

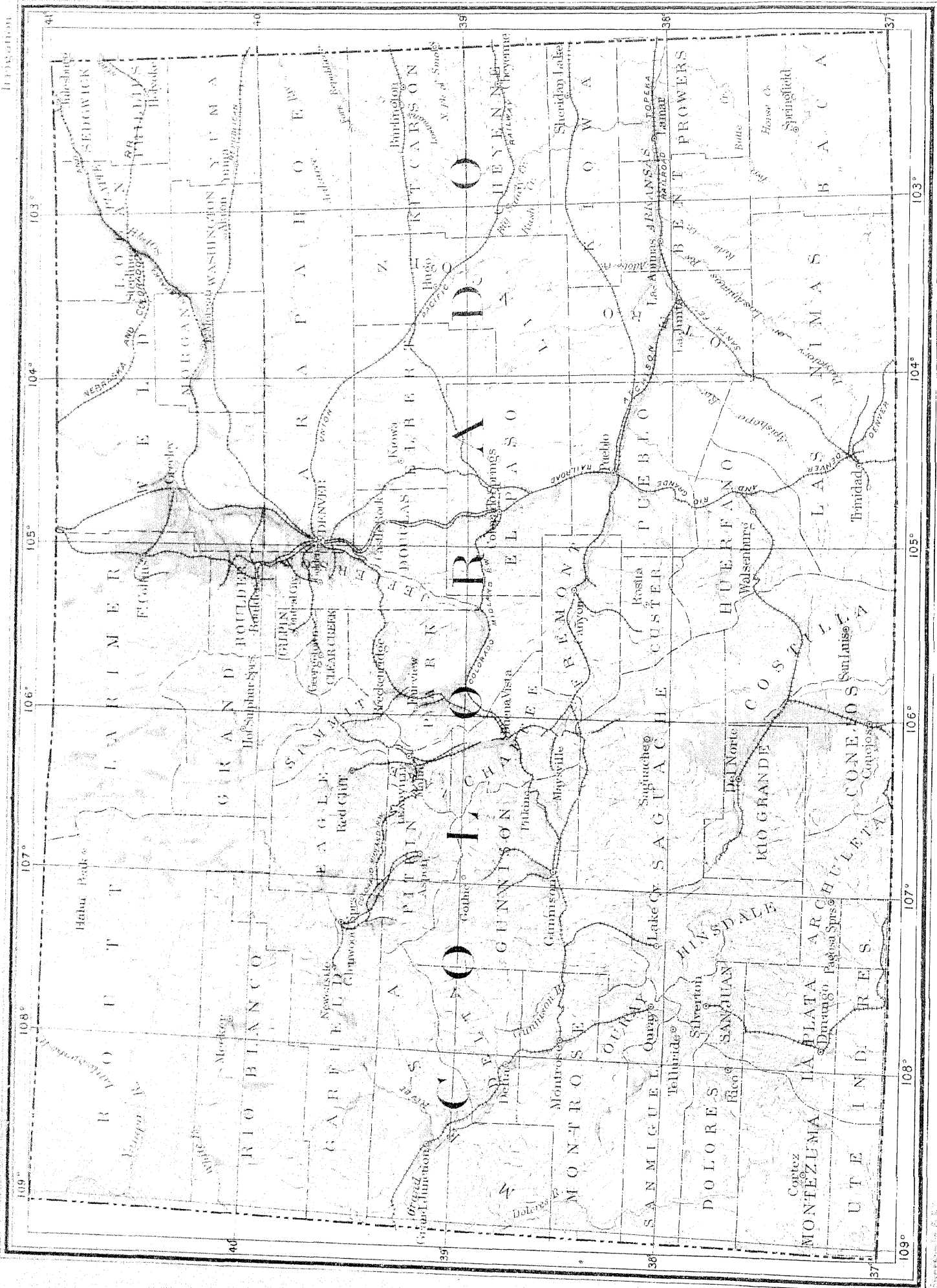
COLORADO.

Total population (average per square mile 3.98)	412, 198
Number of owners of farms (3.98 per cent of population)	16, 389
Number of irrigators (58.94 per cent of farm owners, 2.34 per cent of population).....	9, 659
Area of state, land surface (103, 645 square miles)	66, 332, 800
Area irrigated in census year	890, 735
Area of all farms, 39.65 per cent improved.....	4, 598, 941
Cereals raised in census year, including 117 acres in buckwheat and 4,615 acres in rye	351, 086
Barley, average production, 27.43 bushels per acre	12, 086
Corn, average production, 12.67 bushels per acre.....	119, 310
Oats, average production, 28.59 bushels per acre	87, 959
Wheat, average production, 22.41 bushels per acre	126, 999
Alfalfa	126, 531
Total value of all farms, including land, fences, and buildings.....	\$85, 035, 180
Estimated total value of the farms irrigated in whole or in part.....	\$59, 696, 000
Estimated value of all farm productions (sold, consumed, or on hand) for 1889.....	\$13, 136, 810
Estimated value of productions, as above, from farms irrigated in whole or in part	\$11, 686, 000
Average size of irrigated farms.....	92
Average size of irrigated farms of 160 acres and upward	307
Per cent of acreage of irrigated farms of 160 acres and upward to total acreage irrigated.....	49. 34
Average size of irrigated farms under 160 acres	55
Average first cost of water right per acre.....	\$7. 15
Average annual cost of water per acre.....	\$0. 79
Average first cost per acre of preparation for cultivation.....	\$9. 72
Average value of irrigated land, including buildings, etc., in June, 1890, per acre.....	\$67. 02
Average annual value of products per acre in 1889.....	\$13. 12

COMPARISON WITH OTHER STATES.

The above table, similar to those prepared for Arizona and California, brings together the most important data relating to the proportion of the population of Colorado interested in irrigation and concerning their farms and products. For comparison with other states and territories of the arid regions reference should be made to the general tables given in the first portion of this report. By examining these it appears that Colorado stood third in number of irrigators in 1889 and second in area irrigated. In average size of irrigated farms, 92 acres, it stood fourth, Nevada, Wyoming, and Montana preceding it. As for proportion of state irrigated, however, it stands at the head of the list, 1.34 per cent of the entire land surface of the state being watered. In total number of farms it stood second to California, while in the percentage of number of these irrigated, 58.94, it is eighth. In average value on June 1, 1890, of farm land irrigated, \$67.02 per acre, the state is third, following far behind California and Utah, while in average value of products in 1889, \$13.12 per acre, it was sixth, a number of these states, however, having average values of product per acre within a few cents of each other.

Classifying the irrigated holdings according to size, 160 acres being the dividing line, Colorado comes first in the number of these of 160 acres and upward and second only to California in the aggregate area, while it is fifth in the list in the proportion of these to the total area irrigated, a trifle less than one-half of the total number of acres irrigated being contained in these large holdings; that is to say, 1,432 irrigators owned nearly one-half of the irrigated lands. In average first cost of water per acre, \$7.15 (ranging by counties from \$2 up to \$16 per acre), Colorado was fourth, following California, Utah, and Nevada. In average value of water rights per acre in 1890 it was second only to California, while in average annual cost of water per acre, 79 cents, it was among the lowest, being surpassed only by Washington and Wyoming. This average was low, from the fact that there was a predominance of cases where the irrigators owned small ditches cared for by themselves, the annual expense being from as low as 10 cents per acre up to 50 cents or more. On the other hand, there were many farmers who paid annually a stated sum to a canal company for delivering water, the prices ranging from \$1.50 up to \$3 per acre.



MAP OF COLORADO SHOWING AREAS IRRIGATED IN 1889.

IRRIGATED

The irrigated areas of the state, as shown by the accompanying map, were widely distributed, but in the main were found along the foot of the Front range, extending thus in a general northerly and southerly direction and stretching out to the eastward down the valleys of the South Platte and Arkansas. To the west of this the principal areas were in San Luis park and scattered irregularly along Grand river and its tributaries. As a rule it may be said that irrigation developed gradually and without attracting particular attention from the general public until about the close of the last decade. The earliest irrigating ditches were dug by Mexican farmers, cultivating small patches of land along the foothills, mainly in the southern part of the state. These ditches are still in use, and most of them are in their original condition, few changes or improvements having taken place either in methods of farming or in ways of distributing and applying the water. The earliest large enterprise conducted by English speaking farmers was probably the irrigation system at Greeley built by the Union colony, work being begun about 1870. As the population of the state has increased and the demand for agricultural products has become greater, farmers have gradually brought under cultivation strips or patches of arable land wherever water can be diverted to cover it at moderate expense. Thus all the easily available sources of water have been utilized, and with increase in the number of farmers still more land has been cultivated until the area far exceeds that which can be irrigated in ordinary seasons.

IRRIGATION PROGRESS.

The success of the earlier settlers in rendering valuable the hitherto desert lands stimulated speculators and owners of fertile though arid tracts to attempt to reclaim these from their worthless condition in order that they might be made sources of revenue, and from about 1887 almost innumerable projects for the construction of large irrigation works have been suggested, some being brought to completion. Many of these involved the expenditure of hundreds of thousands and even millions of dollars, the primary object being either to sell shares of stock or to realize in some manner upon the increased value of the land. In some cases stock has been sold to investors having no interest in the land, but in the majority of instances shares of stock entitling the owner to a certain proportion of the water have been disposed of to farmers having land under the canal. Sometimes the canal company has owned a large part if not all of the land, and has sought to colonize this, selling the land with water rights, generally on long time and partial payments.

The multiplication of small irrigating systems by the farmers and their enlargement from time to time continued, as previously intimated, until the demand for water, along the smaller streams at least, far exceeded the easily available supply. Added to this has been the construction of great canals, the capacity of any one or two of which, if ever brought into full operation, would exceed the amount in the principal rivers. This has brought about a condition of affairs in which in many counties the rights of the farmers to the use and employment of the waters are in a most precarious and unsatisfactory state, emphasized by the fact that the water supply of summer varies greatly in quantity from year to year. In the plan for construction of the larger irrigating canals, little if any attention has been or is now being paid to the question of water supply, and large sums have been recklessly expended, especially in eastern Colorado, in digging long lines of canals for which it seems improbable there will be sufficient water during summer.

RAINFALL AND RIVER FLOW.

The necessity of irrigation as well as the reason for the somewhat wide development of dry farming is made apparent by reference to the table on the following page, which exhibits the average distribution of precipitation in many of the counties of the state. This shows that, taking all the points of observation, the average precipitation, in the form of both rain and snow, is about 14 inches for the entire state, ranging from less than 7 inches at points on the plains up to about 30 inches among the high mountains from which come the streams used in irrigation.

IRRIGATION.

MEAN MONTHLY AND ANNUAL RAINFALL AT STATIONS IN COLORADO.

