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Irrigation in Imperial Valley, California

Its Problems and Possibilities

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DESCRIPTION OF THE VALLEY.

What is now known as Imperial Valley occupies the greater portion of what was formerly the Colorado Desert. It occupies the eastern end of San Diego County, but it is now being formed into a new county to be known as Imperial County. The desert is a great basin 110 miles long by 40 miles wide and the part comprising Imperial Valley is mostly below sea level. The basin is formed by mountain ranges on all of its sides except one—the southeast. The basin extends into Mexico, but Imperial Valley is entirely in the United States. By reference to the accompanying map, Plate I, it will be seen that the international boundary line between California in the United States and Lower California in Mexico runs nearly east and west through the center of the map. The basin extends from the northwest to the southeast, being bounded on the northeast and southwest sides by mountain ranges. The northwestern part of the basin beyond Salton Sea is known as the Coachella Valley. At the southeast the open country in Mexico is crossed by Colorado River in its course to the Gulf of California. The mountain range on the northeast is an extension of the San Bernardino Mountains, known as the Chucawalla Range. The mountains on the southwest in California are the San Jacinto and Coast ranges. Those in Mexico are the Cocopah Range. The basin included between these ranges is really a delta of Colorado River.

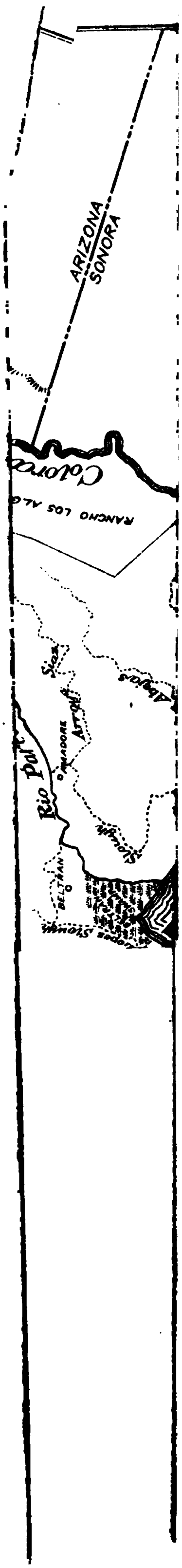
There are evidences that this country was once a portion of the Gulf of California. The old beach line is yet plainly visible entirely around the portion below sea level, except at the southeast, and practically coincides with the sea-level line, which is shown on the map. The soils of the basin are an alluvial deposit. A well was bored at the town of Imperial, about the center of the basin, in the hope that artesian water might be secured, but after reaching a depth of about 600 feet without striking either water or rock it was abandoned. The strata throughout the entire depth were similar to that at the surface, showing that the depth of deposit was something in excess of 600 feet at that point. The river emerging from the mountains and entering the basin on what was once the gulf, at the northeast side near where it now meets the international boundary, deposited the silt with which it is very heavily laden and gradually formed a delta spreading out fan-shaped toward the south and southwest until it reached the Cocopah Mountains on the southwest near the site of Volcano Lake. Here it was interrupted and the water passed to the northwest into the basin or to the southeast into the gulf, and finally it is to be concluded that the main channel became established toward the south. Thus an inland sea was formed which gradually diminished in size by evaporation until nothing remained but a dry basin. The long gradual slope of the delta reached nearly to the farther end of the basin at the northwest and here we naturally find the greatest depression. This lowest portion of the basin is 287 feet below the sea level and has been known as Salton Sink, or Salton Sea, the name being derived from the large deposit of salt which was deposited on complete evaporation. It is probable that the river from time to time by overflow broke into the basin and that Salton Sea varied from a dry bed to a lake of considerable size.

In the triangular section of country in Mexico between Colorado River, the international boundary, and the Cocopah Range there are numerous channels with their general direction to the southwest, chief among which is Rio Paredones, apparently an old channel of the Colorado, and Rio Pescadero. Rio Paredones runs along the top of the ridge of the delta. The altitude decreases from about 100 feet above sea level on the Colorado at Hanlon to about 24 feet above sea level at Volcano Lake. Volcano Lake, like the channels leading to and from it, contains water during flood seasons and approaches a dry bed at other times. Hardy River drains Volcano Lake on the southeast to the Gulf.

New River has its source at Volcano Lake and flows down the slope to the northwest across the boundary line through Imperial Valley and into Salton Sea, having a total fall from 24 feet above sea level at the source to −287 feet at the bottom of the sink. Alamo River, formerly known as Salton River, runs first westward in Mexico, thence northward across the boundary line and through Imperial Valley to the Salton Sea. These two streams are the channels by which any overflow of the Colorado toward the northwest enters the lowest portion of Salton Sink.

The Colorado overflows its banks in Mexico annually and in recent years some of the water found its way into Salton Sink from natural causes, and once, through the work of man, it was unintentionally entirely diverted from its present channel into Salton Sink. Alamo River originally ran through Mesquit Lake by making a sharp turn to the west at that point, but the channel was straightened by a ditch known as the Alamo cut-off, leaving the lake off its course. The lake has also been almost completely drained by another ditch. A few years ago the Alamo was larger than New River, but in recent floods most of the water in the Alamo passed over to New River through Beltran and Garza and Pink Mountain sloughs in Mexico, so that through Imperial Valley New River has been much the larger stream. The recent flood caused by the diversion of the Colorado into Salton Sink forming the sea is described in the latter part of this report, together with the costly measures which restored the river to its former channel and which will prevent any further overflow into New or Alamo rivers in the future.

The Salton Sea as it is at present was formed during 1905 and 1906. It is 42 miles in length and from 10 to 15 miles in width and has a water surface of about 400 square miles. The water surface is now 205 feet below sea level and the greatest depth of the water is 82 feet. Prior to 1905, and since there is any authentic record, it


ARIZONA
SONORA
BELTRAN

was never at any time more than a comparatively small lake. It will now begin to evaporate and will probably again become a salt marsh.

A railroad traverses the Colorado Desert along its northeast side, passes along the shore of Salton Sea, and crosses the Colorado at Yuma, Ariz., a short distance above the Mexican line. A branch line extends from the station of Imperial Junction (formerly known as Old Beach) southward through the center of the valley to Calexico on the international boundary line. Calexico is in the United States and Mexicali is its neighboring town in Mexico. The headquarters of the development company, which constructed the Imperial irrigation system, are at Calexico. Imperial, near the center of the valley, is its chief town; Brawley also is an important town to which the north end of the valley is tributary. Holtville holds a like position for the east side of the valley and is the terminus of an interurban railroad. El Centro is in an important location at the junction of the interurban railroad with the steam railroad. Silsbee and Heber have town sites. The former is a settlement on New River and the latter is a station on the railroad.

Signal Mountain, with an isolated position at the northwest end of Cocopah Range and almost on the international boundary, is an important landmark of the valley. Superstition Mountain is a long, low hill projecting into the valley on its west side. A range of shifting sand hills are situated northeast of the valley and between it and the railroad. A mesa stretches toward the valley from these sand hills, the edge of which limits the valley lands on the east side. Pilot Knob is a mountain near the Colorado at Yuma at the intake of the irrigation system.

COLORADO RIVER.

Colorado River, from which water is diverted for Imperial Valley, has a drainage area of 225,000 square miles and drains portions of seven States. Its principal tributaries are the Green, Grand, and Gila. The following tables give the discharge of the Colorado at Yuma from 1894 to 1906, inclusive, as shown by the measurements of the United States Geological Survey:

Table showing mean monthly discharge of Colorado River, 1894–1906, inclusive.

Month.	Cubic feet per second.	Total mean monthly, acre-feet.	Month.	Cubic feet per second.	Total mean monthly, acre-feet.
January	5,100	314,000	July	20,700	1,226,000
February	6,200	348,000	August	8,700	535,000
March	10,200	628,000	September	6,100	363,000
April	12,500	741,000	October	6,100	375,000
May	30,400	1,870,000	November	5,500	327,000
June	42,600	2,534,000	December	6,200	381,000

It will be seen that the season of flood is through May, June, and July. The maximum occurs in June, when the mean rate of discharge is 42,600 cubic feet per second. The river reaches its lowest stage in January, when the mean is 5,100 cubic feet per second. The floods of the late spring and early summer are caused by the melting of snow in the high mountains of the continental divide drained by the Green and the Grand in Wyoming, Utah, and Colorado. The table shows that the river is fairly constant from September to February, inclusive, during which time the mean discharge is about 6,000 cubic feet per second, but there are often floods during this period when the discharge reaches 20,000 cubic feet per second for a few days. Owing to their irregularity and short duration they do not have the effect of raising the mean to any great extent. These winter floods are usually caused by rains in Arizona, which raise the Gila and its chief tributary—Salt River.

The following table shows the annual discharge of the Colorado River at Yuma from 1894 to 1906, inclusive:

Annual discharge of Colorado River from 1894 to 1906, inclusive.

Year.	Mean cubic feet per second.	Total acre-feet.	Year.	Mean cubic feet per second.	Total acre-feet.
1894	7,400	5,390,000	1902	8,400	6,127,000
1895	9,900	7,162,000	1903	15,600	11,329,000
1896	9,000	6,515,000	1904	13,900	10,119,000
1897	12,400	9,039,000	1905	27,300	19,710,000
1898	9,100	6,581,000	1906	26,800	19,475,000
1899	12,200	8,870,000			
1900	9,400	6,798,000	Mean	13,300	9,651,000
1901	11,700	8,495,000			

The mean annual rate of discharge for Colorado River is 13,300 cubic feet per second and the mean total discharge is 9,651,000 acre-feet. The minimum annual discharge occurred in 1894 and the maximum in 1905. The discharge has been much greater since 1902 than for previous years. The lowest total discharge for one month was 154,100 acre-feet in January, 1894, and the greatest was 5,010,000 acre-feet in June, 1906.

The Arizona Experiment Station found that the lower Colorado carries 35,000 acre-feet of silt annually. Its water is red and opaque and in flood season is much more muddy than at the low stage. The amount of silt carried at Yuma during 1904 varied from 84 to 3,263 parts in 100,000 parts of water by weight. This is roughly from one-thirtieth to one twelve-hundredth part. An acre-foot of the river water contained an average of 9.62 tons of silt. If it is assumed that one-half of the silt in the water in the river is held in suspension until the water reaches Imperial Valley lands a field to which 3 acre-feet of water is applied receives 14.43 tons of silt.

SOILS.

The chief characteristic of the soil in Imperial Valley is its wonderful fertility. The land slopes principally to the north and northwest at an average rate of about 6 feet per mile. The soil is sedimentary in character and is of several grades, ranging from a loose soil, which takes water freely, to a hard soil which water penetrates very slowly. The several grades of soil lie in strata and the soil in each locality is determined by the strata which are at the surface. The hard soil is a clay or "adobe," which is very adhesive when wet. It is found principally in certain places in the central portions of the valley. The class of soil which predominates in the valley is a fine silt loam which packs closely and is of medium hardness. As the borders of the valley are approached the soil becomes in general more sandy. It is a loose mixture of fine silt and sand and absorbs water very rapidly. The yet undeveloped portions of the valley contain much of this excellent soil. At the extreme north end of the valley the soil becomes quite gravelly.

Much of the surface of the valley is dotted with sand dunes or hummocks varying in height from 2 to 20 feet. Naturally the largest hummocks are found where the soil is loosest. The hummocks support the desert plant life, mesquit, sage, and creosote bush. The hummocks are composed of drift sand and gradually shift in the direction of the prevailing winds. These hummocks when leveled down make an admirable soil for irrigation, and the largest hummocks and most luxuriant vegetation are indications of the best soil.

The soil contains some salts but they are not harmful except in limited localities. The salts are principally in the streaks of hard soil, but in few places only has there been any harmful effects on the crops grown. Some of the very hard soil where alkali was most apparent is producing excellent alfalfa.

CLIMATE.

The climate of this section is one of great heat and dryness and the summers are long. On account of the very low humidity and the moderate winds which blow much of the time in the hot weather, the sensible temperature as indicated by the wet bulb, which gives a more correct idea of the degree of heat felt by the human body, is much less than the actual. It is probably safe to assert that a person feels a temperature of 110° in Imperial Valley no more than a temperature of 95° in Los Angeles or of 85° in the more humid sections of the Eastern States. The nights are comfortably cool.

Meteorological observations have been made by the U. S. Weather Bureau at Imperial for five years, and at Calexico for two years. Temperatures as high as 125° have been recorded on one or two occasions, but the maximum for the last year was only 116° at Imperial, in July, and 112° at Calexico, in August. The winters are mild and exceptionally fine. The minimum temperature for the past year was 24° at Imperial, and 32° at Calexico, both being in January. The temperature rarely falls below the freezing point. The following table gives the maximum, minimum, and mean temperatures at Imperial and Calexico for 1906:

Temperature records at Imperial and Calexico, Cal., 1906.

Month.	Imperial.			Calexico.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
	°F.	°F.	°F.	°F.	°F.	°F.
January	96	24	53.6	75	32	52.9
February	88	38	62.4	81	46	61.4
March	103	36	63.8	84	41	63.
April	106	37	69.2	94	48	68.6
May	107	50	73.8	97	54	73.9
June	113	54	83.2	109	58	83.2
July	116	62	91.4	109	70	91.3
August	115	65	91.6	112	68	88.5
September	110	55	81.4	102	58	82.2
October	111	36	73.6	105	42	73.3
November	98	28	60.8	90	32	59.9
December	81	27	53.6	73	34	53.6
Mean average for year			71.5			71.0

The prevailing winds are from the west or southeast. They are usually moderate, but at times in the spring and early summer winds from the west attain such a high velocity that they become dust storms. These are disagreeable but last only a few days.

The precipitation is small and varies greatly from year to year, as it does in all very arid countries. The average annual rainfall for five years at Imperial is 4.45 inches, but no doubt if the period of observations were extended over a greater number of years the average would be smaller. The following table gives the monthly precipitation at Imperial and Calexico for the time during which observations have been made:

Precipitation at Imperial and Calexico, Cal.

Month.	Imperial.					Calexico.	
	1902.	1903.	1904.	1905.	1906.	1905.	1906.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	0.75	0.00	0.00	1.50	Trace.	1.50	0.00
February	.00	.06	.05	6.12	2.50	3.76	1.35
March	.30	.03	Trace.	1.05	.35	.91	.49
April	.00	.00	.05	.15	.25	.50	.29
May	.00	.00	Trace.	.00	.10	.00	.00
June	Trace.	Trace.	.00	.00	.00	.00	.00
July	.55	Trace.	.45	.07	Trace.	.03	Trace.
August	.00	Trace.	.48	Trace.	1.92	.00	.45
September	Trace.	.25	.03	.04	Trace.	.13	.00
October	.00	.00	.00	.00	.00	.00	.13
November	.13	.00	.00	83	.50	1.96	.19
December	1.75	.00	.25	.30	1.46	.54	1.31
Total	3.48	.34	1.31	10.06	7.08	9.33	4.21
	Average for five years=4.45					Average for two years=6.77	

It will be seen from the foregoing table that the rainfall at Imperial has been much greater for the last two years than it was for the three previous years. The average for 1902, 1903, and 1904 is only 1.71 inches, while the average for 1905 and 1906 is 8.57 inches. The amount of rainfall at Calexico for 1905 was nearly equal to that of Imperial, but in 1906 only 4.21 inches of rain fell at Calexico, while Imperial received 7.08 inches. This indicates the local character of showers.

Many people believe that the formation of Salton Sea which has been in progress for the past two years accounts for the comparatively large rainfall for the period. They think that a change of climate has taken place over the entire Southwest, which will be permanent and become even more accentuated in the future if the Salton Sea is maintained. While an examination of the records without further consideration may appear to warrant such a conclusion in regard to the rainfall in the valley, it is very uncertain yet that there has been any lasting change. Climatic conditions in desert localities are often very erratic, and it is more probable that the difference in rainfall has been due to other causes entirely. In any event, the observations have not covered a period of time long enough to establish this theory. Entire southern California is now having a series of wet years. The sea is a large body of water on Colorado Desert, but insignificant when compared with the vast arid country of the Southwest.

The evaporation of water is very rapid in this desert region. Mr. Peck has conducted measurements of evaporation from a tank in Calexico. The following table gives the monthly depth of evaporation for 1904, 1905, and 1906:

Evaporation from a water surface at Calexico, Cal.

Month.	1904.	1905.	1906.	Month.	1904.	1905.	1906.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
January	4.39	2.72	2.51	August	10.98	8.52	8.47
February	6.32	1.47	2.43	September	8.61	7.83	6.73
March	8.86	4.44	5.06	October	8.78	6.77	5.45
April	9.55	4.74	5.99	November	5.40	3.23	3.61
May	10.91	8.38	6.84	December	3.48	3.43	2.40
June	13.89	12.86	7.41				
July	12.47	10.43	6.76	Total	103.64	75.09	63.66

The annual evaporation is shown to be about 6.73 feet. If the rate of evaporation from Salton Sea were the same, it might be expected that if not replenished the sea would entirely evaporate in twelve years, but it is not probable that the rate of evaporation from such a large body of water is so high.

