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THE ARKANSAS RIVER FLOOD OF JUNE 3-5, 1921

BY

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AND

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INTRODUCTION.

Between June 2 and June 5, 1921, heavy rains of an intensity to justify the term "cloud-bursts" in the foothill region of the Arkansas Valley in Colorado caused the severest flood in the valley since its settlement. Flood conditions prevailed during the entire period, but there were three distinct floods in the upper valley. The first flood was caused by heavy rain on Dry Creek just above Pueblo on the night of June 2; the second was the main flood, which occurred during the night of June 3; and the third was that due to the breaking of the Schaeffer reservoir, on Beaver Creek, on the morning of June 5. The area considered in this report is shown in Plate I.

The flood was remarkable for the very small area covered by the rainfall that was its chief cause, and for the swift rise of the river to an unprecedented stage and its almost equally rapid fall. The swift rise and fall indicated very great flood discharges of the tributary streams, which drain a mountainous country of steep slopes. The total discharge of the main flood was less than 90,000 acre-feet.

Immediately after the flood the United States Geological Survey undertook an investigation of its causes and results, and the field work was begun as soon as conditions permitted. An examination was made of all the streams within the area affected by the flood to procure data on maximum run-off in the foothill region and the effect of this tributary run-off upon the main flood. The maximum discharge of each stream was determined from the slope shown by well-defined high-water marks and from the average of several cross sections. As there are no regular Weather Bureau stations in the area, especial care was taken to obtain from local residents as reliable statements as possible regarding rainfall and time of flood flows of each stream. From the field data and from information obtained from various reliable sources it has been possible to show the cause of the flood and the cause of its rapid rise and fall at Pueblo. In

addition every effort has been made to obtain the best possible data for determining the maximum and total discharge of the Arkansas at Pueblo. Although no field work was done below the mouth of St. Charles River, available data regarding the flood in that part of the Arkansas Valley have been compiled and are presented in this report.

The field work, which was begun July 6, was in charge of Edward E. Jones, assisted by Kendall K. Hoyt. The computations connected with the field work were made by Mr. Jones, assisted by P. V. Hodges. The office studies were made and the report was prepared by Robert Follansbee, assisted by P. V. Hodges, J. B. Spiegel, and Mrs. Esther D. Rae.

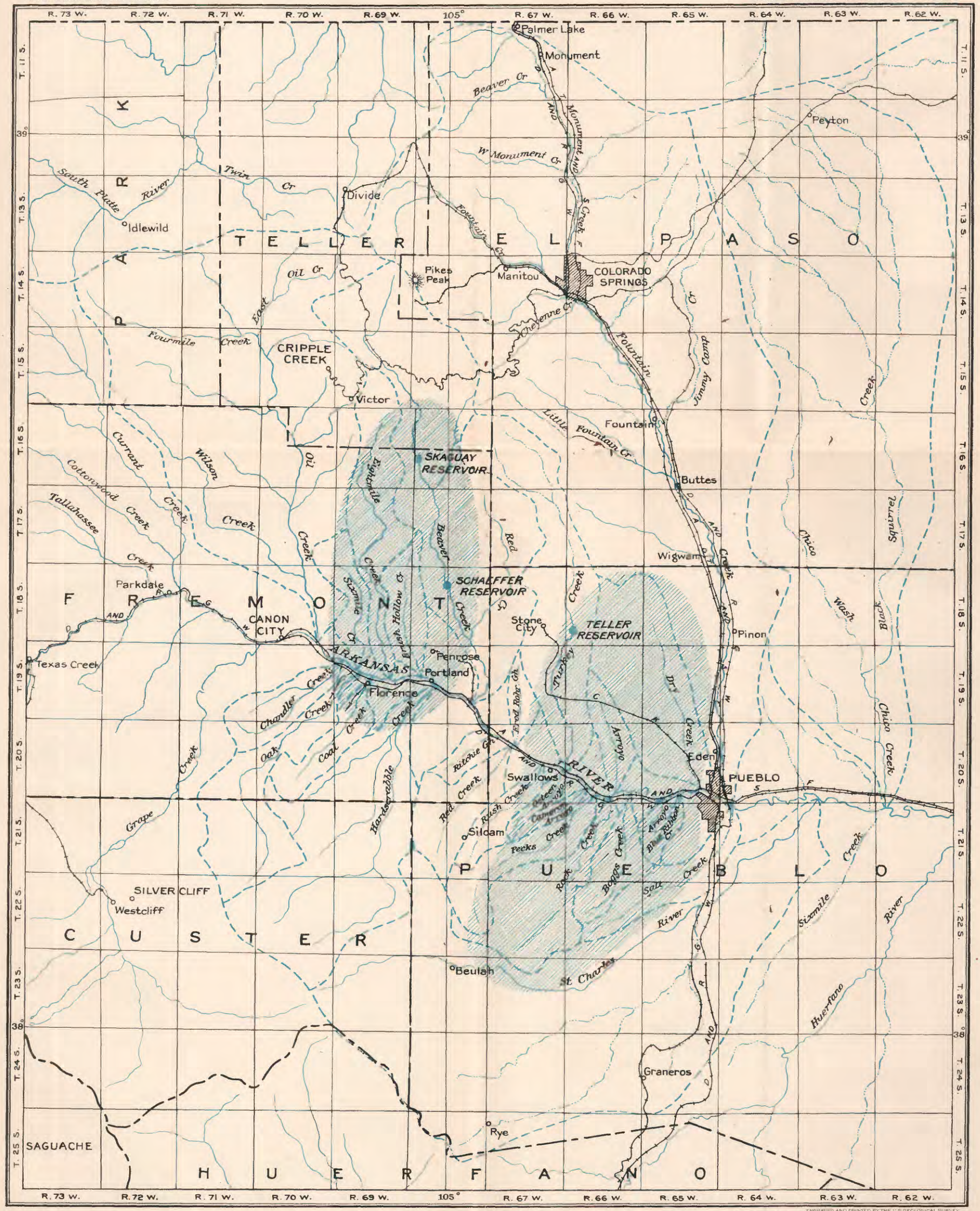
ACKNOWLEDGMENTS.

Acknowledgments are due to the engineering department of the Denver & Rio Grande Western Railroad Co., especially Mr. Arthur O. Ridgway, assistant chief engineer, and Mr. C. M. Lightburn, for placing at the disposal of the Geological Survey data compiled by the railroad in an extensive survey made to determine flood losses; to Mr. R. G. Hosea, deputy State engineer, who furnished data regarding the flood at Pueblo and other valuable information relative to the flow of the Arkansas and several tributary streams; to Mr. H. D. Amsley, State hydrographer, for data on the flood at Pueblo and at other points in the Arkansas Valley; to Mr. J. M. Sherier, meteorologist of the Weather Bureau at Denver, for data and valuable suggestions; to Mr. F. R. Johnson, of the United States Forest Service, for data on rainfall; to Mr. J. L. Savage, designing engineer, United States Reclamation Service, for data on flood losses in Arkansas Valley; and to many local residents for information.

SUMMARY OF FLOOD LOSSES.

The entire Arkansas Valley from Florence, 30 miles west of Pueblo, to the State line, was severely affected, and the loss of life and property was heavy. The greatest damage was done in Pueblo, the chief city in the valley. Below Pueblo the loss was chiefly agricultural, more than 57,000 acres being inundated, of which 4,700 acres was destroyed for agriculture. The headworks of practically every irrigation system in the valley were damaged or destroyed. The valleys of the upper tributaries, notably St. Charles River and Fountain, Chico, and Beaver creeks, were also flooded. By the time the flood reached the Kansas line its crest height had so flattened out that its progress through Kansas caused no damage comparable with that in Colorado.

The exact extent of losses to life and property will never be known. The most complete estimate of property losses was one prepared for the board of United States Reclamation Service engineers who made



MAP OF ARKANSAS VALLEY BETWEEN CANON CITY AND PUEBLO, COLORADO

Blue shading indicates area of intense rainfall; blue dash line boundary of drainage basin of tributary stream

0 10 20 Miles

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an examination of the river and proposed plans for prevention against future floods. This estimate[1] is given below.

Property losses in Arkansas River flood of June, 1921.

Federal, State, and county property	$900,000
Municipal property	800,000
Real estate (city and town)	3,420,000
Personal property (city and town)	3,575,000
Farms	3,675,000
Irrigation works	1,275,000
Railroads	4,275,000
Public utilities	500,000
Other property	250,000
	19,080,000

A report to the Pueblo city council stated that 510 dwellings were washed away, 98 buildings wrecked, and 61 buildings washed from their foundations.

The loss of life in Pueblo was heavy, owing to the swift rise of the river and the unwillingness of many people to heed the flood warnings. The official list places the number of bodies recovered at 78, but many bodies that were washed downstream were not recovered.

All communication with the outside world was cut off, as all telegraph and telephone wires were down. The day after the flood relief measures were started by the city, assisted by local members of the National Guard and the American Legion. Near-by cities sent relief to the flood sufferers as soon as possible, but owing to the impassable condition of the railroads and highways progress was slow. Motor trucks loaded with food, clothing, and medical supplies headed by Army and State highway officers started from Denver and Colorado Springs on the 4th and reached Pueblo on the afternoon of the 5th.

The heaviest loss was incurred by the railroad companies, as the flooded area included nearly all the extensive terminals of the roads that enter Pueblo (Pl. II, *A*). So great was the damage to railroad property not only in Pueblo but in the surrounding territory that not a relief train could enter Pueblo for two days. Of the six railroad bridges over Arkansas River and three over Fountain Creek, only one, the Santa Fe bridge to the Union Depot, escaped. All the others lost one or more spans or large portions of approaches. The Missouri Pacific yard and engine terminal was cut off by a new channel and was left on an island without rail connection. A Denver & Rio Grande train and a Missouri Pacific train were caught in the

[1] Munn, James, and Savage, J. L., The flood of June, 1921, in the Arkansas River, at Pueblo, Colo.: Am. Soc. Civil Eng. Proc., vol. 47, No. 7, September, 1921.

flood while trying to reach higher ground, cars were overturned, and several lives were lost (Pl. II, *B*). The 2,000 cars in the yards during the flood suffered enormous damage; many were floated away and overturned or crushed by the impact or pressure of débris. Some cars were floated great distances and were never recovered.[2] The total property loss in the city was estimated at $10,000,000.

PROGRESS OF FLOOD CREST THROUGH ARKANSAS VALLEY.

The streams that enter Arkansas River between Canon City and the mouth of Chico Creek, 16 miles below Pueblo, were the source of the flood, and in that section of the river the flood crest increased rapidly as it proceeded downstream. Below the mouth of Chico Creek the river received practically no additional flood discharges.

The approximate time of the flood crest at several points, as obtained from local observers, and the maximum discharge at points where it was measured are given in the following table. As the crest flattened out, it became less sharply defined, and the exact time of its arrival at different points was more difficult to determine.

Progress of flood crest through Arkansas Valley.

Point of observation.	Distance between points.[a]	Approximate time of crest.	Rate of progress.	Crest flow.	Duration of crest flow.
	Miles.		*Miles per hour.*	*Sec.-ft.*	
Canon City		8 p. m. June 3		3,740	
Florence	8	8.30 p. m. June 3	16.0	9,000	
Pueblo	35	Midnight June 3	10.0	103,000	6 minutes.
Manzanola	52	9.30 a. m. June 4	5.5		
Rocky Ford	10	11.30 a. m. June 4	5.0		
La Junta	13	3 a. m. June 4	3.7	200,000	45 minutes.
Fort Lyon	28	11 p. m. June 4	3.5		
Head of Amity canal	23	4.30 a. m. June 5	4.2	170,000	3½ hours.
Lamar	7	7.30 a. m. June 5	2.1		
Holly	30	8.30 p. m. June 6	2.3	120,000	

[a] Measured along river.

The table shows that the rate of progress of the flood crest decreased as it traveled down the river. Above Pueblo the decrease was due chiefly to the decreased slope of the river, but this could not have had much effect in the lower part of the valley, as the mean slope decreases only from 8.3 feet to the mile between Pueblo and La Junta to 7.5 feet to the mile between La Junta and the State line. Below La Junta the chief factor in retarding the progress of the

[2] Data on railroad losses taken from Railway Age, June 17, 1921.

A. EFFECT OF FLOOD IN RAILROAD YARDS.

B. OVERTURNED BAGGAGE CAR FROM DENVER & RIO GRANDE TRAIN.

flood was the flattening out of the crest due to the natural storage afforded by the area inundated.

