

PREHISTORIC IRRIGATION
SYSTEMS IN ARIZONA

CARL F. MILLER

PREHISTORIC IRRIGATION SYSTEMS IN ARIZONA

BY

Carl F. Miller

Submitted in partial fulfillment of the
requirements for the degree of

MASTERS OF ARTS

in the College of Letters, Arts, and Sciences,
of the
University of Arizona.

1929.

E9791
1929
24

ACKNOWLEDGEMENT.

The writer wishes to acknowledge his indebtedness to Dr. Byron Cummings for his interest and helpful suggestions given for the compilation of this paper.

TABLE OF CONTENTS.

Defination of Irrigation -----	1.
Probable Development of Irrigation -----	1.
History -----	2.
Salt River Valley System -----	12.
Mode of Construction-----	22.
Gila Valley System (Casa Grande) -----	34.
Mode of Construction -----	36.
Influence of Irrigation on the development of agriculture and the progress of the people-----	38.
Conclusion -----	44.

ILLUSTRATIONS.

Map of the Salt River Valley System ----- 14.

Cross section of prehistoric ditch ----- 19.

Map of the Gila Valley System (Casa Grande) 33.

PREHISTORIC IRRIGATION SYSTEMS OF ARIZONA.

The term irrigation may be defined as the systematic application of water to land with the object of promoting present or prospective vegetation, or to go into greater detail as Knathack would state it, as "the process of artificially supplying water to the soil for the production of crops in countries where the rainfall is either deficient throughout the year or falls at a wrong season of the year to satisfy the requirements of growing crops".

Now, irrigation like anything else must follow along well defined lines of development. I believe that it started with the banking up of small gullies and arroyos with temporary structures like a clay wall reenforced with wattle work or either a loose stone wall with the chinks filled with clay mortar. The water thus accumulated after the showers was stored and used for irrigating purposes. These catch basins served many purposes; that of supplying the drinking water for the family or small group of individuals and for irrigating their gardens.

The water was probably taken from the basin in clay or gourd receptacles and poured separately on

the individual plants by hand from the gourd cup. Later the water was led off from the basin to the crops by means of small ditches. The cultivated area was no larger than a good size garden plot of today and maybe not that large.

Later small intakes were built into the river beds and larger quantities of water was secured for the fields. Eventually the cultivated areas became larger and the amount of water necessary to mature the crops became greater and greater, hence the development of the large canal system.

Going into the history of irrigation as first seen by the white man in Arizona may be taken from Kino's second entrada. "The Soldiers were much delighted to see Casa Grande. We marveled at seeing that it was about a league from the river and without water, but afterwards we saw that it had a large aqueduct with a very great embankment, which must have been three varas high and six or seven wide, wider than the causeway of Guadalupe at Mexico. This very great aqueduct, as is still seen, not only conducted the water from the river to the Casa Grande but at the same time, making a great turn, it watered

and enclosed a champaign many leagues in length and breadth and of very level and very rich land."

The cultivation of the soil by artificial application of water is, without a doubt, the oldest system of husbandry known to man. If we accept the Biblical history of the creation, Adam, after that unlucky affair of the apple, was compelled to build irrigating ditches in order to raise a crop on the dry plains of Mesopotamia; and when that ancient mariner, Noah, found himself high and dry after his lengthy cruise, he planted the vine on the sunny slopes of Ararat, and, by means of irrigation, produced the exhilarating beverage which later on involved the old patriarch in that awkward escapade so graphically described in sacred history. So that if antiquity marks it by a badge of honor or distinction, this mode of agriculture is certainly entitled to high consideration, for its progress can be traced through all the ages to the time when Adam delved and Eve spun and "gentlemen" were not so numerous as in the latter days.

"The powerful kingdoms of the ancient world owed all their greatness to the practice of irrigation, and the corner-stones of their prosperity and

civilization rested upon this system of tillage."

"Irrigation on the American Continent is older than historical records. In various parts of the southwest, notably in the Salt River Valley of Arizona, are well-defined remains of irrigation works which have outlived by many centuries the civilization to which they belonged. It began seventy years before the English colony landed at Jamestown, when Spanish missionaries gained an enduring foothold in the valley of the Santa Cruz. They built churches which still stand and planted gardens which long ago disappeared; but, in watering these gardens, they taught nothing new to the native inhabitants. The Spanish explorers who rode up the valley of this river in the last half of the sixteenth century found Pueblo Indians irrigating the thirsty soil as their fore-fathers had done for centuries before them, and as their descendants are still doing.

