive to the development of convective storms. The area covered by this kind of a thunderstorm is definitely limited by the extent of the convective action. If such a storm passes over a rising terrain, such as the face of a mountain range, it is augmented in violence in proportion to the additional altitude reached by the unstable air masses. Any delay or interruption of the storm travel is only temporary and shows itself as a longer period of high intensity and a greater volume of precipitation.

The general air-mass form of thunderstorm is rare in Utah except in spring. However, a notable example of such a storm occurred August 13, 1923, during which record-breaking precipitation was recorded along the west face of the Wasatch Mountains for a distance of 70 miles north of Salt Lake City. Devastating floods poured from practically all canyons along the affected zone.

Of all the cloudbursts studied in Utah, the great majority were in July and August, the warmest months. Most of the remainder were in June and September. Furthermore, regardless of date, the greatest number occurred during the interval between noon and sundown, or early evening, the period of maximum diurnal temperatures and most intense convection. The fact that several damaging downpours have been reported as occurring during the night does not necessarily detract from this statement.

The damaging effects of heavy rains are proportional to the rates of surface runoff, which are limited by the rates of rainfall, and as only high intensities or rates in excess of the rate at which the surface can absorb or retain water cause appreciable runoff it is obvious that the cloudburst on both accounts is potentially a source of danger and destruction. The many records of disastrous storms and mountain floods in Utah include only one or two isolated storms that were not of the thunderstorm type.

It should be kept in mind, however, that not all thunderstorms are accompanied by excessive precipitation. To produce a large volume of rainfall under barometric and thermal conditions conducive to cloudbursts there must be a large volume of moisture available for condensation and mechanism for the flow of the moisture to the region of instability. The coincidence of high moisture content and strong convection necessary to produce disastrous storms is the exception rather than the rule.

Cloudburst storms recorded by the United States Weather Bureau at Salt Lake City in August 1923 and August 1931 are shown in plates 8 and 9.

On the evening of August 13, 1923, northern Utah was struck by the severest cloudburst in its history. Hundreds of acres of land were destroyed by floods from the canyons, homes were demolished, utilities damaged, and at least nine persons were

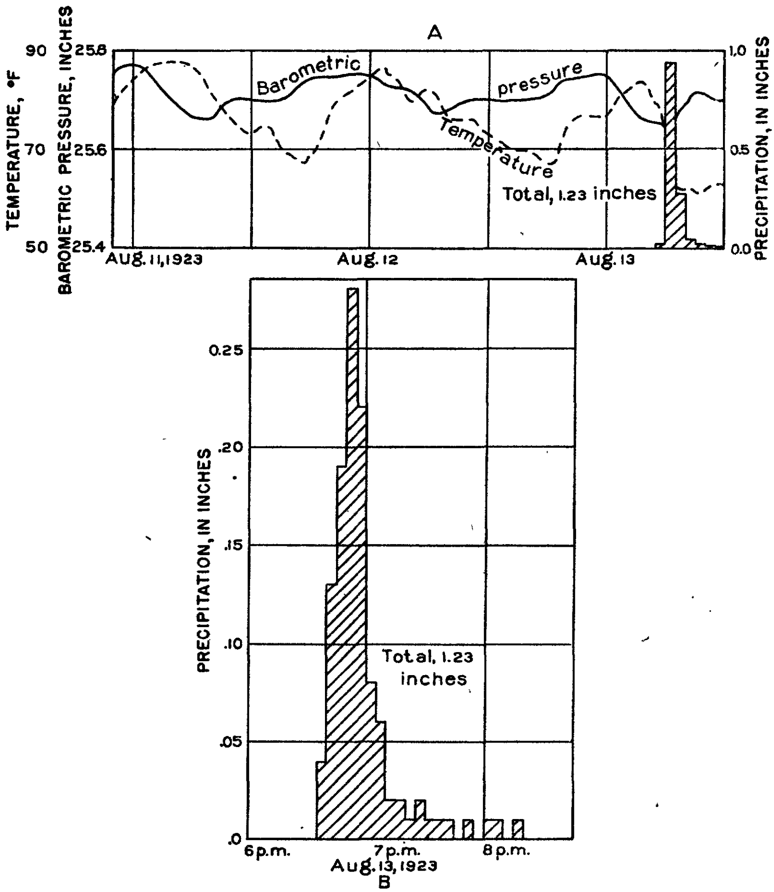

FIGURE 4.—Characteristics of cloudburst storm of August 13, 1923. From records of United States Weather Bureau at Salt Lake City.

drowned. The characteristics of this storm and the barometric and thermal conditions at Salt Lake City from August 11 to 13, inclusive, are shown in figure 4. Uniformly high temperatures and pressures prevailed prior to the storm. As the storm developed the barometric pressure and temperature fell rapidly. Figure 4, A shows the hourly quantities of precipitation during the storm, and figure 4, B shows the 5-minute intensities, as recorded by the tipping-bucket gage during the most violent period. Of the total of 1.23 inches of rainfall, 0.96 inch fell in a period of 25 minutes. On ground with an absorption rate of 1 inch an hour, 0.54 inch of this would be surface runoff.

The volume and intensities of precipitation in the higher altitudes must have been greater in order to produce the terrific canyon floods.

Another storm of this kind occurred August 13, 1931 (fig. 5). It was not so severe as that of 1923 but was severe enough to

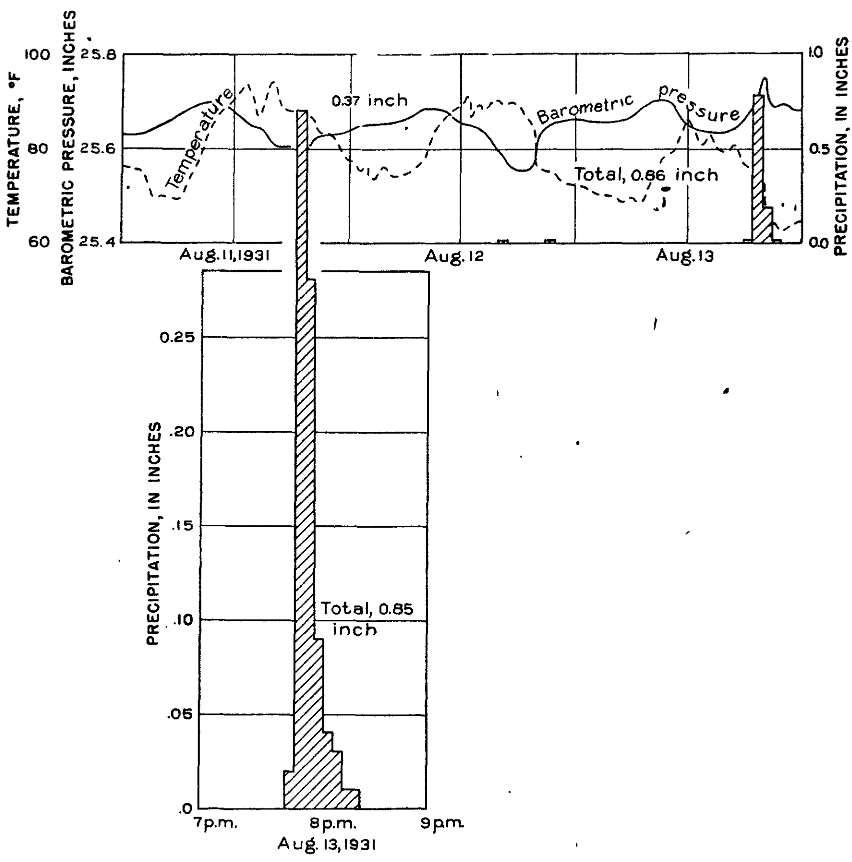

FIGURE 5.—Characteristics of cloudburst storm of August 13, 1931. From records the United States Weather Bureau at Salt Lake City.

cause considerable damage. Two mudflows emerged from the canyons between Salt Lake City and Farmington, burying several automobiles on the State highway. The State spent over $8,000 in clearing away the debris and mud. Characteristics of this storm from records at Salt Lake City are shown in figure 5.

Rain fell at Salt Lake City during this storm at the rate of 0.85 inch in 35 minutes, and of that amount 0.77 inch fell in 15 minutes. Initial intensities were so high that in 15 minutes 0.50 inch would have run off from a ground surface capable of absorbing 1 inch an hour.

A mixed form of storm is illustrated in plate 10 and figure 6. The weather maps (pl. 10) cover the storms of August 23 to 30, 1932. Precipitation was recorded from the 26th to the 29th (fig. 6), but the 26th and the 29th had the greatest rainfall. Cloudburst propensities were manifest at the beginning of both storms, but no strong convection developed. There were only two 5-minute intervals on the 26th and one on the 29th with fall sufficient to have caused surface runoff from ground that would absorb at the rate of 1 inch an hour.

RELATION BETWEEN STORMS AND ALTITUDE

The relation of altitude to precipitation in Utah has been the subject of several research studies,[33] but definite mathematical relationships have not been found. It is apparent, however, that the mountain ranges and the upland plateau areas get more precipitation than the lowland and desert areas. Some exceptionally heavy storms have been recorded at valley stations, but they are too infrequent over the State as a whole to account for the cataclysmic floods that occur almost annually in various parts of the State.

Estimates of runoff from several flood canyons based upon the minimum amount of water required for the liquefaction of the immense debris waves indicate rainfall generally far in excess of any storms recorded at lowland stations. It is apparently axiomatic that a thunderstorm, in impinging upon a mountain range, is materially augmented both in violence and in degree of condensation and rainfall. The incredible runoff and erosion resulting from a single heavy cloudburst support this hypothesis. Thunderstorms and cloudbursts are most common in the mountains and upland areas, and therefore these areas undergo greater erosion owing to the greater volume and intensity of precipitation and the steep declivities and well-defined catchment basins.

[33] Alter, J. Cecil, Normal precipitation in Utah: Monthly Weather Review Sept. 1919: Clyde, G. D., Relationship between precipitation in valleys and on adjoining mountains of northern Utah: Monthly Weather Review March 1931, vol. 59, pp. 113-117.

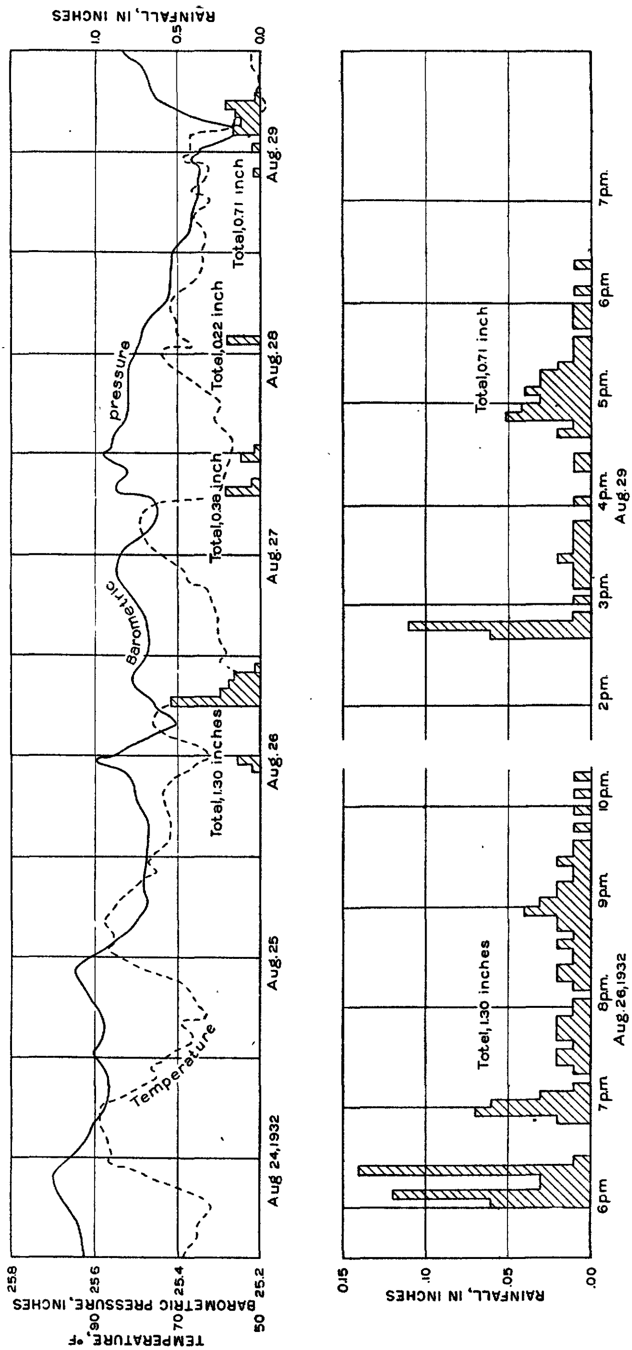

FIGURE 6.—Characteristics of storms of August 26 and 29, 1932. From records of United States Weather Bureau at Salt Lake City.

FREQUENCY OF THUNDERSTORMS AND CLOUDBURSTS

Thunderstorms and cloudbursts are more frequent in the southern and eastern parts of the State than in other parts, but owing to the sparse settlement of these parts the storms do not receive the attention accorded them in more densely populated regions. At Grand Junction, Colo., which is adjacent to southeastern Utah, approximately twice as many thunderstorms occur as at Salt Lake City.

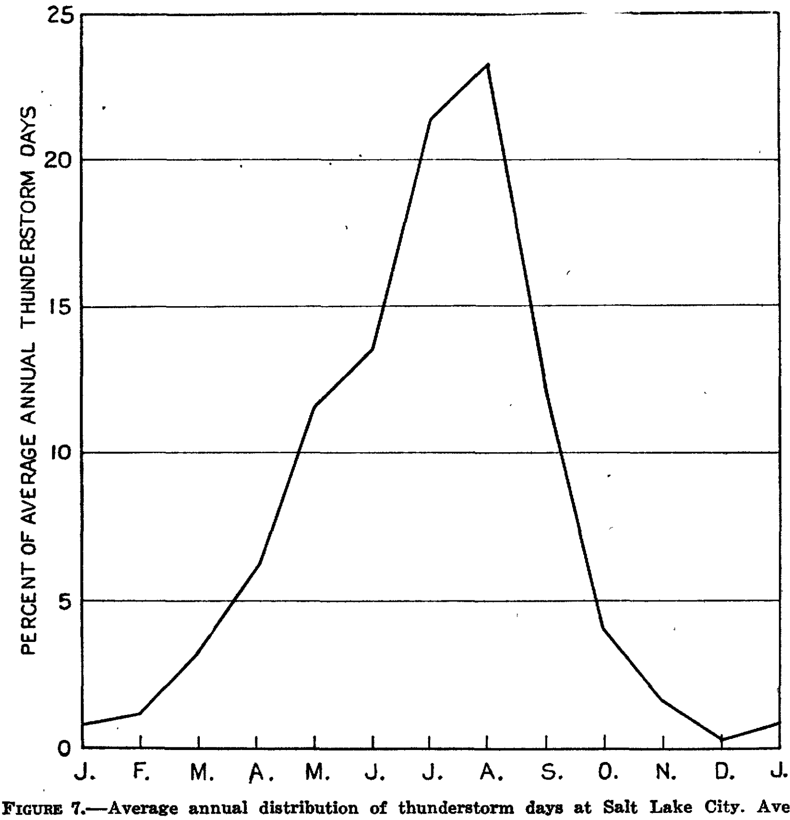

FIGURE 7.—Average annual distribution of thunderstorm days at Salt Lake City. Average annual number of thunderstorm days was 35 for period 1904 to 1938.

The number of thunderstorm days reported, however, varies widely at any given place. For example, the number of days in any one year since 1910 on which thunderstorms were noted at Salt Lake City varies from 17 to 56. A thunderstorm day is defined by the United States Weather Bureau as a day on which lightning is seen or thunder is heard from the station, but not necessarily accompanied by precipitation. The relative distribution of thunderstorm days, as reported at Salt Lake City, is shown in figure 7. The months of July and August alone include about 45 percent of the total number for the year.

CLOUDBURST INTENSITY DURATION

GENERAL STATEMENT

In most studies of storm runoff, the investigations are handicapped by rather meager precipitation data. In the smaller drainage areas the lack of precise records of short-time intensities is particularly serious. Only in areas under close investigation are such records available.

The rates of runoff ensuing from a cloudburst storm can only be completely accounted for by a rather extensive study of the relative intensities of precipitation during the storm period. In a semiarid region, such as Utah, a storm yielding an inch of rain in an hour or less is unusual, but if that amount were evenly distributed through the period of its fall the intensity would scarcely exceed the common rate of absorption by natural ground. When analysis shows, however, that more than 60 percent of that amount may have fallen in only 20 percent of the time, the disastrous effects of surface runoff are quite explicable.

Some storms are on record in which the maximum intensity occurred in the first 5 minutes, and other rarer examples are found in which the maximum did not occur until near the middle or even the latter part of the storm. Sufficient data are not available to determine whether gages placed along the line of travel of a thunderstorm would all show the same intensity distribution, thus further complicating the analysis of runoff.

Records of rainfall intensities in this region are scarce over any lengths of time for the upland areas. Some records are available for Salt Lake City and Modena at the offices of the United States Weather Bureau at those places. Records for shorter periods have been compiled at the Great Basin Experiment Station of the Forest Service on the Wasatch Plateaus east of Ephraim, established in 1914, and also at the Davis County Streamflow Laboratory of the Intermountain Forest and Range Experiment Station of the Forest Service on the Wasatch Front in Davis County, established in 1936. But without additional data it is not yet certain that thunderstorms in other altitudes and latitudes follow the same intensity distribution. It is generally accepted, however, that during the travel of a storm over the windward slopes of mountain ranges convection is orographically augmented, which results in greater intensities and a generally greater total of rain at the foot of the slopes. It seems reasonable to assume that duration, total fall, and intensities are all pro-

LITTLE COTTONWOOD CANYON, WASATCH RANGE.

Note troughlike U-shaped profile of glaciated mountain valley.

portionately affected and that what is known to occur at one spot presumably takes place on a greater or smaller scale at another.

INTENSITY DURATION

Meteorological data for 18 noteworthy cloudburst storms at Salt Lake City were studied for the intensity distribution of precipitation. All these storms were definitely of cloudburst intensity and several were violent enough to cause serious damage.

From the tipping-bucket record sheets the successive 5-minute intensities were compiled for each storm, care being taken to select the intervals so as to include the most intense period of the storm in one interval. To avoid the effect of spasmodic light showers, which sometimes succeed the downpour, the period was considered terminated when the intensity fell to less than 0.01 inch in 5 minutes. These latter periods account for very little rain. In order to analyze these storms comparatively, the intervals selected for each were rearranged so that the maximum intensity was placed in the first 5-minute interval, with other intervals following in decreasing order of intensities.

In figure 8 three of the 18 storms are shown graphically, first, showing the variations in intensity as they actually occurred and then with the intensities arranged in descending order of magnitude. In an actual storm, preliminary fall often satisfies, at least partially if not completely, the requirements of initial interception and surface detention and permits the maximum intensities to contribute to surface runoff, which is then reduced only by the infiltration. In the rearranged storm the initial requirements of interception and detention must be satisfied during the high intensity period, which has the effect of reducing the maximum intensity. As far as the scantily vegetated watersheds of the semiarid West are concerned, this difference does not appear important. For the purpose of comparing storms an assumed infiltration rate of 1 inch an hour has been applied to these storm graphs regardless of the actual hydrologic conditions that prevailed during the storms, but no interception and surface-detention factors have been applied. The excess over the infiltration rate therefore represents theoretical surface runoff from a small unit area of exposed ground. In the decreasing-intensity arrangement of the storms the cumulative percentage of precipitation "*F*" is plotted against the percentage of duration "*T*" from the beginning of the storm. Percentages rather than dimensional data *were* used in order to reduce storms of widely varying total precipitation and duration to a standard basis of comparison. Regardless of volume of precipitation or duration, the shape

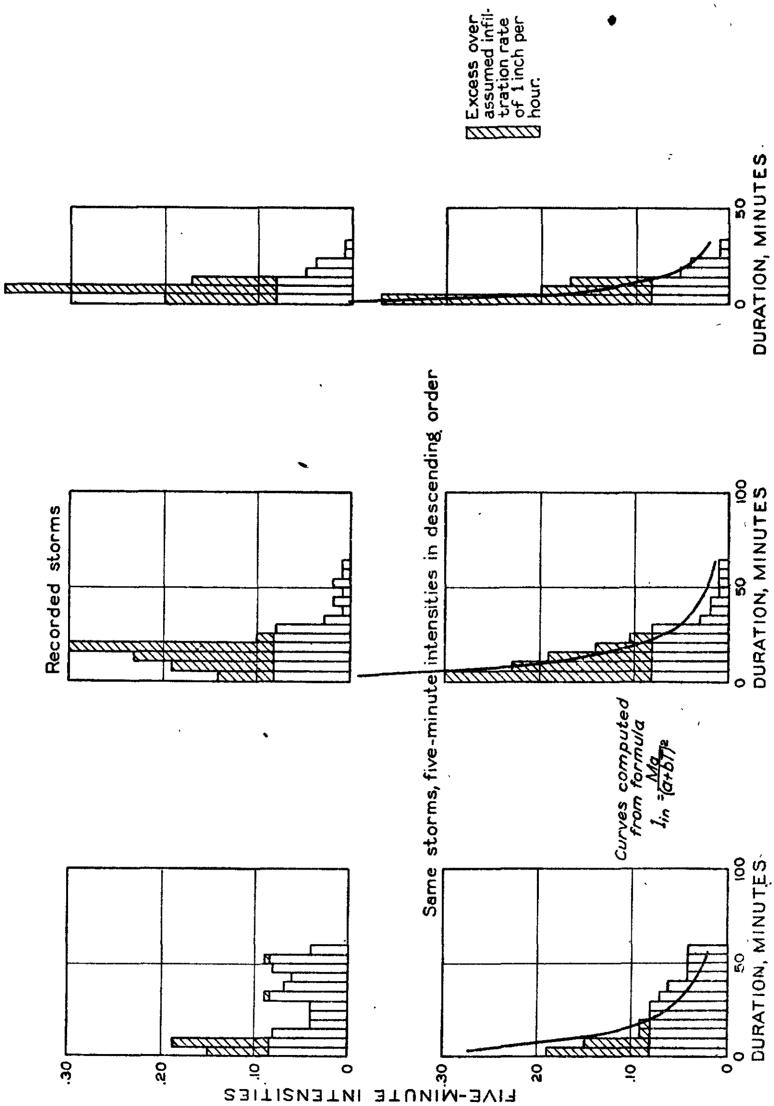

FIGURE 8.—Graphic analysis of intensities of three cloudburst storms.

of these graphs approximated very closely the simple hyperbolic expression $F = \frac{T}{a+bT}$, in which a and b are constants determining the curvature and therefore the intensity deviation from the mean for any given storm.

This formula is similar to the dimensional formula developed by Meyer[34] for storms of 5 to 120 minutes' duration. The advantages of using the percentage relationship lie in the fact that with

[34] Meyer, A. F., Elements of hydrology, 1928.

knowledge of only the duration and total precipitation of a cloudburst storm and with selected values of a and b which range within narrow limits generally, any cloudburst storm can be reconstructed. The relationship between a and b, which are interdependent, is expressed by $(a + 100b) = 1.00$. Safe average values were found to be $a = .18$, $b = .0082$. For the average intensity for any interval from the beginning of the storm $Iav = \frac{M}{a+bT}$, and for the theoretical instantaneous intensity $I = \frac{Ma}{(a+bT)^2}$. M is the mean intensity for the entire storm. Computed intensities for the storms represented in figure 8, using the above value of a, are as follows: $T = 5$ percent, $F = 23$ percent; $T = 10$ percent, $F = 38$ percent; $T = 20$ percent, $F = 58$ percent; $T = 50$ percent, $F = 85$ percent; $T = 75$ percent, $F = 98$ percent.

FACTORS INFLUENCING INTENSITY

A considerable variation in the intensity-duration behavior may be expected in light storms. The causative forces of storms and their relative importance are defined by Humphreys[35] as follows:

> (a) Reduction of temperature, volume remaining constant; (b) reduction of volume, temperature remaining constant; (c) a combination of temperature and volume changes that jointly reduce the total vapor capacity.

In nature (c) is usually most applicable.

Briefly, the volume of precipitation from a thunderstorm and the violence with which it occurs depend upon the degree of saturation of the air masses, the changes in density or pressure and in temperature, and the rate at which these changes take place. As intensity-duration studies indicate a systematic variation independent of the volume of storm rainfall, it must be deduced that temperature, which changes greatly during a thunderstorm, must have a great effect not only upon the amount of condensation from a mass of given moisture content but also upon the rapidity with which the condensation transpires and the resultant intensities of precipitation.

Temperature change is apparently the most important factor affecting the amount and rate of condensation and precipitation. (See fig. 9.) For each storm the temperature drop was taken from the thermograph record sheet and plotted against corresponding values of the factor a in the hyperbolic intensity-duration functions. The correlation, although not exact, is nevertheless con-

[35] Humphreys, W. J., Physics of the air, 2d ed., McGraw-Hill Book Co., Inc., p. 247, 1929.

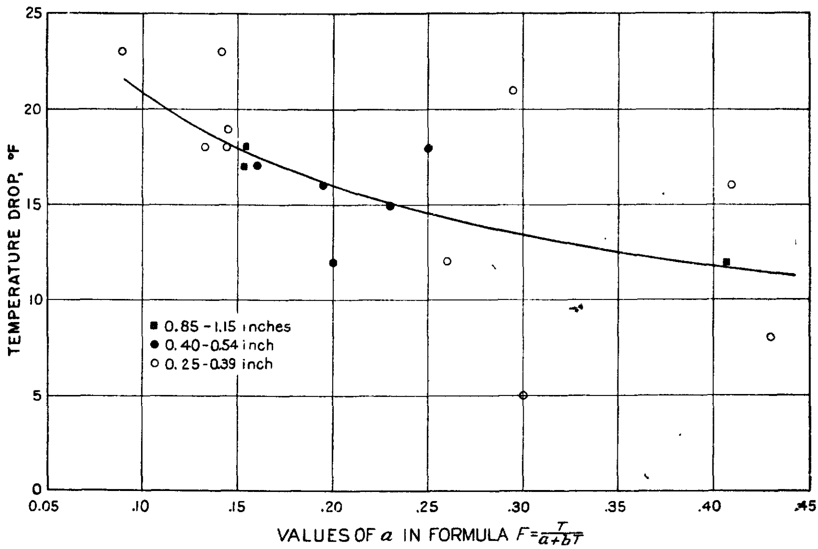

Figure 9.—Association of temperature drop with deviations from mean intensity. Points on chart are values of *a* computed for individual storms recorded at Salt Lake City.

spicuous, especially when it is borne in mind that the temperature change is only one of the several variables which may be present in the complete relationship.

With increasing magnitude of temperature drop, the value for *a* decreases. As *a* decreases the curvature of the intensity-duration curve becomes sharper. In general, then, it appears that, almost regardless of the volume of precipitation, duration, or initial moisture content, the relative violence of a cloudburst is influenced mainly by the temperature change undergone by the air mass involved and that the greater the drop the greater will be the deviation of the intensity from the mean.

In figure 9 the storms were plotted to bring out the effects of quantity of fall, if any were present. It is noted that the heavier storms, those in excess of 0.40 inch of total precipitation, show a closer agreement than do those yielding less than that amount. It is also noted that the heavier storms were accompanied by greater temperature drops and, moreover, that all points tended to fit more closely in that zone. This merely indicates that with an air mass of average moisture content the degree of condensation depends upon the thermal change. The better fit in the higher part of the curve illustrates the fact that the greater the thermal change, the more its effect dominates that of the other variables. The operation gains in stability and precision as the determinate factors of moisture content and temperature drop increase.

Another important factor in bringing about variations in the intensity distribution is the position of the recording rain gage with respect to the center of convection. It is apparent that the area under the influence of a single thunderstorm is definitely limited by the extent of the convective activity and that only a relatively small area in the center of the storm is subjected to the higher intensities.

An idea of the area covered at any instant by a thunderstorm can be gained through a consideration of the storm's velocity and the length of the precipitation period recorded by a stationary gage. The duration of the period of precipitation is 20 to 30 minutes on the average, though rarely it may be an hour or more. Thunderstorms may have a horizontal velocity of roughly 30 to 50 miles an hour in this region. Thus, the area affected by the storm at any instant has a length and breadth of from 10 to 25 miles on the average. It should be kept in mind that this report is dealing with excessive, unusual storms and does not consider the ordinary, light, brief, scattered summer thundershowers.

Furthermore, as the intensity records show, the period in which the dangerous intensities occur is only about 25 percent of the total duration of the storm, so that the actual extent of the endangered area at any moment is relatively small, say 5 to 25 square miles, assuming a circular distribution with a diameter of 2.5 to 6 miles.

This accounts for the generally localized effects of cloudbursts. In general, the smaller the catchment area, the greater the proportionate excess of discharge induced by a thunderstorm in a critical location. A flash flood of 2,000 second-feet or more from a drainage basin of 4 square miles is a potential agent of destruction; the same flood, contributed by a small tributary to a larger stream, may not equal the normal spring peak to which the channel is accustomed.

In accounting for the variable effects of cloudbursts on stream flow, consideration should be given to the relation between basin alinement, the direction of storm travel, and the position of the basin with respect to the storm center.

RUNOFF UNDER THUNDERSTORM INFLUENCE

Runoff occurs from drainage basins whenever the rate at which water accumulates exceeds the rate at which absorption and evaporation take place. As a single thunderstorm seldom affects any given area for more than an hour the effect of evaporation is negligible. The rate of absorption varies from practically nothing, as on roofs and surfaced roads, to as much as 1½ inches an hour.

Two other factors of rainfall retention must also be satisfied before free discharge takes place: (1) Interception by vegetation, and (2) initial or surface detention. Interception by vegetation on the near-barren lands of the semiarid and arid West is generally slight, and the proportion of the total fall of a heavy cloudburst thus affected is insignificant.

Initial detention is defined by Horton[36] as "a surface layer of water which accumulates before run-off begins." He estimates the total amount of rainfall retained because of factors that might properly be associated with initial detention to range from one-eighth to three-fourths of an inch for flat, near-barren areas and from one-half to 1½ inches for cultivated fields and for natural grasslands or forests. On slopes of 35° or more, such as occur in the drainage basins of Utah, it is believed that the values of initial and surface detention are less than those indicated.

In general, the regimen of thunderstorm precipitation consists of a brief period of light intensity merging quickly into the maximum intensity. The maximum lasts for only a few minutes and then tapers off rapidly as the storm passes. The extreme rates of rainfall in the mountains of Utah are not definitely known. Storms recorded at Salt Lake City have shown an intensity lasting for brief periods as high as 0.40 inch in 5 minutes (4.8 inches an hour) and yielding more than an inch of rain in less than an hour's time. An unusual cloudburst occurred July 7, 1933, in Bryce Canyon, in the High Plateaus (8,000 feet in altitude), which lasted only 10 minutes and yielded 0.90 inch of rain, a rate of about 5.4 inches an hour. The heaviest mountain storms undoubtedly exceed those recorded in the lowlands, both in intensity and total precipitation.

Under such rates of precipitation only the densest vegetation, characteristic of climatic conditions that differ greatly from those in Utah, can effectively retard and prevent surface runoff. In the Utah flood canyons under survey vegetal cover was generally sparse and the retention value of the surface and its cover is probably in the lower ranges suggested by Horton.[37] Even during the heaviest cloudburst storms the period in which the intensity rate markedly exceeds the absorption rate is only about 25 to 30 percent of the total duration. Probably in some parts of the basin subsequent rain of an intensity less than the average absorption rate falls on ground covered with excess water or on impervious ground and contributes somewhat to surface flow. At any rate the period of significant direct contribution to runoff rarely ex-

[36] Horton, R. E., Surface run-off phenomena: Horton Hydrol. Lab. Pub. 101, p. 14, 1935.
[37] Horton, R. E., op. cit.

ceeds 20 to 30 minutes. For this reason only small drainage areas with concentration periods of less than 20 to 30 minutes will experience maximum runoff. In the larger areas much of the surface flow is absorbed in transit.

Precipitation records on the higher catchment areas of Utah are scarce. Furthermore, when an unusual summer flood has occurred in a stream on which a gaging station is maintained the gage has frequently been washed out by the flood. Thus, most maximum discharges recorded for summer floods in the smaller streams are necessarily estimates, the making of which is complicated by the fact that the stream beds are steep and tortuous and the flood waters choked with debris.

