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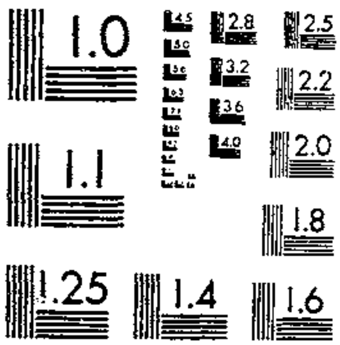

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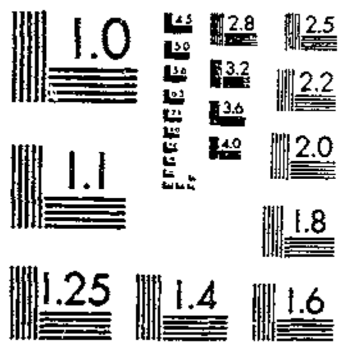

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TECHNICAL BULLETIN No. 185 — JUNE, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

IRRIGATION REQUIREMENTS OF THE ARID AND SEMIARID LANDS OF THE SOUTHWEST

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INTRODUCTION

The expressions "irrigation requirement" and "water requirement" as used in this bulletin are defined below to avoid confusion resulting from the frequent but mistaken assumption that they are synonymous.

The irrigation requirement of arable land is the quantity of irrigation water required for profitable crop production under normal climatic and physical conditions. The water requirement of crops is the total quantity of water, regardless of its source, required by crops for their normal growth under field conditions.

The water requirement is applicable to individual crops grown on relatively small tracts and includes soil moisture and rainfall besides the irrigation requirement. The expression of both requirements is in acre-feet of water per acre.

The design and construction of irrigation systems usually involve consideration of either of two sets of conditions. In one the area to be irrigated has been determined and the water supply is ample; in the other the known water supply is limited, while the area which may be irrigated is restricted only by the available water. In both

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cases the basic quantity of water to be considered by the engineer is the irrigation requirement combined with transmission and other losses in canals.

This report is the third of a series on the irrigation requirements of the arid and semiarid lands of the Western States. In the first of the series, which dealt with the Great Basin (*8*),[1] the conclusion was reached that the seasonal quantity of delivered irrigation water for agricultural purposes would vary from 1.5 acre-feet per acre to 2.2 acre-feet per acre, depending on the locality, and that eventually an area of 5,000,000 acres—nearly double the area irrigated in 1920—might be irrigated with the available water supply, provided that measures be adopted to control and conserve the flood waters and use all diverted water economically.

In the second of the series, dealing with the Missouri River and Arkansas River Basins (*9*), it was concluded that the seasonal net irrigation requirement for the arid and semiarid lands considered would vary from 1.25 acre-feet per acre to 2.3 acre-feet per acre, depending on the locality, and that on this basis the available water supply if properly controlled and used would irrigate about 17,000,000 acres. Deducting the 5,000,000 acres irrigated in 1919 leaves a balance of about 12,000,000 acres still susceptible of irrigation.

In this bulletin, which deals with the Southwest, data are presented in support of the conclusion that the area irrigated in 1919, amounting to 3,771,000 acres, may be increased to 13,000,000 acres, provided the available water supply is efficiently controlled and utilized and the seasonal net irrigation requirements do not exceed the average quantity of irrigation water allotted in Table 5 to each of the 30 subdivisions into which the territory is separated.

The greater part of the investigational work summarized in this bulletin was carried on in cooperation with State agencies. In Texas the board of water engineers contributed funds, labor, and equipment to determine the proper use of water in irrigation in western Texas, the experiments being conducted under the direction of the Division of Agricultural Engineering of the United States Department of Agriculture,[2] W. L. Rockwell initiating them. Like contributions for similar purposes in adjoining States were received from the State engineer and the University of Arizona, the Agricultural Experiment Station of New Mexico, and the Imperial Irrigation District of California.

THE SOUTHWEST

In this bulletin the Southwest includes all of Arizona and New Mexico, the western half of Oklahoma, three-fourths of Texas, a portion of southeastern California, a small part of southern Nevada; also the basins of the Colorado River, the upper part of which extends into Utah, Colorado, and Wyoming, and of the Rio Grande, which extends into south-central Colorado. The region described is shown on Figure 1.

The pertinent characteristics of the territory are (1) its sparse population, (2) low annual rainfall and resultant aridity, (3) large

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[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 37.

[2] The irrigation work of the U. S. Department of Agriculture was originally conducted under the supervision of the Office of Experiment Stations and designated as irrigation investigations. Later, under a reorganization of the department, this and other agricultural engineering activities were grouped in a division of agricultural engineering and made a part of the Bureau of Public Roads.

Figure 1 found
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percentage of nontillable land, (4) small percentage of irrigable land, and (5) high productivity of fertile arable land which can be irrigated.

Its area is about one-fifth of the United States, but in 1920 its population averaged only 3.3 persons to the square mile.

Approximately 85 per cent of the Southwest is unsuitable for farming because of inferior soil, rough and mountainous topography, insufficient rainfall to mature crops, and lack of water for irrigation. There is no known means of utilizing these nontillable lands agriculturally except by grazing.

Grazing and farming are closely related. Because of the aridity of the climate, the prevalence of long-continued and severe droughts, and the occurrence of winter storms at the higher elevations, it is often necessary to supplement range feed. This accounts for the preponderance of forage crops in the total of all harvested crops reported by the 1925 census (*23*), which varied from 96 per cent in southwestern Wyoming to 32 per cent in New Mexico.

In formulating a policy for stock grazing on the public domain or within national forests the interests of the farmer and those who combine farming and stock raising must be considered of first importance. To adopt a policy favorable to the large stockman and detrimental to the farmer owning a small herd of stock would result eventually in a marked reduction in the agricultural wealth of the Southwest. In order to derive the largest possible returns from agriculture, every farmer whose stock can graze on Government lands, and who demonstrates his ability to feed it from home-grown or purchased fodder when there is not enough native grass, should be given access to the range.

Future agricultural development will depend chiefly on the use made of the main resources—the native grasses, arable soils, and the water supply available for irrigation farming. Public grazing lands should be so controlled as to produce the largest possible quantity of fodder consistent with the needs and profits of the owners of stock. The extent of dry farming will be governed largely by the rainfall and the time and manner of its occurrence, whereas future development under irrigation will depend on how fully and skillfully the surface waters are controlled by storage, the use of underground water, and the economy with which water is applied to crops.

SOILS OF THE LARGER IRRIGATED AREAS

In the large area of the Southwest, with its drainage basins and topography ranging from the high mountains of the headwaters of the Colorado and the Rio Grande systems to the low coastal plains of the Gulf of Mexico and the basin of the Imperial Valley of California, soils of several varieties have been formed. Of the many sections of this area which have been mapped by the United States Bureau of Soils, only those which are now irrigated or are susceptible of irrigation will be described.

Much of the soil of Imperial Valley is sediment transported by the Colorado River and many short watercourses draining the surrounding mountains. This valley was once the northern end of the Gulf of California, from which it was later cut off by the formation of the Colorado delta. The water north of this barrier evaporated, leaving a great area, Imperial Valley, lying partly below sea level. Salton

Sea, since formed, now occupies a portion of the valley. Below the ancient beach line the soils are mainly brown, compact, and of heavy texture. Above it they are lighter in color, being generally gravelly materials and wind-blown sands. The valley is level, sloping slightly toward Salton Sea, is easily cultivated, and very productive when irrigated. Certain areas near Salton Sea and in the eastern portion of the irrigated district are heavily charged with salts. Drainage ditches are being dug to relieve this condition.

The Yuma district, in southwestern Arizona, is part of the older delta of the Colorado. Sediment collected and transported from many sources within its drainage area now forms a portion of the Yuma project. The soils are loam, fine sandy loam, sandy loam, sand, and silt loam, the acreage of each decreasing in the order named. They are very fertile and under irrigation produce good yields of cotton, hay, and other crops.

The Salt River Valley of Arizona, one of the Nation's most productive irrigated sections, has been built up from a deep valley to a broad sloping plain by water-deposited materials transported from the surrounding mountains. The valley's irrigable soils are the old transported soils and the recently transported alluvial soils. The former have the denser subsoils, containing amounts of clay and lime carbonate deposited from solution, forming layers of caliche. These soils are found on the upper slopes of alluvial fans and the older surfaces of the valley plain. The recent alluvial soils, which occupy much of the valley, are somewhat more friable; they are found in the stream bottom lands and in areas of alluvial fans lately built up with sediments. They contain considerable amounts of lime, more or less evenly distributed below the first few inches of top soil from which it has been leached. Both classes are irrigable, producing excellent cotton, alfalfa, barley, fruit, and truck and other crops. Alkali occurs in small parts of the area under irrigation, sometimes in excessive amounts. Drainage and leaching of alkali are being facilitated by a lowering of the ground-water plane, which is effected by the operation of deep-well pumps electrically operated.

Soils of the valley of the upper Colorado River, formerly known as the Grand, range from comparatively recent alluvial deposits in the lower areas to residual soils in the higher portions and from fine sandy loams to clay, the two types which constitute most of the valley. The sandy loams are easily cultivated, but some of the heavier soils tend to bake when dry. Alkali is present in limited areas. The clays are heavy, often shallow, hard to cultivate, and bake as the surface moisture evaporates, but are productive, when of sufficient depth, under proper cultural treatment. A limited area of land has become wet and difficult to drain, because the shallow underlying shale in some places forces ground water to the surface and because of seepage from higher irrigated areas.

The San Luis Valley, Colo., an extensively irrigated district about 7,500 feet above sea level, was filled with sand, gravel, and clay in alternate strata, and these form the source of an ample supply of artesian water. Over much of the valley more recent accumulations of sandy loams, loams, or clay loams have been deposited over gravelly subsoils. In the northern part soils are heavier and drainage deficient, causing accumulations of alkali. Streams entering the valley have built up coalescing alluvial fans, which are sometimes gravelly and well drained. In portions of the district crop production depends upon subirrigation, effected by introducing excessive quantities of water into the subsoil, which in time causes the soils to be strongly alkalized. Much land thus affected, however, is being reclaimed at reasonable cost by drainage.

One of the most productive sections of New Mexico is the Mesilla Valley, which extends through the south-central portion of the State along the Rio Grande. The soils of the adjacent mesas are sandy and gravelly and in general are above gravity systems of irrigation. Most of the alluvial valley soils have been transported long distances by the Rio Grande. The types ranging from fine sand to clay are naturally very productive, and sediment deposited by irrigation water tends to maintain their fertility. Alkali brought to the surface by rising ground water has been overcome by the construction of deep drainage canals.

A survey in 1909 by the Bureau of Soils (*6*) of 10,759,680 acres in southern Texas divided the area into three geographic divisions—the rolling to hilly country, the level coast country, and the Rio Grande Valley and delta. The dark soils of the hilly country have a large proportion of humus; the light-colored soils contain little humus. Likewise the soils of the level coast country are divided according to their dark or light color, and both are further subdivided into numerous series and types. In the alluvial deposits of the river and its delta are soils of the Laredo series, together with the Cameron clay and Rio Grande silty clay. This area, except parts of the hilly country, is excellent agricultural land. Much of it is irrigated.

The predominating soils of the Wichita Falls and other districts in north-central Texas are derived from the Permian Red Beds formation, being residual in origin. They are classed as fine sandy loam, sandy loam, and clay. These soils are well drained, retentive of moisture, fertile, and productive under irrigation. The principal crops grown are cotton, fodders, and oats.

CLIMATIC CONDITIONS

It will be shown later that the net seasonal irrigation requirements of crops grown in the Southwest vary from 1 to more than 3 acre-feet an acre. This wide variation is caused mainly by climate, which also varies widely. Data for 24 typical stations, pertaining to precipitation, temperature, and the duration of the frost-free period, compiled from records of the Weather Bureau, are summarized graphically in Figures 2 to 5.

The mean annual rainfall of the valleys of the lower Colorado Basin varies from about 3 inches in Imperial Valley to a little more than 7 inches at Phoenix, Ariz. It is so distributed and usually in such small amounts as to be of little or no benefit to growing crops. In this territory precipitation increases normally with altitude, being about 5 inches or less for elevations under 1,000 feet, 9 inches between 1,000 and 2,000 feet, 12 inches between 2,000 and 4,000 feet, 14 inches between 4,000 and 6,000 feet, and 16 inches or more above 6,000 feet. Almost continuous sunshine, a long frost-free period, and long periods of intense heat also characterize the region. The highest recorded temperature at Phoenix is 117° F.; that at Indio, Calif., 125° F. On account of the low humidity and high temperature, evaporation is rapid, varying from 5 to 8 feet a year.

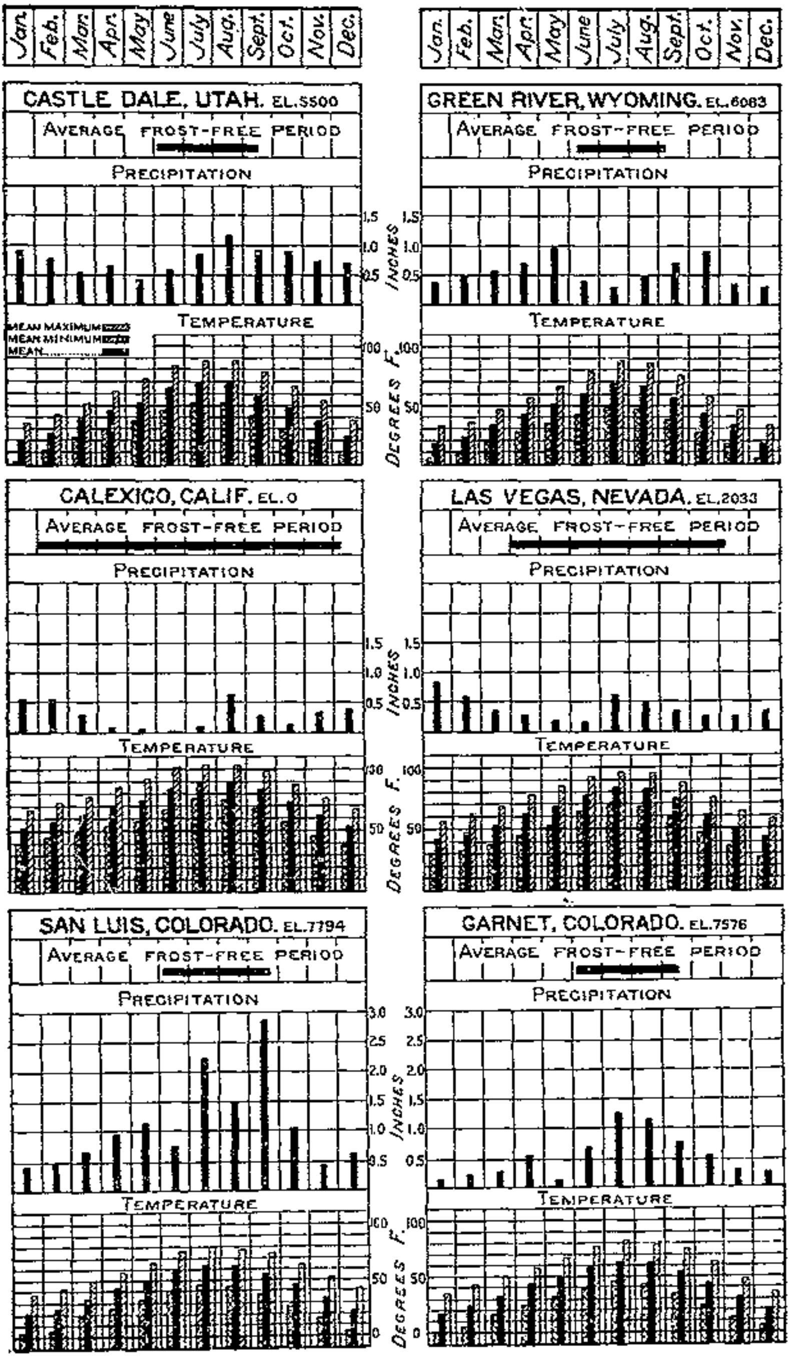

FIGURE 2.—Condensed climatology of typical stations, showing average frost-free period; mean monthly precipitation and mean minimum temperatures (double shaded bars), mean temperatures (solid bars), and mean maximum temperatures (lightly shaded bars)

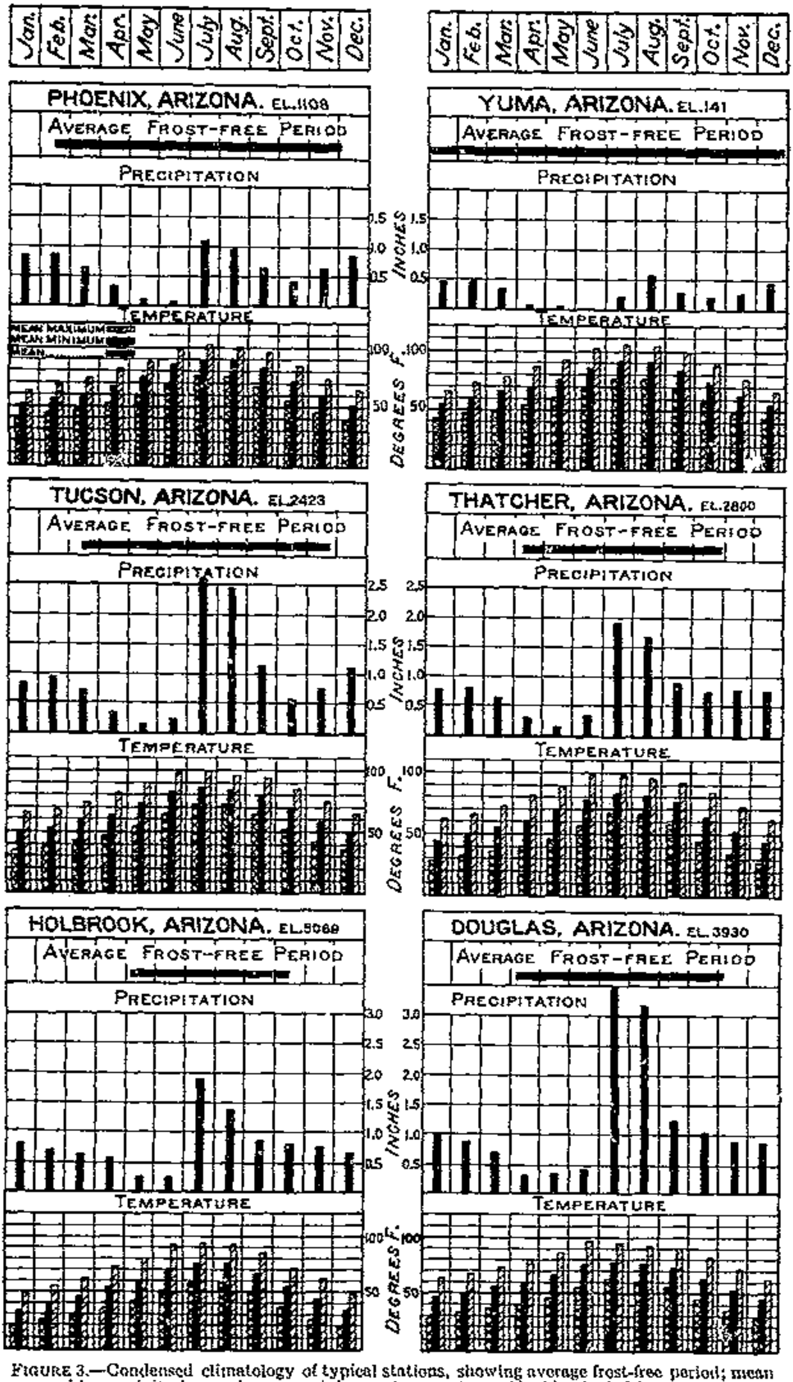

FIGURE 3.—Condensed climatology of typical stations, showing average frost-free period; mean monthly precipitation and mean minimum temperatures (double shaded bars), mean temperatures (solid bars), and mean maximum temperatures (lightly shaded bars)

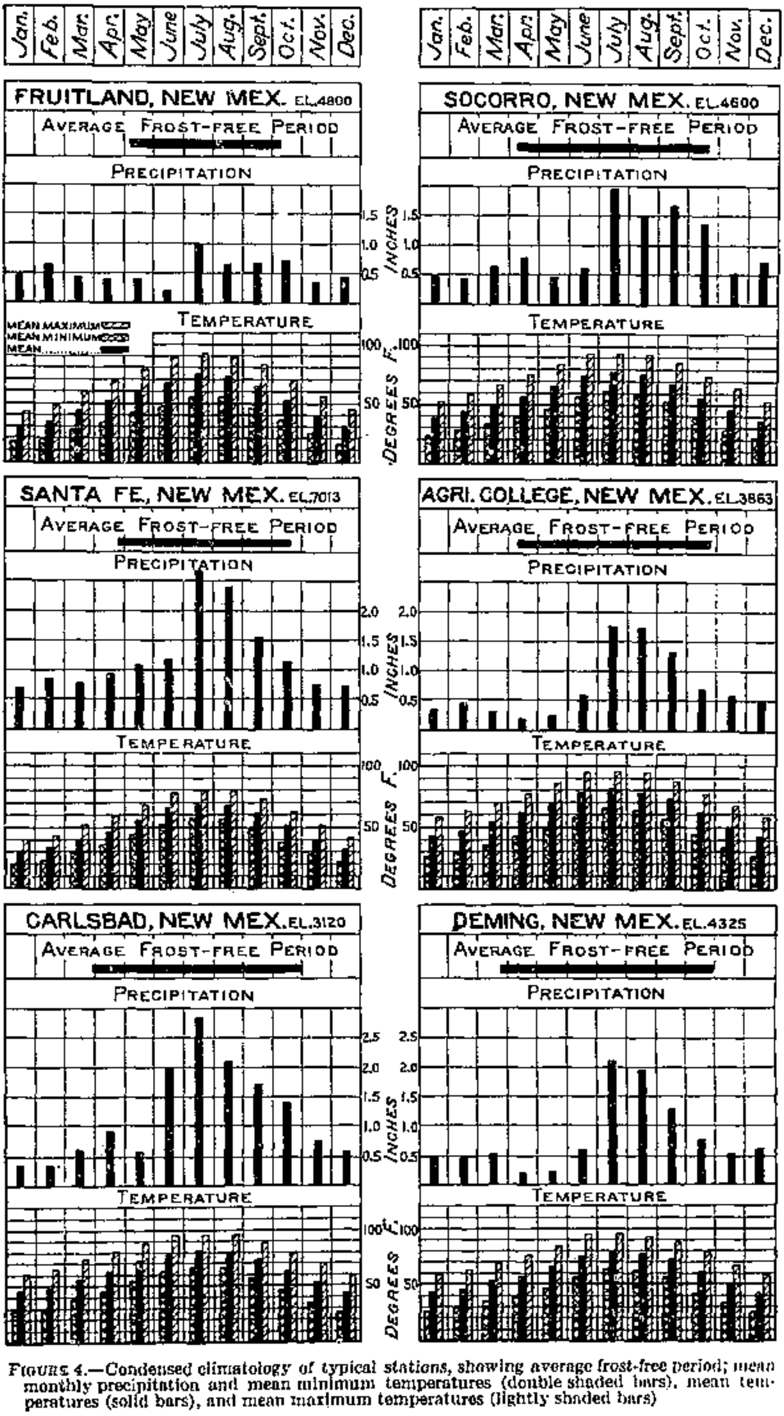

FIGURE 4.—Condensed climatology of typical stations, showing average frost-free period; mean monthly precipitation and mean minimum temperatures (double shaded bars), mean temperatures (solid bars), and mean maximum temperatures (lightly shaded bars)

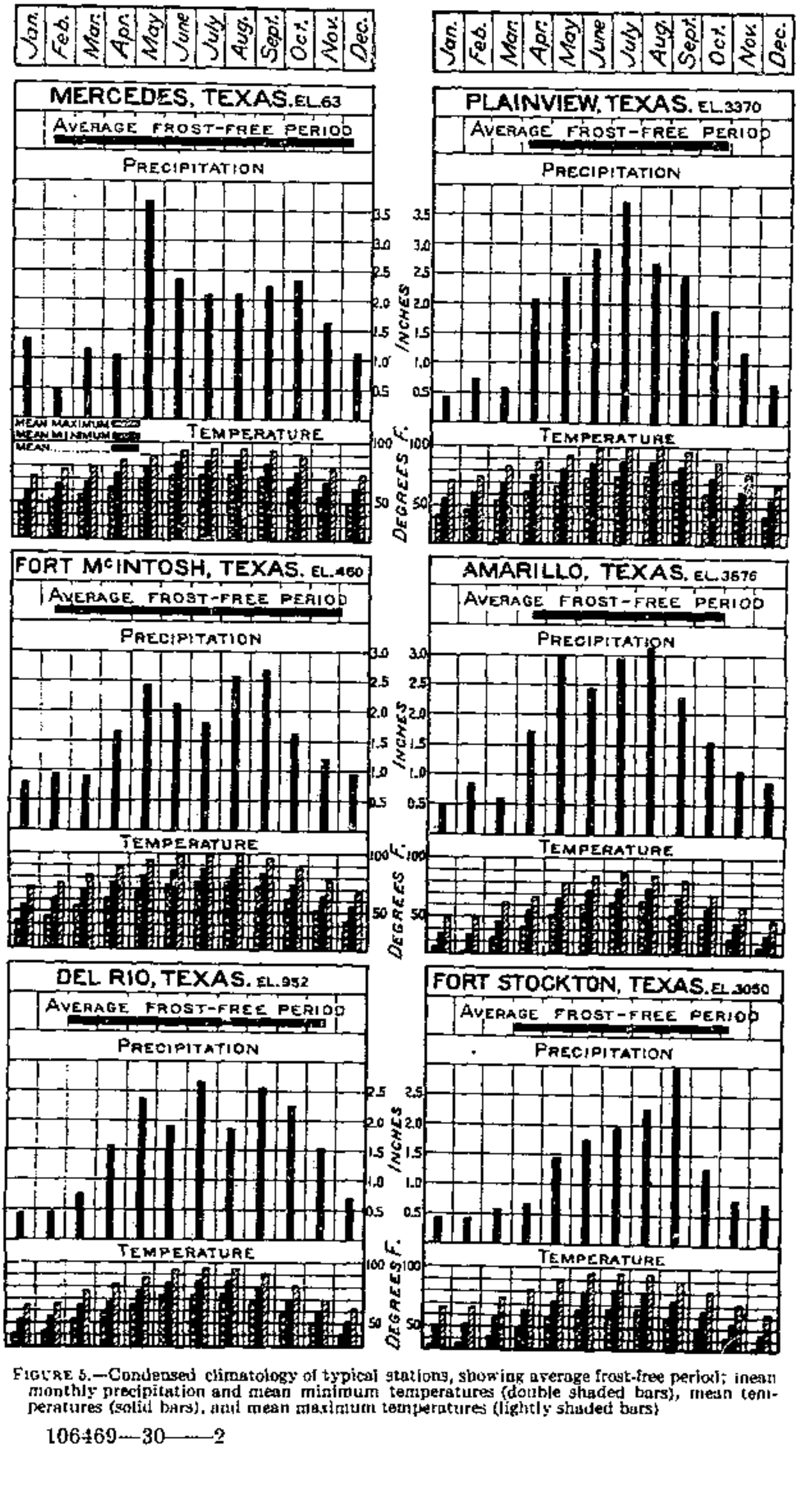

FIGURE 5.—Condensed climatology of typical stations, showing average frost-free period; mean monthly precipitation and mean minimum temperatures (double shaded bars), mean temperatures (solid bars), and mean maximum temperatures (lightly shaded bars)

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The mountainous parts of Arizona, New Mexico, and western Texas, with the intervening valleys, have a wider range of climatic conditions than the lower valleys of the Colorado Basin. The climate of the higher elevations is relatively moderate, but the valleys of Gila, Rio Grande, and Pecos Rivers have summer temperatures frequently ranging from 100° to 115° F. In the extreme western part of Texas, the lower Rio Grande Valley in New Mexico, and in northern and western Arizona, mean annual precipitation is less than 10 inches a year, increasing to more than 20 inches in the higher areas. Without additional moisture, little can be accomplished agriculturally beyond the utilization of native pasture, except in a few high valleys which have enough rain for small crops of hay. The frost-free period shortens rapidly with increasing altitude, extending generally from March or April to October or November in the irrigated valleys of Rio Grande and the Pecos and decreasing from May to September or October at the higher elevations.