"The first irrigation works in the West were of the most primitive character. A simple furrow turned part of a creek or river upon the low-lying bottom-land adjacent. In a few cases the earlier ditch builders had to make a cut of more than five

feet in order to place the bottom of their ditch level with the bottom of the stream. There was seldom need of building dams, usually a temporary structure made of bags of sand or a combination of stone and brush, requiring only a few hours, or at most a few days to construct, would serve. Head-gates were an exception rather than a rule. A few shovels of earth provided an embankment to keep out the water when not needed, and a few strokes of the same shovel opened a way for its passage when irrigation began. No attention was paid to alignment. Ditches followed the contours of the surface, and some of them were so crooked as to be wasteful of both land and water. The needed slope was given to the ditch in some cases by beginning at the head and letting the water follow the excavation, in others by filling a pan with water and sighting across its opposite edges. In time irrigators became more expert in determining where water would or would not run, and could locate their ditches or laterals with surprising success without the aid of any instruments whatever."

According to Mead in Irrigation Systems water

was used in irrigation in Arizona before the Nile was diverted by Joseph to protect Egypt from Famine. The race which built these works with their history and civilization have long passed into oblivion, but the well defined evidence of their engineering skill still remains.

"The Pimas are the earliest irrigators in the state of whom we have any authentic account. When Coronado led his expedition through Arizona, in 1540, these people were found farming the lands of the Gila Valley by the aid of primitive irrigation ditches just as they do today. The communal system of land and water prevailed amongst them as it does now; and the centuries which have since come and gone have brought no changes to the Pima nation. They still till the soil and gather the harvests as their fore fathers did, and as their descendants will, no doubt continue to do, until the last of the race shall have been gathered to the happy hunting ground".

Because of the scarcity of both edible plants and animals the Indian had to conserve what few he had and by means of mutation produce more and different varieties. This is shown especially in the

many different colored corn kernels produced from the common stock. It is said that the Indian has over fifteen different ways of preparing corn. I know quite a few because I have eaten corn prepared by the Indian squaw in at least eight different ways. Whenever fresh meat was on their menu, it was either because they were lucky in the chase or it was the chief dish for some big festival. They were lucky if they had fresh meat to vary their diet at least once a week. The fresh meat was furnished from the rabbit, the turkey, the deer, the elk, and dog as some of the Indians are fond of young fat dog.

While excavating in their refuse heaps the number of bones encountered is very small and the greater number of these bones belong to the turkey. This was probably due to the fact that the turkey was domesticated for the purpose of serving the table with its flesh and the people with its feathers to make blankets.

Carl Hayden in his report entitled THE PIMA INDIAN AND THE SAN CARLOS PROJECT POINTED OUT that by means of irrigation the food supply became greater

than the amount consumed and hence this left greater time to be devoted to things of enjoyment. Life in the Indian village was thus not one big round of activities, and to break the monotony, the Indians had bigger and better families.

Charles D. Poston reports that "The water from the Gila River to irrigate their lands is obtained by canals constructed by the common labor of the tribe". A. B. Gray says, "It is astonishing with what precision they construct their acequias ----- irrigating canals ---- some of them, the acequias madres, are of very large size and made without the use of levelling apparatus, but simply by the use of the eye. Their gardens and farms too are regularly ditched and fenced off into rectangles and circles with hedges and trees planted as if done by more enlightened people". "In a few cases did the earlier ditch builders have to make a cut of more than five feet in order to place the bottom of their ditch level with the bottom of the stream. There was seldom need of building dams, usually a temporary structure made of bags of sand or a combination of stones and brush, requiring only a few hours, or at most a few days to construct, would serve. Headgates were an exception rather than a rule. A few shovels of earth provided an embankment to keep out the water when not needed, and a few strokes of the same shovel opened a way for its passage when irrigation began. Engineering advice was seldom

sought. No attention was paid to alignment. Ditches followed the contours of the surface, and some of them were so crooked as to be wasteful of both land and water. The needed slope was given to the ditch in some cases by beginning at the head and letting the water follow the excavation, in others by filling a pan with water and sighting across its opposite edges. By many ingenious home-made designs the individual irrigator, working alone, was able to water his garden or little farm. In time irrigators became more expert in determining where water would or would not run, and could locate their ditches or laterals with surprising success without the aid of any instruments whatever.

"It was once assumed that irrigation was not practiced by the Indians of the arid region, except to a very limited extent, until after they came under the influence of the Spanish missionaries; but recent systematic study of the archaeological remains in the southwest has removed all doubt that agriculture was conducted in prehistoric times with the aid of irrigation canals, reservoirs,

and dams. The most important of these works are in the valleys of the Gila and its tributaries, in Southern Arizona, where scores of miles of ditches are still traceable, in instances extending more than ten miles from the stream from which the water was diverted; according to some observers there are individual canals that traverse a total distance of twenty five miles. In the Salt River Valley alone it is estimated that from 200,000 to 250,000 acres were made available for cultivation by means of irrigation before the arrival of white men. Some of the ancient canals were seven feet deep and four feet wide at the bottom, but the sides sloped gradually, rising in steps, giving the acequia a width of about thirty feet at the surface. Both the bed and the sides were carefully tamped and plastered with clay to prevent waste through seepage. Remains of what are believed to have been wooden head gates have been exposed by excavation. Where canal depressions have disappeared, owing to cultivation or to sand drift, the canals are still traceable by the innumerable boulders and water-worn concretions that line the banks; these, according to Cushing, hav-

ing been placed there by the natives as 'water tamers' to direct the streams to the thirsty fields. The irrigation works in the valeys mentioned probably indicate greater engineering skill than any aboriginal remains that have been discovered north of Mexico.