In three of the small streams in Davis County rough estimates of the volume of debris added to the fans during the floods of 1923 and 1930 were used in an effort to arrive at the flood discharges. These floods were virtually mudflows, and knowing the approximate time required for the discharge and the volume of water (through shrinkage and porosity tests) required to liquefy the debris, a very rough estimate of discharge is given in the table on page ...... In arriving at these figures several field measurements were made of shrinkage of flood material entrapped in sties, barns, and other buildings by determining the depth of the material that had settled on the floor as compared to the height above the floor of the original mud marks. The specific gravity of solid material and dry weight of soil samples furnished a basis for a rough comparison of the results of these studies with some made by Eaton[38] in California, in which saturated debris made up approximately 70 percent and additional water 30 percent of the flood material. On the basis of this relationship, which is believed to be within acceptable limits of accuracy for the floods here listed, each cubic yard of deposit had 1$\frac{3}{7}$ times as much volume in a flood state as in the dry state. Moreover, if the deposited material has a dry porosity of 30 to 40 percent, the moving flood material will contain water in the following percentages:

$30 \times .70 + 30 = 51$ percent

$40 \times .70 + 30 = 58$ percent

The total yardage of debris deposited on the flood fans by the storms tabulated was estimated in the following manner:

(*a*) Depth of deposits was noted on partially submerged fence posts, wagon wheels, sheds, and other objects.

(*b*) Profiles were made across the fan from natural ground to natural ground.

[38] Eaton, E. Courtlandt, Flood and erosion problems and their solution: Am. Soc. C. E. Trans. 1936, pp. 1302-1362.

(*c*) Conservative consideration was given to all oral statements by local inhabitants.

The determination of the duration of flood flow is based on numerous interviews and a careful analysis of field observations from all sources of information. Obviously a great deal of personal judgment enters into these determinations, and other investigators may disagree considerably with the results. The average discharges for the floods here studied are based on a total water discharge of 52 percent of the moving flood material in cubic feet divided by the estimated duration of flow in seconds.

Estimates of flood discharges in several Utah streams [1]

Stream	Locality	Drainage area (square miles)	Discharge in second feet		Discharge in second feet per square mile		Date of flood
			Average	Maximum	Average for duration of flash flood	Maximum	
Steed Creek	Farmington	2.42	1,120		460		August 13, 1923.
Davis Creek	do	1.48	810		550		Do.
Farmington Creek [2]	do	7.0		2,450		350	Do.
Parrish Creek	Centerville	2.03	1,040		515		July 10, 1930.
Price River [2]	Helper	530.0		[3] 10,000		18.8	September 1927.
Snowslide Canyon	Provo	1.17	660		565		July 13, 1938.

[1] Except as otherwise indicated, estimates were based on volume of water necessary to fluidify debris deposited. Any excess water would increase the figures.

[2] Data taken from table by C. S. Jarvis in "Low dams," prepared and published by Water-Resources Committee of National Resources Committee in 1938.

[3] Discharge indeterminate owing to extreme floods of that period, but estimated as between 9,000 and 10,000 second-feeet.

The effects of varying periods of concentration, confined areas, and brief duration of cloudbursts are indicated by the stream discharges. All these streams have an average annual discharge of much less than 1 second-foot a square mile. The peak flood in the Price River was 60 to 70 times the average annual discharge, whereas the streams with the smallest drainage areas had flood flows for brief periods that were 2,000 or more times the average.

Most of the cloudburst floods originate in regions below the 8,000-foot altitude, in streams more or less directly exposed to the direction of storm travel. A few areas that are not greatly affected by cloudburst storms are found at altitudes almost invariably above 7,500 feet and in rather sheltered positions topographically. These areas usually have a dense forest cover and a thick layer of pine needles and other forest litter, which indicates a natural balance between the factors of precipitation, absorption, and interception, and the rate of occurrence of storms of sufficient violence to cause destructive runoff.

Suggestions are not uncommon that the effects of cloudburst floods might be minimized if the catchment basins of the flood-ravaged canyons could be planted to a denser vegetative cover. In attempts of this kind, however, the fact should be borne in mind that practically all the canyon lands are now bearing a plant cover which, in its original condition, is predetermined by natural conditions of precipitation, percolation, evaporation, transpiration, temperature, and situation, and that any wide-spread attempt to "overload" the watershed will no doubt be disappointing.

The most violent discharges, causing, proportionately, the greatest amount of damage, originate in drainage areas of 10 square miles or less, although some notable floods have occurred under thunderstorm influence in streams whose basins range from 60 to several hundred square miles. It has been estimated that some discharges from streams with only a few square miles of drainage area have yielded a flash peak flow of 1,000 to 2,000 second-feet of water exclusive of the large debris load, which might double that volume. Some streams draining hundreds of square miles have summer thunderstorm peaks in excess of their maximum spring high-water discharges. This is true of the Duchesne River, thunderstorm floods in one or more of whose tributaries produced abnormal peaks, which in turn produced a crest in the main stream that persisted beyond the gaging station at Myton. The drainage area above this station is 2,750 square miles.

It is not uncommon for the channels of some of the larger streams in Utah to be temporarily dammed by earth and debris from tributary drainage basins. This breaks the natural regimen of the stream and produces a peak flow after the dam is overtopped and washes out. The Provo River within its canyon in Utah County has been obstructed in this fashion several times. The water arose behind the debris deposits, covering stretches of highway, railroad track, and canyon camp sites for days until the mass was artificially removed. In these instances the discharges fom the tributary canyons have been thick mudflows which added little free water to the main stream and thus did not materially augment its flow.

Directions of travel and extent of thunderstorms bear important relationships to runoff from any specific drainage basin. The more nearly the direction of travel parallels the course of the drainage over which it passes, the greater will be the flood crest produced by any given precipitation intensity great enough to cause surface runoff. However, if the direction of travel is upstream, a substantial part of the precipitation at the lower end may run off without contributing to the main flood wave, except as the tendency is modified by the condition that the concentration period in the downstream reaches is prolonged by gentle slopes and characteristics favorable to absorption.

In convectional storms the canyons draining the windward slopes receive the heaviest precipitation, and at times drainages on opposite sides of a range have both been in flood, as the storms were not completely dissipated before crossing the divide. However, it is seldom that the leeward slopes produce a serious flood runoff. A storm crossing a long, narrow valley transversely may affect only a small part of it. However, if the width of the storm exceeds appreciably the length of the valley, the entire valley may receive precipitation of similar intensity.

The storm that struck much of northern Utah August 13, 1923, was not the common type of spotty convectional storm but presented some of the characteristics of the general air-mass type, which is relatively infrequent in the semiarid West.

It is estimated that flood discharges from many of the smaller catchment basins in Utah range from 400 to 600 second-feet per square mile as a result of cloudburst storms, probably 10 times that to be expected from the maximum spring peak. Studies using the maximum spring peak discharge for several streams of long record indicate that a channel capacity of 5 second-feet per square mile of drainage area is sufficient for streams like the Bear River at Harer, Idaho, and the Virgin River at Littlefield, Ariz., rivers with drainage areas of 2,780 and 4,400 square miles, respectively, whereas a capacity of 25 second-feet per square mile is required for streams of the magnitude of Weber River at Oakley (drainage area, 163 square miles), the North Fork of Duchesne River (39 square miles), and Little Cottonwood Creek (approximately 28 square miles).

Applying the findings of these studies to small streams with drainage basins ranging from 2 to 10 square miles, it is estimated that such streams would require a channel capacity of 40 to 60 second-feet per square mile of drainage area for their maximum peak discharge of spring runoff.

CLOUDBURST FLOODS

GENERAL STATEMENT

The term "cloudburst" is applied generally to any sudden and excessively heavy downpour of rain, especially in the mountain regions. In the State of Utah, however, rarely, if ever, is the fall during a general cyclonic storm of sufficient intensity and volume to produce a notable flood in any stream. In the larger drainage basins a heavy rainfall on a snow cover will usually cause maximum high-water stages, but this cannot be ascribed entirely to the rain storm. A cloudburst, as defined in the Century Dictionary and Cyclopedia and as used in this report, "is a violent downpour of rain in large quantity and over a limited area." In Utah it is of thunderstorm origin. A flood produced by a cloudburst is usually a flash peak discharge followed by a quickly diminishing flow, as shown by the hydrographs of Price and San Rafael Rivers in figure 10.

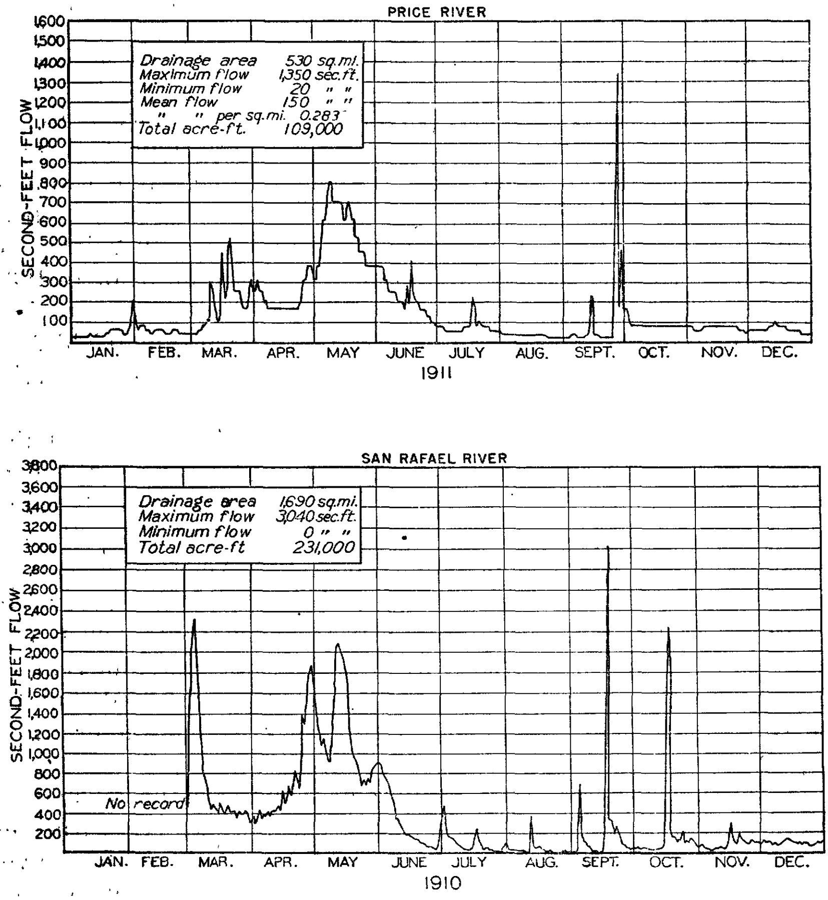

Figure 10.—Typical regimen of Price and San Rafael Rivers. High peaks, July to October, due to thunderstorms.

The streams most seriously affected by cloudburst floods are those in which the flood peak exceeds that of normal spring freshets to which the stream channel has been corraded. Stream profiles and channel cross sections are indicative of flood conditions on the stream. If cloudburst runoff that exceeds materially the maximum spring peak discharge occurs with sufficient frequency, it is then responsible for the preponderance of channel cutting and fan building.

Gilbert[39] writes, with respect to "cloudburst channels" in this region, that precipitation here, as in other desert regions, is extremely irregular and often violent, and

> Sooner or later the 'cloudburst' visits every tract, and when it comes the local drainageway discharges in a few hours more water than is yielded to it by the ordinary precipitation of many years. The deluge scours out a channel which is far too deep and broad for ordinary needs and which centuries may not suffice to efface. The abundance of these trenches, in various stages of obliteration, but all manifestly unsuited to the everyday conditions of the country, has naturally led many to believe that an age of excessive rainfall has but just ceased.

Five-minute intensities of cloudburst storms recorded by the United States Weather Bureau at Salt Lake City indicate a maximum precipitation of 0.40 inch August 13, 1923, and a similar record made by the Forest Service at its Wasatch Front Experiment Station in Davis County July 10, 1936, was 0.42 inch. No records are available from the Davis County station prior to 1936. If it is realized that during such storms the runoff occurs in a period of minutes as compared to months for the same yield from normal snow cover and usual rains, the violent corrasive action of the cloudburst flood is apparent.

In the absence of a mudflow on those streams that are building fans along the foot slopes of the mountain ranges the flood that flows from the canyon distributes the detritus from its catchment basin over the fan by shifting its channel from time to time as the sediments clog it. As the canyon wears deeper at its mouth and the stream discharges at a lower level, the upper part of the fan is excavated and a new fan modeled with lower apex and lower grade. In a general way the coarsest alluvium remains nearest the mountain and the finer is farther removed, but the sorting is very imperfect, and heterogeneity is a characteristic of the fans.

Some conception of the behavior of cloudburst floods may be gained from the following descriptive accounts of eye witnesses.

On August 6, 1901, one of these floods came out of the canyon at the settlement of Milburn, in the northern end of Sanpete County. The editor of the Mount Pleasant Pyramid watched it from the rear platform of a slowly moving train. He says:[40]

> It was an amazing sight * * * an avalanche of water freighted with trees and boulders hurling itself down the mountains. It was really a fearful

[39] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 9, 1890.

[40] Deseret News, Salt Lake City, Utah, Aug. 7, 1901.

sight, for down in the valley there were men struggling to get their stock out of reach of the oncoming flood. The people of Milburn caught the contagion of fright, and a panic followed. But before reaching the village the water spread out over the plateau, but even then it was about 3 feet deep in some parts of the town.

The Eureka Record gives accounts of no less than 23 cloudburst floods in the period 1906 to 1938 at Eureka, a small mining town in Eureka Canyon about 10 miles west of the south end of Utah Lake. Conditions here are indicated by Timothy L. Sullivan,[41] a resident of the town.

He states that:

The heaviest rains and floods occur in this vicinity during the months of July and August each year. Seldom a year passes that storms reaching flood proportions do not occur during these two months. Eureka's Main Street is built near the bottom of the canyon running through the city from east to west, and the storm sewer follows the same course on the north side of Main Street. Most of the buildings on the north side of Main Street are constructed over the storm sewer. Consequently when floods occur these buildings are damaged to some extent.

A typical flood is described by Mr. Sullivan as follows:[42]

July 31, 1912, about 4:30 p.m., one of the worst floods in the history of Tintic occurred. An unusually heavy rain was followed by a cloudburst. Just before the cloudburst it turned so dark that lights had to be turned on in the homes and business houses. Every street in Eureka was washed out. A raging torrent came down Main Street and the storm sewer to the right on the north side of the street. The water and debris from the storm sewer entered the back doors of business houses and came out the front, carrying merchandise of all descriptions with the water down the canyon. It was a very unusual sight to see cases of canned goods, barrels of beer, and empty beer kegs floating out the front doors and being washed down the canyon. The damage to streets and buildings was enormous.

Among the larger streams of the State the Price River is notable for cloudburst floods. One of these is described as follows:[43]

Price, July 20.—Washed out bridges and delayed trains are some of the results of a heavy rainstorm that struck Price watershed yesterday (July 19, 1913) afternoon. The D. & R. G. Railroad bridge at Castle Gate went out about 6:00 o'clock. The Midland Trail bridge above Castle Gate went out, and when the debris swept down against the wagon bridge at Castle Gate that structure also went. The flood washed away two houses at Castle Gate, besides flooding and damaging numerous others. The water poured into the windows of the big boarding house, creating a panic among the boarders. A trunk, said to contain $1,000, was washed away from one of the houses and downstream, and at this writing there are nearly 100 men out searching for it.

As an example of the rather astounding amount of cloudburst runoff from a small catchment basin the following description

[41] Communication to Federal Writers Project of Utah.
[42] Condensed from Eureka Record of Aug. 2, 1912.
[43] Deseret News, Salt Lake City, Utah, July 21, 1913.

is recorded of a flood from Wood Canyon at Mayfield, Sanpete County, in August 1889:[44]

At Mayfield the water which did the most damage came down what is known as Wood Canyon, which is about 1½ miles long. From this canyon poured forth a stream of water 6 rods or more in width and fully 5 feet deep in the center. This torrent came down at a terrific rate.

One man hurrying home to see to the safety of his family, halted his buggy on high ground near the house and handed the reins to a son to hold. Upon entering the house

he found the other five children floating around on a lounge, the water 3 feet deep and his wife holding to a cupboard, partly to steady herself and partly to prevent it from falling onto the children on the lounge. * * * Just as Brother Jorgensen mashed out a window to make an exit for the water the main body of the water reached them. He saw the stable swept from its foundations, buggy and horse rolling over and over in the seething tide, but did not see the gallant boy, who stood at his post of duty to the death * * * his body was found buried in the mud and jammed under the wreck of a wagon a block below. The cattle from the demolished pens went rolling over and over like so many logs.

Depending on the area of the catchment basin, the area covered by the storm, and the intensity and duration of the storm, these cloudburst floods have various characteristics. On a larger stream they may pass unnoticed except for a sharp peak, whereas there may be a terrific flood wave and mudflows from small basins of less than a square mile to only a few square miles in area. At times a giant flood surges down a stream of intermediate size and, reaching to unanticipated heights, destroys highways, bridges, railroad grades, and other works of man.

GEOGRAPHIC DISTRIBUTION

It is apparent from plate 11 that cloudburst floods have occurred throughout the State in a promiscuous fashion. Most of those recorded, however, have occurred within a zone or belt 60 to 80 miles wide, extending southward through the middle of the north half of the State and thence southwestward to the southwest corner. This belt embraces the mountain ranges and west edges of the High Plateaus that form the drainage divide between the deserts of the Great Basin on the west and the Colorado River Basin on the east and includes most of the area of the State in which the annual precipitation exceeds 10 inches. Furthermore, it includes nearly all the towns in the State and more than 75 percent of the total population. Only a few communities within this belt have not experienced cloudburst floods, and a great many have experienced several.

Obviously the geographic distribution of these floods is influenced by the topography. The mountain ranges induce the con-

[44] Deseret News, Salt Lake City, Utah, August 23, 1889.

vective circulation required for thunderstorms and also wring from the air masses more than the normal amount of precipitation. The canyons and gulleys concentrate the runoff from catchment basins and pour it out upon a relatively small area adjacent to the stream, greatly multiplying the effects of direct precipitation. Only infrequently do the few settlements situated in wide, flat areas, away from these topographic influences experience any appreciable damage from cloudbursts.

CHARACTER AND EXTENT OF AREAS AFFECTED

It is an unfortunate coincidence that the localities most suitable for settlement in Utah are also most favorable to the damaging effects of cloudburst floods. In seeking home sites the pioneers of the region followed what appears to be the only logical procedure in a semiarid region. Water is the first essential for domestic occupancy and for the production of agricultural crops. The alluvial fans at the mouths of those canyons yielding perennial streams were the fertile areas where water was near at hand, and the slope of the fans simplified the problems of irrigation and drainage. After these were taken up, new settlement followed up the stream courses, utilizing all the valley bottoms and adjacent slopes to which water could be diverted. Flour mills and saw mills, both very important in community development, were built along the streams that afforded the power supply. Likewise, concentrating mills and mining settlements hugged the mountain slopes along the drainage courses.

Generally, by the time a locality experienced its first major cloudburst it had become established. To abandon the site and withdraw to a safer position seemed economically out of the question, so gashed streets were repaired, destroyed buildings rebuilt on the old foundations, ruined crops ploughed under, and the lands restored, where practicable, in the hope that the first flood or each succeeding flood would prove to be the last.

Although it is finally becoming realized that cloudburst floods are characteristic of this region, the residents are so firmly rooted that relocation is more and more impossible of consideration. Thus the floods have become one of the costs of occupation. Only a very few small settlements have been moved because of floods, although in at least one community floods in the past 15 years have cost in repairs and prevention measures as much as the total assessed valuation of the entire community.

In general it may be said that those areas in Utah affected directly by cloudburst floods now include or eventually will include all lands on alluvial fans, all lands that come within the scope of a possible shift in a stream course, and all lands in or near the bottoms of the canyons and valleys within reach of the peak flow of such floods or that may be eaten away by corrasion of the stream channel. A large part of the inhabited area of the State comes within this classification, and the properties included are of all types—urban, rural, mining, industrial, residential, and business.

FREQUENCY

A statistical frequency analysis of cloudburst floods in a single small drainage basin would be meaningless. Unlike the widespread, steady cyclonic storms of winter and spring, thunderstorms occur in spots, and although during an average summer each locality may receive its quota of precipitation, it may all be received in one or more cloudbursts or in a number of individually inconsequential showers. A stream course susceptible to cloudburst floods may pass unscathed through a succession of years climatically conducive to cloudbursts and then receive a cataclysmic downpour during a year of generally feeble thunderstorm activity. Some areas, owing to their location and topography, are more susceptible to heavy storms than others.

It is apparent that during certain periods of years, because of appropriate atmospheric conditions, many more destructive floods have occurred and will occur in Utah than in other periods, but it is not possible to predict which specific drainage basin will produce the floods.

Previous reports and discussions of cloudburst floods in Utah have popularized the theory that flood frequency is directly dependent upon use of the State's watershed areas for grazing. This theory either completely ignores climatic factors or implies that such factors are likewise influenced by man's flocks and herds. The chief manifestations of climate are temperature and precipitation variations, which are extremely changeable at any given place. Humphreys,[45] however, finds that the curve of worldwide precipitation parallels the curve of thermal variation. A warmer world results in the presence of more water vapor in the atmosphere, yielding greater depths of precipitation. Similarly, as thunderstorms require the presence of warm, moist, electrically charged air masses, the records show that these storms are more numerous and more violent during warm years.

Although these basic facts are apparently characteristic of worldwide climatic cycles, the relatively small areas affected by the cloudburst floods of Utah and those properties of cloudbursts that makes coincidence an important factor in determining the time and place of their occurrence make the results of any attempt at a cyclic

[45] Humphreys, W. J., Physics of the air, 2d ed., pp. 311-315, 1929.

analysis of the flood and thunderstorm data at hand of only meager significance.

It is interesting, however, to note that during the period 1850 to 1920[46] inclusive, world-wide temperatures were above the period mean for a total of 33 years and below it for 38 years. During the higher than normal temperatures 216 cloudburst floods were reported in Utah, and during the 38 years of low temperatures 155 were reported. The average number of floods for a warm year was six and a half and for a cool year four. Years of exceptionally numerous and disastrous floods, such as 1889, 1896, and 1901, were all within high parts of the temperature cycle. It was also found that in years that were above normal in the number of thunderstorm days at Salt Lake City from 1904 to 1938, inclusive, the cloudburst floods reported averaged about 16 a year as against 11 a year for years of subnormal thunderstorm activity.

The belief has been encouraged that serious flooding from cloudbursts did not commence in Utah until about 1880. It will be noted, however, from figure 11 that reports of such floods were recorded in 1852, when the settled parts of the State contained a total of about 15,000 people and 20,000 animal units.[47] These first recorded floods occurred in a year of above-normal world temperatures following a subnormal period of the climatic cycle that extended back to the year of initial settlement—1847.

Reports of floods increased in number through the early decades in almost direct proportion to the increase in population and settlement. Livestock increased in number also but reached a peak in 1900 that had been exceeded only once since that time and then only slightly, according to the 1930 census. The numerical trend of flood reports, however, continued upward along with the greater importance attached to natural phenomena affecting human life and property. A new area is settled, and soon thereafter it becomes a source of reports of cloudbursts; a new railroad or highway is extended into new areas, crossing creeks and washes, and these areas also become potential sources of reports of floods. Communication has increased tremendously in efficiency, news coverage is vivid and detailed, and public interest in sensational news has intensified. These are among the important factors that have induced an upward trend in the number of reports of floods, although the livestock population has changed but little since the turn of the century.

An example of the growth in importance of floods is furnished by the area between Centerville and Farmington, in Davis County.

[46] Humphreys, W. J., op. cit., p. 589 and fig. 227.
[47] One animal unit is one head of cattle or five head of sheep.

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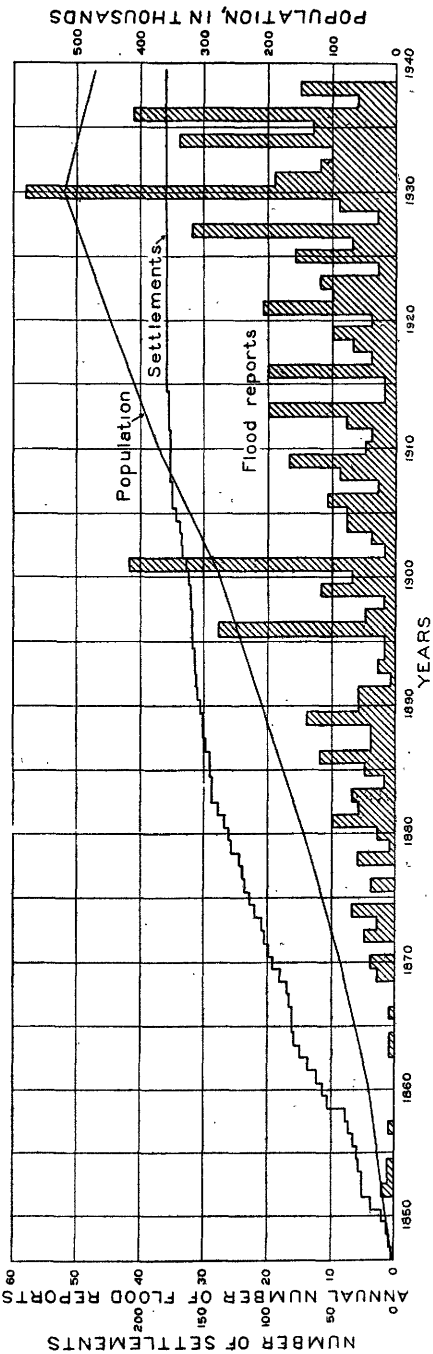


FIGURE 11.—Graphs showing relationship between reports of floods, settlements, and population in Utah from 1847 to 1938.

In 1878 floods from two streams deluged adjacent farms with mud, rocks, and water. Some farm land was ruined, more was damaged, and a team of mules was "badly bruised" through being carried along by a wave of mud and debris. The estimated damage was $3,700. The same streams, along with others in the vicinity, flooded again in 1901, 1923, and 1930, with widely varying degrees of magnitude. In proportion to the size of the floods, however, damage in the areas affected increased with the increase in value of the property. Estimated damage for the floods of 1923 and 1930 was in excess of $100,000.

Some of Utah's canyons have flooded with more or less regularity throughout their history. Others have flooded violently during a two-year or three-year period and then remained quiescent for several decades. Willow Creek, in Carbon County, and Davis, Steed, Ford, and Parrish Creeks, in Davis County, have flooded two or more times in one season.

The present-day news reporting of these flood events has a tendency to dramatize them and intensify the public interest in them until the belief is developed that the floods are much larger and occur oftener than in previous times. Regardless of this belief, however, the 3-year period 1899-1901 had as many reports of cloudburst floods as the 3-year period 1930-32. Both of these periods were the maximum on record.

CATCHMENT BASINS

It is apparent from the wide distribution of cloudburst floods, as shown in plate 11, that the catchment basins must comprise areas of all sizes and shapes with a variety of geologic and topographic characteristics. In those parts of the State where flood damage has become a matter of public concern many of the catchment basins have been given reconnaissance study by certain Federal and State agencies, and detailed studies and surveys have been made of some of them for the purpose of planning ways and means of preventing the recurrence of flood damage. The salient facts obtained by these studies and surveys for a number of these catchment basins are given in the following pages.

WILLARD CREEK BASIN

Location.—In Box Elder County, just east of the town of Willard, in T. 8 N., Rs. 1 and 2 W. Salt Lake base and meridian. (See pl. 12.)

Stream course.—From its headwaters to Willard, Willard Creek is approximately 5 miles long, descending from an altitude of about 9,000 feet above sea level at its headwaters to 4,400 feet at the center of the town. From its source the main stream flows northward, then swings in a long arc to the west, and thence flows through a narrow rocky gorge in the frontal range of the Wasatch Mountains into the Great Salt Lake Valley at Willard. West Fork is the principal tributary. It roughly parallels the main stream in its northward course and finally joins it about 2 miles above Willard. The main stream and the West Fork flow along the bottom of steep V-shaped canyons, and much of the main canyon below the mouth of West Fork is in solid rock.

Basin characteristics.—The outline of the basin is roughly parabolic, with its axis bearing about 25° east of south. Its area is approximately 4 square miles. The highest point on the basin rim is at the south end, at an altitude of 9,768 feet above sea level. The drainage is northward and westward from steep slopes having mainly east and west exposures.

Much rock is exposed as barren talus slopes and ledges. The soil is shallow, loose, and rocky and rather easily eroded. It breaks away in large masses where the streams undercut their banks, and heavy rains render unstable the material on the steep slopes. Over most of the basin vegetation is sparse because of barren rocky areas and restricted areas of suitable soil. The character of the vegetal cover is shown in plate 12. In the lower canyon above the rock gorge the vegetation consists of brush types, such as oak, maple, and sagebrush of only fair to low density. The middle zone of the basin has a denser cover of brush and some patches of aspen trees. The higher areas support scattered alpine firs, with an undercover of grasses, weeds, and some brush. (See pl. 6.) The physiographic features of the lower part of Willard Creek Canyon are shown in plate 12.

Remarks.—This basin is typical of the small basins that drain westward from the Wasatch Mountains into the Great Salt Lake Basin. It and those in the Farmington division of the range have been given considerable study because of densely settled areas affected by their flood runoff. This basin was surveyed in 1936 by the Geological Survey, United States Department of the Interior, in cooperation with the Forest Service, United States Department of Agriculture. The published topographic map made from this survey is entitled Plan of Willard Creek, Utah. It is on a scale of 1,000 feet to 1 inch, with a contour interval of 10 feet, and is available for purchase from the Director of the Geological Survey at 10 cents a copy.

CATCHMENT BASINS IN THE FRONTAL RANGE OF THE WASATCH MOUNTAINS BETWEEN SALT LAKE CITY AND WEBER CANYON

This part of the frontal range of the Wasatch Mountains between Salt Lake City and Weber Canyon for brevity has been called the Farmington division by Gilbert.[48] It forms a part of the range in which the crest of the mountains runs near the western border of the range. The frontal apron is narrow. The canyons draining to the west are short. The high crest of the range is an effective topographic barrier for the interception of storms, and the runoff descends rapidly to the valley floor.

This division of the range is unique in its physiographic features. Remnants of graded plains head at high levels either at or near the crest and slope westward. These are associated with rib crests with similar westward slopes that run from points near the summit of the range to the tops of frontal facets. (See pl. 13.) These features form a series of relatively small, narrow catchment basins with steep drainage profiles, typified by Parrish Creek Basin, shown in figure 12.

Cloudbursts on this division of the Wasatch Mountains have produced floods repeatedly at more than a dozen different places. These floods, together with the small perennial streams that issue from a few of the canyons and other climatic forces, have developed a system of dissecting ravines through the high graded plains of the Wasatch block and are degrading the upland areas as rapidly as wasting by rainwash is possible in an arid climate.

PARRISH CREEK BASIN

Location.—In Davis County, east of the town of Centerville, in T. 2 N., R. 1 E. Salt Lake base and meridian.

Stream course.—From its headwaters to the old State highway at Centerville Parrish Creek is aproximately 3.7 miles long. At the crest of its drainage basin it is 8,750 feet above sea level, and at its intersection with the State highway it is about 4,290 feet above sea level, a total fall of 4,460 feet. Two almost equal branches form the main stream at a fork about 1½ miles from the divide of the basin. Each of these branches descends through small steep channels that deepen into rocky defiles as they advance westward across the graded plain of the Wasatch block. The maximum gradient attained just above the fork is about 2,100 feet to the mile. For the next 1½ miles the descent is on an approximately uniform grade of 1,000 feet to the mile, then it steepens again as the channel cuts across a less compact fault zone and finally emerges from its canyon on a grade of about 800 feet to the mile.

Basin characteristics.—The Parrish Creek catchment basin is one of the larger V-shaped drainages that are cut into the high graded plain of the Wasatch block and descend westward through

[48] Gilbert, G. K., Studies of Basin Range structure: U. S. Geol. Survey Prof. Paper 153, p. 49, 1928.

