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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 235.

A. C. TRUE, Director.

IRRIGATION IN ARIZONA.

BY

R. H. FORBES,

Director, Arizona Experiment Station.

PREPARED UNDER THE DIRECTION OF

SAMUEL FORTIER,

Chief of Irrigation Investigations.

WASHINGTON:
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OFFICE OF EXPERIMENT STATIONS.

A. C. True, Director.
E. W. Allen, Assistant Director.

IRRIGATION INVESTIGATIONS.

Samuel Fortier, Chief.
R. P. Teele, Assistant Chief.

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IRRIGATION FARMERS.

John H. Gordon, R. G. Hemphill, W. H. Lauck, R. E. Mahoney, and John Krall, Jr.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., February 1, 1911.

Sir: I have the honor to transmit herewith a report on irrigation in Arizona, prepared by R. H. Forbes, director of the experiment station of that Territory, under the direction of Samuel Fortier, chief of irrigation investigations. This is one of a series of reports prepared in this Office for the purpose of giving general information regarding the opportunities for settlement on irrigated lands in the several Western States and Territories, the cost of land and water and of establishing homes on these lands, and regarding the crops grown.

Director Forbes wishes to acknowledge helpful criticism of the chapter on laws and usages relating to irrigation by Ex-Governor Joseph H. Kibbey, of the Territory; hydrographic information received from Assistant Engineer Howard S. Reed and Project Engineer Francis L. Sellew, of the U. S. Reclamation Service; and assistance afforded by Mr. F. C. Kelton of the Arizona Station.

It is recommended that this report be published as a bulletin of this Office.

A. C. True, *Director.*

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTION.

HISTORY OF IRRIGATION DEVELOPMENT.

Irrigation, which for the most part is a prerequisite to agriculture in Arizona, was first practiced in this region by ancient peoples. In the valleys of the Little Colorado, Salt, and Gila Rivers, and along the Verde River and smaller tributaries are found unmistakable remains of ditches and reservoirs, together with ruins of the cliff dwellings and the communal houses of tribes which had been scattered long before the advent of the Spanish explorers. The character of these remains indicates that these ancient Indians possessed considerable skill in the art of irrigating. Their ditches and reservoirs were finished with hard linings of tamped or burnt clay, and one instance is known where a main canal was cut for a considerable distance through solid rock. Sometimes a smaller ditch was sunk in the bottom of a large canal to facilitate the carriage of small runs of water, and thus seepage and evaporation were diminished in times of scant flow (fig. 1). The ancient canals in the Salt River Valley aggregated a length of at least 150 miles and were sufficient for the irrigation of 250,000 acres of land,[1] although it is not likely that the whole of this area was ever watered at any one time (fig. 2). In the ruins of the houses of grouted clay are found relics of cotton and corn; beans, squashes, and tobacco were also grown.

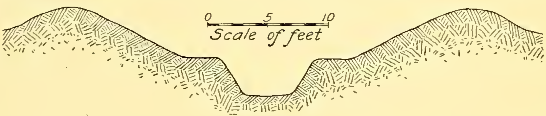

FIG. 1.—Cross section of prehistoric ditch, showing channel in bottom for carrying a small irrigating stream.

The Pimas and Papagos, who are probably descendants of this prehistoric people, have continued to water and till the soil. The Pimas particularly are good irrigating farmers. They are a sedentary tribe which, since modern records began, has maintained itself in the Salt and Gila River Valleys in south-central Arizona. Their nomadic relatives, the Papagos, taking advantage of the uncertain rains which

[1] Prehistoric Irrigation in Arizona, F. W. Hodge, American Anthropologist, July, 1893.

chance upon them, utilize the run-off from summer storms, soak their soil, and plant quick-growing crops of corn, beans, squashes, and melons. The several tribes along the Colorado River—the Mohaves, Chemehuevis, Yumas, and Cocopahs—grow crops in that fertile valley after a peculiar method necessitated by the behavior of the river. Their main crop season begins immediately after the subsidence of the annual flood in July. Millets are sown in the mud flats exposed by the falling waters, much after the fashion of Egyptian irrigators under the old basin system used along the Nile. Other crops, such as corn, squashes, and melons are planted, as soon as the bottom lands are dry enough, in pits sometimes 2 feet deep, from which the plants issue quickly in profuse growth. Sufficient moisture is brought within the reach of the plant roots by this method of deep planting to insure a crop without further irrigation.

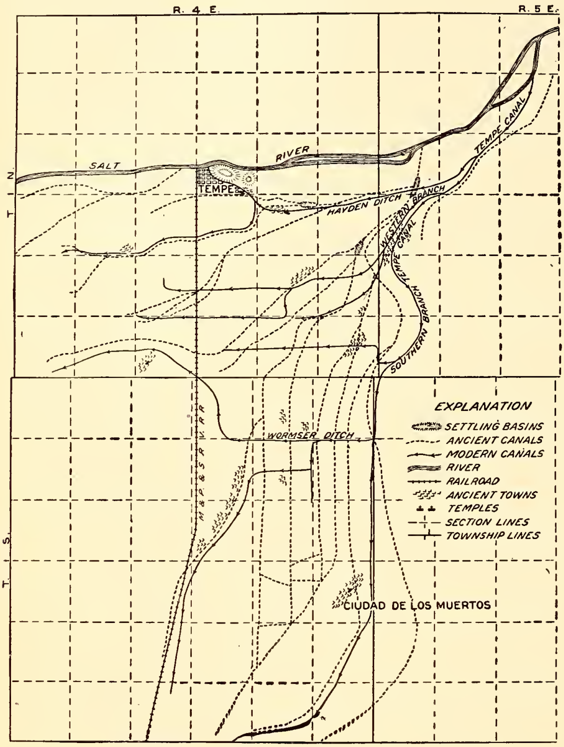

FIG. 2.—Prehistoric and modern canals in a portion of Salt River Valley, located by James C. Goodwin, Tempe, Arizona.

The first European irrigators in Arizona were, without doubt, the Jesuits, who first established themselves at the old missions of Guevavi and San Xavier in 1732. It was not until the more prosperous period from about 1768 to 1822, however, that there was any considerable development of irrigation at favorable points along the Santa Cruz River, near the missions and the Spanish presidios of Tubac and Tucson. During the chaotic period of Mexican rule which followed acequias were maintained, orchards were planted, and annual crops of barley, wheat, corn, tobacco, beans, melons, squashes, and peppers—both native and introduced crops—were cultivated. Although from an engineering standpoint the head works and canals of this period were of the simplest construction and of small extent, the Mexican people were skillful in the management of water and possessed an agricultural aptitude well expressed by them in their phrase "el mano por sembrar"—the planting hand. They also adopted certain ideas in equity, and customs relating to the distribution and use of water, which are approved in the best irrigation practice of the present time. Among these was the rule that water is appurtenant to the land.

The Americans in Arizona received their first instruction in irrigation from the Mexicans. The third, or modern, stage of agricultural development may be said to date from the Gadsden purchase in 1854, after which increasing numbers of Americans—military followers, stragglers from the immigrant stream to California, and pioneers by instinct—began to make permanent homes in the land.

Irrigation in the Salt River Valley began soon after the close of the Civil War, when military occupation of the region was resumed and the Army posts offered the settlers both safety and remunerative prices for their products. Canal construction was rapid, beginning with the old Swilling Ditch in 1867, and 20 years later about as much land had been reclaimed as could be irrigated from Salt River in seasons of scant flow. Nevertheless, during a series of wet years that followed, additional areas were put under cultivation until more ground was nominally reclaimed than could be irrigated by the "critical minimum" water supply. The inevitable hardships which resulted from this condition during ensuing dry years, especially 1898–1904, led to anxious discussion of remedial measures and prepared the way for the construction under United States Reclamation Service auspices of the Roosevelt Storage Dam, which is now (March, 1911), completed.

The second largest irrigated district in Arizona (1911) is in Graham County on the upper Gila River. It was settled by Mexican colonists in 1874 and later by the Mormons in 1879. As in the Salt River Valley, there has been a tendency to overappropriate lands under the available water supply, with consequent distress in dry years. Thus far, however, conditions in this locality are prosperous, owing to the fact that the flow of the Gila River at this point is comparatively regular and fairly adequate to irrigate the area under cultivation, although the total amount of land under ditch is in excess of the water supply.

The Colorado River Valley, although the most extensive and potentially the richest and best watered of the agricultural regions, is the last to be developed through irrigation, principally because of the unmanageable character of this eccentric stream and the large expense of the permanent irrigation works required for its control. Although a few small enterprises near Yuma have achieved temporary successes during the past 15 years, it was not until the United States

Reclamation Service undertook the construction of the Laguna Barrage that the irrigation of considerable areas was assured. The completion of this barrage in March, 1909, presages the early irrigation in Arizona of 90,000 acres of alluvial bottom lands, and later of about 40,000 acres of adjacent mesa.

Along the Little Colorado, the Verde, the San Pedro, and the Santa Cruz Rivers and many smaller streams, numerous ditches take practically the whole of the minimum flow for the irrigation of little farms leveled, often with much labor, in nooks and corners of an angular country.

The progress of irrigation in Arizona during the pioneering stage of American occupation may be suggested by the following summary:

Areas irrigated in Arizona at different dates.

Date.	Source of information.	Area actually irrigated.
		Acres.
1854	Old map in Pima County assessor's office, and Mexican traditions	2,000
1890	Eleventh Census Report	65,821
1899	Twelfth Census Report, Volume VI, part 2, page 820	185,396
1909	Author's estimate	227,770

NOTE.—Lands irrigated by uncivilized Indians within the Territory not included. According to Rev. C. H. Cook, who has lived among the Pimas since 1870, that tribe in 1854 irrigated about 3,000 acres on the Gila below Sacaton. The Moquis and the Navajos in the north, the Mohaves and Chemehuevis on the Colorado River, the Apaches, and the nomadic Papagos of the southwestern district, all irrigated small patches of ground aggregating possibly an additional 2,000 acres. A fair approximation of land crudely farmed by the Indian tribes in 1854 is 5,000 acres.

The continuation of a development which has increased the irrigated area from 2,000 to 228,000 acres in the 55 years of American occupation is worthy of study. With the whole of the minimum surface flow of the Territory now in use and only flood waters escaping, it is evident that any further expansion of agricultural industry must depend upon the storage of flood waters, the development of underground supplies, and improved cultural methods.

AREA AND TOPOGRAPHY.

Arizona has an area of 113,956 square miles, of which all but about 116 square miles,[1] or over 99.9 per cent, is land surface.[2] The Territory is situated in the midst of the semiarid, subtropical region of the southwestern part of the United States and northwestern Mexico. Its remoteness from communications by land or sea and the hereto-

[1] U. S. Dept. Commerce and Labor, Statistical Abstract, 1908, p. 20.

[2] The water surface is occasionally expanded by recurring floods, especially in the Colorado River. The shifting course of this river along the Mexico-California boundary also causes noteworthy changes in the area of the Territory.

fore more attractive domains of Texas and California on either side, have left it to be one of the last of the Commonwealths to be developed. The mining, stock raising, and agricultural industries, however, are now in a stage of rapid advancement.

This great oblong of primitive country—about 340 by 390 miles in its extreme dimensions—may be divided nearly equally into two distinct climatic zones by a somewhat irregular diagonal line running from the point where the Gila River enters the Territory to that point on the Nevada boundary where the Colorado River turns southward. The region north and east of this line consists in large part of comparatively level plateaus 5,000 to 8,000 feet above sea level, diversified by isolated buttes and short mountain chains, and cut by eroded canyons, chief among which is the tremendous chasm of the Colorado River. The southwestern half of the Territory is less elevated and is crossed from northwest to southeast by a succession of low mountain ranges and wide valleys decreasing gradually in altitude from the New Mexico line to the Colorado River. San Francisco Mountain, an extinct volcano in north-central Arizona, 12,794 feet in altitude, is the highest point of land, the lowest being the Colorado River bottoms at the Mexican boundary below Yuma, with an elevation ranging down to 83 feet at times of minimum stream flow.

Nearly the whole visible water loss of Arizona passes by way of the Colorado River to the Gulf of California. The Little Colorado pours most of the run-off of the northeastern plateau into the Grand Cañon of the main stream, while the Gila River collects the drainage of the central and southern parts of the Territory and joins the Colorado just above Yuma.

FLORA.

The indigenous vegetation of the Territory corresponds in different localities to varying climatic conditions, especially rainfall and temperature. Mountain masses and plateaus above 5,000 feet elevation, by reason of their cooler temperature and greater rainfall, are in large part forested, often very densely so. The valleys of intermediate elevation below the forested zone are covered in season with grasses and oftentimes with drought-resistant perennials. These decrease in amount and value as the altitudes grow less, and the conditions become most extreme toward the Colorado River. The narrow ribbons of watered soil along the rivers, widened here and there by artificial means, support a dense and luxuriant growth of vegetation which is largely subtropical in character and indicative of rich returns to the irrigator when the natural resources of climate, soil, and water are administered effectively.

INDUSTRIES.

The principal industries of Arizona are mining, stock raising, agriculture, and transportation. Copper is the principal metal mined, the Territory having led the States of the Union with a smelter output of 256,778,437 pounds in 1907, and of 289,523,267 pounds in 1908.[1] The production of copper in Arizona up to the end of 1909 totals about 3,000,000,000 pounds, with a value approximating $400,000,000.

Stock raising on the open range, principally sheep and cattle, is a very important industry, notwithstanding the great decline in grazing values since 1893. The problems of range administration are now being worked out in the forest reserves of the Territory, which on December 31, 1910, embraced about 14,811,145 acres of important watershed areas wholly or partially forested.

Agriculture, the youngest of the three principal industries of the Territory, is just entering upon a period of rapid advancement both in the areas cultivated and in the intensity of the cultural methods employed. The fluctuating flows of the irrigating streams, with consequent failures of water supply at critical times and unmanageable floods at others, have heretofore restricted and discouraged the operations of irrigation farmers. The installation of the two great Reclamation Service projects, one in the Salt River Valley and the other on the Colorado River near Yuma, and the consequent storage and regulation of the principal irrigating water supplies of the Territory, will soon enable a majority of Arizona farmers to work with their moisture conditions under perfect control. Certainty of crop returns, the diversity of crops possible, the all-year growing season of the southern valleys, and the intensive methods will lead to high and varied productiveness, with land values far above those of the average humid regions of the United States.

By reason of its isolation, Arizona is dependent upon its transportation facilities to an unusual degree. These consist chiefly of three great railroad systems, which, in order of their construction, are the Southern Pacific, the Santa Fe, and the El Paso & Southwestern. The Santa Fe crosses the northern tier of counties from east to west, and with its branches opens up the mining and lumbering districts of the more elevated half of the Territory. The Southern Pacific runs a roughly parallel course south of the Gila River, and its feeders tap the rich mining districts and the warmer irrigated valleys at lower altitudes. The El Paso & Southwestern road affords an outlet for the copper mines of southeastern Arizona and northern Mexico. A few steamboats of shallow draft ply the Colorado River, and in remote localities freighting with teams is still practiced.

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[1] U. S. Geol. Survey, "Mineral Resources of the United States," 1908, pt. 1, pp. 194, 195.

ASSESSED VALUATION AND POPULATION.

The assessed valuation of Arizona property in 1910 was as follows:[1]

Assessed valuation, 1910.

Land and improvements	$12,624,759.90
All mining property	19,714,592.16
Town and city lots and improvements	24,957,628.36
All live stock	7,480,050.00
Railroads	13,224,292.04
All other property	9,912,049.04
Total	87,913,371.50

These valuations are notably low, due to the difficulties incident to the assessment of mines and live stock and to the prevailing custom of rating realty, merchandise, improvements, etc., at one-third to one-half of their actual worth.

The census of 1910 records 204,354 people in the Territory, of which about 26,000 are Indians. The greater part of the population consists of those who have immigrated to the Territory from other States and countries during comparatively recent years and of Mexicans native to the Southwest.

CLIMATE.

The climatic zone within which Arizona chiefly lies may be roughly defined as one which combines a low rainfall with a very high percentage of possible sunshine, a long, hot season, frosty minimum temperatures in winter, and usually a very low atmospheric humidity.

The region of smallest rainfall extends along the Colorado River, the mean annual at Yuma for 38 years being 3.13 inches and at Fort Mohave for 37 years being 5.07 inches. Precipitation increases gradually with elevation east of the river until average maxima of over 20 inches are recorded at the higher stations. The following table shows the average annual precipitation in the three most important watersheds:

Elevation and average annual precipitation of points in Arizona.[2]

Watershed.	Period.	Elevation.	Average annual rainfall.
Colorado—northern Arizona:	*Years.*	*Feet.*	*Inches.*
Fort Mohave	37	604	5.07
Flagstaff	17	6,907	23.87
Holbrook	19	5,069	8.99
Fort Defiance	15	6,500	14.01
Salt River—central Arizona:			
Phoenix	31	1,108	7.27
Camp McDowell	23	1,800	10.38
Prescott	40	5,320	17.40
Fort Apache	32	5,200	18.90
Gila River—southern Arizona:			
Yuma	38	141	3.13
Maricopa	31	1,173	5.83
Tucson	40	2,390	11.66
Bisbee	18	5,500	17.46

[1] Proceedings of the Territorial Board of Equalization of Arizona, 1910.
[2] U. S. Dept. Agr., Weather Bur., Summary of Climatological Data for the United States, secs. 3–4.

The seasonal distribution of the rainfall varies in different portions of the Territory. In the central and western districts the winter rains exceed those of summer, thus favoring the growth of certain winter-growing annuals; while in the southeastern region summer rains predominate, supporting the grasses which constitute the best wild forages.

With respect to temperature and seasons, the Territory may be divided into two distinct regions. The northeastern and more elevated half, although semiarid, is comparatively cool, being frost bound in winter and having temperate summers. The southwestern and lower half may be described as arid-subtropical. The summers are ardent and prolonged, but occasional moderate frosts are known in winter. The mildness of the winters and the length of the summers make possible an all-year succession of crops in southern Arizona, a circumstance which with irrigation will lead to a highly intensive cultural development of that region. The following mean maximum and minimum records, representative of the Territory, are sufficient for illustration:

Mean monthly maximum and minimum temperatures for Prescott and Yuma.[1]

Month.	Maximum.		Minimum.	
	Prescott.[2]	Yuma.	Prescott.	Yuma.
	°*F.*	°*F.*	°*F.*	°*F.*
January	46.9	64.7	20.7	42.0
February	51.6	70.5	24.3	43.8
March	57.8	77.8	29.9	50.3
April	65.3	85.3	36.2	55.2
May	75.2	93.5	42.5	61.6
June	84.2	101.2	48.7	68.7
July	88.1	106.3	59.0	77.4
August	84.9	104.7	58.0	77.8
September	80.3	99.2	48.8	70.3
October	69.0	86.3	38.2	58.5
November	57.4	73.9	27.1	48.6
December	51.2	68.0	26.4	46.0

[1] Arizona Sta. Bul. 20, p. 20.
[2] Altitude of Prescott, 5,320 feet; Yuma, 141 feet.

The daily range of temperature averages about 30° F. and in dry, clear weather it may reach 50° F. occasionally. The extremes of temperature at inhabited points thus far noted are as follows: At St. Michaels, −24° F.; at Parker, 127° F.[1]

The dearth of vegetal covering in the desert regions, the dry air, and the clear skies favor rapid radiation of heat at night. The drainage of cooled air to lower levels further increases the effect of radiation, and the valleys are therefore subject to frosts. In some localities frosts are so late and so variable in time of occurrence as to interfere seriously with the growing of certain fruits sensitive to cold. However, the rise and fall of temperatures are rapid and the

[1] U. S. Dept. Agr., Summary of Climatological Data for the United States, sec. 4, p. 7.

duration of the extremes is short. Low minima of short duration in arid regions, therefore, do less harm than the same temperatures in more humid regions where a certain minimum indicates much longer exposure to killing cold.

The relative humidity is usually low, being least during June, when temperatures are high and rainfall small. Relative humidities of less than 10 per cent are often recorded in June, the annual average for four years at Phoenix being 35 per cent.[1] The so-called dry rains of Arizona, which are of common occurrence during the summer season, attest the extreme aridity of the air at certain times. These "horse-tail" showers start at a few thousand feet altitude, but are entirely evaporated and disappear before reaching the earth.

Wind movement is light ordinarily, averaging from 2.4 miles an hour at Phoenix to 6.9 miles at Prescott.[2] This is a fortunate circumstance in connection with the heat and aridity of the summer season. Dust storms of a few to several hours duration are known, usually during March, April, and May. Thunderstorms occur for the most part in summer. Deep snow falls at higher altitudes, and light snowfall on rare occasions lies in the southern valleys for a short time. Hail storms cause occasional damage, but tornadoes are unknown.

Sunshine percentages are very high, over 80 per cent of the possible being the rule in southern Arizona. Wholly cloudy days are rare. The intense insolation of clear, hot, summer weather is a serious factor in connection with more sensitive crop plants, and shading devices often are employed to advantage.

CROPS.

The northeastern and more elevated part of Arizona, with cold winters and a moderately warm growing season of six to seven months, produces such crops as are grown in the Mississippi Valley in the latitude of the Ohio River. Apples, peaches, pears, cherries, grapes, and other deciduous fruits and berries are very successful with, and sometimes without, irrigation, but the winters are too cold for the subtropical evergreens, such as oranges, olives, eucalyptus trees, and palms. A satisfactory variety of forage and grain crops does well on the plateau. Alfalfa yields two or three cuttings and additional pasturage. Corn, oats, barley, wheat, and rye produce heavily under irrigation, and by dry-farming methods, with proper selection of varieties, are thought to be capable of remunerative returns in favorable localities with rainfall only. Vegetables of various kinds are grown in season in profusion, according to elevation, soil, and moisture available. Flagstaff, with an elevation of

[1] Arizona Sta. Bul. 41, p. 11; Bul. 48, p. 355.

[2] Arizona Sta. Bul. 20, pp. 36 and 37.

6,907 feet, is locally famous for its Irish potato crops, although the acreage is limited. Other small towns along the Little Colorado and its tributaries are distinguished for their comfortable homes and small well-kept farms.

The principal grazing industry of northern Arizona is sheep raising. The flocks of the Territory in 1909 numbered about 1,100,000 head. A considerable number of sheep are driven to southern valleys in the winter for feed, for lambing, and to be shorn.

Under the provisions of the Forest Service lumber also may be counted among the crops of this region. The forest reserves, which now cover all timber not owned privately, are lumbered under expert supervision. Only mature timber may be cut, and the younger trees are thus permitted to expand into the spaces left by the removal of the old ones.

