REPORT ON THE IRRIGATION OF LANDS IN CALIFORNIA AND MEXICO FROM THE COLORADO RIVER, BY THE IMPERIAL CANAL SYSTEMS, THE PROPERTY OF THE CALIFORNIA DEVELOPMENT COMPANY.

by

James D. Schuyler,

Consulting Hydraulic Engineer.

Los Angeles, Cal:, May 1906.

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JAMES D. SCHUYLER
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Authority.

The following report has been prepared at the request of the California Development co. for the purpose of summarizing the results of its work of reclaiming the desert to date; the problems which have been met and solved, and the work yet to be carried out to complete the development undertaken; together with such an expression of opinion from an engineering standpoint as to the future outlook as will convey to those interested or to become interested in the affairs of the Company a clearer conception of the actual physical and financial situation. It is based upon the personal observations of the writer during various visits to the scene of operations within the past two years, and upon the records and surveys of the Company which have been placed at his disposal; the statements of the Chief Engineer, Mr. C. R. Rockwood, during

frequent interviews, and the information gathered from various other officers of the Company, as well as from residents of the valley; from the records of the U. S. Geological Survey, and various other sources of information available.

Location and Topographic Conditions.

The Colorado River, draining an area of 225,000 square miles of territory whose geological formation has rendered it peculiarly susceptible to erosion, carries an unusually large percentage of silt, possibly greater than any other river in the world. It is never clear and limpid like many other silt bearing streams are at certain times, but is always murky, muddy and laden with sediment. This has resulted in building up a delta at its mouth covering many hundreds of thousands of acres of rich, arable, alluvial lands.

The Gulf of California, into which the river discharges, at some remote period undoubtedly extended 130 to 140 miles further to the northwest than its present head, reaching some distance beyond the station of Indio. The river, in the course of ages, by the deposit of silt, built up a bar across the Gulf, the crest of which extended from a point a few miles below Yuma, in a southwesterly direction to the Cocopah Mountains. The elevation of this bar is about 90 feet above sea level at the river, and about 30 feet at the lower end, next to the mountains, and the Paredones River lies upon its summit, and slops over in both directions south and north. The arm of the Gulf, thus cut off by this bar from direct connection with the ocean,, formed an inland lake until finally dried up by evaporation, leaving a

basin whose lowest point is now 287 feet below sea level. The shallow salt pond which has hitherto been maintained for considerable periods at this low level by drainage from the surrounding mountain and valley watersheds, and by occasional overflow from the river, is known as Salton Sink and is about 40 miles long and 5 to 8 miles wide. This basin receiving the surface run-off and seepage from all the surrounding lands that were once submerged with salt water, became a receptacle for the salt which had leached out of the soil and was deposited through the process of evaporation. It is sometimes entirely dry.

The Paredones river takes a portion of the overflow of the Colorado and terminates in Volcano Lake. This lake is a shallow summit pond at the foot of the Cocopah mountains, about 8 miles long in a N. W. and S. E. direction, by 3 miles wide, with a depth of about 10 feet. Since 1890 it has almost every year overflowed into New River, on the north, although the greater portion continues through Hardy's Colorado flowing directly south and southeast to the Gulf. All water leaving the lake on the north side flows northwesterly by the New River channel, crossing into the U. S. at Calexico, and discharges into the Salton Basin. This natural overflow July 10, 1903, measured 2678 sec-ft. above the boundary line.

At the International boundary the elevation of the general surface of the ground is precisely at mean sea level. The distance by New River from the border to Salton Basin is about 55 miles, and

the average fall of the stream about 4.5 feet per mile, although this fall is not uniform, but is largely concentrated to a section of a few miles of heavy fall that is rapidly retreating up stream by erosion.

Between the Paredones river and the American boundary the original and older overflow channel, called the Alamo, occupies a depression at the foot of a series of sand hills on the north side of the valley. This channel was never directly connected with the Colorado river, at least in recent years, but received water from a series of sloughs draining from a slop-over territory of several thousand acres in Algodones Rancho, bordering along the Colorado river for some 10 or 12 miles below the intersection of the boundary with the river at Hanlons. This channel extends to the Salton Basin through the Imperial Valley, and for the lower 20 miles lies parallel with New River, and only one or two miles away. The Alamo channel is the one which has been utilized by the California Development Company as a main canal through Mexico as far as Sharps Heading, where the excavated canals begin, and diverge in several directions, as shown upon the map.