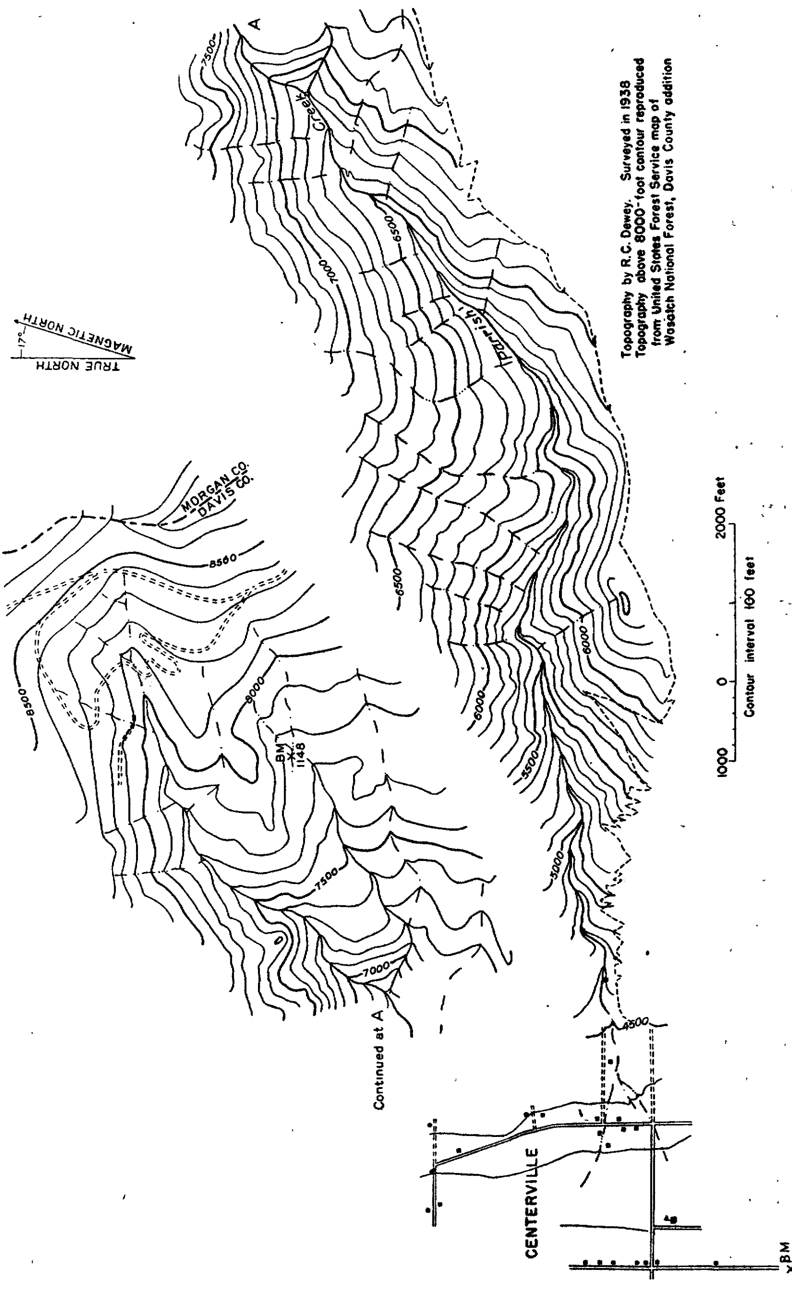


FIGURE 12.—Plan of Parrish Creek.

the frontal range into the Great Salt Lake Valley. Its outline is roughly rectangular, slightly broader in the upper reaches where the small runnels drain to concentrating channels, and having a deeper and narrower cross section through the frontal escarpment. Its area is slightly over 2 square miles, and its altitude ranges from 4,500 to 8,750 feet above sea level.

The physiographic features of the basin are shown in plate 14, and the distribution and density of the vegetal cover are shown in figure 13. The side slopes of the lower reaches of the basin are rather densely covered with oak and maple brush, with a light grass and weed understory. Eighty percent or more of the ground surface, except where rock outcrops, supports this type of vegetation. A few fir trees grow in small areas bordering the stream or in small tributary drainage ravines on the south side of the main canyon. In the upper part of the basin are extensive areas of quaking aspen, mainly in the lower part of the south-fork drainage and on the north slopes of the north-fork drainage. These stands are not thick, and the understory is a light cover of grass and weeds. In the areas near the crest of the range the vegetation consists of a light grass cover with clumps of sagebrush. There are areas of rocky soil and scattered areas of scrubby firs and aspens.

DAVIS, FARMINGTON, FORD, AND STEED CREEK BASINS

Davis, Farmington, Ford, and Steed Creeks drain that part of the Farmington division of the Wasatch Range between the towns of Centerville and Farmington, a distance of approximately 5 miles. Their drainage areas are approximately 1.5, 7.0, 2.4, and 2.4 square miles, respectively. Cloudburst floods have occurred on each of them. All except Farmington Creek have catchment basins and stream courses very similar topographically and geologically to those of Parrish Creek. Farmington Creek Basin shows signs of glaciation. A little to the southeast of Farmington the crest of the range doubles back upon itself to the southeast and then swings around through the east to its original northwest trend, forming a somewhat misshapen reversed S, one part of which is a glacial cirque opening to the northwest and serving as the catchment basin for Farmington Creek. According to Atwood,[49] a glacier at one time moved northward and then, by a right-angled turn, came by way of Farmington Canyon through the main range of the mountains, reaching a point within 2 miles of the mouth of the canyon.

[49] Atwood, W. W., Glaciation of the Uinta and Wasatch Mountains: U. S. Geol. Survey Prof. Paper 61, p. 90, 1909.

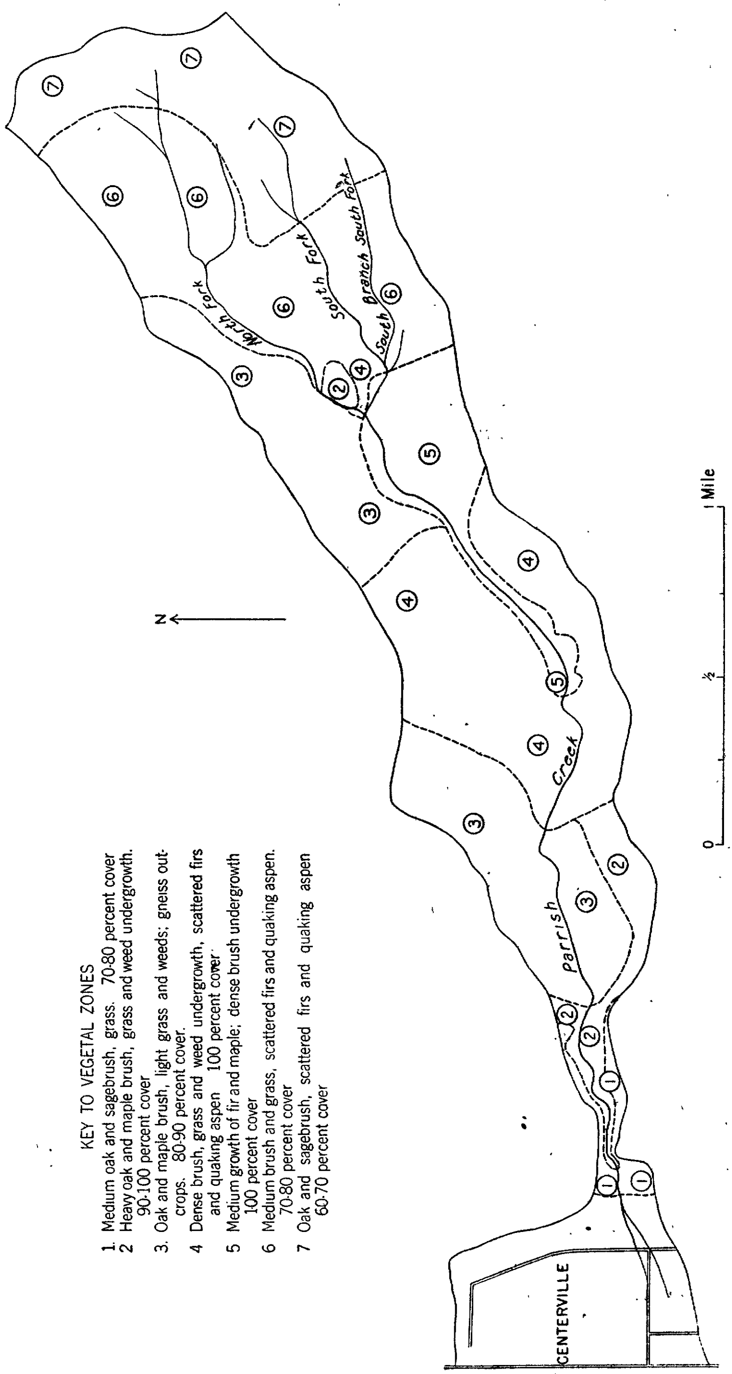


Figure 18.—Map of Parrish Creek catchment basin showing vegetal cover.

A. WASATCH MOUNTAINS LOOKING TOWARD PARRISH CANYON, NEAR CENTERVILLE.

B. WASATCH MOUNTAINS LOOKING TOWARD STEED CANYON, NEAR FARMINGTON.

SNOWSLIDE CANYON BASIN

Location.—In T. 5 S., R. 3 E. Salt Lake base and meridian. Tributary to Provo Canyon about 8 miles from the city of Provo.

Stream course.—The stream channel through Snowslide Canyon lies in the bottom of a sharp V-shaped basin that drains southeastward from the steep barren slopes of Mount Timpanogos for a little more than a mile, then bears southward nearly another mile, where it joins Provo River. The total length of the course is little more than 12,000 feet, and the total fall in that distance is from 10,650 to 5,500 feet above sea level, or slightly more than 5,000 feet in a distance of approximately 2¼ miles. (See fig. 14.)

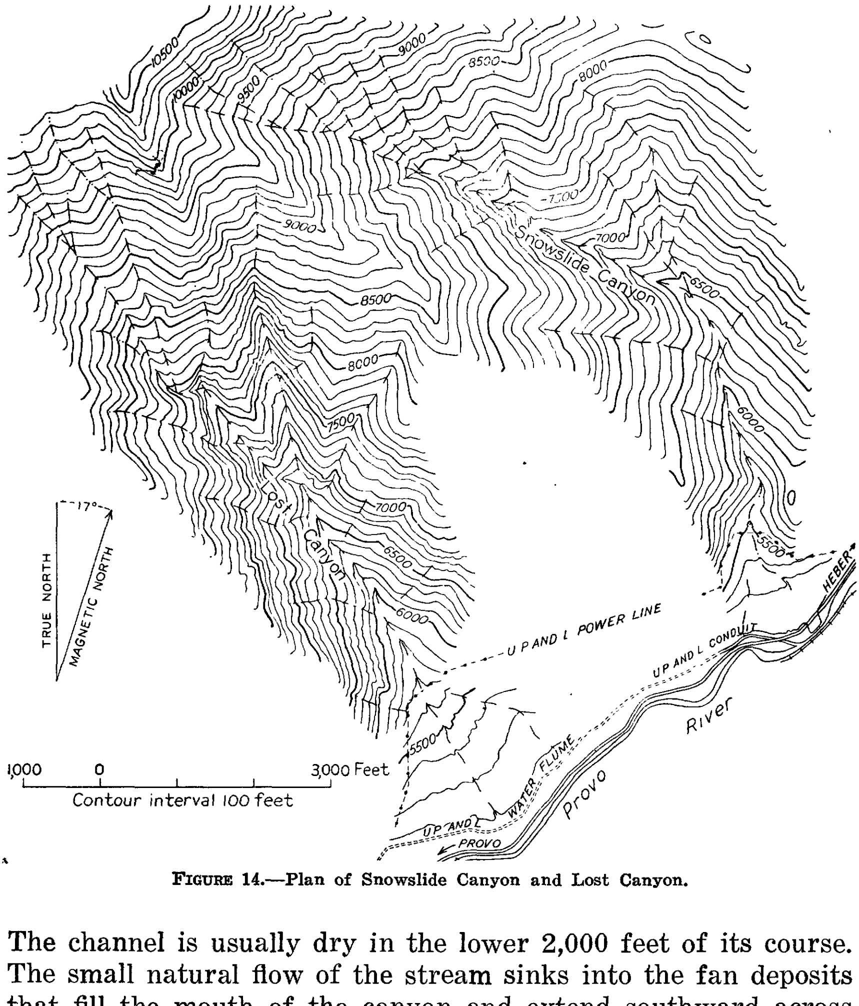
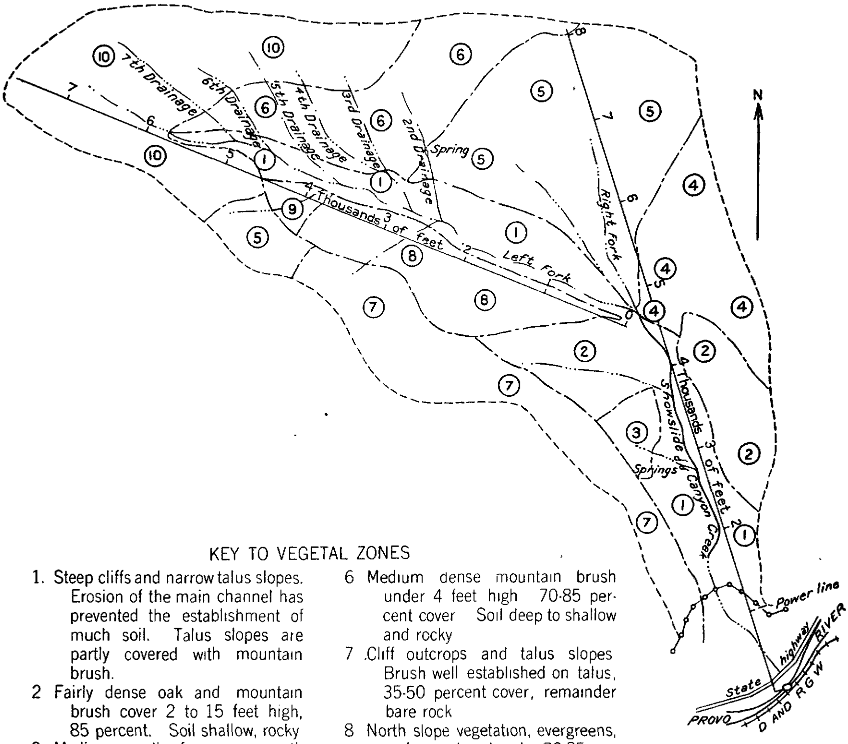


Figure 14.—Plan of Snowslide Canyon and Lost Canyon.

The channel is usually dry in the lower 2,000 feet of its course. The small natural flow of the stream sinks into the fan deposits that fill the mouth of the canyon and extend southward across Provo Canyon. (See pl. 14, *C*.) At a point about 4,600 feet above its junction with Provo River the Right Fork joins with the left Fork or main tributary of the basin.

Basin characteristics.—This catchment basin is roughly triangular in shape and has an area of approximately 1.1 square miles. The surface of the entire area is characterized by steep slopes averaging about 36° from the horizontal. In the lower reaches the walls consist of cliffs in a series of receding steps 10 to 30 feet high, lying in horizontal strata and separated by narrow talus slopes. (See pl. 15, *A*.) The physiographic features of the upper part of the basin, drained by Left Fork, are shown in plate 15, *B*. This part has a shallow soil cover on its steep sides, and several small runnel channels in it drain fingerlike basins



KEY TO VEGETAL ZONES

1. Steep cliffs and narrow talus slopes. Erosion of the main channel has prevented the establishment of much soil. Talus slopes are partly covered with mountain brush.
2 Fairly dense oak and mountain brush cover 2 to 15 feet high, 85 percent. Soil shallow, rocky
3 Medium growth of evergreens with maple and birch brush 100 per cent cover Soil perpetually wet, slopes steep (38°-40°)
4. Sparse cover of small brush and plants under 4 feet, 25-40 per cent. Rock slides and outcrops 60 percent
5. Medium dense mountain brush 8 to 18 feet high, 70-85 percent cover. Soil deep and well established
6 Medium dense mountain brush under 4 feet high 70-85 percent cover Soil deep to shallow and rocky
7 .Cliff outcrops and talus slopes Brush well established on talus, 35-50 percent cover, remainder bare rock
8 North slope vegetation, evergreens, and mountain brush, 70-85 per cent cover Steep slopes (up to 40°).
9 Very heavy brush, 8 to 18 feet high, 85-95 percent cover. Soil deep and well established, slopes steep (39° to 40°)
10 Bare rock slides Sparse brush and scattered plants under 4 feet high, 20-30 percent cover Soil very shallow and poorly developed, fines lacking, slopes steep (36° to 40°)

FIGURE 15.—Map of Snowslide Canyon showing vegetal cover.

from the north. (See pl. 16, *A*.) A number of small springs issue at different places throughout the basin, and on areas of soil that are kept moist by them a good stand of trees and other vegetation is found. (See pl. 16, *B*.) In general, the soil of the basin is very stony and is easily water-washed. Vegetal cover over the basin is indicated in figure 15.

LOST CANYON BASIN

Location.—In T. 5 S., R. 3 E. Salt Lake base and meridian. It is just west of Snowslide Canyon Basin and opens into Provo Canyon approximately 1 mile below the mouth of Snowslide Canyon. About 7 miles from the city of Provo.

Stream course.—The stream channel trends southeastward from the southern slopes of Mount Timpanogos. The total length of the stream course is about 2.1 miles, and the total fall is 10, 350 to 5,500 feet above sea level, or 4,850 feet. About 0.6 mile up the canyon from its mouth its main tributary enters from the northeast.

Basin characteristics.—This catchment basin is roughly triangular in shape and has an area of about 1 square mile. Its cross section is a sharp V with very steep side slopes. Through some parts of the canyon the slope of its channel is as much as 47° from the horizontal. Most of the upper part of the basin above altitude 8,600 feet is in solid rock. (See pl. 17, *A*.) The lower part consists of outcropping cliffs and rocks interspersed with areas of talus. (See pl. 17, *B*.)

Soil in this catchment basin is scarce, shallow, and rocky. Small springs issue at some places, and if soil is present and kept moist by these springs vegetation is luxuriant. Vegetal cover over the basin is indicated in figure 16.

COTTONWOOD CREEK BASIN

Location.—In Sanpete County northeast of the town of Fairview, in T. 13 S., R. 5 E. Salt Lake base and meridian. (See pl. 18.)

Stream course.—Cottonwood Creek rises in several small springs near the divide that separates its drainage basin from that of Gooseberry Creek of the Price River system, about 9 miles northeast of the town of Fairview, at the western base of the Wasatch Plateau. It flows southwestward for about 3 miles, then swings to the west, emerging from its canyon in another 2 miles, and then flows southwestward again across its fan to join the San Pitch River near the southwest corner of Fairview.

Basin characteristics.—This catchment basin is a narrow V-canyon section. The pass over the divide into Gooseberry Creek Basin is a little more than 8,860 feet above sea level. About 200 to 300 feet below this pass small springs issue in two canyons, forming two small streams which converge at altitude 8,400 feet to form the main stream. Through the main canyon the gradient of the creek is uniformly about 450 feet to the mile for the upper 3 miles, thence it decreases gradually to about 100 feet to the mile where the creek reaches the San Pitch River. The topography has a smooth rolling aspect with generally enough soil to support mountain brushes and scattered stands of trees. Along the creek channel is a rather dense growth of brush and cottonwood trees. Runoff is quickly concentrated in the main creek because of the steep slopes and narrow catchment basin.

Remarks.—This basin and those of Pleasant and Manti Creeks are types of the small erosion-drainage basins that drain into the

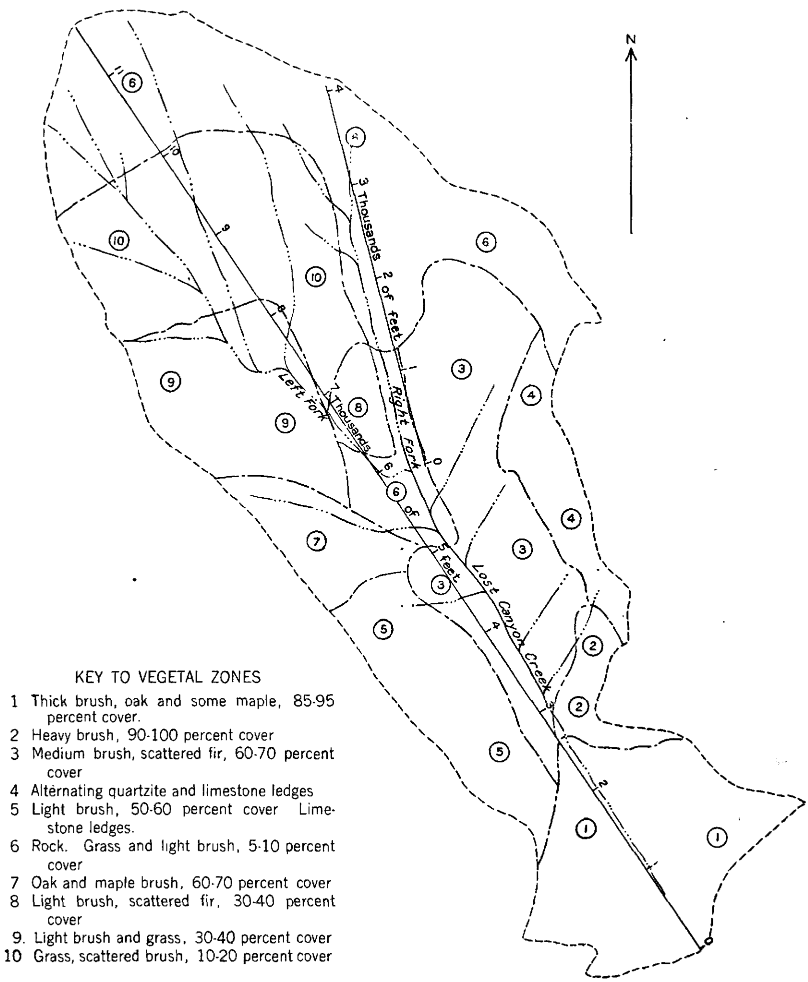


Figure 16.—Map of Lost Canyon showing vegetal cover.

Sanpete Valley of the Sevier River Basin from the west slopes of the Wasatch Plateau.

PLEASANT CREEK BASIN

Location.—In Sanpete County east of the town of Mount Pleasant, in T. 15 S., Rs. 4 and 5 E. Salt Lake base and meridian. (See pl. 18.)

Stream course.—Pleasant Creek flows nearly due west through the town of Mount Pleasant and empties into the San Pitch River about 2 miles beyond the town. It is formed by the confluence of three main branches which form a three-pronged catchment basin above the forks at an altitude of 6,800 feet. The stream gradients exceed 300 feet to the mile above this point, and below it across a broad fan the gradient of the main stream lessens rather uniformly to an altitude of about 5,670 feet at the San Pitch River.

Basin characteristics.—The catchment basin is characterized by a rather smooth-slope, rolling type of topography that terminates in steep barren slopes at the crest of the basin. In general the slopes are well covered with soil and support a dense cover of mountain brush and scattered stands of trees. Runoff is quickly concentrated from the steep slopes, and its degrading power is indicated by the large fan deposit that covers more than 12 square miles in and around Mount Pleasant.

MANTI CREEK BASIN

Location.—In Sanpete County east of the town of Manti, in T. 18 S., Rs. 3 and 4 E. Salt Lake base and meridian. (See pl. 19.)

Stream course.—Manti Creek flows westward from a catchment basin on the west slopes of the Wasatch Plateau. From the rim of the basin to the mouth of Manti Canyon is approximately 10 miles. Thence the stream divides into two main parts, both of which flow through the town of Manti—City Creek northwestward, and South Creek westward. Each stream course normally is completely dry and lost before it reaches San Pitch River about 2 miles west of the town. From its headwaters to the mouth of its canyon, a distance of approximately 9 miles, the creek has a total fall of 3,700 feet. Its gradient ranges from 200 feet a mile in the lower end of the canyon to as much as 700 feet a mile 6 miles above the mouth.

Basin characteristics.—This basin is characterized by steep V-shaped canyons, with the rim slopes almost vertical in places, where great masses break away as landslides and choke the canyons with huge piles of unconsolidated earth, rock, and vegetation. Barren talus slopes and scattered areas of loose rocky soil limit the vegetal cover of the basin to a generally sparse cover of mountain shrubs and small brush patches with occasional patches of quaking aspen trees and denser brush cover in those parts of the basin where suitable soil exists. Runoff concentration is rapid because of the short steep ravines of the basin, and the landslide material is flushed out of the canyon by floods.

CHALK CREEK BASIN

Location.—In Millard County southeast of the town of Fillmore, on the west slope of the Pavant Range, principally in Ts. 21 and 22 S., R. 3 W. Salt Lake base and meridian.

Stream course.—The creek is formed by the union of its two principal forks about 3 miles southeast of Fillmore. Both forks flow through steep V-shaped canyons for about 6 miles before they join, and thence the course is northwestward through Fillmore and out into the lowlands of Pavant Valley. The total fall of the forks from their headwaters to Fillmore, a distance of about 10 miles, is approximately 5,000 feet.

Basin characteristics.—The catchment basin is roughly oval in shape and has an area of about 60 square miles of extremely steep, broken, and rugged mountains, which range in altitude from 5,100 feet above sea level at Fillmore to more than 10,000 feet at the basin rim, or the crest of the Pavant Range. Each runnel that contributes to the stream has carved a narrow and sharp V-shaped canyon whose side slopes have gradients of as much as 70 percent. Bare rock surfaces in cliffs and ledges are numerous in the basin. Soils are generally medium to shallow in depth, dark in color, and of fair humus content. Vegetation consists of a rather scanty cover of pinion, juniper, sage, and mountain brush types and patchy stands of aspens and pines. Shrubs are the predominant plant forms in the basin, although there are scanty growths of grass and weeds. Concentration of runoff is rapid because of steep slopes and small retarding areas, such as mountain meadows and small valleys.

Remarks.—This basin is typical of those that form the west drainage of the mountain ranges and plateaus along the east edge of the Sevier Desert. The other principal basins are those of Oak Creek near Oak City, Pioneer Creek near Holden, Meadow Creek near Meadow, and Corn Creek near Kanosh.

COAL CREEK BASIN

Location.—In Iron County east and southeast of Cedar City, in Ts. 36 and 37 S., Rs. 9 and 10 W. Salt Lake base and meridian.

Stream course.—Coal Creek is formed by the runoff from small springs and intermittent runnels from a network of small sharply-cut drainage channels. From the mouth of East Fork the course of the main stream is northwestward through Cedar City out into the sands and gravels of the Lake Bonneville beds of the Escalante Desert. From Cedar City to the headwaters of the creek is about 13 miles, and the total fall from the basin rim to the city is approximately 4,700 feet.

Basin characteristics.—This basin is roughly circular in shape and has an area of a little more than 70 square miles. It is rimmed on the east by the Markagunt Plateau, into which it has been eroded. Steep slopes, readily degraded by storms and practically barren of vegetation, make up much of the basin. Patches of trees and mountain brush are scattered over the high parts and along the stream courses where soil and water are sufficient to support them. Nearly all the eastern half of the basin is occupied by a series of vast amphitheaters eroded to a depth of some 2,000 feet into the Wasatch formation at the summit of the Markagunt Plateau. This extensive area is known as the Cedar Breaks, and in it are many fantastic and grotesque figures carved by erosion.

Remarks.—Erosional features similar to those at Cedar Breaks are found also at Bryce Canyon, which is a great horseshoe-shaped bowl or amphitheater cut into the southeastern part of the Paunsaugunt Plateau and is part of the catchment basin of the Paria River.

KANAB CREEK BASIN

Location.—Occupies a long narrow area north of the town of Kanab, in southern Utah. In Ts. 38, 39, 40, 41, 42, and 43 S., Rs. 5 and 6 W. Salt Lake base and meridian.

Stream course.—Kanab Creek rises in springs that issue from underneath the Pink Cliffs forming the southern boundary of the Paunsaugunt Plateau and flows south into the Grand Canyon of the Colorado in Arizona. It is a small stream with a comparatively constant flow except for summer floods. It flows through a series of gorges and box canyons interspersed with broad marl plains. At ordinary stages the stream is in part subterranean, sinking into the sand of its bed to reappear only where a ledge of rock rises to bar its way. Its utilization for irrigation has been difficult and expensive because of the high cost of rebuilding dams and headgates and removing sand from ditches after heavy summer floods.

Basin characteristics.—This basin is typical of the lateral basins that drain into the Colorado River in southern Utah. It has a total area of about 2,400 square miles, a little more than 700 miles of which is in Utah. From the Pink Cliffs southward are successive lines of cliffs through which the creek has carved a series of terraced canyons through limestones and sandstones. The upper part of the basin slopes steeply to a broad plain or valley, below which is a region of rough topography broken by a number of short lateral drainage channels. Immediately below this area is the town of Kanab in a narrow valley edged by abrupt sandstone walls, and to the south is a wide open plain in which the creek becomes more and more deeply entrenched in a rock-walled canyon as it approaches the Colorado River Altitudes vary from 4,900 feet above sea level at Kanab to about 7,000 feet in the upper basin and 9,000 feet along the basin rim. From Kanab down to its junction with the Colorado River the creek falls 3,100 feet. Over a large part of the basin the soil is thin and there is a great amount of bare rock surface exposed in cliffs, ledges, and canyon walls. Marl plains have been produced by the erosion of the sandstone and limestone strata, and considerable alkaline salts are present in the soil. A scanty growth of juniper and pinion pines is characteristic of the basin, with sparse stands of sagebrush and other shrubs. Brush types of vegetation are found in the upper part of the basin together with a variety of weeds and grasses. Some pine trees occur in scattered patches.

SMALL STREAMS IN COLORADO RIVER BASIN

In that part of eastern Utah that drains into the Colorado River there are innumerable small catchment basins from which cloudburst floods debouch. The floods that have caused notable property damage and that have thereby attracted public attention have been on tributaries, principally, of the Price and San Rafael Rivers. Both of these rivers drain the eastern slopes of the Wasatch Plateau just over the drainage divide from the catchment basins of the streams that drain into the Sanpete Valley of the Sevier River Basin. Summer thunderstorms strike across their basins, and the effects of these storms on the regimen of the two main streams are shown by the hydrographs in figure 10. These catchment basins are characterized by steep slopes with extensive patches of barren landslides, rock cliffs, and ledges. They are dissected by sharp canyons which are cut through plateau escarpments, terraced mesas, and bench lands as the streams move eastward through the "canyon lands of Utah,[50] where "all the rivers, all the creeks, all the brooks, run in deep gorges—narrow, winding canyons with their floors far below the general surface of the country."

Vegetation on the higher parts of these basins consists principally of sagebrush, grass, and brush types, with patches of aspen trees and small pines occupying favorable sites. On the areas a little lower down pinion-juniper, woodland, or brushland

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[50] Powell, J. W., Lands of the arid region: U. S. Geog. and Geol. Survey Rocky Mtn. Region Rept., p. 105, 1879.

A. UPPER PART OF CATCHMENT BASIN ON SOUTH FORK PARRISH CREEK.

B. LOOKING UP PARRISH CREEK BASIN FROM NEAR WEST END OF THE SOUTH RIM.

C. LOOKING UP ALLUVIAL CONE AT SNOWSLIDE CANYON, IN PROVO CANYON, NEAR PROVO.

types of vegetation predominate, although the cover is sparse, and over the lower reaches there is a relatively sparse cover of sagebrush, shadscale, pinion-juniper, saltbush, and greasewood types. Because of the aridity of the climate in most of this region the vegetation is scanty, and the soil is generally shallow and of poor quality. Accordingly, when cloudburst storms occur the water gathers rapidly into streams, which plunge down the steep slopes, bearing with them great loads of sand and debris. Soon the district is traversed by brooks and creeks and rivers of mud.

MUDFLOWS

GENERAL STATEMENT

The "mudflow" is a well mixed mass of water and alluvium, which because of its high viscosity and low fluidity as compared with water moves at a much slower rate, usually piling up and overtopping the stream channel and spreading over the fan like a huge sheet of wet mortar or concrete. Its inertia is tremendous. Buildings in its path are pushed from their foundations and walls crushed in. Near Willard in 1923 a large dairy barn was carried for half a mile by a mudflow and came to rest on the main highway. (See pl. 20, *A*.) Cellars and ground floors of homes in the path of such flows are choked with mud and gravel. (See pl. 20, *B* and *D*.) Orchards are uprooted or covered so deeply as to destroy the trees. (See pl. 20, *C*.) Lands that have been flooded by water and are temporarily inundated are easily reclaimed, but it is a heartbreaking task to restore to productive use lands that have been covered by mudflows.

Innumerable alluvial fans fringe the bases of the mountain ranges throughout the arid West. There are hundreds of them in Utah. They are composed of the material that is repeatedly being spewed from the canyons as mudflows as a result, primarily, of cloudburst floods and, to a lesser extent, of spring freshets. Many of the canyons are dry except for freshets and mudflows; in others small perennial streams flow, some of which are nothing more than a trickle during low-water seasons. Small catchment basins with steep slopes flush out much more readily than large ones, because the latter absorb a greater proportion of the precipitation that falls on them. For this reason the alluvial fans of small basins are usually greater in volume per square mile of catchment area.