In the southern and western parts of Arizona the great valleys of the Gila, Salt, and Colorado Rivers are distinguished by their extreme conditions of temperature, insolation, small rainfall, and low humidity. These cultural factors enter into varying combinations at different times of the year, thereby causing a succession of growing seasons, each of which is most favorable to certain crops, comparatively few of them being equally hardy to all the climatic combinations. Corresponding to these seasons crop plants of the region may be classified into: (1) Those which are sensitive to extreme heat, but which endure frost; (2) those which are destroyed by frost, but are favored by a long hot growing season; (3) those which are sensitive to extremes of heat and cold; and (4) those which are hardy throughout the entire year. To the class which endures frost, but which is sensitive to heat, belong many garden vegetables, such as lettuce, onions, cabbage, cauliflower, beets, and turnips; grains, including wheat, oats, and barley; and certain legumes, among which are sour clover, lupines, and peas. These frost-hardy crops are planted ordinarily in early fall and harvested in the spring or early summer. A great advantage with their culture is that they grow during the cool season when irrigation water usually is more abundant and labor more comfortable and effective.

The hot-weather crops, which make their growth after danger from spring frosts is over and before the frosts of autumn, include tomatoes, melons, squashes, pumpkins, corn, Kafir corn, sorghum, tobacco, cotton, strawberries, peaches, plums, apricots, almonds, apples, and pears.

Those crops which make their growth after severe frosts in spring and before extreme hot weather include beans, potatoes, summer squashes, cucumbers, and asparagus. These may usually be sown in the mid-fall season, although less successfully because of shorter time before frost.

Chief among the crop plants which are hardy and grow nearly or quite the year round is alfalfa, which in the southern and western parts of Arizona produces five to eight cuttings of hay besides affording two to four months' pasture, and may be made to produce remunerative yields of seed. It is valuable not only for its yield of hay, pasture, and feed, but, by virtue of its contributions of needed nitrogen and organic matter to the desert soils, as a preparation for other crops.

Palms, including the date, the Canary Island, and the Washingtonia, are among the best and most vigorous subtropical evergreens, hardy both to climate and to alkaline or swampy soils. The olive, although somewhat affected by extremes of heat and cold in southern Arizona, is valuable both as an ornament and for its fruit and being drought-resistant and growing in almost any kind of soil, it may be found feasible for cheap lands with a scanty and precarious water supply. Several species of Eucalyptus which are resistant to heat and cold have been introduced successfully, especially *E. rostrata, E. tereticornis, E. polyanthema, E. leucoxylon, E. rudis,* and *E. crebra.* The deep-rooting habit of these trees, their rapid growth, and their many uses point to them as a means of foresting low-lying valleys having an attainable underflow. Citrus trees—orange, grape fruit, and lemon—although more sensitive to frost than date palms, olives, and some eucalypts, prosper fairly well in the comparatively frostless belts, especially those of the Colorado River country and the Salt River Valley. The earliness of Arizona oranges, the first of which are several weeks in advance of the southern California crop, is a commercial advantage, the highest market prices being obtained during November and December for the first shipments. Figs and pomegranates, although deciduous, may be included with this list of trees by reason of their subtropical character. They are both extremely alkali-resistant, and the pomegranate endures drought also.

The following partial list of fruits, vegetables, and forages which mature in different months in southern Arizona may be of interest to prospective settlers:

Fruits, vegetables, and forages grown in southern Arizona.

Months in which they mature.	Fruits.	Vegetables.	Grains and forages.
January	Oranges and pomelos	Lettuce, spinach, radishes, cauliflower.	Alfalfa and barley pasture.
February	Oranges	Lettuce, beets, turnips, cabbage.	Do.
March	Strawberries	Asparagus, carrots, green onions.	Alfalfa and green barley.
April	Strawberries and mulberries.	Peas, cabbage, lettuce, onions.	Do.
May	Strawberries, blackberries, plums, apricots, peaches.	Green corn, new potatoes, squashes, string beans.	Wheat, barley, oats, alfalfa.
June	Strawberries, blackberries, figs, plums, apricots, tomatoes, melons, peaches.	Squashes, cucumbers, onions.	Alfalfa, corn.

Fruits, vegetables, and forages grown in southern Arizona—Continued.

Months in which they mature.	Fruits.	Vegetables.	Grains and forages.
July	Apples, pears, grapes, figs, peaches.	Sugar beets, cucumbers	Alfalfa, cowpeas.
August	Grapes, figs, pears, almonds, peaches.	Chillies, eggplant, beans	Alfalfa, Egyptian corn, sorghum, cowpeas.
September	Dates, melons, pears, grapes, pomegranates, peaches.	Chillies, eggplant, potatoes, beans.	Alfalfa, Egyptian corn, cowpeas, sorghum.
October	Dates, quinces, grapes, pears, apples.	Cucumbers, squashes, string beans.	Alfalfa, sorghum, millet, Indian corn, cowpeas.
November	Dates, olives, grapes, oranges, pears, strawberries.	Celery, lettuce, beans, squashes, potatoes.	Indian corn, sorghum, alfalfa.
December	Dates, olives, oranges, pears.	Celery, radishes, beets, lettuce.	Alfalfa pasture.

Under irrigation the yields of the crops best adapted to the region are high, especially where the soil has been improved by alfalfa and by beneficial river sediments. Some verified records made under fair conditions, collected from time to time in various localities, are as follows:

Yields per acre of various crops in southern Arizona.

Crops.	Yield.	Crops.	Yield.
Alfalfa hay, 4 to 8 cuttings.	6 to 12 tons.	Cabbage	14,000 pounds.
		Onions	5,000 to 20,000 pounds.
Alfalfa, seed crop, 1 cutting.	65 to 650 pounds.	Tomatoes	10,000 to 27,000 pounds.
		Cantaloups	100 to 345 standard crates.
Barley	1,800 to 2,500 pounds.	Strawberries	3,500 to 14,000 ¾-lb. boxes.
Wheat	1,500 to 2,400 pounds.	Egyptian cotton lint	400 to 1,000 pounds.
Barley hay	4 tons.	Corn	2,000 to 2,800 pounds.
Wheat hay	3½ tons.	Seedless raisins	6,000 to 8,000 pounds.
Sugar beets	9 to 19 tons.	Oranges (young trees).	½ to 5 boxes per tree.
Potatoes	3,000 to 15,000 pounds.		
Watermelons	13 tons.	Dates	50 to 250 pounds per tree.

Steer feeding, dairying, poultry keeping, horse and mule breeding, apiculture, and sheep raising are the final and usually the most profitable development of forage production, and the greater part of the forage output of the Territory finds a market in the form of animal products.

MARKETS AND FARM INCOME.

CULTIVATED CROPS.

A large trade in valley products is maintained with the several thriving mining towns of Arizona, which consume large quantities of baled hay, grains, fruits, dairy products, and vegetables. Southern California cities take fat cattle, early fruits, and vegetables. Much finished live stock reaches Kansas City, and more distant eastern markets receive oranges, cantaloups, honey, and other agricultural commodities from Arizona through farmers' shipping associations.

The income per acre to the farmer varies greatly with the character of his operations. Small, intensively cultivated areas not infrequently yield values from $100 to $300 gross per acre annually, while forages and animals may easily return $50 gross per acre annually. Agricultural statistics for 1910[1] indicate that from 183,000 acres of corn, wheat, oats, barley, and hay a total valuation of $5,302,000 was obtained, or an average of $28.97 per crop per acre. This does not include the value of alfalfa seed and pasture produced to an additional value of fully $500,000. When allowance is made for the fact that corn in large part follows barley and wheat on the same ground, the actual productiveness in grains and forages of Arizona lands was more than $30 per irrigated acre. Intensive cultures, including fruits, melons, vegetables, and sugar beets, from an estimated 11,000 acres produced about $2,000,000 worth of products, or about $200 per acre. The total of 194,000 irrigated acres estimated therefore produced values approximating $7,802,000, an average of about $40 per acre. This estimate places Arizona among the first of the Commonwealths of the Union in values per acre produced, a fact due not only to excellent crops, but to the high prices paid in the home markets of the Territory.

LIVE STOCK.

The number, value, and income-producing power of live stock in Arizona on January 1, 1910, were approximately as follows:

Kinds, number, value, and income from live stock in Arizona, January 1, 1910.

Kinds.	Number.[1]	Value.[2]	Income (gross sales during 1909).[2]	
			Amount.	From—
Horses and mules	121,000	$7,778,000	$185,670	Sales.
Milch cows	25,000	1,075,000	1,000,000	Dairy products at $40.
Other cattle	626,000	12,082,000	5,659,261	Beef and veal.
Sheep	1,020,000	3,774,000	4,260,000	Wool and mutton.
Hogs	22,000	209,000	500,000	Pork.
Total	1,814,000	24,918,000	11,604,931	

[1] U. S. Dept. Agr., Crop Reporter, Feb. 7, 1910.
[2] Estimates based on reports of Live Stock Sanitary Commission and current valuations by stockmen.

Besides these there were 5,000 ostriches valued at $1,000,000 and producing $125,000 worth of feathers annually. The number of goats, poultry, and stands of bees or the value of their products is not known.

While the live-stock industry as a whole is but partly supported by irrigation, the irrigated valleys may be considered an essential factor, especially in dairying and the finishing of cattle and sheep for market.

[1] U. S. Dept. Agr., Crop Reporter, Dec. 22, 1910.

FOREST PRODUCTS.

The forests of Arizona should also be included in a broad sense as an agricultural resource, timber being a product of the soil. The pine forests of northern Arizona constitute a timber resource of great value, as yet little encroached upon. Large mills at Williams and Flagstaff have been in operation for nearly 30 years and small mills are scattered at accessible locations elsewhere in the Territory. These mills own considerable forest land which they are now clearing. One of the largest sawmill operators in the Territory states that the annual cut of lumber in northern Arizona is approximately 50,000,000 feet, with a market value of $750,000. The major portion of the forests, however, is included within National Forests. Timber is available within these reserves under Forest Service restrictions, which prevent destructive lumbering.

The stand of merchantable timber thus available for cutting in Arizona, according to available (October, 1909) Forest Service estimates, is as follows: Saw timber, 6,263,800 M feet; cordwood, 14,142,604 cords. Figuring conservatively upon an approximate annual increase of 1 per cent for saw timber and $1\frac{1}{3}$ per cent for cordwood, the annual growth for Arizona would be—saw timber, 62,638 M feet, worth, at $3.25 per M, $203,573, and 188,520 cords of cordwood, worth, at 67 cents a cord, $126,308, making a total output of $329,881.

The National Forest income realized from timber and grazing fees in 1910 was $204,917.52, one-fourth, or $51,229.38, of which was turned over to the Territory for use by the various counties within which the forests lie, and used by them for the benefit of their roads and public schools. In addition to native forests the planting of introduced trees, especially Eucalyptus, offers considerable opportunities in agricultural forestry.

LANDS.

CLASSIFICATION FOR ADMINISTRATION.

Including a limited and variable water surface of approximately 116 square miles, the area of Arizona is about 72,931,840 acres. (Pl. I.) Administratively this area is divided into military reserves, Indian reserves, National monuments and forests, public lands, including those under Reclamation Service restrictions, and lands in private ownership, including railroad grants and private land grants dating from Mexican occupation. The areas of these different classes of lands are approximately as follows:

MAP OF ARIZONA SHOWING STREAMS AND ADMINISTRATIVE DIVISION OF LANDS.

Lands in Arizona.

Class.	Area.	Authority.	Date of information.
	Acres.		
Military reserves	97,932	United States Department of War	Aug. 17, 1908.
Indian reserves	15,055,600	Scaled from General Land Office map.	Do.
National Forests exclusive of alienated lands.[1]	14,083,928	Forest Service Circular 167 and correspondence.	Dec. 13, 1909.
National monuments outside of National Forests and Indian reserves.	61,726	Report of Secretary of Interior	1909.
Total reserves	29,299,186		
Railroad land grants	2,141,435	Proceedings Territorial board of equalization.	Aug., 1909.
Spanish grants and transferred railroad lands.	547,282	do	Do.
Small agricultural holdings	939,142	do	Do.
Patented mining claims	90,000	Estimated from Proceedings territorial board of equalization.	1908–9.
Town lots	8,000	do	1908–9.
Railroad rights of way	34,000	do	1908–9.
Total in private ownership exclusive of unpatented mining claims	3,759,859		
Unappropriated and unreserved public lands, by difference—including a portion of the lands under United States Reclamation Service restrictions.	39,273,755		

[1] The total area of National Forests has been reduced from 15,258,861 to 14,811,145 acres. Figures as to the areas of alienated lands included are not available at this date.

This statement does not include approximately 4,130,100 acres of public lands partly within National Forests and Indian reserves subject to United States Reclamation Service restrictions. Of this area 1,818,300 acres, withdrawn under the first form, can not be entered upon, while the remaining 2,311,800 acres, withdrawn under the second form, may be homesteaded, subject to subsequent decision as to the size of farm unit allowed. University and school lands are not considered separately.

Under the "dry farming" or "enlarged homestead" act, 26,657,280 acres of the unappropriated and unreserved public lands (fig. 3) also have been designated in Arizona as available in 320-acre holdings (November 1, 1910). It is evident, from the above table and statements, that the land situation in Arizona is very complex, and the following brief suggestions are therefore offered as to the acquisition by settlers of lands within the Territory.

METHODS OF ACQUIRING LAND.

UNRESERVED PUBLIC LANDS.

Without going exhaustively into details, the unreserved and unappropriated public lands available under the various provisions of the land laws may be obtained in the following forms:

(1) The homestead of 160 acres, requiring for final proof either five years' residence or 14 months' residence with commutation at $1.25 to $2.50 per acre.

(2) The homestead of 320 acres, for nonirrigable lands which lack sufficient rainfall to produce crops without the system of cultivation commonly known as "dry farming." Proof without commutation privileges is made as in ordinary homestead entry, and one-fourth of the entry must be cultivated continuously, beginning with the third year.

(3) The desert land entry of 320 acres costing 25 cents an acre on entry and $1 an acre annually expended in improvements as evidence of good faith until reclaimed, with $1 per acre in cash to the Government on final proof.

(4) Government land scrip entries, costing from a few dollars to as much as $50 an acre. Scrip sometimes is difficult to obtain.

(5) School lands, which thus far have been leased of the Territory, subject to appraisement in value and purchase when Arizona becomes a State.

(6) For special purposes, as reservoir sites for impounding water, canals, railroad rights of way, etc., public lands may be appropriated so long as they are used in good faith for the purpose for which they were appropriated.

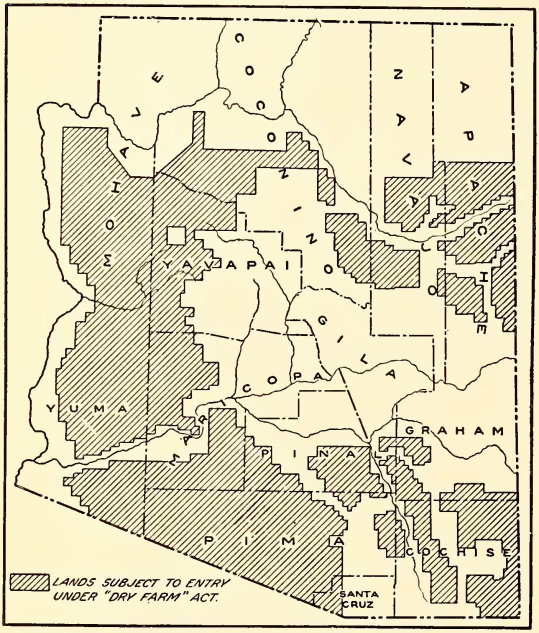

FIG. 3.—Lands subject to entry under the "dry-farm" act.

(7) As mining claims, mill sites, etc., in accordance with the mineral laws.

RESERVED PUBLIC LANDS AND RAILROAD LANDS.

Military and Indian reserves, national monuments, and United States Reclamation Service reserves of the first form are inaccessible to settlers; but in some cases are likely at a future time to be thrown open wholly or in part to entry. Certain of these reserves are of value to irrigation interests as watershed protectors. The Fort Apache and White Mountain reserves, for instance, covering approximately 5,500 square miles, lie in the watershed of the Salt and Gila

Rivers, and conserve and equalize the flow of those important streams. Similarly, the immense but less forested Navajo Indian Reservation may protect a fraction of the Colorado watershed to some extent.

More extensive and important in its relation to irrigation interests is the great system of National Forests, formerly known as forest reserves, which, beginning with the Prescott Reserve in 1899, has grown to a total area of about 15,000,000 acres, comprising all the forest lands in the Territory otherwise unadministered. The National Forests are available for timber, for grazing, for mining, for building and town sites, and for agriculture, under provisions securing the non-destructive use of forest values. Wherever agricultural lands are included within a National Forest they may be listed and entered upon by settlers on practically the same terms as ordinary homestead lands.

The map of Arizona (Pl. II) shows the several Indian reservations, National monuments, etc., as given on the General Land Office map of 1909. The map has been revised so as to show the forest reserves as they existed December 31, 1910.

Considerable areas, mostly along the Colorado River, have been temporarily withdrawn from homestead entry pending investigations as to whether these areas can be ultimately irrigated or utilized in constructing irrigation works. These withdrawals are often only for short periods, and it is not possible to show them on the map with any degree of accuracy.

United States Reclamation Service reserves of the second form may be homesteaded under the United States Reclamation Service regulations, the land laws having been modified so that farm units of 10 to 160 acres, according to the value and productiveness of the land, may be fixed upon as the limit of the entry by the Secretary of the Interior. Commutation privileges do not apply to such entries.

Railroad land grants, more particularly those belonging to the Santa Fe system, are subject to purchase at prices ranging easily from $10 to $200 an acre for unimproved agricultural land favorably situated with reference to irrigating water.

AGRICULTURAL CLASSIFICATION OF LANDS.

According to the general methods by which they may be utilized, the lands of the Territory may be classed as irrigable, dry-farming, grazing, forest, and waste lands. There are considerable tracts of the latter under present conditions.

Except along the Colorado River, lands valuable because of their connection with an actual or possible irrigating or stock water supply have for the most part long since passed into private hands. This area is represented by the 939,142 acres shown in the table, page 23, and lies almost entirely along valley bottoms adjacent to stream courses. The extensive and fertile Colorado Valley is as yet little settled, except under the United States Reclamation Service project near Yuma. This is partly because of the reserved areas situated on this river, but chiefly because of the great annual summer flood and the unmanageable character of the stream. When finally reclaimed by the great engineering projects now under construction or contemplation, the Colorado Valley probably will be one of the most productive agricultural regions within the national boundaries.

Dry farming—that is, farming on rainfall with special attention to the conservation of soil moisture—is apparently feasible in considerable but undetermined areas in the eastern and northern parts of the Territory. In the lower southwestern valleys, excepting during years of unusually abundant or timely rainfall, ordinary dry-farming methods must at least be supplemented by irrigation, and by a careful choice of drought-resistant crop plants and trees especially suited to more severe conditions.

The grazing industries, both cattle and sheep, are at present accommodated in National Forests, upon Indian reserves, and upon unappropriated and unreserved Government lands—the so-called open range. Within the National Forests and the Indian reserves the number of cattle and sheep is under Government regulation, the object being to prevent overstocking and consequent deterioration. The open range, however, is thus far without supervision, and by virtue of the inapplicability of the homestead laws to range country, without ownership also. Lack of ownership and of proper regulation has led to overstocking the ranges during favorable seasons or when prices did not encourage shipment, and when dry years ensue from time to time there are enormous losses, especially of cattle, which are most sensitive to a shortage of feed and water. At these times not only animals suffer, but the ranges themselves sometimes are bared of vegetation and depleted beyond the possibility of complete recovery. Stock raising has been a precarious business because of these conditions. Fortunes have been made during successions of rainy years and lost during the seasons of drought that followed. Under the present lack of administrative control of the open range there is little or no opportunity for further expansion of the grazing industries. Properly controlled, however, with reference to the exigencies of nature and the necessities of individual stockmen, the open range is undoubtedly capable of industrial restoration. The National Forests, including about 14,811,145 acres on December 31, 1910, are probably not more than 50 per cent continuously forested, the remaining area being but sparsely covered with trees, and even the continuous forests often being interspersed with open parks and glades. These unforested portions of the reserves are of interest to settlers, inasmuch as they may be homesteaded for agricultural purposes. Adjacent to purchasable timber and grazing privileges, and oftentimes with small but protected water supply, these forest-reserve locations are usually very desirable. In the northeastern plateau country, also, there are considerable areas of dry-farming lands available for homestead entry within the National Forests.

The waste lands of Arizona are for the most part situated in the western third of the Territory, excluding the Colorado and tributary river bottoms. This vast desert expanse of over 30,000 square miles must always remain waste country, except for doubtful artesian possibilities. There is almost no running water in this region, springs and tinajas are few, and the ground water usually is far below the surface. On rare occasions brief violent storms give rise to short-lived torrents, and are followed by a transient flush of desert annuals, but this can not be utilized by stockmen, because of its distance from dependable forage supply and from water. These desert plains and hostile mountains, peopled with curious and exaggerated forms of drought-resistant vegetation, offer no inducements to the agricultural settler, being a temptation only to the prospector, the naturalist, and the adventurer.

Summarizing briefly, the more apparent opportunities for immigrant farmers in Arizona are: (1) By purchase in irrigated valleys, mainly those of the Salt, Gila, and Colorado Rivers; (2) by homesteading Government lands under Reclamation Service projects and in National Forests; and (3) by homesteading unappropriated and unreserved public lands in localities apparently favorable to dry farming and to development by pumping.

SOILS.

The character of the irrigable valley soils is very variable, both in physical and chemical particulars. Physically, they vary chiefly through the agency of the waters by which they were transported from distant points and through the influence of near-by mountain masses. Coarser soils usually are found nearest the slopes contributing to their formation, where they were deposited from flood waters of higher velocities. Heavy adobe soils, formed of the finest materials, are deposited chiefly through the action of comparatively quiet waters, and at points distant from the place of their origin. In some localities a caliche or calcareous hardpan, formed slowly through the agency of scant rainfall and evaporation, underlies the surface of soils which have remained long in place. The deficiency in humus usual in desert soils is an unfavorable character, in so far as it decreases the water-holding power, injures the tilth, augments losses by erosion, and increases extremes of soil temperature.

Chemically, the arid soils of the Southwest are rich in lime and potash, but deficient in organic matter and nitrogen. These deficiencies may be remedied very cheaply in Arizona by means of leguminous plants, including peas, lupines, sour clover, bur clover, and, chief of all, alfalfa. The latter crop yields remunerative returns and at the same time improves the soil for grain, garden vegetables, or fruit trees through the addition of atmospheric nitrogen and organic matter resulting from the decay and incorporation of its roots and leaves.