Above La Junta the effect of channel storage in flattening the crest was obscured by the flood flows from the tributary streams, which increased the maximum discharge greatly. Below La Junta the flow from tributaries was small and the storage effect more marked, as shown by the decrease in maximum discharge from 200,000 second-feet at La Junta to 170,000 second-feet at the Amity canal, at a distance of 51 miles, and to 120,000 second-feet at Holly, at an additional distance of 37 miles.

The flattening of the flood crest was compensated by its greater duration. At Pueblo it lasted 6 minutes; at La Junta, 45 minutes; and at Amity canal, 3½ hours. The duration of the crest at Holly is not known, but it must have been several hours.

TOPOGRAPHY OF ARKANSAS BASIN.

The part of the Arkansas drainage basin lying in Colorado is roughly rectangular and occupies the southeastern quarter of the State. Its northwest corner reaches the heart of the Rocky Mountains near Leadville, a little west of the center of the State. Arkansas River is formed by the junction of East Fork and Tennessee Fork, each of which rises in the Continental Divide at an elevation of 11,000 feet or more. From the junction of the two forks, 3 miles west of Leadville, the river flows southeastward for 84 miles to a point near Cotopaxi, then turns and follows an easterly course for 245 miles to the State line. In the upper part of its course it flows through mountainous country in a narrow valley formed by parallel mountain ranges. Between Cotopaxi and Canon City it cuts through the front range of mountains, and a few miles below Canon City it enters the upper end of the open valley. This valley gradually widens until it merges into the Great Plains a few miles west of Pueblo.

The drainage basin east of the mountains lies in the western portion of the Great Plains, which extend from the foot of the Rocky Mountains to the Mississippi Valley. These plains present wide areas of smooth surface traversed by the broad, shallow valley of Arkansas River and more or less deeply cut by the narrower valleys of lateral streams. Smooth surfaces and eastward-sloping plains are the characteristic features, especially of the uplands, but in parts of the region there are buttes, extended escarpments, and canyons of considerable depth.[3] One of these buttes is Baculite Mesa, northeast of Pueblo, which rises 400 feet from the plain.

[3] Darton, N. H., Geology and underground waters of Arkansas Valley, Colo.: U. S. Geol. Survey Prof. Paper 52, p. 8, 1906.

Of the 28,000 square miles drained by Arkansas River in Colorado the upper 3,840 square miles is mountainous, with extremely rugged topography. Within this upper area there are many perennial tributaries, but east of the mountains the tributaries are relatively small except in time of spring high water from melting snow or after heavy rains.

The area covered by the rainfall of June 2–5, 1921, lies chiefly between Canon City and Pueblo. It is bounded on the north by the foothills of the Pikes Peak uplift and on the south by the Wet Mountains and their extension, Greenhorn Mountain. The following description of the topography is quoted from Gilbert:[4]

> Twenty miles south of Colorado Springs the line of foothills turns sharply westward for 20 miles and then, near Canon City, swings quickly to the south and southeast, holding the latter course for 40 miles. Within this flexure is a triangular tongue of the plains country half surrounded by mountain ranges.
>
> For half its course between Canon City and Pueblo the Arkansas is closely hemmed in by rock bluffs 200 feet high, with cliffs of limestone at the top. Elsewhere its immediate valley is more open, usually with a sharp ascent on one side to a gravelly mesa and a long, gradual slope on the other. Farther back the ascent is broken by terraces of gravel or sand or by tracts of clayey badlands and here and there by rocky cliffs and mesas.

Within this area there are many tributaries that rise in the mountains that bound the drainage basin. The tributaries from the north are Oil, Sixmile, Eightmile, Brush Hollow, Beaver, Turkey, and Dry creeks, and those from the south are Chandler, Oak, Coal, Hardscrabble, Red, Rush, Pecks, and Rock creeks.

Between the steep slopes of the Wet Mountains and the river a broad area known generally as Boggs Flat slopes toward the river. Across this area the tributary streams heading in the mountains have cut well-defined channels. In addition to these streams a number of arroyos or dry channels, of which Ritchie Gulch, Osteen and Cameron arroyos, Boggs and Blue Ribbon creeks are the chief, rise in the upland area and carry water during the heavy rains to which this area is subject.

The following table was compiled chiefly from topographic maps:

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[4] Gilbert, G. K., Underground water of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 558, 1896.

Elevations and distances along Arkansas River from Canon City to Colorado-Kansas line.

Point.	Elevation above sea level.	Distance.		Descent between points.	
		From Canon City.	Point to point.	Total.	Per mile.
	Feet.	*Miles.*	*Miles.*	*Feet.*	*Feet.*
Canon City	5,320				
Oil Creek	5,245	3.0	3.0	75	25
Eightmile Creek	5,125	9.8	6.8	120	18
Hardscrabble Creek	5,020	14.5	4.7	105	22
Beaver Creek	4,970	18.0	3.5	50	14
Red Creek	4,900	23.2	5.2	70	13
Pecks Creek	4,775	32.0	8.8	125	14
Union Avenue Bridge, Pueblo	4,670	43.0	11.0	105	10
St. Charles River	4,560	51.8	8.8	110	12
Huerfano River	4,430	67.1	15.3	130	8
Apishapa River	4,280	89.8	22.7	150	7
Bridge north of Rocky Ford	4,150	104.8	15.0	130	9
La Junta	4,050	117.6	12.8	100	8
Adobe Creek	3,930	133.1	15.5	120	8
Purgatoire River	3,850	142.5	9.4	80	9
Caddoa	3,760	156.3	13.8	90	7
Lamar	3,600	176.3	20.0	160	8
Big Sandy Creek	3,550	185.0	8.7	50	6
Bridge north of Granada	3,480	194.8	9.8	70	7
Colorado-Kansas line	3,350	211.4	16.6	130	8

CAUSE OF FLOOD.

The cause of the flood was a series of cloud-bursts [5] resulting from heavy rain-bearing clouds striking against the mountains and being deflected upward.

The daily weather maps for the first week in June show that an area of high pressure (exceeding 30.5 inches) appeared over the

[5] The phenomena called "cloud-bursts" are very intense rainfalls of short duration over small areas that are sharply defined. Cloud-bursts are common along the eastern slope of the Rocky Mountains wherever canyons have cut deeply into the mountain masses. Each of these canyons acts like a chimney flue in creating a strong upward draft for the warm and relatively moist air from the plains, which passes up the canyon and reaches an altitude where the temperature becomes low enough to condense the moisture. The upward draft is sufficiently strong to support the moisture for some time after condensation begins, but finally the weight of moisture in the air becomes too great to be longer sustained and it is precipitated in torrents.

Cloud-bursts of less violence also occur on the plains. The air over a small area becomes abnormally heated, and the convectional currents force the air upward.

Coincident with a cloud-burst is the other phenomenon of a "wall of water" rushing down the stream. Where the soil is clayey and has been baked hard by the sun, the conditions are ideal for rapid run-off after a heavy rain. The following explanation of the "wall of water" is taken from Engineering and Contracting for June 8, 1921:

"When rain begins to fall more rapidly than the soil can absorb it, the first thin sheet of water that flows down the watercourses moves slowly, because the friction of the water is proportionately greater the shallower the stream. The friction acts like a dam, holding the stream back. Hence it follows that the water tends to bank up, so that the rain that fell first is overtaken by rain that fell many minutes later. The deeper the stream the faster it flows, for the frictional resistance is then proportionately less. Consequently the time comes when the flood moves rapidly down the watercourse, its front crest often being several feet deep and looking like a huge sea wave about to break on a shore."

province of Alberta on June 1. By the 2d it had displaced a low-pressure area over the upper Missouri Valley, and on the 3d it was over Manitoba and the northern part of North Dakota. Between the 3d and 4th the movement was very slow, and it advanced only as far as northeastern Minnesota. By June 5 the area had reached a point over the Great Lakes. During this period an area of low pressure (29.7 inches) had developed over western Arizona and remained over the southern Rocky Mountain plateau for several days. The difference in pressure between the "high" and "low" areas caused air currents to travel from the "high" to the "low" in an endeavor to equalize the pressure. The movement from the "high" area was outward and downward in a general clockwise direction toward the "low" area.

The relative positions of the areas of high and low pressure caused the storm to come primarily from the east or northeast. All along the front range in Colorado and New Mexico heavy rains occurred when the clouds were forced upward by reaching the mountains, but nowhere else was the rainfall as heavy as in the upper Arkansas Valley.

The general line of the front range and foothills bears to the southeast from the Wyoming boundary to Pikes Peak, a semidetached mountain mass rising abruptly from the plains. South of Pikes Peak the front range and line of foothills turn sharply westward for 20 miles and then near Canon City swing quickly to the south and southeast and keep that course for 20 miles. This reentrant angle in the general line of the front range had a marked influence on the storm, causing it to concentrate at that point. From the statements of observers it is evident that the storm was deflected by Pikes Peak and came into the smaller area of heavy precipitation (pp. 15–16) from the north. Owing to the funnel shape of the valley opening upon the plains, air rushed into it both from the northeast and from the southeast around the end of Greenhorn Mountain. The rushing together gave the combined air currents a more or less circular movement that caused them to swing around to the north and northwest, where they met the storm coming down from the north. This circular motion caused the clouds to impinge against the side of the mountains so violently that they rose quickly and precipitated their moisture with great rapidity. Thunderstorms and hail, which occurred at the beginning of the rain, indicated the strong convective character of the storm.

The Weather Bureau received reports of precipitation at a number of points in this general region, which are summarized in the following table:

Rainfall in upper Arkansas Valley, June 2–6, 1921, in inches.

[Except as noted all records are for 24 hours ending at 8 a. m. The records at Florence were taken by the United Oil Co.]

Station.	Elevation above sea level.	June 2.	June 3.	June 4.	June 5.	June 6	Total.	Precipitation in 48 hours ending afternoon of June 4.
	Feet.							
Canon City	5,343	.....	0.30	2.35	0.75	0.40	3.80	2.65
Florence	5,187	.....	.99	3.31	2.47	.13	6.90	4.11
Pueblo [a]	4,685	1.94	1.64	1.45	1.12	.09	6.24	3.09
Colorado Springs	6,098	.14	2.22	1.87	.55	.40	5.18	4.09
Lake Moraine [b]	10,268	.....	.65	3.68	1.40	.18	5.91	4.33
Fremont experiment station	8,850	.....	2.53	2.61	1.43	.48	7.05	5.14
Victor [c]	10,100	.....	.03	2.08	1.55	.37	4.03	2.11
Monument	7,200	.06	.....	2.90	.82	.05	3.83	2.90
La Veta Pass	9,220	.....	.98	.89	.....	.20	2.07	1.87
Huerfano	6,010	.....	.....	1.06	.56	.04	1.66	1.06
Ordway	4,300	.25	.....	.90	.75	.19	2.09	.90
La Junta	4,052	.....	.....	.80	.81	.08	1.69	.80

[a] Records represent rainfall for 24 hours ending at midnight.
[b] Records represent rainfall for 24 hours ending at 6 p. m.
[c] Records represent rainfall for 24 hours ending at 4 p. m.

No Weather Bureau stations are maintained in the region of heavy rainfall, which, in the Arkansas River basin, extended from a point north of Colorado Springs on the north to the Wet Mountains on the south, and from Canon City on the west to a point just west and north of Pueblo on the east. Within this region in small areas the rainfall was intense. The precipitation in these areas can only be roughly estimated from statements of local residents, many of whom were interviewed for that purpose. The subjoined table and the brief statements that follow it summarize most of the information obtained.

Summarized statements of local residents regarding rainfall on June 3, 1921.

Locality.	Statement regarding amount.	Duration.	
		Began.	Ended.
NORTH OF ARKANSAS RIVER.			
Dry Creek near mouth	Cloud-burst	4 p. m.	
Dry Creek in sec. 26, T. 20 N., R. 65 W.	Hardest at 10 p. m	7.30 p. m.	
Sec. 27, T. 20 S., R. 65 W., just west of Pueblo.	12 inches (measured in concrete box).	Night of June 3-4.	
Teller reservoir on Turkey Creek	10 inches	3 p. m.	Morning of June 4
Skaguay reservoir on West Beaver Creek.	7.5 inches (measured in bucket on morning of June 5).	.....	
3 miles east of Penrose	7 inches (measured in standard rain gage); hardest at 9 p. m.	3 p. m.	8 a. m. June 4.
Penrose	.....	7 p. m.	Morning of June 4.
Brush Hollow Creek in sec. 18, T. 19 S., R. 69 W.	.....	8 p. m.	Midnight.
Eightmile Creek 5 miles above mouth.	10 inches (hardest about 3.15 p. m.).	3 p. m.	
Eightmile Creek in sec. 15, T. 19 S., R. 69 W.	.....	5 p. m.	11 p. m.
Oil Creek in sec. 35, T. 18 S., R. 70 W.	No cloud-burst; ordinary hard rain.	.....	

