

## Mining and Metallurgical Section.

*(Read by title at the Stated Meeting held Thursday, January  
31, 1907.)*

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### **Irrigation and the Government Irrigation Project at Yuma.**

PROF. OSCAR C. S. CARTER.

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Primitive man was doubtless carnivorous much more so at least than is his brother to-day, but there came a time at last in the history of man when his attention was drawn to the vegetable world as a source of food supply; just when or where this was is a question. There is no doubt that environment influenced the food supply of early man as it does to-day his more or less civilized brother. Environment makes the Esquimaux a flesh-eater and the Indian of the tropics more or less of a vegetarian. When man first began to till the soil in arid or semi-arid regions he learned that water was necessary to plant growth and thus received his first natural lesson in scientific agriculture. Irrigation, history teaches us, was practiced centuries ago; it is a very ancient art. It is said the ancient Egyptian, Hebrew and Oriental records contain many references to irrigation. There are remains of ancient irrigation works in Europe, Asia and parts of Northern Africa.

The art of irrigation in Egypt is very ancient; they had extensive systems of lakes, reservoirs and canals, so it is said, as early as the time of Sesostris. Early irrigation was also practiced in Persia, China and India. The Romans practiced it in Italy and the Moors in Spain, Sicily and Algeria. Irrigation has been practiced recently in France to destroy the insect pest phylloxera of the grape vine by submerging the roots. In the arid regions of the Southwest near the Gila, Salt and Verde Rivers, in Arizona, near streams in New Mexico, and near the Rio Virgen in Nevada, are found ancient irrigation ditches, some of which are of great length. These were used

by the aborigines centuries before the time of Columbus. Some of these show considerable engineering skill in their construction, at least good judgment in the selection of sites and great patience in their construction, particularly where



they are cut through solid rock. In the 13th Annual Report of the Bureau of Ethnology is an article by Cosmos Mindeleff on Aboriginal Remains in Verde Valley, Arizona. On page 194 he states: "Irrigation ditches and horticultural works

were found in this region. Fine examples of irrigating ditches were found at the extreme northern and extreme southern limits of the region treated and there is a fair presumption that other examples occur in the intermediate country. These works did not reach the magnitude of those found in the Gila and Salt River Valleys, perhaps, partly for the reason that the great fall of the Verde River renders only short ditches necessary to bring the water out over the terraces." Page 238 he states: "One of the finest examples of an aboriginal irrigating ditch that has come under the writer's notice occurs about two miles below the mouth of Limestone Creek, on the opposite or eastern side of the river. At this point there is a large area of fertile bottom land, now occupied by some half dozen ranches, known locally as the Lower Verde Settlement. The ditch extends across the northern and western part of this area. Plate XXXIV shows a portion of this ditch at a point about one-eighth of a mile east of the river. Here the ditch is marked by a very shallow trough in the grass-covered bottom, bounded on either side by a low ridge of earth and pebbles. Plate XXXV shows same ditch at a point about one-eighth of a mile above the last, where it was necessary to cut through a low ridge. North of this point the ditch cannot be traced, but here it is about forty feet above the river and about ten feet above a modern (American) ditch. It is probable that the water was taken out of the river about 2 miles above this place, but the ditch was run on the sloping side of the mesa which has been recently washed out." "On the southern side of Clear Creek about a mile above its mouth there are, near the ancient village ruin, extensive works covering a large area of the terrace or river beach, for a distance of two miles east and west along the creek and perhaps a half a mile north and south there are traces of former works pertaining to horticulture, including irrigating ditches, reservoirs, farming outlooks," etc.

In South America there are aqueducts which are used to carry water for miles for irrigation and other purposes. They were constructed by the early Indians. Enough has been said to draw attention to the fact at least that irrigation is not new in this country. Mr. E. A. Beals, Official Forecaster of Weather Bureau, states in Year Book Agriculture, 1902, that "Excluding the rice-irrigation system of China, Japan and

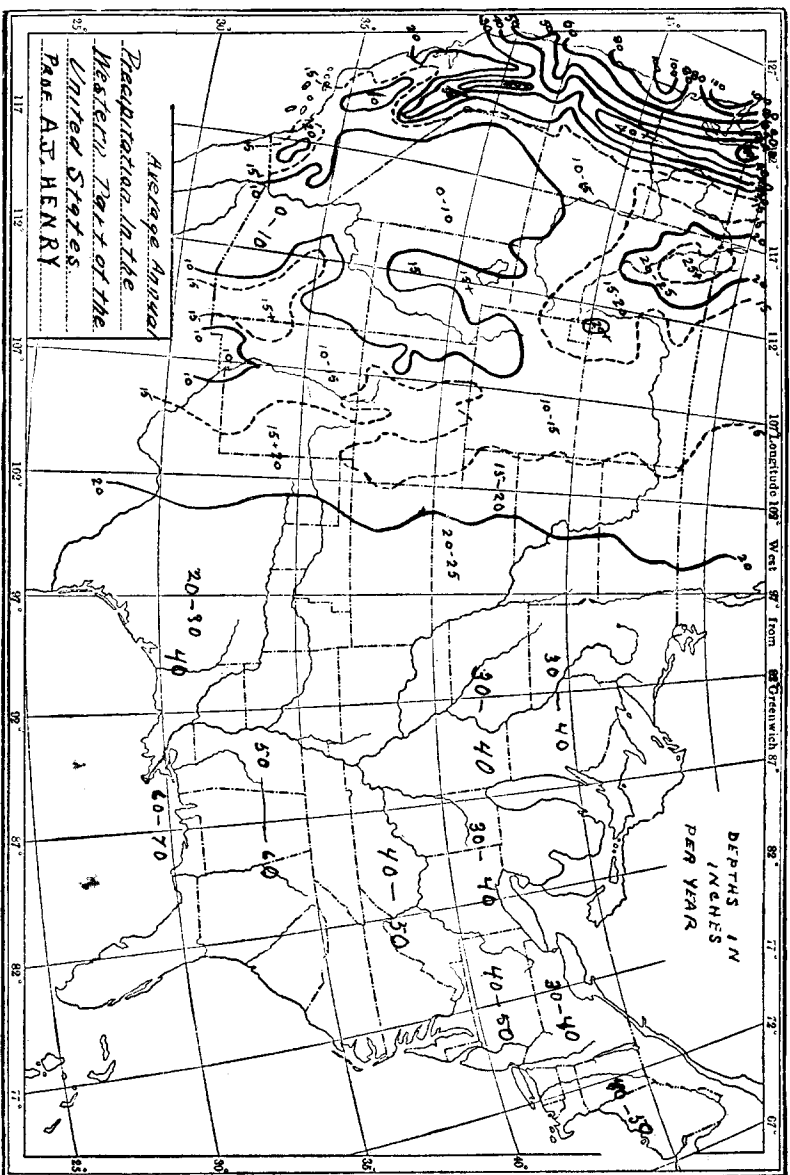
S. E. Asia, there are some fifty or more millions of acres of irrigated land in the world, and of this great area fully one-half is located in countries having a humid or semi-humid climate with an annual rainfall above twenty inches. The really arid lands are confined to scattered sections in the western half of the United States, Argentina and in the valley of the Nile below Assuan, some 500 miles from Mediterranean Sea.