The fertility of irrigated soils in most localities is maintained also by the sediments contributed by the river waters. These sediments often contain large amounts of partially decomposed animal and vegetable matter swept by storms into the irrigating streams from the surface of the range country. When incorporated with the soil by suitable methods of culture, they contribute materially to crop production. In this way the southwestern farmer's fertilizer tax is paid in large part, quietly and without extra expense, by his water supply.

Consequent upon arid conditions, the soils of the Southwest contain notable quantities of soluble or alkaline salts varying locally in amount and kind. The irrigated districts in Arizona being comparatively well drained, injurious percentages of alkali salts are not common. These salts have accumulated, however, in certain localities where irrigation has been excessive and drainage neglected, to a degree that depreciates seriously the productiveness of the land. Intelligent methods of culture and the choice of alkali-resistant crop plants will, to some extent, overcome or utilize alkaline accumulations; but good drainage, which should be secured under any well-planned irrigating system, is the most satisfactory expedient for the purpose.

It may be stated briefly, therefore, that the soils of this region are rich in certain elements of fertility; that their deficiencies in nitrogen and organic matter are remediable; and that the management of harmful accumulations of alkaline salts is facilitated by generally favorable drainage conditions.

WATER RESOURCES.

The critical factor in Arizona agriculture is not land but the water supply. Excellent lands are nearly everywhere in excess of the water available for their irrigation, and under present conditions the minimum flows of the interior streams are consumed comparatively near their sources while the lower courses are left dry except in times of flood. The Colorado River, accumulating its flow from an immense watershed outside of the Territory, carries an amount of water

HYDROGRAPHIC MAP OF ARIZONA

greatly in excess of the requirements of alluvial bottoms and irrigable bench lands lying along its lower courses in Arizona. This excess, however, will be greatly diminished when the possible demands of upstream districts and of the delta in Mexico and the Californias are satisfied. Considering the whole Territory, even after storage has been provided sufficient to retain the floods which now escape from the region so much in need of them, only a comparatively small acreage can be irrigated. (Pl. II.)

This deficiency in run-off, due primarily to scant rainfall, is compounded by thirsty soils, excessive evaporation from land and water surfaces, and the pervious formations common in the débris-filled valleys which often entirely absorb small streams. The following table affords an interesting comparison between the elements of gain and of loss in two streams of the humid region and an arid-region river:

Comparison of rainfall, evaporation, and run-off in humid and arid regions.

Stream.	Date.	Water-shed.	Rainfall.	Evapora-tion.	Run-off.
		Sq. miles	*Inches.*	*Inches.*	*Inches.*
Hudson River, New York [1]	1888–1901	4,500	44.2	20.9	23.3
Muskingum River, Ohio [1]	1888–1895	5,828	39.7	26.6	13.1
Salt River, Arizona	1889–1901	12,260	[2] 16.8	[3] 76.1	2.26

[1] U. S. Geol. Survey Water-Supply and Irrig. Paper No. 80, p. 99.
[2] Average of U. S. Weather Bureau rainfall records, including 1908, for stations at Fort Apache, Arizona Canal Dam, Tonto, Prescott, Jerome, and Natural Bridge.
[3] Average of observations at the station farm, Phoenix, and the University at Tucson.

The precipitation on the Salt River watershed not only is less, but the evaporation—possible, not actual—is vastly greater than on the eastern watersheds. The loss by seepage in the stream bed is probably greater also. It is not surprising, therefore, that under these conditions the proportion of run-off to rainfall is less than from humid-region watersheds. Arid conditions apparently return upon themselves, involving nature in a circle of moisture losses that requires the best skill of the engineer and the irrigator to break.

Irrigating waters, as known and utilized in Arizona, may be classed as surface streams, ground waters, and artesian wells.

SURFACE STREAMS.

COLORADO RIVER.

Nature of watershed.—The lower Colorado River is the largest apparent water supply available for irrigation in Arizona, but it is also the least utilized in proportion to its value. The area of its watershed, including the delta region below Yuma, is about 300,000 square miles, lying approximately between latitudes 31° and 43½° N., within the boundaries of Wyoming, Utah, Colorado, New Mexico, Nevada, Arizona, California, and Old Mexico. The axis of the area lies nearly north and south and its drainage passes off from the southwest corner into the Gulf of California. It rises to an elevation of over 14,000 feet in Colorado.

The upper two-thirds of the watershed consists largely of plateaus 4,000 to 8,000 feet above sea level, bounded by the high mountains in which rise the headwaters of tributary streams. The rain and snowfall in this higher portion of the drainage is equivalent to 8 to 30 inches of water. The climate is temperate in character because of the altitude and latitude, and in the higher mountains there are regions of perpetual snow. The higher plateaus and the mountain ranges of the Colorado watershed are considerably forested, although in some sections serious inroads have been made upon the forest cover. The regions of middle elevation are comparatively bare and are remarkable for the great systems of deep canyons resulting from the slow elevation of the Rocky Mountain masses, the restricted local erosion due to scant rainfall, and the constant attrition along drainage lines of never-failing streams from the higher mountains.

The lower third of the Colorado Valley, for the most part in Arizona and California, is below an altitude of about 4,000 feet. This region is arid or semiarid in character, the average annual rainfall ranging from 13 to 20 inches. By reason both of its low elevation and its southerly latitude its temperatures are semitropical.

The characteristic flow of the lower river is due to the peculiarities of the watershed briefly described above. The winter season for the upper Colorado is a time of water storage due to the accumulation of heavy snowfall in the mountains of Wyoming, Utah, and Colorado. At this time the river sinks to its minimum flow, though occasionally augmented from the Gila at Yuma by the irregular run-off due to somewhat eccentric winter rains in Arizona. With the opening of spring the melting of the winter's store of snow begins in the southern latitudes and at lower altitudes, increasing and extending until during May and June thousands of little streams and rivulets are converging from many mountain sides into the main watercourses. The Green River is formed in this manner from the mountain slopes of southwestern Wyoming, northwestern Colorado, and the eastern half of Utah, while the Grand is derived from the even steeper watersheds of western Colorado. These two rivers unite in southeastern Utah to form the Colorado proper, into which flows successively the San Juan, the Little Colorado, and lesser tributaries, which complete the drainage from the more elevated part of the watershed.

The run-off of this region is comparatively uniform in time and quantity, giving rise to the annual summer flood which begins about April 15 and continues until approximately July 15. Irregularities occur, due to deficient snowfall some years, to the chinooks or warm winds which at times cause rapid melting, and to other climatic influences. In recent years also deforestation of certain areas has left snow surfaces more exposed. This has resulted in earlier and quicker melting and tended toward briefer and higher floods.[1] With the dwindling of the snows the upper river falls gradually to a low stage in September, at which it usually remains with minor fluctuations until the next spring.

The upper Colorado River, with its steep gradients averaging 5.7 feet to the mile, from the source of the Green to Grand Wash at the Nevada line, is an eroding stream which carries a heavy load of sediment. For the last 600 miles of its course, however, from the mouth of the Grand Canyon to the sea, the gradients are gentle, averaging but 1.7 feet to the mile, and as the current slackens the river drops its sediment and changes from a land destroyer to a land builder. By this means the alluvial ground bordering the lower courses of the river has been formed, and the delta extending on the west into the depressions of Salton and Pattie Basins is still being pushed southward into the Gulf of California.

The immense quantities of silt carried in the course of a year are shown in the following statement of results obtained by multiplying the percentage of silt found in daily samples of water by the total flow of the river:

Silt carried by the Colorado River annually.[1]

Year.	Amount of silt.	Equivalent area of submerged mud 1 foot deep.	Equivalent area of dry soil 1 foot deep.
	Tons.	*Acres.*	*Acres.*
1900......	61,000,000	104,960	33,920
1904......	120,961,000	181,900	58,681

[1] Arizona Sta. Buls. 44, p. 200; 53, p. 60.

These figures explain the rapidity with which changes in land surface and in sea room are occurring near the mouth of the Colorado. The building up of the margins of the lower river by deposited sediment also so elevates the stream above the adjacent country that sudden and sometimes disastrous changes result from the breaking of these high banks. Salton Sea was formed by such a break in 1905–6, and other changes of direction in the delta have occurred since that time.

Under primitive conditions agricultural operations are governed by the annual flood which overflows the alluvial margins and delta of the river, and the growth of winter crops ordinarily harvested from April to July is prohibited. The Indians of the Colorado Valley, like the people of ancient Egypt, grow only such crops as can be planted in the

[1] Colorado Sta. Bul. 55; U. S. Geol. Survey Water-Supply and Irrig. Paper No. 234, pp. 10–24; also opposite view in Am. Soc. Civil Engineers, Proc. Sept. 1908, pp. 924–997.

wet soil left by the receding waters. Quick-growing varieties of corn, beans, melons, squashes, and sorghum are among the principal crops thus grown.

Discharge.—In the southern lower watershed the Gila River collects the drainage from lesser altitudes and, flowing west across southern Arizona, delivers its waters to the Colorado River at Yuma, about 90 miles by channel above its mouth. The Gila is a comparatively small and irregular stream, due to its arid watershed and uncertain rainfall, although occasionally it carries enormous floods. Since the appropriation of its upstream waters for irrigation its lower courses are often dry for months in succession.

The following table, compiled from reports of the United States Geological Survey and the United States Reclamation Service, gives the mean monthly flow and the total annual discharge of the Colorado and Gila Rivers at Yuma and other points for the years 1902–1909:

Flows in thousands of acre-feet of the Colorado River at Hardyville and Yuma, and of the Gila River near Yuma, 1902–1909.[1]

Year and place of measurement.	Jan.	Feb.	Mar.	Apr.	May.	June.
1902.						
Colorado at Yuma	229.2	219.7	301.5	367.7	2,211.2	2,530.1
Gila at Yuma	....	....	....	....	....	....
Colorado, net, at Yuma	229.2	219.7	301.5	367.7	2,211.2	2,530.1
1903.						
Colorado at Yuma	189.9	187.3	376.1	852.4	2,074.3	3,162.5
Gila at Yuma	0	0	0	30.2	.8	0
Colorado, net, at Yuma	189.9	187.3	376.1	822.2	2,073.5	3,162.5
1904.						
Colorado at Yuma	223.5	218.4	367.6	479.5	1,703.0	2,607.1
Gila at Dome	0	0	0	0	0	0
Colorado, net, at Yuma	223.5	218.4	367.6	479.5	1,703.0	2,607.1
1905.						
Colorado at Yuma	499.9	1,561.0	3,108.0	2,251.0	2,593.0	4,550.0
Gila at Dome	189.2	680.3	1,020.0	768.2	299.7	43.1
Colorado, net, at Yuma	310.7	880.7	2,088.0	1,482.8	2,293.3	4,506.9
Colorado at Hardyville	....	....	....	....	1,973.0	4,508.0
1906.						
Colorado at Yuma	422.0	531.0	1,560.0	1,930.0	3,330.0	5,010.0
Gila at Dome	136.0	168.0	576.0	422.0	122.0	4.6
Colorado, net, at Yuma	286.0	363.0	984.0	1,508.0	3,208.0	5,005.4
Colorado at Hardyville	297.0	327.0	756.0	1,880.0	3,970.0	5,670.0
1907.						
Colorado at Yuma	1,320.0	1,040.0	1,480.0	2,100.0	2,330.0	5,640.0
Colorado at Hardyville	502.0	600.0	1,030.0	1,890.0	2,760.0	5,110.0
1908.						
Colorado at Yuma	389.0	817.0	990.0	1,060.0	1,670.0	2,550.0
1909.						
Colorado at Yuma[2]	615.7	772.8	975.1	1,805.0	3,324.7	6,240.5

[1] U. S. Geol. Survey, Water Supply and Irrigation Papers Nos. 85, p. 20; 100, pp. 25, 27; 133 pp. 32 206; 134, p. 25; 175, p. 130; 177, p. 16; 211, pp. 99, 125; 213, p. 29; 249, p. 46.
[2] United States Reclamation Service measurements.

Flows in thousands of acre-feet of the Colorado River at Hardyville and Yuma, and of the Gila River near Yuma, 1902–1909.

Year and place of measurement.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1902.							
Colorado at Yuma	770.3	257.2	227.2	264.3	249.1	332.8	7,960.2
Gila at Yuma							(1)
Colorado, net, at Yuma	770.3	257.2	227.2	264.3	249.1	332.8	7,960.2
1903.							
Colorado at Yuma	2,304.5	668.3	403.8	521.5	321.3	267.0	11,329.0
Gila at Yuma	0	9.2	7.3	13.6	0	0	61.2
Colorado, net, at Yuma	2,304.5	659.1	396.5	507.9	321.3	267.0	11,267.8
1904.							
Colorado at Yuma	1,417.1	1,054.1	691.5	715.8	366.0	275.3	10,119.0
Gila at Dome	5.8	139.6	41.7	32.8	6.5	0	226.4
Colorado, net, at Yuma	1,411.3	914.5	649.8	683.0	359.5	275.3	9,892.6
1905.							
Colorado at Yuma	1,864.0	744.0	386.5	494.2	714.0	946.9	19,712.5
Gila at Dome	4.3	0	3.0	11.0	271.2	375.1	3,665.1
Colorado, net, at Yuma	1,859.7	744.0	383.5	483.2	442.8	571.8	16,047.4
Colorado at Hardyville	1,556.0	726.2	414.9	527.0	452.6	559.4	(2)
1906.							
Colorado at Yuma	2,400.0	1,180.0	696.0	719.0	578.0	1,130.0	19,490.0
Gila at Dome	0	25.1	4.3	0	0	332.0	1,790.0
Colorado, net, at Yuma	2,400.0	1,154.9	691.7	719.0	578.0	798.0	17,700.0
Colorado at Hardyville	2,460.0	1,130.0	797.0	719.0	587.0	569.0	19,162.0
1907.							
Colorado at Yuma	5,930.0	2,310.0	1,380.0	836.0	643.0	458.0	25,500.0
Colorado at Hardyville	4,630.0	2,000.0	1,090.0				
1908.							
Colorado at Yuma	2,000.0	1,490.0	678.0	585.0	481.0	978.0	13,700.0
1909.							
Colorado at Yuma[3]	4,896.9	2,508.5	2,888.6	860.8	561.9	517.1	25,967.6

[1] Very small. [2] Incomplete. [3] United States Reclamation Service measurements.

The Colorado proper at Yuma, after deducting the Gila, is shown to deliver from about 8,000,000 to over 25,000,000 acre-feet of water annually; and the Gila from a few thousand to 3,665,000 acre-feet. The flow of the Colorado, excluding the Gila, for the years 1902 to 1909, inclusive, during which regular measurements have been taken at Yuma, has averaged about 16,000,000 acre-feet annually. Allowing for the years of exceptionally high water included above, it is estimated that the Colorado alone at Yuma carries a safe average of 12,000,000 acre-feet of water a year with an eccentric and very variable run-off from the Gila in addition. It is of interest to note that during 1906, 1,500,000 acre-feet less water was carried by the Colorado at Yuma than at Hardyville, 270 miles above. This loss, occurring mainly during the flood season, apparently is due to the absorption of overflow waters by the dried-out lowlands and by evaporation, similar to that of the Nile below the Atbara, its last important tributary.[1] What portion of the total flow of the Colorado River, as measured at Yuma, will be available for irrigation in Arizona, is a matter which can only be approximated at this time.

Storage possibilities.—The Gila floods will be stored in large part in the reservoirs projected on the Salt, Verde, and Gila Rivers. Surveys for reservoirs having an aggregate capacity of about 3,000,000 acre-feet, including the Roosevelt Reservoir of 1,284,000 acre-feet, have been made on the principal sites. The greater part of the run-off of the Little Colorado River and its tributaries in northern Arizona likewise can be utilized and stored.

After deducting these tributaries, the main dependable supply for irrigation in western Arizona, southern California, and the Mexican delta must come from the upper branches of the Colorado in Wyoming, Colorado, and Utah, and the disposition of these upper streams is consequently of vital interest to prospective downstream irrigators. Probable developments can be surmised only in a very general way at this time. According to the best information available, there are now approximately 420,000 acres irrigated above the Grand Canyon of northern Arizona, with additional areas to the extent of a possible 750,000 acres, to which water may be applied ultimately. A rough outline of the probable effect of these extended operations upon the Colorado is supplied by the following table, which is offered as an approximation based upon estimates of agricultural areas derived from irrigation engineers resident in Wyoming, Utah, and Colorado, and of run-off and duty of water from United States Reclamation Service records:

Estimates of upstream water surplus of Colorado River.

Supply streams and places of measurement.	Area irrigated in watershed in 1908.	Estimated additional irrigable area.	Duty of water.	Water required to irrigate additional area.	Average run-off available.	Surplus.
Wyoming:						
Green River at Browns Park, Colo	*Acres.* 100,000	*Acres.* 600,000	*Acre-feet per acre.* 2	*Acre-feet.* 1,200,000	*Acre-feet.* 2,500,000	*Acre-feet.* 1,300,000
Colorado:						
Yampa River at Maybell, Colo	42,680	95,000	2.5	237,500	1,000,000	762,500
White River at Rangely, Colo	3,853	50,000	2.5	125,000	400,000	275,000
Grand River at Palisades, Colo	84,900	232,000	2.5	580,000	3,000,000	2,420,000
Gunnison River at Whitewater, Colo	131,800	190,000	2.5	475,000	2,000,000	1,525,000
Dolores River at Dolores, Colo	9,445	60,000	2.5	150,000	300,000	150,000
San Juan River at Farmington, N. Mex	48,918	123,000	3	369,000	800,000	431,000

[1] Ann. Rpt. Smithsonian Inst., 1908, p. 485, Some Geographical Aspects of the Nile.

Estimates of upstream water surplus of Colorado River—Continued.

Supply streams and places of measurement.	Area irrigated in watershed in 1908.	Estimated additional irrigable area.	Duty of water.	Water required to irrigate additional area.	Average run-off available.	Surplus.
Utah:						
Duchesne and Uinta Rivers at Myton and Fort Duchesne, Utah	*Acres.*	*Acres.* [1] 180,000	*Acre-feet per acre.* 2	*Acre-feet.* 360,000	*Acre-feet.* 660,000	*Acre-feet.* 300,000
Additional run-off below gaging stations, estimated	....	....	....	....	....	1,500,000
Total	321,596	1,530,000	....	3,496,500	10,660,000	8,663,500

[1] Indian reserve.

It is believed that in this table the estimates of additional areas to be irrigated and the allowance of water therefor are liberal, and those of run-off reasonably accurate. It appears, therefore, from these figures that after allowing for prospective upstream developments there remains a vast excess of water, especially in the rivers of western Colorado—an excess which may be stated in round numbers at 9,000,000 acre-feet. This supply, once delivered to the deep canyons which begin in eastern Utah, can not be drawn from again until it emerges upon the alluvial levels of the lower Colorado in western Arizona.

Most of the run-off, however, occurs in May and June; and its complete utilization by downstream districts will require storage to retain this flood and equalize the flow of the river throughout the downstream irrigating season. Fortunately there are many reservoir sites on the upper watershed of the Colorado, some of them very extensive. A few of the largest are named below, there being many smaller sites:

Proposed upstream reservoir sites on the Colorado River and tributaries.

Reservoir sites.	Height of dam required.	Storage capacity.	Authority.
	Feet.	*Acre-feet.*	
Flaming Gorge, on Green River in northeastern Utah.	100	350,000	United States Reclamation Service.
Browns Park, on Green River in northwestern Colorado.	200	2,520,000	Do.
Island Park, on Green River in northeastern Utah.	100	150,000	Do.
Mouth of Minnie Maud Creek, on Green River in eastern Utah.	120	1,200,000	Records of office of State engineer, Salt Lake City, Utah.
Green River, 27 miles north of Green River, Utah.	155	800,000	Do.
Kremmling, on Grand River in northern Colorado.	230	2,200,000	United States Reclamation Service.
Junction of Green and Grand Rivers in southeastern Utah.	160	2,500,000	Records of office of State engineer, Salt Lake City, Utah.
Total	....	9,720,000	

In general there appears to be abundant storage room for the surplus waters shown in the table on page 34, should the sites prove feasible and the expense of construction be warranted by the agricultural values in Arizona, California, and Mexico. The rocky canyons of the Colorado for the 700 miles between the mouth of Grand River and the upper irrigable areas in Arizona should convey the equalized stream with minimum loss to those lower districts whose unusual productiveness may at some future time warrant upstream reservoirs.

As to the maximum probable areas and water requirements of the lower districts, allowing 5.5 acre-feet per acre, we have a fair approximate knowledge, as shown in the following table, derived chiefly from United States Reclamation Service data:

Irrigable areas and water requirements in southern Arizona, California, and Mexico.

District.	Irrigable areas.	Irrigation requirements.
Arizona:	*Acres.*	*Acre-feet.*
Mohave Valley	47,171	1,933,910
Colorado Valley	133,536	
Yuma Valley	90,913	
Mesa lands at Parker (by pumping—estimated)	40,000	
Yuma (irrigable by pumping)	40,000	
Total	351,620	
California:		
Mohave Valley	17,395	2,874,207
Colorado Valley	80,588	
Yuma Valley	24,600	
Imperial Valley	400,000	
Total	522,583	
Mexico:		
Colorado delta and Pattie basin lands	500,000	2,750,000
Grand total	1,374,203	7,558,117

It appears, therefore, estimating acreages liberally and assuming high water duties, that the equalized surplus of 9,000,000 acre-feet, roughly calculated to be available from the upper Colorado, will be adequate for the reclamation of all irrigable downstream areas. The details of the estimates presented above may be considerably modified with increased knowledge of the vast region involved, but in a general way it may be stated with considerable confidence that the water supply of the Colorado, with storage, is sufficient for the whole of its dependent irrigable lands. This is a most fortunate fact in view of the interstate and international character of this stream, looking toward a harmonious and confident development of all portions of the Colorado watershed, including those areas in Arizona with which this publication is chiefly concerned, and for which an ultimate water requirement from the Colorado of approximately 2,000,000 acre-feet, annually, should be anticipated.

In addition to its agricultural value, the Colorado has immense power possibilities, especially along the canyons of the upper river and its tributaries, with their steep gradients and numerous dam sites. By reason of gentler gradients, power development along the lower Colorado will be small in proportion to the size of the stream, but valuable by reason of the contiguous agricultural and industrial population which will occupy this region ultimately.

LITTLE COLORADO RIVER.