H.R.Patrick in his report "The Ancient Canal Systems and Pueblos of the Salt River Valley" says that, "While the greater portion of the ruins of the ancient canal systems have long since been leveled by the agriculturists, there are yet a number of places where the borders and former water ways are quite intact, generally at or near the river banks where the work was necessarily heavy and the ground has not been available for farming purposes:- These works are so extensive as to give unmistakable evidence of their purpose and prove conclusively that this has always been an arid region requiring artificial irrigation.

"It is found ... that the modern systems of canals in the older settled portions of the valley, follow closely the same locations or upon contours parallel with the canals of the ancient systems,

and in many instances the old canal beds have been reconstructed and successfully used and became part of the present system.

"What method of construction may have been employed by the ancients in building these long canals, with deep cuts at the river's bank, with dams for diverting the water from the river to canal and from the main canals to their branches is hard to conjecture, since all vestiges of dams have been washed away or buried in debris by the annual floods of hundreds of years-- for in the earth-work of the several systems there must have been several million cubic yards of earth to remove, while in several instances at or near the river the excavation has been in gravel and the borders of the canals are still standing to heights varying from six to twelve feet.... In all instances where the canals can be traced to the river's bank it is found today that the present bed of the river is from fifteen to thirty feet below the bed of the ancient canal, showing how much the river bed has been lowered by erosion, being another evidence of the great antiquity of

of this last race of people.

If we reason from analogy, we may suppose that this aboriginal people who were workers of wood and stone and not of metals, built only very low diversion dams of stakes, brush and loose stone, consequently of a temporary character which might be washed away or damaged by floods at any time, and would need to be immediately rebuilt. We have seen such constructed by the present races of Indians and the most primitive races of people described in history used similar devices for diverting the water. Even white people in new regions where their resources were limited built such dams which were frequently quite permanent, remaining for many years when properly constructed.

For gates to divert the water from the main canal into a branch, the Yaqui Indians of Mexico, who are a very intelligent and ingenious race, and who are among the most adept Indian farmers of the present day, use large mats woven from palm leaves, supported by a grillwork of bamboo which in turn is held in place by stakes and horizontal poles all lashed firmly together with thongs of Huirote (pro-we-ro-ty) a tough pliable vine that enters

largely into all their building constructions.

"There is nothing to show the manner of applying the water to the land, whether in lands or tables by means of low borders or whether by numerous small ditches or furrows, but the uniformity and smoothness of the surface has without doubt been made by the long use of the land by many generations of ancient farmers, the land today having a grade or slope, the best adapted to artificial irrigation of grains and alfalfa of any country yet tried.

"Of the early inception of the irrigation problem by these ancients a long study of the old landmarks and a close connection with the present irrigation systems has convinced the author, Mr. Patrick, that they began as we have begun at the lower end of the valley and took out small ditches where the river banks were low and by taking advantage of some natural depression or slough where the excavation would be light and easy, and the water soon brought upon the surface. Then as their colonies increased in population and resources, and as their canals were damaged by floods and as they required more extensive tracts of land they went a little higher

up stream, where high and more permanent banks gave better foundation and protection, and there built larger and better canals, and probably found a better supply of water, where it was not as apt to sink in the bed of the river.

"That the founders of this great irrigation system met and overcame great difficulties is shown by various changes made in the alignment where a low ridge of ground was encountered, and only mastered after several efforts to get through. Many other instances of a similar nature are found throughout the system, also at the heads of several of the systems. It is evident that the head-works were washed away and a new head had to be made farther up the stream and in some cases it appears that an old system has been supplied with water from a later and newer system higher up stream.