LOCALITIES.	Altitude in feet.	Length of record (Years and months.)	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Arapahoe county:															
Denver	5,281	20 10	0.63	0.54	0.92	2.07	2.61	1.34	1.60	1.40	0.96	0.78	0.81	0.66	14.32
Baca county:															
Springfield		a1 7	0.40	0.84	0.42	3.32	1.02	1.94	3.15	0.91	0.46	0.67	0.27	0.02	13.42
Bent county:															
Fort Lyon	4,000	a20 7	0.20	0.27	0.36	0.97	1.85	1.38	2.18	1.77	0.93	0.67	0.28	0.21	11.07
Las Animas	3,899	7 10	0.22	0.32	0.38	1.69	2.05	2.19	2.10	1.72	0.92	0.64	0.30	0.48	12.71
Boulder county:															
Longmont	5,000	a3 9	0.28	0.73	0.41	2.90	3.82	0.64	0.73	1.22	0.27	1.77	0.38	0.06	13.21
Cheyenne county:															
Kit Carson	4,289	a3 5	0.18	0.16	0.48	0.21	0.58	1.93	0.96	1.12	0.38	0.20	0.14	0.42	6.82
Clear Creek county:															
Georgetown	8,554	a4 11	0.42	0.39	0.74	1.29	1.75	0.78	2.02	1.88	0.72	0.89	0.78	0.57	12.23
Idaho Springs	7,569	a3 6	0.26	0.44	0.84	1.14	2.47	0.71	3.19	2.29	0.58	0.81	0.47	0.31	13.51
Costilla county:															
Fort Garland	7,937	a21 9	0.54	0.79	0.72	1.07	1.03	1.32	2.41	1.95	1.11	0.51	0.57	0.72	12.74
Custer county:															
Westcliffe	7,800	2 1	0.44	0.50	0.39	5.16	0.60	1.10	4.78	T	1.80	0.95	1.30	0.55	17.75
Delta county:															
Delta	4,950	2 1	0.60	0.66	0.52	0.69	0.24	0.04	0.77	1.10	0.50	1.18	1.55	1.91	9.85
Elbert county:															
Thon	5,795	2 6	0.12	0.18	0.31	1.72	2.70	0.98	1.72	2.32	0.43	0.58	0.18	0.10	11.34
El Paso county:															
Colorado Springs	6,032	a12 4	0.20	0.26	0.55	1.72	2.26	1.69	3.45	2.14	1.28	0.50	0.37	0.31	14.70
Pikes Peak	14,134	14 11	1.55	1.36	2.09	3.66	3.67	1.76	4.43	3.83	1.72	1.41	1.74	1.43	28.65
Fremont county:															
Canyon	4,700	4 1	0.87	0.75	0.44	2.56	1.10	0.34	1.21	1.80	0.34	0.90	0.76	0.45	11.52
Garfield county:															
Glenwood Springs	5,760	a2 6	1.06	1.50	1.00	0.44	1.17	0.54	0.87	2.57	0.58	1.62	2.32	2.92	16.59
Gunnison county:															
Gunnison	7,558	2 4	0.29	0.02	0.50	1.60	0.06	0.14	1.60	1.00	0.30	0.36	1.93	0.64	8.53
Huerfano county:															
Fort Massachusetts	8,365	a5 8	0.34	0.86	0.61	1.15	1.36	0.72	2.01	2.84	1.80	0.87	3.01	1.07	17.24
Jefferson county:															
Golden	5,993	a4 11	0.58	0.96	1.46	2.64	3.34	2.08	1.55	1.11	1.30	0.81	1.20	0.52	17.55
Lake county:															
Climax	11,325	a3 3	0.88	1.72	3.40	2.23	2.32	1.03	2.20	2.15	1.36	1.38	2.08	0.87	22.12
Leadville	10,200	a2 4	0.47	0.58	0.96	0.78	2.20	0.50	1.14	1.11	0.67	1.00	1.16	0.99	11.56
La Plata county:															
Fort Lewis	8,500	a10 1	1.59	1.10	1.22	1.36	0.63	0.73	2.22	2.20	1.17	1.46	1.47	2.04	17.19
Hermosa	6,700	a7 0	1.10	1.44	0.67	0.54	0.52	0.52	1.85	2.32	1.35	1.09	1.35	1.55	14.30
Larimer county:															
Fort Collins	5,000	a9 7	0.73	0.49	0.77	1.90	2.72	1.72	1.56	1.03	0.90	1.15	0.48	0.30	13.75
Las Animas county:															
Trinidad	6,070	a5 1	0.29	1.23	0.06	1.02	2.44	5.30	3.06	3.24	1.34	1.32	1.64	0.67	21.61
Mesa county:															
T. S. Ranch (b)		3 8	0.30	0.61	1.02	0.77	0.92	0.14	0.88	1.90	1.07	1.23	0.96	1.11	11.00
Montrose county:															
Montrose	5,795	5 5	0.56	0.36	0.44	1.48	0.52	0.24	0.82	1.51	0.82	0.97	0.80	0.62	9.23
Morgan county:															
Fort Morgan	4,500	a2 4	0.31	0.44	0.15	0.94	1.72	0.55	1.73	0.92	0.11	0.52	0.35	0.34	8.08
Otero county:															
Rocky Ford	4,100	2 0	0.35	0.14	0.41	2.10	0.97	0.76	2.83	1.03	0.17	1.60	0.54	0.03	10.93
Park county:															
Alma	10,320	a3 9	0.53	0.34	0.98	1.70	0.95	0.52	1.75	3.06	0.54	0.77	0.80	0.46	12.40
Como (ranch near)	9,500	5 9	0.56	0.66	1.05	2.11	1.20	0.95	3.85	2.76	0.80	0.98	1.10	0.69	16.77
Pitkin county:															
Aspen	8,000	a2 9	1.18	2.70	0.54	0.55	3.42	1.10	2.24	2.88	0.07	1.31	1.50	1.55	19.13
Provers county:															
Lamar		1 9	0.14	0.40	0.34	2.74	1.40	2.06	1.88	1.23	0.46	2.39	0.40	0.04	13.48
Pueblo county:															
Fort Reynolds	4,300	4 0	0.70	0.80	1.06	4.38	1.69	0.80	1.51	1.31	1.90	0.40	2.03	0.28	17.01
Pueblo	4,753	9 9	0.25	0.29	0.40	1.86	1.76	0.68	0.90	1.89	0.36	0.73	0.66	0.09	9.87
Rio Grande county:															
Monte Vista	7,665	a4 0	0.24	0.31	0.29	1.40	0.26	0.31	1.24	0.97	0.63	0.63	0.22	0.41	6.91
Summit	11,300	a3 7	1.67	2.74	3.68	4.81	1.94	1.20	3.29	2.87	2.06	2.85	1.62	1.82	30.75
Saguache county:															
Saguache	7,740	a2 9	0.31	0.30	0.08	0.99	0.37	0.64	1.94	1.32	0.41	0.71	0.31	0.20	7.58
Sedgwick county:															
Fort Sedgwick	3,660	a3 2	0.60	1.36	0.72	2.34	1.40	0.56	1.11	1.54	1.10	0.51	0.04	0.52	11.80
Weld county:															
Greeley	4,780	a2 5	0.15	0.28	0.50	2.44	1.98	1.63	1.60	1.51	0.25	1.22	1.73	0.12	13.41

a Record broken.

b Ranch 9 miles from Whitewater, Colorado.

Although the total amount of rainfall as shown by the above table is small, yet this quantity is usually so favorably distributed throughout the year that agriculture succeeds in localities whose mean annual precipitation is less than at places to the west where the rain occurs more uniformly from month to month. In the 5 months from April to August, inclusive, or the crop season, over 60 per cent of the precipitation usually takes place. This fact is brought out more clearly by the following table, in which the average rainfall for most of the important stations of the state is given both in depth in inches and percentage of the whole amount. This is placed in comparison with the average distribution of the available water supply, that is, of the mean monthly percentage of water flowing in the principal streams. The periodical rise of the streams to their spring floods is shown in the case of Colorado to be nearly coincident with the increase in quantity of spring and summer rain, in this respect differing from California, where the streams rise about the time the rainfall diminishes. As shown by the percentages the rivers begin to increase in flow, mainly by melting snow a short time after the rainfall increases, but they decrease in July, falling off rapidly, although this is the time of greatest rainfall, and in August reach comparatively low stages, dwindling or ceasing to flow at the time when the need for water is greatest. Thus it happens that many crops which mature early in the season can be raised successfully by dependence upon

the summer rains, and on the other hand, crops which are slow in maturing, or forage which can be cut a number of times in succession, require an artificial supply of water when the summer rains decrease, or may be entirely destroyed by drought when the streams no longer fill the irrigating ditches.

DISTRIBUTION OF PRECIPITATION AND AVAILABLE WATER SUPPLY.

MONTHS.	AVERAGE MONTHLY PRECIPITATION.		AVERAGE MONTHLY RIVER FLOW.
	Inches.	Per cent.	Per cent.
Total	14.00	100.00	100.00
January	0.65	4.64	3.40
February	0.60	4.28	3.90
March	0.75	5.36	3.60
April	1.45	10.36	5.60
May	1.65	11.79	20.00
June	1.25	8.93	27.50
July	2.35	16.78	13.50
August	1.90	13.57	6.70
September	1.10	7.86	4.40
October	0.80	5.71	4.40
November	0.75	5.36	3.70
December	0.75	5.36	3.30

From a careful examination of the census statistics and of replies from thousands of farmers it would appear that the great need at least for the eastern half of the state is for a more careful use of the water and for its increase by flood storage. Far larger areas could be successfully cultivated with the amount now at hand if the water were used with greater skill and economy, and, as is well known, great quantities run to waste each year in time of flood. As the matter now stands there is a deficiency of supply for the land now cultivated and reported as irrigated, and in addition there are far larger areas without water, although under ditch. The acreage of fertile land to which water can be carried by canals and ditches already constructed can not be definitely ascertained, but, especially in the eastern end of the state, it is of such extent that the patches actually watered in comparison shrink into insignificance.

RESERVOIRS.

Water storage as a relief from the trials and uncertainties of a chance supply has been eagerly taken up by irrigators and others interested in such matters, and many reservoirs have been built, some of these among the high mountains, but the greater number near the foothills in the vicinity of lands to be irrigated. The success of these has not been as marked as anticipated on account of their great first cost when properly constructed and the practical difficulties in filling them each year. With wasteful methods of employing water and the small average value of products per acre the use of water obtained by storage has not always been profitable. As the farmers become gradually more skillful in producing the best results with the least water, enterprises of this character must be more and more successful.

A few small reservoirs have failed by the washing away of dams improperly constructed or so placed as to be exposed to great floods. Other works have been so located that, although perfectly safe in every way, there has not been a sufficient amount of water each year to fill them and make up for losses by evaporation and seepage. There has been the same disregard of facts and physical data shown in the location of storage works as in the construction of large canals, more attention being given to the possible profits than to questions of water supply and stability. Examples of this kind, even though few in number, have caused more or less loss of confidence and have resulted in delays and greater care in planning and executing other structures for such purposes.

The quantity of flood water available for storage has been generally overestimated. The inhabitants of the country, seeing the angry waters rushing down valleys and tearing out bridges, dams, and other obstructions, form ideas and make statements widely at variance with the facts as ascertained by engineering examination. This is brought out most strongly perhaps by the gaugings made by the United States Geological Survey or by the state engineer. Not all of this water can be utilized, since it comes so rapidly and in such great quantities that it can not be diverted into reservoirs as ordinarily constructed. The amount varies so greatly from year to year that a system of reservoirs constructed to hold the average amount might be partly dry for several years in succession, or at other times would receive more than they could hold.

STATE SUPERVISION.

The Colorado laws regarding irrigation have grown much as has the ditch system, by adding here and there, and as a result they are far from perfect, although better than those of many of the other irrigating states. The farmers complain of the inefficiency of present methods of distributing water, of the apparent injustice that sometimes arises, and of the legal costs involved in protecting their property. In the districts where the demand for water is especially great, where old ditches have been enlarged and new canals built, continual vigilance on the part of irrigators and of state officials must be practiced in order to secure and maintain a legal distribution of water.

The theory upon which the law is based is simple, but the details for enforcing this are complicated and not always efficient. The primary object is to secure to each irrigator the use of an amount of water equivalent to that originally employed by him according to the date at which such employment was made. That is to say, the first settler on a stream should be secure in the use ever after of the amount of water originally diverted and used, and if there is a surplus the next settler should have an amount equivalent to that originally used by him, and so on. At times of drought the persons utilizing the water last in order of time should be deprived of it, and this shutting out should continue in the reverse order of the dates of appropriation until those holding what are known as prior rights have a full supply.

In order to enforce the laws regarding the distribution of water the state has been divided into six divisions, the limits of these coinciding with the watersheds of the principal rivers. Division I includes all of the drainage area of the Platte river within the state, and division II that of the Arkansas, these two covering the eastern part. Each of these is subdivided into water districts, which include one or more creeks tributary to the rivers or a portion of the main stream itself with the adjoining land irrigated. In each of these districts is a water commissioner, whose duty it is not only to know the condition of the water supply and of its employment but in time of scarcity to enforce the legal decisions as to priorities by closing the head gates of ditches not entitled to water at such times. These commissioners have police powers and must exercise considerable discretion in the execution of their duties, which require judgment and experience.

The water commissioners in each district are under the general direction and supervision of a division superintendent, and each superintendent in turn reports to the state engineer regarding the amount and distribution of water and other facts incidental to his duties. All questions, however, concerning priorities of right are adjudicated by the courts, the state engineer and his assistants carrying into effect as far as possible these judicial decisions, and unless these have been legally established the state officials can not interfere. One of the greatest sources of weakness in this system is the fact that water measurements have not been made to an extent sufficient to give comprehensive ideas of the amount available, and the decisions of the court, being based upon such evidence as was presented, relate to quantities often larger than can be realized. Decrees have been made to various ditches entitling them to two, three, or even five times as much water as could possibly be carried, the aggregate amount mentioned in the decrees being perhaps ten or twenty times as much as the river from which the water is taken carries even in times of flood.

Questions concerning priorities of right are especially perplexing in division I, where many of the adjudications were made before matters of that kind were as well understood by the public as at present. The distribution of water in some of the districts is surrounded by almost insurmountable difficulties, requiring great tact and experience on the part of the commissioners, superintendent, and state engineer in order to avoid personal conflicts or litigation. Even then in time of drought there is more or less unavoidable friction, and injunctions have been issued restraining the state engineer and his assistants from interference. Each year, however, as the irrigators come to understand the necessity and value of state interference and questions of detail are settled some of the obstacles are overcome, but at the best there are many hardships connected with the matter.

Few persons outside of the irrigating states comprehend the full significance of the statement that certain ditches have been shut down, or that the greater part of some district has been deprived of water in order to satisfy prior claims. To the irrigators under these particular ditches this deprivation may mean the almost complete loss of the results of the season's work and the jeopardizing of trees, shrubs, and other plants upon which years of care have been bestowed. Of course there are many complaints, and state officials are accused of partiality and unfairness by some of the sufferers, but the community as a whole sees in this the unavoidable operations of necessary laws. The doctrine of priority of rights has been so well established that it is not probable that it can be overthrown, although individuals often attack it bitterly.

Owing to unusual droughts and the shutting down of certain canals and ditches there were heavy losses of crops during the census year, especially under some of the larger canals. The condition of farmers thus deprived of water was deplorable, from the fact that they had mortgaged their property to pay for the water rights and paid in advance their annual rates. By being deprived of water their crops were not profitable and interest and partial payments on the mortgage could not be made. The deeds to water rights usually contain a clause practically relieving the company from responsibility in case of failure to deliver the quantity of water called for; but, on the

other hand, the mortgages given by the farmer are so drawn that default of one payment makes the whole amount become due at once. Thus apparently it is in the power of a company failing to furnish water to foreclose a mortgage and obtain possession of the land.

AVERAGE COST OF DITCHES.

In Colorado there are to be found examples of nearly every type of irrigating system. The small, cheaply constructed ditches are in excess, but there are also a few well constructed canals worthy of detailed description. Without discriminating between the different conditions under which the canals have been built a general average has been taken of the cost of construction, dividing these into classes according to the width. Taking those under 5 feet in width, the average cost per mile was \$380; those of 5 feet and over and under 10 feet in width cost on an average \$1,131 per running mile, and those of 10 feet and over cost \$5,258 per mile. This includes expenses of head works, flumes, and all other structures. Most of the older ditches have been poorly located, and a great number have been duplicated by the construction of other ditches running nearly parallel and supplying land in the same vicinity. This results in great waste of water, and the farmers as a whole have had to pay nearly double the amount necessary to have constructed one well planned ditch.