The area of arable land in the United States which can be profitably irrigated from this main canal has not been absolutely determined, but it is approximately estimated at 500,000 acres.

The area which may be brought under irrigation in Mexico from the same system, by proper protection from overflow through the construction of levees and drainage canals, is estimated to equal

or exceed the area irrigable in the U. S., and of a quality quite as fertile.

The total territory to be commanded by the Complete system is therefore about 1,000,000 acres, all of an alluvial formation in many ways resembling the valley of the Nile. It is this empire in embryo which the California Development Co. has undertaken to develop by providing the facilities for irrigation.

Water Supply.

The gagings of the discharge of the Colorado River at Yuma by the U. S. geological Survey do not extend further back than from 1902, when the records begin. They show the following monthly discharges in that period.

Month:	Discharge in acre-feet.				
	1902	1903	1904	1905	1906
Jany.	229,164	189,935	223,507	499,900	422,380
Feby.	219,650	187,271	218,406	1,560,384	
March	301,474	376,120	367,573	3,107,442	
April	367,676	852,456	479,484	2,250,619	
May	2,211,156	2,074,284	1,703,022	2,593,024	
June	2,530,115	3,162,626	2,607,114	4,550,471	
July	770,255	2,304,494	1,417,105	1,863,720	
Augt.	257,203	668,309	1,054,143	744,111	
Sept.	227,246	403,795	691,497	386,456	
Oct.	264,335	521,538	715,839	494,190	
Nov.	249,144	321,263	366,009	713,990	
Dec.	332,771	267,041	275,305	946,790	
Totals:	7,960,189	11,329,032	10,119,004	19,711,067	

A careful inspection of this table shows a volume of water sufficient for the full irrigation of nearly two million acres in the minimum year of 1902, at the rate of 4 acre-feet per annum per acre, provided it could all be utilized. The two months of highest flood during that year, May and June, and in every subsequent year so greatly exceeded the capacity of any feasible canal system that

has ever been considered or is likely to be projected as to indicate that nearly one half the total flow of minimum years must inevitably be wasted. The remainder, however, could supply the stated quotum of 4 acre-feet to 1,000,000 acres.

The California development Company has filed and recorded an appropriation of 10,000 cubic-feet per second, under the laws of California, and this takes precedent to the appropriations subsequently filed by the U. S. Reclamation Service engineers for the Yuma project. The Company has observed "due diligence" in maintaining work upon their canal to effect an actual appropriation of water to the full extent of its ultimate use and need, when the entire area commanded by the projected system shall have been brought under irrigation.

Mexico is undoubtedly entitled to one half of the entire flow, if it shall become her policy to devote the river to agriculture for which it is most valuable, rather than to navigation, for which it is practically useless.

RECLAMATION OF THE GREAT DESERT.

The possibility of reclaiming the vast areas of desert alluvial lands in California, as well as below the boundary in Mexico, has long been a dream with many of the bolder pioneers of the West who were familiar with that region and had faith in its ultimate future. The first organized attempts to study the problem and secure capital for the work were made by a corporation called the Colorado River Irrigation Company, which was promoted by a man named Beatty from Denver. After making extensive surveys

extending over a period of two years the project finally failed in 1893. It was then taken up by Mr. C. R. Rockwood who had been employed as Chief Engineer of the Company and had become thoroughly familiar with the situation. He succeeded in interesting a few friends and in April 1896 organized the California Development Company under the laws of New Jersey for the purpose of continuing the enterprise. The capital stock of this Company was fixed at $1,250,000, divided into 12,500 shares of the par value of $100 each. The rights of the original Colorado River Irrigation Company were acquired and the exploiting of the country was resumed by the prosecution of further surveys, the sinking of wells for supplying water to the surveying camps, and the general study of topographic and hydrographic conditions. A resurvey of the lines of Government subdivisions of land was under taken in April 1900 over several hundred thousand acres in the U. S. and levels were run on these lines. These levels were essential for developing the topography, the slope and configuration of the surface, and the gradients available for canals, to determine the irrigable area, and the general plan of distribution necessary, before a system of irrigation could be planned. Some years were occupied in this work and the search for capital with sufficient faith to begin actual construction.

The surveys developed the fact that water could not be delivered from the river to the lands in what is now known as the Imperial Valley without conveying them through Mexico. A high range of sand hills projected across the border into

Mexico, and to get through them north of the International boundary would have necessitated a tunnel not less than 15 miles long. This sort of a construction for a canal of the size needed was simply impracticable, and unless the consent of Mexico could be obtained for carrying the water through the territory the enterprise could not be made possible.