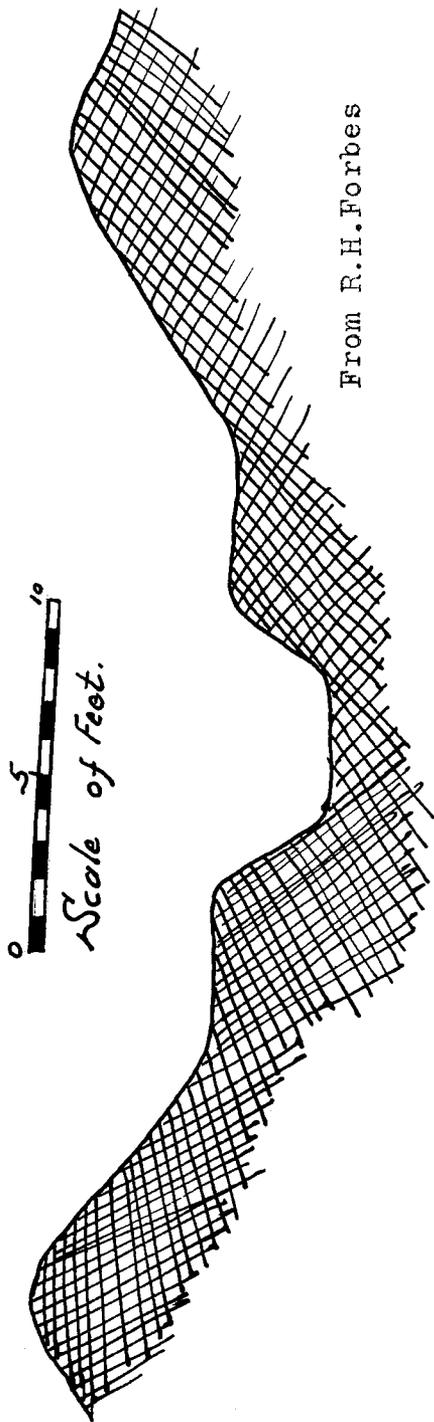
"At the point on the north bank of the Salt River there is shown the work of changing and making new heads, the work being entirely in gravel having a depth of twelve feet in places as heretofore mentioned. Near the western end of this system the

course of the canal was obstructed by a wide swale which was filled in and crossed by means of a high embankment or border on which the canal crossed--- -- at another point on this system a large Sahuara cactus (Cereus Giganteu) which must have attained a great age is growing in the center of the old water way.

"The size and capacity of the canals are quite surprising; the largest being seventy-five feet wide between the centers of the borders and probably not less than forty feet wide in the bottom of the water way, with borders about six feet in height being quite equal to any canal of the present system.

"The longest canal is about twelve miles in length but one of the old systems has about twenty-- eight miles of mains, while in the aggregate there are one hundred and thirty-five miles of mains in the ancient system. While the total mileage of the modern systems is but ten miles more. (1903)

"The ~~ac~~age of land under these old systems is approximately one hundred and forty thousand acres, which, if divided into small holdings such as the present Indians cultivate under their



From R.H.Forbes

Cross Section of prehistoric ditch,
showing channel in bottom for carry-
ing a small irrigating stream.

natural conditions must have represented twenty thousand farms, and with a corresponding number of persons to each family, the ancient system must have supported a population of from 120,000 to 130,000 people, --- but to this may be added a large population in the cities who may not have been farmers or tillers of the soil, so that the population of the entire valley might easily have been 200,000.¹"

F.W.Hodge, in his report "Prehistoric Irrigation in Arizona" printed in the American Anthropologist, July 1893, volume 6 page 323, says that, "In none of the extensive archaeological remains of southern Arizona are the industry, perseverance, and degree of advancement of a large pueblo population more faithfully illustrated than in the many works of irrigation that abound in the valleys and on the mountain slopes of this section (Salt River). Prior to the prosecution of systematic archaeological investigation in this region, it was generally believed that, aside from the employment of catch-basins or rude reservoirs formed at the bases of mountain arroyos,

1. H.R.Patrick, "The Ancient Canal Systems and Pueblos of the Salt River Valley, Arizona.

artificial irrigation was not practiced by ancient pueblo builders, and that the existing pueblo tribes derived from the early Spanish missionaries or conquistadores their knowledge of conducting the water from the streams to their fields. In the valley of the Salado (Salt) and Gila, in southern Arizona, however, casual observation is sufficient to demonstrate that the ancient inhabitants engaged in agriculture by artificial irrigation to a vast extent.

"The arable area of the valley of the Salado comprises about 450,000 acres, a tract almost equally divided by the river. No obstacle is encountered in irrigating the land lying south of the stream for a distance of ten miles, but greater difficulty attended the conducting of water to the northern area by reason of the greater slope of the land, which necessitated the establishment of headworks much farther up the river. This difficulty modern ranchmen have overcome by the construction of the Arizona Canal, which traverses a distance of forty--one miles from the east to west, and has a capacity of 40,000 miner inches, sufficient to irrigate 50,000 acres or over 27% of the 182,000 acres now re-

claimed by the nine irrigating canals of the valley.

"Judging from the remains of extensive ancient works of irrigation, many of which may still be seen passing through tracts cultivated today as well as across densely wooded stretches reaching considerably beyond the present irrigated area. It is safe to say that the principal canals constructed and used by the ancient inhabitants of the Salado Valley controlled the irrigation of at least 250,000 acres, even without considering the economical methods employed by a primitive people in all its undertakings.