In many localities where small parallel ditches cover the ground, it has been proposed in the interest of water economy to attempt to consolidate interests and utilize the highest canal or ditch. In order to do this it will be necessary to purchase many of the older rights, the cost of which will be very large unless condemnation proceedings can be had. While the early and cheaply constructed ditches were in many ways of immediate benefit to the irrigators, enabling them to gain a foothold, yet in the long run they must prove very expensive, especially where attempts are made to improve methods of distribution and to economize water, the outlay required to do away with old methods being far greater than the construction of new.

DUTY OF WATER.

The duty of water in Colorado, that is, the area of land irrigated by a given quantity of water, varies, as in all other states, with the character of the soil, the crops, the amount at hand, the skill of the farmer, and other conditions. As a whole, it is probable that the duty has gradually increased, larger areas being now irrigated than formerly with the same amount of water. To ascertain what is the average duty is a matter of considerable difficulty on account of the varying conditions, but it is possible to arrive at this in an approximate manner by comparison of the amount of water flowing in various streams with the acreage irrigated. Taking, for example, the average discharge of Cache la Poudre, Big Thompson, St. Vrain, and Boulder creeks and comparing this with the acreage reported as irrigated in the census year, it appears that the duty of water was about 120 acres to the second-foot. This method of computation is not wholly satisfactory and yields results of little practical value. It should be noted furthermore that in this year many of the farmers claim that they did not have enough water and that a considerable proportion of the crop was a failure, or, in the case of the cereals, was cut for forage. Figures of this kind, while of use in broad discussions of the subject, can not be safely applied to any one project or used to show the probable amount of land to be irrigated from a definite source.

The best data upon the duty of water in the state are those obtained at the agricultural experiment station at Fort Collins, where careful measurements have been made of the quantities of water used upon different fields. The results obtained have been given in a preliminary report, which shows the duty of water as computed with or without the rainfall and for different periods of the irrigating season. Since the greater part of the irrigation is carried on by means of water from streams which fluctuate from day to day, reaching their flood stage in June, it is necessary to assume a certain number of days during which the discharge of the river or the canal shall be taken, the computed duty of water varying according to the time thus chosen. This report assumes for comparison four periods, viz, May 1 to September 1, 123 days; April 1 to September 1, 153 days; May 1 to November 1, 184 days, and the month of June alone, or 30 days. The corresponding duties thus obtained are shown in the table on the following page for four cases, two of these being canals, the third the whole valley watered by these and other canals, and the fourth, the same valley with an allowance made for the amount of water which probably enters the main stream by seepage below the point of measurement. Summing up the whole matter, it would seem probable that the average duty of water per second-foot, as measured at the head of the canals and flowing constantly, is from 60 to 65 acres in June, or from 175 to 300 acres for the whole season, this last representing the conditions when a reservoir is available in which the water may be stored. (a)

a Colorado State Agricultural College, agricultural experiment station, Bulletin No. 22, preliminary report on the duty of water, page 30.

CONDITIONS FOR IRRIGATION NEAR FORT COLLINS, COLORADO.

DEPTH OF WATER IN FEET.								
CANALS AND FIELDS.	May 1 to September 1 (123 days).		April 1 to September 1 (153 days).		May 1 to November 1 (184 days).		June (30 days).	
	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.	From irrigation.	From irrigation and rain.
No. 2 canal	2.09	2.86	2.09	3.03	2.09	2.96	0.92	1.12
Larimer and Weld canal.....	1.49	2.26	1.49	2.43	1.49	2.36	0.73	0.93
Valley.....	1.25	2.02	1.30	2.24	1.33	2.22	0.64	0.84
Valley, seepage included.....	1.41	2.18	1.50	2.44	1.57	2.46	0.68	0.88
CORRESPONDING DUTY PER SECOND-FOOT IN ACRES.								
No. 2 canal	112	81	146	101	176	124	65	53
Larimer and Weld canal.....	165	109	205	126	246	155	81	64
Valley.....	195	122	233	136	274	168	94	71
Valley, seepage included.....	174	113	204	125	244	151	88	68

YIELD OF IRRIGATED CEREALS.

It has generally been assumed that upon irrigated lands the yields per acre are heavier than on the lands farmed by dependence upon rainfall, but owing probably to the fact that most irrigators did not have sufficient water for all their fields the average yield per acre of the irrigated lands, as shown by the census, did not reach extraordinary quantities. The most that can be said is that irrigation has enabled crops to be produced where otherwise it would have been impossible to produce them, and that with ample water and the exercise of unusual care and skill notable success can sometimes be attained.

Taking the cereals in the order of their importance as regards acreage in Colorado, wheat comes first. For the whole state the average production during the census year was 22.41 bushels per acre, while in Kansas the average was 19.21 bushels per acre, in Iowa 14.09, in Illinois 16.68, in Indiana 14.52, in Massachusetts 16.19, and in Georgia 5.58. Next in importance in Colorado is Indian corn, a great part of this, however, not being irrigated. The average production for the state was 12.67 bushels per acre, while in Kansas the production was 35.49 bushels per acre, in Iowa 41.28, in Illinois 36.84, and in Georgia 11.33. Oats come next in acreage, the average production of these in Colorado being 28.59 bushels per acre, in Kansas 30.49, in Iowa 39.09, and in Illinois 35.56. Of barley the average production in Colorado was 27.43 bushels per acre, in Kansas 23.01, in Iowa 25.84, and in Illinois 28.93.

These cereal averages are not as favorable to Colorado as has been generally assumed, for there has been very great exaggeration both as to the benefits and as to the extent of irrigation. Many of the cereals in the state have not been irrigated, or if water has been applied there has not been sufficient to produce the best results. With plenty of water and a thorough, intelligent cultivation of the soil, the yield under irrigation is large, but unfortunately comparatively few of the farmers possess the requisite water supply and agricultural skill. In many publications on the subject of irrigation, examples of extraordinary success are cited, giving the impression that the majority of farmers attain results as great.

By taking certain counties instead of the state as a whole, and thus eliminating to a large extent the effects of dry farming or of unusual scarcity of water, the results show better the success attained by irrigation. In Weld county, for example, the largest wheat producing county in the state, the average yield of wheat was 24.15 bushels per acre. This unquestionably can be taken as a fair sample of good results by irrigation. For comparison with this may be given, selecting counties at random, Pottawattamie county, Iowa, the average production being 11.54 bushels per acre, and Gage county, Nebraska, where the production was 21.94 bushels per acre. In Weld county the average production of corn was 14.80 bushels per acre, while in Fremont county it was 23.54 bushels per acre. Most of the great corn producing counties of the Mississippi valley have a far larger average production than this. Gage county, Nebraska, for example, averaging in corn 47.49 bushels per acre. The low average in Colorado is evidently due, as previously intimated, to the fact that the corn is not sufficiently watered, if at all. The same thing holds true of oats, for the largest production per acre in irrigated counties is equaled or excelled by other counties taken at random in Indiana, Illinois, and other states.

Comparisons of the staple crops, such as the cereals, do not show such a great advantage for irrigation as might be expected from theoretical considerations. In presenting the benefits of irrigation in popular publications it has been assumed that plenty of water can be obtained, while as a matter of fact this is exceptional. In comparing the returns to the irrigator with those of the farmer well within the Mississippi valley it should not be forgotten that while the irrigator with plenty of water can produce large crops per acre, yet he must pay out a certain amount of money each year for water and spend considerable time in applying the water properly to the

crops, compelling him to cultivate a less acreage. Thus it is that although the yield per acre may be greater on the irrigated land, yet on the nonirrigated the farmer can with the same amount of labor and investment cultivate a larger acreage, counterbalancing often the effect of a less profit per acre.

EASTERN COLORADO.

In the eastern part of Colorado, for example, the 32 counties lying east of the principal watershed of the state, comprising 58,135 square miles, or 56.09 per cent of the total area, greater progress has been made than in the portion drained by the Grand and Green rivers, and therefore a number of computations have been made pertaining to these counties as a whole. In the census year there were irrigated in these 32 counties 565,179 acres, or 883.09 square miles, the portion irrigated forming 1.52 per cent of the total area of these counties, a larger proportion than in the entire state. The total number of farms in the 32 counties on June 1, 1890, was 12,014, and of these 5,768, or 48.01 per cent, were irrigated in whole or in part. The total area of the irrigated land on these 5,768 farms was only 30.32 per cent. of the total area owned by the irrigators, and the average size of these irrigated portions was 98 acres. This portion of the state extends from the continental divide on the north and the Sangre de Christo and other mountains in the south, easterly over the Front range, the Wet and other mountains across the plains to Kansas and Nebraska, embracing thus the drainage toward the Missouri river.

The eastern part of the state is divided by a ridge which, starting in the foothills to the east of Pikes Peak, continues easterly nearly across the state, gradually dying down into the Great Plains. This forms the watershed between the two drainage systems of this part of the state, that of the Platte on the north and of the Arkansas on the south. Both of these rivers, rising in many creeks among the high mountains, flow easterly across the plains, furnishing on their course water for hundreds of ditches and canals. The South Platte rises in the South Park nearly in the center of the state and after passing through its lower canyons flows northerly along the base of the mountains, receiving in its course many large perennial mountain streams, each of which issues upon the comparatively level valley land from a deep, narrow canyon. The water is widely distributed, and the streams are of size and slope such that water can be readily diverted from them at small expense. The relative position of the small tributaries of the Arkansas is on the whole less favorable, although by no means presenting great difficulties to irrigation development. The main stream rises west of or behind the South Park and flows southerly and easterly through a long, narrow drainage area, and finally leaving the mountains starts directly across the plains. The larger tributaries from both north and south flow in a general diagonal course toward the river, passing through portions of the plain region, not emptying at once into the main stream, as in the case of the South Platte. Many of them, especially those heading at a considerable distance, thus lose nearly all of their water in passing through these arid regions and contribute little to the river except after heavy storms.

The mountains forming the western edge of the part of the state above mentioned not only give rise to almost innumerable streams, rendering agriculture by irrigation possible at points along their base, but also contain the great stores of mineral wealth which have attracted a large population, furnishing a market for all agricultural products. Thus it is that population and agriculture are concentrated in a comparatively narrow strip from Fort Collins and Greeley on the north, through Denver, Golden, Colorado Springs, Canyon, and Pueblo, to Trinidad on the south. West of this strip are the high mountains from which come the mineral wealth and water, and toward the east stretch the broad plains devoted mainly to cattle raising, but containing many farms upon which crops have been successfully raised without irrigation.

FARMING WITHOUT IRRIGATION.

It must not be supposed that all of the farming in the state is done by means of the artificial application of water. Especially on the eastern border, where there are no living streams, there are counties within which thousands of acres are cultivated annually and from which fair crops are obtained. As stated above a great part of the corn raised within the state is not irrigated and other cereals have been produced in like manner. The yield per acre by the so-called "dry farming" is, as a matter of course, much smaller unless rain happens to fall at times when most needed. Comparing the production of the three leading cereals on irrigated and "dry" farms, it has been found that in the census year in Boulder and 6 adjoining counties the average yield of wheat was 23.62 bushels per acre, while in Phillips, Sedgwick, and Yuma counties, in the northeastern corner of the state, where no irrigation was possible, it was 9.36 bushels per acre, or considerably less than one-half that in the first named counties. A less difference is shown by the oat crop, which in Boulder, Jefferson, Larimer, and Weld counties averaged 30.81 bushels per acre, while in Phillips, Washington, Sedgwick, and Yuma it averaged 17.21 bushels per acre. A still less difference is shown by Indian corn, which in the irrigated counties of Boulder, Jefferson, Larimer, and Weld averaged 15.39 bushels per acre, and in Elbert, Lincoln, Phillips, Washington, Sedgwick, and Yuma averaged 11.57 bushels per acre. Taking Elbert and Lincoln counties alone, where the rainfall is heavier than in the northeastern counties, the average production without irrigation was 21.10 bushels per acre, or larger than in the irrigated counties.

Besides the localities out upon the plains dry farming to a limited extent has been carried on successfully in a few of the higher valleys, where the temperature is low and where there is a relatively large amount of rain. The principal crops are for hay, and most of the cereals when planted are cut for this purpose. Although farming without a water supply has been successful in many places, it should not be inferred that such success is the rule. Hundreds or even thousands of settlers have attempted to make homes for themselves upon the Great Plains and after struggling against the prevailing droughts and losing crops year after year they have been brought to the verge of starvation. The condition of affairs in eastern Colorado has been similar to that in adjoining parts of Kansas and Nebraska. About the years 1886 and 1887 persons attracted by the representations that the soil was wonderfully fertile and the rainfall sufficient for agricultural operations flocked into the country and began to cultivate the soil. During one or two years many were successful and the majority succeeded in raising small crops, but the severe droughts of the succeeding summers caused much suffering and a rapid diminution in population.

ARTESIAN WELLS.

The artesian wells upon the farms in Colorado are found mainly in two great groups, the first of these being in the western end of Arapahoe county, in the vicinity of the city of Denver, and the second, and more important, in San Luis valley, being thus within the counties of Conejos, Costilla, Rio Grande, and Saguache. Outside of these areas many deep wells have been drilled, in some instances obtaining flowing water in small quantities. These latter wells have been put down usually by municipalities or corporations in search of water for city supply or similar purposes, and have little or no importance in irrigation.