#### IRRIGATION IN INDIA.

"The most extensive system of irrigation is in India where at least 25,000,000 out of a total cultivated area of 144,000,000 acres are irrigated. The principal canals are in the Ganges and Indus valleys, but they are found in nearly every province of the country. Besides canals built under the direction of the government thousands of small reservoirs are distributed throughout the empire. The crops raised from this water support at least 20,000,000 people. The melting of snows on the Himalayas during the hot months of March, April and May furnish water to the canals in Northern India. The rainfall is unevenly distributed, decreasing rapidly from 115 inches near the Himalaya foothills to six inches in the upper Sind province, less than 350 miles away. The greatest known rainfall in the world occurs on the southern slope of the Himalaya Mountains about 200 miles back from the Bay of Bengal. The rainfall at an elevation of 4,455 feet averages 474 inches yearly, nearly all of which falls during the five months from May to September, and as high as forty inches have been measured in a single day. On the Deccan plateau the rainfall is only twenty inches per year.

#### IRRIGATION IN EGYPT.

"The lower valley of the Nile, including its delta, comprise another great irrigation system with over 6,000,000 acres under cultivation. Egypt is wholly different from India as far as rainfall is concerned, being so arid that dry farming is impossible. The irrigated area begins at Assuan, about 500 miles from the Mediterranean Sea. The valley above the delta is



narrow with a tillable breadth averaging less than nine miles. At Alexandria the annual rainfall is 8.8 inches. The annual amount at Cairo is 1.3 inches. As far as crops are concerned the annual rainfall in the irrigated sections of Egypt might as well be ignored. The waters of the Nile are supplied by heavy rains in equatorial Africa near Lake Victoria, Lake Albert and Lake Edward. Here the rainfall is eighty inches per year. These reservoirs keep the Nile from running dry through the long stretch of desert, as it would probably go dry otherwise before reaching the sea. The dam just completed at Assuan has a storage capacity of over 30,000,000,000 cubic feet. It is built of granite and is seventy feet high, twenty-three feet wide at the top, eighty-two feet wide at the bottom, and one and one-fourth miles long. It will regulate the supply of water and natural flow, which is too high during three months of the year and too low during the remaining nine months.

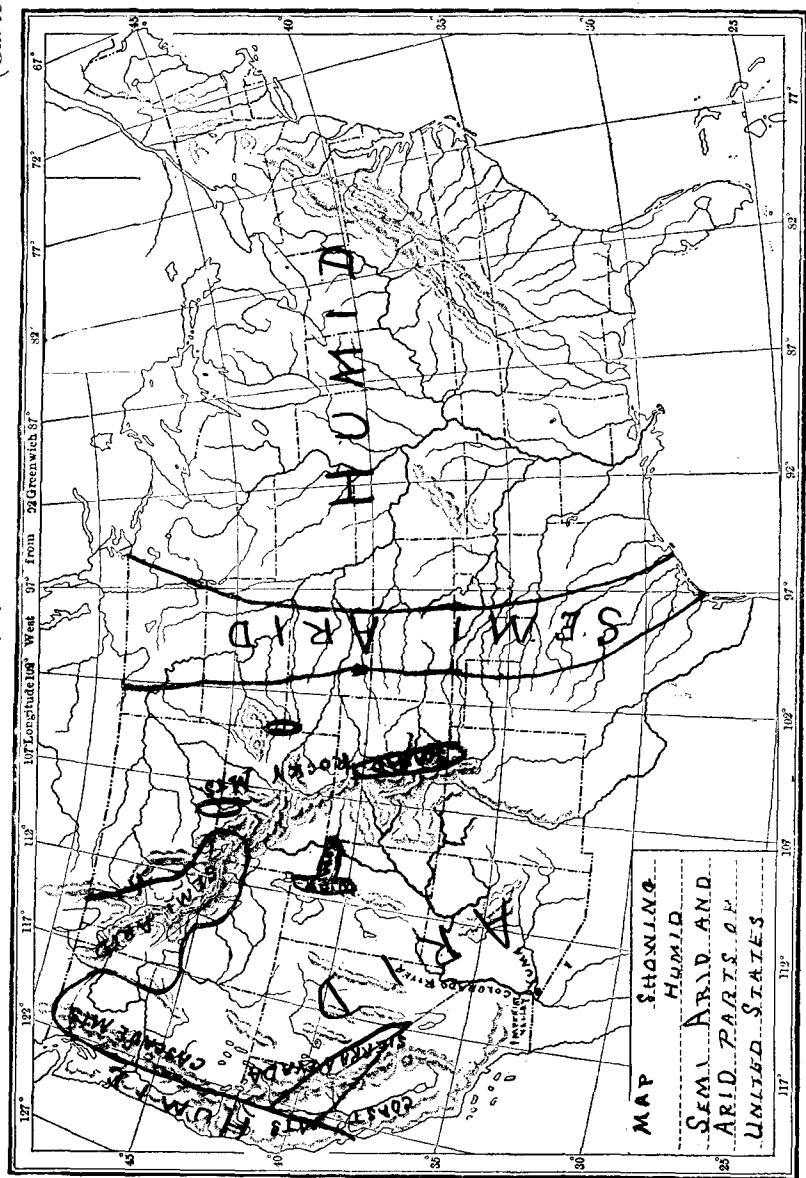
"Italy has irrigated since the time of the Romans and has 4,715,000 acres under irrigation. The rainfall varies from twenty to thirty inches per year. Spain has about 5,000,000 acres under irrigation. On the north coast the rainfall is heavy, over fifty inches per year. Near Madrid the rainfall is seventeen and one-half inches and it is less farther south. France has about 5,800,000 acres under irrigation. Near the English Channel the rainfall is forty inches. At Paris, twenty-two inches. In Southern France, about twenty-five inches. The summers are dry. In Australia little has been done for irrigation, but much has been planned. The rainfall is slight and droughts are frequent. The last three years have been droughty and it is reported that out of a total of 120,000,000 sheep at least 40,000,000 have died on account of drying up of the pastures. The rainfall for the continent of Australia is about twenty-one inches. He states the small rainfall is due to the fringe of mountainss skirting the continent, which are not high enough to collect snow, and therefore it will never be possible to irrigate much land even if all the water be utilized.