IMPORTANCE OF IRRIGATION.

The absolute necessity of irrigation in Imperial Valley is obvious. Until the reclamation was undertaken no man dared make the desert his place of habitation. In 1906, six years after the canals were begun, there were 130,000 acres under actual cultivation and water rights have been purchased for over 200,000 acres. Improvements and extensions are now beginning to take form which will make it possible to extend the cultivated area to over 300,000 acres and there are 400,000 acres of irrigable land in the valley that ultimately will be under cultivation. Unlike the rest of southern California and most irrigated districts in the arid West, the extent of agriculture in Imperial Valley will be limited by the amount of land irrigable rather than by the amount of water available for irrigation, for when the entire 400,000 acres in the valley is irrigated this will require the annual use of not exceeding 1,200,000 acre-feet of water (2 acre-feet per acre being the amount now used in the valley, and 3 acre-feet being sufficient with a large proportion of alfalfa), while the minimum annual discharge of Colorado River has been shown to be over 5,000,000 acre-feet. If we may expect that eventually 40 acres will be the size of a farm in the valley there will be on complete development 10,000 farms, and if each supports a family of five the rural population alone will be 50,000. The valley should have a town population one-half as large as the rural.

CONSTRUCTION OF IMPERIAL IRRIGATION SYSTEM.

For many years before work was begun on the construction of a canal system to irrigate the lands of Imperial Valley the reclamation of the desert had been considered by various promoters. It was regarded as an undertaking that might give the most gratifying results, but one of such magnitude and entailing such great risks that capitalists were unwilling to take it up. A company was formed and complete surveys were made about 1893 to bring water from Colorado River to the desert. This scheme failed, but the surveys were purchased and eventually turned over to a development company.

Two plans for diverting water from Colorado River were considered. One was to make the intake of the canal at a point known as Potholes (now Laguna), 14 miles above Yuma and 22 miles above the international boundary. The other was to make it at Hanlon, just above the boundary where Pilot Knob Mountain extends to the river. Surveys were made from both points, and the site at Hanlon was decided upon. Had the intake been made at Potholes it would have required the construction and maintenance of about twenty additional miles of main canal. The U. S. Reclamation Service has since utilized the site at Potholes for its Laguna dam to divert water for lands along the Colorado near Yuma. The company found that to bring water from the Colorado River into the Imperial Valley and keep the canal entirely within the United States would require a tunnel 15 miles long through the range of sand hills which extends in a southeasterly direction from the mountains at the north and terminates in Mexico only a few miles below the line. Such a tunnel would have cost several million dollars and was beyond the means of the company, while the physical obstacles could be overcome at a much lower cost by leading the canal across the boundary line in Mexico, which gave it the ownership of the land on which the canal was constructed. A concession was granted by the Government of Mexico allowing the company to carry water through that country provided a portion of the water diverted from the river was used for the irrigation of lands in Mexico.

APPROPRIATION OF WATER.

The appropriation of water from Colorado River was made according to the laws of California, April 25, 1899, when a notice was posted claiming 10,000 cubic feet per second to be diverted from the west bank of the river about 1¾ miles above the Mexican line. The amount of this claim is greater than the minimum flow of the Colorado, but when made it was thought that the amount of irrigable land in Imperial Valley and Mexico was much greater than it was later found to be. With 130,000 acres under cultivation at the present time the maximum use of water has been 930 cubic feet per second. On this basis, with the irrigation of the probably ultimate area of 600,000 acres, of which 200,000 acres are in New Mexico, the diversion from the river will not exceed 4,300 cubic feet per second at any one time. The minimum discharge of the river is about 2,500 cubic feet per second, but this occurs in January, while the maximum use of water occurs in April. With an increase in the proportion of alfalfa the use of water will be greater, but it will also bring the maximum use at a later time in the season when there is plenty of water in the river.

The Colorado has been held by the War Department to be a navigable stream, and any diversion of its waters that would interfere with navigation might be held to be unlawful. In 1903 formal application was made to the War Department for permission to divert water, but the reply was that the Department was not authorized to approve work already completed, but the company was informed that its operations would not be interfered with so long as navigation was not affected.

The company in 1904 sought action by Congress to confirm its appropriation of water. A bill was introduced to declare the waters of the Colorado more valuable for irrigation than for navigation, but it failed of passage. The Mexican Company secured a concession to divert water from the river below the boundary line.

Construction was begun in the fall of 1900. A canal 14 miles long was excavated from the point of diversion to a point in Mexico where it entered the natural channel of Alamo River. The Alamo channel was utilized as the canal from this point for a distance of 40 miles to a point about 1 mile south of the boundary known as Sharp's Heading. At Sharp's Heading the Alamo waste gate was constructed to allow any water reaching this point not needed to pass down the river to Salton Sea. The remainder is forced into the main canals for the several portions of Imperial Valley. The Holt Canal branches off to the north about a mile above the waste gate and originally supplied only district No. 7, but it now supplies district No. 5 also. The waste gate when first constructed was used to allow enough water to pass for district No. 5, it being diverted from the river channel into a main canal by a dam near Holtville, but the dam has now been destroyed and the structure is used entirely as a waste gate.

The largest branch of the system leaves the main canal just above the waste gate and runs to the west before crossing the international boundary into Imperial Valley. This canal is the main for districts 1 and 4 and until 1906 supplied district No. 8 also. What is known as Sharp's gate is placed across this canal a short distance from the waste gate to control the amount of water in this branch of the system. The main canal for district No. 6 was led southwest to New River, which is crossed by flume, thence to the northwest to the boundary line.

Both Alamo waste gate and Sharp's gate are timber structures. The waste gate has a width of 80 feet and the water passing through it drops on an incline. A wooden headgate 70 feet in width, known as the Chaffey gate, was placed at the intake on Colorado River, but in the rush to get it finished it was not placed as low as was intended, and later, when the river fell to a lower stage, it was found that it did not admit a sufficient amount of water and it was abandoned. Subsequent intakes constructed on the river are described in the latter part of this report.

The canal company did not own the lands in Imperial Valley. With the exception of each alternate section along the Southern Pacific Railroad at the north end of the valley belonging to the railroad by virtue of its land grant and a few sections of State school land it was all public land. Title to the public land could be secured under either the homestead act or the desert land act, but as the former requires residence for five years the latter was more applicable. One of the requirements of the desert land act is that the settlers have perpetual rights to water, and the company was in a position to sell them such rights.

It was not the purpose of the company to distribute water among the individual settlers in Imperial Valley. It proposed to deliver the water to the settlers through the main canal and its branches and let the settlers at their own expense cooperate in the division of the water through the network of small ditches to the individual owners.

MUTUAL WATER COMPANIES.

For the purpose of securing a supply of water from the American company or the Mexican company and for the maintenance of their distributing ditches at cost the settlers were organized into cooperative companies, known as mutual water companies. Owing to the topography of the valley, the magnitude of the system, and the impossibility of the entire area being settled at the very beginning, it was not practicable to operate the ditches as one system. As each section of the valley became settled the several mutual water companies were organized and their districts laid out according to topographical boundaries. Water was first supplied to the middle portion of the valley between New and Alamo rivers, and this was organized as Imperial Water Company No. 1. Imperial Water companies Nos. 4, 5, 6, 7, and 8 were soon organized and all were in operation within three years of the time when water was first brought into the valley. Imperial Water companies Nos. 2 and 3 were chartered and organized, but they did not proceed to secure a water supply and their distributing systems have not yet been constructed. The proposed district No. 2 is now being added to the district of Imperial Water Company No. 4. Imperial Water Company No. 9 has just been organized, and it is proposed to proceed at once with the development of its territory.

WATER STOCK.

When a mutual company is organized its ditch system is constructed by the canal company and turned over to the mutual company, and becomes its property on completion. In consideration of the canal company constructing the ditches, it is given the right by contract to sell the stock and retain the money received therefrom. The purchase of the stock by the settlers then repays the cost of the system. There is one share of stock for each acre of irrigable land in the district of the mutual company, so that the cost of one share of stock is determined by the cost per acre of the distributing system.

The ditches were to be so constructed as to convey water to a point on each subdivision of 160 acres of the irrigable land, from which it is practicable to irrigate the same, except where one shareholder owned a greater number of acres which could be irrigated from one ditch, in which case the water was to be conveyed to the proper point for his entire tract. The capacity of the system was to be such that each acre of land could be provided with ⅔ acre-foot of water per month.

The canal company proposed to furnish water only to the mutual companies, but it sells stock directly to individuals. Each share of stock carries with it a perpetual right to water for one acre. Stock has been sold or issued to others than landowners and some of it is unplaced or floating. Each landowner must purchase one share of stock for each acre he proposes to irrigate, but the water is not appurtenant to the land. Some landowners have purchased shares of extra stock given to the water companies for damages. The water companies sell stock on which the assessments go delinquent, and at the last sale of delinquent stock the selling price at public auction was from $16 to $20 per share. The price of stock varies slightly in the several companies when purchased in the regular manner. It is influenced somewhat by the number of shares of stock unsold and by the amount of damage stock for sale. Unlocated stock is most rare in Imperial Water Company No. 4, and there nothing can now be had for less than $25 per share.

The expenses for operation and maintenance of the mutual water companies are met by assessments levied on the stock and paid in two semiannual installments. All issued stock, whether located or not, is assessable. The assessment has been about 50 cents per share per annum. The expense of maintenance is chiefly for canal cleaning, while the salaries of the officers and zanjeros are large items in the expense of operation.

The stockholders of the companies elect their own directors annually and stock may be voted by proxy. There are five directors and they elect one of their number president. The board of directors selects a secretary, a superintendent, and their assistants. The superintendent has entire charge of the distribution of water and the maintenance of canals and ditches.

WATER DISTRIBUTION AND DELIVERY.

At the organization of the mutual companies little was known about the amount of water that would be required to produce crops in the valley, but certain assumptions had to be made in the contracts. The contracts between the mutual companies and the canal company require that water not to exceed 4 acre-feet per annum for each outstanding share of stock be delivered on demand of the mutual company and the mutual company is required to order and pay for not less than 1 acre-foot per annum for each share of outstanding stock. The price is fixed by contract at 50 cents per acre-foot. The amount of water paid for by a mutual company is measured at the designated point or points of delivery on the main canals at or near where they enter its district.

Originally the loss by seepage and evaporation was not considered. Later the amount delivered was 2 per cent greater than that ordered by the mutual company, to allow for the loss by seepage and evaporation between the point of delivery and the lands to be irrigated. It was found that this was too low and the canal company and the Mexican company agreed to allow for a loss of 10 per cent, until the the loss could be carefully determined by measurement. The canal company held that the silting up of the canals would soon reduce the loss to a very small amount. In 1903 Mr. Roadhouse measured the loss by seepage and evaporation on nine of the main laterals of Imperial Water Company No. 1, and the results vary from a minimum of 0.8 per cent per mile to 5.9 per cent per mile. The average loss for all the laterals was 2.74 per cent per mile.

The charge of 50 cents per acre-foot delivered to a mutual company's canal is eventually paid by its stockholders. The stockholder must pay for 1 acre-foot per share per annum whether he uses it or not, and since he must have a share for each acre he irrigates, revenue from the sale of water is insured to the canal company. At present 208,282 shares are sold in all the mutual companies. If only the minimum charge is paid on this stock it will result in an annual income of over $100,000. The minimum charge is not being collected from Imperial Water Companies Nos. 6 and 8 while they are without water. The amount paid by the other companies exceeds the minimum charge. The stockholder is not limited to the maximum of 4 acre-feet per year. Any amount can be purchased provided the total of 4 acre-feet per share of the mutual company is not exceeded. It was assumed in the absence of any data that 4 acre-feet per acre per year was sufficient water for alfalfa or any of the other crops to be grown.

Assuming 3 acre-feet per acre to be the average amount of water required in one year, at the rate of 50 cents per acre-foot the stockholder must pay $1.50 per acre as a rental. To this must be added the annual assessment on a share of stock, which may be taken at 50 cents. Finally, the interest on his investment in stock must be included. On a valuation of $20 per share, at 6 per cent per annum, this is $1.20. The total cost of water then is only $3.20 per acre per year. The greater part of the stock now sold does not represent an investment of $20 per share, although the price of stock is apt to advance above that in the future. If the maximum amount of water is used its cost will be $3.70 per acre per annum, and if the minimum of 1 acre-foot can be made to suffice its cost is reduced to $2.20 per acre per annum.

Great freedom is given the stockholder of a mutual water company in ordering water, and he is usually able to use water at such times and in such amounts as suits his convenience. With one or two restrictions, water is delivered on application within a reasonable time after the application has been made, for the period and rate specified in the application. The rate must not exceed the carrying capacity of the distributing ditch, and prior to 1906 nothing less than 1 cubic foot per second would be delivered. Some of the companies have now amended their rules so that there is no minimum rate of delivery, but no delivery will be made for a smaller charge than 25 cents. Water will not be delivered for a period shorter than 24 hours, except in Imperial Water companies Nos. 6 and 7. The company reserves the right to deliver the water one day sooner or one day later than that specified in the application. The company is not required to deliver water to any stockholder in excess of 4 acre-feet per acre in one year.

All applications for water in a mutual company are made to the superintendent, and the water is delivered to the applicant under his direction by a zanjero (water-master). The company has as many zanjeros as are necessary, and each is assigned a certain portion of the distributing system. The zanjeros make daily trips over their sections and adjust the gates to distribute the water according to daily instructions from the superintendent or assistant superintendent. The beat of a zanjero is about 25 miles. The superintendent must use care in his instructions for the division of the water in the main canal between the main laterals in order that each zanjero shall have just enough to supply the demands in his section. The rules of the companies are not always strictly enforced in regard to applications for water. In reality, many of the applications are transmitted to the office by telephone, and if it can be done without inconvenience water is delivered to the applicant in less than three days. The company is, however, not responsible in case of failure from any cause to deliver the water without a three days' advance notice. The mutual companies must know in advance about how much water will be needed on any day in order that they may know how much to order from the main canal.

Imperial Water companies Nos. 5 and 7 do not use the written application for water. The orders are given to the zanjeros, who order enough each day to supply the demands on their sections. The user can order water for any number of hours and is not required to pay for it for a full 24 hours or a multiple of 24 hours.

WATER MEASUREMENT.

The unit of measurement of the rate of flow in canals and ditches is the cubic foot per second, while the quantity of water applied to the land is stated in acre-feet. One cubic foot for 24 hours equals 86,400 cubic feet, which so nearly equals 2 acre-feet (87,120 cubic feet) or $1 worth of water at 50 cents per acre-foot, that records kept in cubic feet per second per day and decimals equal dollars and cents for the charge. Reckoned in inches the charge is 2 cents per inch per 24 hours. The water delivered to the mutual companies is measured at the points of delivery by overpour or pressure measurements or by previously rated flumes. The posts in the structures on the large canals interfere with accuracy in measurement, and in the case of an overpour measurement the weir crest given by 2-inch flashboards with battered edges is at wide variance with the theoretically perfect edge to which the weir formula applies. The present measurements are therefore hardly more than approximate, and both the canal company and the mutual companies realize the need of more accurate ones at these very important points. Cement structures of the best class are to be installed at all points of delivery, and recording instruments will be used.

Water delivered by a mutual water company to its shareholders is regulated by a delivery box and gate. The same type of box is used by all the companies. The box or flume is 7 feet long and 3 feet wide inside. The gate is placed near the middle and is adjusted to allow the desired amount of water to pass under it. The wings at both ends extend into the ditch bank at right angles to the box and sheet piling is placed below the floor at both the upper and lower ends. The wings being perpendicular to the direction of the current instead of at diverging angles, a whirl is produced just below the lower end of the box which sometimes washes away the ditch banks. Much of this action of the water would be overcome by making the wings diverge at an obtuse angle.

The boxes constitute the measuring as well as the regulating devices. Instructions are given to zanjeros regarding the method of setting the gates to deliver any amount of water and the methods of recording the measurements. It is considered that the measurements can be made to come under one of three classes, designated as "submerged opening," "opening with free discharge," and "overpour with free discharge." Most of the measurements are made with the submerged opening. In this case the gate is raised slightly and the water passes under it and over a flashboard placed across the bottom of the box. The two ends of the rectangular orifice thus made are formed by the strips on the sides of the box which form grooves for the gate to slide in. This does not give the exact conditions for a submerged orifice for which the tables used in the calculation of discharges were computed, but it is an approximation. The tables used in all the computations of the discharge by the companies are specified in their rules and regulations as those given by a recognized authority on civil engineering. There must be a head over the top of the opening, both above and below the gate.

When there is a head over the top of the opening above the gate only and the surface of the tail water is low enough to allow a free fall of water from the opening, the measurement comes under "opening with free discharge." In this case there is a contraction of the jet at the top and bottom, but the contraction of the jet at the ends of the opening is insufficient and undetermined on account of the strips on the box.