In Arapahoe county 185 flowing wells upon farms have been enumerated, the depth ranging from 136 feet to 358 feet, the average being 400 feet. The average cost of these was \$420 and the discharge 13 gallons per minute. Comparatively a small amount of this water was used for irrigation, but for each well thus employed an average of 3 acres was irrigated. Most of the wells were drilled or driven for the purpose of obtaining water for domestic purposes, as it is far preferable to that obtained from the surface.

The flowing wells are mainly found within an area which begins about 15 miles south of Denver and extends northerly along the South Platte river for about 40 miles. The principal places within the artesian basin are, besides the city of Denver, Littleton, Petersburg, Island Station, and Brighton. The geological structure of this basin has been described by several writers, and the statistics regarding the artesian wells have been tabulated in detail. Among the first of the descriptions is that given in 1882 in a report upon the artesian wells upon the Great Plains by C. A. White and Samuel Aughey. This report, which covers the general subject of artesian wells upon the Great Plains east of the Rocky mountains, was written before the discovery of flowing water at Denver in 1883. A report upon the artesian wells of Denver, prepared by Whitman Cross and others, was published by the Colorado Scientific Society in 1884, as was also at a later date a second report upon the same subject, prepared by Charles G. Slack. This latter is an abstract of materials collected for use in the monograph upon the geology of the Denver basin by S. F. Emmons.

Besides the reports prepared by Emmons, Cross, White, and other members of the United States Geological Survey, statistics have been collected by other persons, notably by L. G. Carpenter of the State Agricultural College of Colorado, these being printed in reports to the Department of Agriculture and in Bulletin No. 16 of the agricultural experiment station of Colorado. This matter having been so thoroughly discussed in print it is not necessary to enter into further description. It is sufficient to state that the wells penetrate several alternations of clay and sandstone, most of the latter rocks containing water under hydrostatic pressure so great that it rises to the surface.

The number of wells in the basin, especially in the vicinity of Denver, has increased so rapidly that it has resulted in a less discharge than formerly from the older wells. In the city it is plainly seen that the opening or closing of one well affects those in the immediate neighborhood, but in the country this is not so apparent. In some cases the flow has entirely ceased, due either to this cause or to the clogging of the well by sand, or by losing water through some defect in the mechanical construction of the well. The water is generally soft and palatable and well adapted for domestic use. The quantity from any one well is so small that it is difficult to use it effectively for irrigation without the construction of reservoirs in which the water can accumulate until there is sufficient to give the field to be irrigated a complete saturation.

Northeast of the Denver basin, in Weld county, a few deep wells have been drilled by towns for the purpose of obtaining water for general uses. In a few instances the water rises to the surface and flows at the rate of a gallon or more a minute. One of these wells, at Greeley, is reported to be over 2,250 feet deep, and others in the same place and at Evans are about 1,200 feet. The amount of water from the wells which flow is so small that it can not be considered as a factor in irrigation, especially in view of the great expense involved in obtaining it. A few flowing wells are found in Jefferson county, where the water is used to a small extent on gardens. The flow, however, has decreased greatly, and in some instances stopped, so that it is necessary to use windmills to bring the water to the surface.

At Longmont, in Boulder county, 30 miles north of Denver, attempts have been made to secure flowing wells, and also at Loveland, in Larimer county, 45 miles north of Denver, where a well was put down to the depth of over 2,450 feet, but without success.

Toward the southern part of the state, near the base of the Rocky mountains, several deep wells have been drilled, notably in the vicinity of Pueblo. The first well was bored in 1879 for petroleum and reached a total depth of 1,400 feet. At a depth of 1,180 feet water of mineral character, and having a temperature of 80 degrees fahrenheit, was found. This discharged at the rate of about one-quarter of a second-foot, or a little over 100 gallons per minute. Other wells have been drilled in the vicinity of Pueblo, but the water, so far as can be ascertained, has not been used for agricultural purposes. West of Pueblo, in Fremont county, near Florence and Canyon city, a large number of wells have been drilled for the purpose of obtaining petroleum. Many of these wells would discharge water more or less mineral in character if this were not shut off by packers. In the western part of the state deep drillings are reported at several towns, and also a flowing well at Montrose, in the county of the same name. No artesian wells, however, are reported by farmers.

In the eastern end of the state, in the counties far out on the Great Plains, large sums have been expended in the attempt to secure artesian water. Deep wells have been sunk by railroad companies and other corporations, by towns, and in two instances by the national government under the direction of the Department of Agriculture. At Akron, in Washington county, the water in the government well rose to within 55 feet of the surface. At Otis, about 12 miles east, a well 2,400 feet deep did not reach flowing water. In Cheyenne county, at Cheyenne Wells, 2 deep wells were sunk without finding flowing water. One of these, an experimental drilling by the government, reached a depth of 1,740 feet. At Kit Carson, 25 miles westerly from this point, a well has been drilled to the depth of 1,300 feet, but without success. At Sheridan lake, in Kiowa county, about 25 miles southerly from Cheyenne Wells, deep drillings have also been unsuccessful. At Fort Lyon, near Las Animas, in Bent county, the government well, over 700 feet in depth, was unsuccessful. East of this point, in Prowers county, there are reported to be a number of small flowing wells along the Arkansas river, the depth being given as about 230 feet.

The great artesian basin of Colorado is in San Luis valley, flowing water being found at almost every point within the limits of the ancient lake bottom. The largest flowing wells are those in the vicinity of the town of Alamosa, the greater part of the water coming from a depth of 600 to 800 feet. The average depth of all the wells in the basin is only about 200 feet, and the cost was approximately \$150 each. The discharge, taking large and small together, averages 53 gallons per minute. A trifle over one-half the wells on the farms have been used for irrigation, watering an average of 17 acres each. This gives a water duty of approximately 1 second-foot to 144 acres.

In Conejos county the flowing wells are mainly in the northeastern corner, from La Jara to Alamosa. They vary in depth from 40 to 478 feet. The shallower wells yield a cold, palatable water, but that from the deeper wells is considered too warm for drinking. This latter class of wells is more valuable for irrigation on account of the higher temperature of the water, since it does not chill the plants. Many of the farmers report attempts at irrigation, but state that with the small shallow wells possessed by them these have not been successful, as the wells discharge such a small quantity of water that it can not be utilized except by the construction of reservoirs, which would impose additional expense. Other farmers, where the surface of the ground is favorable, have constructed small earth reservoirs in which the water can accumulate until warmed by the sun in an amount sufficient to render irrigation practicable.

There is general complaint that the water is allowed to run to waste and that some of the neighboring wells have been injured thereby. There is clearly a general diminution in discharge, although this is not seen in all the wells, especially in the case of those in the thinly settled country. In the latter part of the crop season, when the small ditches of the farmers become nearly or quite dry, the flowing wells are of especial benefit, since the need of even a small amount of water at that critical time is imperative. In a few cases the water is so strongly impregnated with mineral matter that the farmers have not been successful in employing it for irrigation, but these instances are comparatively rare, and the well and river waters are often used together.

In Costilla county the majority of the wells are in the northern and western part, on the lands irrigated by the large canals from the Rio Grande. The water, as in the case of the other counties, is used mainly for houses, gardens, and for stock, since most of the farmers have an ample supply for irrigation from the ditches which traverse the county in various directions. Some of the wells, however, are used in this manner, but it is stated that away from the vicinity of ditches the wells are of comparatively little use in irrigation, for the reason that where the ground is perfectly dry to the depth of 6 or 8 feet or more, the small amount of water from an ordinary flowing well is completely lost before it can cover an area of any considerable size.

In and near Alamosa are several flowing wells which have attracted considerable attention from the fact that when properly regulated one at least will throw water to the height of upward of 40 feet, and when flowing freely will discharge as high as 1 cubic foot per second. The water from some of these wells is run into depressions, and ponds have been made in which the raising of fish has been begun, and it is possible that enterprises of this character may prove profitable in a small way.

NUMBER OF IRRIGATORS, AREA IRRIGATED, FARMS, AND CROPS IN COLORADO IN 1889, BY COUNTIES—Continued.

COUNTIES.	Number of irrigators.	Area irrigated in acres.	Average size of irrigated farms in acres.	OWNERS OF FARMS.		IRRIGATORS.		Area of counties in acres.	FARM AREA.		Cereals. (Acres.)	Alfalfa. (Acres.)	AREA IRRIGATED.		
				Total number.	Per cent of population.	Per cent of farm owners.	Per cent of population.		Acres.	Per cent improved.			Per cent of area of county.	Per cent of total farm area.	Per cent of land owned by irrigators.
Montrose	462	27,361	59	569	14.30	81.20	11.61	1,472,000	108,345	35.36	9,083	7,659	1.86	26.48	31.88
Morgan	97	16,443	170	147	9.18	65.99	6.06	825,600	52,100	42.14	2,643	2,823	1.99	31.56	37.90
Otero	139	16,431	118	177	4.22	78.53	3.32	1,312,000	61,947	40.72	3,417	4,988	1.25	26.78	31.01
Ouray	94	7,894	84	96	1.47	97.92	1.44	288,000	16,998	59.86	2,539	583	2.74	46.44	46.35
Park	136	24,015	177	171	4.82	79.53	3.83	1,344,000	120,567	36.76	384	.....	1.79	19.92	20.75
Phillips .....	.....	.....	.....	408	15.44	.....	.....	364,800	94,302	26.82	10,061	.....	.....	.....	.....
Pitkin	115	7,041	61	116	1.30	99.14	1.29	608,000	21,066	40.07	1,981	456	1.16	33.42	32.98
Prowers	18	1,808	100	101	5.13	17.82	0.91	1,056,000	46,447	20.92	554	257	0.17	3.89	22.32
Pueblo	206	10,930	53	325	1.03	63.38	0.65	1,536,000	100,697	48.17	2,838	3,372	0.71	10.85	16.93
Rio Blanco	135	7,592	56	101	15.92	70.68	11.25	2,304,000	36,675	47.33	1,366	157	0.33	20.54	21.60
Rio Grande	195	21,797	112	198	5.74	98.48	5.05	806,400	55,793	59.11	7,817	311	2.70	39.07	39.07
Routt	280	16,323	58	367	15.49	76.29	11.82	3,840,000	93,872	59.08	577	339	0.43	17.39	19.38
Saguache	240	52,453	219	262	7.91	91.60	7.24	2,073,600	200,587	25.24	4,267	392	2.53	26.15	25.90
San Juan .....	.....	.....	.....	.....	.....	.....	.....	320,000	.....	.....	.....	.....	.....	.....	.....
San Miguel	57	2,125	37	88	3.03	64.77	1.96	832,000	15,768	28.30	140	30	0.26	13.48	16.96
Sedgwick .....	.....	.....	.....	280	21.66	.....	.....	416,000	52,724	78.94	6,615	.....	.....	.....	.....
Summit	20	1,316	66	20	1.05	100.00	1.05	441,600	3,680	53.53	.....	22	0.30	35.76	35.76
Washington	1	720	720	356	15.47	0.28	0.04	691,200	77,341	28.35	11,762	42	0.10	0.93	90.00
Weld	1,046	112,080	107	1,225	10.44	85.99	8.91	2,608,000	368,781	55.15	65,495	24,380	4.30	30.39	43.29
Yuma	5	373	75	436	16.80	1.15	0.19	755,200	109,870	30.07	17,022	248	0.05	0.34	4.17

ARAPAHOE COUNTY comprises a long, narrow strip of land in the northeastern part of Colorado, extending nearly half across the state. In the extreme western end is the city of Denver, and the county stretches east to the Kansas line. Nearly all of the irrigated land is along the South Platte, which flows northerly through Denver. Many large canals take water out from this river or from the tributaries coming in from the west, the principal of which are Bear and Clear creeks. East of the river are many streams crossing the county from south to north and finally emptying into the South Platte, but most of these only carry water during times of flood, and are dry during the summer. Many attempts have been made to raise crops throughout the eastern part of the county. The soil is rich, but the rainfall is very uncertain. By careful cultivation, some crops are profitable, but there is little certainty owing to the prevailing summer droughts. Near the Kansas line, corn, oats, wheat, barley, and potatoes are raised, but the yield per acre is sometimes less than half that on irrigated land. Many settlers have tried for two or three years, but their attempts at farming have been so discouraging in the results attained that they have either left or are trying to make a living by raising stock. Water in many places can be obtained only by wells of from 80 to 200 feet in depth.

The south fork of the Republican river and its principal tributary, the Arikaree, flow diagonally across the eastern end of the county, furnishing a small amount of water for irrigation, the ditches being very small and taking water to the ranches of one or two individuals. In the Arikaree valley the crops during the census year were fairly good considering the prevailing drought. On the high, level divides between the streams farmers have not been as a rule successful, and it is stated that the surrounding country is fast decreasing in population.

The canals in the vicinity of Denver are among the largest in the arid regions. Taking them in general geographical order, the first of importance on the east side of the South Platte is the Northern Colorado Irrigating Company's canal, which heads in Douglas county and covers lands east of Denver. Below this are the Platte Water Company's ditch and many smaller ditches taking water from Dry creek, Little Dry creek, and Cherry creek. North of the city, and on the east side of the river, are the Burlington, the Duggan, and the Fulton, the latter extending beyond Fort Lupton in Weld county. On the west side of the South Platte in this county are the Last Chance and Nevada ditches, taking water from the river, and the Agricultural ditch, taking water from Clear creek below Golden, besides a number of small ditches depending upon Bear creek for their supply. North of Denver are the ditches from Clear creek, the most important of these being the Colorado Agricultural ditch and the Clear Creek and Platte River ditch. The aggregate capacity of the canals and ditches exceeds the water supply, and except in times of flood some of the canals can not be filled. There is more or less complaint that owing to lack of restrictions speculators have built canals and sold water rights which are practically valueless.