Summarized statements of local residents, etc.—Continued.

Locality.	Statement regarding amount.	Duration.	
		Began.	Ended.
SOUTH OF ARKANSAS RIVER.			
Chandler Creek half a mile west of Florence.	9 inches (measured in bucket); did not extend up Chandler Creek 3 miles.	Hardest at 6.30 p. m.	
Hardscrabble Creek on divide southeast of Florence.	4 inches of water ran over prairie..	3 p. m.....	
Rush Creek in sec. 9, T. 21 S., R. 67 W.	.....	3 p. m.....	11 p. m.
Rush Creek in sec. 22, T. 20 S., R. 67 W.	Cloud-burst for 30 minutes. Hardest rain 2 miles south.	.....	
Pecks Creek 8 miles above mouth...	Tremendous rain; water ran everywhere.	2.30 p. m..	
Pecks Creek in sec. 34, T. 21 S., R. 67 W.	.....	4 p. m.....	
Cameron and Osteen arroyos in sec. 30, T. 20 S., R. 66 W.	Five periods of very hard rain.....	3 p. m.....	Midnight.
Head of Rock Creek in sec. 34, T. 21 S., R. 67 W.	4 inches of water on level.....	{4 p. m..... / 9 p. m....	6.30 p. m. / Midnight.
Between Rock and Soda creeks, sec. 29, T. 21 S., R. 66 W.	Horse drowned in open field.....	3–4 p. m...	
Boggs Flat, about sec. 35, T. 21 S., R. 66 W.	5 inches in 30 minutes; 6 inches of water ran over prairie.	5 p. m.....	Morning of June 4.
Blue Ribbon Creek in sec. 32, T. 20 S., R. 65 W.	Hardest at 10 p. m.....	4 p. m.....	
Blue Ribbon Creek in sec. 2, T. 21 S., R. 65 W.	10 inches (hardest at 10 p. m).....	3 p. m.....	
Beulah, in sec. 3, T. 23 S., R. 68 W..	Hard rain all night.....	6 p. m.....	4 a. m. June 4.

NOTE.—Except where method of measuring rainfall is given above, the amounts can be considered only roughly approximate, as the observers had no means of making accurate measurements.

Several ranchers on Boggs Flat stated that the precipitation during the afternoon and night of June 3 was 14 inches. A hard-surfaced road in that section was washed out to a depth of 7 feet.

The area drained by Dry Creek, unlike those of the other tributary streams, had its severest rain on June 2. Mr. J. F. Wing, who lives in sec. 26, T. 20 S., R. 65 W., stated that the heaviest rain began about 2 p. m. June 2 and continued until midnight or later. At 11 p. m. the bridge over Twenty-fourth Street in Pueblo was washed out. On June 3 it was misty or rainy all day, and at 7.30 p. m. a very hard rain began, which became a cloud-burst at 10 p. m.

The residents living south of Arkansas River agreed that the storm came from the northeast, then worked around north, and finally to the northwest. The most complete statements are summarized below.

Mr. Fred Rosencrantz, who lives in secs. 32 and 33, T. 20 S., R. 65 W., said that the storm appeared to come from the northeast and was met by another storm which came from Old Baldy (local name for Greenhorn Mountain) to the southwest. At that time the water in the Arkansas appeared to be flowing both up and down stream, the up-river current being caused by the inflow from Blue Ribbon Creek and other arroyos from the south.

Mr. C. F. Burke, manager of the Blue Ribbon ranch, in secs. 2 and 3, T. 21 S., R. 65 W., stated that the storm appeared to come from the northeast and was met by a storm from the southwest.

Mr. J. H. Farris, in sec. 34, T. 21 S., R. 67 W., stated that he first noticed storm clouds in the northeast. The storm appeared to work to the west on the north side of the river, then south and southeast, and when it reached his ranch was coming from the northwest.

Mr. E. C. Higgins, who lives at the crossing of the Penrose and Canon City road over Eightmile Creek, 6 miles above its mouth, gave the most complete account of the storm. He said the sky had been very cloudy the entire morning of June 3. From the mesa above his house he could see for many miles along the east face of the Wet Mountain range, which lies south of Arkansas River. A dense bank of black clouds lay along the top and sides of the range during the morning, and about 1 p. m. it dropped down from the mountains and seemed to push out along the mesa top. A similar bank of clouds had hung in the hills to the north, in the direction of Cripple Creek. These clouds gradually dropped lower, and by 1 p. m. it started to rain in the hills. Between 2.30 and 3 p. m. it began to rain at the Higgins ranch, and in a few minutes the rain was pouring down in sheets so continuous that it was impossible to see across the highway lane in front of the house.

Mr. Sim Wells, superintendent of the Colorado Fuel & Iron Co.'s ditch, who lives near the mouth of Rock Creek, stated that at the point where the creek leaves the high mesa lands the water came over the edge of the mesa in great sheets for a distance of half a mile on each side.

The rain began in the foothills north of the narrow mountain valley about 1 p. m. By 3 p. m. it had spread over the upper and middle parts of the valley, and between 5 and 7 p. m. it reached the lower end near Pueblo. On Eightmile, Rush, and Rock creeks the hardest rain occurred between 3 and 4 p. m.; near Pueblo it did not occur until 10 or 11 p. m. The rain continued with intermissions until after midnight.

PRINCIPAL AREAS OF INTENSE RAINFALL.

The Weather Bureau records (p. 13) indicate that for the 48 hours ending on the afternoon of June 4 the rainfall in the drainage basin between Canon City and Pueblo was from 3 to 5 inches and that it was heaviest in the northern part of this area, near Pikes Peak. Within this general region there were smaller areas where the rainfall was very intense but of short duration.

The statements of local residents and the measured maximum discharges of the tributary streams indicate two principal areas of intense rainfall. (See Pl. I.) The larger area, which is roughly elliptical, extends from the northern boundary of Pueblo County to the top of the Wet Mountains near Beulah, a distance of 30 miles, and from a point a short distance above the mouth of Rush Creek nearly to Pueblo, a distance of 15 miles. The smaller area covers the south slope of the Pikes Peak uplift, which forms the northern part of the mountain valley, and extends from a point above Skaguay reservoir to a point 3 or 4 miles south of the river, a distance of 25 miles, and from Oil Creek to Beaver Creek, a distance of 11 miles. The two areas cover 550 square miles.

EFFECT OF RESERVOIRS ON THE FLOOD.

Considerable misinformation relative to the effect of reservoirs upon the flood was disseminated by the general and technical press at the time of its occurrence. There are three reservoirs of considerable size within the areas of intense rainfall, and none of these contributed to the main flood of June 3. The Schaeffer reservoir, on Beaver Creek, failed on June 5, causing the flood of that date, which was very severe in the valley immediately below the mouth of Beaver Creek but flattened out farther downstream. The other two reservoirs, the Skaguay reservoir, on Beaver Creek, and the Teller reservoir, on Turkey Creek, safely withstood the flood. At the time of the main flood the three reservoirs helped in a slight degree to reduce its magnitude by holding back a portion of the run-off above them.

The Schaeffer reservoir, which had a capacity of 3,190 acre-feet, was formed by an earth dam across Beaver Creek in sec. 9, T. 18 S., R. 68 W. The dam had a maximum height of 100 feet above the bottom of the outlet and a length on the crest of 1,100 feet. Its average height was about 90 feet for the middle 500 feet of its length. The width on the crest was 15 feet, the outside slope 2 to 1, and the inside slope 3 to 1. A freeboard of 10 feet was provided. A concrete cut-off wall was provided in the middle portion of the dam, and a timber cut-off wall for the remainder. The inlet was a concrete tunnel 4 feet wide and 5 feet high, constructed on bedrock. The dam was built to a height of 20 to 30 feet by the hydraulic-fill method when it was observed that the material deposited in the center of the dam retained water and did not consolidate, being more nearly liquid than solid. The liquid material was replaced by dry earth, and the dam was finished by depositing the earth by wagons, sprinkling, and rolling in thin layers. The inner slope was riprapped to the top. A spillway 100 feet wide was provided beyond

the east end of the dam, and the discharge was led away from the toe of the embankment by a canal constructed for that purpose.[6]

Mr. C. E. White, superintendent of the water division of the Beaver Park Irrigation Co., gave the following account of the failure of the reservoir (see Pl. III, *A*):

> The storm of June 3 began at the reservoir about 7 p. m. At that time the water in the reservoir stood 7 feet below the spillway level. By 4.30 a. m. June 4 the run-off above the reservoir filled the reservoir and the water began to run over the spillway. By 7.30 a. m. the spillway was discharging 1,500 second-feet, and in addition the large outlet gate was opened halfway. At 5.30 p. m. the water flowing over the spillway had fallen 9 inches, and it was believed the flood had been successfully passed. Two hours later, at 7.30 p. m. June 4, the water flowing over the spillway began to rise again and continued to rise at the rate of 3 inches an hour. At this time the large outlet gate was opened wide, as was also a by-pass gate having a capacity of 88 second-feet. The water dropped slightly about 9.30 a. m. June 5, and shortly afterward the water appeared to give a surge and overtopped the dam for about 75 feet along its middle section. At this time the water flowing over the spillway was 4½ feet deep. The dam failed soon afterward, being almost entirely washed out, and in 30 minutes' time the reservoir was empty.

By the failure of the Schaeffer dam about 3,600 acre-feet of water was released into Beaver Creek within 30 minutes. This resulted in a veritable wall of water rushing down Beaver Creek and causing a flood in Arkansas River. The sudden rush of water down the Arkansas swept all before it for several miles, or until the natural storage of the river channel reduced the peak. The greatest damage was caused near Swallows, where several buildings and all freight cars standing on side tracks were washed away. The following table shows the time the flood was observed at several points between the reservoir and Pueblo:

Observed time of flood of June 5, 1921, at several points between Schaeffer reservoir and Pueblo.[a]

Point of observation.	Time.	Distance below reservoir.
		Miles.
Reservoir	9.30 a. m.	0
Mouth of Beaver Creek	10.45 a. m.	9
Swallows	11.30 a. m.	19
Goodnight	1.30 p. m.	29
Pueblo	2.15 p. m.	34

[a] Data furnished chiefly by Mr. Arthur O. Ridgway.

The distance of 9 miles down Beaver Creek was covered in 1¼ hours, an average of 7.2 miles an hour. Down the Arkansas the flood

[6] Colorado State Engineer Fifteenth Biennial Rept., p. 122, 1911.

traversed a distance of 25 miles in 3½ hours, an average rate of 7.1 miles an hour.

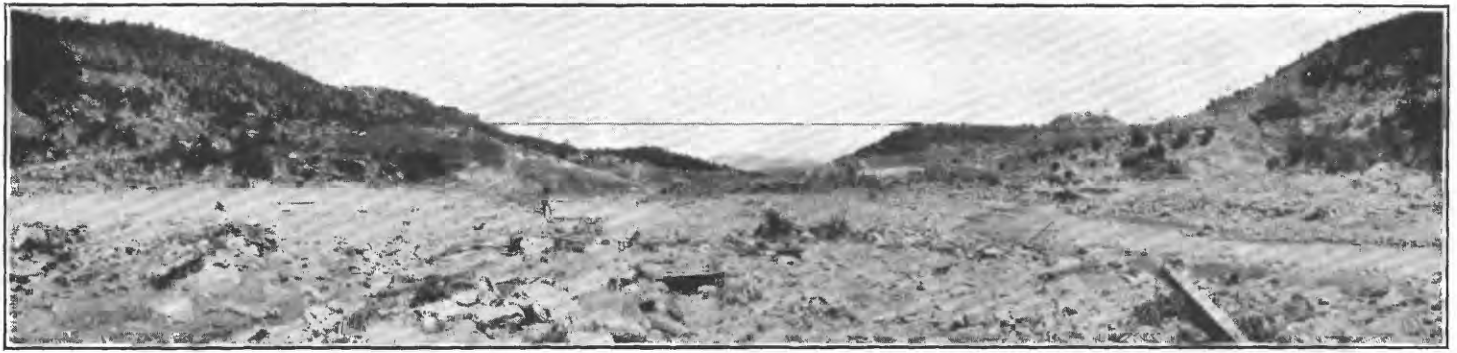
The maximum discharge of Beaver Creek was determined as 153,000 second-feet at a point 1 mile above its mouth. Although this discharge is extremely high, it is entirely reasonable, as the mean discharge required to empty the reservoir in 30 minutes would have been 87,100 second-feet. (See Pl. III, *B*.)