In western Texas the mean annual precipitation increases more or less uniformly from less than 10 inches at El Paso to 33 inches at Austin, the lines of equal rainfall running nearly parallel north and south. In the northern portion the rainfall is favorably distributed for agricultural needs, with about two-thirds of the total amount occurring between April and September, the principal crop-growing season. This gives mean rainfalls of 2 to 3 inches a month, with a probability of rain falling once a week or oftener. In some districts this amount of rainfall is sufficient to produce medium crop yields. Irrigation in addition to rainfall, however, generally increases the yield. In other districts with less regular rainfall, supplementary irrigation saves the crops in dry years and permits a wider variety than could be raised by dry farming.

Over so large an area as western Texas a wide range in temperature is to be expected. The maximums are high, and the hot season extends from April or May to October. Records (*21*) show 115° F. at Eagle Pass and 117° at Big Spring. Temperatures of over 100° are common. Mean minimum temperatures range from 20° to 40°, with an occasional short period of subzero weather; the recorded minimum for the State is −23° at Tulia. Southern Texas and the Rio Grande Valley have a 12-month growing season, being normally free from frosts from February to December, while in the western and northern counties the frost-free period is somewhat shorter. Light falls of snow are apt to occur in winter, but most of the precipitation is rain.

Warm, moist southern winds account for the summer rains, the dryness of the winter being a result of the prevailing northerly dry winds. Tropical storms sometimes strike the coast region, and occasionally cyclones occur over widely scattered areas.

In contrast with the arid plains of the extreme Southwest are the high valleys and mountain ranges of the upper Colorado Basin in Colorado, Wyoming, and Utah and the upper Rio Grande Basin in Colorado. This section lies between the Continental Divide on the east and the Wasatch and Bear River Ranges on the west, and contains the highest mountain peaks and valleys in the Southwest. Consequently its mountain snows are heavier and the growing season of its valleys is shorter than those found elsewhere. Records for the mountains of southwestern Wyoming show an annual snowfall of

12 to 15 feet. In the valley of the Green River, although the elevation is over 6,000 feet, the precipitation amounts to only 7 inches annually. The crop-growing season is shorter than at lower elevations. A frost-free period from June to August or even to September may be expected in southwestern Wyoming, while in eastern Utah or western Colorado it may run from May or June to September or October. Although the summer season is relatively short, temperatures sometimes exceed 100° F., the Colorado maximum being 109°, the Wyoming 114°, and the Utah 116°. Winter extremes occasionally reach −40°.

To sum up, except in central Texas, the agricultural districts of the Southwest are mostly arid and must be irrigated, summer temperatures are high, and the crop-growing season is long. Annual precipitation, except in central Texas and in the high mountains, is less than 15 inches and falls in such small quantities as to be of little or no agricultural benefit. Heavy rainstorms of short duration, resulting in high run-off and a small amount of absorption, occur in many districts, and light rains quickly evaporate; consequently neither heavy nor light rains are of great value to the growing crops. Snow seldom falls except in the mountains, and then only in small quantities. Evaporation is rapid and the total amount large, causing high irrigation requirements. Because of the rapid evaporation and low humidity, extreme heat is not prostrating and seldom uncomfortable.

WATER RESOURCES

In close relation to the climatic conditions of the Southwest are its natural water resources. These depend upon the amount of summer rainfall and winter snows. Part of the rainfall forms streams, to which mountain snow, melting slowly as the season advances, contributes to form the maximum spring and summer flow.

There is an abundance of fertile, arable land, but a scarcity of water for irrigation. Furthermore, the natural flow of the streams, although high in late spring or early summer, is insufficient later in the season. This handicap to agriculture can be remedied only by the construction of reservoirs to store water now wasted.

Structures such as the Elephant Butte Dam on the Rio Grande in New Mexico and the Roosevelt Dam on the Salt River in Arizona are now impounding large quantities of water. Many others, including small farm reservoirs, exist, the 1920 census (*22*) showing over 800 reservoirs in the Southwest with a total capacity of over 5,000,000 acre-feet. Others are under construction or are being planned. As most of the natural low flow of streams is now appropriated, the future reclamation of new lands must depend upon storage.

The water supply is derived mainly from the streams of the Colorado River and Rio Grande Basins. The flow of these systems and other independent streams is shown in Figures 6 and 7. Table 1 also gives the characteristics of discharge of 16 important streams. The Colorado River as a source of water for irrigation, domestic use, and hydraulic power is a present and potential asset of great value. The upper Colorado, Green, and other tributaries rising in the high snow-clad mountains of Wyoming, Utah, and Colorado unite to form a river which drains portions of seven States and a part of Mexico. The Colorado River, which is 1,700 miles long, traverses three distinct

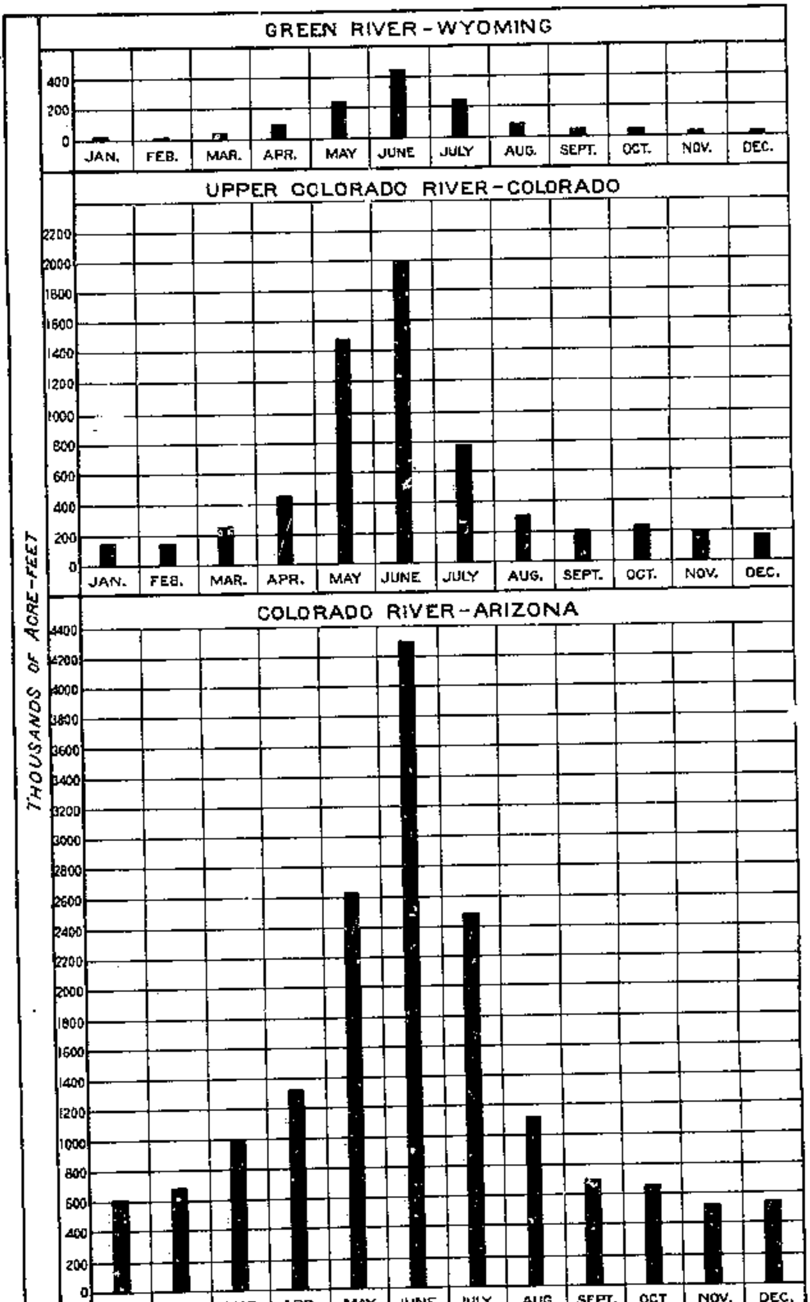

FIGURE 6.—Mean monthly flow of typical streams

topographical sections. The upper basin, with its surrounding snow-clad mountains, contributes about 85 per cent of the total flow from the three large tributaries, the Green, the upper Colorado, and the San Juan. The Grand Canyon, which crosses a high, rough table-land, gashed also by branches of the main stream, divides the upper basin from the broad, low, arid plains of the lower basin. Here

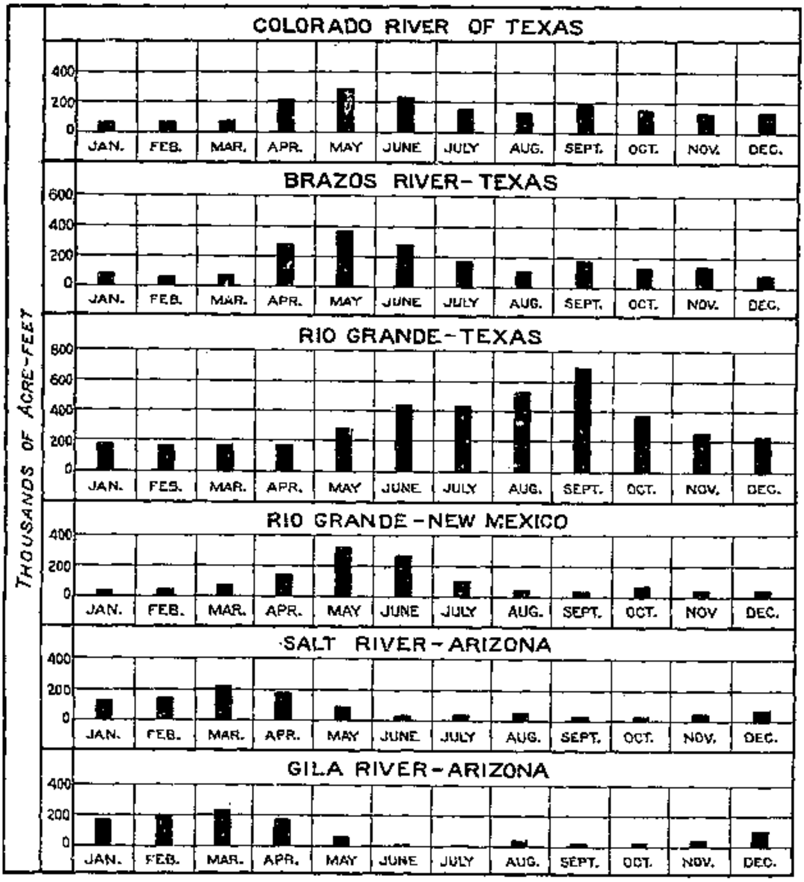

FIGURE 7.—Mean monthly flow of typical streams

the principal tributary is the Gila, joining the Colorado near Yuma. Although the Gila drains a large area and at times is subject to high floods of short duration, its mean annual discharge is but 6 per cent of the total flow of the Colorado River. Projected irrigation development, together with reservoir construction now under way, will largely consume the flow of the Gila River, so that flood flows reaching the Colorado will diminish in volume and intensity in the near future.

TABLE 1.—*Discharge of typical streams of the Southwest*

River	Station	State	Years of record	Watershed area	Yearly discharge		
					Maximum	Minimum	Mean
				Square miles	*Acre-feet*	*Acre-feet*	*Acre-feet*
Colorado	Yuma	Arizona	24	242,000	25,975,000	7,959,000	16,606,000
Gila	do	do	17	71,050	4,490,000	61,000	1,110,000
Salt	Roosevelt	do	16	5,756	3,226,000	240,900	1,072,000
Green	Green River	Wyoming	15	7,670	2,102,000	656,000	1,392,000
Duchesne	Myton	Utah	12	2,750	891,700	352,000	555,000
Virgin	Virgin	do	9	1,010	322,700	139,200	201,300
San Juan	Atmouth	do	28	26,000	3,690,000	847,000	2,350,000
Upper Colorado	Fruita	Colorado	16	23,800	8,122,000	4,213,000	6,365,000
Yampa	Maybell	do	16	3,670	2,100,000	970,000	1,280,000
Gunnison	Grand Junction	do	19	7,920	3,020,000	1,120,000	1,170,000
Rio Grande	San Marcial	New Mexico.	26	30,000	2,420,000	240,000	1,200,000
Do.[1]	Eagle Pass	Texas	14		8,102,400	2,157,600	3,910,000
Pecos	Comstock	do	21		1,007,900	159,300	453,700
Colorado (of Texas)	Austin	do	24	34,200	5,171,000	359,000	1,802,000
Neuces	Three Rivers	do	6	15,600	[2] 1,431,000	16,300	513,000
Brazos	Waco	do	20	25,500	4,762,000	304,000	1,968,000
San Antonio	San Antonio	do	6		116,900	10,250	66,240

[1] Previous to storage by Elephant Butte Dam. [2] 10 months.

The flood period of the Colorado generally occurs in June. During late summer and early fall the river is low. The long crop-growing season of the extreme Southwest makes necessary a constant supply of water for irrigation most of the year. During floods much water is lost to the land by the flow passing directly to the Gulf of California, while in low-flow periods the supply is insufficient for the needs of Imperial Valley. This condition can be remedied only by the construction of storage reservoirs. Irrigation in both the upper and lower basins is reasonably certain to increase with the growth of the Southwest, and it has been estimated that 6,000,000 acres may be irrigated ultimately; for this total the water supply will be ample when sufficient storage is provided. In Salt River Valley, Ariz., the Roosevelt Reservoir furnishes water to about 235,000 acres, and other large storage dams have been completed.

Most of New Mexico is arid. Its principal drainage system is the Rio Grande, which rises in the snow-clad San Juan Mountains of Colorado and flows south through New Mexico, dividing it into two nearly equal parts. At El Paso the river turns southeast and for about 900 miles forms the boundary between Texas and Mexico. In the San Luis Valley in Colorado and in its numerous valleys in New Mexico the Rio Grande has long furnished water for irrigation. With an increase in the cultivated area the natural flow became insufficient in the lower valley in New Mexico, and the Elephant Butte Dam was built. This large reservoir is capable of storing 2,638,000 acre-feet and will hold the river's usual flood flow, furnishing enough water for the irrigation of 150,000 acres in New Mexico and Texas and 60,000 acre-feet annually to lands in Mexico near El Paso. Along the lower Rio Grande other large areas are irrigated from the river by large pumps.

Of the Rio Grande's tributaries in the United States the Pecos is the most important. Rising in New Mexico and flowing through western Texas, it supplies water for irrigation near Carlsbad and Roswell, N. Mex., and Barstow, Tex. As with other southwestern streams, its natural flow is insufficient for the land cultivated, and about 50,000 acre-feet of storage is provided by the Government's Avalon and McMillan Reservoirs.

Central Texas is well provided with direct run-off. The most important streams are the Trinity, Brazos, Colorado, Guadalupe, San Antonio, and Nueces Rivers. Although rain is more plentiful in central Texas than elsewhere in the Southwest, and much of it falls during the growing season, in many places it is supplemented by irrigation. A community near Wichita Falls, for example, organized to irrigate about 100,000 acres. The mean annual precipitation is about 28 inches, 20 inches falling between April and October. This amount during the growing season may produce fair yields, but a wider range of crops can be grown and better yields obtained with supplementary irrigation. Hence a reservoir of about 500,000 acre-feet capacity was built on the Big Wichita River, some 50 miles above Wichita Falls.

Many springs also supply water for irrigation. Some are of considerable size. Comal Springs, at the head of the Comal River, Tex., have an average discharge of approximately 350 cubic feet per second, and much of the cultivated land near Fort Stockton, Tex., receives its water from springs that discharge freely.

Wells likewise serve large areas, the area irrigated by wells in Arizona, New Mexico, and Texas reaching 125,000 acres in 1919. In the Salt River Valley pumping from wells is practiced to lower the ground-water level; then the pumped water is delivered into canals for reuse in irrigation. This combination of drainage and irrigation will undoubtedly extend to other districts in which conditions are similar.

AGRICULTURAL RESOURCES

The agricultural resources of the Southwest are by no means commensurate with its vast extent. Much of it is mountainous and too rough and rocky to be cultivated, while a still larger portion has too little precipitation for plants that are of much value to man. The crops which grow naturally and those producible by human effort may be grouped into three main divisions: (1) The native grasses and other herbaceous plants, which provide food for domestic animals; (2) crops of low water requirement, which can be successfully grown by dry-farming methods; and (3) a large variety of irrigated crops.

In the upper Colorado Basin native grasses thrive where a plow furrow can not be turned. Hence the grass on the open range, when fed to stock, and the products derived from irrigated farms on the limited arable land constitute the main sources of farm revenue. This is especially true of 12,000,000 acres in southwestern Wyoming drained by Green River, where the precipitation on the valley lands is too scanty, as a rule, to grow crops, and the fine pasturage on mountain slopes, supplemented in winter by hay crops grown under irrigation, maintains large numbers of stock. Leaving out of consideration the pasturage on unimproved portions of farms, there remains an area of 11,000,000 acres of grazing land, including the open range of the public domain, national forests, and Indian reservations. Only 211,000 acres are irrigated, and much more stock could be pastured if more winter feed were provided by extending the irrigated area. It is estimated (7) that 910,000 acres can be irrigated, and if it were reclaimed a more profitable use could be made of the remaining 11,000,000 acres of pasture land.

In eastern Utah conditions are somewhat similar, but on a larger scale. Including open range, national forests, and Indian reservations, there is an area of 22,500,000 acres affording pasturage for stock. There are also 362,000 acres of irrigated land and a possibility of extending the area now irrigated to 815,000 acres, on which alfalfa and some cereals are likely to be the principal crops.

Nearly 44 per cent, or 28,812,000 acres, of Colorado is drained by the Colorado River and the Rio Grande. Nearly 24,000,000 acres of this area are not included in farms and are more or less suitable for grazing. Chiefly because of a more favorable climate, irrigation development has progressed more rapidly than in the country farther north within the same watershed. In 1919, 1,387,000 acres were irrigated in the Colorado and Rio Grande Basins, while the Bureau of Reclamation estimates (7) that 1,758,000 acres are susceptible of irrigation. The principal products, exclusive of native grasses, are alfalfa and wild hay.

Less than 13 per cent (about 9,000,000 acres) of Nevada is within the Colorado Basin, and of it only 15,000 acres were irrigated in 1919, although about 87,000 acres are susceptible of irrigation. On the basis of previous estimates, 8,900,000 acres have a limited value as grazing land. Southern Nevada has mild winters and a long growing season, and large quantities of deciduous fruits and other crops might be produced if the available water supply were more abundant.

In this bulletin only that part of southern California in the watershed of the Colorado River and the lands it irrigates are taken into account. The irrigated area in 1919 was 447,400 acres, whereas about 939,000 acres can be irrigated if the river is properly controlled. Owing to the extreme aridity, native grasses have little value as stock feed, but there is some grazing on 3,600,000 acres of unfarmed land. The principal agricultural resources are confined to products of irrigated farms.

Compared with southern Nevada and southeastern California, New Mexico has the heaviest normal precipitation, and because of the resulting favorable soil-moisture conditions native grasses grow profusely on extensive areas. It also provides opportunities for dry farming with such crops as beans, sorghums, and corn. The area irrigated in 1919 was 538,400 acres, but the available water supply is sufficient for about 2,500,000 acres. The area harvested in 1919 was 1,131,806 acres, indicating that more than 50 per cent was dry farmed. In 1924, 50,000,000 acres in national forests, vacant public land, or privately owned land afforded pasturage for stock.

In Arizona there are several million acres of fertile, arable land which would become valuable and yield a high annual revenue if irrigated. These lands can not be dry farmed profitably, and unless water is provided they will remain grazing lands of low value indefinitely. The water supply of the State is mainly in Colorado River and its local tributaries. Satisfactory progress has been made in storing and diverting the waters of tributary streams for irrigation, and development is likely to proceed until all such available water is utilized. In 1919 the area irrigated was 468,000 acres, but it is estimated that the water obtainable from tributaries and the main river below the canyon section, if properly controlled and utilized, together with underground supplies, will irrigate 2,200,000 acres. The results of reconnaissance investigations made recently by Arizona (*1*) indicate that water can be diverted from the Colorado at some point near Diamond Creek and conveyed southward to irrigate an additional area of about 2,000,000 acres in southwestern Arizona.

Exclusive of the unimproved portions of farms, the area which may be grazed includes 61,700,000 acres, of which less than 14,000,000 acres are vacant, 22,000,000 acres are in Indian reservations, and 11,000,000 acres in national forests.

In this report the arid and semiarid portions of Texas have been separated from the eastern humid portion by a line connecting the eastern boundaries of San Patricio and Clay Counties, 153 counties being in the section with which this bulletin is concerned. This division is based on the normal rainfall, which in the western counties varies from 10 to 30 inches a year.

During the past 60 years agricultural conditions in western Texas have undergone far-reaching changes, many of which are still in progress, making it difficult to estimate agricultural potentialities. From the close of the Civil War to near the beginning of the present century, long-horned cattle were grazed on the Staked Plains, constituting almost the only source of agricultural revenue. During the past 25 years both dry and irrigation farming have greatly increased the agricultural returns. In 1924 the cropped land harvested was 12,278,000 acres. In 1919 the area irrigated was 342,600 acres and the unfarmed land available for grazing was about 43,000,000 acres. As development progresses, much of the arable land will be cultivated, and the ultimate extension of the irrigated area will be limited only by the lack of available water. It is believed that the water supply, if properly controlled and used, is sufficient for the irrigation of 4,000,000 acres, and the present dry-farmed area may be increased to 30,000,000 acres.

IRRIGATION PRACTICE

While much of the irrigation development of the Southwest has been accomplished since 1899, irrigation was practiced far back in unrecorded times. The value of water in nourishing such crops as maize, beans, squash, and cotton was well known to the Pueblo Indians. The patience characteristic of the race enabled them, with very meager equipment, to dig surprisingly long canals. These, as the indirect source of a part of their sustenance, were built, maintained, and operated generally as communal enterprises, subject to regulations prescribed by the community leaders. Many of these were retained under Spanish rule, forming, with some innovations, the basis of Spanish-American practice.

The common proprietorship of water supplies, public construction of irrigation works, and the administration of local irrigation affairs by separate communities were very important features of Moorish and Spanish institutions long before the discovery of the New World (*14, p. 264*).

They did not differ essentially from those of the Indians' communal ditch. However, Spain colonized its new possessions by three separate agencies—civil, ecclesiastical, and military—and the effect of this procedure tended to modify native practice. The presidios, designed to develop into towns, afforded military protection; the missions were intended primarily for the conversion of the Indians; and the pueblos themselves developed agriculture, industry, and commerce. In all three the construction of an acequia madre, or main canal, was necessary wherever the rainfall was deficient.

Mexico's attainment of independence and control of the Southwest brought a second confirmation and modification of existing irrigation laws and customs, and when part of the territory was ceded to the United States a final international adjustment was effected. Hence the present irrigation laws, customs, and methods are a composite of Indian, Spanish-American, and Anglo-Saxon, although Anglo-Saxon practices are becoming more marked as time passes. Notwithstanding this tendency, in many parts of the Southwest Indian ditches are still in use and are managed and maintained much as in pre-Spanish times, and many more typical acequias built under Spanish and Mexican régimes are still owned and operated much as they were more than two centuries ago.

Compared with that of former periods, the progress made during the past 25 years in reclaiming desert lands has been rapid. The Nation has expended large sums for irrigation works in Texas, Colorado, New Mexico, and Arizona, and this has influenced private capital to make like investments. Knowledge and experience so gained and avoidance of many former errors have resulted in better plans, more economical means of working, and the construction of more practical and effective systems. In consequence the Southwest, although still operating many faulty irrigation systems inherited from pioneer days, offsets them with several large modern systems, which, as a rule, are well built and managed, and this advantage is reflected in its irrigation practice.

The farmers have struggled with several troublesome problems, some of which still await solution; until they are overcome improvements in irrigation practice can not take place rapidly. In the lower Rio Grande Valley of Texas, which depends entirely on water pumped from the river, a reorganization of enterprises and the reconstruction and enlargement of pumping plants have been necessary. This work is nearing completion, but the question of water rights remains to be adjudicated between the United States and Mexico, and until this is effected by treaty much uncertainty will exist over water allotments and future irrigation development.

The irrigable lands of the Salt River Valley were seriously injured by a continually rising water table, but this menace has been overcome by the operation of a large number of deep-well pumps, which have at the same time supplied much-needed additional water for irrigation (*17*). The Rio Grande Valley in New Mexico likewise was damaged by a high water table, combined with uncontrolled flood waters, but deep drainage canals have reclaimed part of the valley, and organizations are being formed to remedy other portions. In the Imperial Valley the farmers have been contending for the past 20 years with floods, with enormous quantities of silt annually transported by the Colorado River, and with rising ground water. The wet lands are being drained, and adequate steps are being taken to remove the flood menace and to abate the silt nuisance.

The part of irrigation development that is performed by farmers is retarded and rendered difficult and costly by the presence of brush and shrubs. Some localities have a heavy growth, chiefly sagebrush, while others are dotted with mesquite and other shrubs. As a rule the shrubs and heavier sagebrush are grubbed out by hand, adding a heavy expense to new settlers at a time when they can least afford it. The expense of preparing land for irrigation in the Southwest depends partly on the size and density of the desert growth to be removed, the cost of removal varying from about $7.50 to over $50 an acre, and partly upon the preparation of the land to receive water. Successful irrigation depends upon the proper preparation of the land to receive water and the selection of the best method of applying it. Farm distributing ditches or underground pipes so located that water may spread rapidly over the fields are a necessary part of land preparation. Fields should also be leveled so that water will flow evenly over the surface. Unless the fields are so prepared, water will stand in hollows and high spots will remain dry, resulting in damage to crops in each case.

CROPS GROWN UNDER IRRIGATION

The area irrigated increased from 1,504,000 acres in 1902 to 3,771,000 acres in 1919, but the area of the principal irrigated crops did not increase in the same ratio. Staple crops have given place in part to new crops; and the changing conditions involved in production and marketing have brought about corresponding changes in the management of farms, especially in sections where a long growing season makes possible a wide diversification. In the upper basins of the Colorado River and the Rio Grande, where the elevations are much higher, the winters more severe, and the growing season shorter, fewer changes in crop production have taken place, and these have had little effect on the water requirement. The leading crops in the Green River Basin of southwestern Wyoming continue to be, in the order named, wild hay, alfalfa, and oats cut for grain. In the same basin of eastern Utah alfalfa is far in the lead, with wheat, oats, and corn following. On the Pacific slope of Colorado the largest part of the irrigated area is devoted to alfalfa, wild hay, wheat, and oats being next in order.

In the upper basins of these two rivers, in Colorado, Utah, and Wyoming, there has been a gradual conversion of native-grass meadows into other crops, chiefly alfalfa, but this conversion has not materially affected the water requirement of crops, since the native meadows are irrigated, as a rule, by wild flooding which wastes water, and a larger tonnage of alfalfa per acre can usually be produced with no more water than was formerly used on native meadows, on account of a more economical use.

In the agricultural history of the more southerly and warmer portions of the Southwest, from Imperial Valley in California to the lower Rio Grande Valley in Texas, the introduction and extension of cotton planting in the past 10 to 15 years has been most noteworthy. A large area of new land, as well as much formerly in alfalfa, has been planted to cotton. The seasonal water requirement of cotton being considerably less than alfalfa, this change has had its effect on the quantity of water used in irrigation, especially in the Imperial Valley, the Salt River Valley, and the Rio Grande Valley of New Mexico.