The Northern Colorado Irrigating Company's canal, known as the Platte canal, or more commonly the "Highline", heads in the Platte canyon, about 20 miles above Denver, and covers lands on the east side of the river in the vicinity of the city. The total length with the Sand Creek branch is 85 miles, and the average width for the first 50 miles is nearly 40 feet. The grade is 21 inches to the mile and the average depth of water 4 feet. The total cost was \$650,000. The canal was begun in 1879 and used in 1883. Water is diverted by a dam 120 feet long and 14 feet high, made of heavy timbers and provided with a masonry wasteway. There are about 200 laterals, each from one-half mile to 6 miles in length, and all belonging to farmers. Water rights in this canal have sold for from \$35 to \$40 per acre. The annual assessment, \$1.75 per acre, is that established by the county

commissioners. The water supply is usually short once or twice during the season, owing partly to the fact that it is taken by other canals and ditches, although these do not have prior rights to it. (a)

The city ditch heads below the canal just described on the same side and runs along the east bank of the river, carrying water to the city of Denver. It is 28 miles long, 10 feet wide, and cost about \$65,000. It was begun in 1859 and used in 1865. The canal is owned by the city of Denver, which purchased the entire control for the purpose of supplying water to the gutters of the streets of the city, thus irrigating the trees and parking along the sides. Until the construction of the Highline ditch it was the most important work of its kind east of the Platte river.

The Agricultural ditch takes water from Clear creek out upon the lands on the south side and runs in a southeasterly direction, ending at the Platte river at a point 7 miles south of and above Denver. The total length of the ditch is 25 miles, the average width 8 feet, and the cost was \$50,000. It was begun in 1874 and used in the following year. It is owned by a company and the water is divided among the shareholders.

ARCHULETA COUNTY lies west of the continental divide and adjoins Rio Arriba county, New Mexico. It contains a comparatively small amount of agricultural land and has a large, well distributed water supply. The population is small and scattered, mining and stock raising being the principal industries. Nearly all crops can be raised without irrigation, although with water applied at the proper time the yield is increased. The San Juan river and its tributaries flow across this county, carrying at all times a large quantity of water, the amount of which has not been measured. Along each of these streams one or more ditches have been taken out for irrigating grass and other crops finding a ready market at the mining camps. This part of the state, however, is so remote from large markets and the expense of transportation is so great that the development of agriculture must be slow. Surveys have been made for ditches of from 4 to 10 miles in length to irrigate lands in the vicinity of Pagosa Springs. The expense of construction in this mountainous country is great and progress of necessity is not rapid.

BACA COUNTY is in the southeastern corner of Colorado, adjoining Kansas and the public land strip. It is thus far out in the Great Plain region and on a part of it where the water supply is unusually small. The Cimarron river cuts across the southeastern corner, furnishing a small amount of water which can be diverted by ditches to the ranches on the bottom land. The northern part of the county is crossed by the drainage channel of Two Butte creek, which leads into the Arkansas, and by that of Horse creek and other tributaries of Bear creek, which, continuing easterly into Kansas, is lost in sinks among the sand hills. There is very little water in these channels except after heavy rains.

The population of the county is scattered, about the only occupation being stock raising. In 1887 there was an influx of settlers, but many of these left during the succeeding years on account of drought. The principal part of the area in cereals was devoted to Indian corn, besides this there being some sorghum and vegetables raised. A large part of the surface of the county is covered by sand hills, and the agricultural possibilities appear to be small.

BENT COUNTY is northwest of Baca, including lands on both sides of the Arkansas river. Within this county are several large canals, which have been extended from Pueblo and Otero counties on the east, and also a few ditches deriving water from the Arkansas within the county limits and covering lands in the vicinity of Las Animas. Many of the farmers, depending for their supply upon the large canals, complain that at this distance from the head they have not been able to obtain a sufficient amount of water, having only one-half or three-quarters the quantity for which they have paid. For this reason they state that they have been afraid to make many improvements, such as setting out orchards. There is a demand that the canal companies be prevented in some way from selling water rights unless there is reasonable assurance that the quantity of water called for can be delivered. Agriculture in this and the adjoining counties has been but lately developed. In 1887 and 1888 only a few acres were cultivated, the principal industry being the raising of cattle and horses. By the construction of the large canals, however, agriculture is rapidly advancing, the chief drawback being, as previously intimated, the uncertainty regarding the ability of the canal companies to keep the system in repair and furnish water at all times.

Measurements of the amount of water in Las Animas river, which flows into the Arkansas near the town of Las Animas, were made during 1889, giving the results shown in the table on the following page. This stream is also known as the Purgatoire or, in common parlance, the Picket Wire. It is a stream which near its head waters is of considerable importance, but the portion of its drainage channel traversing the plains region does not receive a perennial supply of water and through a great part of the year is completely dry.

^a For a more complete description and a view in the canyon see a paper by H. M. Wilson on American irrigation engineering, Transactions American Society of Civil Engineers, volume 25, pages 117-119.

DISCHARGE OF THE LAS ANIMAS OR PURGATOIRE RIVER AT LAS ANIMAS, COLORADO.

(Drainage area, 3,040 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maxi-mum.	Mini-mum.	Mean.		Depth in inches.	Second-feet per square mile.
1889.						
May 22 to 31.....	55	11	22	1,353	0.01	0.01
June.....	170	27	70	4,165	0.03	0.02
July.....	1,770	8	260	15,990	0.10	0.09
August.....	780	6	69	4,243	0.03	0.02
September.....	275	6	40	2,380	0.01	0.01

BOLDER COUNTY is in northern Colorado, northwesterly from Arapahoe county. It extends from the summits of the range easterly to the plains, and thus comprises on its western side a high catchment area from which a great amount of water comes, and on the east many thousand acres of fertile land upon which the water is used. The facilities for irrigation are almost unrivaled, and the county contains the largest proportion of irrigated land in the United States, amounting to 14.04 per cent of the total area.

The boundaries of the county are so located as to include nearly all of the drainage basin of St. Vrain creek and its principal tributary, Boulder creek. These streams are formed by the union of a number of torrents, which is fed principally by melting snows in the mountains. At and below the point where these creeks enter the canyons and enter upon the plains are the headworks of many irrigating canals and ditches, taking the water upon each side and forming a network over the country. The slope of the land surface and of the canals is sufficiently great to allow the canals to be carried back almost at right angles to the source of supply, thus irrigating the land between the two tributaries. So many systems of irrigation have been constructed that it is possible to fill all with water, and during the summer some of the ditches are nearly dry, thus resulting in a serious loss to the farmers. Each year more land is brought under cultivation than can be satisfactorily irrigated unless there is an exceptional amount of snow in the mountains.

To supply the deficiency of water during the summer season many depressions in the surface have been made as reservoirs in which flood waters are stored. These are comparatively few in number and by no means sufficient for the needs of the farmers. It will be necessary to make use of every facility for water storage not only on the lands to be irrigated but also higher in the mountains, in order to greatly increase the area irrigated.

Even when this is done it is doubtful whether all of the arable land of the county can be cultivated. The farmers complain that ditches are being built or enlarged partly for speculative purposes, and they do not believe it right to encourage the extension of irrigation until water is provided for the lands now under cultivation. In many instances they state that they can not follow any system in the application of water to the land, on account of the fact that they must use the water at times when they can get it, rather than when the plants need it.

St. Vrain creek and its tributaries, with the exception of Boulder creek, form water district No. 5, the lower part of this being in Weld county. In this district it is stated that the amount of water decreed to the various farms is over nine times the average discharge of the creek during the irrigating season; in other words, if the water is divided equally each ditch must receive less than one-ninth of the water to which it is apparently entitled. A report of the water commissioner for this district 61 ditches are enumerated, having an aggregate length of 1,258 miles. The drainage basin of Boulder creek forms district No. 6, which also extends into Weld county. The ditches given in this district have a total length of 258 miles.

The principal irrigating ditches in the county are as follows: on the north side of St. Vrain creek are Supply, 1st, Rough and Ready, St. Vrain and Palmerston, Longmont Supply, Chatman, Oligarchy, Demio and the Farmer ditches. On the south side of St. Vrain creek are South Ledge, Swede, James, Pella, South Flat, and the Bonus ditches. On the north side of Lefthand creek are Tollgate, Table Mountain, Holland, Cochran, and Williamson ditches. On the south side of Lefthand creek are Altoona, Crocker, No. 2, Johnson, Star, Farmers, Hornbaker, and other ditches. On the north side of North Boulder creek are Farmers, Boulder and Whiterock, Boulder and Lefthand, Revolution and Legget. Between North and South Boulder creeks are the McIntosh, Dry Creek, and Howard ditches, taking water from South Boulder creek. On the south or east side of this latter creek are the South Boulder and Coal creek, Community, Davidson, 3rd, Marshallville, Doggett, Dry creek, Cottonwood, Barter, Lower Boulder, Matthews, and other ditches. A portion of a few of these will serve to give the general character.

Highland ditch, on the north side of St. Vrain creek, is about 35 miles long, 15 feet wide, and cost \$1,000,000. It was built in 1871 and partially used in the following year. The water supply is insufficient, but it is

to be increased by the use of reservoirs, filled in April and May and utilized in the latter part of June and July. The present selling value of the water rights is stated to be about \$20 per acre. The Rough and Ready ditch, below this and in a general way parallel to it, is 15 miles long, about 12 feet wide, and cost nearly \$10,000. The value of water right per acre is stated to be about \$10. Attempts are being made to increase the water supply by storage reservoirs, since a large amount of grain is lost each year under this, as well as under other ditches, because of scarcity of water. The Oligarchy ditch is about 15 miles long, 12 feet wide, and cost \$6,000. It is owned by farmers using the water. As in the case of the other ditches, there is complaint of scarcity of supply. The Boulder and Whiterock ditch is about 25 miles long and cost \$35,000. It was begun in 1873 and used in 1874.

CHAFFEE COUNTY is about the center of the state, lying between the Park range on the east and the Saguache mountains on the west. It is near the head waters of the Arkansas river, this stream rising to the north in Park county and flowing southerly through Chaffee and Fremont counties to the Great Plains. The general altitude of the agricultural lands in the valley is from 7,000 to 9,000 feet, these extending along the Arkansas and its principal tributaries. The streams which come from the mountains on each side of the county are utilized for irrigation by many ditches. A map published by the state engineer and covering the irrigated portion of this county shows nearly 150 of these. No crops are raised without irrigation on account of the deficiency of moisture during the summer. The supply of water in the streams, however, is usually good, although there is necessity each year for careful division of it during the summer. Nearly all cereals and vegetables are raised, the altitude being in most places too high for the success of corn and many fruits. Most of the water, however, is used for producing hay or on the meadows and other pasture lands.

The amount of water available for irrigation has been measured at a few points in Lake county (which see) and also within this county. Gaugings of Clear creek were made near Granite from April to October, 1890, showing that the maximum discharge was 435 second-feet and the minimum 12 second-feet, the average for this time being about 133 second-feet. The drainage area at the point where measured is 72 square miles. Both the middle and south forks of the Cottonwood were gauged near their junction west of Buena Vista, the observations continuing from April to August. The average discharge of the middle fork was 65 second-feet and of the south fork 71 second-feet. These measurements were made by the United States Geological Survey for the purpose largely of determining the value of these streams for storage purposes.

For the needs of the county itself there is comparatively small demand for water storage, but there is great necessity for holding at these high altitudes as much of the flood water as possible for the dry lands farther down the river on the Great Plains. There are, however, a number of small projects undertaken by irrigators in this county having in view the saving of water for their own use during the summer, and work has already been begun on small reservoirs. Taking the county as a whole there is probably greater need of more careful use of the water available than there is of increasing the amount by storage.