It became desirable therefore to acquire a substantial interest in Mexican lands and couple the development of these lands with those north of the border to secure the necessary co-operation and consent of the Mexican Government to such use of her territory. It was ascertained that General Guilliermo Andrade, then Mexican Consul in Los Angeles, was owner of a concession or grant from the Mexican Government covering a large portion of the alluvial lands of the valley, and a contract was entered into with him for the purchase of a strip along the boundary of 100,000 acres, extending from the river to a point four miles west of the present town of Calexico, including the Rancho Algodones lying along the river for some 10 or 12 miles. The sand hills, or worthless lands adjacent to the boundary were excluded from this area, and the southern line of the tract fixed far enough south to embrace 100,000 acres of arable lands outside the sand dunes. The purchase of this tract was ultimately concluded, and the land now belongs to the Company, with the exception of about 20,000 acres sold off at the west side. The main canal in Mexico is almost entirely within the bounds of this tract.

To exploit these lands, and secure a concession of water rights from the Colorado River to irrigate them, and to take possession and control of the water for use in the U. S. a

corporation was formed under the laws of the Republic of Mexico called "La Sociedad de Yrrigacion y Terrenos de la Baja California, (Sociedad Anomima)". This Company has a capital stock of $62,500, all of which is owned by the California Development Company. It maintains an office in Mexicali and a legal representative in the City of Mexico. The Secretary of the Company is a citizen of Mexico residing in Los Angeles. A concession was secured from the Mexican Government granting the "Socieded" the right to divert water from the Colorado river in Mexican territory to the extent of 10,000 cubic feet per second, and to deliver one half of it across the line into the United States.

This Mexican Company also taked the water delivered to it by the California Development Company at the boundary line near the Upper Heading, 10 miles below Yuma, and distributes it to the Mutual Water Companies of Imperial Valley at the International boundary, where it re-enters the U. S.

Beginning of Construction.

The effort to secure in advance all the capital needed to prosecute the works to completion was not successful, but a beginning having been made, Mutual Water Companies were projected and from the proceeds of the sale of shares in the initial Company, viz: Imperial Water Company No. 1, the necessary money was procured for the prosecution of the work. The first essential was to get a channel opened which would divert water over the divide separating the Colorado River from the natural drainage lines or channels leading into Salton Sink. Water would frequently slop over this divide in times of extraordinary freshets, and it was found to be only necessary to dig about 8 miles of canal from Hanlons to deliver water

to where it would ultimately get into the Alamo river - a channel which was always dry except in extreme floods. A dredging machine was built and began at Hanlons, or immediately above the boundary, excavating a shallow canal, 4 to 6 feet deep, 40 feet wide. By June of 1901, this work of dredging had reached a point about 7 miles below the heading, where the water following the dredge began to spread out over low flat country, and thence found its way ahead of the excavation by various sloughs into the Alamo channel. From there it followed a somewhat tortuous course, between well defined banks to the Imperial Valley, but could not return to the river. The object sought was to make a beginning as cheaply as possible and demonstrate the capabilities of the soil, conveying the water by any route or method, regardless of waste or loss, leaving the future to develop the refinement of canal construction.

The water on reaching a point called Sharps, which is some 7 miles east of Calexico, was first carried thence on toward Calexico by a temporary ditch, prior to the building of the Main Canal. With this irrigation began June 15, 1901. About 1500 acres of corn, sorghum and barley were planted that summer, yielding in a satisfactory manner, and proving that the desert lands would respond abundantly to the application of water.

Formation of Mutual Water Companies.

At the beginning of the organization for this development it was wisely decided that the Company would not undertake to retail the water to the individual land owners, but would only sell at wholesale to Mutual Water Companies organized to distribute the same over the various natural districts to be supplied. The first district so

organized, called Imperial Water Company No. 1 covers all the land lying between the Alamo on the East and the New River on the West, and from the Mexican boundary North a distance of 19 miles, covering an area of about 160,000 acres in all, of which about 130,000 acres are irrigable. It was incorporated Sept. 25, 1900, with a capital stock of $1,000,000, divided into 100,000 shares, of the par value of $10 each. The number of shares in all of the Mutual Companies is made to correspond to the area which is considered to be irrigable in the district at the rate of one share to each acre. At the time this Company was organized the waste land in sand hills and in lake beds was over-extimated, and as a consequence there are now found to be about 30,000 acres of good arable land without water stock, and hence without the right to have water for irrigation. To provide these lands with water it will be necessary to increase the capital stock of the Company.