During the past 26 years more than 400,000 acres of desert land in California have been reclaimed in Imperial Valley by water diverted from the Colorado River. Barley was first the chief crop. A report (*19*) prepared by the Division of Agricultural Engineering says that in 1906 about three-fourths of the irrigated area was in barley and that the average seasonal duty of water for that year on 120,000 acres was 2.04 acre-feet per acre, ranging from 1 to 1½ acre-feet for barley to 3 to 4 acre-feet for alfalfa. In 1909 the barley acreage had decreased to 36,986 acres, whereas there was an increase in alfalfa to 30,847 acres. In 1926 the land in cereals, whether cut for grain or used as forage, was 80,000 acres; in alfalfa, 155,000 acres. The growing of cantaloupes and lettuce during the winter and early spring has become an important industry, in 1927 these crops covering nearly 80,000 acres.

Prior to 1910 cotton was grown in an experimental way in Imperial County, Calif. The area devoted to this crop increased rapidly, and in 1924 was 80,000 acres. Since then, however, this crop has decreased, and in 1927 was only 23,000 acres.

In writing of alfalfa in the Southwest in 1914, Freeman (*11, p.* [*233*]) said:

> Every agricultural community has its staple product. What corn is to Illinois, wheat to Kansas, and cotton to the Gulf States, alfalfa is to Arizona. More than one-third of all her cultivated land is devoted to its culture. * * * It forms * * * the safeguard of cattlemen in times of drought, the raw material for a growing dairy industry, the natural food for fine, fat stock, and the conserver of soil fertility by its deeply penetrating, nitrogen-gathering roots.

Freeman could not foresee that in another decade Arizona's cotton acreage would be 60 per cent more than that of alfalfa. In the Salt River Valley the acreage planted to cotton increased from a small area in 1910 to 75,062 acres in 1919 and 121,620 acres in 1924, but part of this increase has been at the expense of alfalfa, which decreased from 66,071 acres in 1919 to 60,955 acres in 1924.

A somewhat similar development has taken place in New Mexico. The total area of irrigated alfalfa fields in 1919 was 87,105 acres, while that of cotton was 7,527 acres, whereas in 1924 the acreage of irrigated and nonirrigated cotton was nearly equal to that of alfalfa. Another important change during the past decade has been the rapid extension of dry-farmed sorghums harvested for grain or cut for silage, hay, or fodder. The 1924 area was 289,099 acres, which placed this crop far in the lead as regards acreage.

In 1919 about 340,000 acres, exclusive of the rice fields, were irrigated in western Texas. The principal crops in the order of acreage were corn, sorghums, cotton, and alfalfa. The statement, however, covers only a small part of crop production in this part of the State. On account of a heavier annual rainfall than occurs in either Arizona or New Mexico, the majority of farmers grow crops without irrigation. There being available a large extent of fertile virgin soil at relatively low cost, on which small or medium crop yields can be harvested, the need to utilize water for agriculture has not been urgent except in very dry years. Accordingly, the extent of land dry farmed is far in excess of that irrigated. In 1924 the principal crops grown in 153 counties of western Texas with their respective acreage were: Cotton, 6,442,348; sorghums, 2,230,355; wheat, 1,122,471; corn, 824,519; oats, 635,821; and hay, 260,175.

RELATION OF WATER APPLIED TO CROP YIELD

Investigations have been carried on by the Division of Agricultural Engineering either independently or in cooperation with State or community agencies in several localities of the Southwest to determine the relation of water applied to crop yield. In this work the factors which affect yield other than moisture conditions have been eliminated, as far as practicable, by selecting uniform soil, growing the crops on plots of the same or nearly the same area, and subjecting them to the same cultural treatment and climatic influences. When, under repeated tests, crops fail to produce profitable yields with the natural rainfall, the need for irrigation is demonstrated, and the effective rainfall, combined with the quantity of supplemental irrigation water required to produce a satisfactory yield, is a fair indication of the total water requirement.

The results of such experiments likewise serve to determine how much water farmers should apply in order to obtain profitable yields. By growing plants in duplicate or triplicate plots, applying a different quantity of water to each plot, and noting the effect on the quality and quantity of the product grown, it is possible to determine with fair accuracy, especially for crops of low and medium water requirement, the right quantity of water to apply for their proper development. Most of the results show an increase in yield in proportion to the quantity of water applied until a stage is reached when additional applications injuriously affect the plant and lessen the yield.

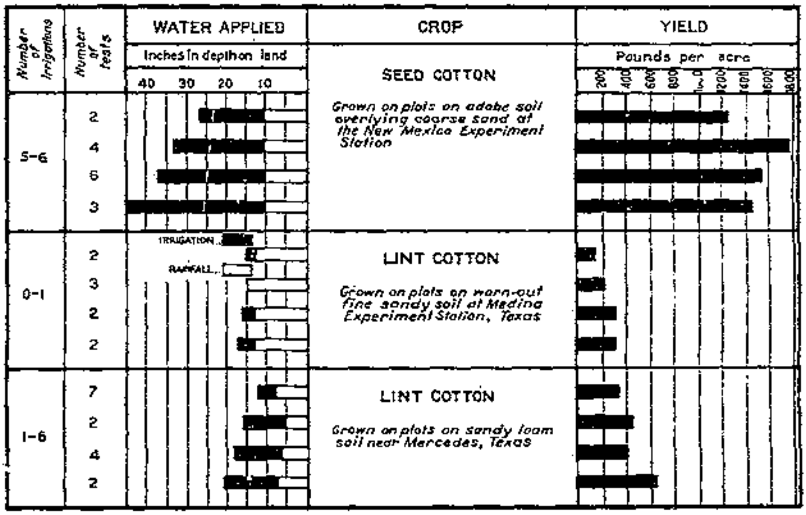

FIGURE 8.—Relationship between amount of water applied and yield of cotton as determined by experiments carried on cooperatively in different parts of the Southwest from 1915 to 1926

In irrigating alfalfa, sugarcane, and other crops of high-water requirement, it is more difficult to ascertain when enough water has been applied. It sometimes happens that the more water used the larger the tonnage harvested. In such cases it is well to consider, besides yield, the value of water, the cost of applying it, and the damage to soils arising from excessive use.

The relationship between quantity of water applied and yield of crop is shown graphically in Figures 8 to 11. The basic data for these charts are selected from Tables 6 to 19. The charts show the number of irrigations; the number of tests involved; the water used by the crop, whether irrigation or rainfall; the kind of crop; the general character of the soil on which it was grown; and the crop yield.

WATER REQUIREMENT OF CROPS

The high water requirement of one set of conditions is offset in a measure by the medium or low requirement of another. The long growing season, high temperature, clear sunshine, dry air, and heavy evaporation require a large quantity of water to mature crops, but the extensive acreage planted to crops having a low or medium water requirement tends to lower what would otherwise be a high average.

SORGHUMS

The climatic conditions in much of the Southwest are well adapted to sorghums. Compared with corn, the grain sorghums need less

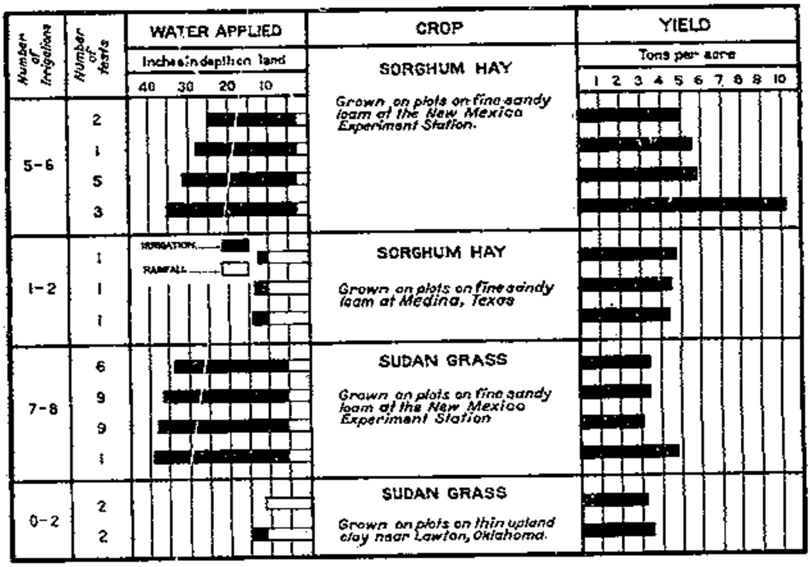

FIGURE 9.—Relationship between amount of water applied and crop yield of sorghum hay and Sudan grass as determined by plot experiments carried on cooperatively in different localities of the Southwest from 1915 to 1921

water, while sorghums cut for hay require more, but both kinds withstand drought better. Most crops receive a permanent setback when the soil moisture remains for a considerable time below the wilting point, whereas the sorghums have the extraordinary ability to revive when rain falls or irrigation water is provided. This peculiar quality, which overcomes to a considerable extent the injurious effects of droughts by furnishing roughage for stock at a time when other crops fail, accounts for the popularity of the sorghums on the dry farms of the Southwest and for the rapid increase in arable land devoted to sorghums harvested for grain. In New Mexico the area planted to grain sorghums in 1909 was 63,570 acres, whereas in 1919 it was 151,685 acres. During the same decade in western Texas the area increased from 570,188 to 1,461,736 acres. The sorghums are also grown quite extensively on irrigated farms to provide fodder and silage and as catch crops. Under favorable weather conditions they can be planted after grain crops are harvested or after other crops have failed.

In growing sorghums on dry farms there is a more or less close relationship between the precipitation and crop yields. This is shown in Table 2. The data (*3*) on which this table is based represent in each case the average of averages. In other words the yields reported represent in each case the average of a large number of plot

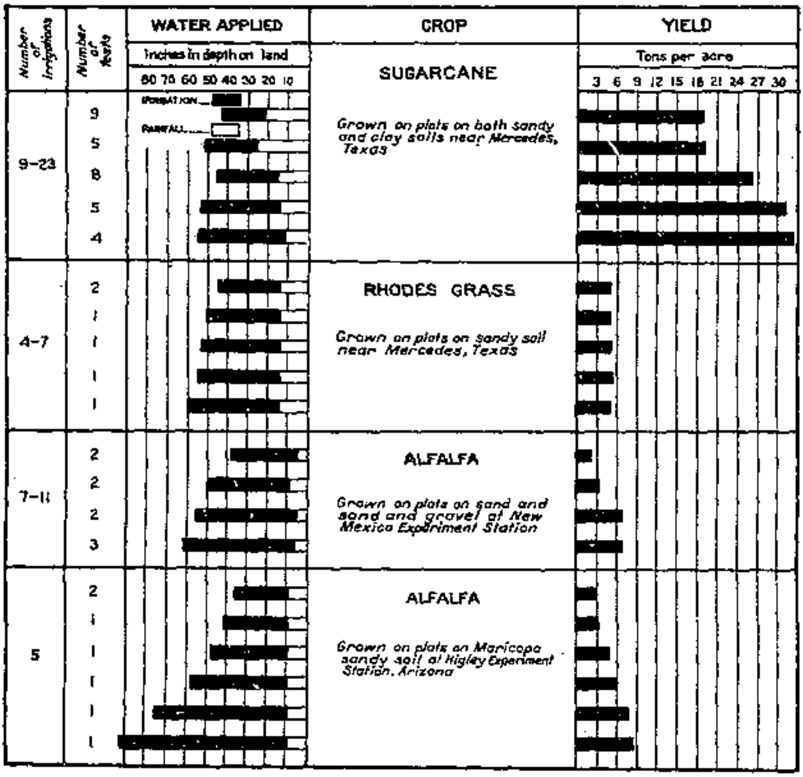

FIGURE 10.—Relationship between amount of water applied and crop yield for sugarcane, Rhodes grass, and alfalfa as determined by plot experiments carried on cooperatively in different localities of the Southwest from 1916 to 1919

yields at each locality. To equalize further the effects of crop hazards of various kinds, the authors have subjected the crop yields at each locality to a second averaging based on yearly precipitation. Thus a variety of sorghum known as milo was grown at Woodward, Okla., for 10 consecutive years. The five years of highest precipitation as well as the five years of lowest precipitation have been averaged, and each is shown in the table in conjunction with the average crop yield for the corresponding period. Like treatment has been given sorghum crops grown in other parts of the Southwest.

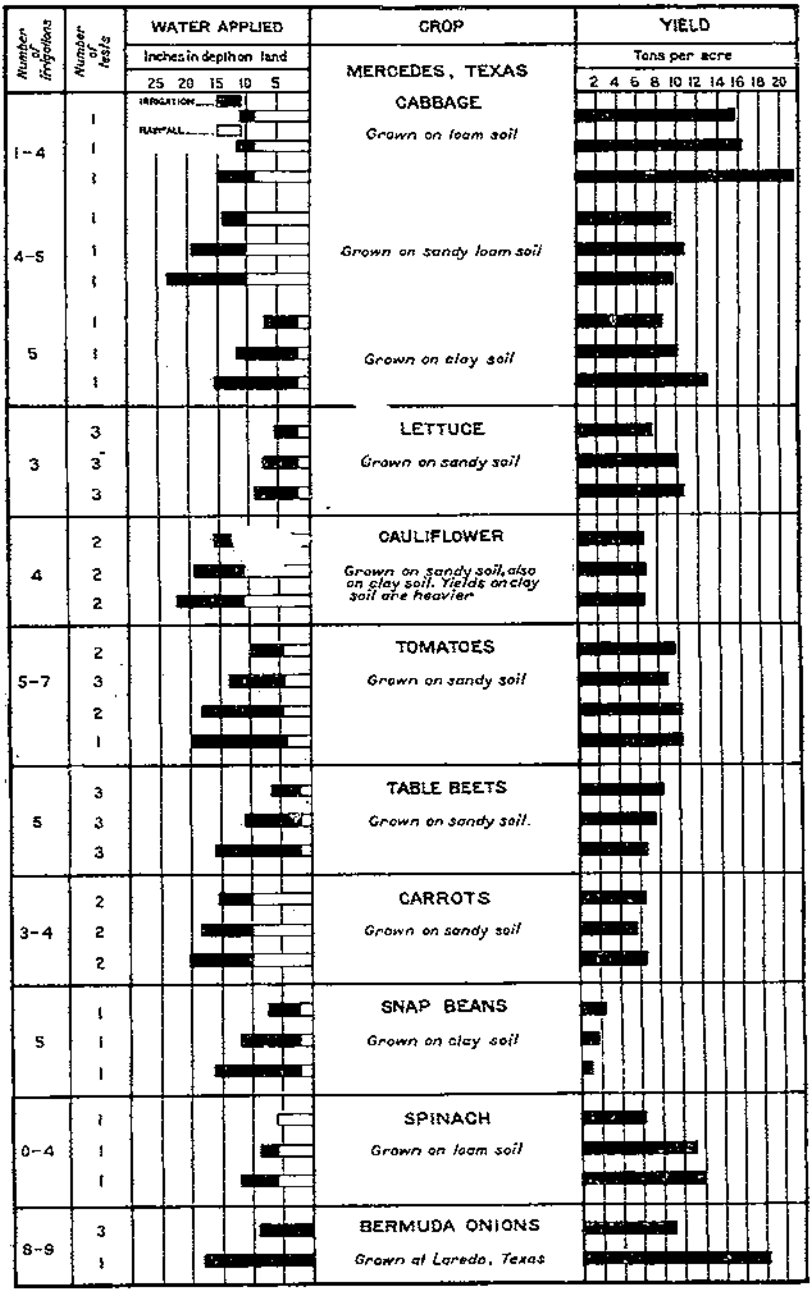

FIGURE 11.—Relationship between the amount of water applied and crop yield of vegetables as determined by plot experiments conducted cooperatively by the Division of Agricultural Engineering and the Texas State Board of Water Engineers near Mercedes and Laredo, Tex., from 1914 to 1920

TABLE 2.—*Relation between crop yields of milo and kafir and precipitation*

Station	Years of tests	Mean annual precipitation	Mean crop yield of—		
			Milo	Kafir	
				Grain	Total
	Number	*Inches*	*Bushels*	*Bushels*	*Pounds*
Woodward, Okla.	5	[1] 30.49	24.1	25.7	5,271
	5	[2] 20.25	14.2	15.9	5,009
Lawton, Okla.	4	[1] 36.35		29.0	5,682
	5	[2] 22.24		5.7	2,658
Dalhart, Tex.	8	[1] 23.07	30.7	26.0	6,392
	8	[2] 14.38	15.4	12.2	5,245
Amarillo, Tex.	7	[1] 22.31	32.6	18.7	5,965
	6	[2] 14.61	12.2	6.7	3,482
Big Springs, Tex.	4	[1] 24.15	34.0	24.0	4,475
	5	[2] 12.72	12.0	8.8	2,832
Tucumcari, N. Mex.	6	[1] 24.95	36.1	26.3	4,527
	6	[2] 12.48	15.3	11.1	2,792

[1] Average rainfall for years of highest precipitation.
[2] Average rainfall for years of lowest precipitation.

Under conditions equally favorable the yields of sorghums are greater when the effective rainfall is supplemented by irrigation water, although the combined quantity of water needed is relatively small. This is shown by the results of irrigated plot experiments of sorghums, a few of which are outlined in the following paragraphs.

In 1919 sorghum for hay was grown on seven plats near Mercedes, Tex. The rainfall during the growing season was 2 acre-feet, and this was supplemented by three light irrigations, the total of which varied from 0.53 to 1.14 acre-feet. The yields of plots which received less than 0.9 acre-foot of irrigation water averaged 10.29 tons per acre, while those that received more than 0.9 acre-foot averaged 11.83 tons.

In 1915 sorghum harvested for fodder was grown on 11 plots at the New Mexico Agricultural Experiment Station and somewhat heavily irrigated six times during May, June, July, and August. The average seasonal quantity of irrigation water applied was 2.36 acre-feet per acre, and there was 0.22 acre-foot of rainfall. The plots produced an average yield of 6.89 tons. Those which received less than 2 acre-feet produced an average yield of 4.98 tons; those which received 2 acre-feet and less than 2.50 acre-feet averaged 5.87 tons; and those which received from 2.67 to 2.77 acre-feet averaged 10.23 tons.

Hence it would appear that sorghums, including Sudan grass grown for fodder, require from 2.5 to 3 acre-feet per acre to produce heavy yields.

COTTON

Compared with the extent and value of the cotton crop in the Southwest, the data pertaining to its water requirement are somewhat meager. Investigations of the relationship of this plant's growth to soil moisture conditions have not kept pace with the rapid increase in the area devoted to its production. The available data seem to demonstrate fairly well that less irrigation water is required to mature cotton in western Texas than in the cotton-producing districts of New Mexico, Arizona, or southeastern California. This is presumably because of the greater humidity, a lower rate of evaporation, and the storage of rain water in the soil and subsoil. When the normal effective rainfall is included, a water requirement of 1.25 to 2 acre-feet per acre seems to be ample for a large yield, whereas in the more arid cotton-growing localities of Arizona, New Mexico, and southeastern California from 2.5 to 3 acre-feet per acre seems to be required. At Safford, Ariz., the summer rainfall (May 1 to September 30) averages 4.73 inches and the yearly precipitation 9.2 inches, and about 30 inches of irrigation water on an average is applied to land planted to cotton.

ALFALFA

The water requirement of this forage plant has been fairly well ascertained by cooperative experiments conducted by the Division of Agricultural Engineering in tanks, on plots, and under field conditions. The results indicate that a large quantity is required per unit of dry fodder grown. Estimating the consumption of water by transpiration and soil evaporation from alfalfa grown in tanks under climatic conditions somewhat similar to those of the lower and warmer portions of the Southwest, about 3 acre-feet per acre would be required to produce a seasonal yield of 5 tons of hay. If to this consumption is added 25 per cent for unavoidable losses of water, the total is 3.75 acre-feet per acre. The average yield of 276 tests of alfalfa grown in plots at the New Mexico Agricultural Experiment Station was 5.55 tons with the use of 4.2 acre-feet of water per acre, including rainfall. Under field conditions in Arizona the average of 49 fields tested gave 4.36 acre-feet per acre and a yield of 5.2 tons. These results and other available data indicate that a heavy seasonal yield of alfalfa requires about 4.25 acre-feet of water per acre throughout the lower and warmer portions of the Southwest. At higher elevations, having shorter growing periods and fewer crops, the water requirement is proportionately less.

RHODES GRASS

The water requirement of this crop can be estimated with some degree of accuracy from the results of cooperative experiments directed by the Division of Agricultural Engineering near Mercedes, Tex., from 1917 to 1920, inclusive. Six plots were seeded to Rhodes grass in March, 1917, the soil type being Brennan fine sandy loam. During the first season the plants were allowed to develop without any tests being applied, and the plots were pastured during the fourth season, thus precluding yields in those years, but the relationship between the yield of each plot for each cutting and the quantity of water applied was accurately determined for the other two years.

In Table 3 the average quantity of water applied to the six plots for each cutting is given, as well as the rainfall and yields.

TABLE 3.—*Quantity of water applied to plots planted to Rhodes grass near Mercedes, Tex., and yield in 1918 and 1919*

Cutting No.	Period of growth	Days to maturity	Quantity of water applied: Irrigation	Rainfall	Total	Yield per acre
	SEASON OF 1918					
		Number	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1	Mar. 7 to May 8	63	0.38	0.59	0.97	1.25
2	May 8 to June 26	50	.54	.24	.78	1.09
3	June 26 to Aug. 6	42	.78	.03	.81	.84
4	Aug. 6 to Sept. 14	40	.98	.02	1.00	1.23
5	Sept. 14 to Nov. 11	59	.39	.30	.69	.78
	Total		3.07	1.18	4.25	5.19
	SEASON OF 1919					
1	Mar. 5 to May 16	73	0.24	0.43	0.67	1.21
2	May 16 to June 25	41	.40	.32	.72	.52
3	June 25 to Aug. 5	42	.00	.55	.55	1.02
4	Aug. 5 to Sept. 22	49	.74	.58	1.32	1.03
5	Sept. 22 to Nov. 6	46	.00	.22	.22	1.26
	Total		1.38	2.10	3.48	5.04

If a determination of the water requirement of this plant from 12 individual plot experiments is justifiable, at least 3.5 acre-feet per acre, including rainfall, seems to be needed for a seasonal yield of 5 tons of air-dried hay harvested in five cuttings.

CORN

In the Southwest the growing of corn is confined mainly to Texas and New Mexico. In that part of Texas considered in this bulletin, in 1924 there were 900,493 acres of corn; in New Mexico the total was 215,811 acres; and in Arizona there were only 31,000 acres.

The results of plot experiments by the Division of Agricultural Engineering, the New Mexico Agricultural Experiment Station, and the Board of Water Engineers of Texas indicate generally the quantity of water required for a satisfactory yield of corn. In 1915, in the Mesilla Valley, N. Mex., 12 plots planted to corn produced an average of 40 bushels per acre with the use of 1.85 acre-feet per acre of irrigation water and 0.22 acre-foot of rainfall, a total of 2.07 acre-feet. In another Mesilla Valley experiment the same average yield was obtained with the use of 1.95 acre-feet per acre, including rainfall. Corn was grown in plots near Mercedes, Tex., for the five years from 1915 to 1919, inclusive. During this period the effective rainfall varied from 0.41 to 0.94 acre-foot and the quantity of irrigation water from 0.20 to 1.53 acre-feet. Of 24 plot experiments in this 5-year period, those which received less than 1.5 acre-feet per acre, including rainfall, produced an average of 54.6 bushels per acre, and those which received 1.5 to 1.96 acre-feet per acre produced 62.5 bushels per acre. On the basis of the tests reviewed the water requirement of corn in the Southwest may be adjudged to be about 1.75 acre-feet per acre, including rainfall.

VEGETABLES

Under this heading are included such crops as cabbage, lettuce, cauliflower, table beets, tomatoes, snap beans, cantaloupes, and spinach. Throughout the Southwest many of these crops are grown under irrigation for home consumption or canning, but those grown commercially on a large scale are confined in the main to the Imperial Valley and the lower Rio Grande Valley. In 1924 (*23*) cantaloupes and muskmelons were grown for sale on 20,241 acres and lettuce on 16,634 acres in Imperial County, Calif. In the same year the acreage in Cameron and Hidalgo Counties, Tex., in cabbages and tomatoes was 9,697 acres and 2,295 acres, respectively.

In September, October, and November of 1914, 1916, 1918, and 1919 measurements were made of the water applied to cabbage grown in plots near Mercedes, Tex. Unpublished results of these experiments show that the average quantity, including rainfall applied during the period of growth, was 1.20 acre-feet per acre, and the average yield was 7.28 tons per acre. More than 1.25 acre-feet per acre did not increase the yield; hence it was concluded that this quantity was sufficient for southwestern Texas. In Mesilla Valley slightly more than an average crop of 10 tons per acre was raised from plots which received 2.31 acre-feet per acre.

LETTUCE

The average quantity of water used on 49 plots of lettuce near Mercedes, Tex., was 1.03 acre-feet per acre, and the average yield was 5.97 tons. The plots which received from 1 to 1.5 acre-feet per acre did not show any substantial gain in yield; hence it appears that for this crop and locality 1 acre-foot per acre is an adequate water requirement.

CAULIFLOWER

In the same locality an average of 1.6 acre-feet was applied to six plots of cauliflower, which produced an average yield of 6.65 tons per acre. The three plots which received an average of 1.43 acre-feet yielded more heavily than the three which received 1.77 acre-feet, and it was concluded that 1.4 acre-feet per acre was a near approach to the water requirement of this crop in that locality.

TOMATOES

The water requirement of tomatoes grown on both sandy and clay soil, as determined on 15 plots in the lower Rio Grande Valley of Texas, was found to be about 1.75 acre-feet per acre, that of table beets about 1.4 acre-feet per acre, and that of snap beans and spinach about 1.2 acre-feet per acre.

SUMMARY OF WATER REQUIREMENTS OF LEADING CROPS

The results of the water-requirement investigations of the leading crops grown in the Southwest show that variation in climate, soils, and other conditions produce variations in the quantity of water required for profitable yields. Accordingly, in Table 4, which summarizes results of plot and field experiments as given in the appendix, the water requirement is expressed in two ways—(1) the lowest general average, and (2) the highest general average—so as to conform more closely to changes due to natural causes.

TABLE 4.—*Water requirement of crops in the Southwest, including irrigation and rainfall*

Crop	Tests	Water requirement per acre		Crop	Tests	Water requirement per acre	
		Lowest general average	Highest general average			Lowest general average	Highest general average
	Number	*Acre-feet*	*Acre-feet*		*Number*	*Acre-feet*	*Acre-feet*
Alfalfa	369	3.47	5.08	Millet	5	0.91	1.09
Barley	3	1.24	1.83	Oats	2	1.90	2.09
Beets (table)	28	.87	1.37	Onions	4	.73	1.52
Beets (sugar)	5	1.77	2.72	Peas	8	1.21	1.56
Broomcorn	9	.97	1.15	Potatoes	12	1.59	2.04
Cabbage	21	.94	1.49	Rhodes grass	12	3.49	4.43
Cauliflower	6	1.43	1.77	Snap beans	9	.83	1.44
Carrots	6	1.27	1.60	Spinach	12	.80	1.07
Corn	42	1.44	1.99	Sorghum	34	1.69	2.08
Cotton	103	2.35	3.51	Soybeans	36	1.66	2.81
Emmer	6	1.19	1.87	Sudan grass	25	2.88	3.16
Flax	3	1.23	1.59	Sugarcane	41	3.48	4.56
Feterita	8	.97	1.10	Sweetpotatoes	3	1.77	2.25
Kafir	16	1.32	1.54	Tomatoes	17	.95	1.42
Lettuce	49	.72	1.35	Wheat	40	1.46	2.24
Milo	35	.96	1.67				

CONDITIONS INFLUENCING THE QUANTITY OF WATER REQUIRED FOR IRRIGATION

In determining the quantity of water required for a project or farm of known area, consideration should be given to each of a number of influential factors. These may be grouped under (1) physical conditions; (2) character of equipment, structures, and methods necessary for handling water; (3) conditions relating to farm management; and (4) economic phases. Legal and administrative conditions constitute a fifth group, but these will be treated under a separate heading.