In the overpour with free discharge the condition approaches that of a suppressed weir and the formula for the suppressed weir is the one used. Here again the strips interfere with the proper condition for a weir measurement without end contractions. The flashboards are 1 inch thick and with continual use their corners become rounded so that they often do not give a good bottom contraction to the jet. Two tables are furnished to the zanjeros for their convenience in setting the gates. One of these is for the first two cases and is the table for "pressure" measurements. It contains the discharge in cubic feet per second per square inch of opening for heads which vary by one-half inch. In the submerged opening the effective head is the difference between the heads above and below the gate. The other table is for overpour measurements and contains the discharge in cubic feet per second at various heads for each inch of length of weir. The zanjeros are instructed to set the gates to the nearest one-half inch and no finer division is made. The maximum error in the head is therefore one-fourth inch. In an overpour or suppressed weir measurement with the length of the weir 3 feet and the head one-fourth inch too low, at 6 inches the calculated discharge would be 3.53 cubic feet per second, which would be an error of 0.22 cubic foot per second, or an error of 6 per cent. The zanjeros are required to record the head and dimensions of the opening in a pressure measurement and the head and length of the weir in an overpour measurement. The head over the opening is taken as the head above the center of the opening. While the cubic foot per second is used as the unit of measurement by the companies the rate of flow in the small ditches is more commonly referred to in terms of the miner's inch. The inch used in Imperial Valley is the one-fiftieth part of a cubic foot per second and is not the statute inch of California, which is defined by law as one-fortieth of a cubic foot per second.

While the measurements are not made with a high degree of accuracy, the companies are desirous of making improvement in this respect in the future. The importance of proper measurements should not in any case be overlooked, but it may be said that refined measurements are not so necessary in Imperial Valley as in many districts, on account of the abundant supply of water for all land under cultivation.

IMPERIAL WATER COMPANY NO. 1.

Imperial Water Company No. 1 was incorporated in March, 1900, and is the oldest and largest of the water companies. It embraces a territory of 161,000 acres situated in the center of the valley, and includes all land from the Mexican line between New and Alamo rivers for 19 miles to the north of the line. Of the total area 125,000 acres can be irrigated, and 70,000 are now cultivated. The capital stock consists of 100,000 shares with a par value of $10 each. The office of the company is in Imperial.

The company has 310 miles of main canal and laterals, and in 1906 the area under cultivation was 72,313 acres.

The main canal, which supplies the district, crosses the international boundary at the south and runs to the west across the southern end of the district to a point known as "the five headings," near New River. The five headings is so called because gates are here constructed to divide the water into five ditches, one being the extension of the main canal to the north to supply district No. 4, one being a waste into New River, and the others laterals of No. 1 distributing system. The greater portion of the district is north of the main canal and the greatest slope is to the north.

The points of delivery by the California development company are along the main canal at the heads of the main laterals of the distributing system, except for two of the laterals, which are taken from the main canal in Mexico, on which the points of delivery are at their crossing of the boundary line. The laterals run to the north, and the sublaterals branch out to the east or west, according to the slope. The chief laterals for the middle portion of the district are the Dahlia, the Date, and the Dogwood. Those for the western portion are the Elder and the Eucalyptus. Those for the southeastern portion are the Alamitos and the Ash, and those for the northern portion are the Rose and the Redwood.

The fall along the main laterals from south to north is about 6 feet per mile. The Dahlia, one of these laterals, is typical. It has a length of 12½ miles, a fall of 5 feet per mile, and was constructed with a bottom width of 14 feet, a depth of 3 feet, and slopes of 2 to 1. Its capacity is about 95 cubic feet per second, but its capacity, like that of most of the ditches in the valley, depends to a great extent on its condition. The aggregate capacity of all the main laterals of the company would be about 1,500 cubic feet per second, if they were all clean at one time, but this probably never occurs.

Until the past year silt and aquatic growth have been removed from the ditches largely by hand labor. A small dredge and a large V-crowder have also been used. The work consists in the removal of the tules, which grow not only along the edges of the ditches, but in the bottoms. The tules make a very rank growth and reach a height of from 6 to 10 feet. The depth of the deposit of silt, which depends on the velocity of the water, varies, and in parts of some of the ditches is 18 inches in one year. The main laterals have enough fall to keep them fairly well scoured out; but the smaller ditches, running east and west with less fall, are very troublesome.

The labor employed in ditch cleaning is mostly Cocopah Indians, who are better adapted to this kind of work than any other class of labor that has been tried. They work only in gangs of 10 or 12 and are at home in the water and mud. The price paid is $1.50 per day without board.

The company recently purchased a new dredge for ditch cleaning at a cost of $5,569.21. It has a 25-horsepower gas engine as power, and its bucket is of a new type particularly adapted to work in tule beds. The dredge floats in the ditch, and the greatest problem in its use is the crossing of the ditch structures. This is done by laying skids up to the top of the structure on the approach and the barge is drawn over the top of the structure, its own engine furnishing the propelling power. When working in a ditch with a bottom width of 16 feet the dredge has removed a depth of 2 feet from the bottom of the ditch and about 3 feet from the edges. Some soil was removed below the deposit of silt. The ditches are left with perpendicular sides and this will prevent a portion of the vegetable growth in the future.

The company has also constructed a V, which is the most satisfactory implement yet employed for cleaning ditches. It is yet in an experimental stage. The cost has been about $1,200. It is not large enough for the larger ditches, and a new and improved machine will be built. It is drawn by a traction engine and cleans one side of the ditch at a time. It is of steel and has a vertical plate or nose at the front which is adjusted by the operator to steer the machine. It is drawn around ditch structures without stopping and has an attachment by which the operator makes it ride over the ditch banks at these points instead of cutting through. It is operated with water running in the ditch, and tules do not interfere unless the growth is very dense. The rapidity with which the V does the work should greatly reduce the cost of ditch cleaning.

On some of the ditches the tules have been removed twice each year in the past, but the system as a whole has required cleaning once each year. The total cost of cleaning the ditches of the company, together with the cost of a few structures, was $19,885.19 in 1906 and it was about the same for the two years previous. This is an expense for maintenance of $64.14 per mile for the entire ditch system and about 20 cents per acre for the entire district.

The superintendent's personal attention is devoted principally to the maintenance work, and the particular work of the assistant superintendent is the management of the zanjeros in delivering water. There have been 10 zanjeros, but the number was increased to 12 in 1907. The zanjeros receive $80 to $90 per month with a house furnished. The total expense of zanjero service was $10,926.87 in 1906, making the total expense for services about $17,926.

The semiannual assessments on the stock of the company for 1906 were 12½ cents and 17½ cents, or a total of 30 cents per share for the year. The assessments for previous years varied from 25 to 50 cents. There are about 100,000 shares of issued stock, making the annual revenue from $25,000 to $50,000.

IMPERIAL WATER COMPANY NO. 4.

Imperial Water Company No. 4, with headquarters at Brawley, is organized for a district of 17,500 acres lying between New and Alamo rivers and joining the northern limit of district No. 1. The number of shares of water stock issued is 17,226. In 1906 the area under cultivation was 15,000 acres. The territory of district No. 2 of from 7,000 to 10,000 acres is now being added to district No. 4. This includes the land between New and Alamo rivers and the present northern boundary of No. 4 and the Salton Sea. About 15,160 shares of the stock of the company were sold by the development company at about $6 per share to a party who constructed the distributing system. Stock was purchased by the settlers at from

$12 to $18 per share. The mutual company later took over all the unsold stock and has made many improvements in the distributing system at its own expense.

The distributing system consists of 50 miles of ditches. The extension of the main canal which supplies district No. 1 is known as the Brawley Main, and this brings water to district No. 4. The point of delivery is where the canal meets the boundary of the district at its southwest corner. The main canal from this point runs northeast along the western side of the district and then turns to the east through the middle of the district. The southern portion of the district is supplied by main laterals running east from the main canal and the northern portion by main laterals running north from the canal. The canal will carry from 100 to 150 cubic feet per second, depending on its condition. The ditch system was very cheaply constructed, many of the laterals having been made with merely the plow and V crowder. The larger ditches were constructed with very wide berms and the water in the canals generally covers the berms to a slight depth only. Portions of the district near Brawley are very flat, but the portion bordering on Alamo River has a high slope. The company constructed some new laterals in 1906, extending the system to lands bordering on Alamo River at the northeast of the district. These ditches were made with the banks as straight as it was possible to make them with the scraper.

The cleaning of the ditches has cost the company about $5,000 per annum, or about $100 per mile of ditch, and about 29 cents per acre. Until the past year the work has all been done without machinery. The superintendent of the company has designed a ditch-cleaning machine which has been used for some of the recent work. The machine was made as an experiment and cost about $100. It consists of a timber framework the base of which spans the canal and rests on the banks, a long beam swinging from the top of the frame which carries a bucket at its lower end. The bucket is drawn across the canal from one side to the other by a team of horses and the bucket is returned to its starting point by the man operating the machine. A man is also required to drive the team and another man moves the machine forward, between each sweep of the bucket, a distance equal to the width of the bucket, by means of a windlass with rope and deadman. The bucket used is an old rotary scraper 2 feet in width. The bucket is held down by its own weight and that of the load, which is dumped automatically. In the backward stroke the bucket is held above the canal until the forward stroke is begun. The silt removed is all brought to one side of the canal. The machine has worked well when the tules are cleared away by hand labor ahead of it, but it has not yet given entire satisfaction when tules are encountered. The trouble is to get the bucket to take hold at the beginning of the stroke. Alterations are being made in the construction where they are shown necessary, and if the machine proves to be practical a new one will be constructed. It will be fitted with an engine which will furnish the power to operate the bucket and to propel the machine along the ditch. The company keeps mowers continually at work on the ditch banks to keep down the growth of weeds and it is expected that this will greatly lessen the cost of cleaning the ditches in the future.

The two semiannual assessments for 1906 were 15 and 45 cents per share. About 10 cents per share of this was required to pay off old debts and 50 cents per share per annum is considered enough to meet the current expenses of the company. The total received at 50 cents per share on 17,226 shares of stock issued would be $8,613.

IMPERIAL WATER COMPANY NO. 5.

Imperial Water Company No. 5 was incorporated with 100,000 shares at $10 per share. Its territory lies along the east side of Alamo River and extends from the north end of district No. 7 almost to the railroad at the northern end of Imperial Valley. The office of the company is in Holtville. At present 39,406 shares have been issued and 25,000 acres are in cultivation. The distributing system has been finished for only about 60,000 acres.

Water was originally supplied to No. 5 district by using the Alamo channel below Sharp's heading to a point at the upper end of the district near Holtville, where a diversion dam was constructed at the head of No. 5 main canal. The dam was destroyed by the flood and the cutting out of the Alamo channel and water was then brought to the main canal through an extension of the Holt Canal in district No. 7. Later a main canal was constructed through No. 7 district to supply the district with water.

No. 5 main canal is 20 miles long and forms the eastern boundary of the district. The slope in the district is the best of any district in the valley. From the south to the north it is from 3 to 7 feet per mile, and from the canal on the east to the Alamo on the west it is from 8 to 15 feet per mile. The canal is 60 feet wide on the bottom and will carry 900 cubic feet per second. Most of the main laterals run to the west.

Imperial Water Company No. 5 is the only mutual company having a system of drainage ditches separate from its distributing system. Such a system is not only desirable for draining surplus water, but it is necessary to protect the irrigation ditches from damage by storm water. While the rainfall is very light there have been local downpours which led to disastrous results, on the comparatively high grade in this district. The grade continues to the east beyond the main canal and here lies an undeveloped strip of the desert from 1 to 5 miles in width between the canal and the mesa. When there is a very heavy fall of rain in a short space of time the water flows rapidly toward the west and northwest to Alamo River. If it is caught by the irrigation ditches they are soon filled to overflowing and their banks are broken, causing much damage. Drainage ditches have been constructed throughout a large part of the northern end of the district where the slope is greatest. They are only one-half mile apart in some places and run from east to west and waste into Alamo River. On section lines the drainage ditches are placed on one side of the public roads and the irrigation ditches on the other. The drainage ditches are large and some of them have been made by excavating two small ditches about 10 feet apart and sluicing out the earth between, a practice that can not be recommended. Small drain ditches may be constructed running east and west to feed into the larger ditches later. The ditches wasting into Alamo River may have to be provided with drops to prevent the cutting back of deep channels.

The company has had to spend very little money on ditch cleaning. The slope of its ditches is great enough to prevent the deposit of much silt.

One member of the company's directorate is the secretary and is responsible for the books, but an assistant secretary performs the duties of the secretary and there are five zanjeros. There is some waste from the canal at times but the last zanjero at the north end of the district often has to contend with a short supply of water.

There has been some contention between the north and the south ends of the district over water distribution and other matters and a proposal to divide into two districts has been considered, but has not been fully acted upon. A division is more likely to be made when the distributing system is extended farther to the north, or when a high-line canal is constructed, as proposed, along the mesa on the east to irrigate all land between it and Alamo River. The entire district would then probably be about 40 miles in length by about 8 miles in width.

The annual assessment for maintenance and operation has been 50 cents per share per year. In 1906 the receipts from the two installments were about $19,000. A small portion of the issued stock went delinquent. In 1906 the company paid out $3,518.13 on construction, $5,963.38 on drainage ditches, $4,640.65 on maintenance, and about $10,000 for salaries, aside from the amount paid for water to the development company.

IMPERIAL WATER COMPANY NO. 6.

Imperial Water Company No. 6 has a district of 25,000 acres lying southwest of New River, between the river and Signal Mountain and joining the Mexican line on the south. The office of the company is in Los Angeles. Of its 25,000 shares of stock, 11,000 shares have been issued, and 4,000 acres have been placed under cultivation. Its main canal was partially destroyed by the flood in New River, but water will soon again be supplied by the new canal on the west side of the valley for districts 6, 8, and 9. This canal will leave the main canal or Alamo channel above Sharp's heading in Mexico and after crossing New River by flume will enter the district at the Mexican line where the water will be delivered. The slope in the district is to the northwest. The Wisteria is the main ditch, and has a length of 9 miles within the district and is constructed on a grade of about 2.4 feet per mile.

During the spring and early summer of 1905 a large part of the cultivated area of district No. 6 was inundated by the overflow of New River. When the channel of the river was deepened by erosion the district was drained and some of the land was damaged by the formation of gullies.

IMPERIAL WATER COMPANY NO. 7.

Imperial Water Company No. 7, with headquarters at Holtville, has a territory of 20,000 acres lying east of Alamo River and extending 10 miles to the north from the Mexican line. The area now under cultivation is 10,000 acres. Its water supply is received through the Holt Canal, which leaves the Alamo channel in Mexico above Sharps heading and runs north, crossing the international boundary, where water is delivered. The Holt Canal continues northward through the district. The slope in district No. 7 is to the north and many of the ditches running east and west are almost on a level. The main canal has a length of 13 miles and has a grade of 3.6 feet per mile. It has a capacity of 240 cubic feet per second. There are about 50 miles of ditches. They are cleaned by teams and scrapers and Mexican hand labor.

The distributing system was constructed by a party to whom the development company gave the stock for as many acres as could be covered from a certain heading, for $25,000, the surveys not then being complete. The canal was constructed to cover an original 9,000 acres, making the cost of the stock very low. The system was later extended. The stock has been purchased by the settlers at from $10 to $20 per share. The assessments are 50 cents per annum and 17,150 shares of stock have been sold. The company was organized in October, 1902.

IMPERIAL WATER COMPANY NO. 8.

Imperial Water Company No. 8 was organized in December, 1902, for 40,000 acres of land west of New River and between Superstition Mountain and Salton Sea. The company's office is in Brawley. The stock of the company consists of 40,000 shares at a par value of $25. The company was bonded by the promoters for an amount equal to $20 per acre. The development company contracted the construction of the distributing system to another company which received in all $10 per share or acre, $2 per share being for locating or selling the stock. The stock and bonds of the water company were turned over to the development company for the distributing system. The settlers then procured their water stock by the purchase of bonds, there being one bond for each acre. It was customary on issuing stock to require a payment of $1 per share, when the settler would be given bonds equivalent to this amount. The bonds then owned by the stockholder were a liability of the water company. The bonds drew interest at 6 per cent, payable semiannually, and the principal was payable in twenty annual installments of $1 each, beginning in 1908. The bonds mortgaged all the assets of the company.

In 1906 about 27,000 shares of stock had been issued but the assessments on about 17,000 shares had been allowed to go delinquent. The company as a whole being responsible for the interest on bonds, only about 10,000 shares were left to carry the total expense. This was impossible and a new contract has been arranged by which each stockholder may pay his proportion of the bonded indebtedness by giving his note secured by a mortgage. The new arrangement requires annual payments of $2 per share for 10 years, beginning in 1910 and the interest at 6 per cent. Stockholders who are delinquent are given opportunity to redeem their stock. The remaining unissued stock will be held at $25 per share. Of this $5 per share will go to the water company.