The watershed of the Little Colorado, situated almost entirely in northeastern Arizona, is a plateau region, lying for the most part between 5,000 and 7,000 feet altitude. This plateau is diversified with square-topped hills or buttes and intersected by watercourses which deepen into precipitous canyons as they approach the Colorado. The rainfall averages about 10 inches, this small precipitation being due to the loss of moisture from north-bound winds on the southern slopes of the Mogollon rim, which divides the plateau from the lower and warmer part of the Territory. The run-off is small, and, because of the porous character of stream beds, hard to estimate satisfactorily. Measurements at various points by the United States Reclamation Service are as follows:

Stream measurements on Little Colorado River.

Place of measurement.	1905	1906	1907	1908
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
Little Colorado at St. Johns		[1] 24,400	50,973	[2] 17,649
Little Colorado at Woodruff	[3] 114,400	85,200	72,543	
Little Colorado at Holbrook	[3] 213,700	117,000	[4] 78,498	
Silver Creek excess at Snowflake		1,440		
Chevelon Fork near Winslow		80,300	176,179	1,047,555
Clear Creek near Winslow		[5] 22,300		282,336
Total	328,100	330,640	378,193	1,347,540

[1] April to December, inclusive.
[2] January to August, inclusive.
[3] March to December, inclusive.
[4] January to April, inclusive.
[5] June to December, inclusive.

Deducting flood waters at St. Johns and Woodruff, the measurement of which is repeated in large part at Holbrook, the net run-off thus far measured has been about 250,000 to 1,300,000 acre-feet from the watershed of approximately 15,000 square miles above Winslow. Storage is possible for this run-off as follows:

Storage possibilities on the Little Colorado River.

Place of storage.	Contour.	Capacity.
Little Colorado from Woodruff to St. Johns:	*Feet.*	*Acre-feet.*
Woodruff reservoir	100	108,000
Forks reservoir above Woodruff	85	148,000
Udall reservoir at Hunt		13,000
Lyman reservoir above St. Johns		20,000
On Silver Creek:		
Snowflake and Taylor reservoirs (large additional storage possible in this vicinity)		3,900
Below Holbrook:		
Le Roux reservoir	35	54,000
Tucker Flat reservoir near Winslow	50	117,000
Total		463,900

So far as these fragmentary data show, ample storage is possible for the entire run-off of the Little Colorado above Woodruff and for a portion of the flood waters of Chevelon and Clear Creeks. With storage, probably 300,000 acre-feet annually of the run-off of northeastern Arizona can be utilized for irrigation, which, assuming a duty of 3 acre-feet annually as necessary for a region of high elevation and relatively short growing season, should irrigate about 100,000 acres.

SALT RIVER.

Nature of watershed.—The watershed of Salt River, including that of its nearly equally large tributary, the Verde River, has an area of 12,240 square miles lying in central and east-central Arizona. Nearly the whole of this watershed is mountainous, ranging from an altitude of 1,310 feet at the Granite Reef diversion dam, 27 miles above Phoenix, to upward of 10,000 feet in the White Mountains, near the New Mexico boundary. The main tributaries of upper Salt River—Bonita, White Mountain, Carrizo, Cibicu, Canyon, Cherry, and Tonto Creeks—all come from the north and drain the southern escarpment of the northern plateau country. The Verde River, with its own system of tributaries, also flows from the north into the Salt River at the head of Salt River Valley.

The region of highest rainfall in Arizona is due to the high south slopes of the Salt and Verde River watersheds which precipitate the moisture of the winds from southerly directions. This rainfall occurs in two not very sharply defined seasons, summer and winter. The summer rainfall, for the most part in July and August, is largely torrential in character, resulting in sudden floods which are largely lost downstream, and in intervening seasons of low flow. The winter rains are usually gradual in character and generate a more uniform stream flow. The winter precipitation on higher ranges also is largely in the form of snow, the melting of which in the spring equalizes and prolongs the irrigating supply.

The watershed of the upper Salt River is largely forested. Fortunately it is also occupied largely by the Fort Apache Indian Reservation. This has resulted in restricted use of the region for grazing purposes, and in the conservation of original conditions of run-off in this important district. The Verde River country, however, which resembles that of the Salt, has remained unreserved until recently and has been overgrazed for many years. Floods here consequently are more sudden and wasteful of water, the minimum flow is less and more prolonged, and greater amounts of sediment are carried by the aggregate run-off from comparatively bare land surfaces. These two streams afford an excellent illustration of the benefits arising to irrigation interests from administrative control of watersheds.

Discharge and storage possibilities.—The flow of the Salt and Verde Rivers has been measured longest and most accurately of the irrigating streams of the Territory. The following table, constructed from data afforded by the Salt River Valley water companies, the water commissioner, the United States Reclamation Service, and the United States Geological Survey, affords an excellent idea of the united flow of the Salt and Verde Rivers just below their junction:

Monthly flow of Salt River below junction with Verde River, in thousands of acre-feet.[1]

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total for year.	Monthly average.
1888	......	......	......	......	......	......	......	21.5	20.8	20.3	50.1	411.9	......	......
1889	365.7	144.6	537.8	236.5	63.9	28.0	30.5	25.6	31.0	27.1	34.3	349.7	1,874.7	156.2
1890	306.4	560.4	394.9	109.4	56.2	30.4	32.2	238.9	139.2	160.2	280.7	384.9	2,693.9	224.5
1891	210.1	2,175.7	303.9	158.9	148.3	79.5	45.9	34.9	48.9	31.7	30.5	35.9	3,304.1	275.3
1892	41.6	24.5	25.2	26.1	29.5	10.4	22.3	24.8	20.3	27.4	30.5	33.5	316.1	26.3
1893	33.8	82.9	849.0	86.2	48.7	13.5	33.0	100.7	65.7	46.2	35.2	38.7	1,433.6	119.5
1894	35.8	31.9	83.5	50.9	31.9	15.7	17.5	55.0	36.2	29.7	27.3	54.3	469.7	39.2
1895	617.7	177.6	345.1	161.5	59.9	29.5	19.9	52.2	26.8	89.1	78.1	65.3	1,722.7	143.5
1896	50.6	33.7	73.5	75.3	42.4	20.6	106.6	106.6	69.0	55.7	58.6	43.3	735.9	61.3
1897	313.0	107.7	237.1	353.8	89.5	32.6	19.3	54.9	104.3	57.4	33.6	34.9	1,438.1	119.9
1898	38.8	63.3	85.3	69.0	40.6	24.0	47.8	50.8	42.9	21.2	25.0	39.1	547.8	45.6
1899	45.9	42.7	48.1	47.7	29.5	22.5	52.9	72.4	41.1	51.4	26.6	26.7	507.5	42.3
1900	27.7	24.5	25.2	26.1	29.5	10.3	7.6	18.9	15.0	22.5	51.2	27.5	286.0	23.8
1901	52.7	250.7	150.3	80.4	56.8	25.4	36.7	74.6	25.8	18.8	26.4	29.4	828.0	68.9
1902	24.6	24.8	27.3	23.9	22.3	14.0	10.6	61.9	134.0	18.0	24.9	57.2	443.5	36.9
1903	26.9	37.0	53.8	62.6	26.7	23.7	22.9	42.7	49.1	33.8	24.0	26.1	429.3	35.8
1904	26.0	22.8	21.4	14.9	14.9	7.5	70.5	204.2	59.2	28.1	23.0	26.6	519.1	43.3
1905	225.6	992.9	1,442.5	1,126.2	374.2	108.9	50.0	71.2	101.2	60.8	796.5	179.7	5,529.7	460.8
1906	151.9	164.9	829.0	364.3	116.2	47.3	45.6	100.8	35.2	29.7	41.0	458.0	2,383.9	198.7
1907	381.8	323.4	517.9	197.9	69.8	45.6	39.2	95.4	94.2	110.4	80.5	56.0	2,012.1	167.7
1908	44.1	342.2	325.5	117.5	86.1	35.8	79.3	188.8	89.5	40.3	39.1	428.2	1,816.4	151.4
1909	178.7	283.3	314.1	306.7	50.7	49.0	......	......	......	......	......	......	......	......
Av.	152.4	281.5	318.6	176.0	70.8	32.1	39.5	80.8	59.5	46.7	86.5	133.9	1,464.6	122.4

[1] From estimates contained in Water Supply and Irrigation Papers Nos. 2, 73, and 83; also measurements in Water Supply and Irrigation Papers 85, 100, 133, 175, and 211.

The fluctuations each year, the differences between years, and the average flows for months and years are shown for 21 years. Reckoning on an irrigable area of 275,000 acres in Salt River Valley, the amount of water delivered each year is sufficient to cover this area to a depth of 1 to 20 feet; that is, there is one-fourth to five times enough water for general agricultural operations. This condition of fluctuation from month to month and from year to year indicates the necessity for water storage in order to equalize the water supply and, especially, to make available the occasional floods which have heretofore escaped in large part to the ocean. Storage capacity exists as follows:

Storage capacity on Salt and Verde Rivers.

Reservoir.	River.	Height of dam.	Capacity.
		Feet.	*Acre-feet.*
Roosevelt	Salt	284	1,284,000
McDowell	Verde	210	280,000
Horseshoe	do	150	205,000

The problem of the irrigating efficiency of the Salt and Verde Rivers with the help of feasible storage sites is of such unusual interest as to warrant especial attention. The accompanying sketch is necessary to an understanding of the elements of that problem (fig. 4). The Salt and Verde Rivers, which unite to afford the Salt River Valley supply, join just above Granite Reef, at which point the irrigating stream is diverted to the valley. Of these two rivers, the Salt is the larger, separate measurements being available since January, 1903, as shown in the following table:

Monthly flow of the Salt and Verde Rivers at McDowell, near Lehi, Ariz., in thousands of acre-feet.[1]

River.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1903:							
Salt	11.6	16.9	21.5	[2] 40.0	[2] 18.0	15.6	8.7
Verde	15.3	20.1	32.2	22.6	8.7	8.1	14.3
1904:							
Salt	11.4	9.8	10.1	7.9	7.2	3.8	25.7
Verde	14.6	13.0	11.3	7.1	7.7	3.7	44.8
1905:							
Salt	138.3	564.8	902.6	815.2	323.0	92.1	34.9
Verde	87.3	428.1	539.9	311.0	51.2	16.8	15.1
1906:							
Salt	102.0	98.3	493.0	303.0	101.0	38.4	31.2
Verde	49.9	66.6	336.0	61.3	15.2	8.9	14.4
1907:							
Salt	232.0	178.0	285.0	148.0	54.3	33.9	25.9
Verde	149.0	146.0	232.0	49.9	15.4	12.4	13.3
1908:							
Salt	25.3	229.0	240.0	99.4	58.8	27.1	50.8
Verde	18.8	113.0	86.1	17.9	27.2	8.7	28.5
1909: [3]							
Salt	64.5	202.8	188.3	232.0	38.4	40.9	....
Verde	114.2	80.5	125.9	74.7	12.4	8.1	....

River.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	
						Salt.	Verde.
1903:							
Salt	22.4	18.6	14.2	11.7	12.1	211.0	....
Verde	20.2	30.5	19.6	12.3	14.0	....	217.9
1904:							
Salt	104.3	30.5	16.5	10.5	11.8	249.4	....
Verde	99.9	28.7	11.6	12.5	14.8	....	269.7
1905:							
Salt	36.3	55.3	27.3	592.3	125.9	3,708.1	....
Verde	34.9	45.9	33.5	204.2	53.8	....	1,822.0
1906:							
Salt	55.1	22.6	18.6	22.4	296.0	1,580.0	....
Verde	45.7	12.6	11.1	18.6	162.0	....	802.3
1907:							
Salt	68.9	70.2	72.6	58.3	34.1	1,260.0	....
Verde	26.4	24.0	37.8	22.3	19.9	....	748.0
1908:							
Salt	135.0	68.4	24.0	22.3	236.0	1,220.0	....
Verde	54.1	21.2	16.3	16.7	192.0	....	600.0

[1] U. S. Geol. Survey, Water Supply and Irrigation Papers Nos. 100, pp. 36, 41; 133, pp. 221, 227; 175, p. 181; 211, pp. 137, 139; 249, pp. 190, 191, 195.
[2] Measurements for only part of month. Monthly flow is estimated from rainfall.
[3] U. S. Reclamation records.

For the period of measurement it appears that the Salt carried about 65 per cent of the united flow, and the Verde about 35 per cent. The elements of the physical situation involved are, therefore—

(1) Salt River carries 65 per cent of the total supply under the following conditions: (*a*) About 10 per cent of its watershed lies below Roosevelt reservoir and the run-off of this area can not be regulated; (*b*) the power canal, skirting the south side of Roosevelt reservoir, has a capacity of 250 cubic feet per second, or 15,000 acre-feet a month, which, theoretically, can not be stored and must be taken as it comes at Granite Reef; (*c*) Roosevelt reservoir, with a capacity of 1,284,000 acre-feet, is available for the storage of the waters of Salt River less the two above subtractions, which leaves approximately 70 per cent of the average whole flow; (*d*) the evapo-

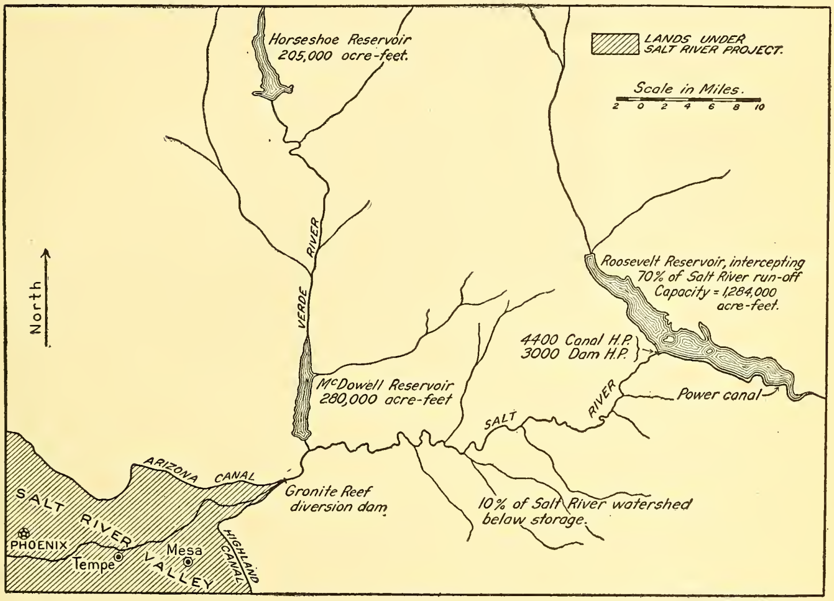

FIG. 4.—Hydrographic features of the Salt River Valley.

ration from the water surface in the reservoir, estimated at 66 inches, less 13 inches rainfall, leaves a net loss of 53 inches in depth each year. This would amount to a loss by evaporation of about 70,000 acre-feet a year, when the reservoir is full; (*e*) the power to be generated by the reservoir supply at times when that supply is being drawn upon can be used to pump supplementary ground waters for irrigation in Salt River Valley, and thus conserve the storage room of the reservoir and lengthen its period of duty during times of prolonged drought; and (*f*) power installations for pumping and industrial purposes derive their motive power from the power canal at Roosevelt Dam and at other feasible sites on Salt River and dependent canals.

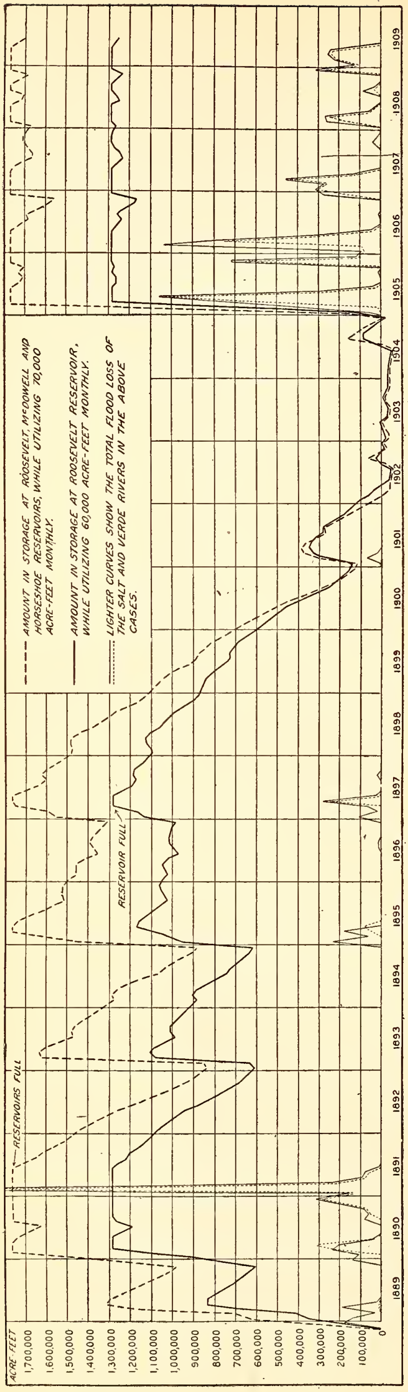

FIG. 5.—Graph showing irrigation possibilities of the Salt River under different conditions.

(2) The Verde River carries 35 per cent of the total water supply, with the following possibilities: (*a*) The McDowell storage reservoir, with 280,000 acre-feet capacity, lying at the mouth of the river and intercepting all of the Verde flood waters; (*b*) Horseshoe reservoir, with 205,000 acre-feet capacity, a short distance above, intercepting nearly all of the Verde flood waters; (*c*) net evaporation, subtracting rainfall, may be approximated at 53 inches for these reservoirs also; (*d*) there are canal and reservoir power possibilities, as at Roosevelt.

Irrigable area in valley.—It is necessary in arriving at the possible future water supply of Salt River Valley to estimate the maximum continuous flow which these two rivers, each with its own storage, coordinately administered, may be made to deliver. The following graph (fig. 5) represents the efficiency of the two rivers under two sets of conditions: (1) With a monthly delivery of 60,000 acre-feet, using, first, the unregulated flow of a portion of Salt River and all of the Verde, and, second, supplementing this with stored water from Roosevelt reservoir, the total storage capacity being 1,284,000 acre-feet; and (2) with a monthly delivery of 70,000 acre-feet, using full storage on both the Salt and the Verde, total storage capacity being 1,769,000 acre-feet.

In both cases the estimates expressed in the graph take into consideration (1) the unstored 10 per cent of Salt River plus the Roosevelt power canal supply, (2) the Verde, with or without storage, as the case may be, and (3) the Roosevelt reservoir supply corrected for evaporation and rainfall. The Verde reservoirs, when used, are also corrected for evaporation. The figure for evaporation used is 66 inches less 13 inches of rainfall, leaving 53 inches of net loss, divided between months of the year as follows:[1] January, 0.2 inch; February, 1.2 inches; March, 2.7 inches; April, 5.2 inches; May, 7.9 inches; June, 9.3 inches; July, 10.1 inches; August, 4.7 inches; September, 5.9 inches; October, 4.3 inches; November, 0.9 inch; and December, 0.6 inch.

The power which can be derived from the reservoir water at the three sites, and which could be used to raise an auxiliary pumped supply, does not enter into the estimates, which relate to surface waters only; neither is a possible small reduction of reservoir capacity, due to filling in of sediments, allowed for.[2]

The tables on which the graph (p. 42) is based, showing the theoretical behavior of the water supply for the last 21 years—August, 1888, to June, 1909—under the two conditions of storage and output considered, are too voluminous to print, but may be summarized as follows:

(1) With a monthly delivery of 60,000 acre-feet, using 1,284,000 acre-feet of storage at Roosevelt only, to supplement the unregulated fraction of the Salt and the whole unregulated Verde:

Water supply of Salt River, 1888 to 1909.

[Total flow, 31,079,000 acre-feet.]

	Acre-feet.	Per cent of total flow.
Flood waste	14,375,000	46.2
Regulated stream flow delivered to Salt River Valley	14,528,000	46.7
Evaporation	1,083,000	3.4
In storage at end of period	1,246,000	4
Total	31,232,000	[3] 100.3
		Per cent of full supply.
Periods of shortage:		
April to August, 1902, 5 months		49
November, 1902, to March, 1903, 5 months		73
May, 1903, to June, 1904, 14 months		43
December, 1904, 1 month		71

[1] This evaporation was observed at the station farm near Phoenix during the dry season of 1901–2. The rainfall is averaged between McDowell and Tonto for a period of years.
[2] Arizona Sta. Bul. 44, pp. 157–159.
[3] Three-tenths of 1 per cent error, due to approximations employed.

(2) With a monthly delivery of 70,000 acre-feet, using 485,000 acre-feet of storage at McDowell and Horseshoe reservoirs on the Verde and 1,284,000 acre-feet of storage at Roosevelt on the Salt:

Water supply of Salt River, 1888 to 1909.

[Total flow, 31,079,000 acre-feet.]

	Acre-feet.	Per cent of total flow.
Flood waste	11,773,000	37.7
Regulated stream flow delivered to Salt River Valley	16,130,000	51.9
Evaporation	1,129,000	4.7
In storage at end of period	1,676,000	5.4
Total	30,708,000	[1] 99.7
		Per cent of full supply.
Periods of shortage:		
October, 1900, to January, 1901, 4 months		55
December, 1901, to August, 1902, 9 months		42
November, 1902, to June, 1904, 20 months		45
December, 1904, 1 month		84

[1] Three-tenths of 1 per cent error, due to approximations employed.

In the first case, with only the Roosevelt reservoir and a monthly supply of 60,000 acre-feet used, four periods of shortage occur, three of which could have been easily tided over with the help of pumped water. The fourth period of 14 months, occurring at the end of a series of dry years, would probably have proved manageable also in the same manner, as a succession of power sites on the Salt River and dependent canals, taking the whole future into consideration, will place great power resources at disposal, even at times of low stream flow.

In the second case, with all three reservoirs and a monthly supply of 70,000 acre-feet used, four periods of shortage occur, two of which are unimportant. A third, of nine months' duration would probably have proven manageable by means of pumped water. The fourth shortage, of 20 months' duration, with less than a half supply of irrigating water available, would probably represent an extreme condition, occurring, so far as present records show, but once in 21 years. Probably such an exigency can be risked for the sake of a larger utilization of Salt River, especially as the water will be less wastefully applied eventually, requirements will tend to grow less, and methods of apportionment in times of extreme need will probably be devised.

It may be reasonably assumed, therefore, that with a total storage at the Roosevelt, McDowell, and Horseshoe reservoirs of 1,769,000 acre-feet the Salt and Verde Rivers may, except on rare occasions, be relied upon to deliver about 70,000 acre-feet of river water each month to the irrigated valley below. This amounts to 840,000 acre-feet annually, which, assuming a requirement under improved conditions of 4 feet deep of irrigating water a year, is sufficient for 210,000 acres. This does not include the pumped water supply, which is to be considered independently of the gravity water supply discussed above.