PHYSICAL CONDITIONS

These include climate, water supply, soils, and topography. Compared with other large divisions of the West, the average irrigation requirement of the Southwest is higher by reason of the greater aridity of its climate. On much of the arable land susceptible of irrigation the annual rainfall is very light—almost negligible in some localities—the summer temperature is high, the intense rays of the sun are rarely obscured, and evaporation from soils and water surfaces, as well as the transpiration from plants, is excessive.

The light rainfall, together with heavy evaporation, results in a small stream flow. Both surface and underground water supplies are likewise affected by the manner in which the rain falls. As a rule the rainstorms are erratic and often torrential in character, resulting in quick run-off, so that the inflow into underground basins is small, and flood storage in reservoirs is necessary.

On the other hand, the character of the soils and topography of the arable lands of the Southwest are such as to call for a small rather than a large quantity of irrigation water. In some cases rivers have transported through long ages enormous quantities of sediment which have formed alluvial deltas like those of the lower basins of the Colorado River and the Rio Grande. In other cases deep depressions have been filled by water-borne material eroded from higher portions of the drainage area, making valleys similar to that of Salt River in Arizona. In both cases the surface, although characterized by gently undulating slopes, is level enough so that it is not difficult to convey and distribute water, and the soil generally contains enough fine silt and clay to prevent excessive losses from deep percolation.

CHARACTER OF EQUIPMENT, ETC.

This group of factors includes the main water-supply ditch, pipe, or other conduit for the farm, the division of the farm into fields suitable for irrigation and cropping, all permanent farm ditches, the preparation of the surface of each field to receive water, and the method best adapted to the application of water. With few exceptions the water channels of the irrigated farms of the Southwest are made of earth. Up to the present, economic conditions have not warranted the use of pipes or other water-tight conduits. More or less water is absorbed by earthen ditches, but the loss of water in this manner is governed largely by the character of the soil, which is on the whole fairly impervious. At first wooden structures were in common use on the farms, but experience showed that the climatic conditions were unfavorable for the preservation of wood, and concrete is now generally used instead.

The chief defect in the farm systems of irrigation has been incomplete and improper planning. Settlers without experience, technical advice, or assistance located and built supply ditches, subdivided their holdings, and prepared a few fields for irrigation. Such work is more likely to be wrong than right, and when wrong it is difficult to make it right. Few settlers have the time or means to prepare their entire farms for irrigation during the first year, but if started in accordance with a comprehensive plan the work can be spread over several years, with the assurance that when completed it will serve the purpose for which it was designed.

CONDITIONS RELATING TO FARM MANAGEMENT

The most profitable crops to grow, the maintenance of soil fertility, and the rotation and diversification of crops are included in this group. Elsewhere in this bulletin the variation in the water requirement of crops is discussed, but little is said of the saving in water by diversification and soil fertility. Few practices in irrigation farming are so well established by experience as that of changing crops periodically, particularly, from leguminous to other kinds, and vice versa. Theoretically, such a change can not be made in most orchards on account of their long life, but it is both practical and economical to grow cover crops between the rows of trees, thus serving the same purpose. No matter how fertile virgin soil may be, experience has shown that it needs to be replenished with decayed vegetable matter. The decayed roots and foliage of such legumes as alfalfa, beans, and peas improve the texture of soils, increase the yields, and reduce the water requirement.

ECONOMIC PHASES

While economic considerations enter into the second and third groups, such subjects as cost of water, manner of payment, and permissible waste are considered of essentially economic importance.

As irrigation development progresses the cost of water increases, and under some proposed projects a stage is being reached at which the cost of water is too high to permit profits. On other projects the cost is so high as to warrant extreme measures to lessen its waste. In general, arable land is cheap and readily available, but water is not plentiful. Therefore if a seasonal water requirement of 2½ acre-feet per acre will suffice instead of 3½ acre-feet, 40 per cent more land can be served and the unit cost of water similarly reduced.

When a farmer pays for water on an acreage basis he has little inducement to economize in its use. His water-right contract may call for enough to irrigate a given number of acres, and if he uses less, those who own the canal system receive the benefits. On the other hand, if he buys water by the acre-foot or other unit, any saving he can effect during the season reduces his water bill proportionately.

Were it possible for all the water delivered to a farm to be absorbed by the roots of crops and transpired by their foliage, an efficiency of 100 per cent would be reached, but this is unattainable. With the best equipment for distributing water and its most skillful use in moistening the soil, it is seldom practicable to utilize more than 80 per cent, and with poor equipment and less skillful handling the efficiency may drop to 30 per cent. This loss has been termed "permissible waste," and its relative quantity depends on economic considerations. If the service which water can perform in producing a larger quantity and a better quality of crops will justify more careful land preparation and more efficient equipment in order to utilize a larger part of the available water supply, such a course should be followed; but if, as is sometimes the case, the returns from farming are too small to warrant such expenditures the farmer must get along as best he can with cheaper methods and equipment and suffer the losses which these entail.

DUTY OF WATER AS AFFECTED BY STATE, COMMUNITY, AND CORPORATE REGULATIONS[3]

Five of the States discussed in this bulletin are also included in part in the Great Basin and Missouri and Arkansas River basins. The present discussion of effect of State, community, and corporate regulations will therefore be limited to conditions in Arizona, New Mexico, and Texas; the reader is referred to the two preceding bulletins (*8*, *9*) of this series for similar discussions relating to the other States, including Oklahoma, which for this purpose may be classed with the Missouri and Arkansas River Basin States.

STATUTES AND COURT DECISIONS

Arizona, New Mexico, and Texas were settled by the Spaniards and for some 250 years were subject to Spanish and Mexican law. So far as they concerned irrigation institutions, these Old World laws prior to the independence of Mexico were of a decidedly miscellaneous character; local customs, therefore, became strong and frequently had all the force of written law in both Spain and the New World. The earliest legislation of Territorial New Mexico and Arizona indicated a clear intention to continue existing Mexican irrigation laws and customs in force, and the intent of an early

[3] The material in this section was prepared by Wells A. Hutchins, irrigation economist, Division of Agricultural Engineering.

Texas irrigation statute was similarly construed by the supreme court of that State.[4] The laws and customs in question, aside from those rights covered by the civil law, dealt mainly with construction, operation, and ownership of acequias, grants of land and water rights, and rights of impresarios and colonists to water for irrigation; and, while they contained some broad provisions regarding the use of water and gave the viceroys and courts authority to make further provision for it, there was apparently no serious attempt on the part of the Spanish officials to reduce such use to an economical basis. Varying local customs had most influence in determining this use.

Within the present century, however, all three States have adopted modern irrigation codes and have set up machinery for their administration. Applications to appropriate water must be made to the State. Beneficial use is declared to be the basis of acquirement of a right to use water for irrigation, and for this purpose, according to the Texas statute—

> beneficial use shall be held to mean the use of such a quantity of water, when reasonable intelligence and reasonable diligence are exercised in its application for a lawful purpose, as is economically necessary for that purpose.

Determination of what is beneficial use in any instance necessarily depends upon the facts in that case. Appropriation rights may be declared forfeited for nonuse. State water divisions are provided for. Hydrographic surveys are authorized. Arizona and New Mexico provide for determinations of existing priorities and regulation under State authority of the distribution of water to various ditches. These measures are all aimed at the orderly appropriation and diversion of water, elimination of unnecessary waste, and substitution of some measure of economy of use for the older practices of applying water without regard to the needs of other users; and they are chiefly valuable to the extent that they bring about a real coordination of water uses into which the point of view of the State has been injected.

RIPARIAN RIGHTS

The Territorial Legislature of Arizona specifically abrogated the common-law doctrine of riparian rights, and in so doing was upheld by the courts.[5] The ensuing State constitution contained a similar provision. In New Mexico the courts have rejected the riparian doctrine and accepted the statutory rule of prior appropriation.[6] A recent Texas decision, reviewing the whole subject of water law in that State, affirms the validity of riparian rights, at least in connection with lands granted prior to the appropriation act of 1889, but definitely restricts riparian waters to "the ordinary flow and underflow of the stream."[7]

COMMUNITY REGULATIONS AND CONTRACTS

Until the present century local usages and regulations have had more to do with determining water requirements than have any state-wide measures, and they still exert a marked influence. Usage

[4] Tolle v. Correth, 31 Tex. 362, 98 Am. Dec. 540.
[5] Austin et al. v. Chandler et al., 4 Ariz. 346, 42 P. 483. See also Clough v. Wing, 2 Ariz. 371, 17 P. 453.
[6] In Hagerman Irrigation Co. v. McMurry, 16 N. M. 172, 113 P. 823, the court stated: "The doctrine of prior appropriation with application to beneficial use has definitely and wholly superseded the common-law doctrine of riparian rights in many of the jurisdictions in which irrigation is necessary to the growth of crops, and among them is New Mexico."
[7] Motl et al. v. Boyd et al.,— Tex. —, 286 S. W. 458, decided June 26, 1926.

on any one of the several hundred community acequias or ditches in New Mexico conformed mainly to the available water supply, method of delivering water to individuals, and ability and disposition of the major-domo, or superintendent, to enforce the regulations impartially; the water rights of some acequias having been derived from Spanish or Mexican sources and those of others acquired under United States laws. The actual quantity of water delivered to an individual depends upon the number of so-called rights he holds, which may be based upon his irrigable acreage, or upon his ditch frontage, or upon the amount of labor he chooses to subscribe to the ditch maintenance in any one season. Such a right usually represents a proportional part of the total available water supply, rather than a fixed quantity of water or rate of flow. The New Mexico Code provides that community customs and regulations having for their object the economical use of water, and not detrimental to the public welfare, shall govern the distribution of water from the ditches to which they apply, but that the authority of the State engineer is not thereby to be impaired.

Contracts between the Federal Government and water users on reclamation projects have unquestionably influenced the quantity of water used on those projects, for they have involved a minimum charge for a given quantity of water used per acre and an additional charge for additional water. Salt River Valley Water Users' Association, which operates the Salt River project, levies a minimum annual charge against each acre of land to which association stock is appurtenant, which entitles that acre to 2 acre-feet of water, and makes a further charge, which may be graduated if the board of governors see fit, for each additional acre-foot. As the Salt River and Yuma projects together included more than half the irrigated area of Arizona reported in the census of 1920 (*22*), the effect of these contracts is obviously important in connection with water requirements in that State.

Commercial enterprises are not relatively important in Arizona and New Mexico, but were reported in the census of 1920 (*22*) as supplying water to 45 per cent of the land irrigated in Texas, some of this area, however, having since gone into districts. Where water is delivered by these companies on a flat acreage basis there is little incentive to economical irrigation. Where a minimum rate per acre is made, with an additional charge for each watering, there is some inducement to irrigate carefully, and where the rate is based upon the quantity delivered the water user is led more forcibly to consider his actual requirements before ordering water. This last type of contract is therefore most desirable from a broad public point of view.

Water improvement districts (irrigation districts) in Texas have an opportunity to influence the use of water for different crops under the statutory requirement that one-third to two-thirds of the annual maintenance and operation funds be paid in advance by applicants for water, in which event the board of directors may take into consideration the acreage to be planted by each applicant for water, the crop to be grown by him, and the amount of water per acre to be used by him, provided, however, that each water user shall pay the same price per acre for use of water upon the same class of crops.

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ARID LAND RECLAMATION AND MONTHLY AND SEASONAL IRRIGATION REQUIREMENTS

Most of the summer flow of the streams of the Southwest is utilized, and the extension of the irrigated area will depend largely on the storage of the flood flow and other unused waters. A substantial beginning has been made in this direction. In 1920 the Federal census (*22*) reported 800 reservoirs having a combined capacity of 5,000,000 acre-feet. Since then other reservoirs have been built or started. Building high dams to impound water not only provides a water supply for agricultural purposes but also creates facilities for the generation of hydroelectric power. A part of this energy can be used to operate pumps to raise water from underground and other sources and to drain water-logged lands. Taking advantage of the cheap electric energy developed at the Roosevelt Dam and accessory storage and power plants below the dam, the farmers of Salt River Valley use part of it to operate deep-well pumps for the dual purpose of lowering the ground-water level and providing water to supplement the gravity flow from the reservoirs. From 1921 to 1926 the average quantity of water pumped from wells was about 200,000 (*15*) acre-feet per annum.

It is likewise true that some of the advantages gained by impounding water and developing power at favorable sites is offset by the deposition of silt wherever the waters of silt-laden streams are stored. All southwestern streams carry more or less silt, which in time impairs, if it does not destroy, the usefulness of storage reservoirs. In Roosevelt Reservoir the average rate of sedimentation for the 20 years dating from the time the dam was begun was 5,050 acre-feet per annum (*10*). In the Elephant Butte Reservoir of New Mexico the average rate of sedimentation from November, 1916, to August, 1925, was 20,470 acre-feet per annum (*13*).

The agricultural resources of the Southwest can not be utilized to much more than one-third their potential extent without water, and, compared with the vastness of the territory, water is extremely scarce. The bulk of it is derived from two streams, the Colorado and the Rio Grande. The storage of flood waters on these and smaller streams will not suffice for all irrigable lands likely to be reclaimed. Measures will have to be taken to collect and utilize the waste water from irrigation. Such waters may be grouped under (1) seepage, (2) return flow, and (3) underground recovery. The meanings of these will be understood from what follows. The inefficiency arising from the use of water in irrigation is readily accounted for. In this practice the discharge of streams, instead of being permitted to flow to the sea in natural channels, is diverted and distributed over wide areas by artificial means. The artificial channels are seldom efficient carriers of water, but permit one-fifth to one-half the intake volume to be absorbed by the porous materials of which they are composed. The water remaining in the channel at the end of its run is distributed to farms, where a second loss is sustained in efforts to moisten dry soil. In most cases the revenue derived from farming does not warrant the installation of water-tight conduits, and in spreading water over fields some loss is unavoidable. Hence the authors have made use of the term "permissible waste" (*9*) in reference to conveyance and use, which, combined, have been found over large areas to average 50 per cent of the quantity of water diverted. Results of recent determinations on 22 Federal projects showed that the percentage of intake water delivered to farms varied from 29 to 77 per cent and averaged 50 per cent. The water absorbed by earthen channels and the deep percolation losses from irrigated fields is acted upon by gravity, causing it to move through soils and subsoils to lower levels. This is usually termed "seepage water."

"Return flow" is a term applied to diverted water which finds its way back to a stream, and is used with reference to an entire stream system or to one or more of its natural subdivisions. The sources of the return flow may be identical in part with those of seepage waters, but the former comprise larger land areas. During periods of high water and abundant supply it is common practice to apply large quantities to cropped land. A part of the water so applied finds its way sooner or later to the channel from which it was derived, but at a lower elevation. If feasible, this return flow is reused on lower lands. The presence of more or less return flow in western streams has given rise to an expression, the "consumptive use" of water, which means in its most restricted sense the difference between the inflow and outflow of a return-flow area. Stated differently, the surface water supply of the upper portion of a stream basin or other natural subdivision may be wholly diverted and used for agricultural purposes and at the same time not represent the potentialities of this portion of the stream for irrigation, since from 20 to 40 per cent of the diverted water may return to the channel and be available for reuse. Accordingly, consumptive use represents the unrecoverable portion of a water supply irrespective of whether it is transpired by plants, evaporated from water and soil surfaces, or permanently retained in the materials beneath the surface.

Underground recovery as a source of irrigation water is quite general in its application and may include seepage and return flow as well as the residue of precipitation, or what remains of the natural supply after surface run-off, evaporation from ground surfaces, and transpiration from vegetation are deducted. Water is recovered from underground basins by (1) drainage conduits, (2) pumping from wells, and (3) combinations of gravity conduits and pumping equipment. An example of the first on a large scale is found in the Mesilla Valley, N. Mex. Here the waste water from a large extent of irrigated land, augmented by rainfall and return flow, was allowed to accumulate for years until a high ground-water table damaged crops and menaced the productivity of the greater part of the valley.

To remedy this situation, deep drainage ditches were installed, which have proved effective in lowering the ground-water table and restoring the fertility of the soil. In Texas underground recovery has likewise resulted in regaining a large quantity of water and rendering it available for use. From 1923 to 1927 the average quantity of water recovered from 66,700 acres of valley lands and returned by gravity drains to the Rio Grande was 189,000 acre-feet per annum. Reference has been made elsewhere to the successfully operated pumping plants in the Salt River Valley, Ariz., which make satisfactory use of waste waters from irrigation. In parts of western Texas and New Mexico numerous pumping plants are operated to recover underground waters for irrigation.

In line with what has been stated, it is evident that the apportionment of water to the arid and semiarid lands of the Southwest should be made with the greatest care and the strictest economy. From a farmer's point of view, nature has not apportioned to this region those essential elements of agriculture—fertile soil and water—in the right proportion. There is an excess of the former and a marked deficiency in the latter. The only remedy for this basic defect is to make the best possible use of the available water supply. The remedy, however, must not be carried too far or it will result in diminished yields and profits to the farmer. On the contrary, if a lavish use of water is permitted it will greatly curtail the extent of land which can be irrigated. The adoption of some safe and sane middle course is desirable, and in order to keep development in this course the needs for water of the various natural subdivisions of the Southwest have been carefully considered and a quantity of water in acre-feet per acre has been tentatively allotted to each.

Table 5 contains a description of each of the 30 divisions into which the Southwest has been divided, as shown in Figure 1, the average seasonal net irrigation requirement for each, and the percentage of total seasonal net requirements used in each month of the irrigation period. This table is based on the results of experiments summarized in this report, on anticipated improvements in irrigation practice, and on the judgment of the authors. In many localities the data available were too meager to enable trustworthy estimates of irrigation requirements to be given, but to the bewildered traveler any guidepost or familiar landmark is welcomed. In like manner those who have to do with land reclamation in future in this part of the West will profit, it is believed, by the guideposts indicative of a wise use of water in irrigation farming herein set up.

TABLE 5.—*Monthly and seasonal net irrigation requirements of the various subdivisions of the Southwest*

Division No.	Location of division	Monthly percentages of total seasonal net irrigation requirements												Seasonal net irrigation requirements in acre-feet per acre
		January	February	March	April	May	June	July	August	September	October	November	December	
1	Imperial Valley, Calif.	5	6	9	10	11	13	12	10	8	7	5	4	3.10
2	Southern Nevada	1	1	4	8	15	23	21	14	8	3	1	1	2.90
3	Southwestern Arizona	3	4	7	12	13	15	14	11	8	6	4	3	3.00
4	Northwestern Arizona	----	----	5	10	26	20	15	9	4	2	----	----	2.30
5	Navaho country, in northern Arizona	----	----	4	12	27	30	13	8	4	2	----	----	2.30
6	Southeastern Arizona	----	2	6	10	15	18	17	13	10	7	2	----	2.60
7	San Juan Basin, N. Mex.	----	----	----	5	20	20	23	17	6	----	----	----	2.20
8	Western New Mexico	----	----	----	4	19	27	30	14	4	2	----	----	1.70
9	Rio Grande Basin, N. Mex.	1	2	7	12	18	22	16	10	6	3	2	1	2.60
10	Pecos River Basin, N. Mex.	1	1	7	13	20	22	16	10	6	2	1	1	2.40
11	Northeastern New Mexico	----	1	5	14	22	26	17	8	4	2	1	----	1.60
12	Rio Grande Basin, west Texas	1	1	6	15	21	24	15	9	5	2	1	----	2.40
13	Pecos River Basin, Tex.	1	1	5	17	22	23	14	9	5	2	1	----	2.25
14	West-central Texas	3	4	6	12	14	15	15	12	9	3	4	3	1.60
15	Lower Rio Grande Basin, Tex.	5	12	12	17	15	12	8	5	3	3	4	4	1.75
16	Upper Nueces and Colorado River Basin, Tex.	3	7	12	14	17	16	14	7	3	3	2	2	1.30
17	Upper Brazos and Red River Basin, Tex.	2	3	6	10	16	18	17	12	8	4	2	2	1.10
18	Eastern Panhandle, Tex.	----	----	3	8	14	22	20	18	11	4	----	----	1.35
19	Western Panhandle, Tex.	----	----	4	7	14	25	23	15	9	3	----	----	1.05
20	Panhandle, Okla.	----	----	----	6	17	24	22	16	10	5	----	----	1.25
21	Western Oklahoma	----	----	----	8	17	22	20	15	12	6	----	----	1.00
22	San Luis Basin, Colo.	----	----	----	----	5	30	35	22	8	----	----	----	1.80
23	San Juan Basin, Colo.	----	----	----	8	17	30	25	13	7	----	----	----	1.90
24	Yampa and White River Basins, Colo.	----	----	----	----	13	35	34	18	----	----	----	----	1.35
25	Upper Colorado River Basin, Colo.	----	----	----	5	20	30	25	15	5	----	----	----	1.70
26	Virgin River Basin, Utah	----	3	7	11	14	18	17	12	10	6	2	----	2.25
27	San Juan Basin, Utah	----	----	----	7	16	30	27	13	7	----	----	----	2.10
28	Green River Basin, Utah	----	----	----	4	10	24	26	22	11	3	----	----	2.00
29	Uintah Basin, northeast Utah	----	----	----	3	18	28	26	20	5	----	----	----	1.75
30	Green River Basin, Wyo.	----	----	----	----	12	36	30	16	----	----	----	----	1.60

APPENDIX

USE OF WATER ON CROPS IN THE SOUTHWEST, IRRIGATION WATER APPLIED, RAINFALL, AND CROP YIELDS IN COLORADO, CALIFORNIA, ARIZONA, NEW MEXICO, TEXAS, AND OKLAHOMA

TABLE 6.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in San Luis Valley, Colo.*[1]

Year	Irrigations	Monthly application of water in acre-feet per acre						Total quantity of water in acre-feet received by crop per acre			Yield per acre
		May	June	July	August	September	October	Irrigation	Rainfall	Total	
ALFALFA											
	Number										*Tons*
1913	3	0.77		0.30		0.28		1.35	0.49	1.84	
1913	4	.82	0.31		0.41		0.19	1.73	.49	2.22	
1913	3	.39	.45		.59			1.43	.49	1.92	
1914	3	.62	1.16	.99				2.77	.70	3.47	2.06
1914	4	.21		.92	.90			2.03	.70	2.73	[2] .46
1914	3	.65		.87	.45			1.97	.70	2.67	[3] 1.30
1914	3	1.31	.61	.97				2.89	.70	3.59	1.34
BARLEY											
											Bushels
1913	2	0.42		0.44				0.86	0.38	1.24	9.8
1913	3	.39	0.45		0.53			1.37	.38	1.75	[4] 10.9
1913	3		.59	.42	.45			1.46	.45	1.91	[5] 15.95
BEETS											
											Tons
1913	4	0.37			0.71	0.42		1.50	0.49	1.99	4.11
EMMER											
											Pounds
1913	2		0.36	0.44				0.80	0.38	1.18	[6] 531
1913	2	0.25		.28				.53	.45	.98	[6] 625
1913	2		.37	.55				.92	.42	1.34	[6,7] 473
1913	3	.55		.26	0.26			1.07	.45	1.52	[6] 622
1914	2	.29		.23				.52	.73	1.25	[6,7] 443
1914	4		.52	.99				1.51	.70	2.21	[6] 604
FLAX											
1913	2		0.43	0.27				0.70	0.45	1.15	[8] 137
1913	2	0.27		.59				.86	.45	1.31	[9] 320
1913	2	.85		.29				1.14	.45	1.59	[8] 85
OATS											
1913	2	0.51		0.47				0.98	0.38	1.36	[10] 1,477
1913	3		0.41	.12	0.19			.72	.45	1.17	[10] 1,083
											Bushels
1913	3	.42		.42	.62			1.46	.45	1.91	69
1914	2		.46	.74				1.20	.70	1.90	41
1914	2		.54	.85				1.39	.70	2.09	41.7
PEAS											
											Pounds
1913	2		0.42	0.44				0.86	0.42	1.28	[11] 352
1913	2	0.61		.46				1.07	.49	1.56	[11] 293
1913	3	.35		.20	0.24			.79	.49	1.28	[11] 205
1914	2		1.02					1.02	.70	1.72	
1914	4		.52	.99				1.51	.70	2.21	

Footnotes on page 38.

TABLE 6.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in San Luis Valley, Colo.*—Continued

PEAS AND BARLEY

Year	Irrigations	Monthly application of water in acre-feet per acre: May	June	July	August	September	October	Total quantity of water in acre-feet received by crop per acre: Irrigation	Rainfall	Total	Yield per acre
	Number										*Tons*
1914	3	------	1.18	0.71	------	------	------	1.80	0.70	2.50	[12] 2.31
1914	3	------	.85	.44	------	------	------	1.29	.70	1.99	[12] 2.31
1914	4	------	.52	.99	------	------	------	1.51	.73	2.24	[12] 2.06

PEAS AND OATS

Year	Irrigations	May	June	July	August	September	October	Irrigation	Rainfall	Total	Yield per acre
1913	3	0.42	------	0.42	0.62	------	------	1.46	0.45	1.91	[12] 1.28
1913	3	.42	------	.42	.62	------	------	1.46	.45	1.91	[12] 1.79
1914	3	------	1.24	1.05	------	------	------	2.29	.70	2.99	[12, 13] 4.44
1914	3	------	.89	.98	------	------	------	1.87	.70	2.57	[12, 13] 4.00
1914	3	------	.70	.89	------	------	------	1.59	.70	2.29	[12, 13] 3.43
1914	4	------	.52	.99	------	------	------	1.51	.70	2.21	[12, 13] 3.07

POTATOES

Year	Irrigations	May	June	July	August	September	October	Irrigation	Rainfall	Total	Yield per acre
											Bushels
1913	2	------	------	0.27	0.33	------	------	0.60	0.45	1.05	([14])
1913	2	------	0.30	------	.24	------	------	.54	.45	.99	[11] 10.8

RYE

Year	Irrigations	May	June	July	August	September	October	Irrigation	Rainfall	Total	Yield per acre
1913	2	------	0.30	0.48	------	------	------	0.78	0.28	1.06	18.3
1914	2	0.57	.74	------	------	------	------	1.31	.73	2.04	[16] 19.6

WHEAT

Year	Irrigations	May	June	July	August	September	October	Irrigation	Rainfall	Total	Yield per acre
1913	2	0.43	------	0.28	------	------	------	0.71	0.42	1.13	11.2
1913	2	------	0.66	.80	------	------	------	1.46	.42	1.88	[17] 9.7
											Tons
1913	3	.61	------	.10	0.19	------	------	.90	.49	1.48	[12] 0.34
											Bushels
1913	3	.42	------	.42	.02	------	------	1.46	.45	1.91	28.8
1914	2	.33	------	.78	------	------	------	1.11	.73	1.84	[17] 15.5

[1] This experimental work was conducted by the Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture, and the Colorado Agricultural Experiment Station in cooperation with the Costilla Estates Development Co., on three tracts near San Acacio, Colo. Each crop was grown on a group of plots, the groups including from 2.1 to 11.1 acres. The soil of farm A is a heavy sandy loam, cut up by gravel deposits; of farm B, much heavier, in some places almost adobe, with a few grave deposits and on one side some sand; of farm C, sandy.

[2] First-year alfalfa.

[3] Damaged by rot.

[4] Nurse crop for alfalfa.

[5] Damaged by wind and animals.

[6] Grain.

[7] Winter emmer; March and April rainfall included.

[8] Seed; crop affected by wilt and thistles.

[9] Seed; affected by thistles.

[10] Sheaf; needed for feed.

[11] Seed.

[12] Hay.

[13] Estimated yield.

[14] Crop practically destroyed by wilt.

[15] Damaged by wilt.

[16] Winter rye; March rainfall included.

[17] Winter wheat; March rainfall included.