The district was supplied with water by a canal branching off from the Brawley main and crossing New River by a 6-foot flume at the southeast corner of the district. From here the distributing system diverges, the main lateral being the Tamarack. The greatest slope is toward the north and the main canal runs north through the district. The canal has a fall of from 2 to 14 feet per mile. It is 32 feet wide on the bottom, 5 feet deep, slopes 2 to 1, and will carry 400 cubic feet per second.

The ditches are cleaned by teams and scrapers and by hand grubbing to remove aquatic vegetation. The main canals keep clean when the vegetation is kept out. The president of the company is also its superintendent or manager.

The annual assessment on the stock of the company has been from $1.40 to $1.70 per share, which included the interest on the bonds at $1.20 per share.

Operations in the district were interfered with by the flood in New River in 1906. The erosion of the river channel destroyed the flume in the main canal supplying the district, and water for irrigation was cut off in May. The new canal now being begun for the districts west of New River will again supply the district with water. Twelve thousand acres have been under cultivation.

IMPERIAL WATER COMPANY NO. 9.

Imperial Water Company No. 9 is newly organized to irrigate about 35,000 acres lying west of New River and between the districts of Imperial Water Company Nos. 6 and 8. There is a possibility of it becoming an addition to Imperial Water Company No. 6. The company has obtained a charter and application will be made to the development company for a supply of water for irrigation. Water will be supplied through the new canal on the west side of New River.

PREPARING LAND FOR IRRIGATION.

There is very little land in Imperial Valley which does not require some preparation before it can be irrigated properly. The land in its original state is a plane surface tilted slightly, dotted with mounds, and covered with more or less brush, most of which is on the mounds. The mounds are sand dunes, or hummocks, varying in size from 2 to 20 feet in height and 5 to 100 feet through the base. The brush is principally cresote-bush, sage, and mesquite. Creosote-bush, commonly but improperly called greasewood in the valley, grows chiefly on the hummocks, and it is usually an indication of excellent soil. It is a large bush growing to a height of from 5 to 10 feet and has the texture of wood. Mesquite trees grow either on the tops of high hummocks or along little channels which carry water when it rains. Their presence is an indication of some moisture in the soil at considerable depth. Sagebrush is common and is the cause of the hummocks, as the sand drifts around it. Arrowweed, now found along the canals, did not grow before the canals were built except along the rivers where there was some ground water. Here and there smooth patches are found without either hummocks or vegetation. These are places where the hard strata appear on the surface, which neither drift nor retain moisture long enough to support plants.

REMOVING BRUSH.

The first process in the preparation of the land is the removal of the brush. Mesquite trees, which have large trunks of very hard wood, and the larger creosote must be chopped and grubbed out by hand, but the sage and all the smaller brush is removed by team work. A long, heavy timber or log is some times drawn over the ground to break off the brush, a team being hitched to each end, but the railroad iron is more effective. A railroad rail is bent in the shape of a "V," or with as sharp a bend as it is practical to make. A team of four horses is hitched to each end, and the rail is dragged over the ground, lying in the same position as it would in a railroad track. The brush is broken off or torn out by the roots and drawn up into large piles where it can be burned without drying. Two men—a driver for each team—are required.

LEVELING.

After the removal of the brush the next process is known as leveling, but it is really smoothing, for the original slope of the land is maintained and is very desirable for irrigation. Hummocks of over 3 feet in height are torn down by scrapers and the earth is distributed over the flat portions of the fields. The scrapers used are 4 feet wide and require four horses. One man does both the driving and the dumping.

The smaller hummocks are more economically removed with a leveler, known as the "smoother" or the "float." In its simplest form

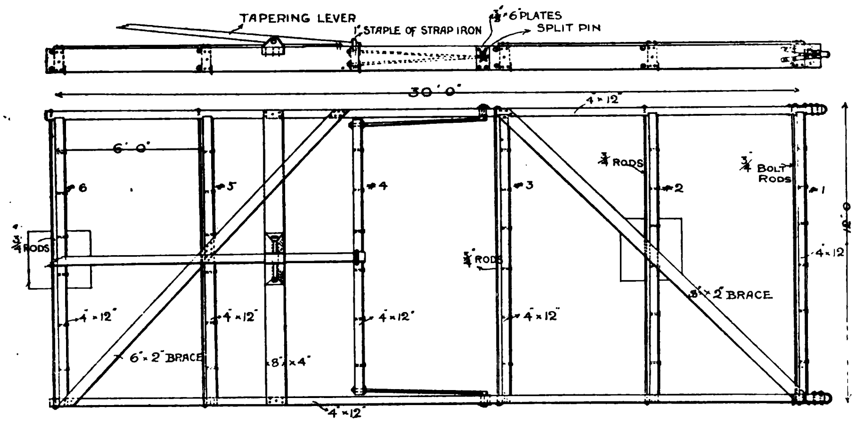


FIG. 1.—Rectangular leveler.

this implement is merely a rectangular frame 8 by 24 feet, made of 2 by 12 inch boards. Two of the boards 24 feet long are placed on edge 8 feet apart, like the runners of a sled. These are then connected by five crosspieces or scrapers on edge and equally spaced. The frame is then strengthened by a few diagonal braces. The team is hitched to one end, and as the leveler is drawn over the land the crosspieces shave off the high points and distribute the earth in the low places, each piece cutting the hummock down a little lower than the preceding one. A more pretentious leveler is made slightly larger, 12 by 30 feet, of 4 by 12 inch timbers. It has six cross scrapers instead of five, and they are shod with ⅜-inch steel plates on their wearing faces. The fourth scraper from the front is made adjustable, and can be lowered by a lever so that it cuts deeper than the others. This is used where there is a hard place in the ground, for more than half the weight of the leveler can be thrown on this one scraper. Sixteen horses are used, and two men are needed—one on the front to drive and one on the rear to operate the lever. (Fig. 1.)

For slightly uneven ground or for finishing the land after the hummocks have been removed the planer or brush blade is brought into use. It may be used to remove brush and small hummocks in one operation. This implement has a cutting edge 14 or 16 feet long, and is drawn by a team of 4 horses hitched to each end. It has a base of timber 4 by 12 inches, as long as the implement and lying flat on the ground. This is beveled on the top of the front edge and forms the blade. A back 2 by 18 inches and 1 foot shorter than the blades at each end is placed on edge behind and against the blades. The sole of the blade is shod with a steel plate, which is bent over the corner at the heel so that it serves to hold the two pieces of timber together. The back is braced by several straps of iron, leading from its top to the toe of the blade. At each end a 1 by 12 by 36 inch board is bolted at right angles across the end of the blade where it extends beyond the back so that one foot of it projects forward from the edge of the blade and one foot projects to the rear of the heel. In using the implement the two drivers stand on these boards and as a mound is approached they step to the front of the boards, thereby

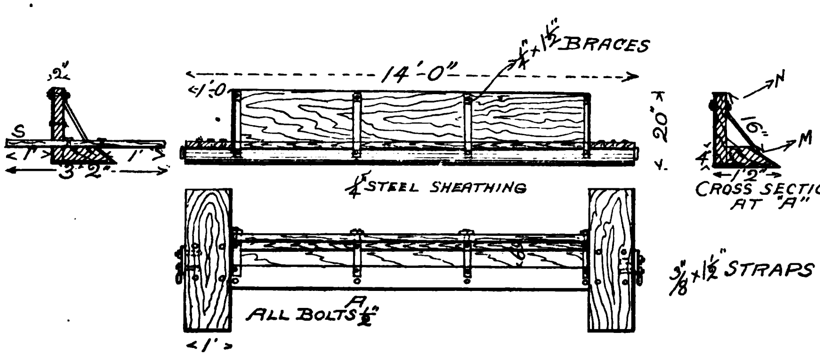


FIG. 2.—Modified buck scraper (planer).

raising the heel of the blade and causing it to cut in deeper. The earth sliced off piles on top of the blade and against the back. To stop the cutting and to distribute the earth the drivers step to the rear of the short bends, thereby raising the edge of the blade, and the earth falls away from the blade and is strewn over the ground. (Fig. 2.)

BORDERING.

After the land has been smoothed, borders must be made to hold the water in flooding. Practically all the new land in the valley is irrigated by flooding at first. The borders are little levees surrounding the fields and passing through them either on contours or in straight lines, dividing them into compartments. Borders are made from 12 to 18 inches in height, about 2 feet wide on top and from 6 to 8 feet wide at the base. The borders are made with the ridger, the scraper, the V, the reversible disk harrow, or the wing plow. The wing plow may be used for small borders, but it makes them too narrow to stand the wear of having machinery hauled over them. The reversible disk harrow may be set to crowd the earth from both ends toward the middle. The best border can be made with the scraper, but this is the most expensive method. The earth for the border may be collected in such a way as to leave no depressions or ditches along the borders for water to stand in. An economical method for making a strong border is by the use of the plow and the ridger. The ridger is constructed by placing two 2 by 16 inch boards 12 feet long on edge, 12½ feet apart at the front and 3½ feet apart at the rear. These are connected and held in position by three beams of 4 by 4 inch timber across the top, fastened and braced to 4 by 4 inch posts on the outside of the boards or runners. The implement is drawn from the wide end by 16 horses and the loose earth along a strip of ground that has already been plowed is gathered in between the runners at the front and forced to pass through the narrow space at the rear, leaving it in a ridge. The runners are faced with steel plates on the inside along their lower edges. These are ⅜ inch thick and 6 inches wide. The front ends of the runners are also protected with iron plates through which a series of holes at different heights are made for attaching the chain bar to which the team is hitched. To make the ridger work deep in the soil the draft is raised. Sometimes in making an outside border it is best to take most of the earth from the outside in order to leave as small a depression or ditch as possible on the inside. To do this the draft is placed near the middle of the runner on the inside and near the top on the outside, which causes the outside runner to cut deeper and crowd up the most earth. Work done with the ridger is continuous, which accounts for its cheapness. The location of contours is determined by a surveyor's level. Borders should be made with a wide base so they will not be damaged by farm machinery.

DITCHING.

There is usually a head ditch if not other field ditches to be made before water can be brought to the land. Small ditches have been made with the plow and a crowder. This implement is probably too well known to need description. It consists merely of two 3 by 18 inch boards placed on edge and meeting at an angle of about 30 degrees at one end. At the other end they are held apart by a strut of 2 by 8 inch board. This piece is not so wide as the two sides so that it will not scrape the ground. This implement is commonly called a V, but it more nearly resembles an A. The team is then hitched to the point and the implement is drawn along a strip that has been loosened by the plow. The earth is crowded to both sides and if necessary the bottom may again be plowed and the operation repeated. This is a cheap method of construction for small laterals, but it makes a poor lateral.

Most of the ditches are made with a scraper. Head ditches are usually intended to have dimensions as follows: Bottom width, 6 feet; depth below the surface, 6 to 10 inches; height of banks, 2 feet; slopes of ditch, 2 to 1; and outer slopes of banks, 1 to 1. This makes the ditch 14 feet wide at the top, and it, together with its banks, occupies a space 21 feet wide. In constructing a ditch of this size a strip 6 feet wide on the ditch line is plowed to a depth of 6 inches. On each side of this another strip 6 feet wide is plowed parallel to it, leaving a strip of unplowed ground 8 feet wide between. The ditch is then crossed back and forth with the scraper to draw the earth from the plowed strips up into banks on the intermediate unplowed strips. Each time the ditch is crossed the scraper is loaded and dumped twice, which makes the process very effective. The first load is taken from the first plowed strips and left on the first bank and the second load is taken from the middle plowed strip forming the ditch bottom and left on the second bank. It is obvious that two loads are taken from the middle and one from each of the two sides. This results in a finish necessary to the slopes of the ditch but not required on the outer slopes of the banks.

COST OF PREPARING LAND.

Nearly all the leveling of land in Imperial Valley is now done by contractors. They and their parties gain great proficiency with the implements used. Each party contains four or five men and they have a full equipment of implements with about 25 horses. When farmers prepare their own land they use the simple form of leveler first described, and often use a log for breaking brush rather than the railroad iron. As the planer requires some ironwork in its construction they usually dispense with its use. If the settler has time at his disposal and can provide the necessary teams he can no doubt save money by leveling his own land, but in many cases it is cheaper to have a contractor do the work.

The cost of preparing land in Imperial Valley varies greatly. When the work is done by a contractor the ditching and bordering are usually included. The price for these alone is $3 per acre. The amount to be added to this depends on the amount and size of the brush to be removed, the size and number of hummocks, and the additional leveling after the hummocks are removed. The last is often the most costly operation. The land may be free from hummocks and brush and yet require much work. The total cost is usually from $5 to $20 per acre. Contractors state that some land has been prepared at a cost of $40 per acre, but this land was nearly covered with very large hummocks and the brush was large. Such land is usually of the very finest quality, and the sand of the hummocks when spread over the surface gives a top layer of soil which is very loose and easily irrigated. The preparation of the land on one farm in Imperial Water Company No. 7 district cost $45 per acre. The preparation of such land requires plenty of capital to begin with, but if the owner has it at his command the excellent quality of the land well repays him for his initial expense. Sometimes contractors are paid by the time required for the work, the price in such case being $6.50 per day for one man and a double team. The cost is about the same, whether the work is done by contract or by the day.

There has been practically no flooding prior to planting to leach out salts. Some of the soil would be difficult to leach, but it is probable that some of the salty streaks can be reclaimed. In leaching, the water passes down into the soil carrying with it the salts in solution and they are drained away to the lower strata or entirely out of the soil with the drainage of the country. If pools of water are left to evaporate slowly they are injurious to plant life. If the land be carefully prepared any surplus can be easily drained off at the lower end of the field. It pays to carefully level the land. Sometimes new land settles unevenly on being irrigated and for this reason it is often leveled only roughly at first and then gone over again and finished after the first irrigation.

USE OF WATER.

The methods of applying water in Imperial Valley are flooding for the field crops and furrows for melons, vegetables, and fruit. Most new land is first planted to barley, but sometimes to alfalfa. Often after two or three years barley land is planted to alfalfa or to crops requiring furrow irrigation. Until the past year there was considerable Kafir and Egyptian corn, but very little is now being grown. Land that is at once planted to alfalfa is of the more sandy type. Hard and medium soils are greatly improved by the growing of barley for a year or two, as the irrigation of the barley loosens the hard soil and crops can afterwards be grown to which it was not adapted at first.

Land is flooded in compartments known as lands and separated by either contour or straight borders. In the former the borders, which are little levees, are constructed on contour lines and the borders themselves are known as contours. This divides the field into plats, usually strips of irregular shape, in which there is a fall of 3 or 4 inches. In the straight border system the field is divided into rectangular strips regardless of the fall. In appearance it resembles to some extent the rectangular check system as practiced elsewhere in California, but it is essentially different as regards the method of applying the water. In the check system the compartments are leveled and the water stands temporarily at a shallow and uniform depth over the entire compartment. In the straight border system the natural fall of the land is but little disturbed and the water used in flooding has a slow passage across this slope. As regards the action of the water the border system is more like the flooding from contour ditches practiced in the Rocky Mountain States. Neither are the compartments entirely leveled in the contour system and it differs from the contour check system used in northern California in this respect.

CONTOUR SYSTEM.

The surveyor's level is used to determine the location of contours. Home-made levels are not much used for this purpose. The level is set to command the entire field, if it is not too large. By rod readings the elevation of all parts of the field can be found. Care must be taken in all rod readings that the particular spot on which the rod rests is of average elevation for the immediately surrounding ground surface. The stakes should not be so far apart that those of one border may be confused with those of another. The line for the border may be traced by a furrow in such a way that there are no sharp angles.

Unless the field is small or the fall of the land very slight, the lands made by the contours are usually long, narrow, and crooked. They are sometimes divided by the supply ditches, which run through the center of the fields, crossing the borders, but more often the supply ditch is at one end of the field. The lands contain from 2 to 20 acres. Unless the field is very large the only ditch is the head ditch running along the high side of the field. The water is turned into the high lands and each successive lower land is flooded by water turned in from the one above it or from the supply ditch. The earth for a border is taken from the upper side of the land below it, so that the lands have their slopes slightly reduced, but not enough to make them level.

In the north end of district No. 5 a modification of the contour system is used. The supply ditch runs down the greatest slope through the center of the field and crosses all the borders. The supply ditch is entirely in excavation and has no banks above the surface. The borders are constructed with a deviation of 1 inch from the exact contour in such a manner that the lowest point in each land is at the crossing of the supply ditch with its lower border. This leads the water used in flooding to the ditch, where it is readily drained to the next lower land by opening the gate. The water floods the land by overflowing the supply ditch. This system has given satisfaction, except in one point. Silt is deposited at the low point in each land near the border gate. The gate in the ditch at each border is set to raise the water to a certain height in the land above.

STRAIGHT BORDER SYSTEM.