At Pueblo the maximum discharge of the river caused by this flood, which lasted from 3 to 4 p. m. on June 5, was 31,000 second-feet. Before and after the flood the discharge of the river was about 15,000 second-feet, and the difference, 16,000 second-feet, represents the flood crest from Beaver Creek as it reached Pueblo. Thus in traversing 25 miles of river that was at medium flood stage the crest decreased from 153,000 second-feet to 16,000 second-feet.

The Skaguay reservoir is formed by a dam across the channel of West Beaver Creek. The dam is a steel-faced granite back-filled structure, having a maximum height of 70 feet to the spillway level. Its length is 405 feet on the crest and 220 feet at the base. The top width is 20 feet. The steel-faced upstream slope stands at an angle of 30° with the vertical, and the downstream slope at an angle of 50°. The spillway is 60 feet wide and is cut through granite beyond the northwest end of the dam. It is divided into six parallel channels by concrete and timber partitions. (See Pl. IV, *B*.) The steel plates are sheets measuring 5 by 15 feet and decreasing in thickness from half an inch at the bottom to a quarter of an inch at the top. This dam successfully withstood the flood, although the water ran over it in the low places. To stop this overflow flashboards in the spillway were blown out with dynamite, and the consequent sudden release of water into the channel below the dam washed out 50 feet of wood-stave pipe-line leading to the power house, 5 miles below.

The Teller reservoir [7] is formed by the construction across Turkey Creek of an earth dam having a maximum height of 106 feet, a crest length of 770 feet, and a bottom length of about 500 feet. The hills that form the abutments of the dam are very steep, and near the top the dam abuts against rock cliffs at both ends. The embankment has a crest width of 22 feet, an outside slope of 1½ to 1, and an inside slope of 3 to 1. The inner slope is protected by a reinforced-concrete pavement 4 inches thick, anchored to the earthwork by concrete plugs 6 inches in diameter and 2 feet long, spaced 12 feet apart. This concrete pavement is connected with a concrete toe wall, which is carried to bedrock across the creek bottom. Concrete cut-off walls were also provided where the embankment abuts against the rock cliffs at the ends. The outlet consists of a concrete tunnel 7 feet wide and

[7] Colorado State Engineer Fifteenth Bienn. Rept., p. 119, 1911.



A. VIEW LOOKING UPSTREAM TOWARD SITE OF SCHAEFFER DAM.

Débris from dam in foreground. Line shows former crest of dam.

B. BEAVER CREEK 1 MILE ABOVE MOUTH.

X-X, Section used to determine maximum discharge.

A. EIGHTMILE CREEK, SHOWING TYPICAL SECTION USED IN DETERMINING MAXIMUM DISCHARGE.

Dotted lines show location of upper, middle, and lower cross sections.

B. SKAGUAY RESERVOIR, WITH DAM (IN FOREGROUND) AND SPILLWAY (IN CENTER).

6 feet 4 inches high constructed in a trench in the natural ground entirely below the artificial embankment. This tunnel is provided with two 30-inch pipe inlets equipped with gate valves. A spillway for the reservoir was provided over a rock cliff some distance from the dam.

This reservoir successfully withstood the flood, storing all the run-off above it until the high water had passed.

FLOOD FLOWS.

METHOD OF DETERMINATION.

As no gaging stations were maintained on the streams within the areas of intense rainfall, it was necessary to determine the maximum discharge by the slope method after the flood had passed. The work was done with a plane-table equipped with a Johnson quick-leveling head, a reconnaissance alidade having a 3-inch striding level, a 14-foot stadia rod graduated to half-tenths, and a 100-foot steel tape. All distances were measured with the tape and checked by stadia.

Each tributary stream was measured as near the mouth as the condition of the channel permitted. A careful inspection was made to locate a segment of channel which was reasonably straight and free from brush or other obstruction and in which the discharge had been confined to the regular channel with little or no overflow. In the portion of the stream measured cross sections were measured at the upper end, middle, and lower end. Plate IV, *A*, shows a typical segment. At each of the three sections stakes were set at the high-water line on each side of the channel. Beginning at the upstream end a level line was run around the six stakes, closing on the initial point with an allowable error of 0.05 foot. The distance on each side between stakes was measured along the high-water line. The cross section between each pair of stakes on opposite sides of the channel was carefully measured. The general location of each measuring point was determined by reference to section corners. Owing to the effect of bends in the channel that could not be entirely avoided, the difference in elevation between adjacent cross sections was not the same on both sides of the stream, nor was the distance as measured along the high-water line the same on both sides. Both distances and differences in elevation were averaged to determine the mean slope between adjacent sections.

Each cross section was plotted on a large scale, and the area was determined by planimeter. By means of tables based on Kutter's formula for flow in open channels the discharge between the upper and middle cross sections and that between the middle and lower sections were determined, the areas of the two cross sections being aver-

aged and the average slope between them being used. The discharge through the upper, middle, and lower sections was also determined by averaging the hydraulic factors for all three cross sections and using the average slope between the upper and lower sections. Thus, three separate determinations of the discharge of each stream were made. In general, the discharge given by the last-mentioned determination was used. Where the difference in area between the upper and lower cross sections made a marked difference in the velocity through each section, a correction for velocity of approach was applied to the slope between them.

Although the conditions of flow were not the same for all cross sections the main channels were uniformly free from vegetation, and as the overflow areas were only a small percentage of each cross section the value for the coefficient of roughness (n) was taken as 0.035 for the tributary streams and 0.030 for Arkansas River above Pueblo.

The best section of Arkansas River for using the slope method of measurement is just west of Pueblo and above Dry Creek. In this locality three cross sections of the river valley between well-defined high-water marks were measured. The lower section was opposite the lower end of the North Side settling basin of the city waterworks; the middle section 1,230 feet upstream, at the upper end of the settling basin; and the upper section 1,740 feet farther upstream. On computing the mean slope between the different sections the slope between the middle and lower sections was found to be so slight that it was believed to be within the influence of backwater from Pueblo and was discarded. The slope for a mean distance of 1,740 feet between the upper and middle sections was found to be 0.00125, and the maximum discharge was determined from the mean of the areas of the two cross sections as 83,500 second-feet.

To determine the maximum discharge at Pueblo it was necessary to add the flow entering from Dry Creek. It was impossible to determine definitely the amount of water in Dry Creek at the time of the peak flow in Pueblo, as Dry Creek had two floods, one during the night of June 2–3 and one the evening of June 3. The maximum discharge of the stream in the first flood was found to be 24,400 second-feet, and as the second flood was somewhat less the discharge at the time of the Pueblo peak was assumed to be 19,500 second-feet. By adding this assumed discharge of 19,500 second-feet in Dry Creek to the discharge of the Arkansas above Dry Creek the maximum discharge of the Arkansas at Pueblo was found to be 103,000 second-feet.

The results of the field work are given in the following table:

Maximum discharge of streams in area of heavy rainfall near Pueblo.

Stream.	Tributary from north or south.	Distance above Main Street bridge, Pueblo.	Maximum discharge.		Drainage area.	Time of flood crest.	Hydraulic factors used in computations.					
			Total.	Per square mile.			Mean distance between upper and lower sections.	Slope.	Wetted perimeter.	Hydraulic radius.	Area of mean cross sections.	Mean velocity.
		Miles.	*Sec.-ft.*	*Sec.-ft.*	*Sq. miles.*		*Feet.*		*Feet.*		*Sq. ft.*	*Ft. per sec.*
Oil Creek	N.	40.2	2,510	6	423	11 p. m. June 3	975	0.0079	107	3.00	3.1	7.81
Chandler Creek	S.	36.2	1,610	118	13.6	7 p. m. June 3	435	.0200	68.3	2.31	158	10.20
Sixmile Creek	N.	35.8	1,890	77	24.6	7.30 p. m. June 3	600	.0066	114	2.60	295	6.41
Oak Creek	S.	35.2	2,760	41	68	7 p. m. June 3	400	.0051	72.0	4.54	327	8.44
Coal Creek	S.	34.5	3,720	167	22.3	7 p. m. June 3	420	.0101	54.3	5.23	284	13.10
Eightmile Creek	N.	33.5	10,000	154	65	8.30 p. m. June 3	927	.0133	243	3.60	872	11.50
Brush Hollow Creek	N.	31.0	5,320	243	21.9	8 p. m. June 3	500	.0063	87	5.62	489	10.88
Hardscrabble Creek	S.	28.8	3,300	19	173	7.30 p. m. June 3	587	.0052	172	3.01	518	6.37
Beaver Creek	N.	25.0	[a] 9,470	45	213	7.30 a. m. June 4	1,787	.0097	715	10.35	7,400	20.65
Ritchie Gulch	S.	22.0	920	41	22.6	5 p. m. June 3	600	.0065	40.1	3.14	126	7.30
Fred Rohr Gulch	N.	20.0	968	104	9.3	5 p. m. June 3	800	.0126	54.6	2.24	122	7.92
Red Creek	S.	19.8	911	22	40.6	5 p. m. June 3	782	.008	66.6	2.19	146	6.23
Rush Creek	S.	16.8	4,670	238	19.6	5.30 p. m. June 3	575	.0159	83.9	4.05	340	13.73
Turkey Creek	N.	14.2	9,000	188	[b] 48	8.30 p. m. June 3	600	.0069	115	6.35	730	12.32
Osteen Arroyo	S.	13.5	9,060	1,160	7.8	9 p. m. June 3	620	.0200	127	4.37	555	16.30
Cameron Arroyo	S.	12.0	13,900	1,900	7.3	9 p. m. June 3	500	.0193	197	4.40	864	16.10
Pecks Creek	S.	11.0	19,400	564	34.4	5 or 6 p. m. June 3	775	.0067	288	5.83	1,680	11.51
Rock Creek	S.	9.8	53,900	913	59	9 p. m. June 3	1,042	.0080	422	8.11	3,420	15.75
Unnamed arroyo [c]	N.	9.5	9,740	619	15.8	5.45 p. m. June 3	600	.0100	76	7.44	566	16.60
Boggs Creek [c]	S.	8.2	15,400	582	26.5	6.30 p. m. June 3	600	.0032	208	7.52	1,567	9.26
Unnamed arroyo [c]	S.	4.8	1,910	1,060	1.8	11 p. m. June 3	400	.0143	56.5	1.66	93.9	6.74
Blue Ribbon Creek	S.	4.2	9,130	1,360	6.7	11 p. m. June 3	800	.0103	285	3.36	958	9.53
Arkansas River [d]		2.5	83,500			Midnight June 3	1,740	.00125	1,782	7.1	12,650	6.52
Dry Creek	N.	1.8	24,400	283	86	11 p. m. June 2	1,100	.0075	274	6.95	1,905	12.80

[a] The maximum discharge given for Beaver Creek is that due to the storm which occurred more than 24 hours before the failure of the Schaeffer reservoir (in the channel of Beaver Creek, 9 miles above its mouth). The amount passing the spillway and waste gates of the Schaeffer reservoir at the time of the maximum natural discharge of Beaver Creek was computed to be 3,100 second-feet. To this was added the drainage to Beaver Creek from 68.5 square miles between the dam and the mouth. The maximum discharge of Red Creek, the chief tributary, was found to be 4,490 second-feet, or 93 second-feet per square mile. Applying this unit run-off to the entire additional drainage area gives a run-off of 6,370 second-feet, which added to the 3,100 second-feet passing the dam gives a total maximum natural discharge of 9,470 second-feet for Beaver Creek at its mouth. For the maximum discharge due to the breaking of the Schaeffer reservoir, see pp. 17–18.

[b] The area of 48 square miles is that of Turkey Creek below the Teller reservoir, as little or no water passed the dam during the period of maximum discharge of the creek.