TABLE 7.—*Irrigation water in acre-feet applied on cotton in Imperial Valley, Calif.*[1]

Year	Acres irrigated	Monthly application of water per acre								Total quantity of irrigation water received by crop per acre
		March	April	May	June	July	August	September	October	
1926	160		0.48	0.43	0.59	1.04	1.21	0.81	0.25	[2] 4.81
1926	160		.67	.25	1.01	1.12	.99	1.00	.58	[2] 5.62
1926	321	0.15	.70	.19	.60	.81	.98	.85	.35	[2] 4.72
1926	160		.34	.48	.59	.28	.71	.48	.26	[2] 3.14
1926	160		.50	.14	.91	1.17	.90	.62		[2] 4.24
1926	200	.66	.11	.38	.86	1.16	1.13	.81	.68	[3] 5.79
1926	160		.43	.45	.50	1.47	1.30	1.25		[3] 5.40
1926	160	.17	.73	.25	.27	.77	1.12	1.45	.21	[3] 4.97
1926	150		.84	.21	.75	1.35	1.10	1.07	.59	[3] 5.91

[1] Information furnished by M. J. Dowd, chief engineer and general superintendent, Imperial irrigation district, Imperial, Calif.
[2] Grown in Calipatria area on soil somewhat harder than Imperial loam.
[3] Grown in Brawley area on soil somewhat harder than Imperial loam.

TABLE 8.—*Irrigation water applied on cotton in Imperial Valley, Calif., and Lower California, Mexico*[1]

Year	Area irrigated	Total quantity of irrigation water received by crop per acre	Year	Area irrigated	Total quantity of irrigation water received by crop per acre	Year	Area irrigated	Total quantity of irrigation water received by crop per acre
	Acres	*Acre-feet*		*Acres*	*Acre-feet*		*Acres*	*Acre-feet*
1923	600	4.44	1924	500	3.00	1925	350	3.38
1923	12,000	3.24	1924	450	3.14	1925	1,221	3.04
1923	3,000	3.22	1924	800	4.72	1926	645	4.06
1923	1,500	3.60	1924	300	3.34	1926	1,000	3.38
1923	450	3.00	1924	1,000	3.06	1926	25	4.00
1923	855	2.54	1925	690	4.28	1926	100	3.02
1923	800	3.66	1925	2,500	4.46	1926	398	2.54
1923	300	3.06	1925	2,400	4.06	1926	280	2.76
1924	650	3.88	1925	400	2.88	1926	1,575	3.34
1924	500	4.52	1925	3,900	3.92	1926	380	2.52
1924	500	4.12	1925	1,828	3.12			

[1] Information furnished by M. J. Gowd, chief engineer and general superintendent, Imperial irrigation district, Imperial, Calif.

TABLE 9.—*Number of irrigations, dates of first and last application, irrigation water applied, rainfall, total water received, and crop yields in Salt River Valley, Ariz.*[1]

WHEAT HAY

Year	Irrigations	Date of first and last application		Total quantity of water received by crop per acre			Yield per acre	Literature cited
		First	Last	Irrigation	Rainfall	Total		
	Number			*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*	
1900	4	Nov. 11	Mar. 10	2.1	0.12	[2] 2.22	3.4	(4)
1900	4	Nov. 10	...do....	2.1	.12	[2] 2.22	3.5	(4)

WHEAT

							Bushels	
1900	4	Nov. 5	Apr. 14	2.2	0.16	[2] 2.36	40.0	(4)
1901	3	Mar. 4	Apr. 6	2.2	.17	[2] 2.37	35.0	(5)
1901	4	Dec. 8	...do....	2.5	.17	2.67	30.9	(5)
1901	3	Mar. 5	Apr. 11	2.1	.17	[2] 2.27	35.4	(5)
1901	3	Mar. 7	Apr. 14	2.1	.17	[2] 2.27	32.0	(5)

[1] Experiments conducted at Phoenix, Ariz., by the Arizona Agricultural Experiment Station. Soils are clayey, gravelly loam underlaid with gravel. Loam is 5 to 6 feet deep.
[2] Includes 0.6 acre-foot before planting.

TABLE 9.—*Number of irrigations, dates of first and last application, irrigation water applied, rainfall, total water received, and crop yields in Salt River Valley, Ariz.*—Continued

Year	Irrigations	Date of first and last application		Total quantity of water received by crop per acre			Yield per acre	Literature cited
		First	Last	Irrigation	Rainfall	Total		
POTATOES								
	Number			*Acre-feet*	*Acre-feet*	*Acre-feet*	*Bushels*	
1900	4	Feb. 17	May 2	2.0	0.11	[2] 2.11	66.7	(*4*)
1900	4	do	do	2.0	.11	[2] 2.11	53.3	(*4*)
1901	4	Mar. 17	May 10	2.4	.17	[3] 2.57	58.4	(*5*)
1901	3	Mar. 27	do	2.0	.17	[3] 2.17	60.0	(*5*)
1901	3	do	do	2.0	.17	[3] 2.17	50.0	(*5*)
COTTON								
							Pounds	
1901	13	Apr. 11	Oct. 3	5.0	0.30	[3] 5.30	400	(*5*)
CORN								
							Bushels	
1901	5	Aug. 9	Oct. 7	2.1	0.20	[2] 2.30	31.0	(*5*)
MELONS								
							Tons	
1900	13	Mar. 29	July 15	3.2	0.20	[2] 3.40	15.0	(*4*)
1901	12	Mar. 26	July 8	3.3	.03	3.33	13.5	(*5*)
STRAWBERRIES								
							Pounds	
1901	36	Feb. 16	Dec. 26	6.2	0.31	[3] 6.51	5,000	(*5*)
TOMATOES								
1901	27	Feb. 26	Oct. 28	4.3	0.25	[2] 4.55	12,300	(*5*)
BARLEY HAY								
							Tons	
1900	3	Nov. 10	Mar. 18	1.6	0.12	[2] 1.72	4.2	(*4*)
CABBAGE								
1900	16	Sept. 15	Feb. 25	5.0	0.20	[2] 5.20	7.0	(*4*)
1900	16	Nov. 22	May 9	5.0	.28	[2] 5.28	6.2	(*4*)
COWPEA HAY								
1900	9	June 9	Sept. 9	3.8	0.11	[2] 3.91	3.6	(*4*)
SUGAR BEETS								
1900	5	Apr. 1	June 26	2.5	0.22	[2] 2.72	14.5	(*4*)
1900	5	Apr. 3	July 15	2.5	.22	[2] 2.72	10.5	(*4*)
ONIONS								
1900	20	Sept. 16	July 11	6.2	0.30	[2] 6.50	2.6	(*4*)
GREEN PEAS								
1900	6	Dec. 10	Mar. 22	2.4	0.08	[2] 2.48	2.2	(*4*)

[2] Includes 0.6 acre-foot before planting. [3] Includes 0.7 acre-foot before planting.

Table 10.—*Number of irrigations, quantity of water received by irrigation and by rainfall, and crop yields in Salt River Valley, Ariz.*

ALFALFA (*16*)

Year	Area irrigated	Irrigations	Total quantity of water received by crop per acre: Irrigation	Total quantity of water received by crop per acre: Rainfall	Total quantity of water received by crop per acre: Total	Yield per acre
	Acres	*Number*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1913, 1914, 1915	25.0		2.34	[2] 0.86	3.20	4.00
1913, 1914, 1915	35.0		4.06	.86	4.92	[3] 6.00
1913, 1914, 1915	28.0		5.68	.86	6.54	[4] 8.00
1913, 1914, 1915	20.0		2.34	.86	3.20	[5] 4.80
1913, 1914, 1915	60.0		3.10	.86	3.96	[6] 8.00
1913, 1914, 1915	40.0		4.38	.86	5.24	[7] 6.00
1913, 1914, 1915	20.0		3.08	.86	3.94	[7] 5.00
1913, 1914, 1915	48.0		2.44	.86	3.30	[7] 4.20
1913, 1914, 1915	40.0		1.77	.86	2.63	[7] 3.00
1913, 1914, 1915	30.1		3.77	.86	4.63	[7] 6.50
1913, 1914, 1915	24.0		4.07	.86	4.93	[7] 6.50
1913, 1914, 1915	24.0		2.85	.86	3.71	[7] 5.00
1913, 1914, 1915	70.0		5.10	.86	5.96	[7] 7.50
1913, 1914, 1915	70.0		3.13	.86	3.99	[7] 5.50
1913, 1914, 1915	70.0		5.60	.86	6.46	[7] 4.30
1913, 1914, 1915	30.7		3.46	.86	4.32	[7] 2.30
1913, 1914, 1915	30.7		2.50	.86	3.36	[7] 5.00
1913, 1914, 1915	48.0		3.03	.86	3.89	[7] 4.80
1913, 1914, 1915	48.0		1.51	.86	2.37	[7] 2.80
1913, 1914, 1915	48.0		1.46	.86	2.32	[7] .80
1913, 1914, 1915	37.68		2.62	.86	3.48	[7] 4.50
1913, 1914, 1915	6.0		4.32	.86	5.18	[7] 4.40
1913, 1914, 1915	34.85		4.16	.86	5.02	[7] 3.73
1913, 1914, 1915	37.68		4.84	.86	5.70	[7] 7.00
1913, 1914, 1915	18.53		4.39	.86	5.25	[7] 7.39
1913, 1914, 1915	18.53		5.61	.86	6.47	[7] 7.60
1913, 1914, 1915	44.0		4.31	.86	5.17	[7] 6.99
1913, 1914, 1915	46.0		5.36	.86	6.22	[7] 7.39
1913, 1914, 1915	100.96		3.22	.86	4.08	[7] 5.35
1913, 1914, 1915	100.96		1.08	.86	1.94	[7] 3.68
1913, 1914, 1915	75.00		4.47	.86	5.33	[7] 6.25
1913, 1914, 1915	51.41		4.71	.86	5.57	[7] 4.97
1913, 1914, 1915	118.53		3.00	.86	3.86	[7] 5.00
1913, 1914, 1915	10.22		4.71	.86	5.57	[7] 6.36
1913, 1914, 1915	154.02		1.72	.86	2.58	[7] 2.24
1913, 1914, 1915	154.02		3.26	.86	4.12	[7] 5.57
1913, 1914, 1915	147.86		5.80	.86	6.66	[7] 7.85
1913, 1914, 1915	42.33		1.82	.86	2.68	[7] 3.00
1913, 1914, 1915	42.33		2.02	.86	2.88	[7] 4.00
1913, 1914, 1915	42.33		3.10	.86	3.96	[7] 5.30
1913, 1914, 1915	19.4		3.55	.86	4.41	[7] 5.70
1913, 1914, 1915	18.0		1.87	.86	2.73	[7] 3.50

LINT COTTON

Year	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre
						Pounds
1913, 1914, 1915	27.0		1.83	[8] 0.28	2.11	[7] 250
1913, 1914, 1915	70.25		1.87	.28	2.15	[7] 371
1913, 1914, 1915	88.80		2.51	.28	2.79	[7] 449
1913, 1914, 1915	105.25		1.41	.28	1.69	[7] 156
1913, 1914, 1915	39.0		1.27	.28	1.55	[7] 86
1913, 1914, 1915	12.76		2.05	.28	2.33	[7] 438
1913, 1914, 1915	1.00	12	2.29	.28	2.57	[7] 375
1913, 1914, 1915	70.25		1.50	.28	1.78	[7] 275
1913, 1914, 1915	40.00		1.50	.28	1.78	[7] 235
1913, 1914, 1915	34.88		1.22	.28	1.50	[7] 175
1913, 1914, 1915	17.00		1.25	.28	1.53	[7] 218
1913, 1914, 1915	55.00		1.84	.28	2.12	[7] 177
1913, 1914, 1915	55.00		3.50	.28	3.78	[7] 400
1913, 1914, 1915	55.00		3.50	.28	3.78	[7] 650

Footnotes on page 42.

TABLE 10.—*Number of irrigations, quantity of water received by irrigation and by rainfall, and crop yields in Salt River Valley, Ariz.*—Continued

SUGARCANE (*16*)

Year	Area irrigated	Irrigations	Total quantity of water received by crop per acre			Yield per acre
			Irrigation	Rainfall	Total	
	Acres	*Number*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1915	Plot.	3	2.68	0.83	3.51	3.87
1915	Plot.	3	1.97	.83	2.80	1.02
1915	Plot.	3	1.85	.83	2.68	.42
1916	Plot.	6	2.81	.78	3.59	5.47
1916	Plot.	6	3.04	.78	3.82	7.81
1916	Plot.	6	3.32	.78	4.10	7.39
1916	Plot.	6	4.19	.78	4.97	16.95
1916	Plot.	6	4.23	.78	5.01	20.53
1916	Plot.	6	4.33	.78	5.11	25.41

WHEAT (*16*)

Year	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre
						Bushels
1915	30	3	1.08	[9] 0.78	1.86	[10] 17
1915	20	3	1.67	.78	2.45	[10] 29
1915	12	4	2.19	.78	2.97	[11] 28
1915	45	3	2.28	.78	3.06	[11] 33
1915	20	2	1.42	.78	2.20	[11] 30
1915	14	3	1.00	.78	1.84	[11] 28
1915	62	3	1.67	.78	2.45	[11] 33
1915	45	4	1.60	.78	2.38	[10] 23
1915	75	3	1.10	.78	1.88	[10] 26
1915	40	4	1.40	.78	2.18	[11] 23
1915	100	4	1.51	.78	2.29	[11] 26
1915	40	3	1.61	.78	2.39	[10] 33
1915	13	4	2.27	.78	3.05	[10] 31
1915	26	[13] 1½	1.10	.78	1.88	[10] 21
1915	36	3	1.61	.78	2.39	[11] 33

MILO (*16*)

Year	Area irrigated	Irrigations	Irrigation	Rainfall	Total	Yield per acre
						Tons
1915	20	4	1.65	[14] 0.17	1.82	[11] 1.5
1915	50	3	1.13	.17	1.30	[11] 1.0
1915	8	5	1.57	.17	1.74	[10] 1.0
1915	7	3	.81	.17	.98	[10] .28
1915	15	4	1.00	.17	1.17	[11] .75
1915	40	4	.75	.17	.92	[10] 1.25
1915	8	3	.95	.17	1.12	[10] 1.00
1915	20	4	1.51	.17	1.68	[10] .75
1915	10	3	2.26	.17	2.43	[12] .75
1915	43	7	2.29	.17	2.46	[10] .75
1915	8	3	1.67	.17	1.84	[10] 1.12
1915	15	6	2.10	.17	2.27	[10] .75
1915	6	3	.70	.17	.87	[10] 1.25
1915	7	1	.23	.17	.40	[10] .75
1915	20	3	1.13	.17	1.30	[10] 1.00
1915	20	10	2.29	.17	2.46	[10] .75
1915	40	3	1.13	.17	1.30	[10] 1.12
1915	60	4	2.20	.17	2.37	[10] 1.00
1915	17	4	1.97	.17	2.14	[10] 1.00
1915	1	2	.35	.17	.52	[10] .67
1915	18	3	.99	.17	1.16	[10] .50

[1] Data gathered under cooperative agreement between Division of Agricultural Engineering and State of Arizona.
[2] Rainfall is average for entire years of 1913, 1914, and 1915.
[3] Maricopa gravelly loam.
[4] Glendale loess.
[5] Maricopa clay loam.
[6] Salt River adobe.
[7] Maricopa sandy loam.
[8] Mean of 1913, 1914, and 1915, April to October, inclusive.
[9] December to May, inclusive.
[10] Sandy loam.
[11] Clay loam.
[12] Loam.
[13] Partly irrigated a second time.
[14] March to July, inclusive.

TABLE 11.—*Use of water on alfalfa (16), irrigation water applied monthly, rainfall, total water received, and yields in Salt River Valley, Ariz.*[1]

Year	Irrigations	Monthly application of water in acre-feet per acre						Total quantity of water in acre-feet received by crop per acre.			Yield per acre
		April	May	June	July	August	September and October	Irrigation	Rainfall	Total	
	Number										*Tons*
1916	5	0.42	0.31	0.31	0.21	--------	0.71	1.96	[2] 0.78	2.74	[3] 2.92
1916	5	.43	.40	.40	.27	--------	.86	2.36	.78	3.14	[3] 3.15
1916	5	.43	.46	.47	.31	--------	.96	2.63	.78	3.41	[3] 3.60
1916	5	.43	.60	.59	.40	--------	1.19	3.21	.78	3.99	[3] 4.84
1916	5	.42	.80	.80	.54	--------	1.51	4.07	.78	4.85	[3] 6.24
1916	5	.52	1.10	1.10	.73	--------	2.00	5.45	.78	6.23	[3] 7.70
1916	5	.46	1.37	1.46	.98	--------	2.64	6.91	.78	7.69	[3] 8.88

[1] Data gathered under cooperative agreement between Division of Agricultural Engineering and State of Arizona.
[2] Rainfall for entire year.
[3] Average from 3 plots.

TABLE 12.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*[1]

ALFALFA

Year	Area irrigated	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
			January	February	March	April	May	June	July	August	September	October	Irrigation	Rainfall	Total	
	Acres	*Number*														*Tons*
1905	Plot.	9	----	----	----	0.20	0.58	0.58	0.88	0.20	----	----	2.62	0.82	3.44	[2] 4.55
1905	Plot.	9	----	----	----	.38	.75	.75	1.12	.38	----	----	3.38	.82	4.20	[2] 4.36
1905	3.4	12	----	----	0.42	.36	.95	1.12	.89	.92	0.46	----	5.12	.82	5.94	4.37
1913	24.4	7	----	----	.50	.50	.73	1.00	----	----	----	0.35	3.08	.64	3.72	1.62
1913	29.95	7	----	----	.55	.47	.78	.87	.37	----	----	----	3.04	.64	3.68	3.05
1913	14.5	6	----	----	.47	.63	.30	.16	.21	----	----	----	1.77	.67	2.44	5.10
1913	6.37	4	----	----	.47	.42	.40	.71	----	----	----	----	2.00	.67	2.67	4.28
1914	24.4	11	----	0.28	.29	.26	.81	.58	.31	.36	.39	.43	3.71	.98	4.69	3.59
1914	6.37	7	0.83	----	.45	.30	.34	.43	.45	.38	----	----	3.18	.50	3.68	4.75
1914	14.5	9	.47	----	.34	.33	.30	.26	----	.62	----	.36	2.68	.51	3.19	4.26
1923	.565	13	----	----	.38	1.01	1.08	1.04	.47	.79	.74	.38	5.89	[3] .50	6.39	6.42
1923	.580	13	----	----	.44	.79	.89	.84	.42	.68	.67	.38	5.11	.50	5.61	6.11
1923	.581	13	----	----	.39	.84	.97	.79	.35	.64	.58	.32	4.88	.50	5.38	5.66
1923	.596	13	----	----	.31	.68	.69	.71	.31	.55	.46	.26	3.97	.50	4.47	5.54
1923	.499	13	----	----	.43	.93	1.02	.96	.42	.85	.73	.38	5.72	.50	6.22	6.42
1923	.494	13	----	----	.37	.92	.92	.92	.40	.72	.70	.38	5.33	.50	5.83	6.01
1923	.503	13	----	----	.40	.86	.84	.86	.41	.72	.66	.35	5.10	.50	5.60	5.99
1923	.513	13	----	----	.33	.77	.80	.79	.36	.65	.44	.29	4.43	.50	4.93	6.08
1923	.336	13	----	----	.43	.92	.97	.99	.43	.70	.69	.33	5.46	.50	5.96	8.08
1923	.338	13	----	----	.38	.82	.78	.92	.34	.60	.59	.27	4.70	.50	5.20	8.83
1923	.332	13	----	----	.33	.76	.84	.68	.32	.56	.52	.26	4.27	.50	4.77	8.21
1923	.353	13	----	----	.25	.60	.73	.62	.23	.54	.36	.17	3.50	.50	4.00	8.13
1923	.170	13	----	----	.29	.74	.81	.61	.32	.42	.46	.36	4.01	.50	4.51	5.66
1923	.174	13	----	----	.36	1.07	.66	.83	.36	.54	.57	.24	4.63	.50	5.13	6.19
1923	.168	13	----	----	.39	.74	.80	.64	.36	.49	.48	.20	4.10	.50	4.60	5.92
1923	.177	13	----	----	.32	.64	.71	.58	.30	.45	.41	.18	3.59	.50	4.09	6.44

CORN

Year	Area irrigated	Irrigations	January	February	March	April	May	June	July	August	September	October	Irrigation	Rainfall	Total	Yield per acre
																Bushels
1913	10.10	3	----	----	----	----	0.68	0.82	0.35	----	----	----	1.85	0.51	2.36	35.4
1915	.55	6	----	----	----	----	.56	.51	.35	0.67	----	----	2.09	.22	2.31	44
1915	.40	6	----	----	----	----	.33	.55	.35	.65	----	----	1.88	.22	2.10	35
1915	.42	6	----	----	----	----	.40	.57	.33	.73	----	----	2.03	.22	2.25	37

1915	.38	6					.38	.58	.32	.82			2.10	.22	2.32	27
1915	.40	6					.29	.47	.32	.91			1.89	.22	2.11	62
1915	.37	6					.19	.57	.30	.82			1.94	.22	2.16	66
1915	.39	6					.36	.52	.34	.71			1.93	.22	2.15	37
1915	.36	6					.30	.58	.37	.94			2.19	.22	2.41	31
1915	.40	6					.35	.39	.30	.70			1.74	.22	1.96	39
1915	.32	5					.32	.15	.16	.54			1.17	.22	1.39	23
1915	.29	5					.37	.20	.21	.69			1.47	.22	1.69	39
1915	.29	5					.37	.42	.18	.81			1.78	.22	2.00	39
SORGHUM																
																Tons
1915	0.63	6					0.32	0.62	0.36	0.69			1.99	0.22	2.21	4.76
1915	.47	6					.59	.79	.52	.77			2.67	.22	2.89	6.42
1915	.43	6					.49	.84	.52	.92			2.77	.22	2.99	9.93
1915	.49	6					.40	.69	.41	.60			2.10	.22	2.32	5.59
1915	.45	6					.42	.68	.41	.88			2.39	.22	2.61	4.77
1915	.46	6					.38	.68	.47	.93			2.46	.22	2.68	7.83
1915	.43	5					.42	.58	.40	.37			1.77	.22	1.99	5.19
1915	.46	6					.42	.57	.46	.86			2.31	.22	2.53	8.67
1915	.33	6					.51	.72	.49	1.01			2.73	.22	2.95	14.34
1915	.38	6					.64	.58	.31	.83			2.36	.22	2.58	3.72
1915	.33	6					.50	.56	.48	.87			2.41	.22	2.63	6.62
SUDAN GRASS [4]																
1915	0.24	8					0.48	0.84	0.25	0.50	0.25		2.32	0.44	2.76	3.05
1915	.26	8					.44	.79	.25	.67	.33		2.48	.44	2.92	3.92
1915	.24	8					.45	.86	.25	.67	.33		2.56	.44	3.00	4.67
1915	.27	8					.45	.80	.25	.67	.33		2.50	.44	2.94	3.29
1915	.27	8					.42	.83	.25	.67	.33		2.50	.44	2.94	4.41
1915	.30	8					.38	.73	.25	.66	.33		2.35	.44	2.79	3.28
1915	.26	8					.53	.92	.33	.67	.34		2.79	.44	3.23	4.75
1915	.32	8					.48	.95	.33	.67	.25		2.68	.44	3.12	3.47
1915	.25	8					1.00	1.00	.33	.67	.25		3.25	.44	3.69	4.85
1915	.32	8					.40	.98	.33	.67	.25		2.63	.44	3.07	4.05
1915	.31	8					.41	.92	.33	.67	.33		2.66	.44	3.10	3.19
1915	.35	8					.32	.97	.33	.73	.33		2.68	.44	3.12	2.84
1915	.39	8					.29	.98	.33	.67	.33		2.60	.44	3.04	2.51
1915	.38	7					.19	.98	.33	.42	.25		2.17	.44	2.61	2.55
1915	.29	7					.60	.95	.33	.42	.33		2.63	.44	3.07	2.53
1915	.24	7					.70	1.00	.33	.42	.33		2.78	.44	3.22	2.85

[1] These experiments conducted cooperatively by the Division of Agricultural Engineering, Bureau of Public Roads, and the New Mexico Agricultural Experiment Station.
[2] Average of 8 experiments.
[3] Mar. 1 to Oct. 1.
[4] Results not as accurate as desired, as plots were flooded with storm water which could only be estimated.

TABLE 12.—*Irrigation water applied, monthly rainfall, total water received, and crop yields in Mesilla Valley, N. Mex*—Continued

SUDAN GRASS—Continued

Year	Area irrigated	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
			January	February	March	April	May	June	July	August	September	October	Irrigation	Rainfall	Total	
	Acres	*Number*														*Tons*
1915	0.27	7					0.64	0.95	0.33	0.42	0.33		2.67	0.44	3.11	3.09
1915	.26	7					.58	.85	.33	.42	.33		2.51	.44	2.95	2.63
1915	.30	7					.70	.86	.33	.42	.33		2.64	.44	3.08	3.08
1915	.27	7					.55	1.04	.33	.42	.33		2.67	.44	3.11	2.39
1915	.29	7					.52	1.08	.33	.42	.33		2.68	.44	3.12	3.13
1915	.26	7					.70	1.00	.33	.42	.33		2.78	.44	3.22	2.28
1915	.29	7					.52	1.02	.33	.42	.33		2.62	.44	3.06	3.82
1915	.26	7					.46	1.00	.33	.33	.34		2.46	.44	2.90	4.23
1915	.29	7					.52	1.06	.33	.33	.34		2.58	.44	3.02	4.08
1915	.28	7					.39	1.07	.33	.33	.25		2.37	.44	2.81	4.16
TOMATOES																
																Pounds
1905	1.1	11				0.18	0.25	0.28	0.28	0.53	0.25		1.77	0.59	2.36	6,591
1905	1.66	10				.15	.53	.29	.37	.20	.23		1.77	.59	2.36	2,314
ONIONS																
																Tons
1904–5	2.51	9				0.47	0.68	0.55	0.38				[1] 2.08	0.15	2.23	11.74
1913	.672	9					.36	.26	1.03	0.54			2.19	.44	2.63	12.10
BARLEY																
																Bushels
1914	3.27	6		0.49	0.36	0.47	0.78	0.46					2.56	0.17	2.73	30

OATS

1914	0.42	6	----------	0.49	0.36	0.47	0.78	0.46	----------	----------	----------	----------	2.56	0.17	2.73	37

SEED COTTON [6]

																Pounds
1926	Plot.	6	----------	----------	----------	0.50	0.44	0.35	0.73	0.61	0.46	----------	3.00	0.47	3.56	[7] 1,352
1926	Plot.	6	----------	----------	----------	.53	.37	.35	.47	.57	.45	----------	2.74	.47	3.21	[7] 1,013
1926	Plot.	6	----------	----------	----------	.36	.56	.44	.57	.51	.34	----------	2.78	.47	3.25	[7] 1,739
1926	Plot.	6	----------	----------	----------	.47	.24	.37	.43	.42	.30	----------	2.23	.47	2.70	[7] 1,780
1926	Plot.	11	----------	----------	----------	.40	.35	1.07	.67	.79	.72	----------	4.00	.47	4.47	[7] 2,113
1926	Plot.	11	----------	----------	----------	.33	.18	.98	.65	.67	.60	----------	3.41	.47	3.88	[7] 1,995
1926	Plot.	5	----------	----------	----------	----------	.49	.35	.43	.39	.34	----------	2.00	.47	2.47	[7] 1,479
1926	Plot.	5	----------	----------	----------	----------	.49	.35	.33	.34	.30	----------	1.81	.47	2.28	[7] 1,167
1926	Plot.	6	----------	----------	----------	.50	.27	.33	.33	.34	.33	----------	2.10	.47	2.57	[7] 1,118
1926	Plot.	6	----------	----------	----------	.50	.28	.35	.33	.37	.33	----------	2.16	.47	2.63	[7] 1,253
1926	Plot.	6	----------	----------	----------	.51	.32	.38	.44	.41	.37	----------	2.43	.47	2.90	[7] 1,527
1926	Plot.	6	----------	----------	----------	.48	.29	.26	.38	.45	.32	----------	2.18	.47	2.65	[7] 1,871
1926	Plot.	11	----------	----------	----------	.33	.31	.95	.63	.67	.63	----------	3.52	.47	3.99	[7] 1,352
1926	Plot.	11	----------	----------	----------	.33	.26	.98	.65	.67	.55	----------	3.44	.47	3.91	[7] 1,231
1926	Plot.	5	----------	----------	----------	----------	.50	.43	.43	.51	.33	----------	2.20	.47	2.67	[7] 1,526
1926	Plot.	5	----------	----------	----------	----------	.49	.39	.45	.50	.43	----------	2.26	.47	2.73	[7] 1,844
1926	Plot.	5	----------	----------	----------	.26	.22	.25	.17	----------	.36	----------	1.26	.47	1.73	[7] 1,000
1926	Plot.	5	----------	----------	----------	.41	.27	.32	.36	----------	.42	----------	1.78	.47	2.25	[7] 1,485
1926	Plot.	5	----------	----------	----------	.26	26	.32	.51	.20	----------	----------	1.64	.47	2.11	[7] 1,500

WHEAT

																Bushels
1914	8.46	----------	0.49	0.36	0.47	0.78	0.46	----------	----------	----------	----------	----------	2.56	0.17	2.73	23

[5] An additional amount equivalent to 0.19 acre-foot used on seed bed Oct. 20, 1904, to Jan. 5, 1905.
[6] Adobe soil overlying coarse sand.
[7] Does not include bollies which varies from 52 to 187 pounds of lint cotton per acre.