The laying out of a field for irrigation with straight borders requires no preliminary survey. The borders divide the field into strips of land from 60 to 100 feet in width, widths of 60 and 66 feet being common, because these numbers divide evenly into the number of feet in a mile. The lands are ¼ to ½ mile in length. The borders are in nearly all cases parallel to one side of the field and the lands always have their length in the direction of the greater of the two slopes. Occasionally a field with very high slope is seen with borders running diagonally across it in the direction of a medium slope. The lands contain from 2 to 6 acres each. The head ditch runs across the high side of the field and across the upper end of each land. Water is turned from the head ditch into each land at one point. The earth for the borders is taken from the higher side of the lands in order that the slope across the width of the lands may be reduced. This prevents water from crowding to one border.

BORDER GATES.

Where the soil is hard the ditch bank or border may be opened with a shovel to let the water enter a land, but care must be taken in sandy soil to keep the water from washing away the banks. After a few years, if not at first, border gates for controlling the water are provided. When these are well made and set they are very convenient and make it easy for one man to handle a large stream of water. There are various forms of border gates. The drawing (fig. 3) shows a good gate which is used on the ranch of Mr. F. N. Chaplin near Holtville. It is built of redwood and the entire structure contains 49 feet of lumber, which at $42 per 1,000 makes the cost of the lumber $2.16. This gate can be used in any kind of soil. The floor of the box is set on grade of the ditch and below the ground surface, and there is then of little tendency for the water to pass under the gate. The advantage of the slant to the gate is that it can be made to hold more tightly when the water is shut off than those in which the gate stands vertical. When closed one or two shovelfuls of earth are placed in the corners against the gate and on account of the slant the earth remains in

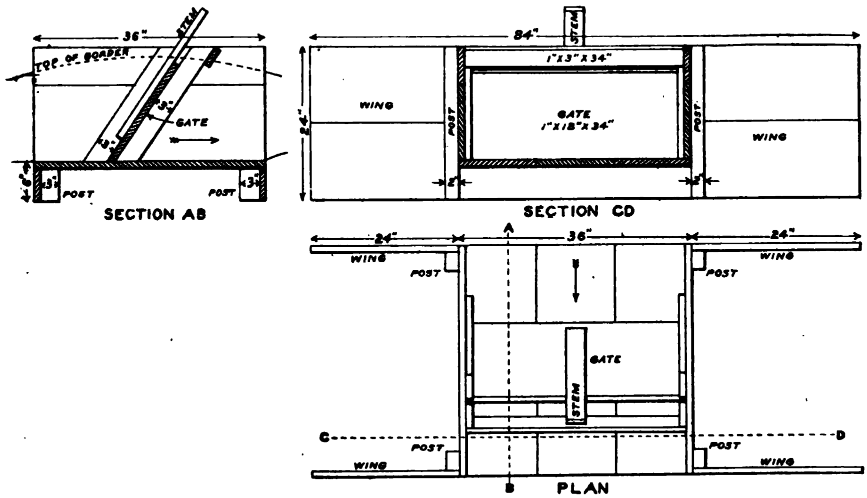


FIG. 3.—A border gate used in Imperial Valley.

place, making it perfectly tight. A slight leakage would not be a serious objection, except that it would keep spots in the field too moist for the use of machinery.

There are several automatic border gates which have been tried, but none has come into general use. These are made for contour borders and are so constructed that when the water behind the gate rises to a certain point the gate is tripped and falls, allowing the water to pass through to the next land, the gate being hinged at the bottom. In one of these a float in the water operates a lever to trip the gate. In another, used near Brawley, the gate is tripped by the melting away of a clod of earth on its becoming wet when the water reaches a certain height. With such a gate, after water is first turned on the field it needs no more attention until the entire field has been irrigated. Where there is much fall in the head ditch checks or check gates are needed to raise the water level to such a height that it will pass through the border gates. Flashboards are placed in the checks to secure the necessary head.

COMPARATIVE MERITS OF CONTOUR AND STRAIGHT BORDERS.

The straight border system is preferred to the contour system for land of small and medium slope, while as to the higher slopes there is a difference of opinion. The contour system has the advantage of making it easier to distribute water evenly over a field with great or medium fall, and many irrigators say they can not flood the greater slopes properly with the straight borders. This is the only advantage contours have over straight borders.

On the other hand, if the soil be loose enough to absorb water freely straight borders can be used on fairly high slopes, and are much more desirable for the appearance of a field and the rectangular lands are much more convenient for the use of farm machinery. When water is turned into a land between contours it soon begins to collect in a pool along the lower contour. In order to wet the surface just below the upper contour the water must be raised to an average depth of over 3 inches for 3-inch contours. What really happens is that when an average depth of 3 inches is applied it stands at a depth considerably greater than 3 inches at the lower contour before the land at the upper contour is covered.

The head of water used may be divided between several lands. The upper lands are usually irrigated first. To force water into one or more lands check gates are placed at intervals along the supply ditch. In the contour system the water to a certain extent soaks into the soil while standing in pools. In the straight border system the most of it sinks in while it has at the same time some horizontal movement. For the system to work perfectly the amount of water entering the land should be proportioned to the slope and texture of the soil, so that the water will be evenly absorbed over the entire surface and there will be no surplus at the lower end nor excess absorbed at the upper end. There is generally no trouble in getting the water to run over the lands fast enough, even on the slight slopes, for large heads of water can be used for a short time. The most common complaint is that a surplus accumulates at the lower end of the lands on the steep slopes. To overcome this trouble the rate of flow into the land must be reduced and it should be allowed to run for a correspondingly longer time to give the land the necessary amount of water. If the surplus can be drained off by opening the border at the lower end great care is not so necessary, but the mutual water companies prohibit the drainage of surplus water into both the distributing ditches and the public roads. Imperial Water Company No. 5 has a system of drainage ditches in part of its district, which, while constructed primarily to carry storm water, may be useful for draining surplus water from irrigated fields. The other mutual water companies do not need a system of drainage ditches for storm water, but they may in the future find it desirable to provide for the drainage of surplus water. It often happens that surplus water can be drained into a lower ditch and used on another field on the same farm. In flooding with contours waste can be prevented by not turning the water into the lowest land of the field until all the other lands have been irrigated. The drainage of the surplus from the upper lands is then enough to fully irrigate the lower end and there need be no waste from the field. On one ranch near Holtville a foot border is run across the lower end of the field at right angles to the other borders and four rods from the lower end. This forms small lands into which any surplus in the lands above can be drained.

Another similar method that has been successfully used to prevent waste at the lower end of lands with straight borders is to construct one or two diagonal borders across the lowest corner of the field forming small lands into which the surplus can be drained.

In flooding with both straight borders and contours water is used in large heads and for a short time. The size of the stream used in flooding varies from 1 cubic foot per second, or 50 inches, to 12 cubic feet per second, or 600 inches. The mutual water companies did not in the past deliver water at a rate less than 1 cubic foot per second or for a less time than 24 hours. Imperial Water Company No. 1 has now amended its rules and will deliver water at any rate. This was to meet the demands of those irrigating with furrows. One man can handle a stream of 10 cubic feet per second to advantage with either contours or borders, and under favorable conditions can irrigate 40 acres in 12 hours. Two men working 12-hour shifts can irrigate 80 acres per day continuously and on some of the large ranches this is the practice. In using 10 cubic feet per second to irrigate a field of 80 acres divided into 20 lands of 4 acres each, the stream would be divided among about 5 lands. Each land would receive water at the rate of 2 cubic feet per second, or 100 inches, for a period of about 6 hours. Thus 20 acres would receive 216,000 cubic feet or about 5 acre-feet of water in six hours, and the 80 acres would be covered in 24 hours. This would amount to the application of about 3 inches in depth. If the land were hard and there was a tendency for the water to run across too quickly the stream would probably be divided among 20 lands at once and allowed to run in each for 12 hours. This would give the field the same amount of water and would require the same time for the irrigation. It usually all disappears in 24 hours and if any remains as long as 48 hours, some measure is usually taken to drain it away.

The sediment carried by the irrigation water has a value as a fertilizer, but on the other hand it may not be desirable for all reasons. So long as the land is cultivated annually, as it is for crops grown by furrow irrigation or even where it is plowed every few years as is likely to be done in an occasional reseeding of barley, the slight deposit of silt is mixed with the soil and is beneficial, but where alfalfa grows year after year it has little chance to become thoroughly mixed with the soil and in time an appreciable coating of silt is left over the land and its power to absorb water is reduced. Much of the silt carried by Colorado River is deposited behind the checks and in canals and ditches where the water has a low velocity and does not reach the lands in Imperial Valley, but it is estimated that lands receiving an average amount of water may receive a coating of one-eighth inch in one year. Alfalfa is often run over with a disk harrow to loosen the soil and this may be accompanied by the sowing of new seed to improve the stand. This greatly improves the ability of the land to take water. It appears on seeing the process that the entire stand is being destroyed but its effect is to revive and stimulate growth to a great degree. The roots are often separated and the growth becomes thicker. This may be compared to a cultivation of the soil. It breaks up the surface crust and mixes in the thin layer of silt.

When alfalfa or grain is first seeded it is often irrigated with shallow furrows within the borders. These may be made by the drill if the seeding is done in that manner. The furrows run parallel to the borders in the straight border system. The furrows then cause the water to move exactly in the direction of the lands and prevent its moving in a diagonal direction and crowding to one of the borders.

FURROW IRRIGATION.

Furrow irrigation has only recently been practiced to any great extent in Imperial Valley. It is estimated that at the present time about 2 per cent of the total area under cultivation is irrigated by furrows. This method is used for cantaloupes and grapes, and also for gardens and fruit trees. But little attention has been paid to it in the irrigation of gardens and fruit trees, but with the advent of cantaloupes and grapes it is becoming more and more general. As yet no certain practice in the use of furrows has become prevalent. Few contrivances of any kind for controlling water in furrows have been introduced. Water is usually turned into the furrows from the head ditch by making an opening in the ditch bank. In a few of the cantaloupe fields little boxes made of laths are placed in the ditch bank at the head of each furrow. The opening in the boxes is about one inch square and is closed with earth. In one orchard larger boxes having galvanized iron gates are used. For both cantaloupes and grapes there is one furrow to each row of vines, the rows being 10 feet apart for cantaloupes and 8 feet apart for grapes. Instead of the furrow being midway between two rows of vines it is as close to one row as it can conveniently be made. There is of course a uniformity in the side of the row so that the furrows as well as the rows are equally spaced in a field. The wind generally trains melon vines to one side and the furrow is then made on the opposite side. The furrows are usually made in the direction of the least slope. The water has a slow movement in them and it seeps into the ground slowly. This is necessary on the closely packed soil. Sometimes water has been turned into both ends of the furrows on flat land. The furrows are made with the plow and are about 6 or 8 inches deep. Their length never exceeds ⅛ mile. Where the water company permits it heads of less than 1 cubic foot per second are used in furrow irrigation.

Cantaloupes are grown in fields of about 5 to 20 acres. The largest vineyard in 1906 was 40 acres. In a 10-acre square tract there are about 80 furrows for cantaloupes and about 60 for grapes. When a stream of 50 inches is used for a 10-acre tract it has to be divided between all the furrows at once for each furrow to receive less than 1 inch of water. The duration of such an irrigation is about 24 hours. In a vineyard near Imperial, where the soil is of medium texture, water percolating laterally met between furrows in less than 2 days. The amount of water entering a furrow is adjusted so that it is distributed throughout the length of the furrows as evenly as possible. If the soil is loose the furrows may be given more water to prevent its all being absorbed near the upper end, but it is usually compact if not hard and the trouble is to get the water to soak in before it gets to the lower ends of the furrows. In the cantaloupe fields the soil can be cultivated only when the vines are young, but the vineyards may be cultivated after any irrigation. The implement most commonly used in cultivating is a triangular harrow, the width of which is adjustable from 1½ to 3½ feet. It has twelve or more teeth, either spike or flat. The fields are not always cultivated, because labor is expensive and water for irrigation is cheap.

If there are any salts in the soil they collect on the ridges between the furrows as the water is evaporated from the soil. The concentration of the salts on the surface about the roots of plants is harmful if allowed to continue indefinitely, but such accumulations may be destroyed by deep and thorough cultivation. This is to be recommended with all furrow irrigation as a means of mixing the soil and preventing injury by salts. The salts, when thoroughly mixed into the entire layer of soil to a depth of several inches, are so evenly distributed that they produce little bad effect. This method can be applied only to such crops as are replanted periodically.

With grapes and asparagus the ridges can not be broken up each year. In such cases the land is flooded once annually. The flooding dissolves the salts from the surface and carries them down into the soil and they pass out with the underdrainage.

Asparagus, cantaloupes, and grapes are grown on the loose and medium soils, where salts rarely occur in amounts that make the application of the remedies described necessary. Rotation of crops is not now regarded as a remedy, for it would not be practicable to start new vineyards and asparagus beds every few years, and farmers yet hesitate to destroy a stand of alfalfa. At present there is no rotation of crops in the valley.

On account of the abundant water supply the conservation of the moisture is not now considered so important in Imperial Valley as it is in some of the citrus-fruit districts of southern California where it is necessary to pump water, but it is certainly worth while to pay for no more water than is needed. It is regarded cheaper to irrigate than to cultivate at the present time. Irrigation in deep furrows moistens the soil to a greater depth than irrigation in shallow furrows, the evaporation of moisture from the soil is thereby reduced and irrigagations may then be less frequent. After each irrigation there should be a thorough cultivation to create a mulch which will prevent the evaporation from the soil. Dr. Samuel Fortier [a] presents results of comparative tests of evaporation from the soil with deep and shallow irrigation and with and without cultivation. The results are very conclusive in showing that deep irrigation and cultivation conserve a large portion of the moisture that would otherwise evaporate from the soil. It is difficult to obtain a good mulch on the hard soil. It breaks up into clods and it is doubtful whether this tends to prevent evaporation or not. It is not difficult to pulverize the soft soils by cultivation and the prolonged cultivation of the hard soil greatly improves it. It has been noticed that it requires less water after the first year. Excellent alfalfa is now growing on very hard soil. There was some difficulty in getting a stand, but when the roots once penetrated to a reasonable depth there was no further trouble. The practice has been in such cases to devote the land to barley for a year or two, after which it is in much better condition for the young alfalfa roots. The irrigation, plowing, and added humus from the turning

[a] Office of Experiment Stations Bul. 177.

under of the barley stubble prepares the way for the deeper roots. The more sandy soil approaches a mulch and it is easy to keep pulverized.

A very striking illustration of the manner in which loose or sandy soil conserves the moisture is to be seen in No. 8 district, where about 300 acres of alfalfa has been without water, except an almost insignificant rainfall, since April, 1906. When the flume supplying this district was washed out by the flood and it became apparent that water could not again be supplied until the summer was over it was supposed that all this alfalfa would be killed. Instead, most of it is yet alive after having passed through a hot summer, and on some of it six light cuttings were made. The soil is mostly of a loose, sandy character and it absorbs water readily. Young alfalfa is sometimes irrigated by furrows. Shallow furrows are made before the seed is sown and they serve for the first irrigations. This moistens the soil to a greater depth than flooding and enables the roots to penetrate deeply. The furrows soon disappear with continued irrigation.

FERTILIZING VALUE OF SILT.

The silt carried by the water used in irrigation has a fertilizing value. It is apparent since the lands of the valley were themselves formed by the deposits of silt from Colorado River that the continued deposit of this same material has the effect of constantly replenishing the land. Just how much this value is can not be known until the amount of silt reaching the land has been determined. It is probable that it is enough to counteract the deteriorating effect of annual cropping and it is probable that the lands will never have to be fertilized artificially. The Arizona Experiment Station has determined that 1 acre-foot of water in the Colorado at Yuma contains on the average silt with a fertilizing value of $1.11. Assuming that one-half of the silt is deposited before it reaches the valley lands the application of 3 feet of water annually would add fertilizing material to the amount of $1.65 per acre. The fertilizing value of the silt is increased by cultivation, which mixes the new deposits with the soil and makes them more effective.

QUANTITY OF WATER USED.

When water was first brought into the valley no charge was made for it by the canal company, and later the minimum charge of 50 cents per acre was imposed, regardless of the amount used. At this time many matters were yet taking form, and the company encouraged settlement in every way possible and assisted in the organization of the mutual water companies. During this early period there was a rather reckless use of water, because of its being free, and through a lack of knowledge of what the requirements were, where the conditions were so unlike those of other irrigated districts. The charge of 50 cents per acre-foot for water began July 1, 1905, and since that time there has been more of an inducement for the water users to economize in the use of water. The company has so far been liberal in the delivery of water and this liberality has been transferred to the water users by the mutual companies. As the valley progresses it is to be expected that there will be more limitaion on the use of water, more accuracy in water measurement, and more economy on the part of the water users.

The following table gives the quantity of water, in acre-feet, delivered each month to mutual water companies in 1904:

Water delivered to mutual water companies in 1904.

Month	Acre-feet.	Month	Acre-feet.
January	[a]20,000	August	27,446
February	17,064	September	24,987
March	24,704	October	27,220
April	26,445	November	32,400
May	27,614	December	26,815
June	20,960		
July	26,999	Total	302,708

It will be noticed that there was great uniformity in the use of water throughout the year. The maximum use was in May and the minimum use in February. In 1905 much less water was used, although the acreage was increased. In 1906 there was an increase in the amount used. The following table gives the quantity of water delivered by the development company to the mutual water companies in 1905 and 1906:

Water delivered to mutual water companies in 1905 and 1906.