It is apparent from the records made of cloudburst floods in Utah since 1850 that, although such floods have been numerous in the past 89 years, the building of the fans has not been rapid, because the volume of alluvium added by each mudflow has been relatively small in proportion to the total volume of the fan. In some instances two or more mudflows have occurred on the same stream in a single season. This happened on several small streams in Davis County during the summer of 1930 when four mudflows were recorded.

At Willard, on the fan of Willard Creek, in Box Elder County, the memorable storm of August 13, 1923, covered about 155 acres of town lots, gardens, and orchards with a layer of alluvium. This attracted public attention to the locality, and in 1924 a basin was constructed to control similar flows in the future. A survey of this basin in March 1939 showed that approximately 200,000 cubic yards of gravel and sand had been accumulated almost entirely during the spring freshets—an average of about 13,300 cubic yards a year. In 1936 another cloudburst flood issued from the canyon, spilled over the south wall of the basin, and spread about 65,000 cubic yards of alluvium over some 30 acres of land which was being slowly reclaimed from the 1923 flood.

Of the several alluvial fans along the Wasatch front in Davis County some limited studies have been made of those of Steed, Davis, and Parrish Creeks between Farmington and Centerville. Lake levels on the fans indicate that they were largely built prior to Lake Bonneville. Steed Creek has had several floods of historical note, namely, one in each of the years 1878, 1901, and 1923, and four in 1930, though only once in that year was the flow of particular consequence. The flood of 1923 was evidently a flood of unusual magnitude as it added approximately 100,000 cubic yards of alluvium to the fan. The flood of 1901 was comparatively small, and no damage was reported from it.

The mudflow of 1923 and subsequent ones covered approximately 70 acres of the Steed Creek fan. About 25 acres of this area is now given over to flood-control works in the form of dike-enclosed basins. The remainder is in varying stages of productive use.

About half a mile south of Steed Creek another alluvial fan is being built by Davis Creek. New material is generally added to this fan by the same cloudburst storms that flood Steed Creek. The two fans are now overlapping along the lower part of their common edge and filling in the area between the two creeks.

All the mudflows since 1923 have covered about the same area on the fan, although there has been a tendency for each successive one to move farther south. Larger boulders 1,500 feet from the mouth of the canyon, embedded in soil and silt to the north of the more recent deposits, apparently mark the course of the flow of 1878. The flows since 1923 have covered about 86 acres. All except 20 acres has been restored to agricultural use, and 15 of the 20 acres is enclosed by dikes, forming a basin to catch subsequent flows.

At Parrish Creek in Centerville, 3 miles south of Davis Creek, the mudflow of 1923 covered about 80 acres of farm and residential land in a long central strip 100 to 600 feet wide extending from the mouth of the canyon 3,000 feet down the fan. A part of this area was reduced considerably in productive value, some of it was only temporarily damaged, and about 20 acres is still unreclaimed. In at least one place the texture of the alluvium was such that the area covered was transformed from a fair alfalfa-producing soil to an excellent truck-garden patch.

A great many boulders were carried down the center strip of the flow. At least one weighing three quarters of a ton was left at the highway, 3,400 feet from the canyon mouth, on a slope of less than 2°. Boulders increase in number and size toward the apex of the fan. One lying about halfway between the highway and the apex, calculated to weigh 40 tons, was carried for some distance down a slope of 3 to 4°. Another about 1,000 feet from the canyon mouth, weighing about 85 tons, was transported along a slope of 5° to 6°.

Mudflows in Provo Canyon near Provo have become a matter of public concern because they have periodically blocked a trunk highway and a railroad, destroyed parts of the flume of the Olmsted power plant, and caused the flooding of homes and camp sites in the canyon by damming Provo River. The most recent of these flows occurred July 13, 1938. On that day mudflows debouched into Provo Canyon from three of its small tributary canyons. Two of these, Snowslide and Lost Canyons, have adjacent catchment basins but enter the main canyon about a mile apart. In this stretch the bottom of Provo Canyon is approximately 1,000 feet wide. Its southern wall is precipitous, and several waterfalls drop in cascades 500 feet or more from small glacial basins. Provo River hugs the talus slopes along the south wall because of the alluvial fill that has been brought in from the small steep canyons that enter from the north side.

Snowslide Canyon is the uppermost of the canyons that flooded in 1938. It is estimated that during this flood some 50,000 cubic yards of alluvium spread across Provo Canyon, damming the river and raising its level 14 feet. The resulting pond was 1½ miles long and covered an area of about 100 acres, some of which was occupied by summer homes and picnic grounds. More than 450 feet of the State highway was buried to a depth of 13 feet under mud and debris, and approximately 400 feet of railroad tracks on the opposite side of the river was buried. About 10 days were required for highway and railroad crews to clear the river channel and transportation lines.

The alluvial fan at Snowslide Canyon has an area of about 50 acres. Its axial length is about 1,300 feet and its total fall about 250 feet; the average slope is 11°. Its surface supports a light cover of grass and annual plants and a few small patches of brush. Boulders having a volume of 15 cubic feet and a weight of about 1¼ tons are not uncommon in the mixture, and one or two having a volume of approximately 500 cubic feet and a weight of about 40 tons have been noted near the apex of the fan. (See pl. 14, *C*.)

At Lost Canyon the alluvial fan has an area of about 78 acres. Its length is nearly 2,500 feet and its total fall about 550 feet. The typical fan shape here is strikingly symmetrical. The surface slope ranges from 11° on the lower part to about 18° on the upper part. The material in the fan is coarser than that in the fan at Snowslide Canyon, with a higher proportion of larger and more angular rocks. Most of the fan is covered with a dense growth of mountain brush. The mudflow of 1938 scarred the surface of the fan in a course 60 to 125 feet wide from the apex down the crest of the slope. The courses of a number of earlier mudflows are marked by windrows or small ridges of alluvium, which remain along the edges of the flow as the channel is cut deeper. These are radial from the apex of the fan and together present a corrugated surface, which is gradually changed as successive mudflows follow new courses from one side of the fan to the other in their building-up process. When these ridges are new they have an inverted **V** cross section, but they are gradually rounded off by weathering to an inverted flat **U** cross section.

The flow of 1938 spread across Provo Canyon and filled in the river channel to a depth of about 9 feet but did not cover the railroad tracks on the opposite side of the river. It demolished 180 feet of flume conduit of the Utah Power & Light Co.'s Olmsted power development and covered about 350 feet of the State highway with 12 feet or more of alluvium. A cross section of the deposited material along the highway indicated that the volume of the flow below the flume line was approximately 16,000 cubic yards. Above the flume line it was estimated that at least 20,000 cubic yards was left in windrows and small fans. (See pl. 17, *B*.)

The Provo Canyon mudflows are typical of hundreds that occur repeatedly throughout the State. The principal damage they do is to disrupt travel temporarily or disable a hydroelectric power development or the water-supply pipe line of a small town. Less frequently canal systems and irrigation structures are either damaged or washed out. The more damaging flows are obviously those that occur where towns and settlements have spread over the alluvial fans. Typical of such areas are the fan at Willard and those on the small streams in Davis County near Farmington but to a greater extent those at Manti, Ephraim, Mount Pleasant, and Fairview in Sanpete County, where the streams and alluvial fans are larger. Manti Creek has built a fan about 8 square miles in extent. Manti occupies approximately 1 square mile of it, beginning at the apex and covering the slopes so completely that channels of the stream cross the thickly settled parts of the city before reaching the fields and meadows on the lower slopes. This is the situation also at Ephraim, Mount Pleasant, and Fairview, as shown in plates 18 and 19.

MUDFLOWS AS A PHASE OF CLOUDBURST FLOODS

A cloudburst flood may occur without producing a mudflow, but a mudflow as here considered is a manifestation of a cloudburst. This is exemplified by the cloudburst floods that occur on such streams as those tributaries of the San Rafael and Price Rivers, Kanab Creek, and others where the catchment basins are comparatively large and where the stream channels are kept open by perennial drainage and the streams empty into larger streams. In streams of this kind cloudbursts produce flashy peak flows in which the ratio of the water to the alluvium carried is such that the mixture is a very muddy, turbulent flow that often carries large numbers of fallen trees and other floatable debris, and by virtue of its volume and high velocity also carries a large bed load of silt, sand, and boulders. By corrasion these streams enlarge and shift their channels, often eating away adjacent agricultural areas and undermining and washing away bridges, roads, railroads, pipe lines, and other works of man. On the other hand, streams with flows of less than 1 to a very few second-feet and streams of intermittent flow that debouch on to the valley plains or are dissipated over their alluvial fans have small catchment basins. Over the slopes of these basins normal weathering produces accretions of loose earth, rocks, and vegetal matter, all of which are flushed quickly into the outlet channel of the basin by a cloudburst storm. The small size of the basin limits the volume of water that is caught from any given storm, and the steep slopes promote rapid runoff with minimum absorption. This produces a discharge mixture in which the ratio of water to alluvium is so slow that the water serves primarily as a lubricant to the solid materials, and the mass moves forward under gravitational force as a mudflow, finally dissipating itself in a layer of mud and debris over part of the fan.

MECHANICS OF MUDFLOWS

Although degradation by mudflows is not an uncommon natural process in the deserts and semiarid areas of the West, there is little information available as to the mechanics of mudflow operation. No doubt one reason for this is the fact that the flows occur quickly under conditions of violent storm in unfrequented areas that may be accessible only with difficulty. Thus very few persons have been associated with them closely enough to observe their development and behavior. Furthermore, too close an association involves a definite personal hazard that none but a scientific investigator would choose to risk.

Research studies for this report form the basis of the following description of the development of mudflows and some of their characteristics.

Quick, intensive storms drop immense quantities of water on the steep slopes of the catchment basins at a rate greatly in excess of the rate at which the slopes can absorb it. This water rapidly gathers from the myriads of runnels into a flood wave, which concentrates in the main drainage channel. The initial flushing of the slopes carries loose material of all kinds into the stream channel. This piles up as it is pushed forward by the water and acts as a dam in retarding the flow, thus permitting further accretion of freer water from upstream. In a short time an immense crest has accumulated and plunges down the canyon with terrific force.

The wave travels with a definite rolling motion; the material in contact with the stream bed moves with relatively little horizontal velocity, and the material occupying a higher position in the mass shoots to the front of the wave and down. Free water accumulating upstream in a sort of traveling reservoir, because of its swifter velocity, continually passes over the surface of the debris mass and falls over the fore part of the wave, to be immediately overridden and mixed into the under part of the flow.

Huge clumps of earth from the banks collapse into the flow, and undercutting induces slides that often extend far up the steep hill slopes. At constrictions in the channel the mass is retarded until sufficient head has been built up to force the flow through at a greater velocity or until the opening is enlarged. Often gigantic boulders will become wedged in narrow places, forming dams, behind which great quantities of debris are deposited. A sudden widening of the channel, as at a forks, also causes the stream to drop part of its debris load. This condition was noted in the Parrish Creek Basin near Farmington. Once arrested by a broadening of the channel or by a sharp flattening in gradient, the deposited matter is not removed by reliquefying but by subsequent erosion. At times two or more successive waves may debouch from a carry-over, but since there is practically never more than one period of high intensity during a single thunderstorm and seldom if ever do two thunderstorms occur in rapid succession, these waves apparently indicate a lack of coincidence in their arrival at the same place in the main channel of flows from the tributaries.

Evidence of this condition was left at the main forks of Lost Canyon, Utah County, by the flood of July 1938. The discharges from these forks were so thick that, wherever the slope of the banks permitted, steep windrows of assorted rock and earth 2 to 3 feet high were deposited along the edges of the flow. An examination of these deposits showed that the flow from the left fork arrived first, leaving a bank deposit across the mouth of the other channel. Then the flow from the right fork came along and left its bank deposit crossing and overtopping that of the other fork.

A mudflow moves under two distinct influences—the fluidity of its mass and the impetus of the free water. In flows in which there is a large excess of water much of the solid material is carried as bed load, and the heap of debris that gathers at the fore part of the wave is carried forward at greater velocity because of the force of the water and the lower viscosity of the mixture. As the percentage of debris in the flow becomes higher, the influence of the water is proportionately reduced, and the flow behaves more and more as a composite fluid mixture of mud, rocks, and water, similar to wet concrete.

The propagation of mudflows across level or gently sloping areas is a process of spreading rather than of simple flowage. As the flow is debouched onto the gentler slopes it flattens out into a layer, the thickness and extent of which are dependent upon the viscosity and the amount of solid material in the mass. A mixture of low viscosity or one containing a liberal amount of water will spread more rapidly and deposit a thinner layer of debris over a greater area than a thick mixture, which may have equal bulk but will come to rest more quickly over a smaller area and produce a layer of greater depth. In a flow of low viscosity the friction of the particles comprising the mass is reduced to a minimum by water and silt lubrication. As the water content decreases with relation to the amount of solid material internal friction increases until finally the gravitational forces in the flow are equalized. The mass then comes to rest and slowly congeals into a new heterogeneous layer of earth and rocks on the flood plain.

When the flood spills from the canyon mouth onto the open fan there is no longer enforced association of debris and free water, as in the confines of the canyon, and they separate. Free water which has not become incorporated in the debris mass runs rapidly ahead, draining over the surface of the mudflow. The outer edges of the mudflow permit some escape of water, and in moving across the ground they become drier and stiffer through loss of water and contact with drier material. For this reason they resist propagation with increasing stubbornness and often come to rest at a very clear line of demarcation, sometimes standing at angles of 30° to 40°, and present the appearance of artificial placements. Two successive flows near Layton, Davis County, show this phenomenon. (See pl. 21.)

In the viscosity of the mudflow, which enables it to maintain appreciable depth even on unconfined surfaces, lies the explanation of its great destructive and transportive power. When it encounters an obstacle such as a house or barn it does not divert easily, as water does, but piles up against the structure until it attains sufficient head to divert all the newly arriving material. Often before this head is attained the pressure of the mass will cave in the walls or thrust the structure from its foundations. Huge boulders weighing more than 100 tons have been moved incredible distances by these flows.

Conjecture as to the method of transporting these boulders not uncommonly considers them as "floating" in the mass, like iron on quicksilver or cork on water. This is hardly true. The mixture in which the boulders are transported is composed of water and disintegrated material in the same general gravity range as the solid rock fragments. Thus its specific gravity is markedly lower than that of the boulders. The so-called "floating" action is therefore in reality a rolling and sliding action whereby the weight of the boulder seen at the surface is transmitted to the stream bed through a layer of well-lubricated silt, sand, gravel, and smaller boulders which may be likened to a mass of ball bearings. The buoyancy of the mudflow, however, is of material importance, for tests indicate that its specific gravity is slightly under 2, so that a boulder weighing 260 tons, with a specific gravity of 2.6, would have a weight of 160 tons in water and only 80 tons in a mudflow. Thus it is not uncommon to find huge boulders weighing 85 tons or more deposited hundreds of feet from the mouths of canyons on flood fans with gradients of no more than 5°. Large angular boulders are apparently pushed along partly submerged in the lubricated mass of rocks and mud that act as ball bearings, but the rounder ones roll as well as slide.

A. LOOKING UP SNOWSLIDE CANYON BELOW FORKS, NEAR PROVO.

B. PART OF SNOWSLIDE CANYON CATCHMENT BASIN.

A. TRIBUTARY DRAINS IN UPPER PART OF SNOWSLIDE CANYON CATCHMENT BASIN.

B. PART OF WEST SLOPE OF SNOWSLIDE CANYON SHOWING DENSELY WOODED MOIST AREA.

A. VIEW OF UPPER PART OF LOST CANYON CATCHMENT BASIN, NEAR PROVO.

B. LOOKING OVER UPPER PART OF ALLUVIAL CONE INTO LOST CANYON, NEAR PROVO.

As the flow progresses over the fan its velocity and depth decrease, and the larger rocks come to a stop, but the finer material continues onward. This sorting takes place not only among the larger fragments but among the finer particles as well.

RELATION OF CLOUDBURST FLOODS AND MUDFLOWS TO TOPOGRAPHY AND GEOLOGY

Cloudburst floods and mudflows are natural agencies of degradation characteristic of Utah and the western desert regions. Their work is supplemental to other climatic agencies, all of which are slowly wearing away the mountains and filling in the valleys or carrying the material to the sea. The work progresses so slowly that during man's span of life it is a unique experience to witness any change in topographic outlines beyond the adding of a foot or two here and the taking away of a foot or two there over very small areas.

The most conspicuous work of the cloudburst flood is the corrasion of stream channels, a notable example of which is furnished by the channel of Kanab Creek near Kanab. Settlement was first made at this place in 1864, but the site was vacated in 1866 owing to trouble with the Indians. It was reestablished about 1870. On August 30, 1882,[51] a terrific flood swept down Kanab Creek Canyon and literally swamped the town. This was followed by similar cloudburst floods each summer until 1886. In that period of 5 years the creek channel was changed almost beyond the comprehension of even those who saw it. Its depth was increased by 50 feet or more and its width by about 200 feet in places. The resulting cross section was a broad flat-bottomed U with steep banks. Now the channel is much too large for the everyday flow of the stream and is no doubt ample to accommodate more floods as large as those of the early 1880's without danger to town property.

Scores of channels like that of Kanab Creek lead through the plateaus of southeastern and southern Utah into the Colorado River. Narrow canyons cut through the steplike features of the plateau topography and connect small valleys with their alluvial fills, which in many places are being corraded to earlier levels. On the other hand, scores of channels in other parts of the State are being aggraded to flatter gradients, and the alluvial fans to which mudflows are generous contributors are building up the valley fills. Thus the general process of degradation is slowly but surely changing the topography of the State. But the small local cuts and fills are inconsequential of themselves, and their cumulative effect must be measured in terms of geologic time.

[51] Deseret News, Sept. 7, 1882.

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Obviously the rate of degradation under given climatic conditions is either retarded or accelerated by the geologic features. Hard rocks, resistant to weathering, naturally retard the process, and soft rocks, readily disintegrated, accelerate it. In regions such as the Colorado River Basin in Utah much of the geologic history of the streams is recorded in their profiles and the structure of their sediments. It is within the province of the geologist to interpret from these features whether or not there was continuous deposition or intermittent filling and channeling of the canyons and valleys during the past ages. Over much of the west half of the State Lake Bonneville left a record to which the geologist commonly refers his studies of stream activity.

HISTORICAL FLOODS

Any discussion of historical cloudburst floods must necessarily be based on man's experience with such floods and the available records of that experience. This involves such factors as dates of settlement, population growth and its encroachment upon nature's flood plains and watershed areas, the efficiency of recording mediums, the most common of which is the newspaper, and the ability of the recorder or reporter to make factual records rather than verbose, sensational, and highly colored ones.

Utah is in an arid region, where the mean annual rainfall is insufficient for agriculture, where the amount of irrigable and timber land is but a small fraction of the whole area, and where grasses on the forage lands are so sparse that the lands are of value only in large tracts. These are natural conditions that have greatly influenced settlement and population growth.

Permanent settlement began in the State with the founding of Salt Lake City in 1847, and most of the present towns were established prior to 1880. Accordingly, man's record of events within the State, except for accounts of early explorers and trappers, covers less than 100 years. Geologically, however, the results of thousands of years of storms are written in the physiographic features of the State. Many lessons may be learned from these physiographic features but the greatest lesson they teach is that of erosion.

Geologists tell us that many thousands of feet of strata have been eroded from large areas in the Colorado River drainage basin and also that thousands of feet of detritus has been deposited in many places in the valleys of the desert drainage area. These great deposits of material are the fertile agricultural areas today.

Bryce Canyon, Cedar Breaks, Zion Canyon, and the canyons of the Colorado River, popular because of their unique and awesome beauty, are magnificent examples of nature's handiwork in erosion. The work is still unfinished, and because of the aridity of the climate, the character of the rock, and the scant vegetation, the little rain that falls, usually in torrential showers, accomplishes much in the way of erosion.

One of these showers, described by Powell,[52] occurred during his exploration of the Colorado River in 1869. Under date of July 26, 1869, he notes that the day was very hot, and after stating that he took observations for altitude he continues as follows:

I notice that a storm is coming from the south. I seek a shelter in the rocks; but when the storm bursts, it comes down as a flood from the heavens, not with gentle drops at first, slowly increasing in quantity, but as if suddenly poured out. * * * It lasts not more than half an hour, when the clouds sweep by to the north, and I have sunshine again. * * * On reaching the bottom of the side canyon, I find a thousand streams rolling down the cliffs on every side, carrying with them red sand; and these all unite in the canyon below, in one great stream of mud.

Traveling as fast as I can run, I soon reach the foot of the stream, for the rain did not reach the lower end of the canyon, and the water is running down a dry bed of sand; and, although it comes in waves, several feet high and 15 or 20 feet in width, the sands soak it up and it is lost. But wave follows wave, and rolls along, and is swallowed up; and still the floods come on from above.

It is obvious that when one of these storms occurs over an area where the geologic and topographic features are conducive to rapid erosion the amount of erosion that actually takes place may be sufficient to change the physical features beyond recognition. This is demonstrated by accounts of cloudburst storms at Kanab in August 1882[53] and July 1883.[54] The storm of August 1882 produced a flood in Kanab Creek that swept through the town and adjacent fields and cut the bed of the creek down "some 10 to 15 feet." The telegraphic report of the 1883 flood to the Deseret News at Salt Lake City reads as follows:

Yesterday afternoon at 3:30 o'clock the heaviest flood known in this part of the country came down Kanab Canyon; the force of the water was so great that masses of earth as large as a common house floated down the stream with willows still standing upright. * * * All the wheat in the upper field washed away. The water covered the entire field from fence to fence, the stream at that point being one mile wide. * * * In the canyon it has washed the channel 30 to 40 feet below the former bed of the creek. A number of cattle were washed away and drowned.

The day following this report a letter from Bishop W. D. Johnson, of Kanab, gave additional information as follows:

The torrent of water in volume, rapidity, and noise resembled the whirlpool rapids of Niagara. Whole portions of soil with willows standing erect

[52] Powell, J. W., Exploration of the Colorado River of the West and its tributaries, p. 65, Washington, D. C., 1875.

[53] Communication from Bishop W. D. Johnson, of Kanab, to John L. Nuttall, dated Aug. 30, 1882 and published in the Deseret News, Salt Lake City.

[54] Telegraphic report from Kanab to Deseret News July 30, 1883, and communication from Bishop W. D. Johnson to Deseret News July 31, 1883.

came floating down the stream; some of these floating islands were several rods in length by one or two wide. It beat everything I ever saw. It lasted for some 7 or 8 hours. * * * The canyon was cut out at the old city dam some 50 odd feet down and 16 rods wide. The canyon is so changed you would not know it.

When the flood of 1882 occurred the settlement of Kanab was 12 years old, and it was an experience that was entirely new to these settlers. There is no doubt that storms and floods such as those of 1882 and 1883 have occurred for ages in many places in the State where man has not been present, and it is reasonable to assume that had Kanab not been settled until 1884 these floods would have come just as they did, but no historical record of the method of the cutting of Kanab Canyon at that time would be available.

In the table following, abstracts of more than 500 accounts of outstanding cloudburst floods in Utah are listed. These give salient information relative to the flood performance and a description of the resulting damage. A cursory summary of these accounts indicates that about 112 times farm crops were destroyed in varying amounts, but the damage was usually to small patches of only a few acres. Stretches of highway were washed away or covered with mud and boulders, and bridges were destroyed at approximately 140 different times; canals and diversion dams were reported damaged more than 70 different times; and railroads have had stretches of track washed out or covered with debris more than 60 different times. Cities and towns have had streets flooded about 100 different times, and in nearly all of these floods homes have been either washed away or filled with several feet of mud. Power plants, pipe lines, and other structures have been damaged more than 25 different times. Livestock, poultry, and farm implements have been swept to destruction and at least 26 persons have been lost in these floods by drowning. Plate 22 shows the location and number of damaging cloudburst floods reported in Utah from 1847 to 1938, and the date of settlement of the communities affected.

Abstract accounts of outstanding cloudburst floods in Utah

SOURCE OF ACCOUNTS

BB	Brigham Bulletin, Brigham.
BCB	Brigham City Bugler, Brigham.
BEN	Box Elder News, Brigham.
DN	Deseret News, Salt Lake City.
DRG	Denver & Rio Grande Western R. R., Denver, Colo.
DSN	Deseret Semi-Weekly News, Salt Lake City.
ECP	Emery County Progress, Castle Dale.
ER	Eureka Reporter, Eureka.
GCN	Garfield County News, Panguitch.
GVT	Grand Valley Times, Moab.
ODH	Ogden Daily Herald, Ogden.
OSE	Ogden Standard Examiner, Ogden.
PDH	Provo Daily Herald, Provo.
PEH	Provo Evening Herald, Provo.
PH	Provo Herald, Provo.
PR	Park Record, Park City.
PRV	Progress Review, Fillmore.
SLH	Salt Lake Daily Herald, Salt Lake City.
SLT	Salt Lake Daily Tribune, Salt Lake City.
TI	Times Independent, Moab.
UCD	Utah County Democrat, Provo.
UEC	United States Engineer Corps, Los Angeles, Calif.
UPL	Utah Power & Light Co., Salt Lake City.
WBA	Weather Bureau Annual, Salt Lake City.
WC	Washington County News, St. George.

Date	Locality	Stream course	Remarks
1852			
June 23, 7 p.m.	Salt Lake City		Cloudburst over city. Gardens and streets were flooded and some damage resulted to buildings from silt and undermining. (DN June 26, 1852.)
July 30	Manti	Manti Creek	Rain very heavy. Water ran through streets 4 to 10 inches deep. Washed woodpiles, haystacks, etc., before it. Yards and cellars flooded. (DN Sept. 4, 1852.)
1853			
Sept. 3	Cedar City	Coal Creek	Tremendous flood carried away bridges and dams. Brought immense quantity of logs and huge rocks. Did considerable damage to the iron works. (DN Oct. 15, 1853.)
1854			
June 13	Salt Lake City	City and Red Butte Creeks	Heavy rain in city, flooding streets, followed by mud and debris flow from creeks. Gardens, walls, ditches, roads, and stone quarry suffered considerable damage. (DN June 22, 1854.)
1857			
Aug. 31, afternoon	Parowan	Center Creek	Flood brought down all bridges for 7 miles up canyon. Tore away the sawmill dam, tore out the ox-frame dam on Cricket Fork, cut down the gristmill dam 12 feet, and covered with drift and rubbish a portion of the field adjacent to the city. (DN Sept. 30, 1857.)
1863			
July 17	Iron and Washington Counties.	Pine and Pinto Creeks	A disastrous flood from a series of cloudbursts raising Pine Creek to 15 or 20 feet high. Swept house away and drowned four children. On Pinto Creek no lives lost but serious damage to property. Some stock was lost. (DN July 31, 1863.)
1864			
Sept. 11, forenoon	Salt Lake City	City Creek	Three-hour rain over city, followed by cloudburst flood in City Creek. Caused debris flow "as thick as molasses." "Stream was large enough to navigate a steamboat for several hours" on North Temple Street. (DN Sept. 14, 1864.)
1866			
June 6, 1 p.m.	do	City and Red Butte Creeks	Heavy rains, culminating in cloudburst and hailstorm. Vines and crops severely damaged. Rain lasted until Thursday, the 7th. Streams were swollen and flooded several wards but carried little debris. Adobe bricks destroyed. (DN June 14, 1866.)
1869			
July 31	do	Little Cottonwood Creek	Cloudburst in canyon washed out bridges and large part of road. Water a foot deep in dwelling houses in canyon. Damage about $3,000. (DN Aug. 5, 1869.)
Aug. 6, p.m.	do	City Creek	Cloudburst caused a small flood near lime kiln. Small section of track washed out. (DN Aug. 7, 1869.)
Aug. 19	American Fork	American Fork Canyon	"Waterspout" in canyon washed out seven bridges and did $1,500 worth of damage to road. (DN Aug. 30, 1869.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
1870			
July 8	St. George		Hailstorm followed by heavy rain of about 1 hour's duration. After storm, flood damaged cotton factory, gristmill, and farms. (DN July 9, 1870.)
July 10	do		Heavy storm of 4 hours' duration. Flood from gap in mountains to northwest of city spread to width of 200 yards, greatly damaging land and crops in west part of town. (DN July 13, 1870.)
July 25	Cedar City		Heavy rain. Streets and cellars flooded. Bridges, fences, and ditches washed out or damaged. Rain washed away "poisonous deposits of the grasshoppers," which had been numerous before flood. (DN Aug. 3, 1870.)
Aug. 22, 1 p.m.	Salt Lake City		Hailstorm near Hot Springs, followed by floods. Considerable damage to railroad and brewery. (SLH Aug. 23, 1870.)
1872			
May 19, 4 p.m.	do		Thunderstorm over city. Lightning strikes house; seriously damaged bench irrigation ditch. (DN May 20, 1872.)
June 4	St. George		Heavy cloudburst. A few cellars filled "with water in place of wine." (DN June 15, 1872.)
July 15	Government Springs	Government Creek	Cloudburst flood "washed the bottom out of the creek" and destroyed irrigation intake. (SLH July 20, 1872.)
Aug. 25, p.m.	Salt Lake City		Flood from foothills struck portion of city, damaging gardens and water ditches. (SLH Aug. 27, 1872.)
Sept. 2 (prior to)	St. George	Santa Clara Creek	Heavy rains for several days. Orchards, fields, and ditches damaged. Water 30 feet deep in Santa Clara Creek, flooding adjacent lowlands. Damage to flume and dams of $2,200. (DN Sept. 2, 1872.)
1873			
Aug. 4	Salt Lake City		Cloudburst in mountains and over city. Flood damaged several orchards, depositing boulders and mud. Ditches were broken and footbridges washed out. (DN Aug. 5, 1873.)
Aug. 11	Beaver		Heavy rain flooded streets and did some damage to hay crops. (SLT Aug. 16, 1873.)
Aug. 21	Bingham	Bingham Canyon	Great damage to railroad. Bridges and track destroyed; ties piled up. (DN Aug. 23, 1873.)
1874			
July 20	Parowan		Flood washed out dams and bridges and flooded portions of the town.
	Summit		Flood washed large boulders into the streets. (SLH July 21, 1874.)
July 21, 1 p.m.	Alta		"One of the most destructive thunderstorms that ever visited this region." Roads washed out and mining properties damaged. (SLH July 22, 1874.)
July 23	Salt Lake City	City Creek	Cloudburst over canyon. Stream greatly enlarged and carried much mud. Portions of Main and South Temple Streets flooded. (DN July 23, 1874.)
Aug. 1 (prior to)	Coalville (mines)	Chalk Creek	Cloudburst and debris flow. Roads washed out; ranches covered with rocks and timber. Resulted in $2,000 damage to mines. (DN Aug. 1, 1874.)
Aug. 1	Salt Lake City		Cloudburst in mountains flooded Lindsay's Gardens area. Little damage. (DN Aug. 2, 1874.)
Aug. 4 (prior to)	West shore of Great Salt Lake.		"Copious downpour." Rain fell so heavily that ground was covered in places with a foot of water. Some damage to hay crop. (DN Aug. 4, 1874.)
1876			
July 24 (prior to)	Shauntie (near Beaver)		Cloudburst does some damage to smelter equipment. (SLT July 24, 1876.)
July 24	Provo		Cloudburst flooded streets and blew down trees. (SLT July 28, 1876.)
Aug. 8, p.m.	Salt Lake City		Severe storm knocked fruit off trees and "prostrated growing crops." (SLT Aug. 9, 1876)