By the terms of the agreement made with the California Development Company all of the stock of the Mutual Water Companies is the property of the Cal. Development Co. and the proceeds of the sale of this stock is impliedly to be used, first, for the construction of the canal system of distribution and regulation before any other disposition is made of it.

As work proceeded on the main canal the shares sold rapidly at $8.75 an acre, the price at which they were first offered, and it was apparent that no outside capital would be needed if this favorable condition could be maintained. As the shares were sold with deferred payments, and their full value was not realized in cash, and as construction was proceeding actively in many directions, it became necessary to obtain more money and it was decided to issue $500,000 in bonds of the

California Development Company, which were sold partly for cash and partly as a bonus to facilitate cash purchases of stock. These bonds to the amount of $485,000 are still outstanding.

In Sept. 1901, after the water had actually been applied to a part of District No. 1, the price of its water stock was advanced to $15 per share, and in June 1904 it reached $20 per share, which is still the prevailing price for all water stock in the valley.

The entire issue of 100,000 shares in No. 1 was practically exhausted in 1903 up to 98,000 shares, at which it still remains. During the winter of 1901-'02, about 3000 acres were put under cultivation, and the summer crops of 1902, consisting of sorghum, Kaffir corn and alfalfa, covered about 12,000 acres.

Contracts with the Mexican and American Parent Companies.

The stockholders of the Mutual Water Companies are secured by joint contract between their Companies, the California Development Co. and the Sociedad de Yrrigacion y Terrenos, etc., by which the two latter Companies agree to deliver the water at the International boundary line, in amount not to exceed four acre-feet per annum for each acre or share in the Mutual Company, at the price of 50 cents per acre-foot, and the Mutual Water Companies agree to receive and pay for not less than 1 acre-foot of water for each share of their stock outstanding upon the first day of July of each year. The Development Company agrees to construct a system of distributing ditches in such manner as to convey the water from the main canal to a point upon each Governmental subdivision of 160 acres from which it is practicable to irrigate the same by gravity; an allowance of 10% for loss by seepage and evaporation to be added to the stipulated amount of delivery at the International boundary.

Since 1903 development has steadily progressed in District No. 1 until the area at present irrigated has reached to about 75,000 acres. The headquarters of Imperial Water Co. No. 1 are in Imperial, a town of 1000 people. The district contains the villages of Calexico, El Centro, Silsbee and Heber.

District No. 2 was organized in the fall of 1900 to cover the strip of land between the Alamo and New River, beyond the boundaries of the original District No. 1, but no distributing system has been built and no further attempt made to develop the territory at present. It will probably be annexed to and absorbed by Imperial Water Co. No. 4.

District No. 3 was organized in 1900, but was never located, and died still born.

District No. 4 was organized in March 1901 out of the North end of the original District No. 1, covering 17,500 shares. The organization was made by J. H. Braly and Andrew Chaffey of Los Angeles under an arrangement by which they were permitted to construct the distributing system, under the supervision of the Engineers of the C. D. Co. The system has recently been practically remodelled and reconstructed and is now in excellent condition. The total shares issued in No. 4 are 16,135 in number, and the area actually irrigated is about 12,000 acres. It receives water from the North end of Main Canal No. 1, 29.8 miles from Sharps Heading on the Alamo.

Imperial Water Co. No. 5 was organized in July 1901, by Geo. W. Bothwell, with 100,000 shares, of which 35,633 shares have been sold. The district irrigated by the Company lies east of the Alamo River

and north of District No. 7. The area at present irrigated is about 20,000 acres.

Imperial Water Co. No. 6 was organized by A. H. Heber, about May 1901, with 20,000 shares, of which 11,626 have been issued. The District lies west of New River, from the International boundary northward. It is watered from the Encina and Wisteria Canals, and has about 3,000 acres under cultivation.

Imperial Water Co. No. 7 was formed by W. F. Holt to irrigate a district of 17,138 acres, the number of shares in the Company being placed at 20,000, of which 13,741 have been issued. It is served by the Holt canal leading from the Alamo at Sharps heading. The area irrigated in 1904 was 7,000 acres, and has greatly increased since that time.