TABLE 13.—*Use of water on alfalfa, irrigation water applied per cutting, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*[1]

Year	Area irrigated	Irrigations	Acre-feet of irrigation water applied per cutting					Total quantity of water in acre-feet received by crop per acre			Yield per acre
			First cutting	Second cutting	Third cutting	Fourth cutting	Fifth cutting	Irrigation	Rainfall	Total	
		Number									*Tons*
1915	Plot.	13	1.33	0.92	1.00	0.33	0.67	4.25	0.48	4.73	8.46
1915	Plot.	14	.75	.58	.50	.33	.34	2.50	.48	2.98	7.05
1915	Plot.	9	.67	.67	.83	.83	.42	3.42	.48	3.90	5.88
1915	Plot.	14	1.00	.75	.75	.67	.50	3.67	.48	4.15	6.12
1915	Plot.	12	.75	.75	.75	.25	.50	3.00	.48	3.48	5.15
1915	Plot.	10	1.08	1.08	.83	.25	.42	3.66	.48	4.14	6.60
1915	Plot.	11	.92	.58	1.00	.33	.67	3.50	.48	3.98	6.35
1915	Plot.	13	1.00	.75	.75	.25	.50	3.25	.48	3.73	6.80
1915	Plot.	14	.75	.58	.50	.33	.34	2.50	.48	2.98	5.81
1915	Plot.	12	1.50	.67	1.25	.42	.83	4.67	.48	5.15	7.37
1915	Plot.	12	1.25	.58	.67	.67	.67	3.84	.48	4.32	6.06
1915	Plot.	14	1.00	.75	.75	.25	.75	3.50	.48	3.98	6.30
1915	Plot.	13	.75	.58	.50	.33	.34	2.50	.48	2.98	4.41
1915	Plot.	13	1.50	1.08	1.25	.42	.83	5.08	.48	5.56	6.97
1915	Plot.	12	1.00	.75	.50	.25	.50	3.00	.48	3.48	5.62
1915	Plot.	12	.75	.75	.75	.25	.50	3.00	.48	3.48	5.66
1915	Plot.	10	.92	.92	.67	.33	.33	3.17	.48	3.65	6.50
1915	Plot.	10	1.08	1.08	.83	.42	.42	3.83	.48	4.31	7.42
1915	Plot.	11	.92	.92	.67	.33	.66	3.50	.48	3.98	7.01
1915	Plot.	11	.92	.58	.67	.67	.66	3.50	.48	3.98	5.85
1915	Plot.	13	.83	.75	.75	.50	.50	3.33	.48	3.81	5.51
1915	Plot.	12	.67	.58	.33	.33	.34	2.25	.48	2.73	4.51
1915	Plot.	14	1.00	.75	.75	.50	.50	3.50	.48	3.98	7.10
1915	Plot.	11	.92	.58	.67	.33	.33	2.83	.48	3.31	6.15
1915	Plot.	13	1.50	1.08	1.25	.42	.83	5.08	.48	5.56	7.36
1915	Plot.	11	.58	.42	.50	.17	.33	2.00	.48	2.48	6.78
1915	Plot.	11	.50	.67	.75	25	.50	2.67	.48	3.15	5.69
1915	Plot.	11	.92	.92	.67	.33	.66	3.50	.48	3.98	7.60
1915	Plot.	14	1.00	.75	.75	.50	.50	3.50	.48	3.98	7.46
1915	Plot.	16	.75	.58	.50	.50	.50	2.83	.48	3.31	5.80
1915	Plot.	10	1.08	1.08	.67	.42	.42	3.67	.48	4.15	8.74
1915	Plot.	15	.75	.58	.50	.50	.33	2.66	.48	3.14	6.65
1915	Plot.	10	.92	.58	.33	.67	.67	3.17	.48	3.05	7.35
1915	Plot.	12	1.00	.50	.50	.50	.50	3.00	.48	3.48	6.79
1915	Plot.	12	.75	.75	.50	.50	.50	3.00	.48	3.48	6.06
1915	Plot.	12	1.25	.92	.67	.33	.66	3.83	.48	4.31	6.63
1915	Plot.	9	.67	1.08	.83	.42	.42	3.42	.48	3.90	5.97
1915	Plot.	14	.75	.58	.50	.33	34	2.50	.48	2.98	4.65
1915	Plot.	13	.92	.92	1.00	.67	.66	4.17	.48	4.65	6.86
1915	Plot.	11	1.00	.92	.67	.33	.67	3.59	.48	4.07	6.35

[1] These experiments conducted cooperatively by the Division of Agricultural Engineering, Bureau of Public Roads, and the New Mexico Agricultural Experiment Station. Experiments were conducted at the experiment station on mesa lands in 1915. Soil: Sandy loam, open, friable, and easily tilled, quite uniform to a depth of 6 feet except where pockets of gravel and coarse sand appear.

TABLE 14.—*Use of water on alfalfa (20), water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*[1]

Year	Area irrigated	Irrigations	Depth applied each irrigation	Total quantity of water received by crop per acre			Yield per acre[3]
				Irrigation	Rainfall[2]	Total	
		Number	*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1916	Plot.	14	4	4.67	0.56	5.23	7.84
1916	Plot.	18	2	3.00	.56	3.56	6.29
1916	Plot.	9	5	3.75	.56	4.31	6.70
1916	Plot.	14	3	3.50	.56	4.06	5.52
1916	Plot.	13	3	3.25	.56	3.81	4.50
1916	Plot.	12	5	5.00	.56	5.56	6.70
1916	Plot.	12	4	4.00	.56	4.56	5.94

[1] These experiments conducted cooperatively by the Division of Agricultural Engineering, Bureau of Public Roads, and the New Mexico Agricultural Experiment Station. Experiments were conducted at the experiment station on mesa lands from 1915 to 1919, inclusive. Soil: Sandy loam, open, friable, and easily tilled, quite uniform to a depth of 6 feet except where pockets of gravel and coarse sand appear.

[2] Precipitation not published with other data, but assumed to be from Mar. 1 to Nov. 1, 1916, 1917, and 1919.

[3] During 1916, 6 cuttings were secured and 5 cuttings in each of the years 1917, 1918, and 1919.

TABLE 14.—*Use of water on alfalfa (20), water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*—Continued

Year	Area irrigated	Irrigations	Depth applied each irrigation	Total quantity of water received by crop per acre			Yield per acre
				Irrigation	Rainfall	Total	
		Number	*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1916	Plot.	17	3	4.25	0.56	4.81	7.00
1916	Plot.	18	2	3.00	.56	3.56	5.45
1916	Plot.	11	5	4.58	.56	5.14	6.15
1916	Plot.	12	4	4.00	.56	4.56	6.02
1916	Plot.	16	3	4.00	.56	4.56	5.98
1916	Plot.	17	2	2.83	.56	3.39	4.12
1916	Plot.	12	5	5.00	.56	5.56	7.27
1916	Plot.	14	3	3.50	.56	4.06	4.83
1916	Plot.	15	3	3.75	.56	4.31	5.90
1916	Plot.	12	4	4.00	.56	4.56	6.02
1916	Plot.	9	5	3.75	.56	4.31	5.49
1916	Plot.	12	4	4.00	.56	4.56	6.52
1916	Plot.	10	4	3.33	.56	3.89	5.62
1916	Plot.	16	3	4.00	.56	4.56	6.10
1916	Plot.	18	2	3.00	.56	3.56	5.98
1916	Plot.	15	3	3.75	.56	4.31	6.34
1916	Plot.	12	4	4.00	.56	4.56	6.36
1916	Plot.	13	5	5.42	.56	5.98	7.45
1916	Plot.	16	2	2.67	.56	3.23	4.55
1916	Plot.	13	3	3.25	.56	3.81	4.16
1916	Plot.	12	4	4.00	.56	4.56	5.78
1916	Plot.	17	3	4.25	.56	4.81	6.32
1916	Plot.	21	2	3.50	.56	4.06	5.65
1916	Plot.	12	5	5.00	.56	5.56	7.03
1916	Plot.	19	2	3.17	.56	3.73	5.66
1916	Plot.	14	4	4.67	.56	5.23	5.53
1916	Plot.	16	3	4.00	.56	4.56	5.56
1916	Plot.	15	3	3.75	.56	4.31	5.29
1916	Plot.	13	4	4.33	.56	4.89	6.41
1916	Plot.	10	5	4.17	.56	4.73	6.08
1916	Plot.	18	2	3.00	.56	3.56	4.18
1916	Plot.	19	4	6.33	.56	6.89	7.01
1916	Plot.	12	5	5.00	.56	5.56	7.20
1917	Plot.	14	4	4.67	.44	5.11	7.36
1917	Plot.	18	2	3.00	.44	3.44	5.51
1917	Plot.	10	5	4.17	.44	4.61	6.53
1917	Plot.	13	3	3.25	.44	3.69	5.68
1917	Plot.	14	3	3.50	.44	3.94	5.65
1917	Plot.	12	5	5.00	.44	5.44	6.82
1917	Plot.	11	4	3.67	.44	4.11	6.08
1917	Plot.	16	3	4.00	.44	4.44	7.00
1917	Plot.	17	2	2.83	.44	3.27	5.43
1917	Plot.	12	5	5.00	.44	5.44	6.04
1917	Plot.	12	4	4.00	.44	4.44	6.23
1917	Plot.	14	3	3.50	.44	3.94	5.71
1917	Plot.	16	2	2.67	.44	3.11	4.32
1917	Plot.	12	5	5.00	.44	5.44	7.30
1917	Plot.	14	3	3.50	.44	3.94	4.96
1917	Plot.	13	3	3.25	.44	3.69	5.52
1917	Plot.	10	4	3.33	.44	3.77	5.68
1917	Plot.	9	5	3.75	.44	4.19	6.09
1917	Plot.	11	4	3.67	.44	4.11	6.07
1917	Plot.	10	4	3.33	.44	3.77	4.05
1917	Plot.	15	3	3.75	.44	4.19	6.13
1917	Plot.	18	2	3.00	.44	3.44	5.55
1917	Plot.	15	3	3.75	.44	4.19	6.29
1917	Plot.	11	4	3.67	.44	4.11	5.91
1917	Plot.	13	5	5.42	.44	5.86	7.53
1917	Plot.	14	2	2.33	.44	2.77	4.10
1917	Plot.	16	3	3.75	.44	4.19	5.23
1917	Plot.	13	4	4.33	.44	4.77	7.35
1917	Plot.	14	3	3.50	.44	3.94	5.52
1917	Plot.	19	2	3.17	.44	3.61	5.26
1917	Plot.	11	5	4.58	.44	5.02	6.62
1917	Plot.	17	2	2.83	.44	3.27	5.60
1917	Plot.	12	4	4.00	.44	4.44	5.33
1917	Plot.	13	3	3.25	.44	3.69	5.08
1917	Plot.	12	3	3.00	.44	3.44	4.53
1917	Plot.	11	4	3.67	.44	4.11	5.32
1917	Plot.	9	5	3.75	.44	4.19	4.35
1917	Plot.	16	2	2.67	.44	3.11	3.37
1917	Plot.	14	4	4.67	.44	5.11	6.77
1917	Plot.	10	5	4.17	.44	4.61	6.47
1918	Plot.	15	4	5.00	.29	5.29	8.64
1918	Plot.	18	2	3.00	.29	3.29	6.16
1918	Plot.	8	5	3.33	.29	3.62	6.11
1918	Plot.	13	3	3.25	.29	3.54	5.17

TABLE 14.—*Use of water on alfalfa (20), water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*—Continued

Year	Area irrigated	Irrigations	Depth applied each irrigation	Total quantity of water received by crop per acre			Yield per acre
				Irrigation	Rainfall	Total	
		Number	*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*
1918	Plot.	14	3	3.50	0.29	3.79	5.57
1918	Plot.	11	5	4.58	.29	4.87	7.58
1918	Plot.	12	4	4.00	.29	4.29	7.27
1918	Plot.	17	3	4.25	.29	4.54	7.64
1918	Plot.	19	2	3.17	.29	3.46	6.33
1918	Plot.	11	5	4.58	.29	4.87	6.77
1918	Plot.	11	4	3.67	.29	3.96	5.78
1918	Plot.	15	3	3.75	.29	4.04	5.22
1918	Plot.	17	2	2.83	.29	3.12	4.34
1918	Plot.	12	5	5.00	.29	5.29	7.89
1918	Plot.	14	3	3.50	.29	3.79	4.92
1918	Plot.	12	3	3.00	.29	3.29	4.35
1918	Plot.	10	4	3.33	.29	3.62	5.42
1918	Plot.	9	5	3.75	.29	4.04	6.33
1918	Plot.	12	4	4.00	.29	4.29	6.38
1918	Plot.	9	4	3.00	.29	3.29	4.75
1918	Plot.	16	3	4.00	.29	4.29	6.10
1918	Plot.	20	2	3.33	.29	3.62	3.84
1918	Plot.	16	3	4.00	.29	4.29	5.71
1918	Plot.	12	4	4.00	.29	4.29	5.28
1918	Plot.	12	5	5.00	.29	5.29	7.46
1918	Plot.	15	2	2.50	.29	2.79	3.55
1918	Plot.	14	3	3.50	.29	3.79	4.90
1918	Plot.	13	4	4.33	.29	4.62	7.31
1918	Plot.	16	3	4.00	.29	4.29	6.06
1918	Plot.	20	2	3.33	.29	3.62	5.00
1918	Plot.	10	5	4.17	.29	4.46	6.68
1918	Plot.	13	2	3.00	.29	3.29	5.58
1918	Plot.	11	4	3.67	.29	3.96	5.66
1918	Plot.	14	3	3.50	.29	3.79	3.87
1918	Plot.	15	3	3.75	.29	4.04	5.40
1918	Plot.	12	4	4.00	.29	4.29	6.08
1918	Plot.	9	5	3.75	.29	4.04	5.95
1918	Plot.	16	2	2.67	.29	2.96	3.76
1918	Plot.	14	4	4.67	.29	4.96	6.93
1918	Plot.	10	5	4.17	.29	4.46	6.50
1919	Plot.	15	4	5.00	.58	5.58	7.03
1919	Plot.	14	2	2.33	.58	2.91	5.50
1919	Plot.	10	5	4.17	.58	4.75	7.16
1919	Plot.	12	3	3.00	.58	3.58	5.22
1919	Plot.	12	3	3.17	.58	3.75	5.31
1919	Plot.	10	5	4.08	.58	4.66	6.76
1919	Plot.	10	4	3.25	.58	3.83	6.44
1919	Plot.		3	3.17	.58	3.75	6.04
1919	Plot.	16	2	2.67	.58	3.25	5.70
1919	Plot.	11	5	4.58	.58	5.16	6.66
1919	Plot.	11	4	3.67	.58	4.25	5.71
1919	Plot.	13	3	3.25	.58	3.83	4.64
1919	Plot.	16	2	2.67	.58	3.25	4.60
1919	Plot.	11	5	4.58	.58	5.16	8.02
1919	Plot.	12	3	3.00	.58	3.58	5.23
1919	Plot.	10	3	2.50	.58	3.08	5.23
1919	Plot.	8	4	2.67	.58	3.25	5.20
1919	Plot.	9	5	3.75	.58	4.33	7.15
1919	Plot.	10	4	3.33	.58	3.91	6.36
1919	Plot.	9	4	3.00	.58	3.58	5.14
1919	Plot.	16	3	4.00	.58	4.58	6.13
1919	Plot.	17	2	2.83	.58	3.41	3.12
1919	Plot.	14	3	3.50	.58	4.08	5.50
1919	Plot.	11	4	3.67	.58	4.25	5.41
1919	Plot.	12	5	5.00	.58	5.58	7.53
1919	Plot.	13	2	2.17	.58	2.75	4.26
1919	Plot.	10	3	2.50	.58	3.08	4.08
1919	Plot.	13	4	4.33	.58	4.91	7.85
1919	Plot.	13	3	3.25	.58	3.83	5.68
1919	Plot.	16	2	2.67	.58	3.25	6.00
1919	Plot.	10	5	4.17	.58	4.75	7.10
1919	Plot.	12	2	2.00	.58	2.58	5.34
1919	Plot.	8	4	2.67	.58	3.25	5.23
1919	Plot.	10	3	2.50	.58	3.08	3.92
1919	Plot.	11	3	2.75	.58	3.33	5.38
1919	Plot.	11	5	3.67	.58	4.25	6.00
1919	Plot.	9	5	3.75	.58	4.33	6.42
1919	Plot.	12	2	2.00	.58	2.58	4.52
1919	Plot.	12	4	4.00	.58	4.58	6.64
1919	Plot.	11	5	4.50	.58	5.08	6.82

TABLE 15.—*Date of first and of last irrigation, irrigation water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*[1]

ALFALFA (2)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Total quantity of water received by crop per acre			Yield per acre	Literature cited
						Irrigation	Rainfall	Total		
	Acres	*Number*			*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*	
	--------	12	Mar. 5	Oct. 15	2	2.00	0.56	2.56	[2,3,4] 3.50	
	--------	18	Mar. 30	Nov. 9	2	3.00	.61	3.61	[2,3,4] 5.79	
	--------	18	Mar. 13	Oct. 23	2	3.00	.56	3.56	[2,3,4] 5.24	
	--------	17	Mar. 15	Oct. 15	2	2.83	.44	3.27	[2,3,4] 4.90	
	--------	18	Mar. 11	Sept. 26	2	3.00	.29	3.29	[2,3,4] 4.82	
	--------	15	Mar. 18	Sept. 29	2	2.50	.50	3.00	[2,3,4] 4.77	
	--------	10	Mar. 5	Oct. 15	3	2.50	.56	3.06	[2,3,4] 3.55	
	--------	14	Mar. 30	Nov. 9	3	3.50	.61	4.11	[2,3,4] 6.20	
	--------	15	Mar. 13	Oct. 23	3	3.75	.56	4.31	[2,3,4] 5.82	
	--------	14	Mar. 15	Oct. 15	3	3.50	.44	3.94	[2,3,4] 5.60	
	--------	15	Mar. 11	Sept. 26	3	3.75	.29	4.04	[2,3,4] 5.37	
	--------	12	Mar. 18	Sept. 29	3	3.00	.50	3.50	[2,3,4] 5.25	
	--------	8	Mar. 5	Oct. 15	4	2.67	.56	3.23	[2,3,4] 3.62	
	--------	12	Mar. 30	Nov. 9	4	4.00	.61	4.61	[2,3,4] 6.77	
	--------	13	Mar. 13	Oct. 23	4	4.33	.56	4.89	[2,3,4] 6.36	
	--------	12	Mar. 15	Oct. 15	4	4.00	.44	4.44	[2,3,4] 6.10	
	--------	12	Mar. 11	Sept. 26	4	4.00	.29	4.29	[2,3,4] 6.32	
	--------	11	Mar. 18	Sept. 29	4	3.67	.50	4.17	[2,3,4] 6.09	
	--------	11	Feb. 25	Oct. 9	4	3.67	.93	4.60	[2,3,4] 2.07	
	--------	7	Mar. 5	Oct. 15	5	2.92	.56	3.48	[2,3,4] 3.88	
	--------	11	Mar. 30	Nov. 9	5	4.58	.61	5.19	[2,3,4] 7.04	
	--------	11	Mar. 13	Oct. 23	5	4.58	.56	5.14	[2,3,4] 6.07	
	--------	11	Mar. 15	Oct. 15	5	4.58	.44	5.02	[2,3,4] 6.55	
	--------	10	Mar. 11	Sept. 26	5	4.17	.29	4.46	[2,3,4] 6.81	
	--------	10	Mar. 18	Sept. 20	5	4.17	.50	4.67	[2,3,4] 7.08	
	--------	6	Mar. 19	Oct. 4	5	2.75	.44	3.19	[2,3,4] 1.62	
	--------	6	Mar. 24	July 16	5	2.67	.44	3.11	[2,3,4] 2.56	
	--------	12	Mar. 3	Oct. 7	2	2.00	.47	2.47	[2,3,5] 3.75	
	--------	11	---do----	---do----	2	1.92	.47	2.39	[2,3,5] 3.42	
	--------	11	---do----	---do----	3	2.83	.47	3.30	[2,3,5] 3.70	
	--------	11	---do----	---do----	3	2.42	.47	2.89	[2,3,5] 3.45	
	--------	10	---do----	---do----	3	2.50	.47	2.97	[2,3,5] 3.39	
	--------	10	---do----	---do----	3	2.50	.47	2.97	[2,3,5] 3.40	
	--------	11	---do----	---do----	3	2.42	.47	2.89	[2,3,5] 3.00	
	--------	11	Mar. 5	---do----	3	2.67	.47	3.14	[2,3,5] 3.80	
	--------	8	Mar. 7	Aug. 8	3	2.00	.48	2.48	[2,3,5] 2.60	
	--------	13	Apr. 3	Sept. 19	3	3.25	.61	3.86	[2,3,5] 2.72	
	--------	12	Mar. 10	Oct. 16	4	3.83	.36	4.19	[2,3,5] 5.97	
	--------	8	Apr. 1	Sept. 14	4	2.67	.23	2.90	[2,3,5] 2.95	
	--------	9	---do----	---do----	4	3.00	.23	3.23	[2,3,5] 3.47	
	--------	8	Mar. 7	Aug. 8	4	2.67	.48	3.15	[2,3,5] 3.11	
	--------	8	---do----	---do----	4	2.67	.48	3.15	[2,3,5] 2.78	
	--------	8	Apr. 10	Aug. 15	4	2.67	.35	3.02	[2,3,5] 4.00	
	--------	8	---do----	---do----	4	2.67	.35	3.02	[2,3,5] 4.03	
	--------	10	---do----	---do----	4	3.33	.35	3.68	[2,3,5] 2.85	
	--------	10	---do----	---do----	4	3.33	.35	3.68	[2,3,5] 3.08	
	--------	13	Mar. 9	Oct. 2	4	4.92	.51	5.43	[2,3,5] 6.78	
	--------	13	---do----	---do----	4	4.58	.51	5.09	[2,3,5] 6.44	
	--------	13	---do----	---do----	4	3.83	.51	4.34	[2,3,5] 6.55	
	--------	13	---do----	---do----	4	4.50	.51	5.01	[2,3,5] 8.31	
	--------	13	---do----	---do----	4	4.08	.51	4.59	[2,3,5] 6.05	
	--------	12	---do----	Sept. 14	4	3.50	.36	3.86	[2,3,5] 5.11	
	--------	12	---do----	---do----	4	3.83	.36	4.19	[2,3,5] 5.27	
	--------	14	Mar. 8	Oct. 2	4	4.67	.46	5.13	[2,3,5] 7.38	
	--------	13	---do----	---do----	4	4.58	.46	5.04	[2,3,5] 5.49	
	--------	13	---do----	---do----	4	4.75	.46	5.21	[2,3,5] 5.90	
	--------	13	---do----	---do----	4	4.33	.46	4.79	[2,3,5] 4.00	
	--------	8	Apr. 1	Sept. 14	5	3.33	.23	3.56	[2,3,5] 4.47	
	--------	8	Mar. 7	Aug. 8	5	3.33	.48	3.81	[2,3,5] 3.61	
	--------	13	Apr. 4	Sept. 10	5	5.42	.61	6.03	[2,3,5] 3.29	
	--------	12	Mar. 31	Sept. 15	5	5.08	.62	5.70	[2,3,5] 4.37	
	--------	13	Mar. 9	Oct. 2	5	5.25	.51	5.76	[2,3,5] 6.64	
	--------	12	---do----	---do----	5	5.00	.51	5.51	[2,3,5] 5.93	
	--------	13	---do----	---do----	5	5.17	.51	5.68	[2,3,5] 6.12	
	--------	12	---do----	Sept. 14	5	4.75	.36	5.11	[2,3,5] 5.84	
	--------	12	---do----	---do----	5	4.67	.36	5.03	[2,3,5] 5.70	
	--------	12	---do----	---do----	5	4.50	.36	4.86	[2,3,5] 5.24	
	--------	12	---do----	---do----	5	4.50	.36	4.86	[2,3,5] 6.18	
	--------	12	---do----	---do----	5	4.67	.36	5.03	[2,3,5] 4.07	
	--------	12	---do----	---do----	5	4.50	.36	4.86	[2,3,5] 5.40	

See footnotes on page 53.

TABLE 15.—*Date of first and of last irrigation, irrigation water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*—Continued

ALFALFA (2)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Total quantity of water received by crop per acre: Irrigation	Rainfall	Total	Yield per acre	Literature cited
	Acres	*Number*			*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Tons*	
	--------	13	Mar. 3	Nov. 23	6	6.08	0.36	6.44	[2,3,5] 8.00	
	--------	13	do	do	6	5.92	.36	6.28	[2,3,5] 5.52	
	--------	13	do	do	6	6.33	.36	6.69	[2,3,5] 5.50	
	--------	13	do	do	6	6.58	.36	6.94	[2,3,5] 5.25	
	--------	8	Apr. 1	Sept. 14	6	4.00	.23	4.23	[2,3,5] 3.13	
	--------	8	Mar. 7	Aug. 8	6	4.00	.48	4.48	[2,3,5] 3.54	
	--------	6	May 2	Sept. 19	6	3.00	.61	3.61	[2,3,5] 2.36	
	--------	8	Apr. 1	Sept. 14	8	5.33	.23	5.56	[2,3,5] 2.30	
	--------	8	Mar. 7	Aug. 8	8	5.33	.48	5.81	[2,3,5] 3.11	
	--------	6	May 2	Sept. 19	10	5.00	.61	5.61	[2,3,5] 3.17	
	--------	8	Mar. 4	Oct. 16	3	2.17	.58	2.75	[2,3,6] 4.26	
	--------	11	Feb. 25	Oct. 20	4	3.67	.93	4.60	[2,3,6] 3.59	
	--------	6	Mar. 18	July 1	4	1.75	.72	2.47	[2,3,6] 5.10	
	--------	4	Mar. 24	June 3	6	2.00	.72	2.72	[2,3,6] 4.28	
		4	Mar. 26	Aug. 7	6	2.00	.58	2.58	[2,3,6] 4.75	
1924	Plot.	12	Mar. 28	Sept. 10	--------	4.32	.29	4.61	2.96	(13)
1924	Plot.	14	Mar. 20	Oct. 3	--------	5.80	.33	6.10	6.87	(13)
1924	Plot.	14	do	do	--------	6.68	.33	7.01	4.57	(15)
1924	Plot.	14	do	do	--------	6.31	.33	6.64	4.53	(15)
1924	Plot.	14	do	do	--------	5.58	.33	5.91	3.87	(13)

CORN (2)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
									Bushels	
	--------	4	May 15	Aug. 26	4	1.25	0.22	1.47	[2,3,7] 39.9	
	--------	4	Apr. 30	Aug. 17	5	1.67	.22	1.89	[3,8] 36.0	
									Pounds	
		4	do	do	5	1.67	.22	1.89	[3,9] 13,719	
									Bushels	
		8	May 5	Sept. 1	4	2.50	.00	2.50	[3,4] 44	
1924	Plot.	8	do	do	--------	2.47	.30	2.83	44	(13)
1924	Plot.	8	--------	--------	--------	2.61	.25	2.86	23.5	(13)

RYE

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
1923	Plot.	7	Nov. 20	May 24	--------	1.76	0.16	1.92	29	(12)
1923	Plot.	6	--------	--------	--------	3.62	.30	3.92	18	(12)

CABBAGE

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
									Tons	
1923	Plot.	10	Mar. 17	June 25	--------	2.27	0.03	2.30	10.42	(12)
1924	Plot.	11	Mar 12	June 17	--------	2.29	.03	2.32	9.84	(12)

CHILI

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
1924	Plot.	14	May 14	Sept. 17	--------	3.11	0.28	3.39	.92	(13)

CANTALOUPES

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
									Crates	
1924	Plot.	10	May 14	Aug. 5	--------	2.26	.22	2.48	105	(15)

See footnotes on page 53.