Aug. 16 (prior to)	do		Cloudburst near Hot Springs gashed hillside and raised Hot Springs Lake about a foot. (SLT Aug. 16, 1876.)
1878			
July 15, 4 p.m	Pleasant Grove		Serious damage to crops. Chickens, birds, and "even muskrats" killed during violent hail- and rain-storm. (DN July 16, 1878.)
July 23, 8 p.m	Farmington	Farmington and Davis Creeks (probably).	Cloudburst over Wasatch Mountains. Farmington and Davis Creeks discharged an immense volume of water and debris. Farms and roads were covered with mud and boulders. A team and wagon swept away and the morning after "one of the mules was discovered embedded in the sand with only his head and neck visible above it. The other was found lodged against a rock a short distance below where it was caught. Both animals were badly bruised." Estimated damage to farms $3,700. Rocks 20 to 30 tons in weight were carried 300 yards from canyon mouth over comparatively level ground. (DN July 25, 1878.)
July 23, p.m	Tooele		Copious thundershower. Streets were flooded and ditches filled with gravel. (DN July 26, 1878.)
July 23, 5 p.m	Johnson's settlement, in Skull Valley.	Skull and Rush Valleys	Cloudburst flood kills two Indians and 20 head of cattle. Farms damaged—one to the extent of $1,000. Stream in Rush Valley said to be 60 rods in width and 4 feet deep. Rocks and gravel were deposited to depth of 7 to 10 feet. (DN July 27, 1878.)
Aug. 9 (prior to)	Wales	Six Mile Creek	Town enveloped by cloud that was suddenly divided by a light. A terrific roar followed. The damage following the cloudburst was considerable to crops and fields. (DN Aug. 16, 1878.)
Aug. 9	Nephi	Salt Creek	Cloudburst submerged farm with rocks and sand. (DN Aug. 16, 1878.)
1879			
Aug. 14 (prior to)	Sevier Canyon		Cloudburst washed away railroad tracks and filled cuts with debris week previous to report. (DN Aug. 14, 1879.)
1880			
July 26	Lehi		Cloudburst washed out tracks of Utah Southern in two places. Damage estimated at $5,000. (DN July 28, 1880.)
July 27, 2 p.m	Spring Lake and Santaquin		Cloudburst and hailstorm. Crops badly damaged; road and bridges in canyon washed out. Logs 30 to 40 feet long carried in stream. Damage estimated, $3,000 to $5,000. (DN July 31, 1880.)
1881			
July 18, 8 p.m	Willow Ranch 5 miles southwest of Grantsville.		Rainstorm in mountains of about an hour's duration, bringing flood. Soil washed away, ground covered with silt, rocks, and other debris. Crops destroyed. (DN July 21, 1881.)
July 24	Pinto		Heavy flood swept down from the southeast and moved stacks, bins, fences, and parts of barns. Some swept away entirely. Gardens covered with debris. One home washed away but no human lives lost. (DN July 27, 1881.)
Aug. 11, 2:45 p.m	Orderville		Cloudburst and hailstorm, followed by heavy rain of an hour's duration. Town was flooded, and "hundreds of loads of rock, timber, and rubbish" were deposited in streets and fields. Damage estimated at $2,800 to $3,000. (DN Aug. 13, 1881.)
Aug. 14, 10:30 a.m. and 12:30 p.m.	Alpine and American Forks		Two cloudbursts in mountains; moderate rain in town. Floods brought quantities of debris out of canyons. "Thousands of cords" of timber, some logs being 1½ to 2 feet in diameter, were carried down. "Torrent was the largest ever witnessed in that neighborhood." (DN Aug. 18, 1881.)
Aug. 14, 4 a.m	Castle Valley	Soldier Canyon	Cloudburst flood washed out road and carried away mercantile supplies for railroad grade crew. Two storms. Storm also did considerable damage in Castle Dale. All ravines and gulches full to overflowing. Water 4 feet deep during first and 10 feet deep during second storm. Cottonwood Springs buried by debris and ceased running. (DN Aug. 20, 1881.)
Aug. 14	Parleys Canyon		Cloudburst caused extensive damage in canyon. (SLT Aug. 16, 1881.)
Aug. 15	Alta	Little Cottonwood Creek	Three floods in canyon washed out roads and trails and damaged buildings in Alta. (SLT Aug. 16, 1881.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 16, p.m.	Provo Canyon		Storm raises river 3 feet. Mudslide estimated "from 200 to 300 feet square and from 4 to 10 feet deep" was reported. (DN Aug. 22, 1881.)
Aug. 18	Brigham City		Cloudburst does considerable damage. (DN Aug. 18, 1881.)
1882			
Aug. 7, p.m.	Beaver	South Mountains	Canyons and gulches filled with roaring torrents, in many cases over 8 feet deep. Mumford farm almost entirely ruined. Brick kilns containing upward of 100,000 bricks partially washed away and collapsed. (DN Aug. 14, 1882.)
Aug. 11	Logan		Logan vicinity visited by heavy storm, flooding streets. (ODH Aug. 15, 1882.)
Aug. 12, 4 p.m.	St. George		Violent rain and hailstorm on two successive days (Aug. 12 and 13). Sidewalks and roads damaged, trees blown down, and "fruit by the ton" knocked from orchard trees. (DN Aug. 17, 1882.)
Aug. 27	Salt Lake City	City Creek	Cloudburst in canyon brings down immense amount of dirt and large rocks.
Aug. 30, p.m.	Kanab	Kanab Creek	Streets flooded, cellars filled, hay and grain damaged. Third floor in season; the first two were not large. Creek bed deepened 10 to 15 feet, and irrigation ditch was filled with sand. (DN Sept. 7, 1882.)
1883			
July 4–5	Beaver and Washington		Good deal of damage by cloudbursts. Cotton factory millrace and dam washed out at Washington. (DN July 18, 1883.)
July 5	St. George		Flood from Pine Valley Mountains damaged farms, dams, ditches, and roads and damaged factory dam and race to extent of $1,000. (DN July 19, 1883.)
July 21	Report from Kanab		Flood in Virgin River tears out all dams between Washington Field and Mesquite. (DN July 28, 1883.)
July 29, 3:30 p.m.	Kanab	Kanab Creek	"Heaviest flood known in this part of the country." Masses of earth as large as a common house floated down the stream with willows still standing. Extensive damage to crops, and all farming land in canyon was destroyed. Some cattle killed. Canyon near old city dam cut 50 feet down and 16 rods wide. Flood lasted 7 to 8 hours. Fresh cutting in channel opened up several new springs. (DN July 30, 1883.)
Aug. 1	Minersville	South Mountains	Cloudburst in mountains south of town. Streets flooded to depth of nearly 2 feet. Unharvested crops demolished. Such a storm not seen for nearly 8 years. (DN Aug. 6, 1883.)
Aug. 17 (prior to)	Spanish Fork Canyon	Tie Canyon	Flood swept away lumber mill and some cabins. Inhabitants, warned by sound of approaching wave, climbed the hillsides in time to escape. (DN Aug. 17, 1883.)
1884			
Mar. 12	Kanab	Kanab Creek	Five successive days of rain bring floods down creek, doing damage to extent of $500. Rainfall unprecedented. (DN Mar. 21, 1884.)
Aug. 8, 4 p.m.	Salt Lake City	City Creek	Heavy rain in city, cloudburst in canyon, causing overflow of aqueduct on North Temple Street. Some adjacent yards were flooded. (DN Aug. 9, 1884.)
1885			
May 8, p.m.	do		Heavy rain over city. Streets were flooded and ditches filled with sand and gravel. Augmented by discharge from hills following roads from gravel pits on North Bench. (DN May 9, 1885.)
Aug. 7, p.m.	Area to south of Salt Lake City.		Railroad tracks undercut or covered with gravel as a result of intense storm. Traffic tied up. (DN Aug. 8, 1885.)
	Alpine	Dry Creek	Heavy rains, washing huge boulders and trees down the canyon. Road gullied in some places, covered with debris in others. Estimated damage, $1,000. (DN Aug. 12, 1885.)

A. MAIN STREET OF WILLARD AFTER FLOOD OF AUGUST 13, 1923.
Photo by L. M. Winsor.

B. RESIDENCE AT WILLARD AFTER FLOOD OF AUGUST 13, 1923.
Photo by L. M. Winsor.

C. ORCHARD NEAR MOUTH OF FARMINGTON CANYON, FLOOD OF AUGUST 13, 1923.
Photo by L. M. Winsor.

D. RESIDENCE AND BARN IN WAKE OF PARRISH CREEK FLOOD OF AUGUST 27 1930.
Photo by L. M. Winsor.

Aug. 23	Price Canyon to Green River.	Cottonwood Wash and Price Canyon.	Heavy rains over the region washed out railroad tracks in many places and undermined pile bridge. Price and Green River flooded. (DN Aug. 26, 1885.)
Sept. 10 (prior to)	Kanab	Kanab Creek	Flood damages irrigation ditches. Estimates of two former floods give fresh cutting at canyon mouth as 64 to 69 feet total depth. Probably exaggerated. (See next item.) (DN Sept. 10, 1885.)
1886			
Apr. 12 (prior to)	Kanab	Kanab Creek	Heavy runoff (probably a spring freshet) washed out dam and added 10 feet to depth of channel. Total depth reported as 50 feet. (DN Apr. 12, 1886.)
Aug. 17	Thistle	Spanish Fork Canyon	Tracks of D. & R. G. W. R.R. flooded and covered with gravel, delaying train several hours.
	Millard County		Flood washed out track bed of Utah Central R.R. in some places and covered it in others. (DN Aug. 18, 1886.)
Aug. 18, 28 (noon), 31 (noon), Sept. 1 (a.m.).	Kanab		Four successive floods. First filled cellar of Tithing Office and caused settlement of building. Second flood deposited sand and gravel on several acres. Third of series caused some damage to three properties. Another flood peak, not so heavy, came down about 8 to 9 p.m. on the same day. Largest flood of series occurred in conjunction with intense rain- and hail-storm. Hailstones as large as 1½ inches were noted. Damage reduced because of preparation for diversion, but considerable damage to fruit crops occurred. Correspondent says, "The dams in the creek* * * went out some time ago, but we are so used to that I had almost forgotten to mention it." (DN Sept. 9, 1886.)
Aug. 19, noon	Cedar Fort (Cedar Valley)		Intense hail- and rain-storm. Streets and cellars were flooded, farm land gullied, and wheat sheaves carried away. (DN Aug. 20, 1886.)
Aug. 25 (prior to)	Fillmore	Chalk Creek	Heavy rain followed by terrific flood. All dams and bridges washed away and gardens buried in mud from 2 inches to 2 feet deep. One house and all contents washed away. Loss estimated at several hundred dollars. No lives lost. (DN Aug. 25, 1886.)
Aug. 30, (prior to 3 a.m.)	Wallsburg		Thirty minutes after rain began a large volume of water came from the mountains, filling cellars and washing away crops. Damage estimated at thousands of dollars. (DN Aug. 30, 1886.)
Aug. 31, p.m	Point of Mountains		Small washout covers section of track with gravel. (DN Sept. 1, 1886.)
Sept. 2 (prior to)	Pleasant Valley		Damage to track by cloudburst interrupted railroad traffic. (DN Sept. 2, 1886.)
1887			
July 10, p.m.	Fillmore		Flood devastated town and surrounding country. Three sawmills swept away. Half a herd of sheep lost. (ODH July 12, 1887.)
	Point of Mountains		Track of Utah Central R.R. covered with rocks, sand, and brush for considerable distance by washouts caused by intense rains. (DN July 11, 1887.)
July 28 (prior to)	Grantsville	Western Mountains	Light rains in town, heavy storm in mountains causing debris flow. About half an acre of cropland was covered with debris to a depth of 2½ feet. Cellars and houses flooded and roads washed out. Severest storm experienced there to date. (DN July 28, 1887.)
Aug. 23	Heber City	Lake Creek	Cloudburst causes stream, dry since spring, to overflow and flood cropland. Considerable damage. (DN Aug. 27, 1887.)
1888			
July 21	Spanish Fork Canyon near Red Narrows.		Cloudburst washed out section of track of D. & R. G. W. R.R. (DN July 25, 1888.)
July 30	Ogden	Ogden Canyon	Heavy rains concentrated in vicinity of Ogden. Several landslides in Ogden Canyon, and road was washed out in places for a distance of 1,000 feet. Heavy torrents in side gulches. River carried a great deal of debris. Storm said to be heaviest ever witnessed in that area. (DN Aug. 1, 1888.)
July 31, night	Grouse Creek	Mountains to north	Flood arising from cloudburst in mountains swept away bridges, fences, and outbuildings; destroyed 40 tons of hay and deposited debris on cropland. (DN Aug. 9, 1888.)
Aug. 3	Orangeville		Cloudburst and hailstorm struck town. Hailstones 1 inch in diameter. Streets and streams were flooded, canyon bridges washed out, and gardens destroyed. (DN Aug. 8, 1888.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
1889			
Apr. 10	Salt Lake City		Hard rain for 15 minutes floods a few low-built homes and washes mud and sand onto gardens. Not much damage, but water was "ankle deep" in the streets. (DN Apr. 10, 1889.)
June 6	Junction of Sevier, Juab, and Millard Counties.	Sevier River	Storm so fierce that Sevier River raised 6 feet in very short time. Principal damage to Utah Central R.R. through Sevier Canyon. Much of track flooded between mouth of Chicken Creek and Leamington. One small bridge washed away, another undermined. Rails bent and alinement destroyed. (DN June 8, 1889.)
Aug. 10, p.m.	Bingham Canyon		Unprecedented rain flooded streets and gulches, washed out gardens and deposited gravel and brush around houses and in streets. Damage, about $1,000. (DN Aug. 12, 1889.)
Aug. 16, p.m.	Manti	Manti Creek	Terrific thunderstorm. Heavy roaring in canyon. Flow 8 feet deep came down creek, carrying huge trees, logs, brush, etc., which was scattered over streets of town. Several farm animals drowned, and much property damage.
	Ephraim	Ephraim Creek	Creek washed out masses of trees, rocks, and soil and deposited them in town. Mud to depth of 3 feet in streets and on gardens. Some homes flooded.
	Between Black Rock and Oasis.		Utah Central R.R. roadbed washed out. Trains delayed 3 to 4 hours.
	Sterling		Great loss of crops. Damage to property.
	Mayfield	Wood Canyon	Canyon only about 1½ miles long. Stream poured forth "six rods or more in width and fully 5 feet deep in the center." Main stream directly against Jorgensen home, within which were Mrs. Jorgensen and six children. Mr. Jorgensen arrived, left buggy and team on dry ground in care of oldest boy who had come out for help. Mr. Jorgensen found other five children in house, floating around on a lounge on 3 feet of water, and his wife holding up a cupboard to steady herself and also to prevent it from falling on the children. Mr. Jorgensen broke a window to make an exit for the water. He saw the stable swept away, buggy and horses rolling over and over. The boy with the buggy was drowned, also cattle and horses. Fences were broken, stables and corrals wrecked, sheds undermined, cellars filled, and orchards buried in debris.
	Dry Hollows, near Frisco		Beds of hollows at railroad crossings washed out so deep that piles were left dangling to the bridge.
	Garfield Beach		Waterspout observed on lake. Excursion boat was nearly swamped. Lasted only half an hour, but in that time the pavilion next to railroad tracks was covered by an inch of water.
	Echo Canyon		Several cloudbursts reported, but not much damage.
	Weber Canyon		Train was halted by landslide. Tracks were flooded in many places and buried by gravel and boulders in others. Landslides and overflowing gulches brought down thousands of tons of debris. Soon after train had crossed a certain section, the whole mass slipped into the river. A little later a freight train, attempting to cross a dangerous spot, was struck by a landslide and washed into a ditch. No casualties were mentioned. Water pouring down mountainside cut a gulch 18 feet wide and 18 feet deep in railroad bed. (DN Aug. 19, 1889.)
Aug. 19 (prior to)	Huntington	Huntington Creek	No serious damage reported but rains were so heavy in hills that "heaps of mud" were brought down every gulch. Trains delayed. (DN Aug. 21, 1889.)
1890			
May 1	Salt Lake City	Parleys Canyon	Heavy rains augmented by melting snow flooded canyon, concentrating at summit. Roads were damaged and hillsides gashed. (DN May 2, 1890.)

July 13	Manti	Manti Creek	Cloudburst 3 or 4 miles up Manti Canyon. Road in canyon covered with rocks and mud. Bridges washed away. Streets flooded. (DN July 18, 1890.)
July 20	Coalville	Chalk Creek	"Freshet" did several thousand dollars' worth of damage. Bridges and roads washed out, and fields covered with debris. (DN July 21, 1890.)
July 20, 12 noon to 1 p.m.	Manti	Manti Creek	Rocks, logs, and debris debouched from canyon. Saw mill and shingle mill washed out of canyon. Machine shop swept away. Bridges carried away and streets of town flooded.
	Ephraim	Ephraim Creek	Logs and debris debouched into town. Yards and gardens flooded and covered with mud and debris. (DN July 21, 1890.)
1891			
July 29, 4 p.m.	Fairview	Oak Creek	Cloudburst in South Fork. Wall of water 7 feet high came out of canyon, rolling rocks and timbers. Sawmill camp at mouth of canyon swept away. Road in canyon badly damaged. Bridges swept away. (DN Aug. 5, 1891.)
Aug. 12, 4 p.m.	Minersville		Tremendous storm. Huge streams of water, mud, and debris rushed down from the mountains and flooded the entire town. Creek beds usually dry carried torrents 4 to 6 feet deep. Ditches destroyed, fences washed away, and fields covered with mud and boulders. Roads badly washed and crops severely damaged. (DN Aug. 17, 1891.)
Aug. 13, p.m.	Manti	Manti Creek	Trees, mud, and other debris carried into town. Considerable property damage. "Thoroughfares in the vicinity of the flood were a sight long to be remembered."
		Six-mile Creek	Much debris carried onto farms at mouth of canyon within reach of flood. (DN Aug. 14, 1891.)
Aug. 16, 1 p.m.	Manti	Manti Creek	Mud and water poured out of canyon into streets, over gardens, etc. Sky clear over valley and no rain. Cloudburst on watershed of creek. Logs, brush, and boulders strewn over flood area. Some houses flooded. Considerable property damage. (DN Aug. 17, 1891.)
Aug. 19, 2 p.m.	Bingham	Bingham Canyon	Intense rainstorm in head of canyon sent flood down the main street of Bingham, carrying logs and boulders and other debris. Subsided by 4:30 p.m. In some places where flood had washed over porches and sidewalks "were left quite large deposits of gold dust and other rich minerals." (DN Aug. 19, 1891.)
Sept. 5 (week prior to)	Plymouth		Third terrific storm of season. Hail and rain fell in torrents. Great flood from mountains cut deep gashes and carried huge boulders and bodies of dead animals. "One dead horse was washed over a hundred yards on level ground." Thousands of bushels of grain were destroyed by hail. (BB Sept. 5, 1891.)
Sept. 10	5 miles above Price		Cloudburst in the vicinity of Price broke through dike and caused considerable property damage. Fields and homes flooded and crops injured. (DN Sept. 14, 1891.)
1892			
June 15	Kaysville	Weber Canyon	Cloudbursts in canyon threaten town. Bridges and tracks badly damaged. Fruit crops in Uintah, Morgan, and Weber Counties suffered appreciably, in some cases being literally swept away. (DN June 16, 1892.)
1893			
July 22, p.m.	Nephi	Salt Creek Canyon	Intense storm in canyon; no rain in town. Flood washed dam out to north of city and diverted part of the flow, but flood was still unprecedented since 1862. Cellars were filled, and haystacks and outbuildings taken away. (DN July 25, 1893.)
July 26, 10 p.m.	Salt Lake City		A cloudburst and hailstorm struck the city. Hailstones stripped orchards and gardens. Following the hail a copious rain flooded streets and yards and partially filled some basements. (DN July 27, 1893.)
Aug. 18 (prior to)	Minersville	South Hills	Cloudburst in South Hills. Much damage done by floods. Considerable grain washed away. Fields covered with mud and debris. (DN Aug. 18, 1893.)
1894			
July 13	Fountain Green	Big Hollow	Flood covered grain fields south of town with mud and trash. (DSN July 14, 1894.)
July 29, afternoon	Heber Valley	Center and Daniels Creeks	Rain was slight in valley but concentrated heavily on the eastern mountains. Canyon floods, however, ruined several acres of cropland by flooding or by deposition of sand and gravel. Poultry was drowned, roads and bridges washed out. (DN Aug. 3, 1894.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
1895			
July 28, 2 p.m.	Hunter		Heavy cloudburst and flood from foothills above settlement. Farms and barnyards were washed over, the water reaching a depth of 2 to 3 feet in some places. Canals, ditches, and fields were covered in places with sand and gravel. (DN July 29, 1895.)
Aug. 19, afternoon	Frisco	Big Wash	Cloudburst in hills at head of Big Wash. Flood tore out several railroad crossings and spent itself in valley near Milford. Large amount of grain destroyed. Farm lands submerged. (DN Aug. 20, 1895.)
1896			
May 29-30	Salt Lake City		Excessive rains flooded the city. Lower areas on the west side were reported to present the appearauce of lakes. Rafts were necessary in some places. Drainage canal overflowed. Much damage to gardens and roads. (DN June 3, 1896.)
	Peoa		Heavy rains benefit crops but damage bridges. (DN June 6, 1896.)
July 5, p.m.	Kanab	Kanab Creek	Cloudburst damages flumes and threatens dam. (DN July 30, 1896.)
July 13, p.m.	Fillmore	Chalk Creek	Enormous body of water swept out of canyon and over a portion of the town, inundating fields and gardens. Trees, drift logs, and boulders strewn over farms. Flow thick with mud, carrying uprooted trees, logs, and boulders. Many homes surrounded by sea of mud from 1 to 2 feet deep. Main street for about half a mile covered knee deep to horses with slimy mass of thick mud. Hogs, chickens, and cattle drowned. Wagons and other implements swept away. Three sawmills destroyed, parts found in fields 12 miles below. Thirty-thousand board feet of lumber carried away. Estimated damage $20,000 to $30,000.
	Fayette		Flood came down from hills. Almost the entire settlement was flooded. Bridges were washed out, fences wrecked, cellars filled, and water in some houses. Crops were destroyed and haystacks washed away. New canal damaged in many places and filled with debris.
	Ephraim		Much damage to crops. Plowed land washed so that only boulders left. D. & R. G. W. R.R. train delayed.
	Fairview		Railroad tracks heavily covered with debris. Crops beaten down. Barns and other buildings swept away. (DN July 14, 1896.)
July 14	Richfield	Cottonwood Creek	Flood swept over and obliterated canal built to divert flood waters from towns. Waters flooded streets, filled cellars, covered fields and gardens with debris and mud. Property damage considerable.
	Scipio		Heavy flood, with another on the 16th. Four floods in two days. Much grain and hay destroyed.
	Kanosh and Meadow		Much of the crops destroyed by mud and water. Haystacks and farm buildings swept away.
	Sigurd	Cedar Ridge Canyon	Heavy floods brought out hundreds of loads of wood, filling up canals with debris, and covering up much hay and grain. (DN July 15, 1896.)
July 14, 2 p.m.	Eureka		Torrential rain of an hour's duration flooded the town. Two people were drowned and one died of heart failure. Great deal of damage including wrecking of a railroad bridge and tearing out of rails.
July 14, 2:30 p.m.	Mammoth		Dam washed out and mining properties damaged.
July 14, 3 p.m.	Mercur		Heavy storm following two hours of moderate rain flooded railroad grade and tore out rails. Not much other damage. (DN July 14, 1896.)
July 16, p.m.	St. George		Reports heaviest storm in years, but one which was considered more beneficial than damaging. Water 3½ feet deep on west side of town. (DN July 16, 1896.)

July 12, 14, 17	Koosharem		Three floods ruined about half the first lucerne crop. (DN July 23, 1896.)
July 17, p.m.	Holden		Cloudburst swept logs, boulders, and mud into town. Barns, corrals, and outbuildings carried away. Some homes entered by water and debris.
	Near Monroe		Small village south of Monroe flooded and great damage done to farms, orchards, roads, and bridges. Roads badly washed out between Richfield and Elsinore. Settlement at Annabella also suffered damage. Driftwood and debris strewn over east bench. Canals badly damaged. (DN July 18, 1896.)
	Joseph	Mountain streams	Cloudburst flooded whole precinct during the week. Streams brought down hundreds of cords of wood from the mountains, filling irrigation ditches with debris. Farmlands covered with debris and crops destroyed. (DN July 23, 1896.)
July 20	Santa Clara		Heaviest rainfall in 40 years. Thousands of dollars' damage. Roads washed out, cellars filled, and fields flooded and covered with sand. (DN July 25, 1896.)
July 23, p.m.	Heber City		Rain amounted to 1.65 inches in one night. Climax of series of floods which destroyed lucerne and damaged roads and bridges. (DN July 30, 1896.)
July 25	Emery County	Nutler Creek	Stage driver was caught in stream bed by arrival of flood wave. Coach wrecked. (DN Aug. 3, 1896.)
July 28, 1 p.m.	Eureka		Four people lost their lives as a result of what was reputed to be the worst flood in the history of the town. Main Street, near the banks of the creek, was turned into a raging torrent.
Aug. 14	Fillmore	Bear Canyon	Flood caused by cloudburst and hailstorm washed out sawmill and carried trees, boulders, and trash down to the town. Some of the trees carried as far as Fillmore were 3 feet in diameter. (PRV.)
Aug. 22	South of Joseph	Clear Creek Canyon	Wagonload of laborers caught in flooding stream. One man killed. (DN Aug. 24, 1896.)
1897			
May 24	Salt Lake City		Heavy storm flooded streets and did considerable damage in steeper portions of the city. (DN May 25, 1897.)
Aug. 2	Summit County		Intense hail- and rain-storm damaged crops and flooded streams. (DN Aug. 12, 1897.)
Aug. 27, p.m.	Head of Parleys Canyon		Cloudburst washed mud into water-supply intake, necessitating a temporary shut-down. (DN Aug. 28, 1897.)
Sept. 12	Castle Dale		Unprecedented flood damages bridge and inundates part of town. (DN Sept. 20, 1897.)
Oct. 7	Moab	Mill Creek	Man drowned while attempting to cross stream swollen by heavy storm. (DN Oct. 9, 1897.)
1898			
May 28 (week prior to)	Chester		Heavy rains caused dam to break and flooded town, damaging fields, orchards, bridges, etc. (DN May 28, 1898.)
July 11, 2:45 p.m.	Fillmore		"First flood of the season" came rushing down from the mountains. Big boulders swept along like chips. Mud and debris so thick it could hardly run. Ditches choked up. (DN July 16, 1898.)
1899			
Apr. 3	Blackrock		Heavy rains wash out railroad track. (DN Apr. 4, 1899.)
July 11, 7:30 p.m.	Manti	Manti Creek	One of greatest floods known to community. Muddy deluge filled with driftwood, haystacks, bridges spread through the streets and lower part of town. Cellars filled and several business houses badly damaged. Main street filled with logs, mud, and rubbish. All streets west of the creek covered with mud and debris. Railroad bridge washed out. (DN July 12, 1899.)
July 11	Torrey Junction	Fremont River	Storms in area flood canals and basements. Fields were flooded and hail beat down standing grain. (DN July 14, 1899.)
	Thurber		Cloudburst does slight damage to ditch banks, etc. (DN July 17, 1899.)
July 12	Frisco		Heaviest rain in years flooding cellars and streets and drowning poultry. (DN July 15, 1899.)
July 14	Sevier County		Heavy showers washed out several hundred feet of railroad track. (WBA 1899.)
July 30	Ferron		"One of the heaviest floods of years" washed out bridge and irrigation dams. (DN Aug. 2, 1899.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 3, p.m.	Lehi	West Mountains	Cloudburst in mountains caused damage to mining properties. Floods brought down boulders weighing 500 to 1,000 pounds. Heavy rains reported over Lehi about 12:30 a.m., Aug. 4, 1899. (DN Aug. 5, 1899.)
Aug. 4 (prior to)	Fillmore		Recent mountain storms did considerable damage by depositing mud and and debris on farming land. (DN Aug. 5, 1899.)
Aug. 6	Between Fairview and Thistle.		Tracks covered to depth of 8 feet by debris. Much damage to crops and other property. (DN Aug. 7, 1899.)
Aug. 6, 12 noon to 2 p.m.	Fairview	Cottonwood Canyon	High water from storms overflowed banks and flooded lucerne fields in lower part of town. (DN Aug. 8, 1899.)
Aug. 9	Price	Wash 2 miles from Price	Two men narrowly escaped drowning when they drove into a flooding wash at a point where a bridge had been washed out. Wash-out on railroad grade in Whitmore Canyon reported. (DN Aug. 9, 1899.)
1900			
Aug. 4	Orangeville		Boy drowned in flooding creek, induced by heavy rain. (DN Aug. 9, 1900.)
Aug. 18	Washington		Heaviest rain- and hail-storm in years. Portions of town under water. Gristmill dam torn out and ditches badly damaged. (DN Aug. 22, 1900.)
Sept. 1–2	Washington		Hard rains flooded town, filled ditches. Diversion dams swept away. (DN Sept. 8, 1900.)
Sept. 3	Moab	Mill Creek	Heaviest rain- and hail-storm in town's history damaged fruit and crops. Wind blew down large trees. Creek flooded, but not much damage from that source. (DN Sept. 6, 1900.)
Sept. 9, p.m.	Fruita		Flood in river drives residents from their homes. Livestock and other property washed away and homes were flooded. Water 13 feet deep and reached across the canyon. Crops were also damaged. (DN Aug. 17, 1900.)
Oct. 14	Washington	Mill Creek	Flood washed out dams, delaying operations of factory and roller mills indefinitely. (DN Oct. 18, 1900.)
1901			
Feb. 19	Eureka		Heavy rains caused flooding of town and tracks of the railroad. Several business houses and stores flooded on lower Main Street. (DN Feb. 20, 1901.)
Mar. 22	Hebron		Reservoir damaged to the extent of $1,000 by heavy rains. (DN Mar. 28, 1901.)
July 31	Bingham		Main streets were flooded by overflow from creek. Resulting damage estimated at $2,000. (DN Aug. 2, 1901.)
	Tropic		A terrific thunderstorm passed over this place on July 31, accompanied by high wind. No damage reported. (DN Aug. 7, 1901.)
Aug. 1	Manti	Manti Creek	Cloudburst in canyon. Principal part of city flooded. Hundreds of cords of logs and masses of debris of all kinds deposited in the streets. Fences swept away, gardens and lawns flooded, cellars filled, and houses flooded. (DN Aug. 2, 1901.)
July 29–Aug. 2	Mount Pleasant	Cedar and Pleasant Creeks	Two floods reported but little damage was done. (DN Aug. 5, 1901.)
Aug. 2, p.m.	St. George		Heavy rainstorm and windstorm washed out all ditches or filled them with debris. Basements of buildings were flooded, fruit and shade trees torn down. Virgin River was greatly swollen. (DN Aug. 5, 1901.)
Aug. 3	Richfield	Cottonwood Canyon	Flood in canyon filled canal and covered some grain fields. (DN Aug. 5, 1901.)
Aug. 3, 5 p.m.	do	do	Cloudburst in canyon. Mud and debris-laden stream poured out of canyon. Part of it diverted from the town by large canal and a "couple of deep hollows north of town." Canal filled up and much damage resulted in flooding fields. (DN Aug. 5, 1901.)
Aug. 3	Santa Clara		Thundershower did some damage to the ditches and washed out the roads very badly. (DN Aug. 14, 1901.)