Month.	Imperial Water Company No. 1.	Imperial Water Company No. 4.	Imperial Water Company No. 5.	Imperial Water Company No. 6.[a]	Imperial Water Company No. 7.	Imperial Water Company No. 8.[a]	Total amount.
1905.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
January	5,531.65	1,356.31	3,595.72	....	1,755.01	1,031.89	13,270.58
February	2,471.19	348.99	2,421.04	....	808.33	280.13	6,329.68
March	6,447.28	892.46	490.09	....	116.50	606.98	8,553.31
April	18,405.50	4,247.62	6,068.58	....	4,101.55	2,314.26	35,137.51
May	10,703.04	2,084.45	2,895.79	....	1,737.43	....	17,420.71
June	10,649.12	1,594.78	1,785.00	....	659.76	....	14,688.66
July	12,291.37	3,344.10	3,074.27	142.34	220.08	....	19,072.16
August	10,954.08	1,943.80	3,074.27	....	2,332.73	....	18,304.88
September	8,807.57	1,253.25	2,975.10	....	2,236.74	....	15,272.66
October	7,786.24	1,033.25	3,371.80	110.15	1,398.53	....	13,699.97
November	5,155.56	1,281.31	1,769.20	152.03	789.35	....	9,147.45
December	6,466.65	3,319.81	4,050.19	62.41	1,435.89	....	15,334.95
Total	105,669.25	22,700.13	35,571.05	466.93	17,591.90	4,233.26	186,232.52
1906.							
January	11,556.47	2,592.61	5,256.18	744.06	1,584.06	....	21,733.38
February	6,715.96	912.59	2,693.59	219.11	1,124.34	....	11,665.59
March	17,475.21	4,741.85	8,880.96	693.82	2,683.33	....	34,475.17
April	16,206.01	4,398.56	8,594.67	....	2,558.24	....	31,757.48
May	12,035.96	2,053.80	5,879.61	....	2,061.84	....	22,031.21
June	11,595.12	1,568.43	7,984.13	....	1,925.28	....	23,072.96
July	10,045.44	1,184.64	6,535.23	....	1,878.50	....	19,643.81
August	9,511.86	1,031.24	5,863.96	....	1,394.96	....	17,802.02
September	8,343.98	933.95	4,601.69	....	1,909.82	....	15,789.44
October	8,862.68	1,422.16	3,804.74	....	1,509.72	....	15,599.30
November	7,836.04	1,867.45	2,982.13	....	1,216.34	....	13,901.96
December	6,674.17	1,600.10	2,201.25	....	1,432.14	....	11,907.66
Total	126,858.90	24,307.38	65,278.14	1,656.99	21,278.57	....	239,379.98

[a] Irrigation in Imperial water companies No. 6 and 8 has been interfered with by the flood.

It will be seen from the foregoing table that the maximum use of water was 35,137 acre-feet in April for 1905 and 34,475 acre-feet in March for 1906. The minimum use was 6,329.68 acre-feet in 1905 and 11,665.59 acre-feet in 1906. The total amount of water used by all the companies was 186,233 acre-feet in 1905 and 239,380 acre-feet in 1906. Imperial Valley is fortunate in getting its water supply from a stream with seasonal fluctuations nearly coinciding with those of the use of water. It has been previously pointed out that the minimum

[a] Estimated.

flow of the Colorado is in January. The mean total acre-feet discharged by the river in January is 314,000, or more than all the water used in Imperial Valley during the entire year of 1906. The mean annual discharge of the river is 9,662,000 acre-feet, about forty times as much as all the water used in 1906.

In many countries the annual floods of the streams occur in the spring while the greatest need for water is in the summer. The annual flood of the Colorado lasts from April to August, and the greatest use of water in Imperial Valley is at its beginning.

DEPTH OF WATER APPLIED.

A knowledge should be had of both the quantity of water now actually used and the quantity required to produce the best results. Although there is an abundance of water for the valley now and is likely to be always, it is very important that no more water be used than is necessary. The use of too much is not only an added expense, but it may be as detrimental to a crop as the use of too little. Continued over-irrigation in any country is usually attended sooner or later with bad results and chances should not be taken, although the danger is not so great as in other sections, because there seems to be no water table within 600 feet of the surface, as evidenced by borings at Imperial. (See p. 5.) It is reported that water has been found at Calexico, El Centro, and Holtville at depths less than 50 feet, but these were no doubt only local accumulations above an impervious stratum of no great extent. The growth of arrow-weed indicates moisture in the soil at depths of 20 to 30 feet, but the fact that arrow-weed is found only in certain places would indicate that the ground water is local instead of general. It is not yet known how far down water percolates in the several soils of the valley, but it is reasonable that if the proper amount be used in irrigation very little will pass beyond the point where it ceases to supply the roots of plants with moisture.

It is probable that in many cases more water is now being applied than is necessary. The farms are large, 160, 320, and 640 acre tracts being more common than 40 and 80 acre tracts. Labor is hard to get and much of the irrigating is done in a careless manner, because an attempt is being made to farm too much land. As water is cheap and plentiful the tendency is naturally to use too much rather than too little. The following table shows the average depth of water applied in the districts of Imperial Water companies Nos. 1, 4, 5, and 7, in 1905. The results for Imperial Water companies Nos. 6 and 8 are not given, because the irrigation was not continuous and they would have no value.

Areas irrigated and quantities and depths of water applied in the districts of Imperial Water companies 1, 4, 5, and 7, in 1906.

Company.	Area irrigated.	Quantity applied.	Depth applied.
	Acres.	*Acre-feet.*	*Feet.*
Imperial Water Company No. 1	70,000	126,858.90	1.81
Imperial Water Company No. 4	15,000	24,307.38	1.62
Imperial Water Company No. 5	25,000	65,278.14	2.62
Imperial Water Company No. 7	10,000	21,278.57	2.13
Average			2.04

The average depth of water applied in the four districts was about 2 feet in 1906. From the above it does not appear that much water is used considering the climate and the continuous irrigation. The average is greatly reduced by the large proportion of barley grown. About three-fourths of the irrigated area is in barley. It is customary to use for barley a little more water than the minimum charge per acre will purchase, or from 1 to 1½ acre-feet per acre. For alfalfa it is customary to use nearly the maximum amount that the water companies are required to deliver or from 3 to 4 acre-feet per acre. Most of the cantaloupe growers believe that 1½ acre-feet per acre is enough, but the amount actually used during the year has been much in excess of this. Measurements are now in progress to determine the amount of water used on barley, alfalfa, cantaloupes, and grapes, but they have not yet been carried on long enough to warrant the publication of the results.

Barley is seeded in the fall, about October, and is allowed to volunteer each year thereafter so long as a good stand is maintained. The ground is irrigated once before being plowed for seeding. After seeding it is given from four to six irrigations—three or four from October to December, and one or two in the spring, usually in March. For a good grain crop it is very important that the last irrigation come just when the grain is in the first milk. About 3 inches of water is applied at each irrigation.

Alfalfa requires more frequent irrigation on the hard soil than on the soft soil. In district No. 8 where the soil is a sandy loam from 8 to 12 irrigations are plenty, while in portions of the valley where the soil is hard or medium it requires from 12 to 18. The sandy soil takes more water at an irrigation and holds the moisture longer. The hard and medium soils do not take the water so readily and it has to be applied in smaller amounts, but more frequently. In each case the total amount applied in a year is about the same, but there is an economy in favor of the sandy soil, because it prevents excessive evaporation and more of the water is utilized by the plants. On the hard and medium soils about two irrigations each month are given alfalfa from May 1 to October 1 and about one irrigation each month for the rest of the year. Alfalfa has been planted in all seasons of the year, but October or March is preferred. Some has been planted on land prepared with the disk harrow only, and in many cases the seed was sown on hard soil without either plowing or disking, an irrigation being depended on to wash the seed down into the cracks in the soil. Better stands have been secured in this way than by plowing on new lands. It is the universal experience that seed does not germinate well if planted immediately after the first plowing, while there is no trouble if the land remains for a season.

The practice in irrigating cantaloupes is not so well established. Most of the fields received from six to ten irrigations during 1906 and many received even more. Some of the growers now believe that three irrigations, one each in the latter part of March, April, and May, would be sufficient. One field of 17 acres of cantaloupes near Holtville was irrigated entirely by the leakage from a gate, a stream of about 2 inches being used continually. For cantaloupes the land is plowed in January and is irrigated once before plowing. The seed is planted in February. The irrigation begins about March 15 and ends about June 15. Many of the cantaloupe growers contemplate using about two-thirds as much water as they did last year.

Instead of one man attempting to care for 15 or 20 acres of cantaloupes many of the growers will reduce their fields to 5 and 10 acres and the irrigating may then be more carefully done.

WATER FOR DOMESTIC USE, LIVE STOCK, AND POWER.

A small amount of water is taken from the ditches for domestic use and for live stock, the water for domestic use being filtered. Small ponds or wallows are made for hogs and water is turned into them from time to time. The rules of the water companies compel owners to keep their live stock away from the public ditches.

Some water is also used by the Holton Power Company in generating electric power, which is transmitted to all towns of the valley for lighting and power. The power plant is at Holtville and is constructed so that it can be enlarged as the demand for power increases. Water is supplied to a pair of Victor turbines of 450 horsepower under a head varying from 40 to 47 feet. The supply is brought several hundred feet by a 52-inch wooden pipe from a reservoir costing $36,000. The waste enters Alamo River and is not used for irrigation at present, but will probably be diverted for Imperial Water Company No. 4 in the future. The power company pays for water $2 per horsepower per month, the charge being based on the average. The right to water for power is secondary to other uses.

PRODUCTS.

The leading products of the Imperial Valley are grain, live-stock, dairy products, and cantaloupes, while grapes and asparagus and other vegetables may soon rank with the others. Barley is the great grain crop. The number of sacks purchased for the grain harvest in 1906 was 500,000, indicating the size of the crop. Barley is grown also for pasture for live stock, and much of it is pastured during the winter and allowed to make a grain crop in the spring. Care is taken to keep the stock off while the ground is wet after irrigation to prevent puddling the surface. The barley is allowed to volunteer after the first year. Occasionally a field is reseeded and sometimes, when this is the intention, the field is irrigated after the harvest to sprout the waste seed left by the harvester. This is then pastured during the late summer. The yields of barley range from 8 to 20 sacks per acre. Twelve sacks per acre is probably an average. It has sold for 90 cents per sack, making the average return $10.80 per acre. Many do not consider barley profitable as a grain crop alone. Practically all of it is pastured and this is the way to secure the largest return.

Wheat was grown extensively in the early period of settlement, but it has now practically disappeared, barley being preferred as grain. Oats also are grown successfully, but there has never been a large acreage.

Kafir and Egyptian corn were grown in large quantities when farming was first begun about six years ago; these grew well, but sometimes the grain was entirely taken by birds. It was thought that corn was needed to fatten stock for the market, but it has been found that barley is sufficient. In 1906 the area in Kafir and Egyptian corn dwindled down to a few hundred acres. Sorghum was also grown in large quantities for feeding stock when the valley was first settled, but other crops have now taken its place. A few fields of sugar cane have also been grown.

The valley has over 20,000 acres in alfalfa. Most of the alfalfa is pastured with cattle and hogs, but some of it is cut and sold. There are usually eight or nine cuttings every year. The yield is from 7 to 10 tons per acre, a ton to a cutting. It has sold for $5 per ton in the stack.

Cantaloupes were first grown in the valley in 1905 at Brawley. About 560 acres were planted. In 1906 cantaloupes were also grown at El Centro and Holtville. The total acreage in the valley was 1,175, and 113,194 crates were shipped. Three associations have been formed to market the melons. The stock of these associations is owned by the growers and their interests are pooled. The associations do not market the melons through their own agents, but each contracts with a commission company to ship and sell after the melons have been packed. The average number of crates per acre for the total acreage was 96. The total gross sales amounted to $290,000 and $130,000 was paid to the associations after deducting freight, express, and refrigeration charges and commissions. The expenses of the associations were then deducted and $94,000 was paid the growers. The earliest planting of cantaloupes has been about February 1, and it continues for a month. They are irrigated through March, April, and May, and the packing begins May 15. In 1907, 1,187 acres were in cantaloupes, 182,428 crates were shipped, and the growers received $327,790 net. Watermelons grow to perfection and fifteen carloads were shipped from Brawley in 1906. Many more were shipped in 1907.

In this valley were 450 acres in grapes in 1906, but none of the vineyards is more than two years old and none is in full bearing. There were 1,500 acres in vineyards in 1907. One vineyard of 400 acres and another of 320 acres have been planted. Many of the grapes are being irrigated more than is necessary, and too much water is very detrimental to them. Cuttings are rotted by the use of too much water.

Asparagus has not yet been grown in any large quantity, but it has been demonstrated that it is one of the most profitable crops, and preparations are now being made to raise it extensively for the market. Excellent Bermuda onions have been grown at Brawley, and they will probably be grown on a large scale in the future. High prices were received for those shipped during the winter of 1906–07.

Winter tomatoes have also given excellent results at Brawley and elsewhere in the valley. They will probably be grown in considerable quantities at Holtville. It is the intention to supply the market at a time when few if any can be had from other localities.

Potatoes have not been considered as being well adapted to the valley in the past, but some good crops were grown in 1906. It is believed that potatoes can be successfully grown if planted at the proper time; but little has been known in regard to this, and experiments are just beginning to show what can be done.

Sugar beets were grown at Brawley, samples of which were tested at one of the beet-sugar factories in California, showing 13 to 17 per cent of sugar and 74 per cent purity. The chemist's report on these beets stated that they had been overirrigated, which lowered the sugar content. It is believed that with proper irrigation beets of a good quality can be grown.

Nearly all the garden vegetables, including sweet potatoes, peas, beans, cabbage, beets, lettuce, radishes, etc., thrive, and while not yet grown for shipment, are grown to supply the home market. Nearly all the vegetables are planted in the fall and winter.

The land holdings in the valley are large and the attention of the farmers during the first years of settlement has been given principally to field crops and live stock; gradually more attention is being given to vegetables and fruits, but there will yet be a great development in this direction.

Among the deciduous fruits apricots, figs, pears, plums, and peaches are well adapted to the country. Apricots and figs especially make a thrifty growth and the oldest trees are already producing fruit. Fruits for home consumption will be produced, but it is too soon to know whether they will be produced for shipment. Cherry trees do not grow satisfactorily, and the valley is not regarded as an apple country. A few olive trees have been planted and the indications are that they will grow well.

Among the berries blackberries and dewberries grow well. While strawberries and raspberries are grown, it is questionable if they give results that would warrant their being grown for the market in large quantities.

The valley was not at first regarded as being altogether suited to citrus fruits; occasionally on winter nights the temperature goes a few degrees below freezing, and it was feared that the fruit would be damaged by frost; also that the spring winds would prohibit the citrus industry. However, orange and lemon trees were planted here and there for experimental purposes, and many of these are now old enough to bear fruit. The trees grow rapidly and the fruit has not been damaged, the result being that there is now much interest in the experiments.

A date farm is located near Heber. The palms are two years old and some fruit has already been produced, but it has so far been ripened artificially. The dates are of the Deglet Noor variety, which is not a heavy producer, but is of the finest quality. It is yet uncertain whether the hot season is long enough for this variety to be grown commercially.

Almond trees grow well, but the English walnut is not a success. Many shade and ornamental trees are being planted. Those that grow well include cottonwood, pepper, locust, Arizona ash, umbrella, Russian mulberry, palm, and all varieties of the eucalyptus except the blue gum.

The principal live stock in Imperial Valley is hogs, there being about 100,000 head. They are pastured on growing barley and alfalfa and fed on barley grain for a few weeks before marketing. The raising of cattle for beef is not so extensive as hog raising, but it is rapidly growing. In 1906 about 7,500 head of cattle were shipped from the valley. Cattle are pastured principally on alfalfa, and two head per acre can be supported if the stand is good. The shipments to market begin in December and last until June. The first sheep were brought into the valley from Arizona about a year ago. One firm has 6,000 head, and states that the valley is admirably adapted to sheep raising. Another company has brought in 3,000 head of sheep. There is a great demand for horses in Imperial Valley and they are raised at good profit.

Dairying is very profitable and promises to always be a leading industry on account of the almost endless market for the products. The number of dairy stock was doubled during the past year, and there are now 3,500 head in the valley. Some of the herds number 60 head. There is a creamery at Imperial, and others are being built at Holtville and El Centro. The cows are pastured on alfalfa during its growing season and are fed alfalfa hay when the alfalfa is dormant. They are fed some grain also in all seasons. Alfalfa is fenced off into small plots and the stock changed from one to the other. This makes better feed and allows the plant to make a growth undisturbed.