"In South America irrigation is confined principally to Argentina; the rainfall varies from three or forty inches per year. In the country of the Incas before the Conquest irrigation was practiced much more extensively than it is to-day."

His above brief extracts on irrigation in India, Egypt,

Europe and Australia are quoted because they will help us by comparison to understand better the conditions as they exist in the United States as regards rainfall and other climatic changes and also the areas under irrigation and to be irrigated. That portion of the United States east of the 100th meridian has a humid climate. The 100th meridian passes through about the middle of the Dakotas, Nebraska, Kansas, Oklahoma and Texas. The rainfall east of the 100th meridian varies considerably. In the Southern States it varies from fifty to seventy inches per year. The southern parts of the States that border on the Gulf of Mexico have a rainfall of seventy inches. The Middle States have a rainfall of from thirty to fifty inches per year and in the New England States the rainfall varies from forty to fifty inches per year. The States that border on the great lakes have a rainfall of from thirty to forty inches, so have Iowa and Missouri, but the rainfall decreases as we go farther west, and the eastern parts of those States through which the 100th meridian passes have a rainfall of from twenty to thirty inches. Between the 100th meridian and the country east of the foothills of the Rockies, roughly speaking, there is a stretch of country which might be called semi-arid. It takes in Western Kansas, Nebraska and Oklahoma and parts of the Dakotas. West of the semi-arid region the United States is arid except Northern California, Western Oregon and a large part of Washington. We might say in a general way that the United States is mostly an arid region between the 100th meridian and the Pacific Ocean. The author would like a classification somewhat as follows: An arid country is one in which the rainfall is from two to fifteen inches per year, and in a semi-arid country the rainfall varies from fifteen to twenty-five inches.

The able Chief of the Reclamation Service says that in a general way it may be said that arid regions are those where the average rainfall is twenty inches or less. According to this the arid regions of the United States include more than two-fifths of the entire area. He says: "As a matter of fact, however, a great part of the countries of the Old World have less than twenty inches annual rainfall and therefore according to our standards must be considered arid. The civilization of former times, however, grew up in those arid regions and we





cannot fully appreciate the writings of the ancients and the true meaning of many familiar phrases handed down to us without bearing in mind the fact that the writers lived in an arid climate where agriculture was successful only through irrigation."

We would like, however, a distinction made between an absolute desert where almost no verdure grows and the rainfall is only say three inches, and a section of country where the rainfall is eighteen inches and verdure is abundant, providing of course the rainfall comes at a time of the year when it will do some good. In considering the rainfall of a country we must know whether the rain falls at the time of year when the growing crops can utilize it. A country may have a considerable rainfall, but if it don't come at the time of year when the crops need it, it don't avail much. Of the 3,000,000 square miles of land in the United States, excluding Alaska and the Islands, about 1,300,000 are arid. The rainfall throughout the arid region varies greatly. In Nevada, Western Utah, Southern Arizona and Southeastern California the rainfall is so slight that it varies only from two to ten inches per year. Parts of these sections are almost absolute deserts. New Mexico, Colorado, Wyoming, Montana and Idaho have a higher rainfall, varying from ten to twenty inches. These are the States through which the Rocky Mountains pass. The mountains are always great conservators of moisture and the rainfall is always more abundant in an arid region where the mountains are high enough to condense the moisture by the cold of elevation than is the rainfall in the plains below. It is this moisture which falls as snow and rain on the mountains and vicinity which feeds the streams that furnish the water for irrigation in the arid West. In fact most of the streams on which the irrigation projects depend have their source in the Sierras or Rockies.

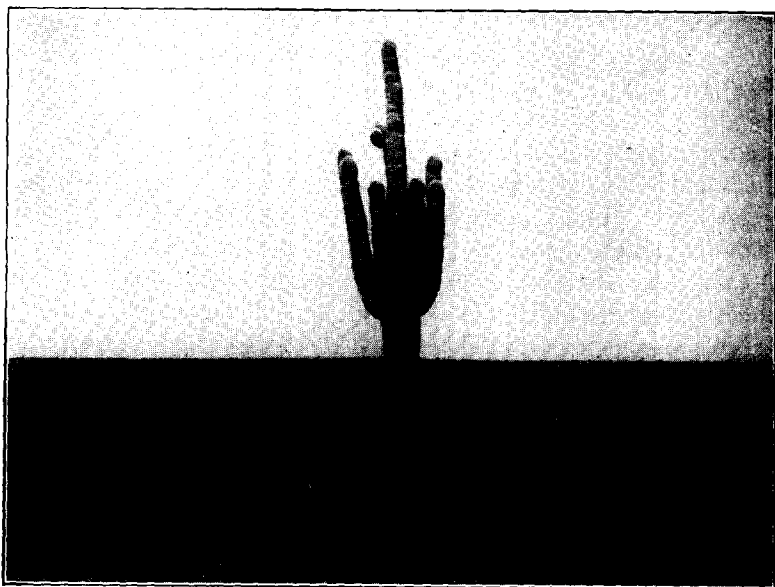
Why have we such an abundant rainfall in Western Washington, Oregon and Northwest California and such a deficient precipitation in the arid region between the Sierra Nevada Mountains and the Rockies? The reason is plain. It is not due to the proximity of the warm Japanese current, but there is a continual procession of high pressure and low pressure atmospheric areas across the United States from west to