Aug. 4, 4 p.m.	Coyote		Cloudburst in hills west of valley. Hunter farm badly damaged. Buildings, corrals washed away. One family caught in flood and one child drowned. Farms covered with mud about 3 feet deep. (DN Aug. 7, 1901.)
Aug. 4, p.m.	Loa	Spring Creek	Severe thunderstorm, the worst in 20 years, swept through Loa, doing damage to crops. Creek overflowed, endangering life and property. (DN Aug. 7, 1901.)
Aug. 5, 8 p.m.	Mineral Flats	American Fork Canyon	Cloudburst and electrical storm flooded mines, washed away much ore, and filled the mines with mud and debris. (DN Aug. 7, 1901.)
Aug. 5	Escalante		Boy was drowned while swimming in the gorge some 15 miles below here when a freshet came down the gully. One other boy barely escaped the same fate. (DN Aug. 9, 1901.)
Aug. 6, p.m.	Milburn and Paragonah		Cloudburst over canyon above Milburn. "Avalanche of water freighted with trees and boulders" came down into the valley. Part of town covered with 3 feet of water and mud, boulders, etc. Places abandoned. Large flood did much damage to crops. (DN Aug. 7, 1901.)
Aug. 6, 1 p.m.	Fairview	Cottonwood Creek	Bridges and culverts washed out. Boulders, logs, trees, and rubbish strewn over farms. Fences, lumber, wagons, harrows, hay rakes, and other farm implements carried away or buried in mud. Haystacks, pigs, chickens swept away. Cellars filled.
Aug. 6	do	Oak Creek	Floods north of Fairview doing considerable damage to dwellings and farm lands. Cellars were filled with water, and people forced to flee to safe quarters. (DN Aug. 8, 1901.)
	Croydon		Cloudburst caused a big landslide, which delayed trains about 4 hours. (DN Aug. 7, 1901.)
Aug. 6, 11 p.m.	Winter Quarters		Terrific flood. Two lives were lost and a great deal of damage was done to property. Railroad was damaged, causing the closing of coal mines. (DN Aug. 7, 1901.)
Aug. 6 (prior to)	Ephraim	Ephraim Creek	Thunderstorms and heavy precipitation caused floods that did considerable damage. (DN Aug. 7, 1901.)
Aug. 6	Coalville	Grass Creek	Flood causing considerable damage to farms in the lower part. (DN Aug. 7, 1901.)
	Farmington	Steed, Ricks, and Davis Creeks.	Cloudburst in mountains caused floods in Davis Creek and high water in Steed and Ricks Canyons. No damage done in the last two named but the wash from Davis Canyon was of great force, depositing on the farming lands below great quantities of mud, with tons of rocks and boulders, covering orchards and damaging croplands and other property.
	Centerville	Ford Canyon	Cloudburst in mountains caused floods and high water in Ford Canyon above Centerville, but no damage was reported from the valley. (DN Aug. 8, 1901.)
	Paragonah		A large flood did much damage to small grain and lucerne. (DN Aug. 14, 1901.)
Aug. 7	Parleys Canyon	Parleys Canyon	Landslide temporarily cut off water supply from Parleys Canyon. (DN Aug. 7, 1901.)
	Springville	Spanish Fork Canyon	Canyon road was washed out in places, and in others covered by landslides, making travel difficult and dangerous. The Spanish Fork River was thick with mud. (DN Aug. 8, 1901.)
	Huntington	Huntington Canyon	The heaviest flood in years came down the canyon, taking hundreds of cords of wood down the river with it. (DN Aug. 15, 1901.)
Aug. 9	Orangeville		Several floods were reported doing little damage outside of carrying away much wood. Crops are very much benefited. (DN Aug. 12, 1901.)
Aug. 10	Cedar City	Coal Creek	Roaring flood came down the canyon, carrying gravel and other debris. (DN Aug. 12, 1901.)
Aug. 13 (prior to)	Vernal	Ashley Creek	Cloudburst caused creek to rise to spring high level. (DN Aug. 14, 1901.)
	Emery		Thundershower in the mountains caused floods which washed out dams and damaged canals and ditches. (DN Aug. 14, 1901.)
Aug. 15, p.m.	Beaver		"Disastrous floods" did great deal of damage to crops. Deposits of rocks and mud spread over fields. Much shocked grain was washed away.
	Adamsville		Adamsville, 9 miles west, had similar flood. Damage to crops very heavy. (DN Aug. 19, 1901.)
Aug. 18	Salt Lake City	Parleys Canyon	Several feet of silt were deposited in reservoir by flash flood discharged from an upstream tributary. (DN Aug. 19, 1901.)
Aug. 18, 5 p.m.	Orangeville		The largest flood in three years came down the canyon. No damage was reported, but the channel was scoured and straightened by the waters. (DN Aug. 21, 1901.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 19	Pinto		Succession of heavy storms and floods during month of August. Considerable damage to crops, roads, and ditches. (DN Aug. 19, 1901.)
	Ogden	Ogden Canyon	Ogden was almost swamped by heavy storm. Many basements were filled, and some streets were badly gashed. Some outlying farms were damaged. Business was practically at a standstill until damage was partially repaired. Some washouts occurred in Ogden Canyon, nearby. (DN Aug. 19, 1901.)
Aug. 20 (week prior to)	Goshen		A flood buried the D. & R. G. W. tracks east of town under 1 to 6 feet of rock and gravel, necessitating the transfer of passengers for two days. (DN Aug. 24, 1901.)
Aug. 20	do		A flood filled the D. & R. G. W. tracks east of town with 1 to 8 feet of rocks and gravel, requiring eight teams and nearly 100 men all day to clear. (DN Aug. 24, 1901.)
Aug. 23 (prior to)	Cainsville		Some damage was incurred by roads and ditches from small floods in valley. (DN Aug. 26, 1901.)
Aug. 27, 11 a.m.	Rockport		A terrific rainstorm filled wells and basements with muddy water and covered fields with mud and water about 1 foot deep. Considerable discharge from surrounding gullies and canyons. (DN Aug. 29, 1901.)
1902			
July 25, p.m.	Bloomington	Virgin River	Heavy storms sent a flood down the river and caused many washes. One diversion dam was partially destroyed. (DN July 28, 1902.)
Aug. 13, p.m.	do	do	The largest flood in many years went down the Rio Virgin, carrying trees, debris, etc. (DN Aug. 22, 1902.)
Aug. 15	do	Fort Pearce Wash	Large flood from Fort Pearce Wash caused a flood in the Virgin River. (DN Aug. 19, 1902.)
1903			
June 11	Vernon		Floods caused by a heavy storm broke two main irrigation canals. (DN July 16, 1903.)
July 22, noon	Winter Quarters	Winter Quarters Canyon	Flood in canyon endangered lives and property of railroad and mining interests. (DN July 24, 1903.)
July 23	Bloomington		A cloudburst flood destroyed two acres of grain and damaged a canal. (DN July 28, 1903.)
Aug. 10, 5 p.m.	Toquerville	Dry Creek	A man was trapped in a flash flood in the creek and drowned. (DN Aug. 18, 1903.)
1904			
May 4, a.m.	Homansville		A landslide caused by heavy rains covered a section of the D. & R. G. W. tracks. (DN May 5, 1904.)
July 21	St. George		The St. George-Cottonwood canal was filled up with boulders and sand for miles as a result of several recent showers. Repairs estimated at $200. (DN Aug. 1, 1904.)
	Bloomington		Recent flood down the Rio Virgin and Santa Clara washed out the Bloomington Dam. Big floods came down the wash west of Washington and tore away a telephone pole. Little other damage reported. (DN Aug. 2, 1904.)
July 22, noon	Cedar City	Coal Creek	"Largest flood for at least 36 years." Main part of flood down main canyon, and the rest from the east range of mountains through Fiddlers Canyon, about 3 miles northeast of town. Parts of town flooded. Damage to barns, hogpens, chicken coops, etc. Crops covered. Dams torn out, and ditches filled up with mud. (DN July 27, 1904.)
July 26, p.m.	St. George	Ash Creek	Ash Creek, a tributary of the Virgin River, was about 4 feet higher than it was ever known to be before. (DN Aug. 1, 1904.)
July 27, 11 a.m.	New Harmony		A cloudburst broke with fury upon the village of New Harmony, driving the inhabitants from their homes. A few homes were washed from their foundations and wrecked, roadways were torn up, gardens and orchards flooded, covering a strip half a mile wide and several miles long. Narrow escapes were numerous. (DN June 27, 1904.)

TWO SUCCESSIVE MUDFLOWS NEAR LAYTON, DAVIS COUNTY.

Aug. 16, p.m.	Giles		A severe storm passed over this part of the country, doing a great deal of damage. All the bridges along the river were swept away. The flume of the South Irrigating Co. was also torn out. (DN Aug. 22, 1904.)
Aug. 25	Tintic		The heavy rains for the past two weeks broke a dam at a ranch west of the town, causing considerable flooding. (DN Aug. 26, 1904.)
1905			
July 22 (prior to)	Park City	East Canyon	Cloudburst over canyon caused flood which lined the banks with fish of all sizes. (PR July 22, 1905.)
Aug. 24, p.m.	Price	Price River	The worst storm in a number of years passed over Price, washing out the tracks of the D. & R. G. W. in several places. Cellars were filled and much damage done to crops and streets. Trains were tied up for some time. (DN Aug. 25, 1905.)
Aug. 24	St. George	Virgin River	A cloudburst up the Virgin caused the largest flood in the history of St. George to sweep down the river. Price Dam was carried away entirely, and the current cut the Jarvis Field Dam and nearly destroyed the Washington Field Dam. Animals and debris were swept away, and cropland flooded in many places. (DN Sept. 13, 1905.)
Aug. 25, 7 p.m.	Ogden		Two tremendous electric storms flooded the streets of Ogden to a depth of several feet in places. Streetcars were stopped for a time and some damage was done to the transformers and transmission system of the Utah Light & Railway Co. (DN Aug. 26, 1905.)
Aug. 25, 2 p.m.	Richfield	Cottonwood and Willow Creeks.	"One of the most destructive floods known in years." Huge body of water emerged from canyons and spread over the valley. Sevier Valley canal filled with mud and rocks. Fields covered and stacks of grain submerged in water and mud or carried away. Main street flooded. Nine head of cattle washed away and drowned. (DN Aug. 31, 1905.)
Aug. 25, p.m.	Kanosh		Streets flooded with mass of mud and debris. Gardens, lawns, and fields covered with stinking, slimy deposit about 12 inches deep, filled with brush and other debris. (DN Sept. 2, 1905.)
Aug. 26	Ferron, Molen, and Clawson.		Extensive storm damage to lands, roads, canals, and bridges. (ECP).
1906			
June 12 (prior to)	Lewiston		Heavy rainfall caused material damage to some beet fields and general damage to other crops. (DN June 12, 1906.)
July 27, p.m.	Parowan	Center Creek	"Biggest flood in 10 years" came down the canyon, carrying all kinds of debris, including several dead sheep and cattle. One horse was drowned, and one man barely escaped in attempting to cross the flood. (DN July 30, 1906.)
Aug. 13, noon	Tropic		In 2 hours 2 inches of rain fell and sent torrents of water through the streets. Cellars were filled with mud. Hailstones as large as walnuts stripped leaves from standing corn. Many chickens were drowned. The flood carried huge boulders with it. In some places the land was gashed deeply, in others it was covered with debris.
Aug. 13	Cannonville		The same flood struck Cannonville, 4 miles below Tropic, as a 5-foot crest of water, carrying rocks and timber, bore down. Roads were severely damaged, and other floods were reported in the canyons, washing out at least one sheep camp. (DN Aug. 17, 1906.)
Aug. 11	Eureka		Town flooded by heavy rain. Sewers were clogged and basements filled. (ER Aug. 17, 1906.)
Aug. 19	do		Hundreds of dollars' damage done by cloudburst. Merchandise and buildings damaged. (ER Aug. 24, 1906.)
Aug. 19, 2 p.m.	Ophir		A cloudburst flood swept down the canyon, heavily loaded with brush, rocks, and other debris. (DN Aug. 22, 1906.)
Aug. 20, p.m.	do		A second flood, twice the volume of that of the day before, poured down the channel, again bearing great quantities of debris, and some boulders weighing tons. No damage specified. (DN Aug. 22, 1906.)
Aug. 20	Bloomington		Quite a flood came down the Rio Virgin and Santa Clara, and the Jarvis and Price Dams were damaged considerably. (DN Sept. 4, 1906.)

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Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 22	Willard		Heavy rains cause numerous washouts in gullies to the north and south of town. Huge boulders were brought down from the canyons. Considerable damage occurred to fruit trees and truck gardens. (DN Aug. 24, 1906.)
Sept. 2	Monticello		The late storms have damaged the crops. Damage also resulted to roads and bridges by the wash-outs. (DN Sept. 6, 1906.)
1907			
Aug. 12	Cedar City	Coal Creek	"One of the heaviest floods and cloudbursts ever witnessed in Cedar." Torrents of mud-laden water filled the streets of the town. (DN Aug. 13, 1907.)
Aug. 21, p.m.	do	do	Cloudburst; water poured into town 2 feet or more in depth; streets flooded and basements filled. Fields covered and crops destroyed. Worse storm than one on 12th. (DN Aug. 23, 1907.)
	Mt. Pleasant		A heavy downpour of rain did considerable damage, especially to the second crop of hay in the process of being cut. (DN Aug. 23, 1907.)
1908			
July 24	La Grange	Cottonwood Wash	A storm caused much damage to ditches, and a flood in the wash tore out several dams. (DN July 30, 1908.)
July 26, p.m.	Huntington	Crandall Canyon	A heavy flood went down the canyon, taking all bridges with it. Logging camps suffered loss of logs and equipment. (DN July 29, 1908.)
July 31, 11 a.m. to 3 p.m.	Ogden		Traffic on Union Pacific R.R. was delayed for several hours when a cloudburst occurred between Ogden and Castle Rock; one at Baskin, 40 miles east of Ogden; and one at Devils Slide, 15 miles east of Ogden; doing considerable damage to railroad. (DN Aug. 1, 1908.)
Aug. 2, 5 p.m.	Pinto		One of the fiercest rain- and hail-storms in 30 years lasted one hour, yielding 1.40 inches of rain. Much thunder and lightning came with it, and no doubt much damage was done down the canyon in washing out dams, etc. (DN Aug. 5, 1908.)
Aug. 2	Eureka	Pinion Canyon	Debris flow down canyon covered railroad tracks and washed out highway. (ER Aug. 7, 1908.)
	Panguitch		Cloudburst at top of Red Canyon. Destroyed the canyon road and carried away the bridge. Syrett home and barn flooded. Hay destroyed and poultry carried away. (DN Aug. 10, 1908.)
Aug. 10 (prior to)	Elsinore		Cloudburst on hills between Joseph and Elsinore. Flood filled the Sevier Valley canal with mud and gravel and cut a gully 35 feet deep, about 25 feet wide, and 500 to 600 feet long. Mud and debris piled about 10 feet over country road. Some farmlands covered. (DN Aug. 13, 1908.)
Aug. 10, p.m.	Near Circleville	Pine Creek	Flood 5 feet deep swept down Pine Creek and carried timber and boulders. Carried away wagon and three horses and buried them under mud and gravel. Much damage to the roads. (DN Aug. 14, 1908.)
1909			
Aug. 10, p.m.	Richfield		Sevier Valley canal filled with debris, and broke from floods from hills. Business section of town flooded. Storm extended along the canal for 8 or 10 miles, filling it with debris in many places. (DN Aug. 12, 1909.)
Aug. 11	Hoytsville		A cloudburst causing torrents of water to pour down the hillside carried down mud, rocks, and brush, tore away fences, and covered fields with mud and debris. The water filled the two irrigation canals with mud and invaded the houses. The damage is estimated at $1,000. (DN Aug. 23, 1909.)

Aug. 17, 12:10 p.m.	Bingham		A cloudburst carrying huge boulders and timber before it washed away part of the mountainside and caused the explosion of a reverberatory in the Yampa smelter with resulting loss of about $3,000. (DN Aug. 17, 1909.)
Aug. 21	Mount Pleasant		"Torrents rushed down the hillsides and into town, carrying everything before them." Huge boulders and logs were brought down. Much damage to reservoirs, irrigation ditches, and highways. Streets flooded, cellars filled, and gardens and orchards washed out.
	Fairview	Cottonwood Creek	Flood down Cottonwood Creek. Cellars filled and streets covered with mud and debris.
	Fountain Green		Yesterday heavy flood ran into homes. Much damage to crops.
	Wales		Visited by four floods recently, doing considerable damage.
	Ephraim		Earlier in week flood did damage to property in Ephraim to extent of $20,000. (DN Aug. 23, 1909.)
Aug. 31	Tintic	Pinion Canyon	Large coal storage bins undermined by heavy rains. Mud-flow in canyon covered railroad track, delaying traffic 12 hours. (ER Sept. 3, 1909.)
	Orangeville and Ferron	Cottonwood Creek	Heavy rains have caused the greatest flood known in this section. The bridges on the Cottonwood were destroyed, and the bridges and roads about Ferron were heavily damaged. Losses in the northwestern part of Castle Valley were estimated at $20,000.
	Between Huntington and Price.		Between Huntington and Price the roads were washed out and all the irrigation ditches were filled with mud and debris. Many of the dams were taken out. No loss of life was reported, but the loss to property was great. (DN Sept. 1, 1909.)
Sept. 1	Vernal	Ashley River	A man was drowned by flash flood while driving wagon across stream. (DN Sept. 7, 1909.)
	St. George	Virgin River and Santa Clara Creek.	"Greatest flood in the history of the county" went down the Virgin River, removing dams and washing many acres of bottom lands. A canal was damaged, and crops suffered from heavy rains. Santa Clara Creek also washed away some adjacent farming land. (DN Sept. 8, 1909.)
	Orderville	Virgin River	About $3,000 damage ensued from recent storms. The river cut away much cropland and destroyed bridges at its height on Aug. 31. Grain in the shock was spoiled by heavy rains, and canyon roads were washed out in many places. (DN Sept. 8, 1909.)
Sept. 4	Bloomington	do	The recent floods damaged 100 rods of the canal and destroyed some bottom lands. (DN Sept. 10, 1909.)
1910			
June 29	Orangeville		Hail and rainstorm said to be worst in 32 years. Crops were "beat into shreds" and hail accumulated to depth of 4 feet (no doubt drifted) in some places. Bridges and roads washed out, cellars filled, and small livestock killed. (ECP).
June 30, p.m.	Valley City		Roads washed out and reservoir "broken" by heavy storms. (GVT July 1, 1910.)
July 22	Moab	Pack Creek	"Largest flood ever known since Moab was settled" spread over farms, covering them with 6 to 12 inches of mud. (GVT July 22, 1910.)
July 23	Eureka		Cloudburst at McIntyre's ranch in West Tintic filled reservoir with mud and shut off the water supply at Mammoth City. (DN July 25, 1910.)
1911			
July 20	St. George		A heavy rain brought damage to roads, canals, and crops, especially hay that had been cut. (DN July 25, 1911.)
July 25	Spanish Fork		Recent storms in the canyon raised the Spanish Fork River about 4 feet, overflowing canals and causing the millrace to be washed out in several places. (DN July 27, 1911.)
Sept. 27	Moab		A general report of the damage done by several rains and cloudbursts during the past month: Much damage done to roads and ditches and 75 to 100 fruit trees were washed down the canyon. (DN Oct. 2, 1911.)
Oct. 13	Price		Recent heavy rains caused great damage to roads in Carbon County, several bridges and grades being washed out. An estimate of the damage was placed at $20,000. (DN Oct. 13, 1911.)
1912			
July 9, p.m.	Willard		Floods caused derailment of train near Willard when debris covered tracks. (OSE July 10, 1912.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
July 19, a.m. and p.m.	Salt Lake City		Rainfall set a new record of 0.96 inch in one hour, stopping streetcar traffic and ruining lawns, besides filling South Temple Street with tons of sand from the foothills and chicken coops, barrels, boxes, and trees from the higher part of town. (DN July 19, 1912.)
July 31, 4:30 p.m.	Eureka and Tintic	Eureka Canyon	Every street in Eureka washed out. Water and debris "entered the back doors of business houses and came out the front," washing out merchandise. "Barrels of beer and empty beer kegs" floated out the front door and down the canyon. (ER Aug. 2, 1912.)
July 31	Farmington		Cloudburst flooded powerhouse substation and damaged several portions of construction job. (OSE July 31, 1912.)
Aug. 2 (prior to)	Ogden and northern Utah		Wash-outs on railroads halted all train service into Ogden. Wagon roads and bridges washed out.
	Uinta Basin		Roads in Uinta Basin damaged. (OSE Aug. 2, 1912.)
Aug. 26	Eureka	Pinion Canyon	Railroad tracks washed out by heavy rain. (ER Aug. 29, 1912.)
1913			
June 2, p.m.	Ogden		Heavy rainstorm flooded streets and cellars, damaging merchandise. (OSE June 3, 1913.)
June 11	Salt Lake City		Some cellars flooded and lawns covered with sand and gravel during cloudburst. (OSE June 12, 1913.)
July 8	Park City		Heavy storms flooded streets and deposited mud and boulders from hillsides. Houses were flooded and the electric system crippled. (DN July 10, 1913.)
July 19	Castle Gate	Price River	High water in river from cloudburst washed out bridges and damaged numerous houses. "* * * the flood waters filled the entire bottom between the two walls of the canyon." (DN July 21, 1913.)
July 21	Laketown	East Canyon	The cellar of one home was filled and the premises were flooded by the heavy rain that enlarged the stream in East Canyon. (DN July 25, 1913.)
July 22, p.m.	Tooele	Middle Canyon	A severe rainstorm, almost to the extent of a cloudburst, wrecked the boarding house and power house of the Utah Metal Mines Co. Houses and office buildings were flooded.
	Ophir		The town of Ophir was also struck and two houses reported washed away. (DN July 23, 1913.)
	Henefer		A cloudburst covered some 50 acres of ground with debris and ruined many tons of hay. Trains in the vicinity were tied up for several hours. (DN July 24, 1913.)
July 23, p.m.	Bingham	Verona Gulch	A cloudburst, followed closely by a roaring flood which carried boulders, dirt, and debris, wrecked eight houses, sweeping the contents away, with losses estimated at $12,000. Railroad tracks and grades were washed away at one spot and buried with silt and gravel at others. (DN July 24, 1913.)
Aug. 9	Near Richfield		Every canyon west of Richfield had its flood. To the north and south of Richfield, considerable damage done to crops. (WBA 1913.)
Aug. 11	Nephi	Salt Creek Canyon	Damage was done to canals, weirs, and bridges by a flood which also put the flour mills and power plant out of commission. Houses and cellars were filled and business sections were flooded. Ditches and canals were flooded and much damage was done. (DN Aug. 13, 1913.)
Aug. 19	Mayfield		A flood came down from the foothills and swept the north side of the town. (WBA 1913.)
Aug. 24	Ephraim		Sunday evening, Aug. 24, the "annual August flood" visited Ephraim and broke all previous records in property damage. Mud, gravel, boulders, and debris. Many cellars filled with mud and lawns covered so deep as to destroy them. One boulder of 25 cubic feet. (WBA 1913.)

Aug. 24, p.m.	Fillmore		Cloudburst in mountains east of town. City dam washed away; much driftwood and boulders brought down. (DN Sept. 1, 1913.)
Aug. 26	Mayfield		Another flood of greater severity than on Aug. 19 swept south side of town. Sand, gravel, and boulders in large quantities in some places covered land so completely as to render it worthless. (WBA 1913.)
Aug. 29	Levan		One of the heaviest rains in years. On west side of valley large streams of water swept down every canyon, doing considerable damage to farm lands. (WBA 1913.)
Aug. 30, 11 a.m. to 12 noon.	Ogden		Rain in this area produced a flood which converted roads into canals and gutters into raging torrents. Much cement and road material was swept away. All traffic had to be stopped for the duration of the storm, which lasted less than an hour. (DN Aug. 30, 1913.)
Aug. 31, 7 p.m.	Provo	Rock Canyon	A violent electrical storm flooded the streets with mud and debris, leaving the city in darkness when four transformers were burned out. Homes were flooded, driving people from them. Some damage was done to land by overflows and deposits of debris. (DN Sept. 1, 1913.)
Sept. 1	Orangeville		Floods, unequaled for years, carrying much debris and timber, did considerable damage to canals and ditches. (ECP.)
Sept. 8	Price		A cloudburst filled business houses and homes with water; cellars were flooded and sidewalks were washed away. Two county bridges, one railroad bridge, and part of a railroad track went out. The city was put in darkness when the municipal light plant was put out of commission. (DN Sept. 9, 1913.)
Sept. 8, noon	Castle Dale		One of the biggest storms in years. Small Wilberg dam and diversion dam of Orangeville Electric & Milling Co. destroyed. Several hundred acres of valuable pasture land was covered, and 200 yards of the road was swept away. (DN Sept. 11, 1913.)
1914			
July 10–21	Manti and Parowan		Record-breaking rains, causing floods. (WBA 1914.)
1915			
July 25	Cedar City		Terrific storm in mountains east of city. Flood washed out roads, bridges, flumes, and dams. Gristmill put out of commission. Canyon road impassable. (DN July 26, 1915.)
Aug. 7	Tintic		Severe electrical storm followed by cloudburst caused considerable damage. One man killed by lightning, and mine workers forced to climb as much as 2,000 feet out of shafts when transmission line was destroyed. (ER Aug. 13, 1915.)
1916			
July 8	Pleasant Valley	Fish Creek	Railroad bridge washed out by cloudburst flood. (DRG.)
July 25	Salt Lake City		Cloudburst in canyon east of city sent 10-foot wall of water down canyon, carrying with it eight head of cattle. Mud and large boulders washed onto streets. (OSE July 25, 1916.)
July 26, p.m.	Milford		Cloudburst in mountains 9 miles southeast of town. Ranches temporarily abandoned to flee the flood. Roads washed out and ranches flooded. (DN July 28, 1916.)
July 28, noon	Price		Cloudburst in mountains east of town. Three houses destroyed and railroad service disrupted. (DN July 31, 1916.)
Aug. 1	Fairview	Cottonwood Canyon	Streets flooded from cloudburst in Blind Fork Canyon, about 6 miles up Cottonwood Canyon. Water from 2 to 6 feet deep. Sleds, buggies, and other farming utensils swept away. Gardens destroyed. Cellars and ground floors flooded. Electric power plant put out of commission. (DN Aug. 2, 1916.)
Aug. 4	Kanosh		Floods from mountains east of town. Streets flooded. Cellars filled with mud and water. Gardens and lawns covered with mud. Hay and other crops greatly damaged.
	Meadow	Meadow and Walkers Canyons.	Big flood of mud, rocks, and timbers swept down upon the town. Fields covered with tons of debris and many crops destroyed. Largest flood since 1896. (DN Aug. 7, 1916.)
Aug. 5, a.m.	Eureka	Eureka Canyon	Storm of hour's duration flooded Main Street and filled cellars with mud and water. (ER Aug. 11, 1916.)
Aug. 5	Kingston		One-half of Piute County's hay crop destroyed by rains. Sevier River out of channel. (DN Aug. 8, 1916.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 8	Duchesne		Cloudburst removed hundreds of feet of road, tying up mail.
	Jensen		Cloudburst inundated dinosaur quarry.
	Allandra		Considerable damage due to cloudburst. (DN Aug. 11, 1916.)
Aug. 13	Moab		Heaviest rain in years. Mail delayed, approach to bridge over Grand (Colorado) River at Court House Wash washed out. (DN Aug. 15, 1916.)
Aug. 14	Croyden		Cloudburst washed tons of dirt and rock onto roads, and washed out road in others. (OSE Aug. 14, 1916.)
Aug. 16	St. George		August cloudbursts and showers damaged irrigation canals. (DN Aug. 21, 1916.)
Aug. 29, 9 p.m.	Ogden		Violent thunderstorm and heavy rains flooded streets and sidewalks. Basements filled and power and light service disrupted. (DN Aug. 30, 1916.)
Sept. 22	do	Wheeler Canyon	Muddy water in city mains due to cloudburst. (DN Sept. 25, 1916.)
Oct. 7	Vernal		One of worst storms in history destroyed bridges and buildings. Roads were washed out. (DN Oct. 10, 1916.)
Nov. 6	Cainville, Giles, and Hanksville.		Storms in eastern Wayne County washed out bridges, dams, canals, and parts of highways, laying waste farms and orchards. All bridges on Fremont River between Pleasant Creek and Hanksville washed away. (DN Nov. 9, 1916.)
1917			
July 28	Morgan		A terrific thunderstorm lasting two hours brought a flood of boulders and gravel out of a dry hollow north of town. Damage to lawns, gardens, orchards, and buildings estimated at $2,000. Basements were filled and porch of Jabin Robinson, Jr., residence was swept away. (DN July 28, 1917.)
	Ogden	Ogden Canyon	Flood through business blocks flooded cellars and streets. Landslides in canyon did thousands of dollars' damage. (OSE July 28, 1917.)
July 28, p.m.	Kaysville	Webbs Canyon	A cloudburst covered water-system intake with boulders and mud and swept debris onto farms near the mouth of the canyon. (DN July 30, 1917.)
July 30	Clarkston		Cloudburst washed great quantities of debris onto farms and roads. Hailstorm threshed thousands of bushels of grain onto ground. Losses estimated at many thousands of dollars. (DN Aug. 1, 1917.)
1918			
June 18, p.m.	Spanish Fork	Spanish Fork Canyon	Diversion dam swept away, leaving town gardens without irrigation water and roller mills without water power. (DN June 21, 1918.)
June 19, 5 p.m.	Mount Pleasant	Pleasant Creek	Cloudburst. One farmer drowned, and property damaged to amount of $100,000. Streets covered with mud, boulders, and debris. One house swept away and many smaller buildings destroyed. Fences torn down. Machinery, wagons, automobiles, and other implements scattered. Cellars flooded. Mud and debris spread over a large area of farm land. Fields and gardens ruined. (DN June 20, 1918.)
June 28	Moab	Mill and Pack Creeks	"Unprecedented" flood swept Mill Creek. Streets flooded. Flood in Pack Creek reputedly largest ever known. (GVT June 28, 1918.)
July 9, 8:00 p.m.	Mount Pleasant	Pleasant Creek	Second flood in three weeks, due to cloudburst. City power plant, out of commission since June 20 flood, was again damaged. Mud, boulders, etc., strewn over the town and fields. Ground floor of hotel flooded. Homes flooded. Several blocks of the railroad tracks covered with mud and debris. (DN July 10, 1918.)
July 21	Alpine		Cloudburst flood partially destroyed power plant at Alta, near Alpine. (OSE July 21, 1918.)
July 23	Tintic	Homansville Canyon	Wall of water 8 feet high completely washed out canyon road. (ER July 26, 1918.)

Sept. 23, 10 p.m.	Salt Lake City		Great boulders were carried several blocks, and lawns and roadbeds were washed out or covered with debris. Storm centered on hill north of State Capitol. Silt carried to Second South Street was 1 foot deep. (DN Sept. 24, 1918.)
1919			
May 28	Veyo		Cloudburst of half-hour duration struck town. Water running "knee deep" on farms, waist deep in low places. Cut hay was washed away or covered with mud. (WC June 3, 1919.)
July 11	Leeds		Cloudburst, said to be worst in 60 years, strikes headwaters and tears out dam. (WC July 14, 1919.)
July 19 (prior to)	Gunlock		Cloudburst damaging roads and ditches. (WC July 19, 1919.)
Aug. 2, 10:30 p.m.	Moab	Mill Creek	"Largest flood ever seen in Mill Creek" swept south part of Moab Valley. Power-plant dam and power house washed out; bridge destroyed. (GVT Aug. 8, 1919.)
Sept. 1, p.m.	Garland		Terrific cloudburst a few miles north of town. A "stream of water waist deep roared down the hillside." Beet fields covered with mud and canals damaged. Many acres covered. (BEN Sept. 2, 1919.)
Sept. 1	Eureka and Silver City		Heavy rain and electrical storm damaged streets and utilities extensively (ER Sept. 16, 1919.)
Sept. 27	Eureka		Heavy rains washed out streets and choked culverts and bridges with gravel and rubbish. (ER Oct. 3, 1919.)
1920			
June 16	Provo	Hobble Creek	Cloudburst flooded town streets. (DN June 17, 1920.)
Aug. 20	Castle Gate	Price River	Flood damaged railroad property to extent of $8,400. (DRG.)
Aug. 23	Springdale	North Creek	Newly completed bridge on Zion National Park highway swept away. Springdale Bridge of Zion Canyon highway destroyed by terrific cloudburst.
	Zion National Park		Several mudslides on Zion Park dugway. (DN Aug. 23, 1920.)
Aug. 25, p.m.	Ogden	Ogden Canyon	Canyon road covered by cloudburst flood. Large hole was broken in Utah Power & Light Co.'s flume, and camps were damaged. Wildwood resort suffered to extent of $700. (DN Aug. 26, 1920.)
Sept. 7	Price	Price Canyon	City was left without culinary water supply or fire protection when main was destroyed by several days of severe storms. Water was brought from Colton in barrels. Road between Price and Helper was washed out. (DN Sept. 9, 1920.)
1921			
May 25	Eureka		Storm of only five minutes' duration washed out streets and damaged property to the extent of several thousand dollars. (ER May 27, 1921.)
June 18, 4:30 a.m.	Ogden		Streets flooded by torrential rains. Lightning struck Healy Hotel, igniting coal bin. (DN June 18, 1921.)
June 21	Echo		State road damaged by cloudburst. (DN June 21, 1921.)
July 15	Eureka		Heavy downpour strikes area, "causing usual damage to streets and buildings." (ER July 22, 1921.)
July 17	Orangeville		"Worst floods in several years" washed out roads and power lines and injured farming land.
July 23–24	Tintic Valley		Highway and railroad damaged by cloudburst. (ER July 29, 1921.)
July 29	Helper		Eight houses filled with mud and debris. Damage, $5,000. Storm came from northwest, washing debris for several miles before reaching town. Railroad tracks were weakened, delaying train service.
	Price	Price Canyon	Water supply temporarily cut off. Bridge between Colton and Scofield was destroyed. Lightning left city in darkness. (DN Aug. 3, 1921.)
July 30	Hatchtown		Heavy rains (13th and 30th) caused worst flood known in Proctor Canyon. Damage, $8,000 to $12,000. (WBA 1921.)
Aug. 13 (prior to)	Tintic Valley		Highway and railroad again washed out. (ER Aug. 19, 1921.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 20, 5:30 p.m.	Cedar City		Cloudburst flooded town and caused considerable damage. Houses damaged, cellars flooded, and ground floors of many homes flooded to depth of few inches to 4 or 5 feet. Cattle, pigs, and chickens drowned. Bridges washed away, and crops damaged. Damage estimated at more than $20,000. Boulders and mud covered farm lands and part of town. (DN Aug. 22, 1921.)
Aug. 21	Thistle	Spanish Fork Canyon	Cloudburst washed 4 feet of mud onto track near Thistle. Damage $1,500. (UEC.)
Aug. 23, 3 p.m.	Wellington		Cloudburst washed out railroad bridge.
	Price		City was isolated, and property damaged to extent of $50,000. Downpour centered north of town. Water to a depth of several feet washed away roads and bridges and swept down the principal streets. A carload of sugar was ruined. Stores and basements were flooded and mud was carried into the front door and out the rear door of several establishments. Highway bridge between Price and Helper washed out.
	Helper		Railroad yards and roundhouse filled with 3 feet of water. Spring Canyon branch of D. & R. G. W. R.R. was out of commission. (DN Aug. 24, 1921.)
Aug. 25, 2 p.m.	Wellington	Spring Canyon	Two spans of newly repaired railroad bridge over Price River again washed out when river rose due to heavy rainstorm in Spring Canyon. Spring Canyon branch line damaged, causing coal mines to shut down at Storrs, Rains, Standardville, Latuda, Moreland, and Peerless.
Aug. 25	Helper		Two feet of water ran through lumberyard, and dwellings were abandoned by their occupants. Highway from Spring Glen crossing to Helper was washed out and damaged to extent of $2,800.
	Kenilworth		Five feet of water on pumping-plant floor. (DN Aug. 26, 1921.)
Aug. 29	Tintic area		Electrical and rain storm caused damage to extent of several thousand dollars to mining properties. (ER Sept. 2, 1921.)
Aug. 31	Escalante		Highways into Escalante Valley washed out. Agricultural land was damaged and crops destroyed. Head gates and irrigation works were swept aside. (DN Aug. 31, 1921.)
Sept. 3 (week ending)	Nephi		Cloudburst washed out several miles of highway between Nephi and Eureka. (DN Sept. 5, 1921.)
Sept. 3	Hanksville	Fremont River	Heavy storms on headwaters destroyed Hanksville Dam. Dam was of stone 25 feet high by 100 feet long. Approximately 15 feet of water was pouring over it when it failed, destroying irrigation water supply. Towns of Hanksville, Gibbs, Caineville, and Notom were isolated. Road through Capital Wash was strewn with boulders too large to allow passage of vehicles. Lives of automobile parties were endangered when 10 or 12 feet of water swept down highway. (DN Sept. 5, 1921.)
1922			
Aug. 1, 10 p.m.	Nephi	Salt Creek Canyon	Worst cloudburst in nine years put waterworks and electric light system out of commission. Plant of Nephi Plaster Co. will be shut down for several weeks. Water swept into town, doing several thousand dollars' damage before the flood-gates could be opened to divert the flood north of town. Roads in Salt Creek Canyon virtually impassable. (DN Aug. 2, 1922.)
Aug. 2, 11 a.m.	Magna		Ellis Yates, 6 years of age, drowned by cloudburst flood which demolished family residence. Utah Copper canal burst, flooding business section. Water about 1 foot deep. Basements were flooded, and rain continued at least three hours. (DN Aug. 2, 1922.)