"The mode of canal construction employed by these pueblo builders was another indication of their patience and industry. Their canals are models for the modern farmer to imitate; yet they could have been dug in no conceivable manner save by the laborious process of hand excavation with stone or wooden implements, the earth being borne away by the means of blankets, baskets, or rude litters. Notwithstanding this, the outlines of at least a hundred and fifty miles of ancient main irrigating ditches may be readily traced, some of

which meander southward from the river a distance of fourteen miles.

"In following the courses of these canals their depressions may more readily be seen in the dense mesquite forests, where protection is afforded against the drifting sand. On more open ground their routes are generally effaced, lines of stone alone remaining to mark their sites. These stones were the implements once used, broken, and cast aside on the banks, as well as concretions grotesquely eroded by the river stream and deposited by the natives along the banks as 'Tamers of the water'. Similar concretions or huacas, according to the description by Mr. Cushing in his article on 'Zuni Bread Stuffs', are placed by the Zunis along the courses of hill streams near their main pueblo and along the ditches of Pescado and Ojo Caliente, in order, presumably, to direct the waters of the rainy season from the foothills to the thirsty fields, and to prevent the overflow of their acequias. It is interesting to note that in no instances were these concretions found to have been used as implements, although many of them are admirably adapted to such purposes;

a fact further attesting their sacred character.

"In the progress of the investigations of the Hemenway Expedition in the Salado Valley,... excavation was undertaken at a point along the course of one of the principal supply canals of the ancient Pueblo de los Muertos, near one of the thirty six large communal structures which formed this now ruined city, and extended for a distance of about thirty feet. The depth of the bed beneath the original banks was found to be about seven feet. Unlike ordinary irrigation ditches, these were constructed in such a manner as to control to some extent the depth of the current as well as to prevent waste through seepage. The bed of the canal was about four feet wide, but the sides broadened in their ascent to within four feet of the bank, where a 'bench' three feet wide on each side of the canal had been made. From these benches the banks continued, broadening until they reached the brinks, which were thirty feet wide. Thus a main ditch consisted, so to speak, of one water course within another; so that if at any time a small current of water only could be supplied at the head gate, owing

perhaps, to drouth, the lower and narrower ditch was doubtless always filled sufficiently to supply the towns beyond, while during the rainy seasons the upper and much broader portion of the great canal could readily accommodate all surplus waters.

"The bottom and sides of the irrigation ditch which was opened, as well as those of a branch of it excavated to the southwest of the ruined-house cluster alluded to, were found to be exceedingly hard, evidently having been tamped while moist, and then, perhaps, roughly plastered with adobe clay. The extreme hardness of the canal lining may be accounted for by the supposition that, instead of burning the dense underbrush for the sole purpose of destroying it, the natives gathered it into their moist canal beds, where it was burned to harden the newly plastered lining. Very little silt was found in the bed of the irrigation ditch, a fact exhibiting either the care taken of them or showing that a current of considerable strength was flowing at the time of the abandonment of the pueblo.

"A few rods south of the canal excavated referred to, the canal was observed, from the course of the chipping stones and concretions or 'water tamars'

along its banks, to decrease in width and branch off into two canals, each at an angle of about 45 degrees from the trunk acequia. Excavations at this point showed a number of post-holes on the outer banks of the two branches, as well as at the angle formed by their juncture, attesting the former existence of a headgate for cutting off or supplying at pleasure the farm lands and house groups to the southwards.

"The great distance to which these ancient canals were extended in order to utilize all available land through which their waters coursed, the depth which they were dug, and the care taken to prevent waste by seepage, are not the only evidences of the indomitable energy of these ancient agriculturists. At the group of ruins near the Mormon settlement of Mesa City, eastwards from Tempe, in Maricopa County, remains of an extensive irrigation system may be seen. Here, more than at any other point in the valley, is demonstrated the degree of skill attained. In the original excavation of the canal referred to, a hill of indurated tuff was encountered, beyond which a large tract of fertile land lies. This knoll or mound of concrete was partly encircled by the irrigation ditch in order

to preserve the proper incline of the canal bed, and to accomplish this it was necessary to excavate through this indurated deposit with implements of stone, a work necessarily attended with inconceivable difficulty and requiring a great length of time.

"Several years ago, when the Mormons first settled Mesa City and began the irrigation and cultivation of the fertile plain about them, they utilized this ancient canal bed for a considerable distance, including that portion encircling the knoll of volcanic tuff mentioned. The writer (Mr. Hodge) has been informed by one of the founders of this settlement and builder of the Mesa Canal, which is nine miles in length, that the saving to them by using this ancient canal was from \$20,000.00 to \$25,000.00. To use the words of my informant: 'The old canal was utilized for fully three miles to great advantage and from one to two miles with but little benefit!. In other words, one-half of the modern canal occupies the ancient bed.