Imperial Water Co. No. 8 was organized in the fall of 1903, for the irrigation of 40,000 acres of the district west of New River north of Superstition Mountain. Of the total number of shares represented in the Company 26,000 have been issued. There are about 7,000 acres actually irrigated with about 55 families resident on the land, but the water supply has been interrupted by various causes, which will be discussed further on, and the affairs of the District are in a dubious and uncertain condition.

Recapitulation.

District.	Shares organized.	Shares issued.	Approximate area irrigated.
No. 1	100,000	98,000	75,000
No. 4	17,000	16,135	12,000
No. 5	100,000	35,633	20,000
No. 6	20,000	11,026	3,000
No. 7	20,000	13,741	10,000
No. 8	40,000	26,000	7,000
Totals	297,500	200,535	127,000

All of these Mutual Water Companies are regularly incorporated, with a President, a Board of Directors, a Salaried Superintendent, and Zanjeros or Ditch tenders, who maintain the distributing laterals, and keep the system in repair. The Companies receive their water at certain fixed points of delivery where it is measured daily and recorded by the Zanjeros of the Development Co.

After the completion of the distribution system in any district and its acceptance by the officers of the Mutual Water Company in that district the expense of maintenance of the system is thereafter borne by the subsidiary Company. The Development Company is obliged to construct, repair and maintain its main canals and lateral headgates in good order and to be prepared to deliver the quantity of water called for at a rate not to exceed four acre-feet within a period of 12 months although the laterals are made of sufficient capacity to deliver two-thirds of an acre-foot per month.

The minimum revenue which the Development Company receives for water is fifty cents per acre-foot per annum for each share of stock issued by the Mutual Water Companies, and the Officers of the latter are obliged to collect and turn over to the Development Co. this amount of money annually. If the total amount of water delivered exceeds one acre-foot for each share of stock the excess must

be paid for at the same rate.

The Mutual Companies make two assessments on its stockholders each year, to cover the water rentals and the cost of maintenance, cleaning of ditches, etc.

In District No. 1 the highest cost of maintenance has been 50 cents per acre per annum. The assessment of the first half of 1906 was 12-1/2 cents per share on the 98,000 shares issued. This covers all cost of administration, division of water, cleaning of ditches and repairs to gates and other structures.

In District No. 4 the assessment for 1905 was 70 cents per share for maintenance, exclusive of water rental.

In the other Districts the annual assessments for maintenance have been about 50 cents per acre. The cost of irrigation in the valley therefore appears to have been very moderate and the expense of keeping the ditches in working order and clear of silt, which has always been regarded as an almost insuperable obstacle, is no greater than in other well established irrigation districts of the West.

The general plan of the organization of the California Development Company in its sale of water-rights and water at wholesale to subsidiary water companies appears to be an admirable one, devoid of the vicissitudes which have wrecked so many irrigation enterprises. By this means the California Dev. Co. is relieved from any interference as to the fixing of water rates by the County Board of Supervisors, to whom the law delegates the right of establishing rates at which all water is sold at retail. The Mutual Water Companies purchase at wholesale from the Mexican Company and fix their own water

rates to suit themselves. The Mutual Companies must pay for water, or have their supply shut off by the Mexican Corporation.

The points of delivery where water is measured are as follows:-

1. Acacia
2. Alamitos
3. Ash
4. Boundary
5. Birch
6. Beech
7. Bay
8. Dogwood
9. Date
10. Dahlia
11. Evergreen
12. Old Style Ditch
13. Eucalyptus
14. Elder
15. Rice
16. Daisy
17. New Side Ditch
18. Lilac
19. Lavendar
20. Dandelion
21. Rose
22. Redwood

Dist. No. 2. At end of Main Canal, at S. W. Cor. of District.

Dist. No. 5. In #5 main, at Boundary heading.

Dist. No. 6. In Encina and Wisteria laterals at boundary.

Dist. No. 7. In Holt and Hemlock laterals at boundary.

Dist. No. 8. In Main Canal at headgate on New River.

In Mexico the California-Mexico Land & Cattle Company receive water at two points of measurement in the Boundary and Encina Canals.

There are also 15 or more individual irrigators in Mexico who take water at separate points of measurement.