Aug. 2, 5:30 p.m.	Heber, Midway, and Charleston.		Storm reported to be worst ever experienced. Streets were flooded, and hundreds of chickens and a number of pigs were drowned. Flume of Heber Light & Power Co. was washed out. Streets were inundated and basements filled, doing thousands of dollars' damage. Uncut grain was covered with mud and stacked grain was carried away. Pea crop was extensively damaged. In half an hour 0.73 inch of rain fell. (DN Aug. 3, 1922.)
Aug. 2	Jordan Narrows		East Jordan canal was washed out by storm. Pumps of Draper canal were out of commission. Damage, $1,000. (DN Aug. 7, 1922.)
Aug. 3	Thistle		Cloudburst near Thistle cost railroad $1,700. (UEC.)
Aug. 9, p.m.	Provo	Provo Canyon	Mudflow near mouth of Provo Canyon derailed train, washing tons of debris onto the tracks. (PDH Aug. 10, 1922.)
Aug. 18, 3 p.m.	Bountiful		State highway and Utah Light & Traction Interurban Railroad blocked by storm. (DN Aug. 19, 1922.)
Aug. 21	Woodside	Price River	Cloudburst on Price River watershed damaged railroad property to extent of $44,755. (DRG)
1923			
July 22	Thistle		Washout at Narrows halted traffic 24 hours. Caused damage of $4,000. (UEC)
July 22, 7 p.m.	American Fork Canyon		Flood from small tributary cut out 80-foot section of power plant pipe line. Plant out of service four days. (UPL)
July 23, 2 p.m.	Henrieville	Henrieville Creek	"Largest flood ever known" in creek washed out 12 acres of farm land. Flow consisted of mud and debris. (From inhabitants.)
July 24	Cache Valley and Richmond	High Creek and others	Widespread havoc caused by cloudbursts in Cache Valley. Many streams discharged heavy floods into valley, washing out roads and inundating farm lands. (BEN July 29, 1923.)
July 30-31, p.m.	Thistle	Spanish Fork Canyon	Mudslides in canyon for more than 16 miles. Road covered with several feet of debris in places. Portions of highway and D. & R. G. W. R.R. grade washed out. Worst slides occurred about noon on July 31. (DN Aug. 1, 1923.)
Aug. 13	Farmington and Centerville	Farmington Canyon, Steed, Davis, and Ford Creeks.	Seven persons drowned or died as a result of flood, the most disastrous in Utah history. Farming section largely destroyed, with houses, barns; orchards and the highway were covered with several feet of mud. One barn burned by lightning. Lagoon resort was flooded and patrons were rescued from trees, etc., where they sought refuge from the rapidly rising waters. Farmington Canyon road, just completed at a cost of $10,000, was completely destroyed. Bamberger Interurban Railway was washed out, and electric-power supply was cut off. Sixty miners were isolated in the canyon without a food supply. Considerable livestock destroyed. Observers in canyon reported crest to be 75 to 100 feet high in canyon, with width of 200 feet. Crest height at Baldwin mine reported to be 30 feet.
	Willard	Willard and Perry Canyons	Two women drowned when their house was demolished. One other was injured. Church was completely destroyed. Several other houses and barns extensively damaged. Road buried under 2 to 10 feet of debris. Tracks of Utah-Idaho Central Railroad buried. Traffic on State highway tied up five days. Six families homeless. Orchards, gardens, and livestock were heavily damaged. Shortage of drinking water occurred. Loss estimated to run into hundreds of thousands of dollars.
	Liberty	Ogden Canyon	Nine persons at Scout Camp barely escaped flood. Damage to camp $1,100. (DN Aug. 14 to Sept. 6, 1923.)
Aug. 16	Moab		"Practically every wash between Moab and Green River overflowed its banks." $10,000-bridge washed out.
	do	Court House Wash	Flood from wash dammed Colorado River. Several hours before river cut through. (TI Aug. 16, 1923.)
Aug. 29	do	Court House Wash	Bridges damaged. "Biggest flood ever seen in Court House Wash." Colorado River dammed. (TI Aug. 30, 1923.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
1924			
July 3	Vernal	Spring Creek	Two boys narrowly escaped death when caught by 10-foot-deep flood. (DN July 12, 1924.)
Aug. 14	Moroni		Flood damaged highways and washed farm lands. (WBA 1924.)
Sept. 9	Wellington		Cloudburst washed out highway bridge, inundated several buildings, and damaged electric lines. (DN Sept. 10, 1924.)
1925			
June 21, 4:30 p.m.	Orangeville	Upper Joes Valley and Straight Canyon.	Storm lasted less than an hour. Ten automobile loads of campers marooned in canyons. Streets were flooded, cellars filled, and crops damaged. Damage estimated to run into thousands of dollars. (DN June 25, 1925.)
July 3	Salt Lake City		Cloudbursts in canyons halted July 4 outings. Some roads damaged and cellars filled with water. (DN July 3, 1925.)
July 4, p.m.	Vernal	Five Mile Creek	Eight-year-old child was drowned as he was swept from an automobile by the flood. Flood struck car containing nine occupants and rolled it down wash, injuring some of the other occupants. (DN July 6, 1925.)
July 21	Thistle	Mill Fork	Cloudburst flood covered railroad tracks with debris 3 to 4 feet deep for 900 feet. (UEC)
	Sigurd		Flood damaged railroad bridge. (UEC)
July 24	Marysvale		Cloudburst flood damaged railroad bridge near Marysvale. (UEC)
July 26	Monticello		Severe cloudburst floods in Dry Valley. Water 10 feet deep in Hatch Wash. (DN July 26, 1925.)
Aug. 1	Rockville	South Mountains	Cloudburst damages new Rockville road, causing washouts and carrying huge boulders onto the road. (WC Aug. 3, 1925.)
Aug. 3, 1 p.m.	Castle Gate	Willow Creek	State highway bridge and railroad flooded. (DN Aug. 12, 1925.)
Aug. 11, 1:15 p.m.	do	do	One hundred yards of D. & R. G. W. R.R. covered. Six houses filled with several feet of water, and automobile traffic held up. (DN Aug. 12, 1925.)
Aug. 20	Eureka	Homansville Canyon	Six-foot wall of water gushed down canyon, completely washing out road, and strewed rocks, gravel, and railroad ties throughout the canyon. (ER Aug. 21, 1925.)
Aug. 27	Salt Lake City		In ten minutes, 0.25 inch rain. Basements flooded. (DN Aug. 27, 1925.)
	Verde	Sunnyside Wash	Three freight trains were caught by sudden deluge. Six cars were washed from roadbed. Nine bridges (six were 40 to 60-foot girders) were washed out. One bridge was 112 feet long. An 85-foot bridge at Woodside was damaged. A total of 1,200 feet of track was washed out. Four miles of telegraph lines were down. Damage estimated to be $150,000. (DN Aug. 28, 1925.)
	Heber	Snake Creek	Flood changed the course of creek, reducing supply to power plant for 16 hours.
	Santaquin	Santaquin Creek	Intake filled with gravel. (UPL)
Aug. 28	Spanish Fork	Spanish Fork Canyon	Mudslide in canyon covered 85 feet of road to depth of 4 feet. (PEH Aug. 28, 1925.)
Sept. 18	Modena		In less than 12 hours, 2.56 inches of rain fell. Main line of Union Pacific R.R. was washed out in several places. (DN Sept 19, 1925.)
	Verde		A portion of the tracks and four bridges of the D. & R. G. W. R.R. were damaged by cloudburst floods occurring at three points between Verde and Green River. (DN Sept. 19, 1925.)
	Gunlock		One of the worst rainstorms known in section. Town 6 inches to 2 feet deep in water in 30 minutes. All canyons reported "full," carrying much debris. Cellars were filled and gardens and crops damaged considerably. (WC Sept. 22, 1925.)
1926			
July 5, 3:50 p.m.	Farmington	Farmington Creek	Flood filled forebay of power-plant intake with boulders and debris. Out of service eight days. (UPL)

July 7	Ogden	Ogden Canyon	Twelve feet of highway covered by mudslide due to heavy rains. (DN July 8, 1926.)
July 10, 2 p.m.	Eureka	Eureka Canyon	Heavy rain- and hail-storm of two hours' duration caused widespread havoc. Hail was 3 inches deep on the ground. Several fires started by lightning. Hail fell during last part of storm, delaying runoff to some extent, but damage amounted to thousands of dollars. (ER July 15, 1926.)
Aug. 6	Garfield		Cloudburst in Oquirrh Mountains washed down mud and boulders. Lawns were covered with mud. Tracks of D. & R. G. W. R.R. and B. & G. Ry. were damaged. (DN Aug. 9, 1926.)
Aug. 7		Echo Canyon	Heavy rain from Saturday night (Aug. 7) to Sunday noon damaged highway between Wasatch and Castle Rock. Numerous wash-outs. (DN Aug. 9, 1926.)
Aug. 8, 2 a.m.	Provo	Provo Canyon	One of heaviest cloudbursts in history caused a score or more mudslides in Provo Canyon. One-fourth mile above Upper Falls, slide covered 100 yards of highway to depth of 8 feet. Intake of Olmsted power-plant flume of Utah Power & Light Co. covered with 14 feet of mud. Boulders reported to weigh a ton. Five hundred autos were reported stalled in the canyon. Tracks of D. & R. G. W. R.R. were damaged. Estimated total damage, $10,000. Precipitation at Olmsted in mouth of canyon, 1.23 inches in 15 minutes. (DN Aug. 8, 1926.)
Sept. 29	Farmington	Farmington Creek	Flood filled power plant intake with sand and gravel. Out of service two days. (UP.L)
1927			
June 14, 3 p.m.	Garfield	Kesler Canyon	Cloudburst flood caused $35,000 damage to plant of American Smelting & Refining Co. One man injured. Gas flues were broken, and several freight cars were carried from spurs. Water rushed through plant grounds to highway, leaving a layer of mud and rocks several feet deep. Los Angeles & Salt Lake R.R. tracks were covered, but damage was slight. (DN June 15, 1927.)
June 14	Lake Point		Mud was washed over highway. Damage, $100. (DN June 15, 1927.)
June 27	Castle Gate and Kenilworth	Willow Creek	Five trains, 75 autos held up by wash-outs. Six Castle Gate families homeless. Price and Helper water lines broken. Damage to D. & R. G. W. R.R. and Kenilworth mine, thousands of dollars. Families were driven to mountainside to escape flood. More than 100 feet of the highway was swept away and grade washed to depth of 15 feet. Rocks and debris were piled high in canyon mouth. Fifty feet of mouth of Kenilworth mine was filled with debris, and surface structures wrecked. A mammoth slide blocked railroad between Helper and Kenilworth, covering several hundred feet of track. Most of the mines in Spring Canyon were shut down, and the Utah Railway was covered for some distance. (DN June 29, 1927.)
	Colorado-Utah State line	Ruby Canyon	Mudslide held up railway traffic.
	Soldier Summit		Mudslide held up two D. & R. G. W. R.R. trains.
	Helper		Main street filled with 8 inches of water. Several buildings settled several inches. Price River filled both old and new channels.
	Price		Price Canal Co.'s ditch overflowed. Water several inches deep in streets. Cellars and basements all over city filled with water. Ten acres of sugar beets were destroyed and at least three farmhouses were filled with several feet of mud and water. In 24 hours, 2.65 inches of water fell.
	Spring Glen		New home was wrecked and part of railroad bridge destroyed. Damage in Carbon County to railroads, highways, canals, homes, crops, pipelines, and other property estimated to be well over $100,000. Price Canyon road will be closed all summer.
	Grant station		Mountainside reported sliding and endangering road.
	Peerless		Jap camp entirely inundated, tramway washed out, and tipple yard and mine property flooded. Four hundred feet of the highway and a longer portion of railroad covered with mud. (DN July 1, 1927.)
July 4, 5 p.m.	Price	Willow Creek and Price River.	Flood of week ago repeated itself. Fifty autos trapped. One railroad and six highway bridges destroyed. Traffic on main line of D. & R. G. W. R.R. tied up 8 hours. Damage to telephone lines, $1,000. Portions of State highway covered with 1 foot of water. Price River highest in 41 years. (DN July 5, 1927.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
July 4	Kenilworth		Town without water supply. More than $1,000 damage.
	Helper		Streets in lower Helper became rivers. Cellars filled. River came up over Main Street.
	Willow Creek Camp		Practically every house below highway undermined. One hundred and fifty feet of track torn up. Three feet of rock covered upper end of town for 100 feet. Portions of highway washed away. Damage to State highway and Utah Coal Co. by floods of June 27 and July 4, approximately $75,000. (DN July 7, 1927.)
	Eureka	Eureka Canyon	Hailstorm followed by cloudburst. Basements flooded and windows broken. (DN July 6, 1927.)
July 21	Price		Temporary bridge over Price River washed out. (DN July 22, 1927.)
July 27	Woodside Cliff		Heavy rains and cloudburst. D. & R. G. W. R.R. tracks washed out in three places. (DN July 28, 1927.)
August 11, 1 p.m.	Scipio		Cloudburst in mountains east of town. Flood covered most of town and fields. Gardens and field crops generally destroyed. Cellars flooded. (DN Aug. 13, 1927.)
Sept. 7 (p.m.), 8 (12 noon), 9 (p.m.).	Price, Kenilworth, and Peerless.	Price River	Cloudbursts on 7th, 8th, and 9th. Electric storm followed by hail on 7th. Two hundred cars isolated. Telephone lines down. Farm lands flooded with debris. Price River swollen ten times. Houses abandoned on First South Street. One hundred feet of culinary water-supply line washed away. Temporary bridges of State highway torn out. Railroad rails washed across highway. Two hundred yards of track suspended as embankment was washed away. Livestock drowned. Newly constructed flume of Jordan Creek Irrigation District, several hundred feet long, destroyed. Utah Railway Co.'s pumping plant undermined and out of service. Coal tipple at Rains undermined. State highway emergency fund previously exhausted. Damage at mouth of Willow Creek many times greater than previously. Property damage, $50,000 to $200,000. Flood of 9th tied up main-line railroad traffic.
	Spring Canyon		Mines flooded with 3 feet of water. Not a window remained in town. Boulders 4 feet in diameter washed into streets.
	Castle Gate		Town isolated from east. Highway and railroad bridges washed out. Tons of debris heaped on railroad tracks. Mine flooded.
	Willow Creek Camp	Willow Creek	Temporary bridge of D. & R. G. W. R.R. destroyed. More than 3 inches of rain in Deep Canyon. Twelve-foot trench cut down Main Street. (DN Sept. 8, 9, and 10, 1927.)
Sept. 8	Roosevelt	Cottonwood Wash	Ten feet of water rushed down Cottonwood Wash. Bridges rebuilt after July flood and head gates to canal system swept away. Two hundred stands of bees destroyed. Loss to crops, headgates, and bridges, $50,000. For a time, report of flood was derided, since no rain fell at Roosevelt of Cedarview, the scene of devastation. (DN Sept. 12, 1927.)
Sept. 12	Price		"Hardest storm Price has seen." Water coursed down Main Street 3 feet deep. Highway underpass beneath D. & R. G. W. R.R. tracks choked with debris. Scarcely a house not damaged. Only three streets open in Price. First Street canal broken. Water 6 inches deep on D. & R. G. W. tracks. Water rapidly rising between Castle Gate and Helper. Heaviest water of season came down Willow Creek. Heavy rain at Hiawatha, Spring Canyon, and Standardville. Rain, hail, and sleet mixed at Price. Flood enhanced by melting snows on high Wasatch. More rain fell in a week than usually falls in a year. River reached a higher mark than ever before at Helper. Relief measures taken. (DN Sept. 13, 14, and 15, 1927.)

Sept. 12 and 13	Valley City		Huge floods in practically every wash and creek in eastern Utah.
	do	Thompsons and Crescent Washes.	Combined floods washed out Valley City reservoir.
	do	Valley City Wash	Wash enlarged from width of 10 feet to width of 50 yards and depth of 10 to 15 feet. (TI Sept. 15, 1927.)
Sept. 13	Woodside	Price River	Cloudbursts washed out track in two places near Woodside. Damage, $2,879. (DRG)
Sept. 19	Junction		Floods in Escalante Mountains damaged roads. (DN Sept. 19, 1927.)
Sept. 21, 5:30 p.m.	Modena		Serious wash outs midway between Modena and Crestline. One place L. A. & S. L. R.R. tracks washed out for 200 feet. (DN Sept. 22, 1927.)
Sept. 21	Price		High water and slight flood damage caused temporary paralysis of traffic. Road impassable for 8 hours. Precipitation at Castle Gate, 0.82 inch. Slight damage to railroad tracks at Heiner. (DN Sept. 22, 1927.)
Sept. 26	Vernal		One of worst floods in Uinta Basin wiped out bridge and highway between Vernal and Colorado State line. (DN Sept. 27, 1927.)
1928			
Aug. 16	Price	Nine Mile Canyon	Sheep rancher drowned when torrential rains at canyon source caused heavy flood covering his automobile. His daughter, who was riding with him, escaped by clinging to brush and crawling to safety. (DN Aug. 17, 1928,)
Aug. 21	Gunnison		Thousands of dollars' damage caused by floods from mountains. Business houses flooded; water 1 foot deep in Main Street. (ECP Aug. 24, 1928.)
1929			
July 20	Thistle		Cloudburst near Rio washed out main line tracks of D. & R. G. W. R.R. Damage, $1,800. (UEC)
Aug. 3	Price		Heavy rains commenced Saturday (3rd) afternoon. Highway covered with several inches of mud. Debris washed onto crops by overflow of Price River. Storm Sunday night washed out city pipe line. (DN Aug. 5, 1929.)
Aug. 4, p.m.	Milford		One of heaviest storms seen in Milford. Main Street flooded with water 13 inches deep. Much merchandise in stores damaged. (DN Aug. 5, 1929.)
	Farmington	Davis Creek	Heavy storms brought down deluge of boulders, tree trunks, rubbish, and water. Three autos crossing the highway were buried. Property was damaged. (DN Aug. 5, 1929.)
Aug. 27	Richfield		Heavy rain and floods. Farmers in front of Flat Canyon lost heavily. (WBA 1929.)
Aug. 29	American Fork	Deer Creek Branch of American Fork Canyon.	Cloudburst closed road 24 hours. (DN Aug. 30, 1929.)
Sept. 2, 1:30 p.m.	Eureka	Eureka Canyon	Thousands of dollars' damage done to streets. Hundreds of tons of mud and rocks deposited in town. (ER Sept. 5, 1929.)
Sept. 3, 10:30 a.m.	Ogden		One foot of water on downtown streets due to one of heaviest rains in history. Pressroom of Ogden Standard Examiner flooded. Damage, $500. Fall of rain, 0.93 inch. (DN Sept. 3, 1929.)
Sept. 21	Castle Gate and Verde	Price River	Heavy rains damaged railroad embankment and structure to the extent of $1,300. (DRG.)
1930			
June 19, 8:00 p.m.	Coalville	Chalk Creek	Cloudburst flood covered road and damaged one farm.
July (?), 2 p.m.	Coalville	Grass Creek	Flood of mud and water washed out tipple of coal mine and damaged some homes.
July 10	Thistle		Cloudburst of brief duration damaged roads and railroad right-of-way. (PH July 11, 1930.)
July 10, p.m.	Salt Lake City	Emigration, Red Butte, and Parleys Canyons.	Cloudburst blocked Salt Lake-Ogden road. Several canyon roads covered with rocks and debris. Storm struck with considerable abruptness and floods came down Emigration, Red Butte, and Parleys Canyons. City conduit in Parleys Canyon was undermined. Some homes were flooded and basements filled with water and mud. Several cottages were washed away in Red Butte Canyon. State Road Commission appropriated $40,000 for damage to highways throughout State. State-wide damage estimated at $500,000.

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
	Farmington and Centerville		Farms swept by water carrying tons of rocks, sand, etc. One house and several farm buildings destroyed. Livestock loss negligible. Road blocked between Farmington and Centerville in three places for eight days. Farm losses estimated at $50,000. Relief fund of $30,000 instituted.
	Ogden		Weber Canyon blocked in gateway. Four miles of U. P. R.R. tracks in canyon blocked by a number of mudslides, which formed small lakes behind them. Trains rerouted via McCammon, Idaho. Property of Bamberger Electric Ry. Co., Utah Power & Light Co., and Mountain States Telephone & Telegraph Co. also damaged.
	Thistle		D. & R. G. W. R.R. Co.'s main line damaged by cloudburst floods. (DN July 11, 12, 15, 16, 18, 1nd 28, 1930.)
July 20	Castle Dale and Orangeville	Straight Canyon	Large headwater floods strewed mountain roads with debris. Storm strictly local. (DN July 28, 1930.)
July 26	Castle Dale and Huntington.		Storms during week damaged crops. Hailstorm on 26th swept district, breaking Mammoth canal. (DN July 28, 1930.)
Aug. 2	Salt Lake City		Heavy floods occurred at North Salt Lake, covering the highway from 1½ to 3 feet deep. State highway was completely blocked near Warm Springs. Water was reported 6 feet deep north of municipal baths.
	Cisco		Highway to Colorado State line washed out.
	Huntington	Huntington Creek	Two small wash-outs between Huntington and Fairview. (DN Aug. 2, 1930.)
Aug. 2, p.m.	Fillmore	Chalk Creek	"Worst flood in over a decade." Thousands of tons of rock and sand swept out of Chalk Creek Canyon over the north part of town. Fields covered with mud and boulders. Many gardens ruined and basements flooded. (DN Aug. 4, 1930.)
Aug. 2 and 3, p.m	Salina	Salina Creek	A series of four cloudbursts in the vicinity of Salina. Flood swept out of canyon and over part of city. Following day floods came out of Denmark Wash, Aurora Canyon, Red Canyon, and Cedar Canyon. Crops were destroyed. The State canal was cut out in six places. A landslide occurred about 17 miles up Salina Canyon, blocking the road. (DN Aug. 4, 1930.)
Aug. 3, p.m.	Orangeville	Cottonwood Creek	Crops flooded, roads washed out by flood following excessive storms in western part of Emery County.
Aug. 7	Moab	Pack and Mill Creeks and Cane Spring Wash.	Torrents down three creeks washed out bridges. (TI Aug. 7, 1930.)
Aug. 8	Pine Valley	Santa Clara Creek	An unusual storm began on the 8th and continued intermittently until the 11th. Town flooded three different days. River at record stage. Without rain gage, local observers estimated 7 inches of rainfall. (DN Aug. 14, 1930.)
Aug. 9, p.m.	Val Verde		Havoc wrought by cloudburst. Gullies 5 to 10 feet deep cut in street. Peach trees uprooted and chickens carried away. (DN Aug. 11, 1930.)
Aug. 11, 3 a.m.	Ogden		Heavy thunder and lightning accompanied by rain. Streets and basements flooded. (DN Aug. 11, 1930.)
Aug. 11, 11:30 a.m.	Bingham Canyon		Cloudburst lasted 2¼ hours. More than a score of houses demolished. Dozen families narrowly escaped death when a 50,000-ton copper drum became saturated with rain and swept down the mountainside. One hundred homes damaged. Electric power off for 2 hours and section of road buried. D. & R. G. W. R.R. and coalyard damaged. Utah Copper Co.'s hospital caved in. Damage estimated at $500,000. (DN Aug. 11, 1930.)
Aug. 11, 2:15 p.m.	Parleys Canyon		Two washouts on highway.
	Farmington	Davis Creek	Cloudburst in hills. No rain in Farmington.

	Centerville		"Worst flood in history." Water swept livestock, barns, and hay away. Highway and railroad tracks covered with debris. A number of houses were partially covered. (DN Aug. 11, 1930.)
Aug. 12, noon	Provo	Provo River	Mud and rocks poured out of Snowslide Canyon for several hours. Large barrier was erected in river above Utah Power & Light Co.'s flume. Water was raised 8 feet and backed up over State highway and D. & R. G. W. R.R. tracks. The impounded lake was not released for two weeks. Three smaller slides in canyon. (DN Aug. 13, 1930.)
Aug. 12	Eureka	Eureka Canyon	Buildings and streets badly damaged by flood from canyon. (ER Aug. 14, 1930.)
Aug. 13	Elberta	Iron King Canyon	Twenty-foot wall of "brown water" flooded canyon, washed out roads and "submerged Elberta in 2 feet of water." Some homes partially destroyed, and basements were filled. (PH Aug. 14, 1930.)
Aug. 13, 2 p.m.	Tintic district		Three cloudbursts struck in vicinity of Tintic Standard mine. Houses and other property washed away. Dam broke in two places. (DN Aug. 14, 1930.)
Aug. 13, a.m.	Mona		Boy killed as auto skidded in mud washed onto highway by cloudburst.
	Pleasant Grove	Dry Canyon	Cloudburst flooded five families from homes.
Aug. 13, 12:30 p. m.	Magna		Three storms in 24 hours. Fences, chicken coops, and outbuildings torn up or washed away. Twelve homes filled with mud.
	Cedar City	Fiddlers Canyon	Flood from Fiddlers Canyon delays highway traffic two hours at a point 3 miles north of Cedar City.
	Enoch		This town, 7 miles northeast of Cedar City, reported extensive damage to outbuildings and crops. Highway covered with debris to depth of 6 feet.
	Arthur		Damage to Utah Copper Co.'s plant, $25,000 to $30,000.
	Goshen	Big Government Creek	Cloudburst struck in vicinity of Apex mine, neat Tintic. Washed three houses away and ended at Elberta. Boy's horse was washed beneath him and drowned. One porch swept away, and town filled with water. Goshen dam overflowed in two places. Grain damaged.
Aug. 13	St. George		Flood hit Shivwits Indian Reservation. Traffic delayed when culvert washed out of highway.
	Zion National Park		Road to Andersen Ranch hit by mudslides. Damage to Iron and Washington Counties' State highways estimated to be $5,000.
	Ophir		Canyon impassable. Center of town filled with tons of mud, rocks, and debris.
	Marysvale		Fish Lake road washed out last week.
	Richfield		Hay and grains damaged by heavy rains.
	Grantsville		Water ran through streets. Many homes filled with mud.
	Springville	Rock Canyon	Flood swept fish hatchery. One thousand stock trout killed. Highway covered with debris for 200 yards near steel plant. One farm home with outbuildings and livestock destroyed.
	Willard		Lawns covered with mud and rocks. Cellars filled. One potato farm covered.
	Garfield		Flood washed through practically all homes in west section of town. Mud and rocks covered Main Street to depth of 2½ feet. Score of farms flooded. Utah & Salt Lake Canal washed out. D. & R. G. W. and B. & G. tracks inundated. Boiler rooms and machine shops filled with water and mud.
	Farmington	Ford Creek	Slide 10 to 20 feet deep. Destroyed one home "as though it were paper."
	North Farmington	Shepard Canyon	Bamberger R.R. tracks undermined.
	Pleasant Grove	Grove Creek	Six farms damaged to extent of thousands of dollars. Water "tore down" on town.
	Salt Lake City		Canyon roads generally passable but seriously damaged. Road up Little Cottonwood blocked by 20-foot slide. Flood relief fund of $35,000 asked by Governor. Salt Lake-Ogden road blocked three days. Overgrazing of sheep blamed in part for disaster by Governor, and scientific conservation investigation instituted. (DN Aug. 13, 14, 15, 16, 18, 25, and 28, 1930.)
	Elberta		Cloudburst in mountains flooded roads and farms. Boulders as large as 3 feet in diameter strewn over fields. Railroad bridge was washed out and homes damaged. Reputed to be worst flood in 60 years. Walls of water from canyons said to be 20 feet high. (ER Aug. 14, 1930.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 14	Goshen		A cloudburst flood destroyed completely a section of the Mosida road. (DN Aug. 15, 1930.)
Aug. 20	Salina	Salina Canyon	Cloudburst in canyon washed out railroad track. Traffic suspended 22 days. Damage, $10,000. (UEC)
Sept. 4, 9 p.m.	Centerville	Parrish Creek	A new flood hit Davis County as a fierce rain struck in the hills. At Centerville at least one block of the State highway was under 15 feet of mud. Since property was already stricken, not a great amount of additional damage was done.
	Farmington	Steed, Davis, and Ford Creeks.	Highway was buried. Bamberger Railway tracks were covered for a quarter of a mile with 2 to 4 feet of debris. Highway again covered by mudslide. A few autos were stalled.
	Grantsville	South Willow Creek	Severe wind and rainstorm. Trees were uprooted, and trans-continental telegraph line blown down. Road was flooded and sand was washed into fields. (DN Sept. 5 and 6, 1930.)
Sept. 6	Richfield		Serious electrical storm continued all night. Floods rushed out of canyons, washing out roads and bridges. (DN Sept. 8, 1930.)
Sept. 7	Hurricane		"Cloudburst caused much damage." (DN Sept. 9, 1930.)
1931			
May 3	Ogden		Business district of Ogden was flooded by heavy rainstorm in spite of recently constructed storm sewer. Water reached the entrance of several stores. (DN May 4, 1931.)
July 13 (prior to)	Callao	Deep Creek	Farms inundated and crops ruined by heavy flood. A normally small creek carried a flow 200 feet wide and 15 feet deep. (ER July 16, 1931.)
July 29, p.m.	Tintic		Four-foot wall of water from narrow canyon washed out two roads, and streets of Eureka "received their usual share of the damage." (ER Aug. 6, 1931.)
July 30, 3:15 p.m.	Collinston, Cutler power plant.		Mudslide filled an irrigation canal; out of service 40 hours. (UPL)
July 30, 5 p.m.	Tintic	Eureka Canyon	Second storm in two days yields 1.09 inches of rain in less than an hour. Extensive damage to roads and buildings. (ER Aug. 6, 1931.)
July 30	Mammoth		Streets washed out. Damage to canyon highway, $5,000. Mining properties suffered considerable damage. (ER Aug. 6, 1931.)
July 30, p.m.	Provo	Provo Canyon	Mudslide originating in Snowslide Canyon covered the road and dammed the river. Slide 20 feet deep and 400 feet wide. Another large artificial lake was created in Provo Canyon. Hundreds of autos were marooned.
	Eureka	Eureka Canyon	Flood waters swept through the streets of the town 4 to 5 feet deep. Business houses badly damaged. One home nearly buried in debris.
	Cedar City		One and two-tenths inches of rain fell, following 0.57 inch on previous day. Portion of Parowan-Cedar City road badly washed.
	Spanish Fork	Spanish Fork Canyon	Floods brought down tons of debris and uprooted trees in canyon. Strawberry project diversion dam threatened. (DN July 31, 1931.)
Aug. 13, 7:48 p.m.	Salt Lake City		Four to 12 inches of water swept through streets in some places. Several autos buried in mudflow near Beck's Hot Springs. Record for rainfall intensity was broken when 0.40 inch of water fell in 5 minutes. Debris 12 feet deep over a length of 350 feet blocked the Salt Lake-Ogden road near North Salt Lake.
	Farmington		Road blocked by rocks and silt. (DN Aug. 14, 1931.)
Aug. 14, p.m.	Eureka	Big Canyon	Cloudbursts struck Eureka and vicinity. Roads and railroad structure badly damaged by wash-outs. Cattle and other property buried in mud and debris.