TABLE 15.—*Date of first and of last irrigation, irrigation water applied at each irrigation, rainfall, total water received, and crop yields in Mesilla Valley, N. Mex.*—Continued

WHEAT (*2*)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Total quantity of water received by crop per acre: Irrigation	Rainfall	Total	Yield per acre	Literature cited
		Number			*Inches*	*Acre-feet*	*Acre-feet*	*Acre-feet*	*Bushels*	
			Oct. 4	May 28	2	1.42	0.22	1.64	[2,3,5] 11.4	
			Nov. 3	do	2	1.08	.22	1.30	[2,3,5] 22.7	
			Dec. 3	do	2	.92	.22	1.14	[2,3,5] 22.9	
		5	Jan. 17	May 29	2	.83	.22	1.05	[2,3,5] 16.5	
		5	Feb. 3	do	2	.83	.22	1.05	[2,3,5] 17.6	
		5	Mar. 3	do	2	.83	.22	1.05	[2,3,5] 13.2	
		8	Jan. 5	June 15	2	2.00	.54	2.54	[2,3,5] 15.1	
		6	do	do	3	1.50	.54	2.04	[2,3,5] 10.6	
			Oct. 4	May 28	4	2.17	.22	2.39	[2,3,5] 14.3	
			Nov. 3	do	4	1.83	.22	2.05	[2,3,5] 18.9	
			Dec. 3	do	4	1.50	.22	1.72	[2,3,5] 30.0	
		4	Jan. 17	May 29	4	1.33	.22	1.55	[2,3,5] 16.8	
			Feb. 3	do	4	1.25	.22	1.47	[2,3,5] 19.1	
			Mar. 3	do	4	1.25	.22	1.47	[2,3,5] 4.4	
			Jan. 5	June 15	4	2.42	.54	2.96	[2,3,5] 16.6	
		7	do	do	5	2.92	.54	3.46	[2,3,5] 18.0	
		6	Oct. 4	May 28	6	3.00	.22	3.22	[2,3,5] 16.2	
		5	Nov. 3	do	6	2.50	.22	2.72	[2,3,5] 21.1	
			Dec. 3	do	6	2.17	.22	2.39	[2,3,5] 30.7	
			Jan. 17	May 29	6	1.67	.22	1.89	[2,3,5] 14.9	
			Feb. 3	do	6	1.67	.22	1.89	[2,3,5] 13.0	
			Mar. 3	do	6	1.75	.22	1.97	[2,3,5] 9.6	
			Apr. 18	May 30	4	1.08			[2,3,6] 43.5	
		6	Feb. 21	June 10	5	2.50	.08	2.58	[2,3,6] 23.1	
1909	Plot.	4			4	1.33	[11] .29	1.62	[10] 24.6	
1909	Plot.	5			3	1.25	[11] .29	1.54	[10] 15.1	
1909	Plot.	7			2	1.17	[11] .29	1.46	[12] 16.6	
1909	Plot.	4			3	1.00	[11] .29	1.29	[10] 14.9	
1909	Plot.	5			2	.83	[11] .29	1.12	[12] 9.0	
1909	Plot.	7			1	.58	[11] .29	.87	[12] 11.7	
1909	Plot.	5			1	.42	[11] .29	.71	[12] 2.2	
1924	Plot.	5	Feb. 14	June 7		1.06	.15	1.21	7.3	(*13*)

POTATOES [1] (*2*)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
		7	Mar. 14	June 20	3	1.75	0.06	1.81	[2,3] 58.4	
		4	do	June 13	5	1.67	.06	1.73	[2,3] 86.2	
		3	do	do	5	1.25	.06	1.31	[2,3] 60.5	
		2	do	May 30	5	.83	.06	.89	[2,3] 58.7	
		3	do	June 15	5	1.25	.06	1.31	[2,3] 54.0	
		2	do	May 30	5	.83	.06	.89	[2,3] 11.7	
		3	do	June 13	5	1.25	.06	1.31	[2,3] 39.9	

SOYBEANS (*24*)

Year	Area irrigated	Irrigations	First irrigation	Last irrigation	Depth applied each irrigation	Irrigation	Rainfall	Total	Yield per acre	Literature cited
									Pounds	
1911	Plot.				1	0.88	0.30	1.18	[10] 678	
1911	Plot.				2	1.36	.30	1.66	[10] 980	
1911	Plot.				3	1.50	.30	1.80	[10] 1,028	
1911	Plot.				4	1.72	.30	2.02	[12] 1,022	
1911	Plot.				4	2.83	.30	3.13	[10] 1,404	
1911	Plot.				3	2.19	.30	2.49	[10] 745	

[1] These experiments conducted cooperatively by the Division of Agricultural Engineering, Bureau of Public Roads, and the New Mexico Agricultural Experiment Station.
[2] Experiments covered several years and are here grouped together.
Fields and plots vary from 0.6 acre to 29.95 acres.
[4] Soil: Coarse sand, and sand and gravel.
[5] Soil: Equal parts sandy loam with adobe or clay.
[6] Good soil, fairly deep, with sandy loam texture.
[7] Corn, grain.
[8] Corn on cob.
[9] Corn, silage.
[10] Average of 6 plots.
[11] Rainfall from Apr. 1 to Nov. 1
[12] Average of 3 plots.

TABLE 16.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Texas* [1]

CORN [2]

Year	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	
	Number														*Bushels*
1920	0												0.88	0.88	32.9
1920	1					0.25						0.25	.88	1.13	33.3
1920	1					.37						.37	.88	1.25	32.5
1920	1					.50						.50	.88	1.38	35.4
1920	0												.88	.88	32.1
1920	1					.25						.25	.88	1.13	36.2
1920	1					.37						.37	.88	1.25	40.0
1920	1					.50						.50	.88	1.38	38.1
1920	0												.83	.83	35.4
1920	0												1.02	1.02	[3] 22.4
1921	1					.17						.17	1.03	1.20	34.1
1921	1					.25						.25	1.03	1.28	31.8
1921	1					.33						.33	1.03	1.36	32.9
1921	0												.98	.98	42.2
1921	1					.17						.17	.98	1.15	41.8
1921	1					.25						.25	.98	1.23	44.4

COTTON [2]

Year	Irrigations	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
															Pounds
1920	0												1.24	1.21	[4] 233
1920	0												1.24	1.24	214
1921	1						0.17					0.17	.85	1.02	160
1921	1						.25					.25	.85	1.10	252
1921	1						.33					.33	.85	1.18	348
1921	1						.17					.17	1.27	1.44	153
1921	1						.25					.25	1.27	1.52	274
1921	1						.33					.33	1.27	1.60	176
1921	1												1.27	1.27	182
1921	0														

PIMA COTTON[2]

1920	0												1.42	1.42	[4]418
1921	2						0.33					0.33	1.22	1.55	209
1921	2						.50					.50	1.22	1.72	219
1921	2						.67					.67	1.22	1.89	289

COWPEAS[2]

1920	0												0.76	0.76	[6]632
															Bushel.
1921	1						0.33					0.33	.32	.65	[7]14.2

MILO[2]

														Pounds
1920	0											0.78	0.78	[5]777
1920	0											.62	.62	1,905
1921	1				0.25							0.25	.98	1.23	3,910
1921	1				.16							.16	.98	1.14	[9]2,560
1921	1				.25							.25	.98	1.23	[9]2,319
1921	1				.33							.33	.98	1.31	[9]2,282

SORGHUM[2]

														Tons
1920	1				0.17							0.17	0.83	1.00	0.80
1921	1					0.21						.21	.85	1.06	[10]4.79
1921	1					.25						.25	.85	1.10	[10]4.51
1921	1					.32						.32	.85	1.17	[10]4.41
1921	2							0.44				.44	.32	.76	[11]1.75
1921	2							.48				.48	.32	.80	[11]1.60
1921	2							.59				.59	.32	.91	[11]1.70
1921	1					.20						.20	.52	.72	[10]3.17
1921	1					.25						.25	.52	.77	[10]3.14
1921	1					.33						.33	.52	.85	[10]2.57
1921	2						0.19	.19				.38	.27	.65	[11]1.27
1921	2						.25	.25				.50	.27	.77	[11]1.30
1921	2						.33	.33				.66	.27	.93	[11].86

See footnotes on page 61.

TABLE 16.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Texas*—Continued

Year	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	
SUGAR BEETS [2]															
	Number														*Tons*
1921	4				0.05	0.17	0.17	0.16				0.55	0.97	1.52	[12] 14.08
1921	4				.05	.25	.25	.25				.80	.97	1.77	11.60
1921	4				.05	.33	.33	.34				1.05	.97	2.02	12.88
SWEETPOTATOES [2]															
															Bushels
1921	5				0.17		0.35	0.33				0.85	0.80	1.65	[13] 175
1921	5				.09		.50	.50				1.09	.80	1.89	[13] 225
1921	5				.12		.67	.66				1.45	.80	2.25	[13] 215
TOMATOES [2]															
															Pounds
1921	2				0.04		0.17					0.21	0.80	1.01	[14] 5,785
1921	2				.04		.25					.29	.80	1.09	[14] 5,810
1921	2				.05		.33					.38	.80	1.18	[14] 6,806
WATERMELONS [2]															
1921	1						0.17					0.17	0.55	0.72	[15] 7,742
1921	1						.21					.21	.55	.76	[15] 15,668
1921	1						.25					.25	.55	.80	[15] 21,394

CORN [16]

															Bushels
1915	3				0.08	0.12						0.20	0.46	0.66	[17] 65
1915	4			0.13	.27	.28						.68	.46	1.14	[17] 75
1915	4			.34	.46	.42						1.22	.46	1.68	[17] 87
1916	4		0.25		.22	.11						.58	.65	1.23	[18] 29
1916	4		.25		.34	.17						.76	.65	1.41	[18] 46
1916	4		.25		.49	.22						.96	.65	1.61	[18] 55
1916	3		.25		.33							.58	.65	1.23	[18] 35
1916	3		.25		.50							.75	.65	1.40	[18] 49
1916	3		.25		.58	.08						.91	.65	1.56	[18] 60
1917	5		.12	.17	.17	.33						.79	.41	1.20	[18] 53
1917	5		.12	.21	.25	.50						1.08	.41	1.49	[18] 59
1917	6		.13	.25	.33	.82						1.53	.41	1.94	[18] 58
1918	4		.14	.10	.10	.17						.51	.79	1.30	[18] 56
1918	4		.14	.14	.15	.25						.68	.79	1.47	[18] 70
1918	4		.14	.19	.19	.33						.85	.79	1.64	[18] 81
1918	3		.23			.33	0.54					1.10	.78	1.88	[19] 60
1918	3		.23			.29	.54					1.06	.78	1.84	[19] 55
1918	3		.23			.37	.54					1.14	.78	1.92	[18] 54
1918	3		.22			.54	.42					1.18	.78	1.96	[19] 59
1918	3		.22			.42	.37					1.01	.78	1.79	[19] 55
1918	3		.22			.46	.28					.96	.78	1.74	[19] 55
1919	3		.21		.17	.16						.54	.94	1.48	[18] 64
1919	3		.21		.25	.25						.71	.94	1.65	[18] 65
1919	3		.21		.33	.33						.87	.94	1.81	[18] 68

LINT COTTON [16]

															Pounds
1915	4			0.04		0.10	0.09					0.23	0.24	0.47	[17] 700
1915	5			.04	0.12	.28	.13					.57	.24	.81	[17] 1,000
1915	5			.04	.25	.49	.25					1.03	.24	1.27	[17] 1,125
1916	3		0.25		.15	.09						.49	[21] .58	1.07	[20] 388
1916	5		.25		.12	.06	.07					.50	[21] .58	1.08	[20] 252
1916	5		.25		.24	.33						.82	[21] .58	1.40	[20] 273
1916	6		.25		.34	.26						.85	[21] .58	1.43	[20] 427
1916	5		.25		.39	.49						1.13	[21] .58	1.71	[20] 779
1916	6		.25		.47	.43						1.15	[21] .58	1.73	[20] 510
1917	4	0.25			.16	.17						.58	.47	1.05	[20][22] 270
1917	4	.25			.17	.16						.58	.47	1.05	[20][22] 300
1917	5	.25			.36	.22						.83	.47	1.30	[20][22] 430
1917	5	.25			.36	.22						.83	.47	1.30	[20][22] 495
1917	5	.25			.53	.39						1.17	.47	1.64	[20][22] 440
1917	5	.25			.53	.39						1.17	.47	1.64	[20][22] 480
1918	1		.13									.13	.79	.92	[20] 378
1918	2		.08			.11						.19	.79	.98	[20] 414
1918	2		.08			.20						.28	.79	1.07	[20] 414

See footnotes on page 63.

TABLE 16.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Texas*—Continued

RHODES GRASS [15]

Year	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	
	Number														*Tons*
1918	7		0.31		0.48	0.38	0.43	0.50	0.63	0.50		3.23	1.18	4.41	[18] [23] 5.26
1918	7		.31		.67	.50	.50	.50	.87	.50		3.85	1.18	5.03	[16] [23] 5.29
1918	7		.38		.42	.42	.41	.41	.60	.42		3.06	1.18	4.24	[16] [23] 5.18
1918	7		.38		.64	.41	.42	.42	.69	.42		3.38	1.18	4.56	[15] [23] 5.30
1918	7		.46		.47	.42	.33	.25	.38	.25		2.56	1.18	3.74	[18] [22] 4.62
1918	7		.46		.57	.25	.36	.25	.39	.25		2.53	1.18	3.71	[16] [23] 5.44
1919	4		.30			.50		.83				1.63	2.09	3.72	[18] [23] 5.35
1919	4		.33			.50		1.00				1.83	2.09	3.92	[19] [23] 5.30
1919	4		.25			.42		.75				1.42	2.09	3.51	[15] [23] 4.64
1919	4		.25			.42		.75				1.42	2.09	3.51	[15] [23] 5.06
1919	4		.17			.26		.52				.95	2.09	3.04	[18] [23] 4.97
1919	4		.17			.33		.58				1.08	2.09	3.17	[19] [23] 4.89

SNAP BEANS [16]

Year	Irrigations	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
															Pounds
1918	5							0.38	0.30	0.50	0.25	1.43	0.27	1.70	[15] [24] 5,493
1918	5							.31	.27	.33	.17	1.08	.27	1.35	[15] [24] 5,593
1918	5							.23	.21	.19	.08	.71	.27	.98	[15] [24] 3,527
1918	4								.17	.17	.10	.44	.30	.74	[19] 4,281
1918	4								.33	.34	.21	.88	.30	1.18	[19] [25] 3,470
1918	4								.49	.50	.31	1.30	.30	1.60	[19] [26] 3,875
1920	5		0.08	0.25	0.09							.42	.19	.61	[19] 4,740
1920	5		.12	.50	.17							.79	.19	.98	[19] 3,594
1920	5		.17	.75	.25							1.17	.19	1.36	[19] 2,188

SORGHUM [16]

															Tons
1919	3	----	0.11	0.25	----	----	----	0.17	----	----	----	0.53	2.00	2.53	[19, 27] 10.25
1919	3	----	.22	.33	----	----	----	.25	----	----	----	.81	2.00	2.81	[19, 27] 10.04
1919	3	----	.23	.42	----	----	----	.33	----	----	----	.98	2.00	2.98	[19, 27] 12.23
1919	3	----	.23	.50	----	----	----	.41	----	----	----	1.14	2.00	3.14	[19, 27] 11.53
1919	3	----	.16	.25	----	----	----	.25	----	----	----	.66	2.00	2.66	[18, 27] 9.63
1919	3	----	.17	.33	----	----	----	.33	----	----	----	.83	2.00	2.83	[18, 27] 10.03
1919	3	----	.18	.42	----	----	----	.42	----	----	----	1.02	2.00	3.02	[18, 27] 11.74
SUGARCANE [16]															
1918-19	9	----	0.21	0.12	0.17	0.20	----	0.94	0.62	----	----	2.35	2.24	4.59	[19, 28] 16.02
1918-19	9	----	.13	.08	.10	.17	----	.52	.34	----	----	1.34	2.24	3.58	[19, 28] 22.16
1918-19	9	----	.17	.10	12	.21	----	.75	50	----	----	1.85	2.24	4.09	[19, 28] 20.43
1918-19	9	----	.21	.12	.17	.20	----	.94	.62	----	----	2.35	2.24	4.59	[19, 28] 22.85
1918-19	9	----	.13	.08	.10	.17	----	.52	.34	----	----	1.34	2.24	3.58	[19, 28] 14.61
1918-19	9	----	.17	.10	.12	21	----	.75	50	----	----	1.85	2.24	4.09	[19, 28] 20.87
1918-19	9	----	.21	.12	.17	.20	----	.94	.62	----	----	2.35	2.24	4.59	[19, 28] 15.00
TOMATOES [13]															
1918	5	----	----	0.11	0.17	0.16	----	----	----	----	----	0.44	0.52	0.96	[11, 18, 29] 12.50
1918	5	----	----	.11	.33	.34	----	----	----	----	----	.78	.52	1.30	[11, 18, 29] 12.78
1918	5	----	----	.11	.50	.50	----	----	----	----	----	1.11	.52	1.63	[11, 18, 29] 14.10
1918	5	----	----	----	----	----	----	----	0.13	0.17	0.17	.47	.22	.69	[12, 18] 6.53
1918	5	----	----	----	----	----	----	----	.16	.33	.33	.82	.22	1.04	[12, 18] 5.68
1918	5	----	----	----	----	----	----	----	.19	.50	.50	1.19	.22	1.41	[12, 18] 6.46
1918	5	----	----	----	----	----	----	----	----	----	----	.54	.22	.76	[19] 4.32
1918	5	----	----	----	----	----	----	----	----	----	----	.92	.22	1.14	[19] 2.67
1918	5	----	----	----	----	----	----	----	----	----	----	1.30	.22	1.52	[19] 3.16
1920	7	----	0.27	.21	.19	----	----	----	----	----	----	.67	.34	1.01	[18] 8.27
1920	7	----	.31	.36	.29	----	----	----	----	----	----	.96	.34	1.30	[15] 10.94
1920	7	----	.38	.54	.41	----	----	----	----	----	----	1.33	.34	1.67	[15] 10.18
1920	6	----	----	----	----	----	----	----	----	----	----	1.01	.34	1.35	[19] 6.05
1920	6	----	----	----	----	----	----	----	----	----	----	.73	.34	1.07	[19] 6.07
1920	6	----	----	----	----	----	----	----	----	----	----	.51	.34	.85	[19] 5.53

See footnotes on page 63.

TABLE 16.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Texas*—Continued

KAFFIR [30]

Year	Irrigations	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	
	Number														*Bushels*
1918	2						0.33	0.34				0.67	[31] 0.49	1.16	58.6
1918	2						.25	.25				.50	[31] .49	.99	65.7
1918	2						.17	.16				.33	[31] .49	.82	38.7
1919	1							.33				.33	.85	1.18	40.1
1919	1							.25				.25	.85	1.10	40.7
1919	1							.17				.17	.85	1.02	48.5

MILO [30]

Year	Irrigations	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1918	2						0.33	0.31				0.67	0.40	1.07	[20] 66.5
1918	2						.25	.25				.50	.40	.90	[20] 67.8
1918	2						.17	.16				.33	.40	.73	[20] 43.5
1919	1							.33				.33	.85	1.18	[20] 65.5
1919	1							.26				.26	.85	1.11	[20] 65.2
1919	1							.17				.17	.85	1.02	[20] 67.9

MILLET [30]

Year	Irrigations	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
															Tons
1918	2					0.66						0.66	0.48	1.14	3.69
1918	2					.50						.50	.48	.98	3.10
1918	2					.33						.33	.48	.81	2.90

SORGHUM[30]

															Tons
1919	1						0.33					0.33	1.11	1.44	[32] 1.77
1919	1						.25					.25	1.11	1.36	[32] 1.61
1919	1						.17					.17	1.11	1.28	[31] 1.66

WINTER WHEAT[30]

															Bushels
1918-19	1					0.25						0.25	1.42	1.67	29.3
1918-19	1					.08						.08	1.42	1.50	29.3
1918-19	0												1.42	1.42	25.1

[1] These experiments were conducted under cooperative agreement between the Texas State Board of Water Engineers and the Bureau of Public Roads, U. S. Department of Agriculture.

[2] These experiments were conducted on plots at Medina Experiment Station. The soil is fine sand or sandy loam, varying to sandy clay with depth.

[3] It is estimated this yield was cut 30 to 50 per cent by lack of water in critical stage.

[4] Suffered from lack of water, on account of break in canal.

[5] Suffered from lack of water followed by heavy rains.

[6] Crop of hay only. Lack of irrigation, due to canal break, caused low yield.

[7] Result from average small section of field containing perfect stand.

[8] Yield reduced about one-half by midge and birds.

[9] Thinned to 1 stalk to a plant.

[10] First crop.

[11] Second crop.

[12] Plot was so small results should not be considered.

[13] Slight damage by weevils.

[14] Entire crop of very poor quality, indicating insufficient moisture.

[15] Culls not included.

[16] Plot experiments conducted at station 1 mile south of Mercedes. Soil of west 14 acres consists of light-colored sandy loam underlaid with yellowish sandy loam. Soil of the east 17 acres consists of dark, heavy clay loam underlaid at 4 feet with sandy clay. Soil at Mercedes a gray-black soil of fine texture underlaid with sandy clay subsoil. Rainfall under 0.25 inch, unless followed by another rain in 24 hours, was generally not counted, although lighter showers on shallow-rooted plants during winter seasons were sometimes included.

[17] Loam soil.

[18] Sandy soil.

[19] Clay soil.

[20] Sandy loam soil.

[21] 4.48 inches deducted from rainfall as being ineffective.

[22] First irrigation occurred 11 days before planting.

[23] Total of 5 cuttings.

[24] First irrigation applied 5 days before planting to moisten a very dry soil. Probably 3 inches of water was lost in the first and second application.

[25] 2 inches of first application lost in cracks in the soil and of no benefit.

[26] 3 inches of first application lost in cracks in the soil and of no benefit.

[27] Total from 3 cuttings.

[28] Stubble second-year cane.

[29] Rainfall in April following transplanting increased moisture at least 2 inches above beneficial use.

[30] The larger portion of this district consists of black to gray sandy clay loam, underlaid at 3 feet by a light calcareous formation which drains quickly.

[31] Includes 1.19 inches rainfall, occurring 10 days before planting.

[32] Cut for grain.

TABLE 17.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in lower Rio Grande Valley, Tex.*[1]

TABLE BEETS

Year	Irrigations	Monthly application of water in acre-feet per acre							Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Irrigation	Rainfall	Total	
	Number											*Tons*
1917-18	8	------	0.17	0.10	0.34	0.34	------	0.44	1.30	0.04	1.43	[2,3] 10.32
1917-18	8	------	.17	.10	.31	.34	------	.44	1.36	.04	1.40	[2,3] 11.84
1917-18	8	------	.17	.10	.31	.34	------	.44	1.36	.04	1.40	[2,3] 8.53
1917-18	8	------	.17	.17	.32	.34	------	.37	1.37	.04	1.41	[2,3] 11.45
1917-18	8	------	.17	.17	.30	.34	------	.37	1.35	.04	1.39	[2,3] 6.70
1917-18	8	------	.17	.17	.29	.33	------	.33	1.29	.04	1.33	[2,3] 7.50
1917-18	8	------	.12	.13	.25	.25	------	.29	1.04	.04	1.08	[2,3] 7.40
1917-18	8	------	.12	.13	.25	.25	------	.29	1.04	.04	1.08	[2,3] 9.90
1917-18	8	------	.12	.13	.23	.25	------	.29	1.02	.04	1.06	[2,3] 8.58
1917-18	8	------	.12	.13	.23	.25	------	.29	1.02	.04	1.06	[2,3] 7.78
1917-18	8	------	.12	.11	.24	.25	------	.27	.99	.04	1.03	[2,3] 7.03
1917-18	8	------	.12	.11	.26	.25	------	.23	.97	.04	1.01	[2,3] 7.29
1917-18	8	------	.08	.11	.23	.25	------	.21	.88	.04	.92	[2,3] 6.86
1917-18	8	------	.08	.11	.19	.27	------	.21	.86	.04	.90	[2,3] 5.72
1917-18	8	------	.08	.17	.19	.27	------	.21	.92	.04	.96	[2,3] 5.79
1919-20	5	------	.33	.42	------	.25	.25	------	1.25	.15	1.40	[2,4] 11.12
1919-20	5	------	.25	.31	------	.17	.17	------	.90	.15	1.05	[2,4] 10.44
1919-20	5	------	.17	.23	------	.08	.08	------	.56	.15	.71	[2,4] 10.33
1919-20	5	------	------	.16	------	.08	.08	.09	.41	.15	.56	[4,5] 9.90
1919-20	5	------	------	.16	------	.08	.08	.09	.41	.15	.56	[4,5] 7.68
1919-20	5	------	------	.16	------	.08	.08	.09	.41	.15	.56	[4,5] 7.36
1919-20	5	------	------	.27	------	.17	.17	.16	.77	.15	.92	[4,5] 8.09
1919-20	5	------	------	.27	------	.17	.17	.16	.77	.15	.92	[4,5] 7.26
1919-20	5	------	------	.27	------	.17	.17	.16	.77	.15	.92	[4,5] 7.42
1919-20	5	------	------	.42	------	.25	.25	.25	1.17	.15	1.32	[4,5] 7.47
1919-20	5	------	------	.42	------	.25	.25	.25	1.17	.15	1.32	[4,5] 7.36
1919-20	5	------	------	.42	------	.25	.25	.25	1.17	.15	1.32	[4,5] 5.39

CABBAGE

1914-15	1	------	------	0.17	------	------	------	------	0.17	0.76	0.93	[6,7] 15.7
1914-15	3	------	------	.13	------	0.01	0.06	------	.20	.76	.97	[6,7] 16.3
1914-15	4	------	------	.13	0.11	.12	.14	------	.50	.76	1.26	[6,7] 21.5
1916-17	14	------	0.17	.26	.26	.30	.36	------	1.35	.21	1.56	[8,9] 3.81
1916-17	14	------	.17	.24	.25	.31	.28	------	1.25	.21	1.46	[8,9] 12.04
1916-17	14	------	.14	.18	.17	.20	.20	------	.89	.21	1.10	[8,9] 4.84
1916-17	11	------	.15	.20	.15	.14	.25	------	.89	.21	1.10	[8,9] 7.87
1916-17	11	------	.16	.16	.20	.14	.22	------	.88	.21	1.09	[8,9] 8.38
1916-17	11	------	.17	.12	.14	.10	.18	------	.71	.21	.92	[8,9] 3.74
1918-19	4	------	.20	.16	------	------	------	------	.36	.86	1.22	[3] 9.52
1918-19	5	------	.28	.33	.17	------	------	------	.78	.86	1.64	[3] 10.72
1918-19	5	------	.36	.50	.25	------	------	------	1.11	.86	1.97	[3] 9.72
1919-20	4	0.23	.17	.08	------	------	------	------	.53	[10] .55	1.08	[8,11] 6.06
1919-20	4	.28	.33	.17	------	------	------	------	.78	[10] .55	1.33	[8,11] 6.24
1919-20	4	.28	.50	.25	------	------	------	------	1.03	[10] .55	1.58	[8,11] 9.57
1919-20	5	------	------	.13	------	.08	.08	0.17	.46	.17	.63	[8,12] 9.72
1919-20	5	------	------	.08	------	.17	.17	.33	.75	.17	.92	[8,12] 9.39
1919-20	6	------	------	.13	------	.25	.50	.50	1.38	.17	1.55	[8,12] 7.37
1919-20	5	------	------	.14	------	.25	.25	.50	1.14	.17	1.31	[4] 13.02
1919-20	5	------	------	.14	------	.17	.17	.33	.81	.17	.98	[2] 9.98
1919-20	5	------	------	.14	------	.08	.08	.17	.47	.17	.64	[2] 8.49

CARROTS

1918-19	3	------	0.17	0.25	------	------	------	------	0.42	0.85	1.27	[5,13] 6.97
1918-19	3	------	.17	.25	------	------	------	------	.42	.85	1.27	[5,13] 5.81
1918-19	4	------	.17	.33	0.17	------	------	------	.67	.85	1.52	[5,13] 6.30
1918-19	4	------	.17	.33	.17	------	------	------	.67	.85	1.52	[5,13] 5.25
1918-19	4	------	.16	.42	.25	------	------	------	.83	.85	1.68	[5,13] 6.94
1918-19	4	------	.16	.42	.25	------	------	------	.83	.85	1.68	[5,13] 6.29

See footnotes on page 61.