"A number of writers, mainly in the public press, have given expression to opinion in regard to irrigat-

ion in the Salado Valley by means of water stored in catchment-basins or represas, constructed on the various mountain slopes, in addition to irrigation by canal system. Great stress has been laid upon this supposed irrigation by means of reservoirs in order to give color to the theory, entertained by some, of an extensive prehistoric population in the Salado Valley. This cannot be proved to be the case, although a very large population, as Indian populations go, doubtless did occupy the greater portion of the lower valleys of both the Salado and the Gila as shown by the extensive irrigation operations once engaged in.

"Reservoirs at the mouth of mountain washes for holding in reserve rainwater for the irrigation of the lands which, on account of their elevation, could not be redeemed by the canals are not found in the valley of the Salado. While most of the valley lands were once covered by a net-work of irrigation ditches, yet there were tracts capable of redemption over which it appears water was never conducted, and which could have been reclaimed

by merely extending the canals, before represas were resorted to for irrigating the inferior land about the mountain bases.

"Receptacles for the storage of rain water occur in this region, their remains being found in many parts of the area of the lower Gila drainage; but it is safe to say that they were not constructed because of lack of sufficient land irrigatable by canals, as the low, level tracts in both the Salado and Gila valleys showing no evidence of former tillage will testify. The population of an agricultural tribe cannot well be estimated by the extent of its habitat, particularly in the arid region, but by the amount of land actually cultivated.

"It seems reasonable to presume that in an arid territory like our Southwest, where so many of the streams are intermittent, the valleys of the larger streams were first occupied, and, as the population increased, the land drained by their lesser affluents were next settled upon. As the pueblos of the Gila, as shown by their ruins were generally larger than those of the Salado or

Verde, and the irrigation canals of the former more extensive than those of its tributaries, it is not improbable that these little hill-side reservoirs or catchment-basins were built previously to the construction of the irrigation ditches, at a time when the population was small. Should this prove true, the occurrence of these hillside reservoirs may be accounted for, since their construction might be undertaken with much less expenditure of labor and skill than the building of an irrigation canal would entail, and at the same time the wants of a small population would be supplied.

"In tracing the routes once pursued by many of the canals, great depressions --- the sites of ancient reservoirs --- are observable. The remains of one of these reservoirs nearly a mile long by about half a mile wide, occur on the open plain at the terminus of one of the canals that formed the source of water-supply of Los Muertos, and about three miles south-west therefrom. It is possible that this great depression was, in part at least, a natural sink, deepened by artificial means to serve more fully the purpose of a storage basin of surplus waters from the Los Muertos

irrigating system. Every cluster of communal-structures in Los Muertos was supplied with a reservoir on a smaller scale than the one just mentioned, a single canal forming both its inlet and outlet. Sometimes, a lesser communal dwelling shared with a neighboring structure in the water supply from a single storage basin.

"Doubtless the largest reservoir within the limits of Los Muertos was that lying directly west of the ruined communal dwelling --- and extending almost to its walls. A trench run through the lesser diameter of this reservoir showed its original depth to have been about fifteen feet. This artificial basin was elliptical, measured about two hundred feet in length by fully a hundred feet in width, and like the canal had apparently been tamped and burned. The bed and sides of this reservoir were covered by a thick stratum of silt.

"The existence of the remains of so many extensive irrigation works scarring the broad, level valley of the Salado seems sufficient to prove the contemporaneous occupancy of the pueblos

formerly within its limits, for had a village been built and for some reason abandoned by one community, it would scarcely be in keeping with the Indians idea of economy for subsequent settlers not to utilize the enormous labor already expended in gathering building material and digging ditches and reservoirs. While the population of these pueblo settlements was undoubtedly large, it would be unreasonable to estimate the number of inhabitants of the dozen distinct ancient pueblo settlements formerly in the valleys of the Rio Salado at from two hundred to three hundred thousand. This, however, has been done."

Dr. Byron Cummings published in the Progressive Arizona, November 1926 an article entitled "Ancient Canals of the Casa Grande" in which he says, "The Gila River now follows its muddy course a mile and a half from the Casa Grande Ruins and considerable of the land of that section has been cleared and leveled for cultivation so that ancient ditches and laterals have been obliterated; but ^{it} is still possible to trace two main canals on the south side of the river and three on the north side. The longest one on the south side had its intake at the granite reef where now the diversion dam known as the Ashurst-Hayden dam is located about six miles above Florence. This took its course through the present town of Florence and ends south of the ruins of the Casa Grande, some sixteen miles in extent. The other took water from the Gila north of the ruins and irrigated a large area to the west of the Casa Grande. Traces of only a couple of laterals can be found now, but from the courses of the main canals across the region, one can readily see that a number of important laterals must have carried water to extensive areas.