Power and pumping.—It is estimated by the United States Reclamation Service that about 26,000 horsepower will be developed at the Roosevelt Dam, at several sites along Salt River between Roosevelt and Granite Reef, and in the canals of the Salt River Valley. The respective amounts of horsepower contemplated are: Roosevelt power canal, 4,400; reservoir power, 3,000; three sites on Salt River between Roosevelt and Granite Reef, 10,500; four sites in Salt River Valley canals, 8,000; total, 25,900.

This is much in excess of the amount of power necessary to lift the estimated underground water supply within the limits of the project, leaving a valuable surplus which may be sold for industrial purposes in the valley and in neighboring mining towns. The amount of pumped water now contemplated will be about 200,000 acre-feet annually, an amount sufficient to irrigate 50,000 acres. This pumped supply, moreover, may be economized or supplemented from time to time by a judicious use of occasional flood waters, just as on the other hand lowering reservoir waters may be supplemented by pumped supplies. Estimating liberally that 6,000 horsepower will care for pumping operations contemplated within the district, a residue of approximately 20,000 horsepower remains, which, in operation, it is believed will have a market value of not less than $1,000,000 annually. Salt River, therefore, as it will be developed ultimately is to be considered not only an irrigating stream of great value, but, in a region of limited fuel supply, an immensely important source of power also.

GILA RIVER.

Watershed and run-off.—The Gila River, rising in southwestern New Mexico, pursues a general westerly course across southern Arizona, joining the Colorado about 90 miles above the mouth of the latter. That portion of the watershed of the Gila lying west of its confluence with Salt River is of little or no value for irrigation on account of its very arid character. The water-productive territory east of Florence, Ariz., has an area of nearly 18,000 square miles. This region is for the most part of low elevation, and is forested only on the upper slopes of the mountains and in the bottoms of the valleys, where mesquite thrives. The extensive plains at higher elevations are grass or browse covered in season, while those in the western more arid districts are usually barren. The Gila watershed has been occupied by cattle for the last 40 years, and at times has been overstocked and overgrazed. This has resulted in destruction of the grass cover, in permitting rapid run-off from the bared surfaces, and in consequent erosion along lines of water flow, so that fully 500 miles of the valley bottoms are now gullied and the hydrographic conditions greatly changed. In striking contrast to the Salt River, the Gila is an example of a stream whose watershed has suffered irreparable damage to the land surface in years past from a total lack of administrative care.

The run-off of the Gila is difficult to estimate, differing in this respect from the Salt and Colorado Rivers, which, confined in rocky beds in their upper courses, can be quite definitely and completely measured at established gauging stations. The Gila, flowing in a pervious bed of low gradient, is in varying proportions an underground river, and rising and sinking as it does, according to local formations, can not be measured definitely by ordinary methods. The amount of surface flow, as estimated from the not very continuous or prolonged measurements available, indicates a limited but comparatively constant stream in the upper Gila near the New Mexico line, but an increasingly variable and inconstant irrigating supply between San Carlos and Yuma. The San Pedro and the Santa Cruz Rivers resemble the Gila and give tribute to it mainly in flood waters. The seepage from the Salt River irrigation appears near its confluence with the Gila and affords a very constant and reliable supply for the irrigation of the lands near Buckeye and Arlington. Below the latter point the Gila supply is so uncertain as to preclude satisfactory farming operations.

An approximate idea of the run-off of the Gila at the New Mexico line, at Florence, midway of the Territory, and at Yuma may be derived from somewhat fragmentary observations taken during the last 20 years. At the New Mexico line the combined measurements at Cliff, N. Mex., on the Gila River, and at Alma, N. Mex., on the tributary San Francisco River, approximate the upstream supply upon which irrigation in Graham County depends. Available measurements, by years, as given in the reports of the United States Geological Survey, are as follows:[1]

Run-off of Gila and San Francisco Rivers near the Arizona-New Mexico line.

Date.	Place of measurement.	Run-off.
		Acre-feet.
1905	The Gila at Cliff, N. Mex	[2] 190,100
1905	The San Francisco at Alma, N. Mex	263,300
	Total	453,400
1906	The Gila at Cliff, N. Mex	243,760
1906	The San Francisco at Alma, N. Mex	111,812
	Total	355,572
1907 [3]	The Gila at Cliff, N. Mex	373,020
1907	The San Francisco at Alma, N. Mex	147,859
	Total	520,879

[1] U. S. Geol. Survey, Water-Supply and Irrigation Papers, Nos. 175, pp. 162, 170; 211, pp. 123, 128.
[2] Jan. 1–May 22, not measured.
[3] U. S. Reclamation Service records.

The average for these three years is about 443,000 acre-feet, although measured incompletely. Even this figure is somewhat high, inasmuch as the run-off was exceptional for 1905 and 1907. Only a small portion of this run-off is available for irrigation, however, without storage, as is shown by the records by months for the three years of measurement.

Combined flow, by months, of the Gila at Cliff, N. Mex., and the San Francisco at Alma, N. Mex.[1]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
1905	....	....	....	....	....	17,477	9,641
1906	17,430	44,200	97,200	49,000	17,210	4,356	7,350
1907[2]	143,188	90,740	54,453	34,528	17,266	13,195	15,063
Mean	80,309	67,470	75,826	41,764	17,238	11,676	10,685

Year.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1905	14,676	21,540	11,966	93,350	44,669	....
1906	32,070	8,590	5,846	7,220	65,100	355,572
1907[2]	54,290	45,917	17,537	20,320	14,382	520,879
Mean	33,679	25,349	11,783	40,297	41,384	....

[1] U. S. Geol. Survey, Water-Supply and Irrigation Papers, Nos. 175, pp. 162, 170; 211, pp. 123, 128.
[2] U. S. Reclamation Service records.

The fluctuations here shown range from 4,356 acre-feet in June, 1906, to 143,188 acre-feet in January, 1907. As in other unregulated southwestern streams, irrigation is to a considerable extent limited by the summer minimum flow, usually occurring in June.

At Florence, midway of the course of the Gila River and below the mouth of the San Pedro River, probably the best knowledge of average flow is due to J. B. Lippincott,[1] who, on a basis of 60 months' observations made at various times from 1889 to 1899, estimated an average annual run-off of 469,093 acre-feet. This estimate, however, did not include the wet season of 1891. The mean monthly flows in acre-feet of the Gila River at Florence, as compiled by Lippincott, are as follows: January, 40,828; February, 26,675; March, 23,783; April, 20,481; May, 8,030; June, 4,072; July, 65,745; August, 77,247; September, 52,503; October, 83,109; November, 36,491; December, 30,129; annual total, 469,093.

The Gila River is not infrequently dry at Florence, sometimes for several months at a time, as, for instance, from March to July, 1899. Without storage, therefore, agriculture at this point is less assured of its necessary irrigating supply than near the New Mexico boundary, where, even in driest years, the river has never failed entirely.

At Yuma the Gila is even more variable than at Florence, and the discharge has ranged, it is said, from nothing for a period of a year

[1] U. S. Geol. Survey, Water-Supply and Irrigation Paper, No. 33, p. 30.

to as high as 3,665,148 acre-feet in 1905. Following are available records of annual discharge of the Gila near Yuma, Ariz., taken from the reports of the United States Geological Survey: [1]

Annual discharge of Gila River near Yuma, Ariz.

Year.	Acre-feet.	Year.	Acre-feet.
1903	61,196	1905	3,665,000
1904	226,400	1906	1,790,000

With such fluctuations in the unregulated supply, agriculture has never succeeded in establishing itself permanently on the lower Gila to any important extent.

It may be stated summarily that the fluctuations in water supply become more and more extreme from the source to the mouth of the Gila. In obedience to this fact and to the increasing appropriations of the headwaters, agricultural development for the past 40 years has readjusted itself gradually toward upstream locations. In the absence of measurements the actual use made of the waters of the Gila may be best estimated by the areas of land irrigated therefrom. This amounted in 1909 to about 36,000 acres adjacent to the main stream above its confluence with the Salt. This area, assuming an average application of 4.5 feet in depth on the land, would account for about 160,000 acre-feet of water per annum. Although this is but little more than 30 per cent of the supposed average flow above the Salt River junction, without storage it is very nearly the maximum possible use of this stream. The remaining flood waters escape, part being absorbed by the porous river bed and the residue sometimes reaching the sea.

Storage possibilities.—A considerable number of storage sites exist on or near the Gila River, the chief ones being given in the following table:

Storage sites on the Gila River.

Site.	Stream.	Location.	Height of dam by contour.	Capacity.
			Feet.	*Acre-feet.*
Red Rock	Gila	Above Duncan in New Mexico	100	80,000
Alma	San Francisco	Alma, N. Mex.		135,000
Dix Creek	do	22 miles north of Clifton	110	12,000
Guthrie	Gila	Guthrie, Ariz.	140	256,000
San Carlos	do	San Carlos, Ariz.	130	241,000
Riverside	do	Riverside, Ariz.	153	344,000
Buttes	do	Near Florence, Ariz.	150	174,000
Queen Creek	Queen Creek	do	130	51,000
Total				1,293,000

[1] U. S. Geol. Survey, Water-Supply and Irrigation Papers Nos. 100, p. 27; 133, p. 206; 175, p. 166; 211, p. 125.

Storage sites on the Gila River, however, though of large total capacity, seem peculiarly subject to misfortune. The Guthrie site is traversed from end to end by the Arizona and New Mexico Railroad; the San Carlos site is at present (March, 1911) in controversy between railroad and irrigation interests; the Riverside site is controlled by mining properties located within its limits; and both the Riverside and the Buttes sites are traversed by the Arizona Eastern Railroad. Further storage than that described above is believed to be possible by means of a series of comparatively small earth-embankment reservoirs in the tributary valleys southwest of Florence, and a large site exists on the main stream north of Sentinel, Ariz., 90 miles east of Yuma.

Aside from the administrative difficulties in which most of them are involved, prospective reservoirs on the Gila are all endangered by the excessively muddy character of the flood waters which would be used to fill them. Daily samples of such waters were collected during August and September, 1900, and allowed to settle for one year. The sediment deposited was then found to occupy from 5.2 to 17.4 per cent of the original volume of the muddy waters.[1] No economical method of removing such volumes of sediments from large and deep reservoirs having yet been demonstated, the life of such reservoirs, on muddy streams, is a matter as yet under discussion by engineers. It is estimated that the Buttes reservoir, with 174,000 acre-feet capacity, would fill with sediment in 18.6 years; and that the San Carlos site, with 241,000 acre-feet capacity, would fill in 28.5 years.[2]

The problem of storage on the Gila River, therefore, is at present fraught with serious difficulties, both administrative and physical, which will probably tend to retard further development in irrigation on this important stream for years to come.

SMALL STREAMS.

There are a number of small streams, besides the four main rivers already discussed, which altogether afford water supply for a considerable acreage. These small streams are quite completely utilized as to their critical minimum flow, and storage is projected here and there for the utilization of flood waters. Few measurements have been made upon these small streams, the amount of use of which can be best approximated by multiplying irrigated acreages by an assumed average water requirement.

Upper Verde River.—The Upper Verde River, including Clear, Beaver, Oak, Dragoon, and Granite Creeks, is tapped by a large

[1] Arizona Sta. Bul. 44, p. 188.

[2] U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 33, p. 40.

number of small ditches which utilize upstream waters not included in the Salt River supply discussed on preceding pages. Probably the best estimate now available of water used in this region is that made by the subcommittee representing the Salt River Valley water users, which visited the Verde Valley in July, 1901, and measured the ditches and areas irrigated.[1] At that time about 7,000 miner's inches of continuous flow was in use. This is 175 cubic feet per second, or 350 acre-feet per day, or 70,000 acre-feet for an irrigating season of about 200 days. This amount of flow was applied to about 7,650 acres, indicating probably a too liberal use of water in the district, although a portion returns as seepage to the river channel and was used again downstream. It is stated that since 1901 not much additional irrigation has been undertaken, so that with small increase this estimate still stands.

San Pedro and Santa Cruz Rivers.—These rivers are tributary to the Gila River from the south. They resemble the Gila in character of water supply, which is most constant near their sources, but fluctuate between floods and complete dryness along their lower courses. Measurements of both streams midway of their courses have been made at Charleston and Tucson, Ariz., as follows:

	Acre-feet.
San Pedro River at Charleston, Ariz.: [2]	
1904 (April to December)	115, 300
1905	45, 200
1906 (January to August)	29, 100
Approximate average	63, 200
Santa Cruz River (including ditches) at Tucson: [3]	
1906	22, 370
1907	37, 200
1908	22, 530
1909	22, 275
Approximate average	26, 100

But measurements at any one point on streams of this character are of little value in showing the entire run-off. Flowing in pervious beds, such waters are forced to the surface only at points where they are confined by underground barriers and spread out and disappear rapidly in the wide, sandy valleys. Probably the best method of approximating the available water supply from such imperfectly measured streams is to multiply the irrigated acreage by the assumed average depth in feet of water applied. Estimated in this manner, the San Pedro, with about 5,800 irrigated acres, and an average

[1] Water-Supply and Irrigation on the Verde River and Tributaries, 1901, by O. A. Turney.

[2] U. S. Geol. Survey, Water-Supply and Irrigation Papers Nos. 133, p. 211; 175, p. 173; 211, p. 130.

[3] Arizona Sta. Bul. 64, pp. 115, 116.

application of 3.5 feet in depth to the land, affords about 20,000 acre-feet of water annually. Similarly, the Santa Cruz and tributaries, with about 6,000 irrigated acres and an average application of 3.5 feet deep applied, affords about 21,000 acre-feet annually.

Storage sites exist on both the San Pedro and the Santa Cruz Rivers. Just below Charleston, on the San Pedro, a dam 120 feet high would impound about 120,000 acre-feet of flood waters, which amount is occasionally available from this stream. All known sites on the Santa Cruz are broad and shallow, and are favorable to the construction of retaining embankments of earth of comparatively low elevation. The Santa Cruz Reservoir Land Co. is now constructing (January, 1910) one such reservoir 50 miles northwest of Tucson. This company proposes to develop 295,000 acre-feet of storage capacity by means of an earthen dam 22,200 feet long with a maximum height of 45 feet.

Bill Williams Fork.—This stream, which drains west-central Arizona and empties into the Colorado River, is as yet unmeasured, but is known to vary from a few miner's inches to occasional floods of large volume. A reservoir site is said to exist 40 miles east of its mouth at the junction of the Big Sandy and the Santa Maria Creeks.

Other small supplies.—Throughout central and eastern Arizona small creeks are being more and more closely utilized. Even the waters pumped from mines at Tombstone and Bisbee are employed in gardening operations. These scattered increments of water, by reason of their proximity to mining markets, are often very valuable and yield their owners excellent returns for fruit and produce. The area irrigated from these small creeks and springs may be approximated at 4,300 acres scattered throughout the Territory, mostly at higher elevations. This area, at 4 feet in depth of water required a year, means a total annual water resource of 17,000 acre-feet.

SEEPAGE AND RETURN WATERS.

The initial application of irrigating waters, however, does not in many situations terminate its usefulness. A considerable percentage of the water applied to the soil may work its way back gradually to stream channels and again be taken and applied. In certain of our irrigated districts, where soils are pervious, gradients steep, and the lands disposed in comparatively narrow areas along river courses, conditions are very favorable for the return of seepage waters. The Upper Verde and Gila Rivers in Graham County and the Salt River are examples of streams whose waters are thus in part used over and over again. Decreasing increments of the waters of Salt River are thus used not less than four times between their first application at the head of Salt River Valley and their last appearance at Arlington. As much as 65 per cent of the original application has been found to be recovered and again applied along the Upper Gila River,[1] and in Salt River Valley 30 per cent of return waters has been observed.[2] No data are available as to the actual amount of seepage made use of on the streams mentioned, but the return waters from Salt River Valley and from the Gila are in part measured separately and applied to subjacent lands, including the Buckeye and Arlington districts to the west of the confluence of these two streams. About 13,000 acres are thus irrigated, which, allowing for the very liberal use of water made here, would require the application of approximately 80,000 acre-feet of water annually. W. H. Code,[3] measuring these return waters in 1900, when they were less than normal, found a total of 260 cubic feet per second, or about 190,000 acre-feet of water annually between Tempe and Gila Bend. Improved water supply with increased and prolonged irrigation in upstream districts will result in augmenting the return flow so that this water resource will in future become of larger volume and importance than at present. The return waters now in evidence from the Salt and Gila River valleys and not otherwise included in the above estimates may therefore be stated conservatively at 200,000 acre-feet annually.

RESERVOIR SITES.

As has been noted already, storage possibilities of greater or lesser size exist on nearly all of the streams of the Territory. About twenty-five of these have been surveyed by the United States Geological Survey and the United States Reclamation Service, or by private parties, and their capacities ascertained or estimated. The location of these reservoir sites is shown on Plate II, page 28, and their capacities at the highest contours are given in the following table:

Capacity of reservoir sites in Arizona.

No.	Name of reservoir.	Contour.	Capacity.	Authority.
		Feet.	*Acre-feet.*	
1	Laguna	[4] 19	25,650	U. S. Reclamation Service.
2	Bill Williams	75	1,300,000	Do.
3	Aquarius	250	1,500,000	Arizona Republican, Mar. 21.
4	Bulls Head	20	15,993	U. S. Reclamation Service.
5	Tucker Flat	50	117,567	Do.
6	Le Roux	35	54,298	Do.
7	Woodruff	100	108,644	Do.
8–9	Forks	85	147,943	Do.
10	Udall		13,000	Private correspondence.
11	Lyman		20,005	Do.
12	South Gila	[4] 50	([5])	U. S. Geological Survey.
13	Walnut Grove	135	60,000	Personal correspondence.
14	Agua Fria	150	150,000	U. S. Geological Survey.
15	Frog Tanks	100	50,000	Do.

[1] U. S. Geol. Survey, Ann. Rpt. 1899–1900, pt. 4, pp. 343–347.
[2] U. S. Dept. Agr., Office Expt. Stas. Bul. 104, pt. 2, p. 104.
[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 104, pt. 2, pp. 103–104.
[4] Height of dam already constructed.
[5] Capacity not ascertained, but very great.

Capacity of reservoir sites in Arizona—Continued.

No.	Name of reservoir.	Contour.	Capacity.	Authority.
		Feet.	*Acre-feet.*	
16	New River			U. S. Geological Survey.
17	Cave Creek	100	100,000	Do.
18	Horseshoe	150	204,935	Do.
19	McDowell	[1] 210	279,635	Do.
20	Roosevelt	[1] 284	1,284,000	U. S. Reclamation Service.
21	Queen Creek	130	50,665	U. S. Geological Survey.
22	Florence Canal		(2)	Do.
23	Santa Cruz Reservoir Land Co	[1] 45	295,330	Personal correspondence.
24	Buttes	150	174,040	U. S. Geological Survey.
25	Riverside	153	344,308	Do.
26	San Carlos	130	241,396	Do.
27	Dix Creek	110	12,000	Personal correspondence.
28	Guthrie	140	255,800	U. S. Geological Survey.
29	San Pedro	120	120,000	U. S. Reclamation Service.

[1] Height of dam already constructed. [2] Capacity small.

GROUND WATERS.

WATERS WITHIN 50 FEET OF SURFACE.

Surface flow, however, by no means exhausts the water resources of the Territory. Beneath the surface in favorable locations there is immense capacity for the storage of flood waters. These ancient valleys are filled with detritus from adjacent mountain ranges and may contain in the interstices of their porous contents 20 to 40 per cent of their volume of water. The storage possibilities of such a valley are illustrated by the disastrous flood of 1903 at Clifton. This flood was 30 feet deep, and after destroying the town, passed down the Gila River, but disappeared entirely before it reached the head of the Buckeye Canal, 180 miles below, the entire flood, with the exception of the minor portion that found its way into ditches or escaped by evaporation, having been absorbed into the underground storage.[1] Irrigated valleys in like manner fill up with water escaping by percolation from the surface where it is applied. The ground-water level, due to this cause, in some parts of the Salt and Upper Gila River valleys has risen from a depth of 20 feet or more to the surface.

There are considerable areas in southern Arizona, as shown by the map (Pl. II, p. 28), where ground waters are found within 50 feet of the surface. This is assumed as the maximum depth from which irrigating water may be pumped. These ground waters are often spoken of as underflow, and sometimes are developed by means of ditches dug upgrade to water level. This is not practicable, however, in some localities, and the utilization of ground waters must be mainly by pumping.

The subject of ground waters within the Territory has as yet been studied in only a few localities, and it is impossible therefore to forecast

[1] U. S. Geol. Survey, Water-Supply and Irrigation Paper 104, pp. 38, 39.

the extent to which they will be used ultimately, especially as this depends not only upon the amount and accessibility of the supply, but also upon the cost of pumping and the value of products grown. One of the most detailed studies of ground-water supply thus far made is that of G. E. P. Smith, who finds that the Rillito Valley between Fort Lowell and a point 10 miles west may probably be made to supply 23,000 acre-feet annually by pumping.[1] Willis T. Lee, in his study of the ground waters of the Gila between the Buttes and the Salt River junction, found a reserve of 1,120,000 to 1,960,000 acre-feet of water within 50 feet of the surface, and estimates that each year this store is replenished by an underflow of not less than 175,000 acre-feet.[2]

The same author finds under Salt River Valley between the Verde and the Agua Fria, a reserve of approximately 4,704,000 acre-feet of water within 50 feet of the surface, replenished each year by an estimated underflow of 287,760 acre-feet.[3] These three streams, in the localities studied, are estimated to carry about 500,000 acre-feet of ground water annually within pumping distance of the surface without drawing upon the reserve. As shown on Plate II (p. 28), there are large additional areas along the Agua Fria, New, Hassayampa, and lower Gila Rivers, and in the Santa Cruz, San Pedro, Sulphur Springs, and San Simon Valleys, which also carry ground waters within 50 feet of the surface, replenished by underflow derived from adjacent mountain ranges. Sulphur Springs Valley, particularly, probably will prove a source of large ground-water supply, valuable in supplementing dry-farming operations at times when rainfall is inadequate.

These great bodies of ground water have, for the most part, been drawn upon but little. Several successful pumping plants in the Salt River Valley have been in operation for something less than 10 years, and exhaustive pumping plants are under construction by the United States Reclamation Service. More or less crude attempts at pumping are to be found elsewhere within water-bearing areas, but the underground supply is as yet almost untouched. The significance of this supply is suggested by the history of irrigation in semiarid southern California, south of Tehachapi. Ground waters in that region, which was first irrigated from surface streams, now afford probably 75 per cent of the whole supply. Arizona is 20 to 25 years behind California in the development of its ground-water supplies, judging by the chronology of well-drilling operations in the two sections. Considering the all-year growing season in southern

[1] Arizona Sta. Bul. 64.
[2] U. S. Geol. Survey, Water-Supply and Irrigation Paper 104, p. 50.
[3] U. S. Geol. Survey, Water-Supply and Irrigation Paper 136, p. 171.