The measurements are made either through orifices under pressure, or over weirs, and in conformity to printed instructions by which all janzeros are guided in filling out their daily reports. The farmers and zanjeros of the Mutual Companies are able to check these measurements and are given tables with which they may make their own computations of output to each lateral. A sufficient uniformity and exactness is attainable by those methods to make a satisfactory distribution, even though the measurements may be lacking in scientific precision. No fault has been found with these

methods or the results, and no disputes have arisen over water measurements.

The records of measurements kept at Calexico for the past two years since the system of measuring water was fully inaugurated, show a total distribution in 11 months of 1904, (no measurement in January) of 282,709 acre-feet, and in 12 months of 1906, of 204,071 acre-feet. The amounts used in each district are as follows:-

	11 mos.1904 Acre-feet	1905. Acre-feet.	1st 3 mos. 1906. Acre-feet.
District No. 1.	116,858	105,958	35,747
District No. 4	25,600	23,000	8,247
District No. 5	39,708	35,332	16,830
District No. 6	965	4,812	1,658
District No. 7	24,240	17,592	5,391
District No. 8	23,834	4,233	-----
Mexican irrigators	1,504	13,144	3,139
	282,709	204,071	71,012

The reduced consumption in 1905 as compared with the preceding year was chiefly due to heavy rains in Feby. and March, which rendered irrigation unnecessary, and to the fact that no charge was made to No. 8 after May 1905 owing to interruption in service.

The use of water is continuous throughout every month of the year, but varying in quantity with climatic variations. This is to be expected in a desert region, where two crops a year are produced and where all domestic and stock water must come from the canal systems. Grain crops require much less water than alfalfa, which is expected to need the full quotum

of 4 acre-feet per annum. The sowing of alfalfa is increasing very rapidly - twenty thousand acres having been added the past year. As this is the most productive and profitable crop that can be grown it is certain to predominate and create a maximum demand upon the system, and consequently a maximum revenue for the Company, when confidence is restored and the water supply is brought under absolute control.

THE CANAL SYSTEM.

The main canals have been planned with the following capacities:-

Main No. 1, supplying Districts 1 & 4	1250	sec-ft.
" " 5, " " 5	1000	"
Wisteria " " 6	154	"
Holt and Hemlock supplying district 7	128	"
Main Canal, supplying district No. 8	300	"
Total	2832	"

These capacities appear to be ample except the main for No. 5, which will need to be greatly increased from the head of the Holt Power Canal through the district, although from the boundary to the point of division of the water with the Power Canal its present capacity is about 1000 sec-feet.

Districts Nos. 2 and 4 will ultimately be supplied through the Main Canal which supplies No. 5, as far as the division gate at the head of the power canal near Holtville, together with the water for the New Rose lateral in District No. 1. This water will all pass through a Power House which has been built at Holtville with an effective drop of about 55 feet. To produce 3000 H. P. gross, or 2000 H. P. net, for which floor space in the power house has been provided, will require 500 sec-ft. of water - which is about what may ultimately be needed for districts 2 and 4, and the territory supplied by the Rose.

The distribution system of canals varies in capacity from about six sec-ft., which is the smallest size used for individual farm laterals, not over half a mile in length, to 120 sec-ft. - the dimensions varying of course with the area to be supplied by each.

These laterals are commonly made to follow the section lines, either in a northerly direction, or to the east and west, as the contour of the land requires. The slope of the valley is generally favorable for the easy distribution of water, varying from 5 to 20 feet per mile.

The Mileage of canals already constructed is estimated by Mr. C. N. Perry, Res't Engineer, as follows:-

Water Co. No.	1	307.25 miles
" " "	4	33.25 "
" " "	5	134.04 "
" " "	6	20.00 "
" " "	7	36.40 "
" " "	8 (by map)	80.50 "
In Mexico		40.70 "
		652.15 "

Construction Features.

The history of the construction of these works is one of a constant struggle to accomplish results under adverse conditions, always with an insufficient fund of capital to draw upon, and handicapped by much bad judgment and unwise decisions on most important matters, not to speak of the fraudulent mismanagement and peculation which have been publicly alleged. Some engineering mistakes have also been made, as is inevitable in all such large enterprises at

the outset, due to the haste with which unforeseen emergencies have to be met and important constructions often times have to be planned and rushed to completion.