[c] The discharge given above represents the computed discharge at the mouth. The measuring point was a considerable distance above the mouth, and the unit run-off above that point was applied to the area above the mouth to determine the total discharge. The hydraulic factors are those for the point of actual measurement.

[d] The discharge of Arkansas River at Pueblo as given on p. 20 was 103,000 second-feet.

Maximum discharge of streams in area of heary rainfall near Pueblo—Continued.

Stream.	Tributary from north or south.	Distance above Main Street bridge, Pueblo.	Maximum discharge.		Drainage area.	Time of flood crest.	Hydraulic factors used in computations.					
			Total.	Per square mile.			Mean distance between upper and lower sections.	Slope.	Wetted perimeter.	Hydraulic radius.	Area of mean cross sections.	Mean velocity.
		Miles.	*Sec.-ft.*	*Sec.-ft.*	*Sq. miles.*		*Feet.*		*Feet.*		*Sq. ft.*	*Ft. per sec.*
Fountain Creek	N.	[e] 1.5	34,000	36	932	3 a. m. June 4	1,591	00.34	764	5.60	4,280	7.95
Salt Creek [f]	S.	[e] 1.5	32,100	.....	.....	2 a. m. June 4	870	.0208	179	7.50	1,340	24.00
St. Charles River [g]	S.	[e] 8.8	71,800	.....	.....	1 a. m. June 4	1,820	.0034	718	9.04	6,494	11.07
Chico Creek [h]	N.	[e] 15.0	28,600	38	750	4 a. m. June 4	.....	.....	.....	.....	.....	.....

[e] Below Pueblo.

[f] The discharge of Salt Creek was increased greatly by water from St. Charles River through the Colorado Fuel & Iron Co.'s feeder ditch, the headgate of which was washed out. As the discharge of Salt Creek was so greatly increased from St. Charles River the unit run-off has no value.

[g] The measured discharge of St. Charles River does not include the overflow to Salt Creek; no unit run-off given.

[h] Measurement made by State engineer's office.

THE FLOOD BETWEEN CANON CITY AND PUEBLO.

From Canon City to Florence, a distance of 8 miles by river, the valley is comparatively narrow and was little damaged by the flood. The maximum discharge increased from 3,740 second-feet at Canon City to 9,000 second-feet at Florence.[8] The tributary streams in this section—Oil, Chandler, Sixmile, Oak, and Coal creeks—lie partly within the upper of the two areas of intense rainfall but did not have as high unit discharges as the tributaries nearer Pueblo. (See table of maximum discharge, pp. 21–22.)

Between Florence and the mouth of Beaver Creek, a distance of 10 miles, the discharge must have increased considerably, as the principal tributaries, Eightmile, Brush Hollow, and Hardscrabble creeks, had their flood crests between 7.30 and 8.30 p. m. on June 3, about the time the river was highest at Florence. At Portland, 5 miles below Florence, the highest water occurred at 11 p. m., when the water was 4 feet deep in the Denver & Rio Grande Railroad station. The water started to fall here at 11.30 p. m. and in an hour had fallen 3½ feet.

From Beaver Creek to Turkey Creek, a distance of 11 miles, the maximum stage during the evening of June 3 could not have increased very greatly, as the tributary streams, Rush and Red creeks and Ritchie and Fred Rohr gulches, had their flood crests about 5 p. m., several hours before the passage of the main flood crest in the river. In this stretch the greatest damage was caused not by the flood of June 3 but by that of June 5 due to the failure of the Schaeffer reservoir on Beaver Creek (p. 17). (See Pl. V, *B*.)

Between Turkey Creek and Pueblo the discharge of the river increased very rapidly, as this was the section which received the maximum run-off from the areas of intense rainfall.

THE FLOOD AT PUEBLO.

GENERAL FEATURES.

Pueblo, the second city in size in the State, is on Arkansas River a few miles east of the foothill region and just above the mouth of Fountain Creek. The 1920 census gave its population as 42,908. It is an important railroad center, being on the lines of the Atchison, Topeka & Santa Fe, Denver & Rio Grande Western, Missouri Pacific, and Colorado & Southern railways. It is also an important manufacturing center, the steel mills, smelters, railroad car shops,

[8] Engineers of the Denver & Rio Grande Railroad Co. measured a cross section of the river 300 feet below Pikes Peak Avenue bridge and also measured the slope from a point 1,100 feet upstream to a point 1,100 feet downstream. The slope was found to be 0.0031, and the discharge was computed as 9,000 second-feet.

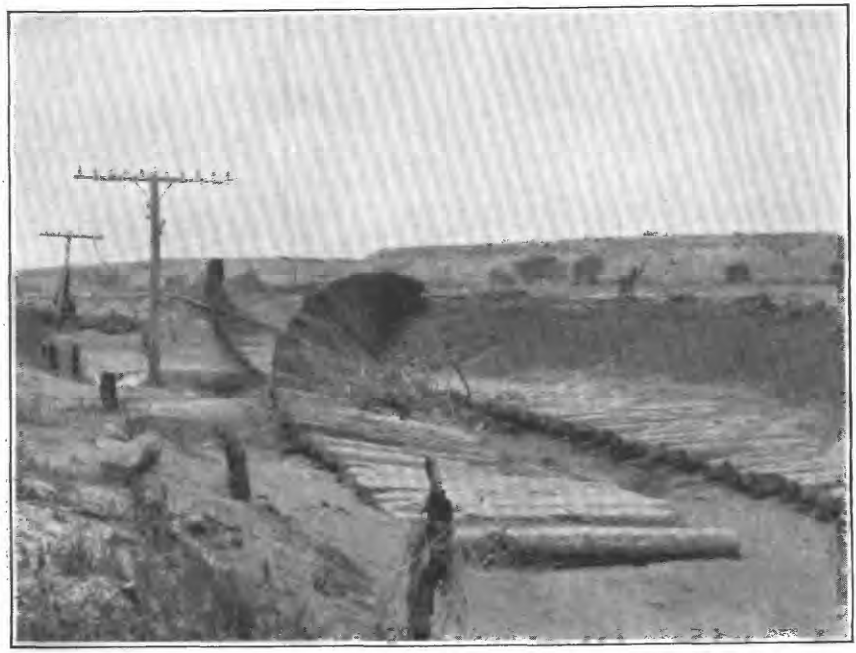
foundries, and other manufacturing plants employing about 18,000 men. The city lies mainly on the flood plain of the river but extends onto the bluffs on either side. Originally the river pursued a winding course through the city, but its channel was straightened and levees were built to furnish protection against a flood of 40,000 second-feet, slightly greater than the maximum discharge of the flood of 1894.

The heavy rains on June 2 and 3 in the region west of Pueblo caused several successive rises in the river. The highest rise and the one that caused the great damage was the second, which occurred on the night of June 3. Dry Creek, which drains an area of 86 square miles just west of Pueblo on the north side of the Arkansas, was subject to its severest flood the night of June 2. This flood caused the river at Pueblo to rise by 2 a. m. June 3 to a stage of 13.7 feet on the State gage just below the Main Street bridge. This rise subsided in a few hours, and as the river channel could safely carry a flood of that stage, little damage was done. The intense rains that began on the afternoon of the 3d caused the river to rise rapidly at 5 p. m., and by 8.45 p. m. the levees were overtopped at a stage of 18.1 feet. The river continued to rise until at midnight the maximum stage of 24.66 feet was reached. This stage was maintained for only a few minutes, and then the river fell almost as quickly as it rose, until about 4 a. m. June 4 it had receded to the top of the levee (18.1 feet). By 2.30 p. m. the river had fallen to a stage of 9.5 feet and by midnight to 9.1 feet. About the time the levees were overtopped they broke at several places near the west end of the city, and large quantities of water flowed directly through the heart of the business section. A third rise reached a stage of 11.1 feet at 4 a. m. June 5, but the river quickly subsided again and remained at a stage of 9.1 feet until 2.15 p. m., when a fourth flood, caused by the breaking of the Schaeffer dam on Beaver Creek, reached the city. The river reached a stage of 13 feet from 3 to 4 p. m. and then fell to 9.1 feet at 7 p. m. By this time the flood run-off from the area of heavy rains had passed, and the river continued to recede gradually, except for a temporary rise to 8 feet at 5.30 p. m. June 6.

When the levees were overtopped an immense volume of water flowed across the old flood plain and through the heart of the business section, which lies on both sides of the river. The area inundated covered 3 square miles and extended from Sixth and Main streets north of the river to the bluffs south of the Denver & Rio Grande Railroad yards on the south side of the river.

The following table shows the height of the high-water mark above the sidewalk level on different buildings in the city:

A. SILT 18 INCHES DEEP DEPOSITED IN FRONT OF UNION DEPOT.



B. OVERTURNED TRACKS ON DENVER & RIO GRANDE RAILROAD WEST OF PUEBLO.

Rails attached to underside of ties.

A. HIGH-WATER MARK ON ELECTRIC BUILDING.

Picture taken at 5.30 a. m. June 4, 1921.

B. UNION DEPOT ON THE MORNING OF JUNE 4, 1921.

High-water mark near top of windows.

High-water mark on different buildings in Pueblo.

Building.	Location.	Height above sidewalk.
		Feet.
Union Depot	Victoria Avenue and B Street	9.8
Fulton Candy Co	Santa Fe Avenue between Third and Fourth streets	9.8
Electric	Union Avenue and North Main Street	11.9
McCarty Block	Union Avenue and C Street	12.5
Central Block	Main and Second streets	12.6
Post Office	Main and Fifth streets	5.5
Western National Bank	Main and Second streets	13.2
	First Street and Santa Fe Avenue	14.4

Plate VI shows views of the Union Depot and Electric Building, and Plate V, *A*, shows the 18-inch deposit of silt left by the flood at the Union Depot.

The first warning of the approaching flood reached the city about 6 p. m. on the 3d, stating that a wall of water was rushing down the river. Messengers were sent out at once to warn the people living in the lowlands called Peppersauce Flats. Hundreds of people rushed to the levees to witness the approach of the great wall of water, not thinking that the city could be inundated, as the levees were believed high enough to protect it. The sudden breaking of the levees cut off the people from the higher land, and in endeavoring to escape many were drowned, as were many others in the houses in the lowlands who had refused to heed the flood warning. Fires broke out almost simultaneously in different parts of the city, terribly illuminating the darkness caused by the failure of the lighting system. Burning piles of timber from a blazing lumber yard drifted through the streets of the city, lodging momentarily against frame buildings and setting them on fire. It was almost impossible to fight the fires, as the buildings were surrounded by water, which prevented the fire department from reaching them. Even if the buildings could have been reached, however, the breaking of the city water system would have made it impossible to put out the flames. The fires finally burned themselves out.

ARRIVAL OF TRIBUTARY FLOOD CRESTS.

A study of the tributary flood crests in their relation to the maximum discharge of the Arkansas at Pueblo requires the determination of the time of their arrival at that point. This can not be determined absolutely but can be estimated with a fair degree of accuracy. The time required for the flood from the Schaeffer reservoir to travel the 25 miles from the mouth of Beaver Creek to Pueblo on June 5 is known to be about 3½ hours, a rate of 7.1 miles an hour. (See p. 18.) At that time the stage of the river was much lower than when the bulk of the water from the tributary streams formed the flood of the 3d. Consequently the retardation due to channel storage was prob-

ably greater on the 5th than on the 3d. For the earlier period the mean rate of the flood crests from the tributary streams has been assumed as 7.5 miles an hour. On this basis the following table has been computed:

Time of arrival of tributary flood crests at Pueblo on June 3–4, 1921.