east. These are the highs and lows of the weather map and are known as anti-cyclonic and cyclonic areas. They have nothing whatever to do with tornados, which are storms of very narrow path but exceedingly great velocity, although they are sometimes confused. In the anti-cyclonic or high pressure area the barometer is high and the cold air is coming down from above just as if through a gigantic funnel and spreads out in all directions with a spiral motion. The diameter of the area may be 1000 miles or over and three or four miles high. In the cyclonic area the barometer is low. It is a low pressure area and the warmer air is rising and the air comes in from all sides to take its place with a whirling motion. You might say the high pressure area pushes the low pressure area ahead of it across the United States. The Weather Bureau, in order to make it plain to the public, have likened them to a series of atmospheric waves traveling across the continent. The high pressure areas might represent the crest of the waves and the low pressure areas the trough. This brief explanation is inserted here because twenty years or more ago the weather was not taught in the public schools, and the average man if he can interpret a weather map carefully has been obliged to give the subject considerable study during his leisure moments. These high pressure areas start in the Pacific and push the air eastward, and as the warm vapor-laden air ascends the Coast Range of mountains it is chilled by the cold of elevation, and Western Washington and Idaho and some of the finest forest areas in the United States have a rainfall of over 100 inches per year. When these same winds cross the Cascade Range or the Sierra Nevada Mountains to the westward they part with more of their moisture either as rain or snow, so that by the time they reach the eastern slope of these mountains the winds are dry winds and don't contain enough moisture for abundant rainfall. Hence Oregon east of the Cascade Mountains is a sage brush and in places a lava desert due to deficient rainfall, while Western Oregon is a magnificent forested area. The principal reason then for the aridity of the West is; the winds have parted with their moisture to the Coast, Cascade and Sierra Nevada and Sierra Madre Mountains.

In the hottest summer months the mountains like the Coast

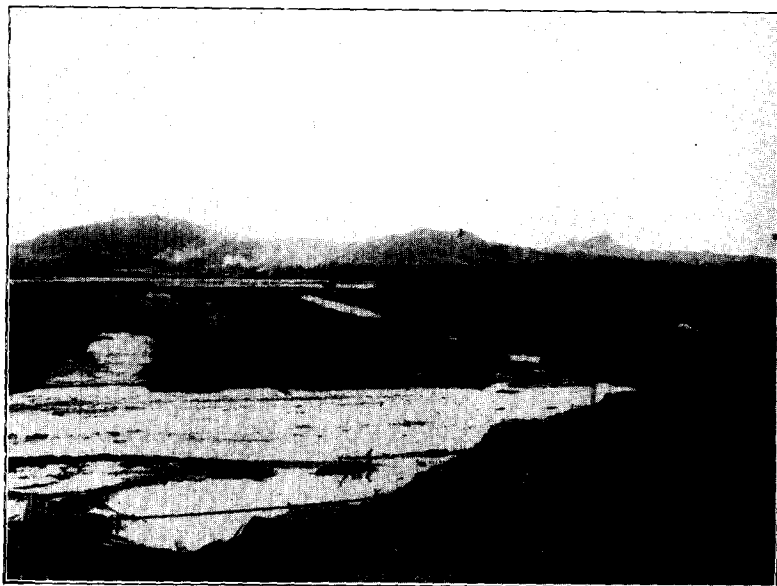
Range, which are only of average elevation, become warmed by the sun's rays and allow the vapor-laden winds from the Pacific to pass over them without chilling them enough to condense the moisture as rain; so they pass over the mountains, no rain falls, and we have the summer drought of the Pacific Coast. In Southern California no rain falls during May, June, July, August, September and October. But little rain falls then from May to November. Another reason for the scarcity of rains in Middle and Southern California during the summer is (See Year Book of Agriculture, 1902, Wet and Dry Seasons in California, by McAdie,) "few atmospheric pressure areas or disturbances pass eastward from the Pacific over Middle and Southern California during the summer. There seems to be an area of permanent high pressure over the ocean unfavorable for rain bearing winds on the Pacific Coast. During the winter months an area of permanent low pressure overlies the Pacific, resulting in an air circulation such that south, southeast and southwest winds prevail. During this period numerous atmospheric disturbances are experienced in the Northern Pacific and these in their eastern passage cross the coast at any latitude from Sitka to San Francisco, the larger number passing inland north of 45th parallel. The rain for the year falls practically in the months of November, December, January, February and March. Showers in April and early part of May bring the growing crops to fruition. When little rain falls in December, January or February, the outlook is poor for the crops in California."

Leaving California let us consider the arid region as a whole and we will find that there are other reasons to account for the aridity. The principal reason is that conditions are not favorable for the precipitation of moisture in certain desert divisions of the arid region even if the air had moisture enough to produce copious showers. Where there are high mountains in the arid regions the rainfall is much more abundant because as the winds ascend the slopes the air expands and hence its capacity for moisture decreases; then again it is chilled by the cold of elevation. It gets about one degree colder on an average for every 300 feet you ascend a mountain. The expansion and cold serve to condense the moisture in the air and it falls as rain or snow. So we see that in parts of the arid region the



What irrigation will do in southern Arizona deserts. An unusual sight—the giant cactus *cereus giganteus* or (saguaro of the Mexicans) 40 feet high, growing in a field of alfalfa. This is not in the Yuma region, but in the Salt River Valley.

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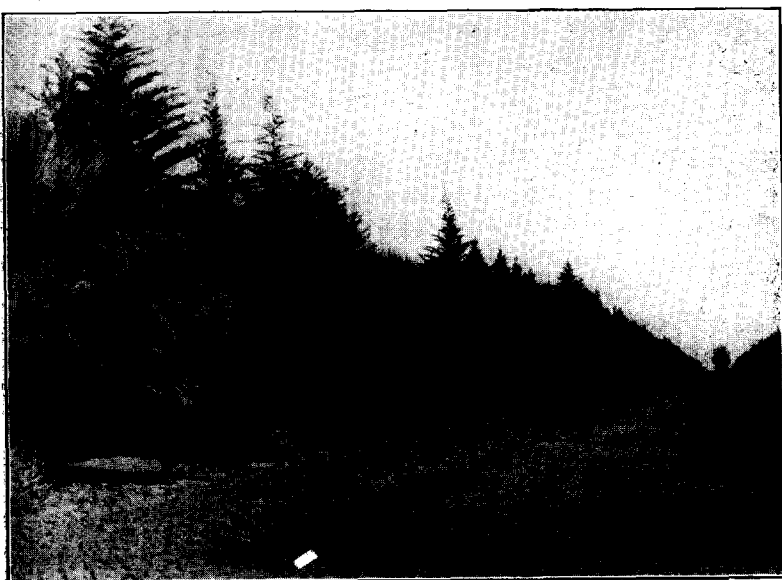


Laguna dam site

(*Carler*)