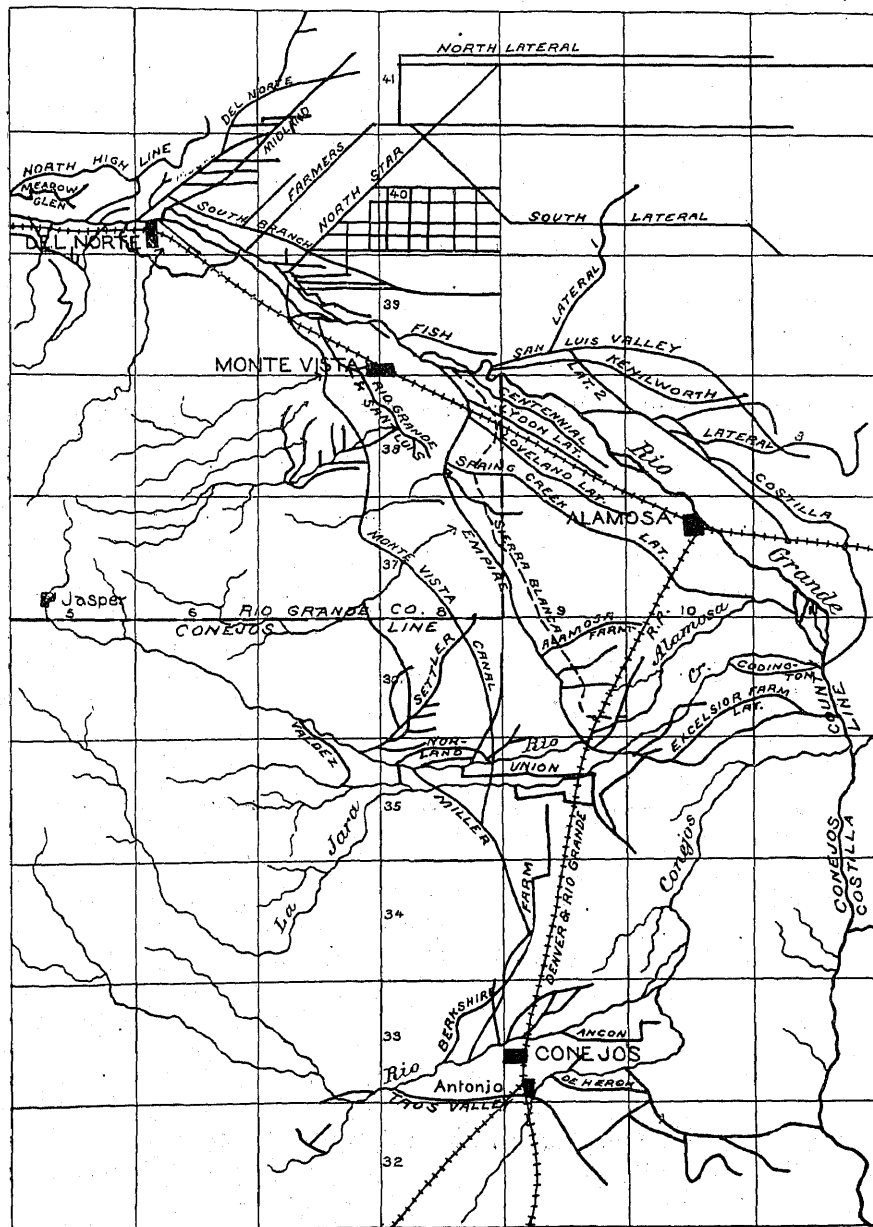
Among the principal ditches of the county may be mentioned the Missouri Park ditch, taking water from the South Arkansas and carrying it out on the north side northeasterly to the valley of the Arkansas. It is about 4 miles long, 10 feet wide, and cost about \$5,000. It was begun in 1880 and used in 1882. Below this is the Hill and Sprague ditch, coming out on the same side and in a parallel direction. It is about 6 miles long, 4 feet wide, and is owned by private parties. The Willowdale ditch takes water from Chalk creek out on the south side of the valley. It is about 5 miles long, 6 feet wide, and cost \$2,500. It is owned by private parties and irrigates about 250 acres. From all sources of water supply there are to be found many little ditches running in nearly parallel courses, a number of which might be replaced by one good canal carrying water to the land with less loss and greater efficiency.

CHEYENNE COUNTY is on the eastern side of the state. It is far out on the Great Plains and may be taken as a fair representative of the counties within this almost arid region, where cattle raising is the principal industry. Few crops can be produced without irrigation, and for this latter method of agriculture there is almost no water supply. Farming without the application of water has been tried and in some localities has been partly successful. Fruit trees have been set out as an experiment, and many of these survived the drought of 1890. Sorghum has been cultivated, but with little success. Big Sandy creek and its tributary, Rush creek, are in the western end of the county, but these seldom have any water in the channel except that which may be percolating through sandy beds. Occasionally after a heavy storm these creeks and the dry arroyos become torrents for a few hours, the flood quickly disappearing. In the eastern end of the county are the head waters of the Smoky Hill river, which, rising in springs, flows easterly. The amount of water in these is almost insignificant, and it is soon evaporated or lost. Attempts have been made to secure water by means of wells. The town of Cheyenne Wells is supplied by a steam pump drawing from a well 256 feet deep. Within 5 miles there are two other wells, one 250 feet, the other 200 feet in depth, both of these being pumped by windmills. At other parts of the county water is obtained at less depths and in quantities sufficient for cattle. The soil, as usual on the prairie, is rich, and with sufficient rainfall produces large crops, but unfortunately there are comparatively few years during which the precipitation is heavy.

CLEAR CREEK COUNTY covers a small area of the eastern slopes of the Front range west of the city of Denver. It consists largely of high mountains with narrow valleys, and is notable for its mineral wealth. There is very little land favorable for agriculture, and the altitude is too great for the success of most crops, Georgetown, the county seat, being at an elevation of 8,484 feet. Along the creek below Georgetown small areas of land have been brought under irrigation, mainly for the purpose of raising hay.

CONEJOS COUNTY is on the south side of the state, west of the Rio Grande, and between it and the summits of the San Juan mountains. It thus includes the southwestern portion of San Luis park and adjacent watershed. The altitude of Alamosa is 7,531 feet, and of the town of Conejos 7,880. The principal agricultural land of the valley is between or in the vicinity of these places, and thus is at an elevation higher than that at which many of the crops of the temperate zone are ordinarily raised. The climate, however, is relatively mild, and the yield of the cereals and forage crops is large, as is the case throughout this valley. The water supply of the county is unusually good, a number of large streams coming out from among the San Juan mountains. The principal of these are Alamosa, Lajara, Conejos, Pinos, and San Antonio creeks. All of these on reaching the valley rapidly change in character from mountain torrents and apparently lose a large proportion of their waters in the pervious bottom lands. The larger streams cross the low lands and flow into the Rio Grande, while others do not contribute water to this river except at flood times. Few ditches are taken from the Rio Grande in this county on account of the difficulty of diverting water, but there are a number of large canals, mainly in Rio Grande county, which extend

MAP OF PRINCIPAL IRRIGATING CANALS OF CONEJOS AND RIO GRANDE COUNTIES, COLORADO.



over the line and irrigate lands west and south of Alamosa. The amount of water in most of the creeks is large, and when properly used is probably ample for lands now cultivated. Under the various ditches and canals there are, however, large tracts which, if fully irrigated, will require the maximum amount discharged by the creeks. Many of the farmers are of Mexican descent, cultivating their land according to old methods and using the small ditches constructed years ago.

The opinion is commonly expressed by the irrigators that in order to utilize all the land under ditch it will be necessary to store flood waters at suitable places in the mountains or near the foothills. The amount of water claimed by each ditch is in most cases far greater than is usually received, and the aggregate amount of water adjudicated to various claimants is throughout the valley enormously in excess of the quantity discharged by the streams even in times of flood. During the drought of 1889 some of the crops were lost or injured by the fact that one or more of the large canals was deprived of water at a critical time owing to legal complications and decrees. In 1890, however, there appears to have been ample water for all.

The principal ditches of the county, omitting the large canals heading on the Rio Grande, are: on the north side of Alamosa creek, the Settler, Norland, Scandinavian, and on the south side the Valdez, Miller, Union, and others; on the north side of the Conejos, the Northeastern, Mogote, Berkshire Farm, and on the south side Taos Valley, Aucon, and others. The Scandinavian ditch, covering land on the north side of Alamosa creek, is 5 miles long, 14 feet wide, and cost \$5,000. It was begun in 1887, used the following year, and finished in 1890. In 1889 about 200 acres were irrigated, the greater part of this being in wheat and the rest in oats and potatoes. The Valdez ditch, on the south side of the creek, heads higher up near the foothills. It is 6 miles long, 12 feet wide, and cost \$1,500. Work on this ditch was begun in 1873 and it was used soon afterward. In 1889 about 400 acres were watered, the principal crops being wheat, oats, potatoes, and peas.

The Miller ditch heads on the south side of Alamosa creek about 5 miles below the Valdez. It is 6 miles long, 10 feet wide, and, since an old dry channel was used for about 4 miles, the cost is estimated to have been only about \$500. Work was begun in 1885 and completed in the following year. The Union ditch heads about 3 miles below the Miller and not far from the Scandinavian on the opposite side. It follows a course in general parallel with Alamosa creek and at a distance of a mile or more. It is 10 miles long, 10 feet wide, and cost \$8,000. It was built in 1876, and in 1889 irrigated about 2,500 acres in wheat, oats, potatoes, barley, and grass.

The Los Pinos ditch may be taken as an example of one of the old works of the country. It heads on the south side of Pinos creek near the state line. It is a little over 3 miles in length and 4 feet in width and was built probably in 1851. It is owned by private parties, who select one of their number to take care of the ditch and divide the water. In 1889, 405 acres in wheat, corn, oats, barley, potatoes, and pease were irrigated. The Mecitos ditch takes water from the north side of Conejos river about 5 miles above the town of Conejos. It is 4 miles long and 6 feet wide. It was built in 1857 and is owned by private parties. The Mogote ditch heads about 2 miles below the Mecitos and continues in a general northerly direction to Lajara creek. It is 17 miles long, 12 feet wide, and cost \$10,000. It was begun in 1887 and finished in the following year. It is stated that in this vicinity, as the years go on, less and less water is needed for irrigation, and that some of the lower lands are becoming so saturated as to require drainage.

COSTILLA COUNTY is on the eastern side of San Luis valley and extends from the Culebra range to the Rio Grande, this stream forming the boundary line between this and Conejos county. In the northern end are the San Luis lakes, which in time of floods receive some water from San Luis river and from creeks rising in the Sangre de Christo mountains. The principal streams flowing toward or into the Rio Grande in this county are Trinchera, Culebra, and Costilla creeks, each of these draining a considerable area of mountain land. The valley as a whole falls toward the center with very gentle inclination and also has a decided slope toward the south. The Rio Grande, however, is upon a low ridge, the bed of the stream being higher than lands a mile away on each side. Thus the water of the river can be carried to great distances away from the main stream, as is the case in the northwestern corner of the county.

The soil in San Luis valley varies greatly in quality, requiring very diverse methods of applying water for irrigation. To produce the best results it has been found that each farmer must have long experience with the particular soil and crop, and there can be no such thing as uniformity in quantity of water to be used or time of application. In the vicinity of some of the larger canals the ground has become so saturated with moisture that water can be found at from 3 to 5 feet below the surface or even less where in former times the earth appeared perfectly dry to depths of 50 feet or more. The presence of this water beneath the surface greatly alters the conditions necessary to produce crops. On some fields with apparently a porous soil the largest yield has been obtained by simply allowing water to stand in the ditches around the tracts, but without applying any to the surface. This is commonly known as subirrigation. At the other extreme there are soils composed mainly of stiff, heavy clay, or adobe, where the water does not seem to penetrate more than a few inches. Between these extremes are all varieties of conditions. A common method of watering is to run the water in laterals at a distance of from 100 to 150 feet apart, allowing it to seep each way. As in the case of Conejos county, most of the crop irrigated is for forage purposes.

The area of land brought under canal is very great, to all appearances far greater than can be supplied by the present amount of water available, even though economical methods are practiced to their full extent. There is complaint from the farmers that canal companies have been reckless in selling shares or rights to the use of water to an amount far in excess of that which can be had. There is, as a matter of course, more or less friction between the smaller irrigators and the large canal companies, the latter being denounced as oppressive monopolies, and some of the former characterized as ignorant and wasteful in their use of water. The diversion of water from the Rio Grande, so far as the summer supply is concerned, is almost complete, and, as in August and September, 1890, the stream near Alamosa may be dry. The river in its natural state probably never ceased flowing in summer, although it has been stated by old settlers that it has been nearly dry twice in 20 years. Most of the larger canals head in Rio Grande county. The Costilla, however, takes water from a point about 8 miles above Alamosa and carries it out easterly and at a distance of about 3 miles from the stream. The total length is about 20 miles, the width 18 feet, and the cost was \$10,000. One share in this canal is supposed to furnish 100 inches of water, an amount sufficient for 160 acres.

The condition of irrigation in the eastern part of the county along the Culebra and Costilla rivers is perhaps best given by the following facts, obtained from Mr. E. C. Van Diest, civil engineer. He states that the amount of water carried by the Culebra river varies from 125 to 150 second-feet at its lowest stage, from about July 20 to October 25. From this as a minimum it reaches a quantity of from 850 to 900 second-feet at its highest point, usually about June 25. Costilla river fluctuates at the same times, varying from 60 to 70 second-feet at its lowest stages up to from 800 to 900 second-feet as a maximum.

These 2 streams furnish water for 45 ditches, the larger carrying from 6 to 40 second-feet. These supply a large number of irrigators, mostly Mexican, each cultivating on an average about 15 acres. The water is diverted in nearly all cases by means of wing dams constructed of brush, rock, and logs, only a few ditches having head gates. These dams are usually washed away by each flood and must be renewed or repaired each year. No estimate of the cost of these ditches can be given, as all have been constructed by farmers whose land is supplied. The owners of each ditch elect yearly one of their own body to act as major-domo, whose duty it is to direct the work of cleaning and repairing the ditches and to apportion water in times of scarcity. The annual repairs are often heavy, as the ditches have been constructed in the most primitive fashion with little regard to grade or character of soil, the slope of the ditch being in places so excessive that channels upward of 10 feet in depth have been washed out. From 1 to 4 days' work is generally required annually from each irrigator.

Water is taken by the Mexican owners from the ditches to the small laterals by simply cutting the bank, measuring boxes being exceptional. In times of abundance each person takes as much as he wishes whenever he desires, using often an excess. In times of scarcity, however, the major-domo decides which of the consumers shall be supplied each day, basing his judgment on the appearance of the crops. All irrigating is done by flooding a small area inclosed by checks or borders, keeping the water at a depth of from 2 to 3 inches or more and then allowing it to escape to the next small square or rectangle. Owing to the peculiar methods of subdividing the land among the families of the Mexicans, much of it is held in narrow strips having a length of a mile or more, one ditch or sometimes two crossing each holding. There is often great negligence and carelessness in the control of these ditches and a great part of the water is wasted, so that the water duty appears to be excessively low, 1 second-foot being applied to about 50 acres during the months of May and June and to from 65 to 70 acres in July and August.