Stream.	Distance from tributary to Pueblo.	Time flood crest entered river.	Time flood crest reached Pueblo.
	Miles.		
Dry Creek	1.8	10 p. m. June 3	10.15 p. m. June 3.
Blue Ribbon Creek	4.2	11 p. m. June 3	11.35 p. m. June 3.
Unnamed arroyo	4.8	11 p. m. June 3	11.40 p. m. June 3.
Boggs Creek	8.2	6.30 p. m. June 3	7.35 p. m. June 3.
Unnamed arroyo	9.5	5.45 p. m. June 3	7 p. m. June 3.
Rock Creek	9.8	9 p. m. June 3	10.20 p. m. June 3.
Pecks Creek	11.0	5.30 p. m. June 3	7 p. m. June 3.
Cameron Arroyo	12.0	9 p. m. June 3	10.35 p. m. June 3.
Osteen Arroyo	13.5	9 p. m. June 3	10.50 p. m. June 3.
Turkey Creek	14.2	8.30 p. m. June 3	10.25 p. m. June 3.
Rush Creek	16.8	5.30 p. m. June 3	7.45 p. m. June 3.
Red Creek	19.8	5 p. m. June 3	7.40 p. m. June 3.
Fred Rohr Gulch	20.0	5 p. m. June 3	7.40 p. m. June 3.
Ritchie Gulch	22.0	5 p. m. June 3	7.55 p. m. June 3.
Beaver Creek	25.0	7.30 a. m. June 4	10.50 a. m. June 4.
Hardscrabble Creek	28.8	7.30 p. m. June 3	11.20 p. m. June 3.
Brush Hollow Creek	31.0	8 p. m. June 3	12.10 a. m. June 4.
Eightmile Creek	33.5	8.30 p. m. June 3	1 a. m. June 4.
Coal Creek	34.5	7 p. m. June 3	11.35 p. m. June 3.
Oak Creek	35.2	7 p. m. June 3	11.40 p. m. June 3.
Sixmile Creek	35.8	7.30 p. m. June 3	12.15 a. m. June 4.
Chandler Creek	36.2	7 p. m. June 3	11.50 p. m. June 3.
Oil Creek	40.2	11 p. m. June 3	4.20 a. m. June 4.

Apparently the first flood crests to reach Pueblo were those from Boggs, Pecks, Rush, and Red creeks and Fred Rohr and Ritchie gulches, all tributaries within a distance of 25 miles. The time of their arrival was between 7 and 8 p. m. June 3. These crests were probably greatly diminished in volume when they reached Pueblo, being affected by the natural storage in the river channel. Although the heavy rains continued during the afternoon and evening, and a considerable volume of water reached the Arkansas during that period, no more flood crests reached Pueblo until late in the evening. From 10 p. m. until midnight the floods from the tributaries near Pueblo, which were the streams having the greatest flood discharge, reached the city. At the same time the flood crests from the most distant tributaries also arrived. As the river-channel storage became less with increasing stage, the later floods must have reached Pueblo in much more nearly their original volumes than the earlier ones. The effect of the arrival of all these flood crests is shown on the accompanying hydrograph (fig. 1, p. 28).

MAXIMUM DISCHARGE.

The State engineer maintains a gaging station at the Main Street bridge in Pueblo, but the gage was entirely destroyed by the flood of

June 3, and because the area inundated was so wide it was impossible to make discharge measurements during the peak flow. After the flood the United States Geological Survey determined the maximum discharge as 103,000 second-feet. (See p. 20.)

An idea of the unprecedented discharge of the river during the flood is given by the following table showing the available records of maximum discharge:

Annual maximum discharge of Arkansas River at Pueblo for certain years.

Year.	Date.	Discharge.	Year.	Date.	Discharge.
		Second-feet.			*Second-feet.*
1885	June 5	4,530	1907	July 28	4,640
1886	May 29	7,660	1908	June 15–16	1,930
1887	July 18	6,520	1909	Aug. 18	5,800
1894	May 31	39,100	1910	June 1	8,000
1895	July 31	5,000	1911	July 6	7,000
1896	Aug. 18	3,440	1912	June 9	10,000
1897	June 2	3,750	1913	July 23	7,800
1898	July 13	5,380	1914	Aug. 3	7,500
1899	June 20	4,890	1915	June 24	17,000
1900	June 2	6,980	1916	June 17	8,900
1901	May 21	10,700	1917	June 19	6,800
1902	Aug. 5	8,320	1918	June 23	9,600
1903	June 9	6,100	1919	May 30	5,230
1904	June 15	3,310	1920	June 10	4,800
1905	June 10	6,460	1921	June 3	103,000
1906	June 14	4,880			

NOTE.—For 1901 and from 1909 to 1920 the discharge is that for the maximum stage recorded. For the other years the maximum discharge is that for the 24-hour period.

TOTAL DISCHARGE.

The recording gage at Pueblo was destroyed by the flood, and no continuous record of river height exists. From the testimony of local observers and from high-water marks it has been possible to construct a fairly complete and accurate hydrograph of the Arkansas at Pueblo from June 2 to 5 (fig. 1). The most complete record of the river during the time of the principal rise was that obtained by Mr. B. Milton Stearns, assistant chief train dispatcher of the Denver & Rio Grande Railroad. As the water rose in the Union Depot the distance to the water surface from a fixed point was measured with a level rod and the time noted. This was done at frequent intervals from 9 p. m. on the 3d to 7 a. m. on the 4th, the period during which the river was above the floor of the Union Depot. The reference points used were later connected to the city datum by level, and the maximum stage was found to be at 4,684.75 feet above the sea. The maximum stage at the river gage at the Main Street bridge was determined after the flood, from a well-defined water mark on the outside of the new city hall, 150 feet distant. This mark was found to be 24.66 feet above the zero of the gage, or 4,681.70 feet above the sea, 3.05 feet lower than the maximum observed at the Union Depot.

The difference is due chiefly to the fact that the Union Depot is 750 feet upstream from the river gage and 1,700 feet away from the river. A line of levels between high-water marks on the Victoria Avenue bridge, in line with the Union Depot, and the Main Street bridge showed a difference of 2.1 feet. The remaining difference is probably due to the fact that the water surface at the Union Depot was higher than at the river, 1,700 feet distant, as shown by level lines run after the flood.

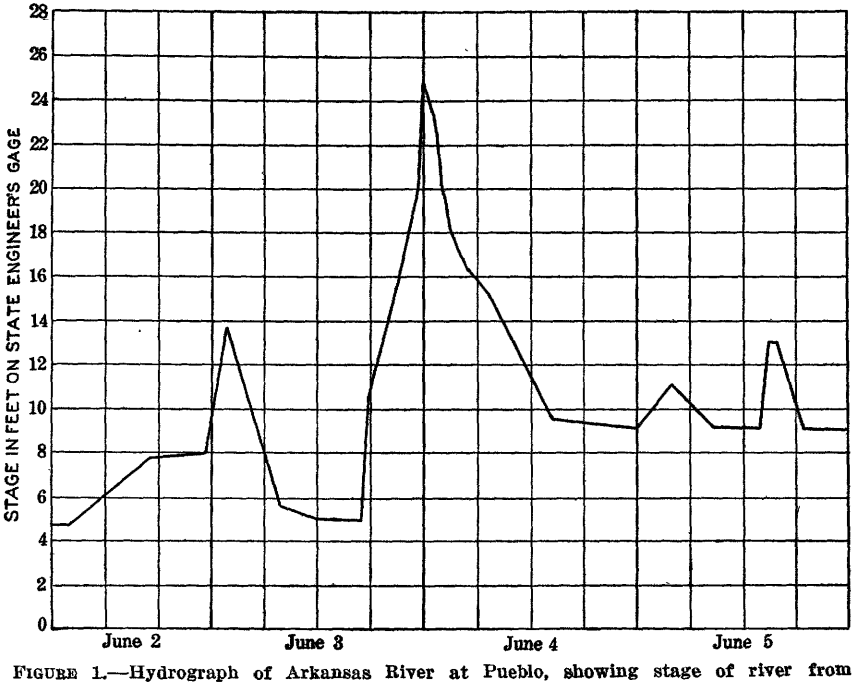


FIGURE 1.—Hydrograph of Arkansas River at Pueblo, showing stage of river from June 2 to June 5, 1921.

The data covering the rise from the Dry Creek flood in the early morning of June 3 were taken from the continuous chart on the recording gage shortly before it was destroyed. Data for the remainder of the time were obtained by the State engineer's office from several reliable sources.

The hydrograph of June 2–5 (fig. 1) shows that although the maximum discharge was high the river rose and fell so quickly that the total discharge in acre-feet for the flood period was comparatively small. The rainfall in the affected area was very heavy, but it ceased so soon that the extremely high run-off from the steep slopes of the tributary streams was of very short duration. Furthermore, the time of maximum rainfall was not the same on all tributaries but in general was latest on the tributaries near Pueblo.

This caused the peak flows from the near-by tributaries to reach Pueblo at the same time as the peak flows from the more distant streams, producing the most favorable conditions possible for a flood of great height.

It is impossible to determine accurately the total discharge at Pueblo during the flood, owing to the great size of the area overflowed, the breaks in the levee, and the scour in the main channel caused by the flood. The discharge up to the time the levees were overtopped and broke, about 9 p. m. June 3, can be determined satisfactorily, as a fair rating curve for the State gage is available. For the remainder of the period only a rough estimate can be made. The peak flow at the maximum stage of 24.66 feet was 103,000 second-feet. (See p. 20.) To determine the discharge at the time the levees were overtopped it was assumed that of the total scour of 1.4 feet noted after the flood, about 0.5 foot had occurred at that time, and the flow through the breaks in the levees was estimated to be 10,000 second-feet. Although this estimate may be as much as 100 per cent in error the effect of such an error on the entire discharge would be very small.

As explained on page 24, the levees were built to protect the city against a flood flow of 40,000 second-feet, which would reach a gage height of 18.1 feet. The additional flow permitted by the scour of 0.5 foot, however, would give a discharge of 40,000 second-feet at gage height 17.6 feet. Adding the 10,000 feet that escaped through the breaks would give a flow of 50,000 second-feet at gage height 17.6 feet. From this figure and the maximum discharge at 24.66 feet (103,000 second-feet) an approximate rating curve was plotted for use between 9 p. m. and midnight.

As the river fell the scouring action continued until at the time the river was once more within its channel the gage height was 0.9 foot lower for the same discharge than it was when the break had just occurred.

The lower part of the rating curve was defined by a measurement made by the State engineer's office at a stage of 5.6 feet, showing a discharge of 6,270 second-feet. By applying the above-described rating curve to the hydrograph the total discharge from 8 a. m. June 2, at the time the river first started to rise, until midnight of June 5, after the flood had passed, was found to be 145,000 acre-feet. Of this amount 90,000 acre-feet was the total flow from noon of June 3 to midnight of June 4.

It was impossible to determine the total discharge of the tributary streams.

THE FLOOD BELOW PUEBLO.

GENERAL FEATURES.

Practically all gages on the river between Pueblo and the Kansas line were destroyed by the flood, making it impossible to obtain records of maximum discharge in the regular manner. Data regarding flood discharges were obtained chiefly from the State engineer's office for different points in the Arkansas Valley.

The stages and discharges of Arkansas River at La Junta during the passage of the flood crest are given in the following table:

Stages and discharges of Arkansas River at La Junta, June 4–5, 1921.

Time.	Gage height.	Approximate discharge.	Time.	Gage height.	Approximate discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
June 4, 7 a. m	3.65	3,050	June 4, 3.15 p. m	17.7	200,000
12.30 p. m	4.35	6,400	4 p. m	16.8	162,000
1.30 p. m	4.75	9,000	9 p. m	15.1	125,000
2 p. m	5.0	11,400	June 5, 4 a. m	11.15	69,000
2.30 p. m	16.8	162,000	2 p. m	7.4	21,000
3 p. m	17.7	[a] 200,000			

[a] The State engineer's office measured a cross section of the river at the head of the Fort Lyon canal, 3 miles west of La Junta, and the slope of the river from a point 2,700 feet upstream to a point 2,400 feet downstream. The mean slope was found to be 0.0015, and the discharge was computed as 200,000 second-feet.

The increase in the maximum flood flow from 103,000 second-feet at Pueblo to 200,000 second-feet at La Junta was due to the discharge of the intervening tributaries, St. Charles River and Fountain, Salt, and Chico creeks, all of which were affected by the heavy rainfall. The table on page 22 shows the quantity and approximate time of the maximum discharges of these tributaries, obtained from local residents.

The crest flow of the river was increased chiefly by the flood from St. Charles River, which reached its crest within an hour of the arrival of the peak flow from Pueblo. Although Fountain Creek did not reach its maximum until about 3 a. m. June 4, or three hours after the peak at Pueblo, it is certain that at the time of the Pueblo peak the Fountain Creek discharge was at least 15,000 or 20,000 second-feet. Salt Creek also contributed 32,000 second-feet to the peak flow, much of it from the St. Charles River basin, although its own peak did not occur until two hours later.

Information regarding the flood between La Junta and Holly is

The crest stage of the flood of October 19, 1908, was 10.1 feet, or 4.9 feet lower.