Steam dredger at work, Laguna dam



A driveway on irrigated land near Yuma, Arizona

air may have enough moisture to form rain, but conditions are not favorable for its precipitation and it may happen that heavy showers in a humid region were condensed or precipitated from air that originally traveled over part of the arid region. For example, warm, dry air which is rising from the desert will not condense moisture in the clouds above. The tendency is just the reverse; it tends to dissipate the clouds. Prof. Henry states, (See U. S. Weather Bureau Bulletin D, 1897): "Tables of annual precipitation tell us how much rain or snow falls during the course of the year, but they afford no indication as to whether the rain comes when it will be of the greatest service to agriculture or whether it falls after the time of maturity of the staple crops. The distribution of precipitation throughout the year is fairly uniform in the States along the middle Atlantic, in New England, in the Ohio Valley and along the borders of the Great Lakes. It is strongly concentrated in the summer months upon the Great Plains. On the other hand it shows a pronounced maximum during the winter season in the Great Basin (Nevada), where summer rains are most needed. At Winnemucca, near the center of the Great Basin, the midwinter (January) fall is nearly twelve times that of the midsummer (July) fall, while the Great Plains show a difference between the records of these months in the ratio of about five to one, on the average, the other way. For example, Garden, in Western Kansas, is upon the High Plains; the record is 17.4 inches for the year, of which 14.1 inches are credited to the six months from April to September. It is evident then that rain water in order to be of much benefit must fall during the time of year when the crops are growing. The winter rainfall is not entirely lost, however, as it keeps the soil moist and sinks below the surface to the ground water; then again evaporation is less during winter when the air is cold. In order to conduct agriculture successfully and raise fair crops at least twenty inches of rain per year are required. It may be a little less will suffice if it falls at particular favorable times, but when the rainfall is less than twenty inches per year we cannot raise abundant crops without irrigation. Even trees require for successful growth from twenty to twenty-five inches per year. One curious and interesting fact about climate and rainfall is that on the barren staked plains of Texas (Llano

Estacado) that are so dry that agriculture is almost impossible, the rainfall is as great as in the center of the wheat belt in Dakota. For example an eighteen year record at Amarillo on the staked plains in the Panhandle of Texas shows an annual rainfall of 21.94 inches; this is a grazing region, not agricultural. Yet in the center of the great wheat belt in Dakota at St. Vincent the rainfall is but 19.5. (See 21st U. S. Geological Survey Report, Part IV, page 659.) But this is explained by the fact that the hot dry south winds of Texas take up moisture like a sponge. The days are hotter, the rains spasmodic, so that the water evaporates quickly and does not sink into the soil freely enough. The facts given in this article about rainfall are necessary in a discussion pertaining to irrigation. You cannot separate rainfall and irrigation. The U. S. Geological Survey Reclamation Service state:

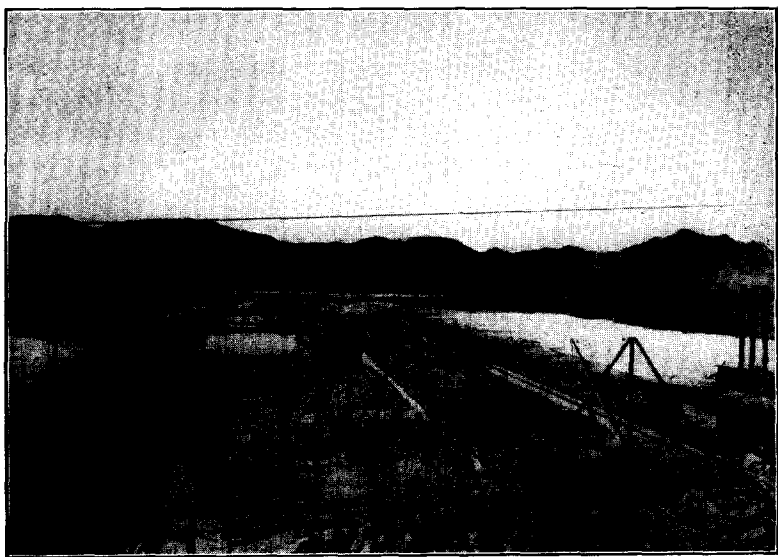
"The following brief statement regarding irrigation projects under consideration and construction by the U. S. Reclamation Service and concerning irrigable lands in public and private ownership, which will eventually be reclaimed by means of proposed system, is published in circular form for convenience in answering inquiries and for the information of the public generally."

Their statement about the Yuma Project reads as follows:

#### CALIFORNIA: YUMA PROJECT.

"This project contemplates diversion of the waters of Colorado River by means of proposed Laguna dam and sluiceways, about ten miles northeast of Yuma, Arizona, into two canals, one on each side of the river. In Arizona these canals will irrigate all the bottom lands of Colorado and Gila Rivers between the Laguna Dam and the Mexican boundary (an area of 84,000 acres in round numbers), and in California the bottom lands in the Yuma Indian Reservation (an area of 17,000 acres), all tributary to the Southern Pacific Railroad. Plans also contemplate the construction of a complete system of levees to protect the bottom lands from overflow, and a pumping system to remove the surplus water from the low-lying areas. Lands under this project have been withdrawn under the provisions of the reclamation act of June 17th, 1902, from

all forms of entry except by homestead. The mesa lands have been withdrawn from all forms of entry. Under the provisions of this act an individual holding may not exceed 160 acres. Definite decision has not been reached as to the farm-unit area, but it will probably not exceed forty acres to each entryman. The method by which the lands of the Yuma Reservation will be disposed of to settlers has not yet been announced. It is probable, however, that the reservation will be thrown open upon the completion of the irrigation works. The cost of



Laguna dam, 4780 feet long. General view of dam taken from above Arizona sluiceway

the works will be assessed proportionately upon each acre of land reclaimed, to be paid by settlers in ten annual installments without interest. The only additional charge will be for maintenance. The distribution of water, collection of payments, maintenance charges, etc., will be looked after by the Yuma County Water Users' Association, M. Winsor, President, at Yuma, Arizona. The members of this Association are the landowners of the district to be affected. Printed matter and information of a local character regarding the section may be had upon application to Association headquarters, at Yuma, Arizona. On July 6th, 1905, a contract was awarded to J. G.



White & Co., New York, for the construction of the Laguna dam and sluiceways. Excavation is being carried on and other preliminary plans are under way with a view to the construction of the dam. On September 13, 1905, a contract was awarded for the construction of Yuma dikes on which actual work is now under way."