"On the north side one canal can be traced for some distance near the railroad station another tapped the river/^ashort distance above the Sacaton bridge and watered a large area between the railroad and the ruin, while a third had its intake above Cholla Mountain and watered quite an extensive area across the river from the Casa Grande ruins. By consulting the map that accompanies this article one can get a fairly accurate idea of the course of these canals and the area covered. It must be borne in mind, however, that this is only the remnant of the system, still surviving, the merest skeleton of an irrigation plan that made thousands of acres productive and brought life and hope to a people who certainly demonstrated their worthiness to be classed among the civilized tribes of the world. Knowledge of agriculture, home building, the arts of spinning and weaving and pottery making are as truly indices of human intelligence and culture as the ability to express one's self by drawings that forms a written system of characters. They are all forms of human expression, and one is quite as indicative of intelligence and

human service as the others.

"The canals also stand as witness to the tragic drama once enacted in the Gila Valley. The river evidently was larger and the flow more constant than now. These ancient engineers were able to build dykes out into the stream, where points made diversion easy, and so fill their canals without attempting to dam the entire flow. Floods often tore away these dykes and dug the channel deeper until the intakes of these canals were left high above the water line except in times of greatest flood. Thus their great canals were left high and dry above the river and the poor people were helpless. With the materials and methods of construction with which they were acquainted they could roll rocks into the edge of the stream, drive down poles and weave in brush until they had built a dyke sufficiently long and high to divert enough water to fill a canal when the canal was practically on a level with the stream, but to extend that dyke entirely across the channel and raise the water high enough to flow into the channel after the river had cut its channel several

feet lower, was an engineering problem which they were not able to solve. Consequently, when a long drought occurred and the river was low, their clay, alkali soil baked and grew ever harder until it refused to respond to their persistent efforts to keep it moist and mellow. In vain they carried water from the river in large jars on their backs, in vain they broke up the hard clods with their stone picks; the Sun God was angry and scorched and burned everything that they coaxed into life."

"The practice of irrigation is of very great antiquity, and one of the earliest examples of irrigation works of which we have any record is of interest as illustrating not only the prosperity which accompanies a well-managed irrigation system, but also the ruin and desolation, which, in a country dependent on irrigation, inevitably follows neglect of the proper maintenance of its irrigation works. The country referred to is Mesopotamia, and particularly the alluvial plain in the south-east lying between the Euphrates and the Tigris, and which is known to us as Chaldea or Babylonia. Much of the history of Chaldea has been deciphered from local inscriptions, and not the least interesting are those relating to irrigation. These inscriptions fully bear out the statements of comparatively recent historians, of whom perhaps the most trustworthy is Herodotus. The whole of Chaldea is described by Herodotus as densely populated and thickly studded with great cities, and the cultivation of the country was regulated by large canals, of which the three principal carried the waters of the Tigris towards the Euphrates above Babylon.

Such was the fertility of the soil that grain yielded as a rule a two-hundred-fold return to the cultivators, and Pliny mentions that two crops of wheat could be reaped annually.

"Chaldean chronology is somewhat obscure, but from an inscription of one of the Kings of Babylon, whose epoch is fairly well determined, we know that one, at least, of the great canals was in existence 2,200 years before Christ, and most of the Chaldean and later Assyrian monarchs of Babylon appear to have devoted considerable attention to the maintenance and development of the canal system. As irrigation was the foundation of Babylonia's prosperity, so was the want of irrigation the chief cause of her decline. In the course of centuries the canal system of Babylonia suffered many vicissitudes; time and again the canals were ruined by floods or by neglect of the works, but it was not until the thirteenth and fourteenth centuries of our era that the irrigation system received its death--blow, during the troublous times of the invasion of the country by the Mongols and Tartars.

With the destruction of the canals cultivation became impossible, and Babylonia rapidly sank into the state of barren desolation which it now presents.

"This ancient irrigation system is interesting for reasons other than its antiquity. The flood season in the Euphrates and the Tigris occurs six months later than in the Nile, and in consequence the flood system of irrigation as practiced in Egypt becomes impossible, as the summer has already arrived before the waters recede, and though crops would germinate if sown, they could never arrive at maturity under a parching sun and in the absence of rainfall. There is good presumptive evidence therefore that the success of Chaldean irrigation must have been attained by what is known as perennial irrigation, a system which is usually supposed to be of very recent development.

"Without going further into details of ancient works, it may be mentioned that the hieroglyphics of the Pharaohs of the Twelfth Dynasty

shows that irrigation was practiced in Egypt about 2,500 B.C..