Mr. Oscar Hellbeck, engineer for the Arkansas Valley Sugar Beet & Irrigated Land Co., made the following computations of the discharge of Arkansas River over the diversion dam of the Amity canal, 2 miles east of Prowers:[9]

Discharge of Arkansas River at Amity canal, June 4–5, 1921.

Time.	Depth over dam.	Discharge.	Time.	Depth over dam.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
June 4, 11.00 p. m.		2,000	June 5, 4.00 a. m.	8.5	155,000
12.00 p. m.		6,000	4.30 a. m.	9.0	170,000
June 5, 1.00 a. m.		10,000	8.00 a. m.	9.0	170,000
1.10 a. m.	2.5	15,000	8.30 a. m.	8.5	155,000
1.30 a. m.	3.0	20,000	9.00 a. m.	8.0	130,000
1.40 a. m.	4.0	28,000	10.00 a. m.	8.0	130,000
2.00 a. m.	5.5	45,000	11.00 a. m.	8.0	130,000
2.30 a. m.	6.0	55,000	12.00 a. m.	7.5	110,000
3.00 a. m.	7.0	80,000	1.00 p. m.	7.0	80,000
3.30 a. m.	7.5	110,000	9.00 p. m.	6.0	55,000

At Lamar the river started to rise at 4 a. m. June 5. At 8 a. m. the gage read 10.4 feet, and at 11 a. m. the crest height of 11.9 feet was reached. This stage continued until 1 p. m., when the river started to fall. The flood was 2 or 3 feet higher than that of 1904, the greatest flood previously recorded.

At Holly the high-water mark was determined from levels after the flood to be about 9.1 feet above the datum of the State gage. The discharge was estimated as 120,000 second-feet.

TRIBUTARY STREAMS.

The tributary streams below Pueblo chiefly affected by the flood were Fountain, Chico, and Salt creeks and St. Charles River. These streams, unlike the tributaries above Pueblo, which had a very high but short flood run-off, had sustained high stages. This was due to the fact that the rain extended over the greater part of their drainage areas, and although it was not as heavy as that over the smaller areas of the upper tributaries, it caused high stages in the streams, on account of the comparatively large drainage areas. For the same reason the high run-off was not concentrated at one time but continued for 24 hours or longer.

FOUNTAIN CREEK.

Fountain Creek is formed by a number of small streams on the north slope of Pikes Peak, of which Catamount and Cascade creeks

[9] Hosea, R. G., unpublished report on Arkansas River flood, dated August 15, 1921.

are the largest. In its upper course Fountain Creek flows through canyons and has a heavy fall, which in the lower part of Ute Pass amounts to 300 feet in a little more than half a mile. Near Colorado Springs the creek leaves the mountains and enters upon the plains across which it flows southward to its mouth a short distance below Pueblo. At Colorado Springs it is joined by Monument Creek, which rises in Palmer Lake, on the divide between the Arkansas and South Platte drainage basins. Other important tributaries are Rock and Little Fountain creeks, which rise in the mountains south of Colorado Springs. Fountain Creek flows over a sandy bed, and although it has considerable underflow, ordinarily it carries very little water at the surface. Its drainage area is 932 square miles. The only marked topographic features on the generally level surface of the plains consist of scores of little conical hills called "tepee buttes," most of them less than 50 feet high.

The following table has been compiled from topographic maps:

Elevations and distances along Fountain Creek from Monument Creek to mouth.

Point.	Elevation above sea level.	Distance.		Descent between points.	
		From Monument Creek.	Point to point.	Total.	Per mile.
	Feet.	*Miles.*	*Miles.*	*Feet.*	*Feet.*
Monument Creek	5,960				
Near Widefield	5,700	10.0	10.0	260	26
Fountain	5,500	16.1	6.1	200	33
Buttes	5,300	23.4	7.3	200	27
Wigwam	5,200	28.0	4.6	100	22
Pinon	5,000	36.2	8.2	200	24
Bragdon	4,850	43.8	7.6	150	20
Eden	4,700	49.6	5.8	150	26
Mouth	4,660	52.0	2.4	40	17

On June 3 a heavy rain that extended over the greater part of the drainage basin began about 9 p. m. and lasted all night. From Fountain station to Pueblo, according to local residents, the storm was the worst in many years, but no estimates have been made regarding the total rainfall. At Colorado Springs, near the north end of the basin, the Weather Bureau record showed the rainfall for the 24 hours ending 8 a. m. June 4 to be 1.87 inches. It was evidently heavier farther south, as indicated by the statements regarding the storm, but it is not believed to have been as severe as that in the area of intense rainfall.

Time of flood flow at points on Fountain Creek.

Point of observation.	Distance above mouth.	Approximate time of flood flow.
	Miles.	
Buttes	28	11.15 p. m. June 3.[a]
Wigwam	23	Between 11 and 12 p. m.
Pinon	15	11.30 p. m.
Bragdon	11	About midnight.
Eden	8	After midnight.
Mouth	0	3 a. m. June 4.

[a] Flood came very suddenly.

Stage and discharge of Fountain Creek at mouth.

Time.	Stage.	Approximate discharge.
		Second-feet.
June 3, 9 p. m.		100
Midnight	2.5 feet deep, 400 feet wide	4,000
June 4, 2.30 a. m	6 feet deep, 400 feet wide	12,000
3 a. m	Crest	34,000
5 a. m		25,000
6 p. m	6 feet below crest	12,000
Midnight	4 feet below crest	18,000
June 5, 5 a. m	6 feet below crest	12,000
5 p. m	7 feet below crest	10,000
June 6, 3 p. m		4,000

The total discharge was about 70,000 acre-feet.

ST. CHARLES RIVER.

St. Charles River drains the eastern slope of the southern half of the Greenhorn Range and the foothill region lying between that range and the Arkansas. After leaving the mountains the St. Charles flows through a canyon for 10 miles, below which the valley widens, and the river finally emerges upon the plain, across which it flows in a northeasterly direction to its junction with the Arkansas, 8 miles below Pueblo. Its chief tributaries are Spring Branch and Greenhorn Creek. The topography of its drainage basin is very rough, as the stream traverses the steep slopes of the mountains, the deeply eroded foothill region, and the rolling plains next to the Arkansas. The drainage area is 482 square miles.

The following table has been compiled from topographic maps:

Elevations and distances along St. Charles River from source to mouth.

Point.	Elevation above sea level.	Distance.		Descent between points.	
		From source.	Point to point.	Total.	Per mile.
	Feet.	*Miles.*	*Miles.*	*Feet.*	*Feet.*
Source	9,000				
Contour crossing	6,250	6.5	6.5	2,750	420
Do	5,750	10.7	4.2	500	119
Do	5,250	18.5	7.8	500	64
Do	5,000	24.7	6.2	250	40
Do	4,800	31.9	7.2	200	28
Do	4,700	36.0	4.1	100	24
Do	4,600	40.7	4.7	100	21
Mouth	4,560	41.9	1.2	40	33

Although little if any of the St. Charles drainage basin lies within the area of intensest rainfall, it was subject to very heavy rain, which began during the evening of June 3, and lasted through the night. The crest flow occurred about 1 a. m. June 4 and lasted for an hour. From measurements of cross section and slope this discharge was estimated to be 71,800 second-feet.

Estimated discharge of St. Charles River, June 3–7, 1921.

Time.	Stage.	Approximate discharge.
		Sec.-ft.
June 3, 4.00 p. m.	Before flood	50
June 4, 1.10 a. m.	Crest	71,800
2.30 a. m.	Slightly below crest	60,000
4.00 a. m.	3 feet below crest	34,000
9.00 a. m.	6 feet below crest	7,500
6.00 p. m.	8 feet below crest	4,000
8.30 p. m.	Started to rise	
June 5, 8.00 a. m.		1,000
5.00 p. m.		550
Midnight		1,650
June 6, 6.00 p. m.		1,000
June 7, Noon.		350

The total discharge was about 60,000 acre-feet.

CHICO CREEK.

The area drained by Chico Creek joins that of Fountain Creek on the west. Chico Creek rises in the central part of El Paso County, 15 miles east of Colorado Springs, and flows southward to the Arkansas, which it joins 14 miles east of Pueblo. Its principal tributary, Black Squirrel Creek, enters Chico Creek a few miles above the mouth. Throughout the upper half of its course the creek has an average fall of 65 feet to the mile; in the lower half the fall is 29 feet to the mile. The drainage basin lies wholly within the area of the Great Plains and has a rolling topography. On account of the small normal rainfall, Chico Creek carries little water except after heavy rains. The total drainage area is 750 square miles.

No information regarding rainfall in this basin during the flood is available; but as Chico Creek drains an area adjacent to that of Fountain Creek the general storm probably extended over its basin also.

The State engineer's office measured the cross section and slope of Chico Creek near the mouth and determined the crest discharge to be 28,600 second-feet.

Estimated discharge of Chico Creek, June 3–6, 1921.

Time.	State.	Approximate discharge.
		Sec.-ft.
June 3	Creek dry	0
June 4	Rise after midnight	
4 a. m.	Crest	28,600
9 a. m.	4 feet deep	4,000
Midnight	75 per cent of crest flow	21,000
June 5, 8 a. m.	3 feet deep	2,500
9 a. m.	2 feet deep	1,050
9 p. m.		800
June 6, 6 p. m.	Creek dry	0

The total discharge was about 36,000 acre-feet.

PREVIOUS FLOODS.[10]

FLOOD OF INDIAN LEGEND.

As the permanent settlement of Pueblo and the upper Arkansas Valley began about 1859, records of floods prior to that time are not available. Reports were common among the early settlers of an Indian legend regarding a flood occurring before the whites came, in which, it was stated, the water reached from bluff to bluff. The truth or falsity of this legend can be determined only by circumstantial evidence.

One of the early settlers of Pueblo, a Mr. Proffitt, who passed through the Arkansas Valley on his way to the Mexican War in 1846, stated that he saw evidence of a former flood along the river below the site of the present city of Pueblo. The cottonwood trees along the river were tipped downstream and still bore drift in their branches. The flood causing this must have occurred prior to 1846, as Oliver ("Old Scout") Wiggins, an early settler of Colorado, who testified to the early flow of Arkansas River in the Kansas-Colorado water suit, stated that in that year there was a great drought, during which all the buffalo perished or left the country. This statement is substantiated by Ruxton, an English Army officer, who visited the region in 1847 and recorded ("Adventures in Mexico and the Rocky Mountains") that there were no buffalo but many skeletons.

In writing of Fremont County, Rockafellow[11] states that the first white settler was a French trader named Maurice, who lived near the mouth of Adobe Creek. Maurice told the pioneers that 4 feet of snow fell all over the valley in 1844 and lay there three "moons." He fixed the year as that of the great flood at St. Louis, which was 1844. Maurice did not mention a later flood, but authentic history records

[10] Based chiefly on data furnished by Mr. A. J. Weston, of the Denver & Rio Grande Western Railroad Co.

[11] History of Arkansas Valley, Chicago, O. L. Baskin & Co., 1881.

one of the greatest floods in the lower Arkansas River as occurring in 1844. Rufus Sage,[12] who crossed this region in that year, records the fact that the streams in the lower Arkansas Valley were of unprecedented size and velocity, and this caused frequent delays to his journey. At Paunee Fork his party was compelled to wait four weeks to ford the river.

The foregoing evidence indicates that the flood of Indian legend probably occurred during 1844.

Mr. Archie Proffitt, a resident of Pueblo, states that an Indian showed his uncle, who came to Pueblo in 1859, river silt in crevices of the rock along the mesa near City Park, which the Indian claimed was the high-water mark of an old flood. This mark was at about the elevation of the floor of the viaduct, which is 12 feet above the flood of 1921. It may have been made by the flood of Indian legend.

FLOODS OF AUTHENTIC RECORD.

Regular observations of the stage of Arkansas River began in 1885, when a gaging station was established at Rock Canyon, 9 miles above Pueblo. This station was maintained until late in 1887. The station at Pueblo was established in the fall of 1894 and has been maintained almost continuously since that time. Records of floods from the settlement of the Arkansas Valley to the establishment of the gaging station on the river are found chiefly in the files of the local newspapers and in the testimony of witnesses in the Kansas-Colorado water suit before the United States Supreme Court.

The first flood of authentic record occurred in 1855, after a winter of very heavy snowfall, although the flood itself was probably caused by hard rain during a period of melting snow. No information regarding the exact date and approximate height of this flood is available.