The valley is well adapted to poultry raising and although there are not as yet any exclusive poultry ranches, many chickens and turkeys are raised.

An estimate of the total value of the products in the Imperial Valley in 1906 may be based on the value of the product of the four largest industries. It is estimated that one-fourth of the 500,000 sacks of barley grain is fed to stock in the valley and that the other three-fourths was shipped out. It is also estimated that 15,000 head of hogs and 7,500 head of cattle were shipped and that the others were retained on the ranches. Dairy products average $78 per head per year. No account can be taken of alfalfa, although one of the chief crops, because it is all fed to stock.

The values are approximately as follows:

Value of products of Imperial Valley, 1906.

375,000 sacks of barley, at 90 cents per sack	$337,000
15,000 head of hogs, at $12 each	180,000
7,500 head of cattle, at $38 each	285,000
3,500 head of dairy cows, product at $78 each	273,000
113,194 crates of cantaloupes, at 84 cents each	95,000
Total	1,170,500

FURTHER WORK ON IMPERIAL IRRIGATION SYSTEM.

When describing the construction of the Imperial canal system by the California Development Company in 1900 in the first part of this report, the original intake on Colorado River was referred to with its head gate known as the Chaffey Gate. Since that time several changes have been made in the intake of the system and it was not until 1906 that the present permanent intake was completed and used. It is the purpose to describe here the changes made.

The first intake and head gate are shown on the map, figure 4, at Hanlon, just above the international boundary line. The gate was 60 feet wide. In the hurry to get water into the valley the floor of the gate was placed several feet above the grade of the canal instead of on grade, as was intended. It admitted enough water so long as the river was high, but when the first low stage came it did not admit sufficient water on account of its elevation. A cut was made around the north end of the gate, but the flow was interfered with by the deposit of silt where the velocity was low, and it soon became necessary to cut other channels. One was cut just below the international boundary and was known as the Upper Mexican intake. Neither of these cuts had any controlling gates. The settlers were clamoring for water and instead of attempting to keep these channels clean it was decided to cut the lower Mexican intake at a point where the fall would be such that the water would have velocity enough to prevent the deposit of silt.

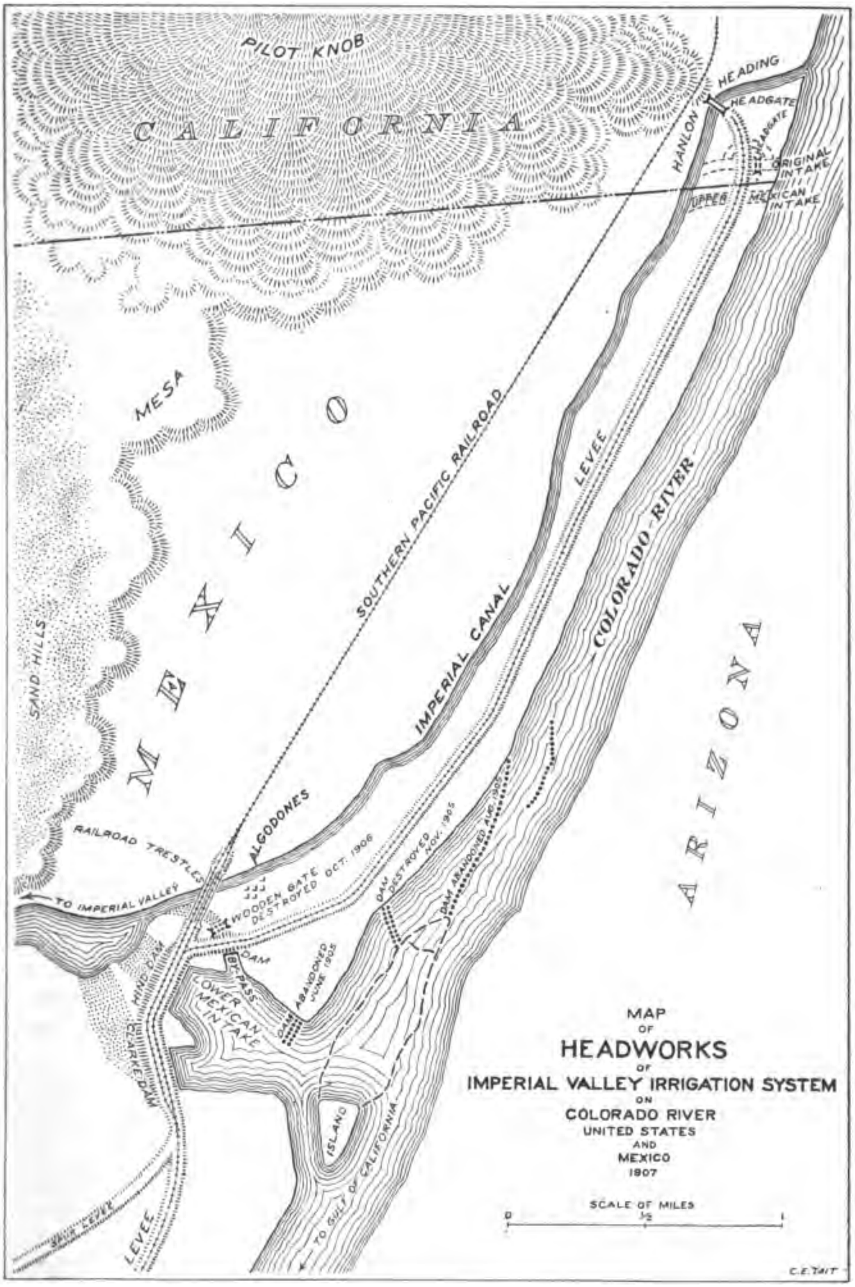


FIG. 4.—Map of headworks of Imperial Valley irrigation system.

The Lower Mexican intake is about 4 miles south of the international boundary line. The Mexican Government permitted the cutting of the channel and the diversion of water from the river in Mexico, thereby giving the development company a water right in Mexico. It will be seen from the map that it was a channel leading from the river to the original canal where the latter turns to the west around the southern end of the sand hills. The channel was 50 feet wide and 3,300 feet long. The fall was 1½ feet in the entire length. This intake was cut in the fall of 1904. No head gates were provided, as it was thought that the trouble would be to keep the channel open rather than to keep it from enlarging. The company was having difficulty to provide funds, but it is probable that gates would have been built had it been considered necessary. At first it seemed that there would be a repetition of the experience with the upper channels, for the channel silted up, thereby strengthening the opinion that gates were not necessary. Finally an erosion began with high water in the river, and more water entered the canal than was needed for irrigation. The tendency now was for the water to enter the intake rather than to stay in the river, on account of the slope being greater toward the west than in the river channel.

It was apparent what the outcome would be if some action were not taken to control the amount of water entering and force the rest to pass down the river. All water flowing to the west not used for irrigation eventually went into Salton Sink, which had no outlet. The water began to rise in the sink and it was evident that it would continue to do so until it reached the elevation of Volcano Lake, the lowest point in the rim of the basin, unless a point would be first reached where the evaporation from the surface would counterbalance the inflow. There has been much conjecture in regard to this. A theory, and a theory only, can be formulated as follows: The mean annual discharge of Colorado River is about 9,662,000 acre-feet. Assuming that the annual evaporation of 7 feet measured from a tank in Calexico would apply to such a large water surface, it would require a surface of about 1,288,000 acres for the evaporation to balance the inflow. Since that portion of the basin below sea level includes approximately 1,150,000 acres it would be concluded that the evaporation would not prevent the water level reaching the sea-level line. Further, the evaporation would be less for such a large area. The area of the water surface would increase comparatively little in rising from sea level to the elevation of Volcano Lake, which is 24 feet, as the sea-level line runs along the hills and mesa except at the southeast. It is not certain what would have happened if the inflow to Salton Sea had continued, but since nearly all the Imperial Valley lands are below sea level it is probable that they would have been inundated.

First attempts to control the river.—Attempts were made at four different points to control the river before it was finally accomplished. The first attempt to close the intake was made before the summer flood of 1905. Two lines of piling 3 feet apart were driven across the entrance to the intake and the space between filled with brush and sand bags. The supply of sacks provided for the work was exhausted and the rising river washed the work out. The company was unable to furnish money for further work, and Imperial Water Company No. 1 offered to assist in another trial and advanced money for that purpose. The work was begun on the same site in May, 1905. Two rows of piles 15 feet apart were driven across the intake, and the space between was to be filled with brush. The channel eroded very rapidly, and the work had to be abandoned in June. The railroad track had already been moved to higher ground along the northeast side of Salton Sea to prevent its being covered by the rising waters, and the turning of the river was of as much concern to the railroad company as it was to Imperial Valley.

The development company no longer had funds to renew the work at the intake, and the chief engineer began an effort to reorganize the company, which resulted in the railroad company making loans and being given in trust 51 per cent of the stock of the development company as security. The loans were primarily for the development of the system, the turning of the river being considered at that time an easy matter. The next attempt was made on a new site. The map shows the former location of an island in the river in front of the intake. A diversion dam consisting of a line of piles and brush from the upper end of this island to a point several hundred feet up the river on the west bank was begun in July, 1905. Another line of piles had been driven a little farther up the river in the middle of the channel to deflect the current toward the east bank. When the brush was added, the piles were undermined, and the plan was given up in August, 1905.

The next attempt was made at still another point. In October, 1905, a pile and brush dam, known as the Toland Dam, was begun across the west channel of the river at the upper end of the island. The island had now been shortened by part of its upper end being washed away in the previous flood. The dam had a mattress foundation and was completed to such a height that only about 3 feet of water was passing over it when the river rose from 6,000 cubic feet per second to 102,000 feet per second in three days and destroyed the work in November, 1905.

Floods of 1905 and 1906.—The greatest flood on Colorado River for volume of which there is any record was that in 1905. The next greatest was in 1906. The latter reached a maximum of 99,200 cubic feet per second June 27. When the river was high, some water went down its channel to the Gulf of California, and some went also to the Gulf by way of Rio Paredones to Volcano Lake and thence through Hardy River. But the greater part of the water, and all of it after the high water passed, went by way of New and Alamo rivers to Salton Sea. The water entered the Lower Mexican intake and filled Alamo River in Mexico to overflowing. Part of this went to Volcano Lake by way of Beltram Slough, whence it was divided between Hardy and New rivers. The remainder went directly into New River through Garza and Pink Mountain sloughs, New River carrying about nine-tenths of the water through Imperial Valley. The water which crossed the boundary line in Alamo River had to pass through the Alamo waste gate.

New River overflowed its banks in Mexico and in Imperial Valley near Calexico and during May, June, and July, 1906, practically all of district No. 6, in which 4,000 acres were under cultivation, and 3,900 acres in district No. 1 were under water. The flooded section in district No. 1 was a strip between the river and the main canal near Calexico and between the river and the Elder Lateral at Silsbee. The channels of New and Alamo rivers had already been deepened by erosion near their mouths into Salton Sea by the flood of 1905.

Alamo River had cut back beyond Mesquit Lake. The deep gorge of New River extended farther back than Brawley. With the large volume of water carried in the flood the erosion became very rapid. The channel of Alamo River was cut out to a depth of from 40 to 80 feet to Holtville and beyond. The rapids in New River formed by the erosion in which the river dropped about 30 feet were about ½ mile long. The continued sluicing out after the rapids had passed left the water in a gorge from 50 to 80 feet deep and several hundred feet wide.

The towns of Calexico and Mexicali were in great danger of being flooded and were protected only by a levee 6 feet high and several miles long, which had been built by the citizens. It was seen that their great danger would be past as soon as the cutting out of New River channel reached the inundated country. In order to assist the process the channel was blasted for many days. Thirty sticks of giant powder were used in each charge thrown into the water. The explosions loosened the bottom of the channel so that it was washed out more rapidly. The cutting back reached the overflowed country in July and this broad sheet of water was quickly drained off. Some of the land near the river was left in a damaged condition by the formation of gulleys into the river as the water was drained. In some places the channel cut away from its original course, doing much damage. June 4 it cut into the main canal for district No. 1 just above the five headings and took out 1 mile of the outer bank where its course turns from west to north. As it was just time for the last irrigation of cantaloupes it was necessary to reconstruct this portion of the canal in great haste for the melons in district No. 4 at Brawley depended on this canal for water, as did also a large portion of district No. 1. It was reconstructed in one week by the development company assisted by Imperial Water companies Nos. 4 and 1. Blue Lake, at Silsbee; Cameron Lake, near Calexico; and Pelican, Diamond, Badger, and Long lakes, west of New River, were drained and left dry permanently. In July after Calexico and Mexicali were out of danger from the breaking of the levees, the cutting back took a sudden turn towards the towns and destroyed a portion of Mexicali. The flume carrying water from Brawley main canal across New River to district No. 8 and the flume across the river in Mexico to supply district No. 6 were washed out in June, 1905. The cutting continued beyond Mexicali, but at a decreasing rate as the flood subsided.

There was great fear that the cutting would cross from New River to the Alamo through Pink Mountain Slough and leave Sharps Heading from 20 to 50 feet above water, thus cutting off the water supply of the entire valley. One erosion began in the slough and this was watched very carefully through the fall and winter. It became necessary to send a force of Indians to this point to spread the water over a larger surface by the use of brush to hold the cutting in check until the closing of the intake on the Colorado was completed. On August 29 a current meter measurement was made of the Alamo above the head of Pink Mountain Slough showing the discharge to be 6,626 cubic feet per second. Deducting the amount passing Sharps Heading in the Alamo it left about 4,900 cubic feet per second as the amount carried by the slough. This indicated that the greater portion of the flood passed through Beltran and Garza sloughs. Had the cut in New River continued to the Colorado by way of the slough and the Alamo before the intake was closed it would have made it almost impossible to turn the river back to its old channel.

The railroad track had been moved back to higher ground along the shore of Salton Sea for the second time and the water was again within 6 feet of the track when the river was turned. The sea had risen at the rate of 1 to 4 inches per day. The sea now has an area of nearly 400 square miles.

Work at the intake in 1906.—All attempts to turn the river in 1905 having failed, many engineers said that further attempts were useless. The undertaking demanded not only great engineering skill, but means and equipment as well. The railroad company was able to furnish these and the engineers now realized the magnitude of the problem before them. It was thought necessary to provide free but temporary passage for the water while a dam was being constructed across the intake in order that the water against the dam while building would be kept as low as possible. Two plans were considered. The contract had already been let for the construction of a new permanent intake with head gate above the international boundary. One plan was to rush the gate to completion and allow the water to pass through it while the dam was constructed across the lower intake. The other plan was to construct a by-pass for the water, consisting of a channel leaving the intake channel on the north side and returning to this channel several hundred feet below. The by-pass was to carry the greater portion of the water of the flood expected in the summer and prevent the further erosion of the intake, but it was not completed in time to serve this purpose. The dam was to be constructed across the intake between the entrance and exit of the by-pass. A large wooden gate was put in the by-pass to be used temporarily in turning the river. The gate was to be left open, allowing the water to pass to Salton Sea until the dam was completed when the final act was to be the closing of the gate which would force the water to take the only remaining open channel, its old channel to the Gulf. The first-mentioned plan was considered the safest and was preferred, but it was feared that the permanent intake could not be completed soon enough, so both plans were carried on simultaneously. In case of failure with the by-pass there would be another plan to fall back upon, already well under way. One of the first things done was to build a railroad from Pilot Knob station to the intake, on which to haul material and machinery. The dam could not be commenced until the summer flood began to subside. In the latter part of June, when the maximum of the flood had passed, active work was commenced. The channel was then 2,600 feet wide, and not only the intake but the river above the intake had sluiced out to a depth of 8 feet below the old channel to the Gulf. The old channel had also silted up about 1 foot.

The by-pass was cut about 80 feet wide and 7 feet below the bottom of the river so that the water would have a tendency to enter it. The temporary wooden gate was 200 feet wide and its floor was 60 feet long in the direction of the channel. The floor rested on 500 anchor piles and there were three rows of sheet piling below the floor. Its framework was 25 feet high and its width was divided into forty openings by "A" frames of timber. Flashboards were to be used to close the openings. Bulkheads of piling, brush, and sand bags were built out from each bank for closing the intake until the water was confined to a width of 600 feet. A line of piles 40 feet apart was driven across the channel, 180 feet above the center line of the dam, and to these brush mats as a foundation for the dam were anchored by wire cables. These mats were woven on a barge remodeled for the purpose, and as fast as the mat was completed the barge was moved out from under the mat, leaving it to float on the water. The brush for the mats was cut by Indians south of the intake and brought by a steamboat. The mats were 100 feet up and down stream, and one was built out from each bulkhead, the two lapping at the middle. The mats were made of bundles of brush 18 inches in diameter, being placed with the butts of the brush downstream. Each bundle was continuous across the entire mat in the direction of the current. The bundles were brought tightly together by continuous sewing with $\frac{5}{16}$-inch wire cable and were held by clamps. These cables, which were the warp serving to hold the filling of brush together, were 6 feet apart. When the mats were floated the anchor cable was pushed down to the bottom of the channel on the piles, and this caused the mats to dip at the upper edge and they soon silted up and sank. Rows of piling were then driven through the mats for a railroad trestle, from which the rock and other material forming the dam were dumped. The dam was gradually raised until all the water was going through the by-pass. Then a flood from the Gila raised the Colorado, and on October 11, with about 14,600 cubic feet per second of water in the river, the wooden gate was washed away. This gate cost about $130,000.