#### THE COLORADO RIVER.

The Colorado River is the great river of the arid southwest. In an arid region rivers are scarce and generally of small volume on account of deficient rainfall and rapid evaporation, but the Colorado is an exception. One branch of the Colorado River, the Grand River, rises in the Rocky Mountains in the highest peaks of the Park Range in Colorado west of Long's Peak, where it is fed by Alpine lakes and hundreds of brooks formed by the melting of snow. The other branch of the Colorado, the Green River, rises just south of Yellowstone Park, in Wyoming, near Fremont's Peak, on Wind River Mountains, at an elevation of 12,000 feet. These two rivers unite in Utah and form the Colorado, which flows southwest 200 miles, then west for 150 miles, then south 300 miles into the Gulf of California. After leaving Utah it flows through the Grand Cañon in Arizona for a distance of 218 miles. This stupendous cañon is from 4000 to 6500 feet deep and from five to thirteen miles across and is the greatest scenic wonder in the world. The length of this river is 2000 miles. In Utah and Northern Arizona it flows through the plateau country which is from 4000 to 8000 feet above tide. After leaving the Grand Cañon below the mouth of the cañon the river forms the boundary between Arizona and California and flows through a region as absolute desert as the Sahara, almost rainless, and but a few feet above sea level. Near the Gulf its flood plain is ten or more miles in width. If you call the Green River the source of the Colorado and the Grand a tributary, then it has but four principal tributaries, the Grand, San Juan, Colorado Chiquito and Gila, and these are all on the eastern side in marked contrast with hundreds of tributaries on each side of the Mississippi, but we must remember the Colorado flows through an arid region the greater part of its course where the rain fall varies from two to fifteen

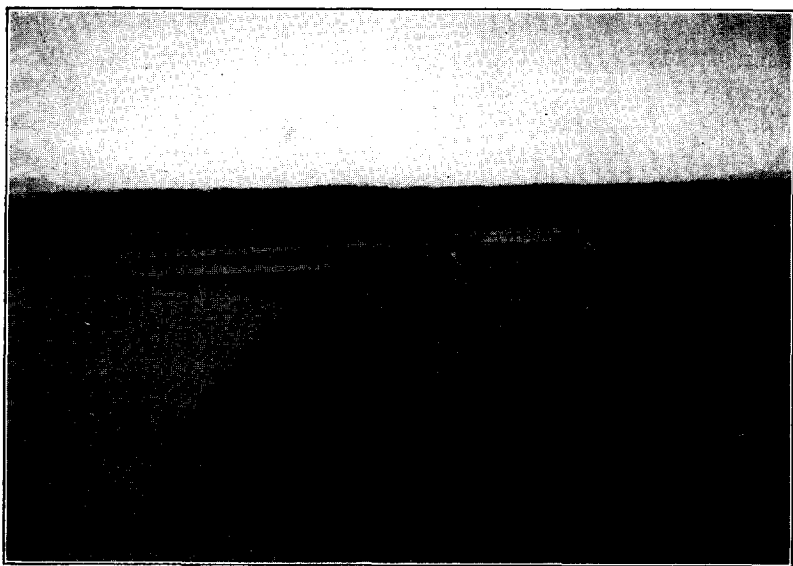
inches. It is the melting of the snows and the rains on the mountain tops which furnish most of the water, but they told me at the Grand Cañon that the river would sometimes rise sixty feet in a night after the cloudbursts in the plateau region, and many of us know what cloudbursts mean in the plateau region. Streams of liquid mud six feet deep will flow across the desert which in a few hours will be as dry as punk. The Colorado River drains an area much larger than the New England and Middle States together, an area of over 200,000 square miles, and several writers have called it the American Nile. They have some features in common. The Nile also flows through an arid region and it flows 1000 miles without receiving a branch; it has a flood plain from five to fifteen miles wide. The Nile flows north from Lake Victoria, Nyanza, and the lake basins near the source of the Nile have breakings or faultings of the earth's crust like we see in the plateau region in Arizona.

The Nile would probably dry up before it flowed its long course were it not fed from the humid lake region of Africa. So would the Colorado perhaps during part of the year were it not fed by the snows and rains from the high and humid mountains, because it flows through a Sahara-like region in its lower course. As the rainfall around Yuma is but from two to fifteen inches per year and it has the reputation of being one of the hottest places in the country, the highest official temperature being 118 degrees in the shade, it can be readily understood that irrigation is absolutely necessary if any crops at all are to be raised.

The Gulf of California originally extended 150 miles farther northwest than it does to-day; it extended as far as Indio.

The Colorado is a muddy river and brought down thousands of tons of sediment, the wear and tear of the western part of the continent, produced by erosion. As it poured its waters into the Gulf the velocity was checked and the sediment deposited produced a delta. Even at the present day it is calculated by the Reclamation engineers that the Colorado River in twenty-four hours during a high flood carries past the dam site 1,500,000 tons of silt. In past times this delta traveled southwest across the Gulf and finally isolated the northern portion of the Gulf entirely.

In a region whose torrid heat is almost tropical and where evaporation is exceedingly rapid, an average of at least eight feet per year, this isolated inland sea gradually evaporated and left a large depressed area, most of which is below sea level. The old beach line is plainly visible in the north and is on a level with the Pacific. This area north of the Mexican boundary line is now known as the Imperial Valley. The deepest part of this valley contains the so-called Salton Sink, now called the Salton Sea, and is over 300 feet below sea level. From time to time the Colorado overflowed its banks and de-



Reversed abatis and screen dike for the protection of the Yuma Valley dike.  
five miles west of Yuma, Arizona

posited silt rich in plant food over the floor of the valley, so that much of the Imperial Valley contains fertile soil. There were two parallel dry river courses or *arroyos* which extended from the Colorado River northwest and emptied into Salton Sea. As a rule the high water in the Colorado only overflowed enough to fill these rivers for a short distance from their sources, and it was a rare occasion for the Colorado to overflow sufficiently for its waters to reach the Salton Sea. In 1891 these rivers were not only filled but overflowed their banks and the surrounding country and in some places even united, as they were

but a few miles apart. The Salton Sea rapidly increased in volume.

The report of the Mexican Boundary Commission states "that the channels of these streams are fringed with a thick growth of mesquite while the limits of overflow are plainly marked by a most luxuriant growth of an amaranthus (called quelite by the Mexicans), a plant much esteemed as food for cattle. The growth of quelite, mesquite and grass following the overflow of 1891 furnished a fine pasturage for several thousand head of cattle, brought here from the overstocked ranges of Arizona and California."