CUSTER COUNTY includes a portion of the eastern slopes of the Sangre de Christo range and the higher peaks of Wet mountains. Between these lies the broad area known as Wet Mountain valley, the altitude of which is about 8,000 feet. Streams flow into this from nearly all sides and the water escapes toward the north into Arkansas river through either Texas or Grape creek. On the eastern side of the Wet mountains are the head waters of St. Charles river, which flows through Pueblo county. On these high lands farming is sometimes carried on without irrigation, for there is often sufficient rainfall. Occasionally the season is too dry for crops, and the losses are heavy. The greater part of the area irrigated in the census year was for meadow or hay. As in the adjoining county, mining and stock raising are the principal industries, and there is thus a home market for all produce. With proper irrigation and cultivation a great variety of crops succeed in spite of the high altitude. The water supply is well distributed, coming, as it does, from so many small streams. Each farmer usually has his own ditch, which has been dug with no regard to system and with little reference to the needs of his neighbors. The amount of water available has been quite completely utilized, and during July and August there is usually a deficiency. There are many localities favorable for saving water, notably in the Sangre de Christo range, where there are reported to be a number of small lakes.

DELTA COUNTY is on both sides of the Gunnison river above its junction with the Grand. The Uncompahgre river flows into the county from the south and the north fork of the Gunnison comes in from the mountains on the east. These, with the main stream and numerous creeks, furnish a large amount of water for irrigation. The broad valley of the Uncompahgre extends northerly on both sides of the river, and, uniting with that of the Gunnison, continues down that river, this open land extending into Mesa county. Agriculture is carried on not

only in this valley but also in its prolongation northeasterly from the town of Delta along the creeks flowing from the Grand mesa. The altitude of Delta is under 5,000 feet, and as a consequence the climate is mild and favorable to fruit culture.

The water supply of the county is so large and well distributed that irrigation has developed rapidly, and all of the more easily available sources of supply have been long since utilized. The Gunnison river itself, flowing for so much of its course through canyons, is employed with great difficulty, and as a consequence has been of relatively small value in irrigation development. The expense of taking water out of this river is so heavy that irrigators have endeavored to supply their needs by storing the flood waters of creeks. It is possible in this way to gradually increase the area of land cultivated by the expenditure of moderate sums from time to time, although if funds were now available the construction of a large canal from the Gunnison would in the end prove most economical and serviceable. Those persons having prior rights to the use of water are successful in raising crops each year, but the large number of persons not having these suffer to a greater or less extent from scarcity of supply during the critical season.

The creeks flowing south from the Grand mesa have near their head waters lakes or depressions which can be readily converted into reservoirs by the construction of low dams. A number of farmers whose water supply is deficient have begun the construction of small storage systems, in one case at least \$12,000 having been spent. There have not been along these creeks any serious failures, as the farmers have learned by experience to regulate the area of crop planted by the amount of snow on the high lands. If the depth is small the water supply will probably be deficient and the area planted is correspondingly less than it would be otherwise. One group of farmers on Surface creek depend upon the water of that stream until about June 20 or July 1, and when the supply fails take water from a reservoir on the head of Forked Tongue creek, carrying it by ditch over to Surface creek and taking it out a second time to their ditch. The Park reservoir, built at the head of Surface creek, is formed by a dam 150 feet in length and 60 feet wide at bottom, built of timber, earth, and rock. The capacity of this reservoir is stated to be 2,300 acre-feet, and the cost of the dam is estimated to have been \$4,000. In many places economy could be enforced if small ditches could be consolidated into one canal, but unfortunately priorities of rights interfere. A man having a prior right on a certain ditch often fears that by any change or consolidation he may lose some advantage, and so jealously guarded are these rights that it is almost impossible to persuade a farmer to make any concession for the public good.

The irrigating ditches in the county are not large, that of greatest extent being probably the canal extending from Montrose county down the valley. The Alfalfa ditch takes water from Surface creek at a point about 14 miles northeast of the town of Delta. It is 9 miles long, 10 feet wide, and cost about \$4,000. It was begun in 1880 and used in the following year. In 1889 about 700 acres were irrigated, over one-half of this being in alfalfa and the balance mostly in wheat and oats. The Minnesota canal takes water out of the creek of that name, the head of the ditch being about 3 miles above Paonia. It is 7 miles long, about 5 feet wide, and covers land south of the creek. The North Fork Farmers' ditch takes water from the north fork of Gunnison river about 4 miles above its junction with Minnesota creek. It is 12 miles long, 5 feet wide, and the cost of both of these ditches is estimated to have been \$26,000. Both ditches are owned by irrigators, who divide the water in proportion to the ownership. The supply of water in the north fork is large, but in Minnesota creek is sometimes small.

The Ironstone ditch takes water from the south side of Uncompahgre river at a point 9 miles northwest of Montrose. It covers land on the southwesterly side of the river, the total length of the ditch being 14 miles and average width 14 feet. The total cost is estimated to have been \$25,000. The canal was begun in 1884 and finished in 1888. Water is diverted by a permanent brush and stone dam and is divided among the shareholders proportionally. The principal crops irrigated are wheat, oats, and barley. The amount of water in the river is insufficient for the needs of the ditch, owing to the fact that other canals have priority of right. The Relief ditch takes water from the Gunnison river about 11 miles above Delta, covering land on the south side of the stream. It is 7 miles long, 8 feet wide, and cost \$15,000. It was begun in 1887 and completed in 1891. The ownership is divided into shares, the value of each being about \$15, entitling the holder to a certain proportion of the amount of water in the ditch.

DOLORIS COUNTY comprises a relatively small portion of the mountain and plateau area near the southwestern corner of the state. By its position beyond the high mountain ranges and the lack of railroad communication it is comparatively isolated. Mining is carried on to some extent in the vicinity of Rico, in the eastern end, and there is fairly good grazing in many localities on the plateaus and hillsides. Agriculture has made but little progress, as the area of fertile land upon which water can be easily diverted is limited. The water supply as a whole is large, but the small creeks first utilized for irrigation sometimes become dry in July or August. Water has been diverted from Disappointment creek, one of the tributaries of Dolores river, and utilized upon land in the vicinity of the little settlement of Lavender.

DOUGLAS COUNTY is near the center of the state, south of Denver and east of the South Platte river, which forms its western boundary. The river in this part of its course flows through canyons and narrow valleys, the western half of the county thus being rough and mountainous, while the eastern part partakes more of the

character of the plain region. The area as a whole falls toward the north from the summit of the divide between the Arkansas and Platte rivers. The waters of the South Platte, the principal stream in or near the county, can not be used within this area to any considerable extent, but are taken out by canals running toward the north into Arapahoe county. The tributaries of the river, Plum and Cherry creeks, are utilized as far as possible for irrigation. Besides the cereals, large quantities of potatoes were produced, most of these without irrigation. In this county, especially on the high lands toward the south, the rainfall is relatively large and many crops are raised without the artificial application of water. Probably one-half of the cereals are cultivated without irrigation, the returns obtained being sufficiently large to be profitable. Wherever possible ditches have been taken out from the creeks and springs and water used as far as the supply will go. The creeks are very irregular in behavior, becoming very low or almost dry during the summer, at which time, especially in July and August, they are subject to sudden floods. On this divide heavy rain storms or "cloud-bursts" occur frequently and an enormous volume of water is discharged at such times into one or more of the drainage channels. In Cherry creek the water generally fails by the 15th of June, and as a consequence the farmers must irrigate very early in the season.

There are in this county two notable systems of irrigation. The first of these is what is known as the English Highline canal, owned by the Northern Colorado Irrigating Company, and briefly described in remarks on Arapahoe county. Although the head works and upper 15 miles of canal are in this county the waters are used to but a small extent, being carried to points farther north.

The other large enterprise in the county consists of the storage reservoir upon Cherry creek built by the Denver Water Storage Company for the purpose of supplying water to a canal and smaller storage reservoir at points nearer Denver. This large reservoir is formed by what is known as the Castlewood dam, built at a point where Cherry creek flows through a canyon about 30 miles southeasterly from Denver. (a) The dam is of masonry, is 586 feet in length, and its greatest height is over 63 feet. The capacity of the reservoir has been estimated to be 5,300 acre-feet. The canal, heading at the diverting dam on Cherry creek about a mile below the dam, has been built along the west side of the valley in order to carry water to fruit lands in the suburbs of Denver, the length being about 30 miles. The total cost of the system is stated to have been over \$500,000. Other small reservoirs have been built, mainly by private parties, but some of these have been washed out by the heavy rains or cloud-bursts of July and August.

Most of the ditches of this country are short, being from 1 to 2 miles in length, and irrigating alfalfa or other hay crops on cattle ranches. The creeks, as before stated, are very uncertain as regards water supply. There is always a small amount coming from springs, increased by the melting of snow in early spring and by rain from thunderstorms during July and August, but in May and June, when water is most needed, there is usually little to be had. The average discharge of Cherry creek, for example, is estimated to be less than 10 second-feet.

EAGLE COUNTY includes the greater part of the drainage basin of Eagle river, a tributary of Grand river. Irrigation is practiced on the ranches along the valley of this river mainly in the vicinity of Gypsum, Castle, Edwards, and other settlements. The altitude of these lands ranges from about 6,300 up to 8,000 feet. The water supply is large, Eagle river at all times carrying a quantity far greater than can be used upon the cultivated land. The valley is narrow and the fall of the river sufficiently great to enable diversions to be cheaply made, especially upon the hay lands. At places the soil contains a large amount of mineral matter known by the farmers as gypsum, which dissolves rapidly when water is brought in contact with it. When first irrigated the ground often settles, and ditches when built in this soil are for one or two years continually breaking. The solution of the earthy salts causes the sides of the ditches in places to wash out and crops have been lost before the numerous holes could be repaired. In many seasons the amount of water required by the crops is small. Most of the fields received only one or two irrigations, potatoes generally having one wetting, while oats and hay, the principal products, have two wettings.

ELBERT COUNTY is for the most part upon the northward slope of the divide which, projecting out into the Great Plains, separates the head waters of the Platte and Arkansas. On the higher grounds there is no available water supply, but along some of the creeks which flow northerly across Arapahoe county there are irrigating ditches. The earlier settlers have taken up nearly all the water to be had, and those who can not obtain water rights are forced to content themselves with dry farming. Over three-fourths of the crops are raised in that manner, corn, rye, and potatoes being usually a success, though the first two are cut for fodder before maturity. The rainfall is relatively large and even under irrigating ditches the first cutting of alfalfa is usually obtained without the artificial application of water. Attempts have been made to secure water for irrigation by sinking pipes or boxes into and through the sandy channels of the creeks. Considerable money has been spent by the farmers, but with little success, as the amount of water percolating through these sands is very small, and whenever a flood occurs the whole arrangement is liable to be washed out. The ditches of the county are very short, from 1 to 2 miles in length, and derive their water from Running, Bijou, Kiowa, Comanche, and other creeks.

^a The reservoir and distributing system have been described by H. M. Wilson in the transactions of the American Society of Civil Engineers, volume 15, pages 210 to 212.

EL PASO COUNTY is south of Elbert and includes within its western end Pikes Peak and adjacent portions of the Front range. From the mountains it extends easterly along the southerly slope of the central divide between the Platte and Arkansas rivers. In the western or mountainous end of the county, where the water supply is relatively large, irrigation is carried on, but out toward the Great Plains sheep and cattle raising is the only occupation possible. In the higher valleys among the mountains crops are raised without irrigation, such, for example, as potatoes, oats, corn, rye, and wheat. One farmer states that he obtained \$40 per acre for his potato crop, to which water had not been applied. Out on the higher parts of the divide the cereals and potatoes and other vegetables are cultivated in the ordinary manner, as there is no source of water supply, and it is claimed that, as in some of the northern counties of Utah, by careful cultivation fair profits can be made, for the farmer does not incur the expense of the purchase and application of the water. The yield per acre is less than in the case of well irrigated land, but, on the other hand, the cost per acre of production is greatly reduced.

The only stream of importance in the county is Fountain creek, sometimes known as Fontaine qui Bouille, and its tributaries. Its head waters rise on the slopes of Pikes Peak and the range toward the north and flowing easterly unite to form Monument creek. This and Fountain creek, into which it empties, have a general southerly course along the foothills. Near the southern part of the county the creek becomes nearly dry in June and July, its waters being diverted by innumerable small ditches. Nearly all the irrigators suffer for want of water during the height of the season, and there is general demand for systems of storage. Attempts have been made to increase the amount of water available by means of wells, but the water in them is often from 100 to 200 feet below the surface, and the quantity which can be pumped by ordinary windmills is small. In a few instances excavations have been made into the porous beds of sand in valley bottoms and water raised from these by steam vacuum pumps, the required height being but a few feet. At Franceville a deep boring has been made in the hope of obtaining artesian water, and it is stated that a depth of 1,200 feet has been reached, but without success.

Irrigation in the county is carried on mainly by means of small ditches, taking nearly the entire amount available from each mountain stream. Among the larger of these may be mentioned the Lincoln ditch, taking water from the west side of Fountain creek about 2 miles above Little Buttes station. It is 3 miles long, 5 feet wide on bottom, and cost \$1,000. It was built in 1864. Water is diverted by a tight brush dam, replaced after each freshet. It is owned by a farmer, who irrigated in 1889 about 235 acres, the greater part of this being in hay. The Lock ditch takes water from Fountain creek near the town of the same name, irrigating land on the east side. The ditch is 3 miles long, 3 feet wide, and cost about \$1,000. It was built in 1862 and is owned by private parties, who irrigate about 350 acres, the greater part of this being in blue-stem hay.