It was now necessary to close the by-pass before work could continue on the dam. The railroad track crossed the by-pass a short distance below the wooden gate. Two other spurs were now run on two additional trestles across the by-pass. From these three trestles large quantities of rock were dumped. A head of 3 feet was raised at the lower dam and an additional head of 3 feet at each of the upper dams. This distributed the head on the three dams and the overpour passed down three inclines. These dams forced the water to flow over the dam in the intake and the upper dam in the by-pass was then raised to the required height to permanently close the by-pass.

Attention was again turned to the dam. Another trestle was built 30 feet above the first trestle. The dam was gradually raised by dumping rock, gravel, and clay in large quantities from the railroad trestles. The material dumped from the upper trestle raised the head 2 feet higher than that dumped from the lower trestle. Rock was dumped at the rate of 280 carloads per day during part of this work, and all the rock and gravel equipment of the railroad from Los Angeles to Tucson was brought into service. All the water was forced down the old channel November 4. The dam is 42 feet high and has a top width of 31 feet; its slopes are 3 to 1. There was a head of 15½ feet of water against the dam when the river was turned. The cost of turning the river was about $1,000,000. A levee was built from the dam northward to the new head gate, a distance of 3½ miles, and from the dam southward for 5 miles, to keep out the overflow from floods and prevent its flowing through Imperial Valley. The levee was given a top width of 10 feet and slopes of 2½ to 1 on the side toward the river and 2 to 1 on the other side. Its height varies from 5 to 12 feet.

Permanent intake of Imperial Canal.—The new intake with its head gate for the irrigation system is intended to be the permanent intake. The canal leaves the river at Hanlon a short distance above the original intake in the United States. The head gate is a massive steel and cement structure on a solid rock foundation at the end of a spur of Pilot Knob Mountain and about 1,500 feet from the river bank. It was begun in December, 1905, and completed in June, 1906. Water was admitted through the gate for irrigation after the closing of the intake in November, 1905, although the canal was yet being enlarged and it is now in use after the closing of the crevasse in February, 1907. The structure is of reenforced concrete and has 11 culverts 10 feet high and 12 feet wide, being separated by walls 18 inches thick. The floor of the structure is 96 feet above sea level and is 5 feet below the bed of the river. The gates are of "Taintor" type, having radial arms and are of steel. Instead of sliding in vertical grooves they revolve for a portion of a circle about a horizontal shaft placed behind them with 14-foot radius. The pressure of the water against a gate is thus transmitted to the turning point on the shaft and the gate should require but little power to move it. The lifting apparatus is powerful and may be operated by hand. The gate structure has a height of 12 feet above the culverts to hold back high water and to provide room for the gates when they are raised. The capacity of the gate is much in excess of 10,000 cubic feet per second, the amount of the claim of the development company. The gate structure cost $26,770, and the iron and steel work $14,813. The total cost was $44,408.

The canal was cut from the river to the gate and from the gate southward to the original canal, and was then enlarged from the international boundary to the lower Mexican intake with a dredger and by blasting. The development company has constructed a large dredge at Yuma. The first use of the dredge was to be in turning the river and in opening the head of the main canal, but it was not completed in time. The dredge will be used for cleaning silt out of the intake and for other work the company may have on the river in the future. It cost $80,000 and is designed to move 200 cubic yards per hour. The beam has a sweep of 250 feet and the bucket holds 5 cubic yards.

Work at intake in 1907.—In December, 1906, while the levees were yet incomplete a flood from Salt River raised the Gila and the Colorado. The latter carried about 40,000 cubic feet. Water found its way through cracks in the soil underneath the base of the new levee, and by December 10, three days after the trouble began, the entire river was again flowing to Salton Sea. The levee broke just below the Hind dam and entered the former channel a short distance below the dam. The water concentrating at the crevasse soon sluiced out another deep channel with a width of 730 feet. The railroad company was unwilling to again undertake the turning of the river at its own expense or to advance further to the development company for that purpose unless given assistance. The stockholders of the mutual water companies pledged themselves to favor issuing $500,000 in bonds to be used in turning the river and building levees, provided the railroad company would do the work. A land and cattle company pledged an additional $250,000, a power company $100,000, and the Imperial Valley Improvement Company $100,000, making a total of $950,000 from the valley.

A proposition was then made to the railroad company and the development company by the mutual water companies through their directors that they, the mutual water companies, issue bonds for $500,000, to be used by the railroad company in turning the river and constructing dikes, and they virtually agreed to prevent any claims for damages by the flood being made to the Mexican Government or to the railroad company, provided the railroad company presented no claim for damage to its tracks. The people, knowing that the railroad company was the only power that could turn the river before the coming floods, appealed to the Government. It was expected that the actual work would be performed by the railroad company with its equipment, but the expenses would be paid by the Government.

The President, in response to the appeal for aid, requested the Southern Pacific Company to close the break without delay, signifying his intention to urge an appropriation by Congress to reimburse the Southern Pacific Company for its expenditures. The order was given December 20 by the railroad company for the work to proceed. On December 29, after the work commenced, the Mexican company, under control of the California Development Company, was ordered by the Mexican Government to demonstrate within ten days its ability to turn the river and to complete the work within three months, else the concessions would be annulled.

The plan of work followed in closing the crevasse was similar to that followed when the intake was closed a few months before, except that it was decided to dispense with the brush mattress foundation for the dam. On account of a number of floods in the river bringing drift in large quantities, great obstacles were encountered in building trestles across the crevasse. Piles from 40 to 80 feet in length were driven, some of them in 32 feet of current. Two trestles 50 feet apart were built. Several times portions of the trestles were washed out as they were nearing completion, but by January 27 one trestle was completed and the dumping of the rock began. The second trestle was completed by February 2, and by February 11 all the water was again going down the old channel. An average of about 165 cars were dumped per day. The dam is 1,200 feet long, of which 700 feet is of rock and gravel, with clay on its upper slope. The remaining 500 feet is of earth. The water was raised about 9½ feet when most of it was flowing down the old channel. The cost of this work is stated unofficially to have been about $750,000. The levees have been completed. It was decided that more careful construction was necessary. The peculiar nature of the soil, which cracks in drying after being moistened by the overflow, required that greater care be taken to prepare the ground beneath the levee. A muck ditch was made under the levee which is deeper than the cracks in the soil at all points. Its average depth is over 5 feet. After the excavation was made the earth was thrown back and puddled. The upper 2¼ miles of levee had its inner slope torn down and reconstructed over a muck ditch in conformity with the new plan. The levee extends from the new head gate at Hanlon southward along the river bank to the Hind-Clark dam, thence to the southwest along the course of Rio Paredones.

Eleven miles of levee have been constructed, and as there was no trouble during the flood of 1907 it has been decided that no further construction is necessary. Some water overflowed the river banks in Mexico below the levee, but as it went over in a thin sheet, as in former years, and could not concentrate at any point no damage was done. The first 4½ miles of new levee was constructed with the muck ditch under the toe on the land side and with the borrow pits on the same side. The last 4¼ miles has the muck ditch and the borrow pits on the river side. The borrow pits on the river side were preferred, but they were placed on the land side for the upper portion of the new levee in order that high water should not interrupt construction. Where the muck ditch is under the river toe it should prevent water getting under the middle of the levee. Where it is under the other toe the ground under the middle of the levee may be moistened, but as it is not exposed to the air it should not crack in drying. Fig. 5 shows sections of the levee. It is 10 feet high, 10 feet wide on top, and has slopes of 3 to 1. The outer slope is riprapped with 1½ feet of gravel. The levee is 3 feet above high-water level, and it is believed that it will stand any flood that comes against it. A spur is built out from the main levee on the land side below the Hind-Clark dam to divert water toward Volcano Lake in case the main levee breaks. Probably the levees did not cost over $500,000.

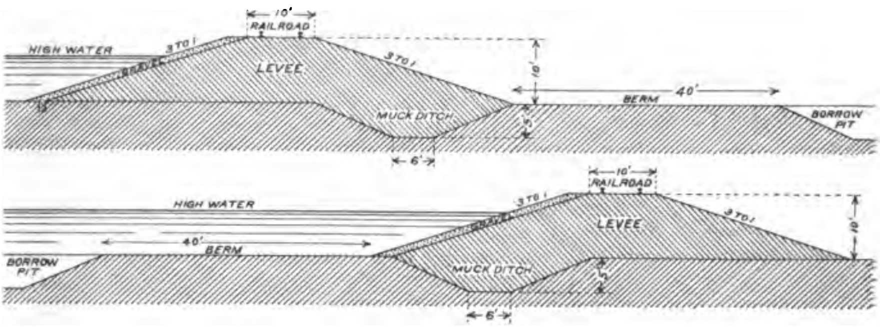


FIG. 5.—Cross sections of levee on Colorado River.

It is not expected that there will be any trouble in making the levee stand high water. The only danger is the erosion of the river banks, which might undermine the levees. This is one of the reasons that the ordinary practice in levee construction of placing the borrow pits on the river side of the levee was not followed throughout.

PROBABLE OWNERSHIP OF IRRIGATION SYSTEM BY THE PEOPLE.

The President's message sent to Congress January 12, while the work on the river was in progress, recommended an appropriation of $2,000,000 to turn the river and to construct the necessary levees for its permanent control. The message pointed out that the Southern Pacific Company, through its equipment, transportation facilities, and control of the California Development Company, was the only agency that could control the river, and that the amount to be paid them for the work then in progress was a matter for future consideration. It recommended that after the river was turned the Government take charge of the protective works and complete and maintain them. The message recommended that the problem be considered one of reclamation rather than river control, and that the work be done by the Reclamation Service. The message recommended also that the Reclamation Service be authorized to construct an irrigation project in Imperial Valley under the terms of the reclamation act; that the money for such construction be not taken from the Reclamation funds, but that a special appropriation be made for the purpose. It was recommended that the Government acquire the rights of the California Development Company and of the mutual water companies, also that the necessary permission be obtained from Mexico to carry water through that country.

A bill embodying the recommendations of the message was introduced in Congress. It provided first for the construction of a reclamation project in Imperial Valley and for the construction of any necessary storage reservoirs in connection with the project subject to the provisions of the national reclamation act and for the construction of the necessary works in Mexico to prevent Colorado River overflowing its banks and inundating lands in the United States; second, for an appropriation of $2,000,000 for the works to prevent the overflow of the river, and for the reimbursement of the Southern Pacific Company for money expended in turning the river; third; that no construction be undertaken in Mexico until rights have been secured from that country for the works to control the river and for a canal to carry water into the United States as a part of the proposed reclamation project; fourth, that the money expended for protective works and their maintenance be included in the cost of the Imperial Valley project and be repaid, according to the provisions of the reclamation law. This bill passed the Senate, but failed to pass the House.

River control was urgent but was joined with measures not requiring immediate action. The water users did not object to the discrimination between the work on the Colorado River and that on other rivers in regard to refunding the money expended to the Treasury, because they realized that the mischief was the result of negligence by a company with which they had allied themselves. The settlers, however, were not responsible and were the ones that suffered from the result.

The situation has now changed, for with the Southern Pacific management of the development company they neither doubt the company's ability to furnish the necessary funds for the extension of the irrigation system over the entire valley nor the intention of its officers to do so.

There are two ways in which the valley can be entirely developed and the ownership of the entire irrigation system placed in the hands of the people. One is by the construction of a reclamation project by the Government and its acquisition of the present canal system; the other is by the completion of the canal system already begun by the Southern Pacific Company and by the purchase of the system by the people. In either case it merely amounts to the people being granted a loan.

The most economical system for the valley will be one in which all lands are irrigated by one system. The plans for the Imperial irrigation system and the filings for water were made with a view to the reclamation of all irrigable land in the valley and the new head gate and canal have been constructed with sufficient capacity to carry out these plans.

EXTENSIONS AND IMPROVEMENTS.

When the river was turned back to its old channel in November plans were made for many improvements and extensions in the canal system of the valley. The reconstruction to again supply water to Imperial Water companies Nos. 6 and 8 was already begun, but when the levees broke in December the contractors transferred their forces to the more urgent work on the river. Now that the river is again under control the reconstruction in the valley is being resumed.

A new canal is being constructed for the country west of New River, including districts Nos. 6 and 8. Its route is shown on the map, Plate I, p. 6. The canal is to cross New River by flume in Mexico and will run northward west of district No. 6 and to district No. 8. The territory lying between districts Nos. 6 and 8 will be the district of Imperial Water Company No. 9, which has just been organized, or will be an addition to Imperial Water Company No. 6. The canal will be constructed with a capacity to supply 25,000 acres, but it will be enlarged later as the demand for water increases with settlement.

Imperial Water Company No. 2, which was organized several years ago for a territory north of district No. 4 and between New and Alamo rivers, but which did not have its distributing system constructed, has now been added to Imperial Water Company No. 4. The distributing system for about 6,500 acres is expected to be finished within a year.

A few years ago surveys were made for a canal to cover the undeveloped strip of land on the east side of the valley and such a canal will no doubt eventually be built. This strip extends from near Holtville to and beyond Imperial Junction and lies between the No. 5 main canal and the mesa at the south and between Alamo River and the mountains at the north. It will add about 100,000 acres to the reclaimed area. The location has been made for a new canal to supply Imperial Water Company No. 4 in place of the Brawley main canal. The new canal will take water from the Alamo below Holtville, where a diversion dam will be constructed, and will follow the general course of the Rose Lateral in district No. 1 to the southwest corner of No. 4. There is a possibility of the territory northeast of this canal, which is the country around Mesquit Lake, being separated from district No. 1 and added to district No. 4.

It is the intention to replace all wooden structures at important points on the main canals with cement structures of the most permanent character and to greatly improve the smaller wooden structures. Structures for the accurate measurement of water are to be placed at all points of delivery where automatic registers of gage heights are to be installed. It is the intention to make the system second to none, either public or private.

The channels cut in New and Alamo rivers by the flood are of inestimable value as drainage mains for the valley. The flow of the rivers increases materially through the valley and the salty water is an indication of the effect they will have on the lands in removing alkali.

SUBJECTS FOR INVESTIGATION.

Imperial Valley offers a most interesting field for the study of the problems of irrigation. Its importance lies in the fact that the country is large and is still in a stage of development, in its having conditions peculiar to itself, in the possibility of growing a great variety of crops, and in the present lack of data. The growing season is practically twelve months in duration and this, together with the fertile soil and hot climate, is conducive to exceptional yields. It has already been proved that an unusually large variety of crops and industries are profitable in the valley, and that a few crops are unsuited to it, but the limitations are not known.

Irrigation in a country like the valley is such a large factor in the growing of crops that nearly all problems are largely, if not entirely, ones of irrigation. The problems are not those of contention with objectionable features, but rather of the improvement of already satisfying results. The conditions in the valley are unlike those of any other irrigated district in this country. The only places with problems in any degree similar are in Arizona. It follows that the results of studies elsewhere can not be applied to the valley. The data on all subjects pertaining to the use of water are yet meager. When the companies were organized it was necessary to assume what the requirements for water would be as a basis for contracts. There was no knowledge of what the loss by seepage and evaporation would be, and there is practically no reliable data on this subject yet aside from the results of measurements made in 1903.

The subject of the proper quantity of water to apply in growing any crops is one of importance. The tendency is to use more water than is necessary because it is cheap and plentiful. It is believed that often as good or better results would be obtained if less water were used, and continued overirrigation can in the long run only be disastrous. Even though no effect is shown on the plant from over-irrigation, it may be harmful to the soil.

There is not yet any well-defined practice in the methods of applying water. A certain amount of water applied in the proper manner and at the right time may be more beneficial than many times that amount improperly applied. Closely connected with the quantity of water to use and the methods of applying it is the study of soil moisture. It too often happens that irrigators do not study the condition of the soil enough as regards the moisture contained. Water is sometimes applied when the appearances on the surface indicating its necessity are misleading. Water should be applied in such a manner that the moisture is conserved and it should be put in the proper place. The effect on crop production of applying different amounts of water by the different methods should be studied, together with a study of the action of the water in the soil.

The amount of silt deposited on lands in the valley by the water used in irrigation should be determined. Some data is available showing the percentage carried by the Colorado River, but the amount reaching lands in the valley should be known. The silt may not be beneficial on land that is never cultivated, but if it is mixed with the soil it should be valuable as a fertilizer. This value should be ascertained. There is another phase of the silt problem. There is need for improved methods in removing the deposits of silt from the ditches, together with vegetable growth which it promotes. The water companies are now making considerable advance in this direction.

Any light that can be thrown on the question of the most practical and accurate method of water measurement for the valley should be of value.

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