	Elberta		Water swirled through streets, and bridges on Mosida road were washed out. Two cattle were completely buried in mud.
	Glenwood		Floods covered the highway between Glenwood and Richfield with water 3 to 6 feet deep. Grainfields badly damaged.
	Sigurd	King Meadow Canyon	Jumbo Plaster Mills at Sigurd damaged by flood from King Meadow Canyon. (DN Aug. 15, 1931.)
Aug. 14, 5:30 p.m.	Eureka	Eureka Canyon	Streets gashed badly, and highways damaged.
	Mammoth and Silver City	Mammoth Gulch	Tons of debris washed down from mountains. (ER Aug. 20, 1931.)
Aug. 15	Silver City	Dragon Canyon	Dam of debris, left in canyon by flood of previous day, was washed out suddenly, sending 10-foot wall of water down canyon. No further damage reported. (ER Aug. 20, 1931.)
1932			
June 12	Lehi		Cloudburst at point of mountain washed out irrigation canal of Provo Water Users' Association. Damage, $1,000 to $1,500. East Jordan irrigation canal was also washed out. (DN July 13, 1932.)
July 10	Junction	City Creek and Sevier River	Rain and hail caused canals and irrigation ditches to overflow. Streets were filled with water. The worst flood known for some time occurred between Antimony and Escalante. (DN July 14, 1932.)
	Panguitch and Dog Valleys		Floods spread havoc over 5-mile stretch. Roads and farms damaged. (UEC)
July 17	Spanish Fork	Spanish Fork Canyon	Canyon road seriously damaged by cloudburst. (PH July 18, 1932.)
Aug. 20	Escalante		Vicinity struck by heavy storm, which washed out bridges and culverts and damaged crops. (GCN Aug. 26, 1932.)
Aug. 21, p.m.	Antimony and Widtsoe		Cloudburst in mountains east of town. Dry washes filled with torrents carrying boulders, timbers, and mud, which was strewn over farms, gardens, and roads, covering a stretch of about 2½ miles. Hay was swept away, and stacks left standing were badly damaged by water and mud. Some houses were partly inundated and furniture ruined. Cellars filled with mud and water. Dry Wash bridge swept away. Bridge over Antimony Creek badly damaged. (DN Aug. 24, 1932.)
	Tropic		Hailstorm followed by flood wreaks havoc in vicinity. Hailstones were unusually large, resembling irregular chunks of ice. Bridges and culverts washed out. (GCN Aug. 26, 1932.)
Aug. 26 (prior to)	Junction		Heavy storm east of town caused $20,000 loss, including crop damage and drowned livestock. (GCN Aug. 26, 1932.)
Aug. 26, p.m.	Provo		Violent storm, yielding 0.9 inch of rain, caused as much as 50 per cent damage to nearby farm crops. (PH Aug. 28, 1932.)
Aug. 27 (?)	Davis County		Salt Lake-Ogden road blocked at Beck's Hot Springs and between Centerville and Farmington by mudslides. (DN Aug. 29, 1932.)
1933			
July 7, 4:25 p.m.	American Fork	American Fork Canyon	Intake to power-plant pipe clogged by flood. Out of service two days. (UPL)
July 9, p.m.	Provo	South Fork of Provo Canyon.	Cloudburst washed tons of debris onto road. (PH July 10, 1933.)
	Eureka		Streets washed out, windows broken, and chimneys blown over during violent thunderstorm. (ER July 13, 1933.)
July 10	Ephraim	Ephraim Canyon	Thunderstorm of short duration but of intense volume started a flood in Ephraim Canyon. Several farms were covered with silt and mud. (DN July 10, 1933.)
July 11 (prior to)	Strawberry Valley	Diamond Fork	Cloudburst washed out a 300-foot section of road. (PH July 11, 1933.)
July 12	Castle Dale	Cottonwood Creek	Heavy cloudburst. Gardens and streets flooded, plants knocked down. Creek unusually high. (DN July 14, 1933.)
July 16	Elberta		Town flooded by heavy discharge from East Tintic Range. Orchards and farms suffered damage. (ER July 20, 1933.)
July 30	Monroe	Main Canyon	High flow in canyon tore out road, dam, and pipe line. Hailstorm on previous day did considerable damage to crops and subsequent flood submerged portion of town. (DN Aug. 1, 1933.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Aug. 11	Salina	Salina Canyon and Denmark Wash.	Cloudburst in canyon caused flood which did considerable damage to roads and crops in vicinity of Salina. (ECP Aug. 11, 1933.)
	Junction	Kingston Canyon	Heavy rains cause flood down Kingston Canyon. Road washed out. Debris spread over area about a quarter mile. (DN Aug. 11, 1933.)
1934			
July 4	Milford		"Heaviest rain since 1929" struck town. Ensuing flood washed out streets and gardens and filled cellars. (DN July 6, 1934.)
July 21	Salina	Lost Creek	Boy drowned by sudden flood in creek.
	Copperton		Cellars filled with mud and water. (DN July 21, 1934.)
	Tooele		Rain of 1.07 inches flooded town and "piled dirt" on the streets.
	Mount Pleasant	Pleasant and Twin Creeks	Two floods "roared into town," flooding streets and lots.
	Gunnison	San Pitch River	High water from cloudburst damaged irrigation system.
	Holden, Lynndyl, and Meadow.		Three other towns received floods, but no details available. (DN July 23, 1934.)
July 20 and 21	Manti	Manti Creek	Cloudbursts in canyon sent three floods through town. Roadway washed out; power-plant canal damaged.
	Pleasant Grove		City culinary water sources damaged by flood. (DN July 24, 1934.)
July 24	Spring City		Heavy downpour of rain followed by a flood. Irrigation ditches and canals overflowed. Several gardens and yards covered with mud and refuse.
	Riverton	Bear Canyon	Mud, rock, and debris brought down. Culinary supply line clogged. (DN July 24, 1934.)
July 27	Ephraim		Power dam in Oak Creek washed out.
	Lindon		"Thousands of dollars' damage done." Sixteen men working in water-development tunnel were nearly trapped. Flood swept down canyon. (DN July 27, 1934.)
Aug. 5, 4 p.m.	Nephi	Salt Creek Canyon	Highway covered with rocks and debris for 6 miles. City power plant tied up. Damage to Nephi Plaster Plant, $10,000. The D. & R. G. W. R.R. tracks in the canyon were covered with mud, rocks, and trees. Grain and alfalfa fields were covered with mud and water.
	Bingham	Bingham Canyon	Deluge blocked the highway. (DN Aug. 6, 1934.)
Aug. 6, p.m.	Thatcher		Violent storm resulted in flood. Flood covered a farming area one-eighth mile in diameter. Tons of rock and debris was carried on farm land. Canal was filled with mud.
	Monroe	Monroe Canyon	Flood in Monroe Canyon late Monday following a terrific storm. Pipe line and road washed out. Culinary water hauled from nearby towns. Fields south of town covered with water, rocks, and debris. Grain and alfalfa fields badly damaged. (DN Aug. 8, 1934.)
Aug. 8, 3 p.m.	Willard	South Willow Creek	Cloudburst washed out 20 feet of flume and 130 feet of pipe. Power plant out of service eight days. (UPL)
Aug. 8, p.m.	Richfield	Willow	Road in canyon badly washed. One team overtaken by flood, drowned, and occupants of wagon had narrow escape.
	Junction	City Creek	Flood Wednesday afternoon rushed in upon the city.
	Tooele		Small flood in Dry Canyon. Road covered with debris and rocks. (DN Aug. 10, 1934.)
Aug. 14, p.m.	Panguitch		"Heaviest rainstorm of season" brought a terrific flood from foothills.
	Monroe	Main and Sand Canyons	Two hundred feet of pipe line repaired 10 days previously was torn out. Residents again hauling water for culinary purposes. South Bend canal and Bertelsen ditch filled with mud. (DN Aug. 16, 1934.)
Aug. 15, p.m.	Eureka		Rain amounting to .85 inch in 22 minutes. Four feet of water swept autos down Main Street. Water poured over the floors of several establishments. (DN Aug. 18, 1934.)

Aug. 16, 1 p.m.	Park City		Hailstorm followed by sheets of rain. Road damaged. (DN Aug. 17, 1934.)
Aug. 16, 2 p.m.	Elberta		Third flood of year. (DN Aug. 16, 1934.)
Aug. 19, p.m.	Richfield	Flat and Cottonwood Canyons.	"Heaviest rainstorm all summer." Sevier Valley canal was filled with sand. Some fields damaged.
	Kanosh		Other day flood struck town, tore up water lines, and filled trenches prepared for new pipe line. (DN Aug. 21, 1934.)
Aug. 28	Beaver		Two heavy storms caused floods in the Buckhorn Mountains and near Cedar City. (DN Aug. 30, 1934.)
Aug. 29, a.m.	Salt Lake City		"Most intense rain in years drenched Salt Lake." Storm started in Tintic district and moved northward through Utah, southern Idaho, and into Wyoming. (DN Aug. 29, 1934.)
	Provo	South Fork of Provo River	Flood threw high waters, gravel, and rocks in canyon highway. (DN Aug. 30, 1934.)
1935			
July 4, 1:46 p.m.	Heber	Snake Creek	Flood filled forebay of power-plant intake with gravel. Out of service 40 hours. (UPL)
Aug. 17	Lehi	West Canyon	Heavy rains in Oquirrh and Wasatch foothills culminated in a cloudburst. Grain in fields heavily damaged. Salt Lake & Utah R.R. track washed out. (DN Aug. 19, 1935.)
Aug. 22, 6 p.m.	Bingham		Heaviest cloudburst in years. Basements filled and flume destroyed. Two feet of debris on road. Twelve houses damaged. (DN Aug. 23, 1935.)
Aug. 26, 12 noon	Bryce Canyon National Park.		All washes filled, and trails and roads damaged by storm of an hour's duration (Weather Reports, Bryce Canyon).
	Price	Willow Creek Canyon	Cloudburst at head of canyon filled cellars and houses at Willow Creek and Upper Castle Gate with debris and water. Railroad switchyards at Castle Gate torn up. Several autos buried in mud. (DN Aug. 27, 1935.)
Sept. 1	Beaver and Monticello		Thousands of dollars' damage was done by cloudbursts covering an area from Beaver on the west and Nephi on the north to Monticello on the east.
	Nephi	Salt Creek, Reese, and Foote Canyons.	Nephi inundated by flood of mud and water. Canals filled, highways covered, and railroad tracks submerged. (DN Sept. 2, 1935.)
Sept. 2, 2 p.m.	Beaver	Beaver and Bakers Canyons	Cloudburst struck city about 2 p.m. Water poured down mountainsides and strewed boulders across the highway for several miles. Beaver city power canal filled with sand and boulders. City without electric power.
Sept. 2, 4 p.m.	Oak City	Oak Creek	Storm struck about 4 p.m. Flood one of worst experienced by residents. Campers and fishermen in canyon narrowly escaped drowning. One automobile with five occupants, caught in flood before it could be started, was carried by the flood several hundred feet and lodged against a tree. Flood carried trees and rocks onto the gardens and fields and carried away bridges. (DN Sept. 2, 1935.)
Sept. 4	Huntington	Huntington Creek	A number of floods killed fish. (DN Sept. 4, 1935.)
Sept. 25	Nephi		Cloudburst on west side of Mount Nebo. Highway covered with mud and debris. Streets flooded. (DN Sept. 25, 1935.)
1936			
July 9	Cedar City		Cloudbursts in various parts of southern Utah. Streets in Cedar City flooded about 1 foot deep. Cellars filled. Traffic on all highways within 50 miles at standstill.
	Milford	Frisco Canyon	Cloudburst in Frisco Canyon above Milford. Heavy streams of water washed over the entire south end of the city. (DN July 9, 1936.)
July 10, 2 p.m.	Henrieville		Cloudburst to north washed out several acres of farming land along creek. (ER July 16, 1936.)
July 10, 5:30 p.m.	Provo	Snowslide Canyon	Mudflow covers 200-foot stretch of canyon highway with debris 2 to 10 feet deep. Several basements flooded in town. (PH July 12, 1936.)
July 11	Cedar City		For third successive day city was center of heavy rains. City was covered with red mud from flood waters.
	Circleville Canyon		Washout blocked U. S. Highway 89 for two hours.
	Marysvale Canyon	Sevier River	Debris in road caused delay in travel.
	Kanarraville		Mud deposit on highway. (DN July 11, 1936.)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
July 21, 3:15 p.m.	Provo	Rock Canyon	Heavy rains south of Provo deposited tons of debris on State highway in three places. Steel-plant property damaged. (PH July 22, 1936.)
July 23	McIntire Ranch	Cherry and Death Canyons	Floods in two canyons completely washed out road and injured pipe line.
July 24	Coalville	Chalk Creek	Flood washed out bridge and damaged roads.
July 29, p.m.	Central Utah		The 19th storm in that part of State since July 1.
	Ephraim		Flood swept out pipe line of new power plant although buried 8 feet. Heavy boulders and logs debouched from canyon.
	Fillmore		Storm started about 11:30 a.m. yesterday. First flood reached peak about 1:30 p.m. Second flood came about 6 p.m. Basements in city north of creek flooded. Hay and grain cut in fields badly damaged.
	Manti	Manti Creek	Bridges washed out. More than 3 feet of water washed along Main Street. Basements filled.
	Fillmore		Homes endangered by flood from North Fork of Chalk Creek.
	Provo		Erosion-control dam and flood barriers of Civilian Conservation Corps swept away, covering valuable farms with silt and mud.
	Farmington		Cloudburst brought debris down canyons.
	Willard		Debris carried over spillway of flood-control works.
	Ferron		Woman drowned in flood which swept down dry wash following cloudburst.
July 30	Richfield		Sudden cloudburst caused several floods in canyon. Fields and crops badly damaged, and canals filled with silt. Tons of mud and silt washed into streets.
	Minersville		Heavy damage to property. One woman drowned.
	Manti	Manti Creek	Basements filled with sand and debris by sudden flood.
	Adamsville		Crops washed away. Lands covered with mud and debris.
	Mount Pleasant		City water mains washed out. Dividing dams in irrigation ditches destroyed. Haystacks and crops damaged. Roads near Scipio, Sigurd, and Glenwood closed by storm. (DN July 31, 1936.)
July 31, 2:30 a.m.	Willard	Willard Canyon	Cloudburst sent torrent down Willard Canyon. Farms and highways stricken. Main road was buried under mud for nearly two blocks. Several homes were damaged. Autos were tipped over and Bamberger R.R. was washed out in two places. Seven homes were partially buried. Basements were filled with mud. Damage estimated at $100,000. Flood filled and overflowed flood-control works.
July 31, p.m.	Minersville		New floods poured over same areas as previous day. Basements filled and several homes endangered. (DN July 31 and Aug. 1, 1936.)
Aug. 1, p.m.	Spanish Fork	Spanish Fork Canyon	Mud- and rock-slides caused considerable damage to roads. (PH Aug. 2, 1936.)
Aug. 2	Eureka		Storm, yielding 0.9 inch in less than half an hour, badly damaged streets.
Aug. 3	Ibapah and Tooele County		Worst flood in history of Deep Creek Valley. Seventeen ranches were flooded, seven buildings destroyed. Flood spread half a mile and was 6 feet deep. (DN Aug. 8, 1936.)
Aug. 14, 4 p.m.	Coalville	Echo Canyon	Cloudburst paralyzed traffic in canyon for 10 hours. Bridges washed out and tracks covered with debris.
Aug. 16	Salt Lake City	Big Cottonwood Canyon	Road damaged and three persons injured.
Aug. 16, p.m.	Beaver		Worst flood of season Sunday afternoon (Aug. 16). Within an hour, 1.56 inches of rain. Crops destroyed. Hail 5 to 6 inches deep.
	Adamsville	Dry Gulch	Huge mudslide in Dry Gulch. Monstrous boulders and mud strewn over highway.
	Kanosh		Flood late on August 15 washed out bridge and about 75 feet of highway. (DN Aug. 17, 1936.)

Aug. 30	Stockton		Cloudburst above Stockton. Twenty feet of U. P. R.R. washed out. (DN Aug. 31 and Sept. 1, 1936.)
Aug. 31, 3 p.m.	Oak City		Heavy cloudburst and battering hailstones struck fruit and farm crops. Road blocked with debris.
	Minersville		Cloudburst of unusual violence. Streets covered with 2 to 5 feet of water. City water system and canals badly damaged. Two thousand acres around the town under 2 feet of water. Number of livestock killed. (DN Sept. 1, 1936.)
	Ephraim		One of heaviest storms in history of town. Three severe storms in two days. (DN Sept. 2, 1936.)
Sept. 2	Moab		Floods came down all small canyons. Basements filled; "entire town covered with mud and debris." (TI Sept. 3, 1936.)
1937			
June 29	Spanish Fork and Echo Canyons.	Spanish Fork and Echo Canyons.	Cloudbursts blocked roads in two canyons. Five-mile stretch covered in Echo Canyon. (PH June 30, 1937.)
July 9, p.m.	Eureka		Cloudburst damages streets and dirt sidewalks, and destroys Works Progress Administration construction work. (ER July 14, 1937.)
July	Upton	Josh Hollow	Flood injured hay crop at mouth of canyon. (PH July 19, 1937.)
July 11	State of Utah		Many highways blocked. (DN July 12, 1937.)
July 29, p.m.	Price		"One of worst floods in Carbon County history." Huge boulders loosened, rolled through house, killing 6-year old girl. Three others injured.
	Myton	Antelope Canyon	Cloudburst.
	Echo	Echo Canyon	Cloudburst brought tons of mud and debris onto highway. (DN July 30, 1937.)
Sept. 4	Beaver		Cloudburst accompanied by spectacular thunder and lightning display lasted 2 hours. "Most severe rainstorm that has struck this section for a long time." (DN Sept. 4, 1937.)
Oct. 17	Brigham	Brigham Canyon	Cloudburst caused landslide in canyon, blocking highway. One inch of rain fell in 30 minutes. (DN Oct. 18, 1937.)
1938			
June 30, p.m.	Bountiful		Cloudburst hit Davis County "in its annual devastating fashion." Two feet of water swished across the highway at Perry Station. (DN June 30, 1938.)
July 4	Salt Lake City		Brief storm brought torrents of water onto highway at North Salt Lake. Davis County Commissioner reported "no damage." Forest flood-control works credited. (DN July 6, 1938.)
July 13, 9 p.m.	Provo	Provo River	Mudslide from Snowslide Canyon covered highway, dammed river, and covered D. & R. G. W. R.R. tracks. Water was backed up for a mile and a half, and resorts and summer homes were inundated. Slide was 400 feet wide and up to 20 feet deep. Two other mudslides occurred in the lower portion of the canyon. One, at Lost Canyon, also dammed the river and covered up the highway for 300 feet. The lower slide covered 250 feet of highway. Both of these slides removed portions of the wooden flume of the Olmsted plant of the Utah Power & Light Co. Drag lines were able to break through the upper barrier nine days later, releasing the impounded water. (DN July 14, 15, 16, 18, 19, and 21, 1938.)
Aug. 26, 6 p.m.	Thistle	Spanish Fork Canyon	Westbound tracks of D. & R. G. W. R.R. were covered with tons of mud and rock when a flood poured out of Chicken Hollow. A second flood covered the Marysvale branch line, 4 miles south of Thistle. (DN Aug. 27, 1938.)
Aug. 30	Cedar City		Spectacular electrical storm flooded streets and basements of Iron and Wayne Counties. U. S. Highway 91, between Kanarraville and Parowan, was flooded with mud and water.
	Fruita and Hanksville	Fremont River	Bridge near Fruita ripped out. Sixty acres of orchard land destroyed. (DN Aug. 31, 1938.)
Aug. 30, 4:14 p.m.	Santaquin	Santaquin Creek	Flood tore out 35 feet of pipe. Power plant out of service two days. (UPL)
Aug. 30, 3:30 p.m.	Tintic	Homansville Canyon and Eureka Canyon.	Storm of 3 hours' duration. Hail at outset damaged roofs. Streets and canyon roads washed out in many places. (ER Sept. 1, 1938.)
ept. 1, 5 p.m.	Pleasant Grove	Battle Creek	Flood damaged power-plant intake. Out of service 16 hours. (UPL)

Abstract accounts of outstanding cloudburst floods in Utah—Continued

Date	Locality	Stream course	Remarks
Sept. 1-2	North Tintic (Bullion mine)		Flow of debris spread over mining property, damaging machinery and buildings. (ER Sept. 8, 1938.)
Sept. 2	Vernal		Tons of debris washed onto main highway throughout Uinta Basin. Portions of secondary roads washed out. (DN Sept. 3, 1938.)
Sept. 5	Price and eastern Utah		Cloudbursts struck eastern Utah. Traffic temporarily blocked. (DN Sept. 6, 1938.)
Sept. 9	Utahn		Highway closed. Seven and a half hours of rain.
	Bridgeland		Road damaged.
		Indian Canyon	Highway covered with debris.
	Price		Highway 50 was flooded with debris. (DN Sept. 9, 1938.)

RELATION OF CLOUDBURST FLOODS TO SETTLEMENT AND USE OF THE LAND

The population of Utah is a little more than half a million, scattered through 29 different counties but concentrated in small areas where water supplies are available. If the population were distributed evenly over the State, the average would be little more than 6 to the square mile. The density varies in the different counties from a minimum of 0.5 to the square mile in Daggett, Grand, Kane, and San Juan Counties to a maximum of 257 to the square mile in Salt Lake County. In no county other than the last-named does it exceed 100 to the square mile. In the decade ending with 1930 the population increased in 17 counties, and in the remaining 12 counties it decreased. The net increase for the State was 58,451. The proportionate population of the State in each county and the localities that have been visited by destructive cloudburst floods are shown in plate 23.

More than 230 places at some time or other have experienced a cloudburst flood, and many places have undergone several such floods. Most of the present towns in Utah were established by 1880, and at that time the total population was about 144,000. There were 9,452 farms, with an aggregate area of 655,524 acres and an average area of 70 acres each.

The following table shows the population and its relation to farm lands in Utah for each decade since 1850, two years after permanent settlement began. The data, except for those on cloudburst floods, are taken from reports of the United States Bureau of the Census.

Relation between population, farm lands, and cloudburst floods in Utah, 1850–1930

Year	Population	Farm lands				Cloudburst floods	
		No. of farms	Area in farms (acres)	Average area per farm (acres)	Area per capita of population (acres)	No. of places	No. of reports
1850	11,380	926	46,849	51	4.1	0	0
1860	40,273	3,635	89,911	25	2.2	4	5
1870	86,786	4,908	148,361	30	1.7	3	6
1880	143,963	9,452	655,524	70	4.6	18	30
1890	210,779	10,517	1,323,705	126	6.3	43	67
1900	276,749	19,387	4,116,951	210	14.8	43	67
1910	373,351	21,676	3,397,699	155	9.1	64	110
1920	449,396	25,662	5,050,410	195	11.2	51	82
1930	507,847	27,159	5,613,101	206	11.1	58	117

Attention is directed to the fact that after 1880 the farms rapidly increased in area, at a rate much in excess of the rate of population growth or the rate of increase in number of farms. Obviously the new boundaries embraced more and more lands of uncertain agricultural value — lands that were not suitable in themselves for individual farms and for this reason were added to existing farms. The result is that during the period 1880 to 1930, although there was a population increase of 350 percent, the number of farms increased only 290 percent, but the area included in farms increased 860 percent. Naturally this enormous increase in farm area, through a selective process of taking the most desirable areas first, has included practically all lands adjacent to watercourses and consequently those subject to cloudburst floods. This fact is significant in any study of flood frequency, because prior to 1880 such floods were reported from only 24 different localities in the State, whereas after that time they have been reported from more than 200 different places.

In relation to land use it is interesting to note that although there have been numerous cloudburst floods over a period of years and they have been scattered freely over the State, the areas they have affected are small and in total constitute only an insignificant part, much less than 1 per cent, of the total area in farms. Devastation from these floods is naturally of great concern to that small group of citizens whose homes and highly developed orchards, garden farms, and city lots have suffered obliteration. Instances of such devastation, however, are few, and their recurrence will not be likely until such time as the now abandoned areas are again occupied by venturesome settlers who, on the premise that two or more decades may have passed with no floods, are willing to take the chance of not being molested in the future. Experience has demonstrated, however, that plains built by past floods should not be chosen for homesites, because in many localities "cloudbursts" have brought destruction to the works of man that have encroached on these flood plains.

Other uses of the land that are of great public importance are those that involve locations for pipe lines and canals for water supplies, power developments, and irrigation enterprises and for railroads and highways for transportation. In most places where land is put to these uses it is not practicable to abandon flooded areas. For this reason, recurring floods repeat the damage to rebuilt structures.

The land use in which flood damage attracts least public notice is the cultivated field, where the damage is confined usually to the destruction of the field crops. Such damage is occasionally heavy to individual property owners but is not of material public concern unless it should remove permanently from production extensive areas of needed agricultural land.

It is unfortunate that the localities in Utah most suitable for settlement are generally on creeks subject to cloudburst floods, but without the creeks settlements as well as agriculture and other industries would be impossible. The small streams with flashy and often intermittent regimen and the erratic precipitation with violent thunderstorms and cloudbursts are characteristics of arid and semiarid regions such as that embracing Utah. As a result of aridity, natural vegetation is sparse; and because of the smallness of most of the streams, settlement is necessarily concentrated in small areas adjacent to them.

ECONOMIC IMPORTANCE OF AREAS AFFECTED BY CLOUDBURST FLOODS

The economic value of any area, small or large, is relative, and it fluctuates as the variable factors change. Such factors as climate and the marketability of the products of the area are of fundamental importance. Utah has a climate suitable for diversified agriculture and is delightful to live in. Agriculture is practiced on more than 5,000,000 acres, or approximately 10 percent of the land area of the State, which is divided into about 31,000 farms (1935) having an average value of little more than $25 an acre and a total population of about 140,000 (1935), or a little more than a quarter of the total population of the State. When it is realized that more than two-thirds of the area occupied by farms is classified as "pasture" and that in 1934 only slightly more than 800,000 acres was crop-harvested, it is not difficult to see why the farm population is sparse—only one person to each 40 acres or more of farm land. Utah ranks forty-second among the States in the net value of all agricultural crops and livestock—a little more than $46,000,000 (1937); in value of manufactured products it is thirty-ninth, with about $114,000,000 (1935); in value of mineral products it is seventeenth among the 20 leading mineral-producing States, with nearly $42,000,000 (1935).

These facts serve to allocate the State with reference to its relative economic importance, without regard to the sociologic factors involved in the establishment of homes and stable communities. An analysis of the several hundred reports of cloudburst floods indicates that more than 50 percent of the floods damaged highways, bridges, irrigation structures, and railroads; about 20 percent of them damaged fields and crops; and about 18 percent flooded city streets and basements of homes with mud and debris. In a few places small areas of relatively high-priced land and comfortable homes were rendered useless.

According to valuations set by the State Tax Commission for the year 1938,[55] the assessed value of all farm lands was a little

[55] Fourth Biennial Report of the State Tax Commission of Utah to the Governor and the Legislature of the State of Utah, for the period July 1, 1936-June 30, 1938.

more than $64,000,000. Town and city lots were assessed at approximately $53,000,000. Improvements on agricultural lands were valued at about $26,000,000 and improvements on town and city lots at a little more than $99,000,000. The total assessed value of all property in the State was approximately $570,000,000.

Places in the State that have attracted most public attention because of floods and that have experienced 10 or more cloudburst floods since their settlement are listed in the following table:

Places in Utah where 10 or more cloudburst floods have been recorded since settlement

Place	County	Number of floods recorded
Salt Lake City	Salt Lake	44
Farmington	Davis	14
Manti	Sanpete	14
Ogden	Weber	17
Cedar City	Iron	13
Fillmore	Millard	11
Provo	Utah	15
Ephraim	Sanpete	10
Beaver	Beaver	11
St. George	Washington	17
Richfield	Sevier	11
Eureka	Juab	26
Kanab	Kane	10
Tintic	Juab	13
Price	Carbon	25
Moab	Grand	14
Orangeville	Emery	11
Thistle	Utah	12
Total		288

The reports from these 18 places account for nearly 42 percent of all the cloudburst floods recorded in the State. A classification of the damage done by the floods and the number of times damage has been reported are shown in the following table:

Reports of property damage from cloudburst floods since dates of settlement

Place	Type of property and number of reports										Remarks
	Farms and fields	Roads and bridges	Dams and canals	Railroad property	Cities (streets etc.)	Homes	Mining property	Livestock	Water-supply systems (culinary)	Hydro-electric power plants	
Salt Lake City	11	11	4	6	12	9		1	4		
Farmington	6	8		3	1	4		1		3	
Manti	4	6			9	7		1		1	
Ogden	1	7	1	3	10	8			1	4	
Cedar City	3	9	4		8	6		1			
Fillmore	5	1	3		5	5		2			
Provo	3	8	1	5	3	2				3	
Ephraim	4			1	3	3				2	
Beaver	5	1			1					1	
St. George	9	3	9		2	2		1			
Richfield	8	2	6		4	1		2			
Eureka		6		6	19	13		1	2		7 persons killed.
Kanab	5		4		2	2		1			
Tintic		6	2	3	2	4	3			1	1 person killed.
Price	5	18	4	9	6	10	2	1	5	2	Do.
Moab	3	7	2		2	1				1	Do.
Orangeville	5	6	1		2	2		1		1	Do.
Thistle	1	3		12							
Totals	78	102	41	48	91	79	5	13	12	19	

This classification covers 288 flood reports. Of these, 25 give cash estimates of damage, which total nearly half a million dollars, mostly for highways, bridges, and railroad lines in the Price River Basin in Carbon County. Records of expenditures by the Denver & Rio Grande Western Railroad Co. for damage due to cloudburst floods in the Price and Provo River Basins since 1907 show a total of a little more than $200,000. Expenditures by the Utah State Road Commission for clearing State highways and repairing damage done by such floods amounted to more than $191,000 for the period 1923 to 1932. The actual value of physical property that has been rendered useless by cloudburst floods in the State would be exceedingly difficult to determine. However, it is apparent from available data that, beyond an insignificant amount of improved farm land, a few small homes, and some small power plants, there would be little of material value involved. These facts do not support the cursory estimates of cloudburst flood damage that mount as high as $13,000,000 throughout the State, or approximately 2.3 percent of the total property valuation. In Davis County, where such floods have attracted considerable public attention, these apparently hasty estimates of damage total $3,000,000. This is not readily reconciled with the facts that the total value of irrigated farms and buildings in the county is approximately $14,000,000 and that the areas flooded approximate only 1 percent of the land occupied by irrigated farms.

Furthermore, the records of the State Tax Commission fail to show any devaluating effect on property in any county or community of the State because of damage from cloudburst floods. Apparently such damage is absorbed as a charge for occupancy of the areas involved. Further indication of the relatively insignificant effect of these floods on the economic status of the State is the fact that fire losses, which attract practically no public attention, have totaled more than $24,000,000 in the period 1904 to 1938, inclusive, and crop losses from droughts have been placed at more than $6,000,000 in a single year.

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