This Imperial Valley was practically uninhabited then, but when the settlers saw the abundant forage crop produced by the overflow of the river they reasoned that by diverting the Colorado into canals and irrigating ditches the desert would bloom like a rose. Finally in this desert valley 100,000 acres were irrigated, new towns started connected by branch lines to the Southern Pacific Railroad system. The people poured into this fertile valley almost like the exodus from the settlements into a new mining camp when a rich find is made, until nearly 10,000 people were living below sea level in a valley which was once a trackless desert waste, made fertile by irrigation. One of the canals that the settlers built tapped the Colorado just a short distance below the Mexican boundary line. Of course it was down grade from there to the Imperial Valley. They simply ran the canal into one of the dry streams or arroyos and gave it the name Alamo River. There were no headgates to regulate the flow, so that during a time of flood when the Colorado was unusually high the greater volume of water left its usual river channel and poured its waters into the canal and finally reached the Salton Sea through one of the river courses formerly called Alamo River. This sea is now an immense inland body of water increasing in size. The New River channel also filled and finally these two streams united forming a stream several miles wide flowing into the Salton Sea. The Southern Pacific Railroad tracks have been submerged. At Salton one of the most remarkable and valuable deposits of salt in the United States was ruined by the rising waters. There was a field of salt of 1000 acres where the crust formed from six to sixteen inches thick looking like a great deposit of

snow. It was of unusual purity (95%) and was simply plowed and raked into rows. The salt would soon form again after it was raked from the marsh. The waters of Salton Sea continued rising until the salt fields were submerged. The Southern Pacific tracks were moved twice and finally the telegraph poles were covered. The curious sight of fields of waving sage brush and other desert plants along a shore line of white caps is seen.

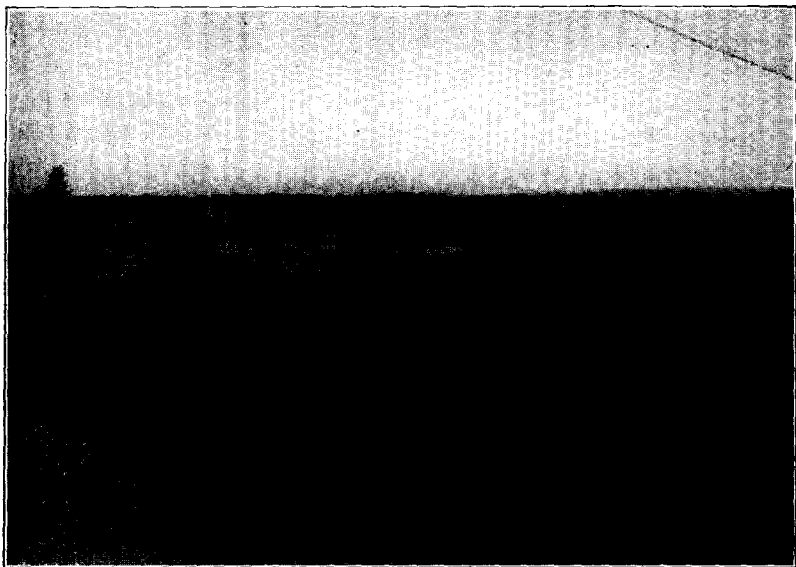
The Colorado is still pouring its water into the Salton Sea which is daily rising. The dimensions of this sea at the time of writing (September, 1906,) I am not certain of, but estimate that it is from forty-five to fifty miles long and from fifteen to twenty-five miles wide and perhaps forty to fifty feet deep in the deepest parts that have recently been submerged.

It is absolutely necessary that the Colorado be diverted into its proper channel, otherwise parts of the fertile lands in the Imperial Valley will be submerged permanently. Then again it is not fair to our sister Republic, Mexico, because thousands of fertile acres on the other side of the boundary line will be rendered worthless without irrigation. A dispatch from San Francisco dated August 24th states that the Salton Sea in the Colorado Desert is now rising less than an inch a day and they expect in a few weeks to begin work on a plan by which the Colorado River will be restored to its original channel. This, it is stated, will probably cost the Southern Pacific Railroad \$700,000. Heavy embankments are to be built where the river is overflowing into old channels. This will be a tremendous undertaking and an engineering feat of rare skill, as the break in the banks of the Colorado is three-fourths of a mile long. The water of the Salton Sea will soon evaporate when the overflow is stopped.

This description of the Salton Sea and the overflow of the Colorado River are features that could not be omitted from an article on irrigation near Yuma.

The irrigation dam which the Government engineers are building is located twelve miles above Yuma at Laguna. It will not rest on rock because borings did not reach bed rock, which is buried under many feet of silt. The dam, which stretches across the river channel from bank to bank, will have a length of 4780 feet, its height will be but nineteen feet, but

its width up and down stream will be 267 feet. Its contents will be 356,000 cubic yards, the weight about 600,000 tons and the cost about \$1,000,000. It will hold back the waters of the Colorado, forming an artificial lake about ten miles long. The dam is of the East India weir design and has been tried at many places in Egypt and India. On the Nile River to-day they are in successful operation and the conditions there are similar to Yuma. The solid masonry rests on sand and silt. For these later facts about the dimensions and construction of the dam, disposition of silt and other details, I am indebted



Reversed abutment constructed for protection of Yuma Valley dike, about five miles west of Yuma, Arizona, showing accumulation of driftwood during one flood. Yuma project, March 31, 1906

to the Reclamation Service and to excellent articles by J. B. Lippincott, Supervising Engineer, (Annual Report Smithsonian Institute, 1904.) and C. J. Blanchard, Statistician of U. S. Reclamation Service, (National Geographic Magazine, February, 1906.)

The engineers explored with the diamond core drills all the sites between Yuma and Picacho for bed rock before the Laguna site was selected. They considered a high dam and a

high line canal out of the question. Mr. Lippincott describes the weir dam as follows:

"This type of weir consists of loose rock structure with a paving of stone two feet in thickness on the down stream slope, the structure being tied together with three parallel walls of concrete run longitudinally between the granite abutments on the two sides of the river, and the entire structure being further made secure by an apron of loose rock pitching ten feet in thickness and fifty feet in width at the lower toe of the dam below the sloping pavement. The height of this weir is to be ten feet above low water and the slope of the down stream side is twelve feet horizontal to one foot vertical, with the fifty foot apron below. The design calls for the upper core wall of concrete to rest upon a row of sheet piling driven into the bed of the river. The handling of the silt he states is one of the most difficult features of this undertaking. It is known that its amount is very large.