Arizona, the diversity and value of crops, the intensive agriculture possible, and the progress being made in pumping economy, Arizona is entitled to look with much hope upon the future value of its ground waters. It is perhaps not in excess of possibility to place the future utilization of groundwaters of the Territory by pumping at 750,000 acre-feet annually.

ARTESIAN WELLS.

There are three well-defined artesian districts within the Territory and indications of a fourth. The oldest of these is in the San Pedro Valley, extending from just north of Benson, southward for about 45 miles. This valley was once filled by an ancient lake and is bedded with clay strata favorable to the retention, under pressure, of artesian waters. These waters are derived apparently from adjacent mountain slopes whose run-off is caught under the edges of the old lake deposits and confined there until released by artesian borings. The first well was discovered in 1885 at St. Davids, 6 miles south of Benson. A reconnaissance of the district by the writer, in January, 1909, discovered 219 wells, 178 of which were at St. Davids. They range from 125 to 800 feet deep, and from 1.5 to 12 inches in diameter. Most of the flows are small, ranging from as small as 2 gallons a minute to a maximum, in one well at Hereford, of 180 gallons a minute. The total discharge for the district was estimated at about 3,500 gallons a minute, which is equal to 7.8 cubic feet per second, or about 5,700 acre-feet of water per annum.

The second artesian district is in Graham County, lying between Pima and Solomonville, along the northeast slope of Graham Mountain, roughly parallel to the Gila River. This district has been developed at intervals for a distance of about 20 miles. The water supply evidently is derived from the run-off of Graham Mountain, which accumulates, with pressure, under clay strata which were probably also laid down in the waters of an ancient lake. Artesian springs in this district are said to have appeared along the line of an earthquake crack opened in 1885. The first well was bored in 1897, and there are at the present time about 100 wells, large and small, ranging from 80 to several hundred feet in depth, with an aggregate flow possibly of 4,000 gallons a minute. This is about 8.9 cubic feet per second, or about 6,500 acre-feet per annum, mostly flowing in the vicinity of Lebanon and Artesia, 6 to 10 miles, respectively, south of Safford. Recently (February, 1911) this district has been considerably extended by the discovery of another large well at San Simon, 50 miles south, upon the Southern Pacific Railroad.[1]

Forty miles east of Bisbee, at San Bernardino, on the Mexican line, is a third small artesian district on the south slope of the

[1] Not shown on Plate II.

Chiricahua Mountains. Ten wells were flowing in 1909, but measurements were not available. This district was not discovered until 1905 and its area is unknown. An artesian salt well has been known for several years at Adamana, on the Santa Fe Railroad, and recently (December, 1909) another well was discovered near St. Joseph. At the latter point, at a depth of 400 feet, a flow of 20 gallons per minute has been secured in a formation probably of considerable extent. These discoveries are important, being the first artesian water found in northern Arizona, and if sustained by further discoveries will be of great value to that region.

Summarizing all artesian districts, the entire well flow at this time is probably not in excess of 15,000 acre-feet per annum. Unfortunately, this small but valuable asset is very wastefully handled. Drillers, aiming at economy in outlay, usually make the wells of small diameter without casing. For this reason they frequently choke and their flow is lost subterraneously. Oftentimes small flows are not properly stored, but are allowed to run without control, being thus a source of injury rather than of benefit to subjacent lands.

SUMMARY AND ESTIMATE OF WATER SUPPLY.

Summing up the surface stream flow of the Territory conserved by storage and replenished by seepage, and placing a moderate estimate upon the little-known ground waters, the potential, but as yet only partly developed, annual water supply for Arizona is as follows:

Water resources of Arizona.

	Acre-feet.
Colorado River, portion of flow sufficient to irrigate adjacent lands in Arizona	2,000,000
Little Colorado River, with storage	300,000
Salt River, with storage	840,000
Gila River above the Salt, without storage	160,000
Upper Verde River, without storage	70,000
San Pedro River, without storage	20,000
San Cruz River, without storage	21,000
Small streams, without storage	17,000
Seepage waters not included in above estimates, under improved upstream conditions, probably	200,000
Ground waters within 50 feet of the surface, replenished by percolation from irrigation and surface stream flow	750,000
Artesian wells	15,000
Total	4,393,000

In round numbers, therefore, the water supply reasonably within expectation in Arizona, as now seen, is between 4,000,000 and 5,000,000 acre-feet a year. This is sufficient for 1,000,000 acres of intensively cultivated land.

LAWS AND USAGES RELATING TO IRRIGATION.

Irrigation law in Arizona, as in most other western commonwealths, is in a state of development rather than of completion. Irrigation practice as it now stands is derived from Mexican law, from Mormon customs, and from legislative attempts of American irrigators to solve problems new to them.

OLD MEXICAN LAWS.

Under the terms of an act of the first legislative assembly in 1864, "The regulations of acequias, which have been worked according to the laws and customs of Sonora and the usages of the people of Arizona, shall remain as they were made and used up to this day." [1] The laws and customs of Sonora referred to, transmitted from Spain, are based upon Old World experience. Water is strictly appurtenant to the land. Distribution is in rotation to users for time in proportion to acreage irrigated. Charges for water and for maintenance of main ditches are in proportion to irrigated acreage. In brief, the irrigated acre of land is the unit of rights and of responsibility in the water supply. This legal inheritance, however, applies to only a limited acreage in the Santa Cruz Valley, which was under cultivation at the time of the erection of Arizona into a separate Territory.

COOPERATIVE ORGANIZATIONS.

The first American ditches on the Salt, the Gila, and the Little Colorado Rivers were built by small companies of farmers who labored cooperatively to secure a water supply which, in early days, being sufficient for all, aroused no controversy. In course of time, appropriations of water and nominally irrigated lands proved to be far in excess of actual water supply. Also, many of the older canals fell under the control of corporations or were constructed by them. Certain ditches, however, including those operated by Mormon farmers, maintained their cooperative character, their affairs being managed by officers elected by the users of water, and assessments of money and of labor for maintenance of ditches being levied in accordance with shares or acres owned. The Tempe Canal in Salt River Valley, the San Jose, Montezuma, and other ditches on the upper Gila, and the canals along the little Colorado have all remained essentially cooperative in character.

Shares of stock in these organizations entitled the owners to their proportion of the water flowing in the ditch, but unfortunately these shares were not attached to specified areas of land, and the water derived from them was sometimes shifted from place to place. These floating water rights therefore became a cause of insecurity in values

[1] Revised Statutes of Arizona, 1901, par. 4199.

of improved lands and were a serious evil, especially when drought led to the manipulation of a scant water supply.

The democratic character of the cooperative ditches, however, has made them for the past 40 years of the irrigation history of the Territory the most satisfactory means of water supply, but to a considerable extent the internal operation of these ditches has been through the consent of those interested rather than through the rigid application of the Territorial law.

DEVELOPMENT OF IRRIGATION LAW IN ARIZONA.

While the old Mexican acequias and the more modern cooperative ditches have in the main operated satisfactorily within themselves, the usages governing them apply mainly to limited and contiguous acreages and are not adequate to settle the questions which arise in connection with the irrigating interests of an entire watershed. These necessarily have been matters of Territorial law, an outline of whose development and character should be known to all irrigators.

In the bill of rights, enacted by the first Territorial legislature in 1864, it is provided that "All streams, lakes, and ponds of water capable of being used for the purposes of navigation or irrigation are hereby declared to be public property; and no individual or corporation shall have the right to appropriate them exclusively to their own private use, except under such equitable regulations and restrictions as the legislature shall provide for that purpose."[1]

At the same legislative session it was enacted, with other provisions relating to irrigation, that—

(1) All rivers, creeks, and streams of running water in the Territory of Arizona are hereby declared public, and applicable to the purposes of irrigation and mining, as hereinafter provided.

(2) All the inhabitants of this Territory, who own or possess arable and irrigable lands, shall have the right to construct public or private acequias, and obtain the necessary water for the same from any convenient river, creek or stream of running water.

(3) It shall be the duty of overseers of ditches to distribute and apportion the water in proportion to the quantity to which each one is entitled, according to the land cultivated by him; and, in making such apportionment, he shall take into consideration the nature of the seed sown or planted, the crops and plants cultivated; and to conduct and carry on such distribution with justice and impartiality.

(4) During years when a scarcity of water shall exist, owners of fields shall have precedence of the water for irrigation, according to the dates of their respective titles or their occupation of the lands, either by themselves or their grantors. The oldest titles shall have precedence always.[2]

These provisions, which are still a part of the statutory law of the Territory, establish that the rivers and streams are in the nature of

[1] Revised Statutes of Arizona, 1901, par. 22.

[2] Revised Statutes of Arizona, 1901, pars. 4174, 4176, 4190, 4191.

a public resource, bestow upon irrigators the right to appropriate water from these streams for their lands, specify the beneficial use of water upon land, and secure priority of rights to water in the order of its application to the land.

In default of legal machinery wherewith to secure a comprehensive and thorough application of these principles to irrigated lands within the Territory, abuses demanding judicial or legislative correction have developed from time to time. Most of these have been associated with corporations organized for the purpose of managing or constructing ditches, diverting water, and, in some cases, expressly for sale, rental, and distribution of water. These organizations, in carrying out their purposes, not only deprived certain older canals of water rightfully theirs by priority, but public water supply was treated as corporate property, and water, instead of being strictly appurtenant to the land, was sold to users as a separable commodity. The resulting litigation culminated in the Kibbey decision announced in 1892. This decision reaffirmed the fact that the water of the streams and rivers is public property; that only owners and occupants of land are entitled to appropriate water from the public supply; that in so doing "no man has a right to waste a drop of water," but must apply it economically to the extent of its beneficial use; that priority of appropriation by actual use of water constitutes the better title to water; and that the right to irrigating water is permanently appurtenant to the land in connection with which it was acquired. Moreover, it was affirmed that canal companies are only carriers and not owners of water; that ownership of stock in a canal does not constitute ownership of water; and that the rights of canal companies are limited to carriage of water to the lands of appropriators.

The court did not specify the rights to water of individual landowners, the case for decision relating not to individuals but to the rights of different canal companies in the water supply. In accordance with this aspect of the case the decision provided a chronological table of totals of irrigated land under each canal year by year. A water commissioner was appointed whose duty it was to apportion the water between canals according to total prior rights under them.

The necessary want of explicitness in the decree gave opportunity for shifting water rights in violation of the intention of the court. Moreover, while the decision was pending an agreement was entered into between all but two of the canal companies of Salt River Valley whereby the available water supply was divided among them by agreement and not according to the provisions of the Kibbey decision. The operation of this agreement in default of adequate means to enforce the court decree was to defeat the principles of priority and of attachment of water to land. The result was that for the greater part of the 15 years following 1892 a majority of the Salt River Valley farming population was unlawfully dominated by the water companies which controlled the water supply as though it were their own instead of acting as distributing agents only. An onerous and chaotic condition of affairs supervened in consequence, especially during the years of drought that occurred in the late nineties in the Salt River Valley, where, in the main, legal questions with reference to irrigation in Arizona have been fought out. Various legislative attempts were made toward improvement. The Ivy bill, introduced into the twenty-first session of the legislature, reaffirmed the original water law of the Territory and the essential features of the Kibbey decision and, following the Wyoming law, provided machinery for making the Arizona law effective. Although defeated, the discussion of this bill was enlightening to the water-using public.

The Fowler bill was passed at this same legislative session, providing that counties with an assessed valuation of over $8,000,000 should be enabled to levy a tax for a water-storage fund to be used for reservoir construction. This bill has been in effect superseded by the National Irrigation Act, the passage of which in 1902 marked the beginning of the end of this formative period of irrigation history.

In accordance with the National Irrigation Act, the Salt River Valley Water Users' Association was organized and incorporated in 1903, to provide an adequate supply of water by diversion, storage, and pumping, for the lands of holders of shares in the association, and to enter into necessary agreements with the United States Government whereby to secure the benefits of the reclamation law. The articles of incorporation, which before adoption were found to meet the views of Government representatives, provide that only owners of lands shall hold stock in the association; that this stock shall be inseparably appurtenant to lands described in connection therewith; that the apportionment of water for irrigation of land shall be limited to its beneficial use; and that vested priority rights to water should be maintained. The government of the association is vested in a council, a board of governors, president, and vice president elected by shareholders in the association. These officers transact business under restrictions provided in the articles of incorporation. This association has been very influential in bringing about similar organizations elsewhere.

Through the medium of this organization and of the United States Reclamation Service, arrangements were made resulting in the construction of the Roosevelt Dam for storage and power, and the necessary means for distribution of the supply. The cost of construction is secured by lien on the lands of shareholders and is to be repaid to the United States Government in 10 annual installments without interest. When the major portion of the water shares has been paid for, the management and operation of the irrigation works, with the exception of reservoirs, pass to the owners of the lands irrigated.

In completion of the preparations for an equitable dispensation of benefits flowing from the Roosevelt Dam, the Kent decision, March 1, 1910, defines the irrigation status of every parcel of land in Salt River Valley, and thus secures to each, by virtue of its vested rights in the original stream flow, or its share in reservoir water, or both, an equitable interest in the now augmented and thoroughly administered water supply.

The situation on the lower courses of the Gila River is even worse than the old order of affairs on Salt River, but the possibilities of storage point to a similar solution. At Florence, for instance, several thousand acres were irrigated in former years from what seemed at first a reliable flow, but subsequent diversions of water upstream have deprived the prior appropriators of their supply and annihilated farm values. By means of storage, should it be found feasible, not only can prior appropriations be honored, but more recent developments in the eastern part of the Territory can be safeguarded in a manner precisely similar to that employed in the Salt River Valley.

It is, in fact, quite generally true in Arizona that storage sites offer a means whereby the fundamental principle of priority may be made to apply without hardship to those interests which, in default of any effective system of control, have developed during the past 20 years to the detriment of the first appropriators. It is fortunate that all the irrigation rivers, except the Colorado, are practically within the Territorial boundaries. In so far as this is true, interstate complications over the use of irrigating streams can not arise, as they have between New Mexico and Colorado over the Rio Grande or between Colorado and Kansas over the Arkansas River.

Summarizing the legal progress and tendencies at the present time it may be stated that after many years of costly experience in the difficulties incident to water distribution, the people of Arizona are at last in a fair way to adopt and practice those simple principles which for many centuries have been recognized by irrigators in the arid regions of the Old World.

IRRIGATION ENTERPRISES AND AGRICULTURAL PRACTICE.

The Territory may be divided into seven somewhat distinct districts, each with its own climatic conditions and its own water supply, as follows: The Colorado River Valley, the Salt River Valley, the Gila River and its tributaries, the Verde River and tributaries, the Little Colorado River, districts where rainfall may be supplemented by irrigation, and grazing ranges supplied by springs and wells.

IRRIGATION IN THE COLORADO VALLEY.

The alluvial lands bordering the lower Colorado River will probably develop into one of the richest agricultural sections of the Southwest. The cultivated areas are limited as yet, but a successful beginning has been made under the United States Reclamation Service operations, and rapid progress in the exploitation of this rich region seems to be assured. The peculiar advantages of the region reside in its favorable climate, its abundant water supply, and its unusually fertile soils.

CLIMATE.

The climate is distinguished by its mild winters, its all-year growing season, and the nearly rainless summers, which minimize the losses due to untimely precipitation. As commonly observed in arid regions, occasional frosts of some severity occur at lower levels, due to air drainage. Minimum temperatures recorded 1 to 2 feet above the ground, at the Arizona Experiment Station date orchard near Yuma for several years past, are as follows:

Minimum temperature record at experiment station date orchard, Yuma, Ariz.

Winter.	Record below 32° F.		Minimum record.	
	Number of frosts.	Date.	Degrees F.	Date.
1905–6	34	Nov. 29 to Apr. 3	20	Jan. 1.
1906–7	39	Oct. 21 to Mar. 29	21	Nov. 30.
1907–8	32	Nov. 17 to Feb. 15	23	Feb. 14.
1908–9	21	Oct. 29 to Mar. 13	24	Nov. 29.
1909–10	32	Nov. 8 to Feb. 19	17	Dec. 4.

These temperatures are too low for citrus culture and will occasionally damage the more tender winter truck crops. The adjoining mesas, however, are above the levels where the cold air collects, and are not subject to these low minima. The lowest record available from Blaisdell Heights, about 80 feet higher than the date orchard, is 26° F., and frostless winters have been recorded there. These bench or mesa lands, adjoining the Colorado bottoms, are suitable for citrus and other slightly frost-resistant crops, but are not adapted to such distinctly tropical crops as pineapples, bananas, or coconut palms. Maximum field temperatures under shelter, during June to September, range from 110° to 116° F., but are relieved to some extent by daily breezes coming from the Gulf of California. These temperatures permit of an all-year growing season for a succession of crops consisting largely of forages and fruits in summer and of grains and vegetables in winter. The rainfall is usually light, though occasionally much damage to fruits and hay is done by unexpected downpours in July and August.

WATER SUPPLY.

The water supply is in excess of the land and it is only necessary to bring it under control. The quality of these waters is usually good, ranging from 21 parts soluble salts in 100,000 of water in June floods to as high as 125 parts observed in one small October flood coming from a salty watershed.[1] In character the salts are white alkaline containing a large proportion of calcium sulphate, which is a chemical antidote for black alkaline lands.

The sediments of the Colorado River, considered chemically, are beneficial to the soils upon which they are carried by irrigation. These sediments have been observed to range from 0.45 to 28.2 tons per acre-foot of water, and often contain considerable organic matter which is of especial value on light, sandy soils deficient in humus and nitrogen. The deposition of sediments in irrigating ditches, however, necessitates frequent ditch cleaning. Settling sluices with which to partially clarify the supply are a necessary feature of irrigation works on this stream.

SOILS.

The river-bottom lands of the Colorado Valley range from dense, sticky adobe to light sands, the lighter soils predominating. These warm sandy soils, draining and working readily, are especially suited to intensive cultivation. The heavy soils, which take water slowly and bake and crack readily, are more difficult to handle, especially when charged with alkali salts.

The higher mesa soils are for the most part rather coarse sands, less fertile than the valley soils and considerably in need of the addition of river sediments and of organic manures and the benefits of leguminous green manuring crops. The mesa lands are quite rough and the river bottoms are diversified with dunes and old river channels. Leveling of such lands is necessary in preparing for irrigation. Alkali salts are generally present, but not usually in injurious amounts, except where ground waters wet the soil surface and there evaporate, leaving alkali crusts. Good drainage conditions should be assured in connection with irrigation in the region, so that soluble salts may be kept under control. The character of the alkali is sometimes "black," containing sodium carbonate; sometimes "white," consisting chiefly of sulphates and chlorids. The tendency of the river waters, containing calcium sulphate, will be to ameliorate the black alkaline lands and convert the more harmful sodium carbonate to sulphate.

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[1] Arizona Sta. Bul. 44, pp. 202, 203.

The Mohave, Chemehuevi, Yuma, and Cocopah Indians grow crops by crude methods in the Colorado flood plain. Millets, corn, sorghum, melons, squashes, beans, and other crops are planted in the wet ground as the summer flood waters recede, maturing before the ground dries out. Without means of controlling the Colorado, however, these people can not make use of the valuable spring and early summer season, which is the flood time of the river. White irrigators have made a number of attempts to operate pumping plants and construct ditches along the stream, in some cases with fair success, but in most instances with failure due to floods, changing currents, sand bars, and inadequate engineering devices.

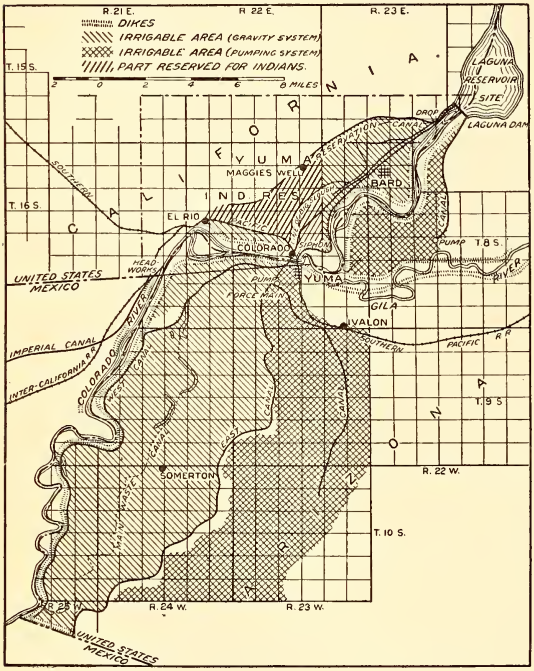


FIG. 6.—Yuma, or Laguna, project.

The principal irrigating plants now installed are: The pumping plant of the Camp Mohave Indian School Reservation; the Rio Colorado Land and Irrigation Co.'s gravity canal system below Camp Mohave Indian School Reservation; the pumping plant of the Colorado River Agency, Parker, Ariz.; the pumping plant (10-inch centrifugal) of the Cibola Canal, Cibola, Ariz.; the centrifugal pumping plant of the United States Reclamation Service, at Yuma, Ariz.; the scoop wheel; and the gravity canal of the United States Reclamation Service, at Yuma.

The United States Reclamation Service has entered upon the construction of engineering works of the Yuma project near Yuma, adequate for the control and utilization of the Colorado River on a large scale. The principal features of the work are:

(1) Laguna Dam, crossing the river 14 miles upstream from Yuma (fig. 6). This dam, completed in March, 1909, is 4,780 feet long,

250 feet wide, up and down stream, and 19 feet high. This broad, low structure raises the minimum river level about 10 feet, assuring an irrigating supply at all stages of flow of the river.

(2) The reservoir above the dam and the sluiceways at either end, which are designed to clarify the irrigating supply of a portion of its sediments, thus lightening the burden of ditch cleaning.

(3) The main canal, running from the west end of the dam to Yuma, where it will cross under the Colorado River to Arizona by means of a 14-foot inverted siphon. This is now nearing completion (March, 1911).

(4) Levees 73 miles in length along the Colorado and Gila Rivers, which are required to prevent untimely flooding of cultivated lands. These have been largely completed.

(5) Drainage, by means of low-level canals and water-elevating apparatus, to be provided in order to prevent swamping and accumulation of alkaline salts in the soils.