FREMONT COUNTY is southeast of the center of the state and includes land along the Arkansas river below Chaffee county. A number of creeks flow into the river from both sides, those from the north being larger than those from the south, since these latter come as a rule from less elevated regions. In the western part of the county the Arkansas flows through narrow canyons where agriculture is impossible, but toward the eastern end the rocky walls suddenly open out into a comparatively wide valley. At this point the town of Canyon has been built. From here down to Pueblo the valley lands, lying in a narrow strip on each side of the river, have been brought under cultivation by irrigation, and large crops are produced each year. The climate is favorable for fruit culture, and the yield from some of the orchards has been very great.

Water for the irrigation of this part of the Arkansas valley is taken not only from the river but also from the creeks entering on both sides. Most of the ditches are small, having been built by the early settlers so as to cover the ground at little expense, no regard being paid to economy in the use of water or to systematic development of the country. As a consequence low lying lands along the river are in many cases irrigated by water from side creeks, although these could be covered by a canal from the main stream. Thus the higher lands which could be reached by the waters of the creek, but not by the river, are left dry and unproductive.

Many of the farmers state that it will be necessary to resort to water storage in order to cultivate all of the land now under ditch. There is, as in all the adjoining counties, an ample supply of water in the spring, but by the first of July nearly all crops dependent upon creek water begin to suffer on account of its scarcity. There are as usual many complaints regarding the injustice of the distribution of water to prior claimants, and hopes are expressed that legislation regarding water rights will be improved and simplified. As a rule if land is well watered once in May or June it will produce a cutting of alfalfa or a crop of wheat or corn if the ground has been well tilled. The yield per acre under these circumstances is light, but still may be profitable. The creeks of most importance in irrigation are, on the north side, Oil, Four Mile, and Beaver, and on the south side Oak and Hardscrabble. Those on the north side drain mountain slopes south and westward from Pikes Peak, and thus carry a relatively large amount of water throughout the year. Few if any attempts are made to raise crops without irrigation even in the higher parts of the county. Where water is plentiful from three to four crops of alfalfa are obtained.

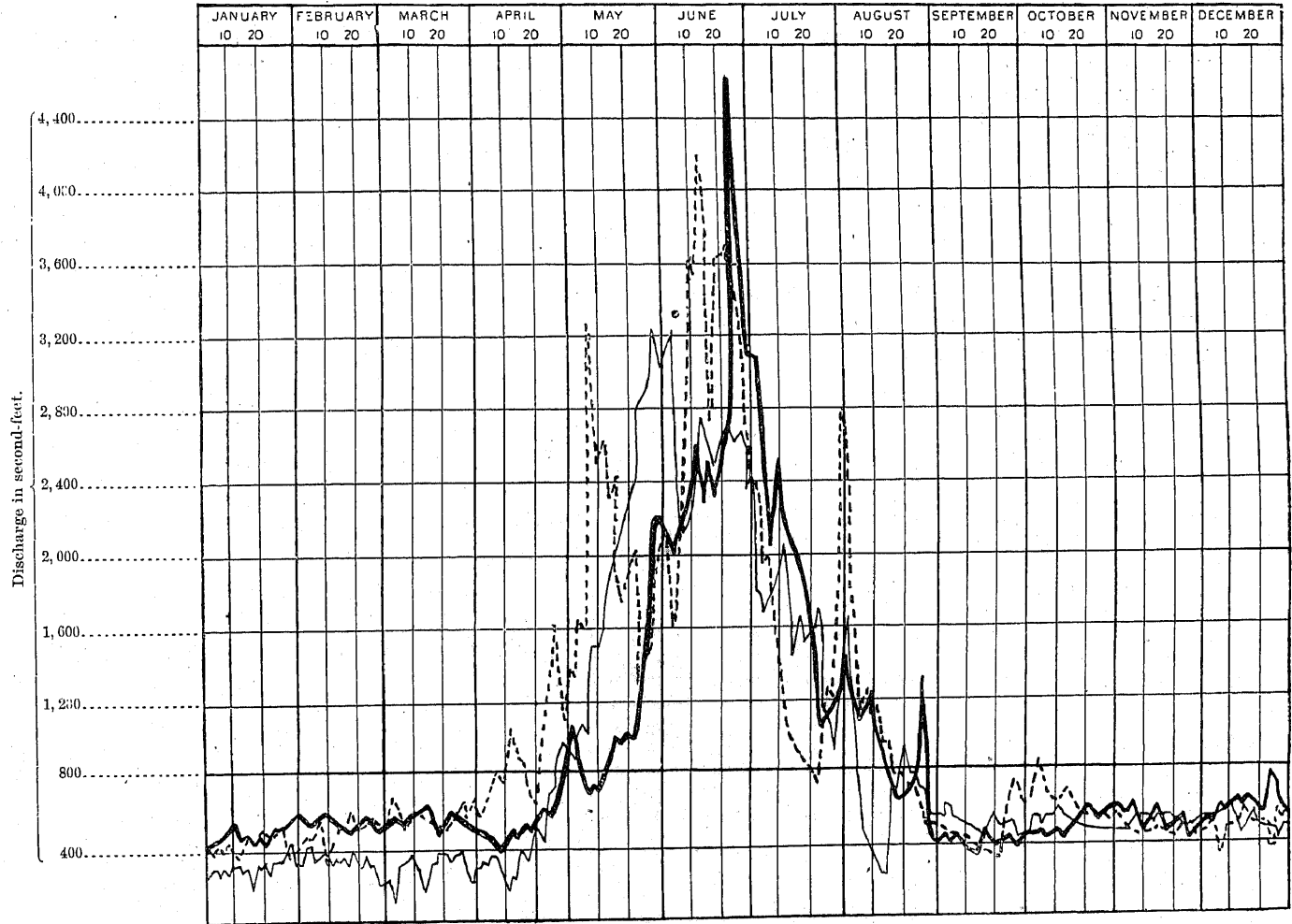
The largest canal system in the county is being constructed by the state, making use of convict labor. The canal heads in the canyon above town and the course as projected follows along the north side of the river, gradually getting away from it and covering more and more land. After passing into Pueblo county it skirts the edge of the foothills and winds its way northerly up the valley of Fountain creek. Near the head the canal

passes through tunnels in the mountain spurs and a large amount of stonework has been done, everything being constructed in a substantial fashion under the direction of the state officials. Nearly all the ditches in use are short, from 1 to 3 miles in length, and have been constructed by a few irrigators acting in partnership.

The best series of measurements of the amount of water in the Arkansas have been made at Canyon, a gauging station having been established there by the state engineer in the spring of 1888. In 1889 the work was continued by the United States Geological Survey. (a)

a The following diagram gives in graphic form the fluctuations day by day for the years 1890 and 1891. The horizontal space, as shown by the headings, represents duration of time, while the vertical distance gives the quantity of water in cubic feet per second. The thin, continuous line represents the quantity during 1890, the dotted line during 1891, and the heavy, full line during 1892. Thus the diagram gives at a glance the changes from day to day and the relative quantities in the various years.

DIAGRAM OF DAILY DISCHARGE OF ARKANSAS RIVER AT CANYON, FREMONT COUNTY, COLORADO.



The following are the gaugings for a series of years :

DISCHARGE OF ARKANSAS RIVER AT CANYON CITY, COLORADO.

(Drainage area, 3,060 square miles.)

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.		MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maxi-mum.	Mini-mum.	Mean.		Depth in inches.	Second-foot per square mile.		Maxi-mum.	Mini-mum.	Mean.		Depth in inches.	Second-foot per square mile.
1888.							1888.						
January			400	24,600	0.15	0.13	August	1,100	800	932	57,318	0.35	0.30
February			500	27,750	0.17	0.16	September	850	430	605	35,997	0.22	0.20
March			600	36,900	0.22	0.20	October			500	30,750	0.19	0.16
April			1,000	59,500	0.36	0.33	November			500	29,750	0.18	0.16
May	1,570	1,280	1,440	88,560	0.54	0.47	December			400	24,600	0.15	0.13
June	2,760	1,120	2,090	124,355	0.76	0.68	Per annum	2,760	400	860	623,105	3.80	0.28
July	1,870	850	1,350	83,025	0.51	0.44							

IRRIGATION.

GARFIELD COUNTY includes a comparatively narrow strip of land on the western side of Colorado, mainly within the drainage basin of Grand river. The principal part of the agriculture, as well as the population, is in the valley along this river, extending from Carbondale and Glenwood Springs down beyond Parachute. The earlier settlers built small ditches leading from creeks and streams, draining the mesas on each side of the valley, the difficulties of taking water from Grand river itself being too great for their scanty means. The waters from these small streams have been overappropriated, and there is a deficiency of supply except in time of flood. Wherever sufficiently irrigated good crops are produced, and fruit is of high grade, the climate being well adapted to fruit culture. Grand river carries at all times of the year a large amount of water, and by the construction of suitable canals much of the valley could be brought under irrigation. The mesas, which bound the valley and form the greater part of the county, are too high to be irrigated, and, although having a good soil, are of little value except for cattle raising. Within Grand valley cattle find fair grazing, not only on the lower lands but up to heights of 1,000 feet or more above the river.

Most of the water rights in the county have been adjudicated, but there is more or less dissatisfaction expressed, especially by those whose supply is less than their requirements. Probably at least 25 per cent of the crops are lost in ordinary years on account of the insufficiency of water supply and difficulty of properly distributing it. Although in this county there is as a whole a large quantity of water, yet the greater part can not be utilized by the present ditches, since it is in the Grand river, too far below the general level. The small amount in the side streams being insufficient for the needs of the irrigators there are innumerable conflicts, which can only be settled, if at all, by greater economy on the part of individuals and by systems of storing flood water.

The following descriptions of a few of the larger ditches will serve to give the general character. The Rockford ditch heads about 4 miles above Satank, carrying water out on the east side of Rock creek, one of the tributaries of Roaring Fork river. It is 4 miles long, 4 feet wide, and cost about \$2,000. The canal was begun and used in 1883. It is owned by private parties, who in 1889 irrigated about 150 acres, most of this being in hay, oats, and other grain, with some vegetables and fruit. The water supply in this valley, being near the head waters, is generally abundant and large crops are raised when properly irrigated.

DISCHARGE OF ARKANSAS RIVER AT CANYON CITY, COLORADO—Continued.

MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.		MONTHS.	DISCHARGE IN SECOND-FEET.			Total for month in acre-feet.	RUN-OFF.	
	Maxi-mum.	Mini-mum.	Mean.		Depth in inches.	Second-foot per square mile.		Maxi-mum.	Mini-mum.	Mean.		Depth in inches.	Second-foot per square mile.
1889.							1891.						
January			300	18,450	0.11	0.10	January	505	325	431	26,506	0.16	0.14
February			300	16,620	0.10	0.10	February	580	365	474	26,307	0.16	0.15
March			300	18,450	0.11	0.10	March	685	530	586	36,030	0.22	0.19
April 17 to 30	438	214	300	17,850	0.11	0.10	April	1,600	580	857	50,992	0.31	0.28
May	1,960	324	600	36,900	0.23	0.20	May	3,700	1,340	2,012	123,738	0.76	0.66
June	2,010	1,002	1,374	81,753	0.50	0.45	June	4,230	1,600	3,291	195,814	1.20	1.07
July	1,150	290	602	37,023	0.23	0.20	July	2,810	770	1,468	90,282	0.55	0.48
August	2,620	243	340	20,910	0.13	0.11	August	1,925	530	951	58,486	0.30	0.31
September	258	190	220	13,090	0.08	0.07	September	715	345	473	28,143	0.17	0.15
October	284	190	223	13,715	0.08	0.07	October	825	530	624	38,376	0.24	0.20
November	335	243	299	17,790	0.11	0.10	November	530	430	498	29,631	0.18	0.16
December	438	274	335	20,602	0.13	0.11	December	605	345	476	29,274	0.18	0.16
Per annum	2,620	190	433	313,153	1.92	0.14	Per annum	4,230	325	1,012	733,588	4.40	0.35
1890.							1892.						
January	494	180	310	19,065	0.12	0.10	January	630	345	496	30,504	0.19	0.16
February	440	250	363	20,146	0.12	0.12	February	555	430	493	28,347	0.17	0.16
March	391	180	320	19,683	0.12	0.10	March	605	430	524	32,226	0.20	0.17
April	980	200	477	28,381	0.17	0.16	April	715	410	522	31,059	0.19	0.17
May	3,270	841	2,090	128,535	0.79	0.68	May	2,250	685	1,241	76,322	0.47	0.41
June	3,260	2,068	2,611	155,354	0.95	0.85	June	4,750	1,780	2,787	165,826	1.01	0.91
July	2,132	920	1,571	96,616	0.59	0.51	July	3,050	1,060	1,798	110,577	0.68	0.59
August	1,425	580	670	41,205	0.25	0.22	August	1,425	455	769	47,293	0.29	0.25
September	625	455	519	30,880	0.19	0.17	September	530	365	435	25,882	0.16	0.14
October	605	505	531	32,656	0.20	0.17	October	605	410	511	31,426	0.19	0.17
November	555	480	522	31,059	0.19	0.17	November	605	455	527	31,356	0.19	0.17
December	580	455	502	30,873	0.19	0.16	December	630	480	561	34,502	0.21	0.18
Per annum	3,270	180	874	634,453	3.88	0.28	Per annum	4,750	345	889	645,320	3.95	0.29

The above table gives not only the greatest, least, and average flow of the stream but also shows the total quantity discharged for the whole month and the relation of this to the total area drained. This latter, the run-off, is expressed in two ways. In the next to the last column is given the depth in inches which the quantity which flowed away during the month would have if put on a plane of an area equal to that of the catchment basin. In the last column is the average amount flowing during the month divided by the area of the basin, thus showing the average amount of water furnished per square mile drained.