"The river is on a grade of approximately one foot to the mile above the Laguna weir site, so that this weir, ten feet high, will make a settling basin of relatively quiet water, approximately ten miles in length above it. At each end of the weir and constructed in solid granite rock will be a sluiceway 400 feet wide on the Arizona side and forty feet wide on the California side, with provision for its enlargement to 200 feet when desired, and excavated to the depth of two feet below low water in the river. These sluiceways will be closed by large gates operated mechanically. The diversion canals will take their water above these gates from the sides of the sluiceways. The area of these sluiceways being so great, the water movement toward the canal will be slow, and most of the sediment will be deposited before reaching the canal intake. When this has accumulated to a considerable extent, the sluice gates will be opened, and it is estimated the flow will be approximately 20,000 cubic feet per second. This great volume of water passing through the sluiceways when the gates are opened will carry out with it the sediment deposited above the intake of the canal. The ordinary low stage flow of the Colorado River is from 3000 to 4000 cubic feet per second; so that the capacity of these sluiceways will be about five times the low

water flow of the river. These figures are given for the purposes of comparison only.

"As the result of a number of experiments it has been found that the principal quantity of silt is carried along near the bottom of the river and that the surface water is relatively free from sediment. It is planned therefore to take the water into the canals by a skimming process over a long row of gates, so that the entire capacity of the canal can be furnished by drawing but one foot in depth of water from the surface of the river. Every portion of this weir and headworks as designed would be of rock concrete or steel with the exception of the sheet pilings, which will be driven entirely below water level and so will not decay. The capacity of these canals at their intake will be 1600 cubic feet per second on the Arizona side and 200 cubic feet per second on the California side. The amount of silt that would be daily delivered into the Arizona canal if diversion were made directly from the stream would approximate 17,000 cubic yards of wet mud by volume. It is not believed to be possible for a canal to continuously operate successfully for the irrigation of lands along the valley of the Colorado River unless some very substantial arrangements are made at the headworks for the handling of silt, and this is believed to be a justification for the expenditure proposed for these headworks; also the water must be held to a fixed level at the canal heading for all stages of the river. This structure will cost approximately \$1,000,000. It is not considered possible to remove all of the silt from the water, but the canals have been designed so that the velocities will be sufficient to convey through to the fields the light material entering the canals from the intake.

"One of the most difficult problems in connection with this project is the crossing of the Gila River. It has been considered necessary to make this perfectly safe and for this purpose a structure has been designed that will cross beneath the bed of the river, the top to be several feet below the lowest point of the stream bed. This structure will be of steel and concrete some 3000 feet in length. It will be an inverted syphon consisting of four concrete pipes ten feet in diameter reinforced with steel rods. Because of the annual rise of the Colorado River, a large portion of the lands along this stream are sub-



ject to annual overflow, which practically prevents residence thereon, as well as the farming of them without protective works. The levee therefore is considered an essential feature of the enterprise. The shape of the levee adopted is one that has been developed by years of experience along the Mississippi River. It will have a slope of three feet horizontal to one foot vertical on the water side, and two and one-half feet horizontal to one foot vertical on the land side. It will be eight feet wide on top, and be built five feet above the highest water marks of the year 1903. These levees will be 4000 feet apart (one on each side) along the Colorado River and 3200 feet apart along the Gila River. Because these lands are so flat and the level of the water in the ground so near the surface, it is considered necessary for their permanent safe irrigation to supply a drainage system. A main drainage canal has been designed to run through the central portion of the areas to be irrigated and when possible the natural drainage lines of the country will be utilized, deepening them with a steam dredger to such depth that they will carry off the water returning from irrigation or seepage through the levees during the high water stage of the river. When lands in any district tend to become alkaline they may be connected by means of local drainage canals, with this main drain, and in this manner they could be kept free from alkali by holding down the level of the ground water. During the greater portion of the year when the river is low, this drainage water would be discharged into the stream, but when the river is in flood its elevation will be such as to prevent a discharge into it from the drains. A pumping plant has therefore been designed to lift the drainage waters over the levees during the flood period of the river to prevent the lands becoming water logged.

"The Secretary of the Interior has set aside \$3,000,000 of the Reclamation Fund for the construction of this project, contingent upon the action of the landowners of this valley and their entering into contracts with the Department in accordance with the provision of the Reclamation Act, passed June 17th, 1902. On March 15th, 1905, bids for the construction of the dam were opened and responsible bidders offered to build this structure for the amount estimated upon by the engineers."

Too much praise cannot be awarded Mr. F. H. Newell, Chief of the Reclamation Service, and the very able body of engineers under the employ of the Government. One has only to study the water supply and irrigation papers and the annual reports of the U. S. Geological Survey that treat of hydrography to learn of the thousands of painstaking observations that were made before the irrigation projects were planned.

The projects require engineering skill of the highest order. The Roosevelt dam in the Salt River Cañon, Arizona, will be solid masonry 285 feet high, and will join the cañon walls several hundred feet apart and form a lake twenty-five miles long and 200 feet deep. The United States will soon take the lead as the foremost country where irrigation is practiced on a grand scale.

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#### EFFECT OF DURATION OF STRESS ON STRENGTH AND STIFFNESS OF WOOD.

It has been established that a wooden beam which for a short period will sustain safely a certain load, may break eventually if the load remains. For instance, wooden beams have been known to break after fifteen months under a constant load of but 60 per cent of that required to break them in an ordinary short test. There is but little definite and systematic knowledge of the influence of the time element on the behavior of wood under stress.

This relation of the duration of stress to the strength and stiffness of wood is now being studied by the Forest Service at its timber-testing stations at Yale and Purdue Universities. The investigation should determine: the effect of a constant load on strength; the effect of impact load or sudden shock; the effect of different speeds of the testing machine used in the ordinary tests of timber under gradually increasing load; and the effect of long-continued vibration.

To determine the effect of constant load on the strength of wood a special apparatus has been devised by which tests on a series of five beams may be carried on simultaneously. These beams are two and three inches in section and thirty-six inches in length, each under a different load. Their deflections and breaking points are automatically recorded upon a drum which requires thirty days for one rotation. The results of these tests extending over long periods of time may be compared with those on ordinary testing machines, and in this way safe constants, or "dead" loads, for certain timbers may be determined as to breaking strength or limited deflections.

The experiments of the Forest Service show that the effects of impact