The next flood recorded was that of June 11, 1864, caused chiefly by very heavy rains. The early settlers in Pueblo agree that this flood reached a point near Third and Santa Fe avenues. The flood of 1921 was nearly 3 feet deep at this point, and if, as seems probable, the street has been graded down since 1864, the latest flood may have been but very little higher than that one. As Pueblo was then but a small settlement of less than 100 inhabitants, with only a few houses to obstruct the flood flow, it is probable that the same amount of water now would reach a considerably higher stage in the city. During this flood all the streams in the valley were very high and overflowed their banks for great distances, Turkey, Beaver, and Hardscrabble creeks being especially high. Fountain Creek was the first to rise, and many cabins on its banks at a point back of the

[12] Rocky Mountain life, Boston, Wentworth, Hewes & Co., 1858.

present steel works were washed away. No loss of life was reported. No records of precipitation covering the period of the flood are available.

A flood during May, 1867, caused the removal of Fort Lyon to a point 17 miles farther west. The rainfall for May was 4.84 inches, as compared with a normal of 2 inches.

During a flood in June, 1869, the river, it is said, contained an immense amount of water.

The files of the Pueblo Chieftain contain notes concerning several floods during 1875, of which the largest was on September 16 and was caused by heavy rains. The following statement concerning this flood is taken from the Las Animas Leader of September 18 and 25, 1875:[13]

> On September 16 a rush of water came down from Purgatory River at Las Animas, Colo. The water was 5 feet higher than at any previous time that year. The Atchison, Topeka & Santa Fe Co.'s tracks were under water for one-half mile on each side of the Purgatory, the bridge being 3 to 4 feet under water. At Fort Lyon the water was 4 feet higher than ever known before. The bottom land between the bridge and the post trader's (a distance of three-fourths of a mile) was a swift, raging flood. Up the Purgatory considerable damage was done, the greatest losses being of cordwood, stacked hay, cattle, fences, and adobe houses. The Arkansas above the mouth of the Purgatory was also in flood at this time, there being reports of damage as far up as Pueblo. The Apishapa brought in a large amount of this water, and the flood height was the highest in 15 years.

This flood could not have been unusually high in the upper river, as the Pueblo papers did not give any great space to it.

Some minor floods occurred during July and August, 1880, and August, 1881. For 1880 the few available rainfall records show nearly twice the normal amount during the flood months, and for 1881 the Pikes Peak record showed nearly three times the normal rainfall during August.

A flood of considerable magnitude in the Arkansas and Purgatoire near Las Animas occurred July 20–25, 1886. The rainfall at Las Animas was 3.36 inches during July 24 and 25 and 4.66 inches for the month, or more than twice the normal. This flood was not severe at Pueblo, as the newly established gaging station showed a maximum of only 3,080 second-feet on July 21. The rainfall at Pueblo for July was only 0.39 inch.

The next flood recorded was that of August 10, 1889. The Denver Republican of that date stated that rain began falling about 5.30 p. m. August 9 and flooded the region around Pueblo. The issue of August 11 stated that "a terrible and disastrous rainstorm visited Florence August 9 in the evening, lasting two hours. The Denver & Rio

[13] Meeker, R. I., Purgatory River flood: U. S. Geol. Survey Water-Supply Paper 147, p. 165, 1905.

Grande is having lots of trouble caused by the cloud-burst of Friday night. The Hardscrabble bridge washed out." That this flood was of considerable magnitude at Pueblo is inferred from the statement that the city council on August 12 appropriated $3,000 to repair and strengthen the levee. All obstructions in the channel were ordered removed. Pueblo reported 1.02 inches of rain in one hour August 9. This intense rainfall, with a temperature of 98° before the storm, indicated a cloud-burst, which was local to the valley between Pueblo and Canon City.

No unusual floods are recorded after 1889 until 1893. Although this was the second driest year in 35 years, as shown by records of precipitation at Pueblo, the flood on July 26, 1893, seems to have been the fourth in magnitude in three-quarters of a century. The river reached a stage 10 feet lower than that of 1921. The Rocky Mountain News of July 27, 1893, stated as follows:

Heavy rain at Pueblo broke the levee and did $200,000 damage. At 9 p. m. July 26 the river began to rise and rose 8 feet in 2 hours. A saloon standing in the levee became undermined and fell into the channel. Water rushed through the break in the levee, and in 10 minutes the city hall was surrounded by 6 feet of water. The crest of this flood is said to have reached the floor of the Union Depot.

The rainfall at Pueblo was 1.36 inches on July 26 and 0.22 inch on the 27th. The precipitation for the year was 6.84 inches, as compared with a normal precipitation of 12.50 inches.

The most destructive flood in the history of the Arkansas Valley prior to the flood of 1921 occurred May 30, 1894. Heavy precipitation on May 30 and 31 extended over the Arkansas drainage basin, taking the form of snow at the higher elevations, notably on Pikes Peak and the mountains in the upper end of the basin. On the evening of May 30 Salida reported that rain had fallen continuously for 36 hours and probably would continue during that night. For duration and volume the storm at that point exceeded anything in the memory of the oldest inhabitant. At the same time Florence reported that rain had fallen for the preceding 24 hours and that the amount was estimated at 3 to 4 inches. Castle Rock and Palmer Lake reported rain on May 30. The rainfall on the 30th and 31st at Pueblo was 3.02 inches and at Canon City on the 29th and 30th 5.06 inches. The following account of the flood is printed in the Rocky Mountain News of May 31, 1894, in a communication dated at Pueblo May 30:

In consequence of an all-day downpour of rain such as has not occurred in this valley in 20 years, the Arkansas River to-night came up and broke the levees in four places on the north side and two on the south side. Everything is a sea of water from Union Avenue viaduct to the post office. All business cellars are filled in that territory, and the water is over the floors from 6 inches

to 2 feet. This is a worse flood than any that has occurred since the town became a city. The water flows with a strong current through the streets, and everything is confusion. The flood covers the city from Union Avenue on the south side to Fourth Avenue on the north side, an area of three-quarters of a mile.

The issue of the News on June 1 stated that on Second Street between Santa Fe Avenue and Main Street the water was 4 feet deep over the floors of the buildings. Five lives were lost in Pueblo and damage amounting to nearly $2,000,000 was done to property.

At its highest stage the water was 3 feet deep in the Denver & Rio Grande Railroad freight yard and kept that stage from 2 to 8.30 a. m. May 31. It receded slowly and by 6 a. m. June 1 had fallen only 4½ feet. The highest stage was about 7 feet less than that of the flood of 1921.

Subsequent to the flood the city engineer, Mr. E. W. Hathaway, measured the slope of the river and its flood cross section just west of the city. He found the maximum discharge of the flood to be 39,100 second-feet, of which 24,200 second-feet had been carried by the river channel and the remainder flowed through the city on both sides of the river. Subsequently the river channel in Pueblo was widened and the levees raised so that the improved channel would carry 40,000 second-feet.

In the Arkansas Valley above Pueblo the flood of 1894 reached a higher stage than that of 1921, the high-water mark on the old Denver & Rio Grande Railroad pump house at Florence being 2 feet higher than that of June 3, 1921. The crest of the flood reached Rocky Ford some time during May 31. Lamar reported the flood crest at noon June 2. The upper limit of the flood area was about Hardscrabble Creek, which carried an unusual flood flow. Coal and Chandler creeks were also very high.

Heavy rains on June 5, 1894, extending from Canon City to Pueblo, again raised the Arkansas until it reached a stage at Pueblo about 8 inches lower than that of May 31. The rainfall on June 5 was 1.82 inches at Canon City and 0.64 inch at Pueblo.

The lower Arkansas Valley was visited by very severe floods during 1904, but they did not reach the upper valley. Between Wichita and Arkansas City the flood of July 9, 1904, was the severest known. For ten days before that date the maximum discharge at Pueblo was 1,520 second-feet. On September 30, 1904, the severest flood known occurred on Purgatoire River. This flood caused a great amount of damage on Arkansas River below the mouth of the Purgatoire,[14] but it did not affect the Arkansas Valley above the Purgatoire. The maximum discharge at Pueblo for the week preceding September 30 was 1,100 second-feet.

[14] Meeker, R. I., U. S. Geol. Survey Water-Supply Paper 147, pp. 165–168, 1905.

The next serious flood in the Arkansas Valley, and the last one before 1921, occurred October 19–21, 1908, and affected the area east of La Junta. It was due to very heavy rains. Records kept by the Amity Canal Co. at various points showed a rainfall of 6 inches or more extending from Prowers to Holly. Practically all the rain was believed to have fallen in eight hours during the night of October 18. The area affected by the flood extended from La Junta on the west to Lamar on the east and from the Missouri Pacific Railroad on the north to the south boundary of Otero, Bent, and Prowers counties on the south. The maximum stage of the river at Holly was 11 feet on the river gage. The maximum discharge at this point was estimated from cross sections and slope measurements made after the flood as 136,000 second-feet. The flood at the Amity dam was estimated as greater than 100,000 second-feet.[15]

That this flood did not affect the upper river is shown by the fact that the maximum discharge of the Arkansas at Pueblo for a week prior to the flood was only 298 second-feet, which shows that there was no flood at Pueblo within the time it would have taken for flood flow there to reach La Junta by October 19.

MAXIMUM DISCHARGES PER SQUARE MILE PREVIOUSLY RECORDED.

During the flood of 1921 the tributary streams had maximum discharges per square mile that were almost unprecedented in the Rocky Mountain States. The only recorded unit discharge that equaled them was that of Hogan's Gulch near Eden, Colo., a station on the Denver & Rio Grande Western Railroad between Colorado Springs and Pueblo. Here a cloud-burst on August 7, 1904, caused a flood that was estimated to have a maximum discharge of 9,640 second-feet from a drainage area of 6.1 square miles, or 1,580 second-feet per square mile.[16]

It is apparent that streams draining small areas in the foothill region subject to cloud-bursts must have had as high discharges in the past as those that caused the recent flood, but no record of such discharges has been made.

The following table shows the greatest previously recorded unit run-offs in the Rocky Mountain States, arranged in order of unit magnitude:

[15] Freeman, W. B., U. S. Geol. Survey Water-Supply Paper 274, pp. 33–40, 1910.
[16] Data furnished by Denver & Rio Grande Western Railroad Co.

Maximum discharges previously recorded for streams in Rocky Mountain States.

Stream.	Date.	Maximum discharge.		Drainage area.	Period of maximum discharge.
		Total.	Per square mile.		
		Sec.-ft.	*Sec.-ft.*	*Sq. mi.*	*Hours.*
Mora River at La Cueva, N. Mex	Sept. 29, 1904	22,200	140	159	12
Gallinas River at Hot Springs, N. Mex	Sept. 30, 1904	11,600	129	90	1
Canadian River at French, N. Mex	October, 1904	156,000	105	1,480	.5
Mora River at Weber, N. Mex	Sept. 30, 1904	27,700	94	294	2
Purgatoire River at Trinidad, Colo	....do.....	45,400	61	742	1.5
North Fork of Sun River near Augusta, Mont	June 21, 1916	32,300	54	600	.....
Bear Creek at Morrison, Colo	July 24, 1896	8,600	48	180	.....
Willow Creek near Augusta, Mont	May 26, 1917	3,740	42	90	5.2
Two Butte Creek at mouth, Colo	October, 1908	35,000	39	900	.....
North Fork of Cache la Poudre River at Livermore, Colo	May 20, 1904	20,000	38	532	3
Willow Creek near Augusta, Mont	June 23, 1916	3,400	38	90	9.5
Crow Creek at Cheyenne, Wyo	May 20, 1904	8,500	34	251	.5
Cherry Creek at Denver, Colo	July 14, 1912	11,000	25	445	.....

One of the most complete lists of flood flows in various parts of the country is contained in a paper by Emil Kuichling.[17] A general discussion of destructive floods in the United States is given in the following water-supply papers of the United States Geological Survey:

96. Destructive floods in the United States in 1903, by E. C. Murphy.

147. Destructive floods in the United States in 1904, by E. C. Murphy.

162. Destructive floods in the United States in 1905, by E. C. Murphy and others.

Many references to flood literature are also given in appendix 7 of the report of the Flood Commission, Pittsburgh, Pa.

[17] Flood flows: Am. Soc. Civil Eng. Trans., vol. 77, pp. 650–662, 1914.

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