(6) Pumping stations, operated in part by power generated at a drop in the main canal, which are to elevate water to the bench or mesa lands.

(7) A temporary water supply, which has been provided by means of the old Ives and Colorado Valley Pumping and Irrigation Co. equipments, and by one of the scoop wheels which is to be used finally for drainage work.

As shown by this outline, the Yuma project provides for every contingency incident to a complicated situation. It will soon make possible the irrigation of 130,000 acres, as follows:

Lands to be irrigated under the Yuma project.

	Acres.
In Arizona:	
Gila bottoms	20,000
Yuma Valley	53,000
Yuma mesa	40,000
In California:	
Reservation lands	17,000

Of this area, 6,179 acres were in crops January, 1910.

The cost of the project will be about $55 per acre, payable in ten annual installments, without interest, beginning after the project is declared open.

FARM PRACTICE.

Leveling of the land is usually necessary because of the old river channels and wind-blown dunes of silt and sand. The buck scraper is one of the most effective tools known for moving dirt by horse-power, and is well adapted to smoothing land, building levees, and constructing the wide ditches necessary to carry water in a region of such low gradient as the Colorado Valley. The cost of leveling land and constructing the necessary head ditches with a buck scraper, man, and four horses at $5 per day is rarely less than $20 an acre.

The main crop is alfalfa, which is started easily on new lands, yields prompt returns, and enriches the soil. Seven cuttings are harvested, and with proper care should yield 7 to 12 tons of hay, salable thus far at $10 to $15 per ton. Crops of seed averaging 400 to 500 pounds per acre may be harvested. This seed is worth 12 to 17 cents per pound.

Barley and corn also are grown, especially on new land, and yield remunerative crops. Eucalypts and date palms are among the trees adapted to the district. Following alfalfa, orchards, fruits, and vegetables can be grown to excellent advantage under intensive cultivation. The rotation of alfalfa with other crops will renew the soil, enable the salts, which tend to accumulate with ridge and furrow cultures, to be flooded out, and arrest the plant diseases and pests incident to certain of these crops. The whole range of products enumerated on page 19 is possible in the Colorado Valley region, but time has not sufficed to settle the details of agricultural practice.

The markets at Yuma have been strong thus far, and a good shipping trade with Arizona and California points is possible. During three years of mixed alfalfa and truck farming at the Arizona Experiment Station date orchard, the following acreages were cultivated and crops having the following gross values produced:

Acreage and gross values of alfalfa and truck products produced at the Arizona Experiment Station date orchard.

Year.	Acres.	Gross value of crops.
1906–7	4.73	$928.09
1907–8	5.46	1,483.43
1908–9	5.10	852.08

The amount of labor used each year was such as could be furnished for the most part by an industrious family of five.

Alluvial lands below Yuma are mostly owned privately and can be purchased for $50 to $250 per acre, according to their character and distance from a railroad. A smaller area of bottoms and a large area of mesa lands will be available, probably in 40-acre homesteads, under the United States Reclamation Service restrictions when the project is complete. This district offers excellent opportunities to the homemaker having capital sufficient to purchase a small acreage and the necessary horses and tools. In addition, he should have cash, or the means of earning $500 to $1,000 the first year. The following is a statement of expenses and income derived from the first two years' operations on the station garden mentioned above.

Expenses and income for the first two years' operations on a small intensively cultivated farm.

EXPENSES.

Land, 7.2 acres, at $100 per acre	$720.00	
Survey and papers	20.00	
Leveling, by contract	124.00	
Fencing, headgate, pump, drive point, small 2-room cottage, and shelter for horses	271.00	
Team, wagon, plow, harrow, garden tools, mowing machine	615.00	
Total preliminary outlay		$1,750.00
First year: Cash for seed, water, crates, etc	127.92	
Second year:		
Seed, water, crates, etc	226.19	
Improvements	59.28	
Hired labor	72.00	
Total operating expenses for two years		485.39
Total cost		2,235.39

RECEIPTS.

Cash for produce first year	928.09	
Cash for produce second year	1,483.43	
Total		2,411.52

IRRIGATION IN THE SALT RIVER VALLEY.

Salt River Valley is at this time the largest irrigated district within the Territory. Beginning in 1867 irrigation increased rapidly, until 20 years later the unregulated stream was overtaxed by the demands made upon it in times of shortage. Since that time the most important problem of the valley has been the adjudication and management of the water supply. This problem has been solved through the operation of the reclamation law, and, with 561,024 acre-feet of water now (April, 1911) in the Roosevelt reservoir, its efficiency is demonstrated.

CLIMATE.

The climate of Salt River Valley resembles that of the Colorado Valley at Yuma, but both its frosts and summer temperatures are slightly more extreme, consequent upon a 1,000-foot higher altitude, and the absence of tempering gulf winds. The rainfall is sufficient to necessitate the protection of hay and other perishable crops, and in summer often interferes with the drying of such fruits as figs and raisins.

The severest frosts are at the lowest levels. The slopes adjacent to the Phoenix and Salt River Mountains and the high ground near Mesa are, however, so mild in winter as to admit of citrus culture. Minimum temperatures at the station farm, 1,090 feet altitude, taken 4 inches above the soil surface, have been observed as follows:

Minimum temperatures at the experiment station farm in the Salt River Valley.

Winter.	Records below 32° F.		Minimum record.	
	Number of frosts.	Season.	Degrees F.	Date.
1900–1901.	51	Oct. 30 to Apr. 9	14	Dec. 31
1901–2	64	Dec. 8 to Mar. 27	15	Dec. 14
1902–3	70	Nov. 16 to Mar. 23	18	Feb. 16
1903–4	72	Nov. 17 to Apr. 22	14	Jan. 29
1904–5	33	Nov. 12 to Feb. 14	20	Dec. 29

Maximum temperatures, under shelter, of 111° to 117° F. in June and July, were recorded at the same place each year during the years 1904–1909. At Ingleside (1,265 feet altitude) in one portion of the citrus district, the minimum winter temperatures for the years 1899–1902 were 22°, 21°, 20°, and 29° F., respectively. Hardy vegetables grow all winter, but the planting time for spring crops averages about two weeks later than in the Colorado Valley.

WATER SUPPLY.

The surface water supply, with storage, as shown on pages 43 and 44, may be developed finally to irrigate 210,000 acres, with occasional runs of flood water in excess of this estimate. Ground waters, mainly south of the Salt River, are assumed sufficient at this time to irrigate 50,000 acres, and seepage waters are now utilized for the irrigation of about 14,000 acres in the Buckeye and Arlington districts west of Salt River Valley proper.

The quality of this supply has been observed to vary from 52 to 157 parts of soluble salts in 100,000 parts of upstream water, the larger amount being associated with the low summer flow. The reservoir will equalize the quality of the irrigating supply as well as its flow, a fact of advantage to localities where conditions favor the accumulation of soluble salts in the soil. Seepage waters have been observed to contain from 118 to 182 parts in 100,000 of salts, increasing downstream. Ground waters pumped for irrigation have been found to contain as high as 509 parts in 100,000 of soluble solids. The writer believes that under conditions favorable to the rise of the alkali, 100 to 150 parts of soluble solids in an irrigating water will accumulate harmfully in the course of a few years, but that with good drainage, abundant supply, and correct cultural methods whereby the rise is prevented, it is possible that even the seepage waters mentioned above may be used without harmful effects. The extreme of 509 parts is, however, dangerous in the average situation, and usually within a few years will result in an overcharge of soluble salts in the soil. The waters of Salt River usually carry white alkali and contain calcium sulphate, which tends to neutralize the originally slightly black alkaline soils of Salt River Valley. Rare floods have been observed, however, evidently from black alkaline watersheds.

The amount of sediment is much less than in the Colorado waters, 0.05 to 12.95 tons per acre-foot of water having been observed during one year. The Roosevelt reservoir, which will retain the sediments from the Salt River proper, will lessen the amount carried upon valley lands by so much. Salt River, because of its protected watershed and its reservoir, always will afford the clearest large water supply in Arizona.

SOILS.

The soils of Salt River Valley range from heavy adobe to gravelly river wash. Loess and sandy loam soils of great fertility constitute more than half the area, while less fertile gravelly loams and sands and less easily cultivated clay soils make up the remainder. The chief need of all these soils is organic matter and nitrogen, both of which are supplied by the principal crop, alfalfa.

Alkali salts, originally slightly black in character, have been concentrated in certain localities where drainage is poor to an injurious extent through the action of irrigating waters. These salty districts, however, are all susceptible to drainage, either by sumps and pumping or by lines of tile, and will be reclaimed ultimately.

SALT RIVER PROJECT.

All of the Salt River Valley canals have been acquired by the United States Reclamation Service as a part of the Salt River project, with the exception of the Tempe and part of the Utah systems. To these three main systems using upstream waters should be added the Buckeye and Arlington canals, which water a westerly downstream extension of the main Salt River Valley with water that has returned to the river channel as seepage.

The main features of the Salt River project, concerning which full information may be obtained from the United States Reclamation Service, may be described briefly as follows:

(1) A watershed drained by the Salt and Verde Rivers, a large portion of which is protected and conserved as National Forests.

(2) Roosevelt Dam and reservoir on Salt River, with a capacity of 1,284,000 acre-feet. The dam is now complete and the reservoir has been in service since February, 1910. The McDowell and Horseshoe reservoir sites on the Verde River, with a combined capacity of 485,000 acre-feet, possibly may be developed as a part of the project

at some future time. Figure 7 gives a general view taken when the dam was nearing completion. Plate III is a view of the completed dam.

(3) Electric power, already developed through a power canal, and further to be developed at the dam and at various sites in river and canals below.

(4) Pumping plants operated by electric power at points where ground waters are economically near the surface. The excess of power possible under the project may be sold for industrial purposes, thus contributing to the repayment of the project.

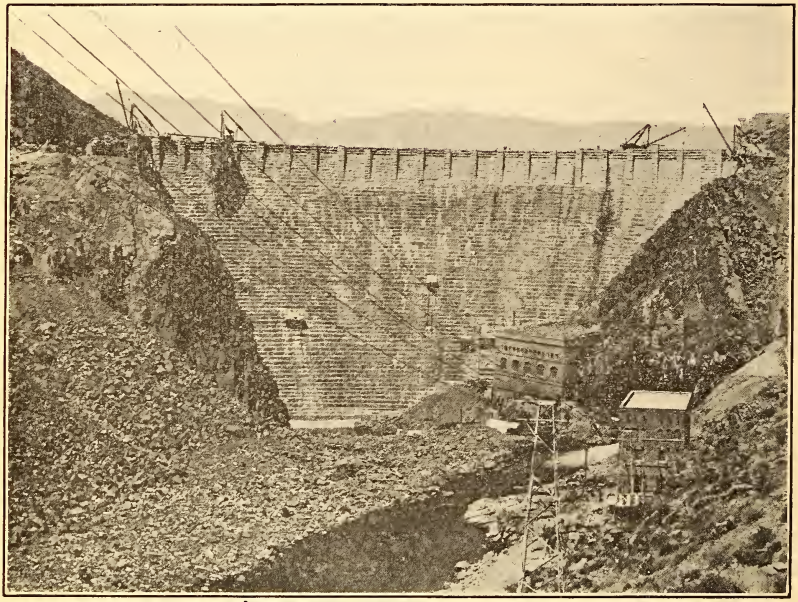


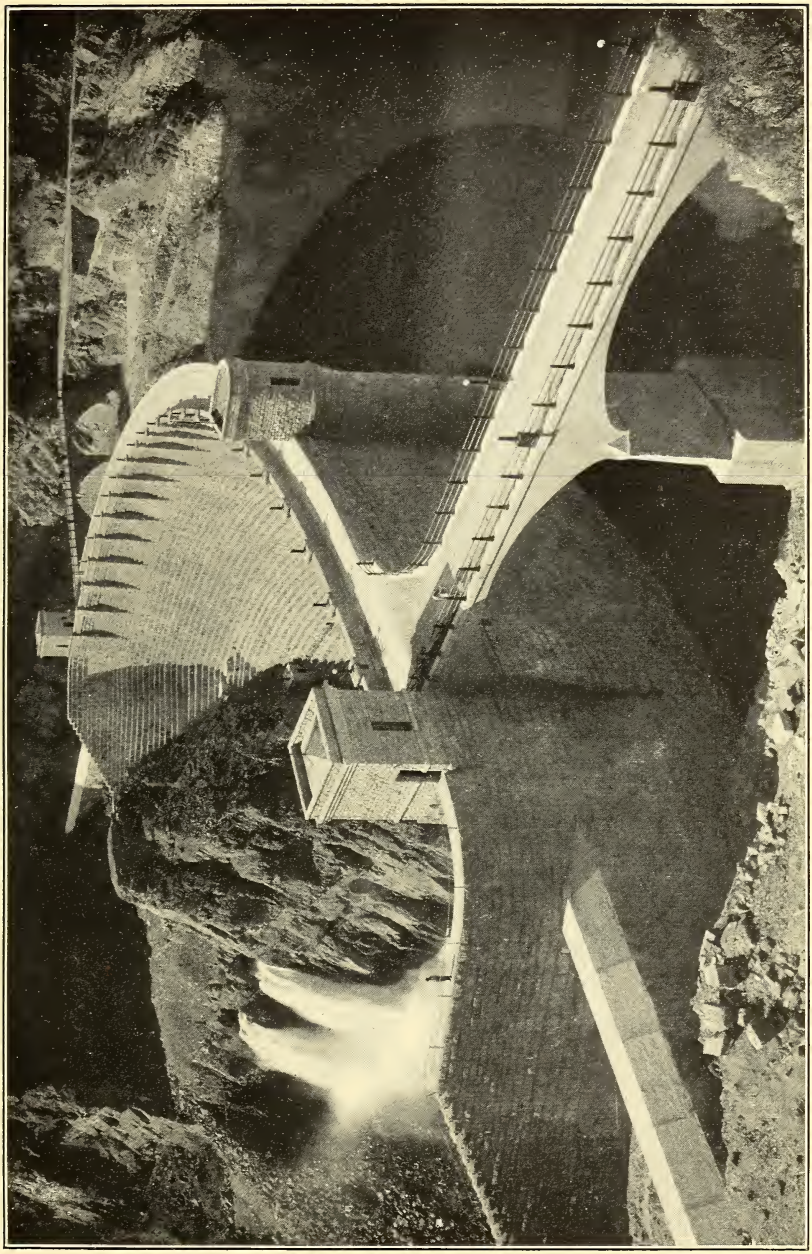
FIG. 7.—The Roosevelt Dam, nearing completion, May 10, 1910.

(5) Drainage plants operated by electric power in cultivated districts where ground waters have risen injuriously near the surface.

(6) Granite Reef diversion dam at the head of Salt River Valley, making sure the diversion of regular river flow and storage waters to irrigated lands. Temporary diversion dams, destroyed by floods and causing loss of irrigating waters at critical times, have been a serious drawback heretofore to the region.

(7) Distributing canals and laterals on both sides of Salt River. These now (March, 1910) include main canals as follows (fig. 8):

North of Salt River: Arizona, Crosscut, Grand—appropriators, Maricopa, and Salt River Valley Canals. South of Salt River: Eastern and Mesa Consolidated Canals.



VIEW OF COMPLETE ROOSEVELT DAM.

This project, as outlined above, will secure the irrigation of 240,000 acres, of which about 190,000 acres will be irrigated with surface water, and not less than 50,000 acres with pumped water.

The Salt River project, as now outlined, will cost about $45 an acre for the lands subscribed to the undertaking, or a total expenditure of about $8,000,000. The income from the sale of surplus power from Salt River, however, will contribute materially to the repayment of the project and will lighten the burden of the 10 annual payments upon the shareholders.

Adding the McDowell and Horseshoe reservoir sites to the project would make possible the irrigation of 20,000 to 30,000 acres additional with surface water. The ground-water supply also, which can

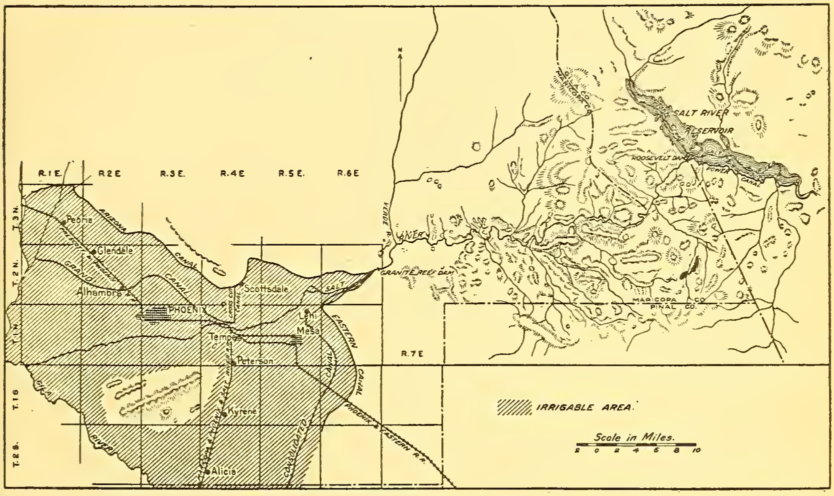


FIG. 8.—Salt River project.

only be roughly estimated at this time, is likely to prove adequate for the irrigation of a greater area than that now planned. The Buckeye and Arlington districts, while not within the Salt River project, are benefited indirectly, as extended irrigation on upstream areas will tend to increase their supply of seepage waters.

FARM PRACTICE.

Land surfaces in Salt River Valley are very smooth, requiring little leveling, and slope from less than 10 to as much as 20 feet to the mile. Such slopes afford excellent gradients for ditches, and facilitate irrigation. The average cost of bringing land under irrigation in Salt River Valley is therefore minimum.

Alfalfa, as elsewhere in southern Arizona, is thus far the most important crop. It yields five to six cuttings of hay, or, if desired, produces profitable crops of seed; affords two or three months' pasturage, convertible into mutton, beef, and dairy products; endures well both extremes of temperature and periods of drought, and, with all this, enriches the soil for other crops, and therefore is perfectly adapted to the conditions and needs of the region. Following is a fair statement of profits per acre from well-farmed alfalfa:

Cost of raising alfalfa hay and profit per acre.

COST.		
Labor—making and stacking five cuttings—6 tons of hay	$9.00	
Water	1.50	
Labor irrigating	1.00	
Incidentals	.50	
		$12.00
RETURNS.		
6 tons loose alfalfa in stack	42.00	
2 months' pasture for two animals	6.00	
		48.00
Net gain on 1 acre of hay, not deducting interest on investment		36.00

When fed to beef cattle, allowing 2 acres for three animals, the statement becomes as follows:

Cost of producing alfalfa and profits per acre when fed to steers.

COST.	
Making 3 tons of hay for winter feed	$4.50
Water	1.50
Labor irrigating	1.00
Incidentals	.50
	7.50
RETURNS.	
900 pounds increase in weight of steers, not deducting shrinkage or allowing for loss by accident, at 4.5 cents	40.50
Net gain on 1 acre, not deducting interest on investment	33.00

Because of high prices for baled hay, often ranging to $15 per ton in Salt River Valley in early spring, much alfalfa is sold in that form, although a considerable portion of the crop is fed and handled in the form of beef. Dairying is profitable also, and several creameries and one condensed-milk factory afford markets for the product. Range sheep are prepared for market in increasing numbers on alfalfa; bees forage upon it for honey, and even ostriches are satisfied with it as their main food staple.

An important, though recent, feature of agricultural practice in Salt River Valley is developing from the successful operation of the beet-sugar factory at Glendale. Sugar beets for the factory are planted from December to February, inclusive, and harvested from June to early in August. Cowpeas may then follow the sugar beets in time to make a summer crop of 1 to 3 tons of cowpea hay, which may in turn be followed by another crop of sugar beets. Meantime the waste products from the initial crop of sugar beets may be utilized in various ways. The leaves and crowns may be piled with pulp from the factory and this carbohydrate ration fed to cattle in a balanced combination with cowpea hay from the same ground. The molasses waste may be combined also with alfalfa meal and used as a concentrated feed. The land may be cropped in this manner throughout the year, and the fertility of the soil may be maintained by the cowpeas, the irrigating sediments, and manure from the feeding pens. Incidentally, the climate makes possible the preservation of sugar-beet pulp in piles or pits in the open air, and facilitates the drying of the coarse cowpea hay. In this seemingly perfect combination of crops and conditions nothing, theoretically, is removed from the land but the sugar and the meat, the elementary constituents of which are inexhaustably available, without depletion of the soil, from the air and irrigating sediments.

Citrus culture, prospectively the most important fruit-growing industry of the valley, is confined to the slopes where orange-killing frosts do not occur. The early ripening of oranges in the region is a very favorable circumstance, the first shipments often reaching eastern markets in time for the Thanksgiving trade. The bright color and excellent quality of the fruit, due both to climatic conditions and the absence of citrus pests, is another reason for the high prices which have been received for this product. The culture of oranges and pomelos, with an assured water supply under the Roosevelt reservoir, will expand considerably in those parts of Salt River Valley where winter temperatures permit. Cantaloups are an established and remunerative crop and are marketed mainly in eastern cities through growers' associations. Ostriches are an interesting and profitable novelty of recent development. In brief, with an assured water supply, a remarkable diversity of profitable crops possible, and a scientific and intensive agriculture already well under way, Salt River Valley is certain to make rapid advancement in agricultural practice and development.

Lands are nearly all in private ownership, and under the project are purchasable at $75 to $250 an acre, according to condition, character, and locality. The present tendency is toward small farms and more intensive cultivation. Reservoir water is, in fact, limited to 160 acres for any one user.

The Buckeye and Arlington districts immediately west of Salt River Valley resemble it in climate, soil, and water supply, but there are no railroads. This fact tends to limit the people to those products which can be transported easily to market. Alfalfa seed is one of these, the yield and value of which are expressed in the following estimate:

Cost and profits per acre of raising alfalfa seed.

COST.		
2 tons alfalfa hay sacrificed, at $6 per ton	$12.00	
Water, 3 months' supply	.25	
Cutting and hauling	1.75	
Thrashing, 400 pounds of seed, at 3 cents	12.00	
Sacking, at 15 cents per hundred pounds	.60	
Hauling, at 25 cents per hundred pounds	1.00	
		$27.60
RETURNS.		
1 ton alfalfa straw	4.00	
400 pounds seed, at 14 cents	56.00	
		60.00
Net gain on fair average seed crop, not deducting interest		32.40

In addition to the seed crop, two cuttings of hay and winter pasturage are obtained. Much of the crop is fed to beef steers which are then driven to Gila Bend or Phoenix for shipment. Land values are moderate, ranging from $60 to $120 an acre. Being outside the Salt River project this district will not share in its cost, although it will be benefited by the seepage waters escaping from the upper valley. Two canals, the Buckeye and the Arlington, cooperatively owned by the farmers, serve these lands which, at present prices, without reservoir payments to be made, and with railroad transportation at hand, still offer excellent opportunities to incoming farmers of moderate means.