"Babylon and Nineveh, whose grandeur and extent is attested by their ruins, derived their wealth and magnificence from the elaborate system of canals which covered the valleys of the Euphrates and Tigris. Those immense waterways made of that region one of the most fertile countries of the earth --- the seat of learning, the arts, the sciences, and the splendor of the earlier ages. Both the Assyrians and the Medes were an agricultural people, and carried the art of artificial cultivation to a very high degree. Persia, the mightiest monarchy of ancient times, was then, as now, a rainless region, yet irrigation made of it the seat of an empire extending from the Indus to the Hellespont. The pages of history shine with the achievements of this great nation, and the wealth and dazzling magnificence of the court of Xerxes and Darius is the theme of the historians and poets. Yet this vast fabric of empire rested upon the canals which brought beauty and verdure to the plains and valleys of Iran. Egypt, the seat of our earliest civiliz-

ation, the land of religious thought and philosophical research from which many ancient nations derived their sacred and secular ideas of government, practiced irrigation from the remotest ages. The mighty monuments of that early time, whose ruins, are the wonder of our modern world, speak mutely, yet eloquently, of the power and greatness of ancient Egypt. But the whole structure of mental progress and material power ~~was~~ dependent upon the network of canals through the Valley of the Nile. A rich and a goodly land it was -- the granary of the ancient world -- and, today, after constant cultivation for unnumbered ages, this famous valley remains one of the most productive on the globe.

"In India and China irrigation has been carried on since man first tilled the soil in those olden lands. The oriental magnificence of the potentates of historic Hindostan, the gorgeousness of their courts and the wealth and beauty of their cities, have tempted the cupidity of successive conquerors. The swarming hive of humanity, who dwell in the southern Asia, have made of that

portion of the globe a veritable garden, solely by the aid of irrigation. Greece and Italy have practiced the art of artificial cultivation ever since Cecrops laid the foundation of Athens or Remulus chose the site of the Eternal City. The great cities that flourished around the eastern shores of the Mediterranean, including Carthage, the warlike rival of Rome, fostered and encouraged irrigation, for upon it rested their wealth, their power, and their very existance. When the Roman eagles were planted in Gaul and in the Iberian peninsula, the Roman law of waters was made a part of the civil polity of the conquered provinces; and the system of irrigation was perfected and assisted by the establishment of wise regulations and the construction of massive aqueducts, canals and reservoirs. Thus it will be seen that nearly all the great nations of antiquity rose and flourished in lands where the artificial application of water to the soil was a necessity for the growth of crops. The ruins of dead cities which strew the now desolate regions of Asia Minor, Syria and Northern Africa, were once the centers of wealth

and luxury, culture and power. Canals and aqueducts brought beauty and productiveness to the now barren wastes; and dense populations once lived and labored where the jackal's cry is now the only sound that disturbs the ear of the wandering tourists."

Irrigation, a sketch of its history and practice in various countries, by Patrick Hamilton.

BIBLIOGRAPHY.

- Davis, Arthur Powel, Irrigation near Phoenix, Arizona.
- Forbes, R.H., Irrigation in Arizona.
- Indian Rights Association
Irrigation --- Arizona.
- Patrick, H.R. The Ancient Canal System and Pueblos of
the Salt River Valley, Arizona, with notes and charts.
- Grabham, G.W., and Black, R.P, Egypt Ministry of
Public Works.
- Hamilton, Patrick, Irrigation, a sketch of its history
and practice in various countries.
- Indian Irrigation Commission
Report of the Indian Irrigation Commission.
- Wilcocks, Sir W., The Irrigation of Mesopotamia.
Irrigation and flood protection
United States Office of Indian Affairs.
- Kanthack, Francis Edgar, The principles of irrigation
engineering with special reference to South Africa.
- Mackenzie, N.F., Notes on irrigation works.
- Smythe, William Ellsworth, The conquest of arid
America.
- Mead, Elwood, Irrigation Institutions.

Hancock, Wm. A., Some papers on the subject of National aid in the storage of water for the irrigation of the arid West.

Prescott, Wm. H., The conquest of Mexico Vol I.

Wilson, Herbert M., Ancient ruins of the Southwest.

Wilson, R.D. and Wilson, E.W., Agriculture for young folks.

Heitland, W.E., Agricola. A Study of agriculture and rustic life in the Graeco-Roman world from the point of view of labour.

King, F.H., Farmers of four centuries.

Miscellaneous papers on Agriculture.

Simkhovitch, Vladimir G., Agriculture -- Rome.

Carrier, Lyman, The beginning of agriculture in America.

Gras, Norman Scott Brien, A history of agriculture in Europe and America.

Olin, W.H., American irrigation; a systematic and practical treatment of every phase of irrigation farming, including its history, with statistical tables and formulas.

Bureau of American Ethnology

Bulletin 30 Part I.

Turney, Omar A. The Land of the Stone Hoe.

Mead, Ellwood, Rise and future of Irrigation in the
United States.

Hedrick, Ellen, Irrigation

Thomas, Clarence, Johnson Irrigation--- Egypt.