TABLE 17.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in lower Rio Grande Valley, Tex.*—Continued

CAULIFLOWER

Year	Irrigations	Monthly application of water in acre-feet per acre							Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Irrigation	Rainfall	Total	
	Number											*Tons*
1919–20	4	0.21		0.17		0.08			0.46	0.90	1.36	[2,14] 5.12
1919–20	4	.21		.33		.17			.71	.90	1.61	[2,14] 5.37
1919–20	4	.21		.50		.25			.96	.90	1.86	[2,14] 5.45
1919–20	4	.19		.50		.25			.94	.90	1.84	[2,14] 7.72
1919–20	4	.19		.33		.17			.69	.90	1.59	[2,14] 8.24
1919–20	4	.19		.17		.08			.44	.90	1.34	[2,14] 8.03

LETTUCE

Year	Irrigations	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Irrigation	Rainfall	Total	Yield per acre
1914–15										0.74	0.74	[3,15] 10.65
1914–15	4					0.04	0.14		0.18	.74	.92	[6,15] 13.91
1914–15	4					.17	.42		.59	.74	1.33	[6,15] 14.57
1916–17	8		0.15	0.46	0.49	.21			1.31	.24	1.55	[3,16] 3.86
1916–17	8		.15	.37	.42	.17			1.11	.24	1.35	[3,16] 4.29
1916–17	8		.10	.31	.36	.17			.94	.24	1.18	[3,16] 3.50
1916–17	8		.10	.31	.32	.07			.80	.24	1.04	[3,16] 4.16
1916–17	8		.06	.19	.18	.06			.49	.24	.73	[3,16] 3.71
1916–17	8		.07	.20	.22	.08			.57	.24	.81	[3,16] 5.50
1917–18	6		.08	.10	.21	.08	.13		.60	.04	.64	[2] 1.72
1917–18	6		.08	.10	.21	.08	.13		.60	.04	.64	[2] 2.89
1917–18	6		.08	.10	.21	.08	.13		.60	.04	.64	[2] 3.05
1917–18	6		.08	.10	.21	.08	.13		.60	.04	.64	[2] 2.70
1917–18	6		.08	.11	.21	.08	.10		.58	.04	.62	[2] 2.25
1917–18	6		.08	.10	.21	.08	.13		.60	.04	.64	[2] 3.88
1917–18	6		.12	.17	.31	.13	.13		.86	.04	.90	[2] 4.33
1917–18	6		.12	.17	.31	.13	.13		.86	.04	.90	[2] 3.60
1917–18	6		.12	.17	.31	.13	.13		.86	.04	.90	[2] 3.77
1917–18	6		.10	.17	.33	.13	.15		.88	.04	.92	[2] 3.68
1917–18	6		.10	.18	.32	.13	.15		.88	.04	.92	[2] 3.53
1917–18	6		.14	.18	.41	.19	.14		1.06	.04	1.10	[2] 2.53
1917–18	6		.14	.19	.42	.17	.14		1.06	.04	1.10	[2] 3.49
1917–18	6		.12	.21	.42	.17	.16		1.08	.04	1.12	[2] 2.90
1918–19	4		.17	.47		.25			.89	.78	1.67	[3,17] 4.97
1918–19	4		.17	.47		.25			.89	.78	1.67	[3,17] 4.72
1918–19	4		.17	.39		.16			.72	.78	1.50	[3,17] 4.46
1918–19	4		.17	.39		.16			.72	.78	1.50	[3,17] 3.91
1918–19	3		.17	.30					.47	.78	1.25	[3,17] 4.04
1918–19	3		.17	.30					.47	.78	1.25	[3,17] 4.47
1918–19	2		.52	.33					.85	.90	1.75	[2] 3.89
1918–19	2		.29	.33					.62	.90	1.52	[2] 3.76
1918–19	2		.17	.33					.50	.90	1.40	[2] 4.30
1918–19	2		.35	.25					.60	.90	1.50	[2] 4.30
1918–19	2		.25	.25					.50	.90	1.40	[2] 5.09
1918–19	2		.25	.25					.50	.90	1.40	[2] 3.85
1918–19	2		.29	.16					.45	.90	1.35	[2] 3.04
1918–19	2		.25	.16					.41	.90	1.31	[2] 2.80
1919–20	5		.33	.26		.08	.09		.76	.18	.94	[2] 13.61
1919–20	5		.25	.32		.17	.16		.90	.18	1.08	[2] 14.23
1919–20	5		.17	.29		.25	.25		.96	.18	1.14	[2] 11.36
1919–20	3			.19		.08			.27	.18	.45	[5] 6.69
1919–20	3			.19		.08			.27	.18	.45	[5] 8.07
1919–20	3			.19		.08			.27	.18	.45	[5] 9.65
1919–20	3			.27		.17			.44	.18	.62	[5] 8.19
1919–20	3			.27		.17			.44	.18	.62	[5] 10.57
1919–20	3			.27		.17			.44	.18	.62	[5] 11.46
1919–20	3			.33		.25			.58	.18	.76	[5] 9.15
1919–20	3			.33		.25			.58	.18	.76	[4] 10.84
1919–20	3			.33		.25			.58	.18	.76	[2] 11.62

See footnotes on page 64.

TABLE 17.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in lower Rio Grande Valley, Tex.*—Continued

SPINACH

Year	Irrigations	Monthly application of water in acre-feet per acre							Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Irrigation	Rainfall	Total	
	Number											*Tons*
1914–15										0.49	0.49	[8] 6.15
1914–15	4					0.03	0.07	0.12	0.22	.49	.71	[5] 11.20
1914–15	4					.12	.20	.18	.50	.49	.99	[6] 11.85
1918–19	2			0.15	0.11				.26	.68	.94	[5] 3.34
1918–19	2			.15	.11				.26	.68	.94	[4] 3.04
1918–19	2			.18	.17				.35	.68	1.03	[4] 3.01
1918–19	2			.18	.17				.35	.68	1.03	[5] 2.20
1918–19	2			.25	.25				.50	.68	1.18	[2] 2.12
1918–19	2			.25	.25				.50	.68	1.18	[5] 2.78
1918	2		0.27	.17					.44	.48	.92	[2] 1.13
1918	2		.25	.25					.50	.48	.98	[2] .89
1918	2		.26	.33					.59	.48	1.07	[2] .98

[1] These experiments were conducted under cooperative agreement between the Texas State Board of Water Engineers and the Bureau of Public Roads, U. S. Department of Agriculture. These were plat experiments conducted at station 1 mile south of Mercedes. Soil of west 14 acres consists of light-colored sandy loam underlaid with yellowish sandy loam. Soil of the east 17 acres consists of dark, heavy clay loam underlaid at 4 feet with sandy clay. Soil at Mercedes a gray-black soil of fine texture underlaid with sandy clay subsoil. Rainfall under 0.25 inch, unless followed by another rain in 24 hours, was generally not counted, although lighter showers on shallow-rooted plants during winter seasons were sometimes included.

[2] Clay soil.

[3] 3 frosts occurred, retarding growth, lengthened production period, and increased water requirements.

[4] A normal year.

[5] Sandy soil.

[6] Loam soil.

[7] Estimated 4-inch rainfall was of no benefit to shallow-rooted crop.

[8] Sandy loam soil.

[9] Yield damaged twice by frost.

[10] Rainfall 3.23 inches immediately following irrigation has been deducted.

[11] First crop.

[12] Second crop.

[13] Irrigations 3 and 4 followed by 1-inch and 3-inch rainfall probably reduced effective applications at least 3 inches.

[14] It is probable that 5.94 inches rainfall in September, immediately following an irrigation, was wasted.

[15] At least 2 inches of the 4.04 inches of rainfall in January was of no benefit.

[16] Growth checked by temperature of 24° F. in February.

[17] Crop injured by heavy rains.

TABLE 18.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in lower Rio Grande Valley, Tex.*[1]

SUGARCANE

Year	Irrigation	Monthly application of water in acre-feet per acre										Total quantity of water in acre-feet received by crop per acre			Yield per acre
		Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Irrigation	Rainfall	Total	
	Number														*Tons*
1916	18			0.67	0.34	0.16	0.42	0.35	0.12		0.07	2.13	1.88	4.01	[2, 3, 4] 19.67
1916	13			.67	.26	.25	.36	.31	.18			2.03	1.88	3.91	[2, 3, 4] 21.75
1916	23			.67	.31	.28	.50	.42	.25	0.13	.15	2.71	1.88	4.50	[2, 3, 4] 23.33
1916	15			.67	.28	.28	.42	.41	.22	.15	.12	2.55	1.88	4.43	[2, 3, 4] 25.25
1916	21			.67	.38	.19	.62	.50	.32	.19	.13	3.00	1.88	4.88	[2, 3, 4] 20.00
1916	15			.67	.32	.33	.49	.50	.27	.20	.16	2.94	1.88	4.82	[2, 3, 4] 27.50
1917	15		0.12	.12	.13	.32		.67	.50	1.17		3.03	.97	4.00	[5, 4] 26.3
1917	15		.12	.13	.13	.44		.79	.67	1.33		3.61	.97	4.58	[5, 4] 33.6
1917	17		.13	.08	.22	.25		.50	.33	.83	.17	2.51	.97	3.48	[5, 4] 20.0
1917	17		.13	.12	.29	.36		.67	.50	1.25	.25	3.57	.97	4.54	[5, 4] 33.9
1917	17		.13	.08	.22	.25		.50	.33	.83	.17	2.51	.97	3.48	[5, 4] 30.9
1917	17		.13	.12	.29	.36		.67	.50	1.25	.25	3.57	.97	4.54	[5, 4] 32.18
1917	17		.13	.08	.22	.25		.50	.33	.83	.17	2.51	.97	3.48	[5, 4] 22.94
1917	17		.13	.12	.29	.36		.67	.50	1.25	.25	3.57	.97	4.54	[5, 4] 28.30
1917–18	15	0.19	.09	.08	.14	.08		.22	.35	.51	.34	2.00	1.04	3.04	[5, 4] 18.34
1917–18	15	.16	.09	.08	.18	.10		.25	.50	.75	.50	2.61	1.04	3.65	[5, 4] 26.13
1917–18	16	.32	.08	.08	.22	.13		.33	.78	.93	.62	3.49	1.04	4.53	[5, 4] 37.05
1917–18	15	.19	.09	.08	.14	.08		.22	.35	.51	.34	2.00	1.04	3.04	[5, 4] 14.88
1917–18	15	.16	.09	.08	.18	.10		.25	.50	.75	.50	2.61	1.04	3.65	[5, 4] 26.55
1917–18	16	.32	.08	.08	.22	.13		.33	.78	.93	.62	3.49	1.04	4.53	[5, 4] 35.99
1917–18	15	.19	.09	.08	.14	.08		.22	.35	.51	.34	2.00	1.04	3.04	[5, 4] 18.29
1917–18	15	.16	.09	.08	.18	.10		.25	.50	.75	.50	2.61	1.04	3.65	[5, 4] 29.77
1917–18	16	.32	.08	.08	.22	.13		.33	.78	.93	.62	3.49	1.04	4.53	[5, 4] 30.10
1918–19	9				.13	.08	.10	.17		.52	.34	1.34	2.24	3.58	[5, 6] 20.25
1918–19	9				.17	.10	.12	.21		.75	.50	1.85	2.24	4.09	[5, 6] 21.75

[1] These experiments were conducted under cooperative agreement between the Texas State Board of Water Engineers and the Bureau of Public Roads U. S., Department of Agriculture. Plot experiments conducted at station 1 mile south of Mercedes. Soil of west 14 acres consists of light-colored sandy loam underlaid with yellowish sandy loam. Soil of the east 17 acres consists of dark heavy clay loam underlaid at 4 feet with sandy clay. Soil at Mercedes a gray black soil of fine texture underlaid with sandy clay subsoil. Rainfall under 0.25 inch, unless followed by another rain in 24 hours, was generally not counted, although lighter showers on shallow-rooted plants during winter seasons were sometimes included.

[2] Sandy soil.
[3] Due to excessive rains at least 10 inches was not beneficial.
[4] Plant cane.
[5] Clay soil.
[6] Stubble second-year cane.

TABLE 19.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Lawton, Okla.*[1]

BROOMCORN (DWARF)

Year	Irrigations	Monthly application of water in acre-feet per acre: June	July	Aug.	Sept.	Oct.	Nov.	Total quantity of water in acre-feet received by crop per acre: Irrigation	Rainfall	Total	Yield per acre
	Number										*Pounds*
1919	1		0.06					0.06	0.94	1.00	1,235
1919	2		.07	0.08				.15	.94	1.09	1,550
1919	0							.00	.94	.94	850

BROOMCORN (STANDARD)

Year	Irrigations	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1919	2		0.10	0.14				0.24	0.94	1.18	1,525
1919	2		.10	.15				.25	.94	1.19	1,975
1919	1		.06					.06	.94	1.00	1,076
1919	1		.06					.06	.94	1.00	1,360
1919	0							.00	.94	.94	1,630
1919	0							.00	.94	.94	1,690

FETERITA

Year	Irrigations	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1919	1		0.06					0.06	0.94	1.00	2,275
1919	1		.06					.06	.94	1.00	2,602
1919	1		.05					.05	.94	.99	3,336
1919	1		.11					.11	.94	1.05	3,658
1919	1		.21					.21	.94	1.15	3,905
1919	1		.17					.17	.94	1.11	3,195
1919	0								.94	.94	2,502
1919	0								.94	.94	2,790

KAFIR

Year	Irrigations	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1919	1		0.14					0.14	1.60	1.74	2,628
1919	1		.15					.15	1.60	1.75	2,737
1919	1		.11					.11	1.60	1.71	2,975
1919	1		.11					.11	1.60	1.71	2,550
1919	1		.16					.16	1.60	1.76	2,020
1919	1		.14					.14	1.60	1.74	2,128
1919	0								1.60	1.60	1,825
1919	0								1.60	1.60	2,100
1919	0								1.60	1.60	2,551
1919	0								1.60	1.60	2,111

MILLET

Year	Irrigations	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1919	1		0.23					0.23	0.94	1.17	5,076
1919	0								.94	.94	3,960

MILO

Year	Irrigations	June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	Yield per acre
1919	1		0.10					0.10	1.08	1.18	2,750
1919	0								1.08	1.08	2,000

[1] These experiments were conducted under cooperative agreement between the Bureau of Public Roads and the Oklahoma State Board of Agriculture at the Cameron School of Agriculture, near Lawton. The plots included 0.1 acre each. The soil is a thin upland clay.

TABLE 19.—*Irrigation water applied monthly, rainfall, total water received, and crop yields in Lawton, Okla.*—Continued

Year	Irrigations	Monthly application of water in acre-feet per acre						Total quantity of water in acre-feet received by crop per acre			Yield per acre
		June	July	Aug.	Sept.	Oct.	Nov.	Irrigation	Rainfall	Total	
	Number										*Pounds*
ORANGE CANE											
1919	1		0.14					0.14	1.08	1.22	9,500
1919	0								1.08	1.08	7,500
PEAS											
1919	1		0.10					0.10	1.08	1.18	5,250
1919	1		.07					.07	1.08	1.15	6,700
1919	0								1.08	1.08	5,700
RIBBON CANE											
1919	1		0.31					0.31	1.08	1.39	22,800
1919	0								1.08	1.08	15,800
SUDAN GRASS											
1919	2		0.05	0.41				0.46	0.94	1.40	7,200
1919	1		.10					.10	.94	1.04	7,200
1919	0								.94	.94	7,100
1919	0								.94	.94	3,800

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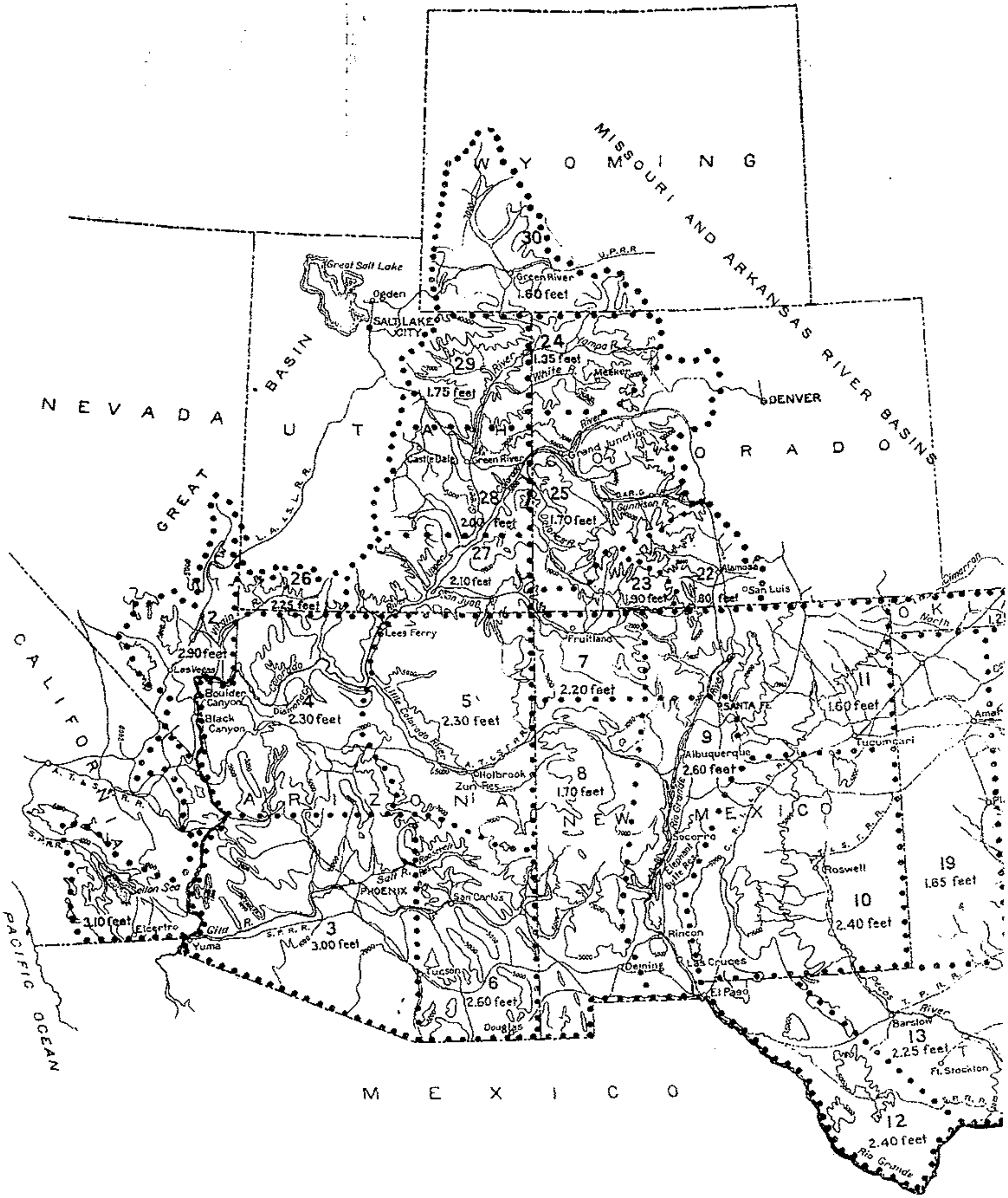
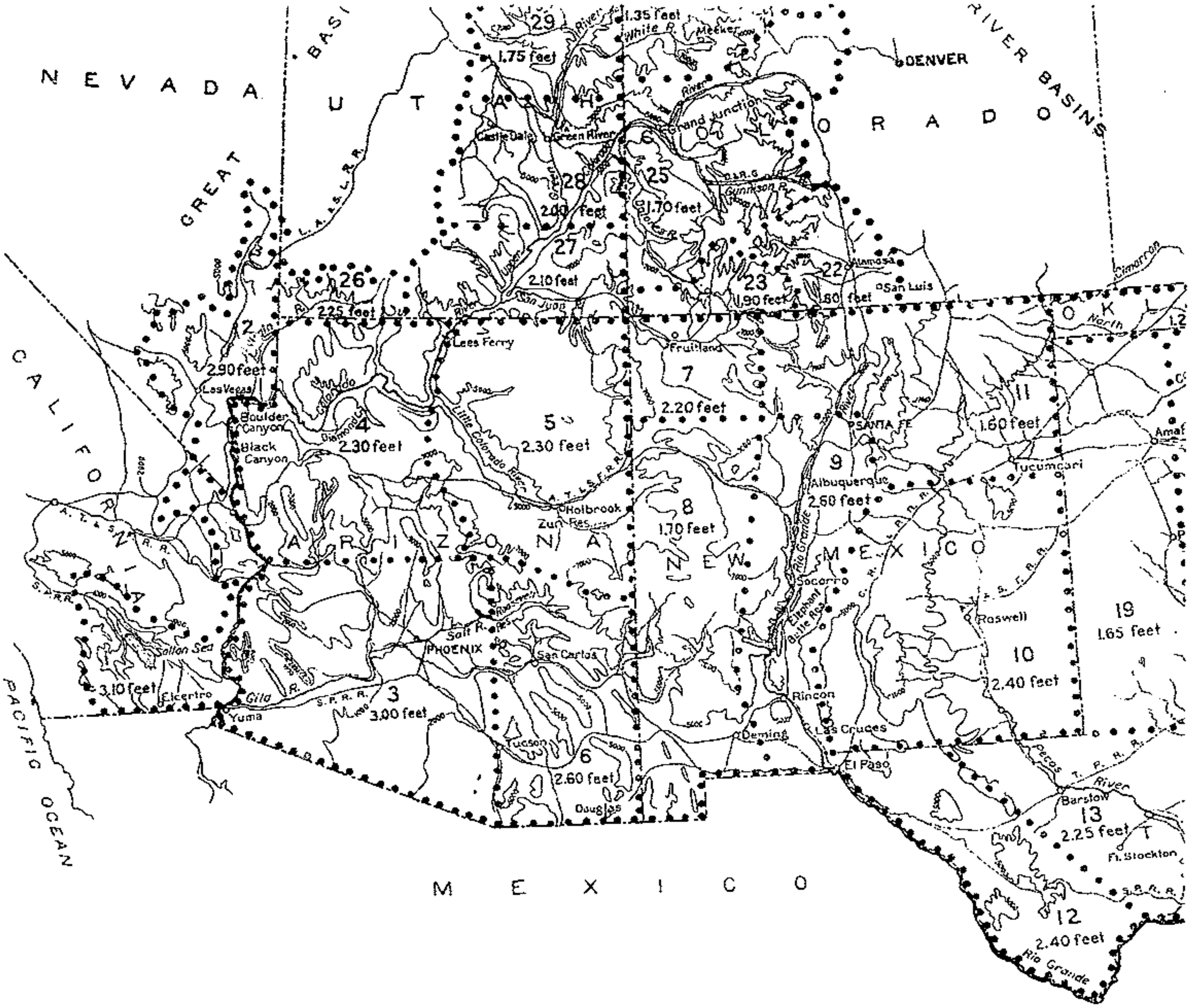


WYOMING
MISSOURI AND ARKANSAS RIVER BASINS
NEVADA
GREAT BASIN
UTAH
COLORADO
CALIFORNIA
ARIZONA
NEW MEXICO
MEXICO
PACIFIC OCEAN
30
Green River
1.60 feet
U.P.R.R.
Great Salt Lake
Ogden
SALT LAKE CITY
24
1.35 feet
Yampa R.
White R.
Meeker
DENVER
29
1.75 feet
Castle Dale
Green River
Grand Junction
D.&R.G.
Gunnison R.
28
2.00 feet
25
1.70 feet
27
2.10 feet
26
2.25 feet
San Juan R.
23
1.90 feet
22
.80 feet
Alamosa
San Luis
Cimarron
North
L.A.&S.L.R.R.
2
2.90 feet
Las Vegas
Lees Ferry
Fruitland
7
2.20 feet
Boulder Canyon
Black Canyon
Colorado
4
2.30 feet
5
2.30 feet
Little Colorado River
A.T.&S.F.R.R.
Holbrook
Zuni Res.
SANTA FE
9
Albuquerque
2.60 feet
11
1.60 feet
Tucumcari
8
1.70 feet
Rio Grande
Socorro
Elephant Butte Res.
Roswell
10
2.40 feet
19
1.65 feet
Salt R.
PHOENIX
San Carlos
Roosevelt Res.
Salton Sea
1
3.10 feet
El Centro
Gila R.
Yuma
S.P.R.R.
3
3.00 feet
Tucson
6
2.60 feet
Douglas
Rincon
Deming
Las Cruces
El Paso
Pecos River
T.&P.R.R.
Barstow
13
2.25 feet
Ft. Stockton
12
2.40 feet
Rio Grande

MISSOURI AND ARKANSAS RIVER BASINS
W Y O M I N G
30
Green River
1.60 feet
Great Salt Lake
Ogden
SALT LAKE CITY
24
1.35 feet
Yampa R.
White R.
Meeker
29
1.75 feet
DENVER
C O L O R A D O
Grand Junction
Castle Dale
Green River
Gunnison R.
28
2.00 feet
25
1.70 feet
27
2.10 feet
San Juan
23
1.90 feet
22
1.80 feet
Alamosa
San Luis
Cimarron
O K L A H O M A
20
1.25 feet
Lees Ferry
Fruitland
7
2.20 feet
5
2.30 feet
Little Colorado River
11
1.60 feet
SANTA FE
9
Albuquerque
2.60 feet
Tucumcari
Amarillo
Canadian
OKLAHOMA CITY
21
1.00 feet
Lawton
Red River
Wichita Falls
Holbrook
Zuni Res.
8
1.70 feet
N E W M E X I C O
Rio Grande
Socorro
Plainview
18
1.35 feet
17
1.10 feet
Fort Worth
Salt R.
PHOENIX
San Carlos
Roswell
10
2.40 feet
19
1.65 feet
Abilene
3
Rincon
Deming
Las Cruces
El Paso
Big Spring
Waco
Tucson
6
2.60 feet
Douglas
San Angelo
Colorado
Pecos River
Barstow
13
2.25 feet
Ft. Stockton
T E X A S
14
1.60 feet
16
1.30 feet
AUSTIN
M E X I C O
12
2.40 feet
Rio Grande
Comstock
Del Rio
San Antonio
Hondo
Eagle Pass
Nueces River
Laredo
15
1.75 feet
OF MEXICO



116469—30. (Face p. 3)

FIGURE 1.—The Southwest, showing the various duty of water divisions (bounded by dotted lines), with the net irrigation requir

RE 1.—The Southwest, showing the various duty of water divisions (bounded by dotted lines), with the net irrigation requirement of each

END