IRRIGATION ALONG THE GILA RIVER AND ITS TRIBUTARIES.

The lower Gila River from Florence to Yuma is very similar in climate and soils to the Salt River Valley, but the uncertain surface flow, the lack of storage, and a want of knowledge concerning its ground waters have thus far nearly prevented agricultural development, except under the Florence Canal.

The upper Gila River near the eastern boundary affords a water supply adequate for the irrigation of about 23,000 acres between Duncan, on the Arizona-New Mexico line, and San Carlos. This district, with an altitude between 2,500 and 3,700 feet, is distinctly less subtropical than the Colorado and Salt River Valleys. Winter temperatures range as low as 8° F., a temperature which excludes Eucalyptus and citrus trees. The hardier vegetables, such as onions, beets, and cabbage, grow through the winter season. Killing frosts for tender vegetation cease usually early in April and begin late in

October. The climate of the artesian belt, on the north slope of Graham Mountain, is somewhat milder than that of the valley bottom.

Soils here, as in other Arizona valleys, subject to the sorting action of flood waters, range from light sands to heavy clays. Much of the land in this district is steep and rough, and to reduce expense of leveling often is irrigated through furrows deep enough to carry water across uneven ground. For this purpose a homemade furrower or drag is much used, consisting of a heavy beam, to the underside of which are fixed four or five shovel blades or similar parts, which furrow the soil as the tool is dragged broadside across the field. The steep gradients of this district necessitate waste ditches at the lower sides of fields to carry off surface waters for use on adjacent lands.

The irrigating waters are somewhat less saline than those of Salt River, ranging from 39 to 120 parts in 100,000 of water during one year's observations. Through the action of irrigating water, alkaline salts have accumulated to an injurious extent in some localities, but in most cases these accumulations may be washed out by flooding and drainage.

Immense quantities of sediments are carried by Gila River floods, due to the eroded condition of the watershed. These sediments have been observed to vary from 0.11 ton per acre-foot of water at a time of low flow to 128 tons during high water. Such amounts of sediment dropped in ditches necessitate expensive cleaning operations and require attention when deposited on irrigated fields. If allowed to accumulate upon alfalfa or other uncultivated crops they will blanket the soil gradually with a more or less impervious layer, which hinders access of water and air to the roots of the plants. Thorough cultivation of soils irrigated with muddy waters is therefore an especially important item of farm management in the region.

IRRIGATION WORKS.

Most of the irrigating ditches of the district are small, and are owned and operated by individuals and by companies of farmers. The following is a partial list of existing canals named in order from the New Mexico line downstream:

Canals from the Gila River.

Duncan Valley canals.[1]—In New Mexico: Telles, Rucker, Hughes, Martin, Wilson, Hill, Schriver, Johnson.

In New Mexico and Arizona: Casper and Windham, Valley, Owen, Franklin, Model.

In Arizona: Day, Ward & Courtney, Duncan, Black & McCloskey, Waters.

[1] U. S. Geol. Survey, Ann. Rpt. 1899-1900, pt. 4, p. 336.

Solomon Valley canals:[1]

	Acres irrigated.		Acres irrigated.
Brown	100	Smithville	1,760
Sanchez	400	Bryce	515
Mejia	320	Dodge	450
Fourness	260	Nevada	800
San Jose	3,000	Curtis	800
Michelena	450	Kempton	850
Montezuma	3,750	Reid	100
Union	2,900	Fort Thomas	960
Sunflower	400	Thompson	240
Graham	962	Military	400
Central	2,675	Saline	36
Oregon	1,100	Zeckendorf	500

Between San Carlos and Florence: Shields Canal, Winkleman Canal, Brannaman Canal, Florence Canal.

The United States Reclamation Service has no project under construction on the Gila River and the Carey Act is not in operation in Arizona, so that water developments in this district are wholly a matter of private enterprise.

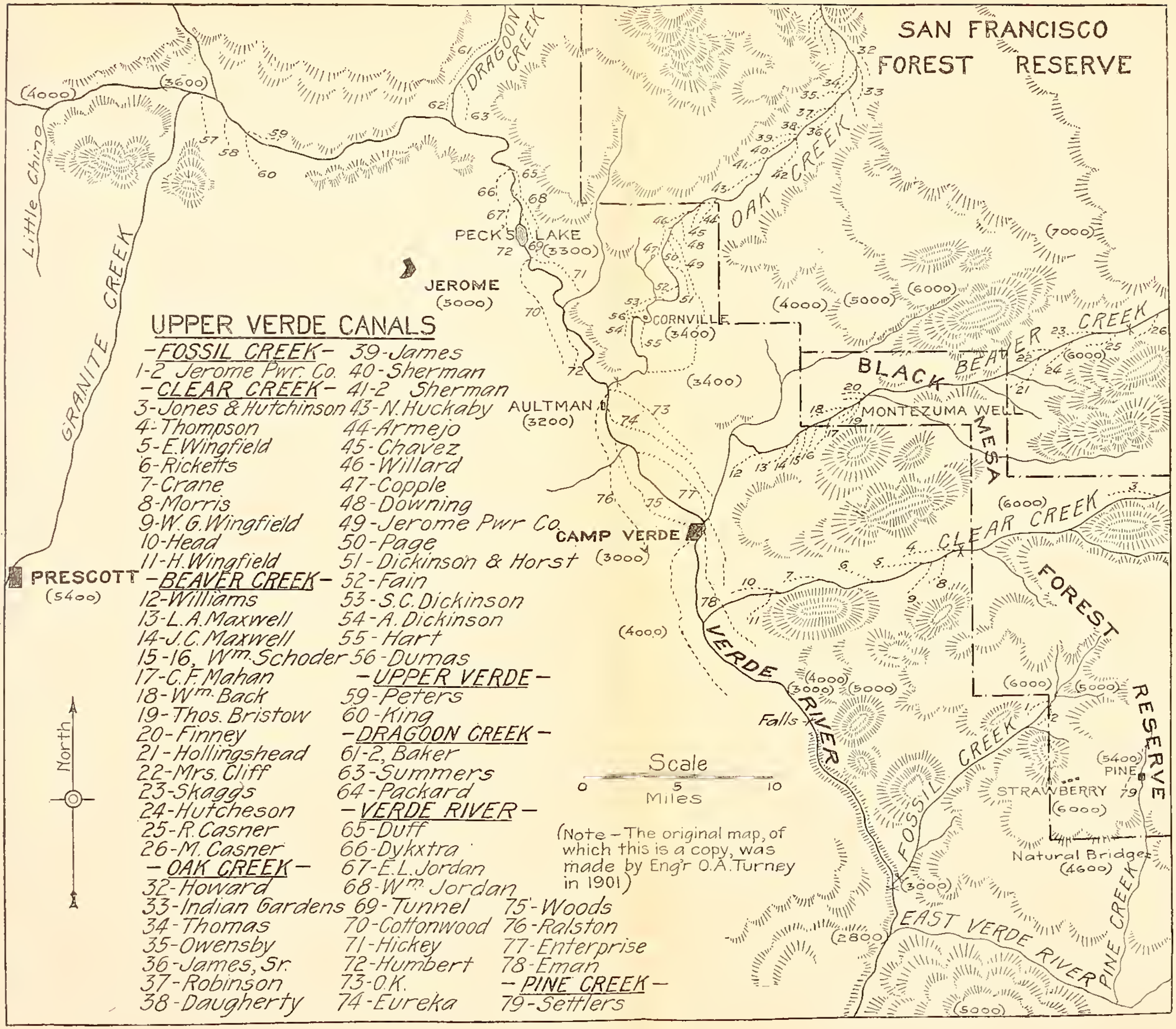
FARM PRACTICE.

Alfalfa hay is the principal crop of the district, bringing high prices in the several surrounding mining towns. Four to five cuttings are harvested, with additional pasture, and in early spring hay usually reaches $14 a ton baled, at the cars. The culture of alfalfa is developed highly on the upper Gila River. Renovators are used to break up silt accumulations and make the soil surface receptive to irrigating waters, and hay loaders, improved stacking machinery, and gasoline power balers are used. By reason of the high price of hay and the convenience with which it is made, dairying is but little followed, although with good cows it is more remunerative than the raising of hay. Other important crops in this region are oats, wheat, and barley. Deciduous fruits produce well, especially pears, peaches, and apples. Where the codling moth is under control apples of superior quality are grown and marketed in the near-by mining markets of Globe, Clifton, Morenci, Douglas, and Bisbee.

Land values are high by reason of excellent markets, high prices, and limited areas under cultivation, ranging from $100 to $200 per acre. The farms are small, and the people, largely of the Mormon faith, incline toward intensive methods of farming. The Arizona & New Mexico and the Gila Valley, Globe & Northern Railroads traverse the district.

The San Pedro and Santa Cruz Valleys resemble the upper Gila agriculturally. St. David on the San Pedro, watered both by stream

[1] Fifth judicial district court decree, Feb. 10, 1906.



Upper Verde River Canals.

flow and by wells, is a place of gardens, the produce from which finds a ready market in Bisbee and vicinity. The Santa Cruz Valley is less developed than the San Pedro, partly because railroad connections have not been so good until recently. Summer flood waters are utilized on both these streams for a quick-growing crop of corn planted in July and harvested in October, while in similar manner the winter rains afford water for crops of wheat and barley harvested in May.

About 45 small canals take water from the San Pedro River, and probably 60 draw upon the Santa Cruz and its tributaries. The El Paso & Southwestern and the Southern Pacific Railways in the San Pedro, and the Southern Pacific in the Santa Cruz Valley afford transportation facilities. Ground waters in considerable quantity underlie both these valleys and are being developed in considerable quantity by artesian wells on the San Pedro and by pumping plants along the Santa Cruz.

IRRIGATION ALONG THE VERDE RIVER AND ITS TRIBUTARIES.

The upper Verde River, including Clear, Beaver, Oak, and Dragoon Creeks, is distinctly a deciduous fruit-growing district, producing the finest apples, peaches, pears, and other temperate-region fruits grown in Arizona. The altitude is 3,500 to 5,500 feet; the winters are sharp, with occasional snow, and the summers milder than in the larger, lower irrigated valleys. The farms are small for the most part, being situated in the nooks and angles of comparatively narrow creek valleys The numerous small ditches are owned by individuals or small companies of farmers. Alfalfa, corn, and grains are considerably grown under some of the large canals in the main Verde Valley. Jerome and Flagstaff afford markets for fruits and vegetables, and the United Verde and Pacific Railway at Jerome affords further outlet for fruits to more distant points. (Pl. IV.)

There are a number of small tracts throughout central and southeastern Arizona where altitude and limited water supply combine, suitable for deciduous orchards and market gardens. These are often very remunerative when situated convenient to mining towns.

IRRIGATION ALONG THE LITTLE COLORADO RIVER.

The northeastern plateau, drained by the Little Colorado River, has an altitude of 5,000 to 7,000 feet. The climate is temperate in character, with cold winters and a summer season similar to that of Kansas or Kentucky. Rainfall ranges from 8 to 20 inches, but the watershed is favorable to the rapid loss of storm waters, and without storage the irrigated area must remain small. Railroad facilities are limited to the Santa Fe, which does not connect immediately with the larger irrigated settlements.

Alfalfa yields two to three cuttings a year. Winter wheat and barley are grown, and summer crops of corn. Vegetables and deciduous fruits are also successful, sometimes without irrigation, at higher elevations. Farming in this district is combined with the ranging of sheep and cattle. Cattle formerly predominated, but in recent years sheep have become the main industry. The following statement of operations of a representative sheep owner for one year will afford an insight into expenditures and profits of this business:

Beginning with November 1, 1908, with 4,000 ewes, the owner's account for one year is as follows:

Expenditures and profits of sheep raising.

EXPENSES.		
Wages of 4 men, November to May	$1,200	
Wages of 6 men, May to November	1,800	
Wages of 8 extra men, 1 month in lambing time	400	
Buck herding	150	
Dipping once	160	
Shearing	280	
Chuck wagon and team	50	
Salt	100	
Renewal of bucks	300	
Miscellaneous items	100	
County taxes	250	
Forest reserve tax	360	
Total expenses		$5,150
RETURNS.		
26,600 pounds of wool, at 16 cents per pound	4,256	
2,450 lambs, at $3 each	7,350	
		11,606
Profits, not deducting interest or owner's time		6,456

The net increase of lambs, after deducting 15 per cent taken by coyotes and wildcats, was 70 per cent, or 2,800. Three hundred and fifty of these were required to replace ewes lost during the season. Conditions were favorable and profits high for the period stated. Forest Service restrictions limit the number of sheep permitted in reserves and have in a measure secured the industry against losses incident to overstocking.

Water storage is essential to increase of agriculture in this district, which, during the 35 years since its first settlement by Mormon farmers, has been developed to the full extent of its dependable water supply.

FARMING WITH RAINFALL SUPPLEMENTED BY IRRIGATION.

In those portions of Arizona having 10 or more inches of rainfall annually so-called dry-farming methods, supplemented by irrigation at critical times, will often mature crops successfully. During occasional wet seasons, as the winter of 1905, sufficient moisture falls to make crops without unusual effort on the part of the farmer, but rainfall in the Southwest is too variable in both time and amount to be depended upon. It is essential, therefore, in the average year, for the dry farmer to have available a supplementary supply, perhaps to bring up seed in a dry soil, or to mature a crop which otherwise would be lost through a failing rainfall. In practice, as it now begins to take form, this supplementary supply is secured either by small water storages possible on many sites in swales and little valleys near the crests of our watersheds or by pumping from the somewhat extensive areas of our valley bottoms, where ground water is found at 50 feet or less from the surface.

One of the largest supplies of supplementary ground water for pumping is that of Sulphur Springs Valley, which will serve as an illustration. In May, when corn, beans, melons, etc., may be planted to the best advantage, the soil usually is dry because of the preceding rainless months. A single irrigation in the seed furrows will cause germination and carry the plants until the rains begin in July. This single supplementary irrigation, therefore, even if costly, is of great value in securing an early start and a matured crop. The seeding time for wheat, barley, etc., in this valley is October, which usually is a dry month also. Supplementary irrigation at this time is similarly useful, and in many cases irrigation is required again in the spring to bring the crops to maturity. The rainfall of this and similar valleys, although in itself inadequate and untimely for the sure maturing of crops, may be utilized with the help of ground waters within easy reach of pumps.

In the ways suggested above—by conserving the rainfall, supplementing it with flood, reservoir, and ground waters, and by employing varieties suited to arid regions, considerable areas will be reclaimed gradually. This expectation is encouraged by the fact that for portions of Algeria, with similar climate and a rainfall of 10 to 16 inches per annum, recent statistics give the following productions of different kinds:

Yield of crops in Algeria.

Crop.	Production per acre.	Total product.
Wine..............gallons..	1,000	175,000,000
Wheat............bushels..	10	24,500,000
Corn.................do....	8	58,000,000

Even at the beginning of operations in comparable locations in southeastern Arizona, part crops of beans, corn, sorghum, and melons indicate final success by the methods above suggested.

GRAZING RANGES.

Springs and deep wells throughout the grazing sections of the Territory are of great value, since they are the key to the adjoining range. A Hereford steer will travel about 8 miles between water and feed, so that the strategic value of occasional springs in the more arid districts is evident. For the same reason heavy expense is incurred sometimes to secure water where there is a desirable range. An instance is the Fresnal well, 786 feet deep, southwest of Tucson.

The range country for the most part is used as a breeding ground, and the increase is shipped as yearlings and 2-year-old stock to the irrigated valleys of Arizona and southern California, to be finished on alfalfa. Under the old conditions of free range without governmental control the cattle business was a very uncertain one, being very profitable in years with abundant and timely rainfall, but disastrous in years of drought when feed and even stock water was short. It is difficult to make a fair statement of income available from range cattle at this time, conditions being generally severe, with an outcome varying each season from serious loss to fair and easy profit, according to local circumstances affecting the owner's operations.

THE AGRICULTURAL PRESENT AND FUTURE.

On the basis of present agricultural practice, of an approximately known water supply, and of irrigation history in older States, it is possible to outline roughly at this time the future of irrigation in Arizona.

AREAS NOW UNDER CULTIVATION.

The area actually cropped in the Territory during the year 1909, as ascertained by exact data for United States Reclamation Service projects, and by personal reconnaissance and correspondence for other districts, is about as follows:

Areas cultivated in 1909.

	Acres.
Yuma Valley, United States Reclamation Service project (January, 1910)	6,179
Colorado Valley, Camp Mohave to Laguna	500
Salt River Valley, United States Reclamation Service project (January, 1910)	129,571
Buckeye and Arlington districts	14,000

	Acres.
Gila Valley from Monument to San Carlos, including Indian reservations	12,700
Gila Valley from San Carlos to San Jose	21,000
Gila Valley from San Jose to the New Mexican line	2,700
San Francisco, Blue, Eagle, and Pinal Creeks	820
San Pedro Valley, excluding artesian waters	5,800
Santa Cruz River and tributaries	6,000
Upper Verde River and tributaries	7,650
Little Colorado River and tributaries	10,650
Miscellaneous small streams and springs	3,050
Indian lands not included above	5,000
Irrigation from mine waters	700
Artesian irrigation at St. Davids, San Bernardino, Lebanon, and Artesia	1,450
Total irrigated area	227,770

Certain of the areas included in this statement are not farmed the year around owing to fluctuating water supply, but for irrigated land that is actually cropped at least once a year the above total is probably within 5,000 acres, or 2 per cent, of being correct.

There are limited additional areas on higher mountain slopes and in the northern parks which are farmed on rainfall, but these probably do not exceed 10,000 acres actually cropped, even including the beginnings in dry farming now under way in Sulphur Springs Valley.

ESTIMATED AREA POSSIBLE TO CULTIVATE.

With a possible water supply of 4,000,000 to 5,000,000 acre-feet annually, the limit of intensive irrigation in Arizona may be set at 800,000 to 1,000,000 acres, divided among different watersheds, approximately as follows:

	Acres.
The Colorado Valley between Camp Mohave and the Mexican line	350,000
The Little Colorado Valley	100,000
The Salt and Verde Rivers	280,000
The Gila and tributaries	140,000
Small streams and wells	30,000
Total	900,000

The use of a portion of the ground-water supply to supplement rainfall will result in the cultivation of additional areas of less intensively cultivated land of unknown extent. For gardens in towns and in favorable locations, for stock water supply, and for an increasing number of summer homes at higher elevations, there are also being developed numerous small waters of large aggregate value. Reckoning that each two irrigated acres will, directly or indirectly, add one to the population, and including those interested in range and forest industry, the future agriculture of Arizona may easily support a population of 500,000 people, outside of those connected with mines and transportation industries.

The valuation of irrigated crops produced in 1907 on about 200,000 acres in Arizona was about $9,000,000. Allowing for the crude methods in large part employed, it is fair to say that under improved conditions intensive farming will result in probably twice this return from irrigated lands. Five times the present area of doubly productive land will yield an annual product worth $90,000,000, which, with a possible output of $20,000,000 annually from grazing ranges, would give a total for the agricultural industries of over $100,000,000 annually. This is well in excess of the mining output of the Territory at the present time and suggests the possibility that finally in Arizona, as in the once mining States of California and Colorado, agriculture will become the leading industry.

LINES OF PROGRESS.

The lines of progress along which such outcome is possible relate to the legal, to the scientific, and to the social aspects of irrigation.

In a region of limited water supply a thorough understanding of the principles of law relating to the use of water is absolutely essential to harmony among irrigators and to the integrity of farm values. Fortunately, the two water users' associations in the Salt River and Yuma Valleys, working in cooperation with the United States Reclamation Service, are schools of irrigation law for those whose lands are included within these projects. These associations are organized in compliance with the principles of beneficial use of water on land; that particular shares of water shall be appurtenant to specified areas of land; and that priority of appropriation gives the better right to the use of water, etc. They therefore provide for the enforcement of these necessary but hitherto much neglected features of the Territorial law. With a constant influx to the Territory of settlers knowing nothing of the principles governing irrigation, sustained effort is needed on the part of the associations of irrigators, those called upon for legal advice, and educational institutions, to the end that all users of water may understand and observe willingly these indispensable equities in the use of water.

Along scientific lines progress is variously possible and essential. Water conservation and development is a fundamental subject, calling for engineering, mechanical, and general scientific attention, beginning with the watersheds and ending only when the supply is delivered to the irrigator. The beneficial and effective use of water not only requires scientific study of climate, soils, and water, but expertness in the irrigation and culture of crops by water users. Rotation of crops and advantageous methods of farm management are of special importance in a region capable of an all-year succession of crops. Maintenance of fertility, control of alkali salts and plant diseases, and the management of domestic animals are all factors in farm practice in the region. The introduction and breeding of new plant varieties is of the highest importance in a region originally in possession of an extremely meager agricultural flora. Almost all important forages, fruits, and vegetables of the Territory originated in other regions, and the breeding of varieties especially adapted to the conditions is necessary to the best use of the limited water resources. Particular types of animals, as Algerian sheep, ostriches, and white Leghorn fowls, are favored to some extent also by the subtropical semiarid conditions.

Cooperative social development is another necessary feature of farm life in the Southwest. The first act of an irrigator usually is to associate himself with others for the purpose of constructing a ditch and appropriating water. Cooperation can not stop, however, with water development. It is equally necessary, by reason of distance from large populations, to associate for the purpose of marketing products, and to this end there is now a small but increasing number of producers' associations within the Territory which standardize, ship, and account to their members for oranges, cantaloups, and bee products sent to distant markets. This cooperative spirit is favored by the intensiveness of the agriculture and the consequent smallness of the farms and the nearness of neighbors. Such communities, with interurban lines of travel, good roads, rural delivery of mail, and the numerous meetings necessitated by their canal, shipping, and other organizations, will necessarily attain a degree of social development far in advance of that possible to a country of large farms without the incentives to organization existing in an isolated irrigated region.

In conclusion, it may be said that the Arizona farmer is fortunate: (1) In the possession of water resources adequate, when developed, to irrigate about 1,000,000 acres and support probably a half million people; (2) in an immigrant population, which, coming from every State in the Union and most of the countries of the world, brings with it an extraordinary assortment of knowledge and every phase of character and social training; (3) in the operation of State and Federal institutions which are actively engaged in the development of water resources and in the solution of many agricultural problems offered by this newly settled and unique region; and (4) in the possession of incentives to industrial and social cooperation which will result in a high type of rural society.

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