During the first three years after irrigation began the struggle was to keep water in the main canal in sufficient amount to supply the demand. The original headgate in the main canal at Hanlons was not placed at sufficiently low elevation to draw at the low stage the quantity of water required to keep the canal full, and silt accumulated so rapidly as to cut down the canal capacity. Dredging was constantly maintained in an attempt to keep up the full supply needed for irrigation, first, by deepening the canal for the first eight miles from the river down and subsequently by widening it to 80 feet from the original cut of 40 feet. The deficiency in the capacity of the headgate was overcome by dredging a deeper channel around the gate, but the widening of the canal for the first mile produced a deposit of sand in that section by a reduction of velocity, and this had the effect of cutting down the discharge and creating the shortage and loss of crops which gave rise to serious complaints and claims for damages in 1903.

Upper Mexican Intake.

In the spring of 1904 a second intake from the river was dredged out from the main canal immediately below the International boundary, through which for a time practically all the water was drawn. This intake was not provided with a headgate and has since remained open until it was recently closed by natural silt deposit to the extent

that no water will pass through when the river is at low stage.

Lower Mexican Intake.

In the summer of 1904 the shortage of water became so considerable that a second cut into the river was decided upon as necessary to give the water required for the seasons irrigation. This was located four miles below the headgate, and was 3300 feet in length. It was made 50 feet wide and 6 feet deep and went into the river at right angles to its normal course, at a point where the stream divided into two channels around an inlet or bar, about one mile in length. The intersection was somewhat below the center of the island. The grade of the river being less than that of the canal the fall received by this difference was available for giving increased velocity to the new intake. This sufficed to keep the channel clear of silt, and give the requisite amount of water. All previous troubles with silt seemed to have been solved by this work, and the outlook for a water supply appeared to be brilliant and encouraging. A controlling gate was planned for this canal, 60 feet wide, and preparations were begun for its construction, but before it could be erected, or before its construction was commenced, a sudden rise in the river resulted in a rapid enlargement of the cut until it carried a greatly increased volume, largely in excess of what was needed for irrigation. This occurred in the Spring of 1905. The excess began to fill up the Salton Sink, flood out the salt works of the Liverpool Salt Co. and encroach upon the Southern Pacific R. R. tracks in the margin of the Sink. The enlargement continued notwithstanding all efforts by the Southern Pacific and the California Development Co. to divert it, and return the stream to its original channel, until the entire river

had changed its course and was discharging through the Alamo and New River channels into the Salton Basin. This has continued without interruption to the present time, causing great damage to the Southern Pacific R. R. Co. compelling the rebuilding of the roadbed for more than forty miles, and placing the entire property of the Development Company and the interests of the settlers in the valley in greatest jeopardy.

The several efforts to build dams of piles, brush and earth across the stream to divert it to its old channel having failed, the measures now under way and which give greater promise of success are as follows:-

First: the construction of a gate 200 feet long, 26 feet high at the junction of the lower intake cut with the main canal. This gate is placed with its floor 11 feet below the surface of the river at low water, and when it is completed a large part of the normal flow will go through it naturally without compulsion. This division of the stream will reduce the velocity in the channel outside the gate, and less resistence will thereby be offered to piles, brush and sand bags to be placed in this channel than was encountered at the previous attempts to divert the stream where the level had to be raised four to six feet to effect a complete diversion. With any discharge less than 20,000 sec.ft.the river can probably be successfully turned through this gate with a head not to exceed two feet. At the present writing the gate is near completion, and should the discharge fall below the limiting volume for a few weeks the river may again be brought under control. With the entire volume passing through the gate until the dam is made strong enough to resist

the water pressure it will then be a question merely of placing sufficient flash boards in the gate to keep all the water (not required to pass down the canal for irrigation) in the river.

Second: If, by any accident, or misfortune, this gate should be washed out and destroyed, reliance must then be placed on diversion of the river through the permanent re-inforced concrete gate being built on a solid rock foundation about 800 feet north of the International boundary. This consists of 11 openings 12 feet wide, 10 feet high, closed by radial steel gates, the floor of which is at elevation 98 feet above sea level, or 12 feet below ordinary low water. This structure is expected to be completed in the month of May. With the canal enlarged to full capacity for four miles below to the lower intake the gate is estimated to carry 6000 sec-ft. which is in excess of the normal flow water discharge of the river. With 3 feet rise above low water the gate will discharge 15,000 sec-ft. It will not be possible to enlarge the canal to the required capacity before November 1906, or later, on account of the length of time required to erect a special dredge for that purpose, but this is a sure and infallible resource when the canal is thus enlarged and the river has reached a moderately low stage.

Meantime the enormous volume of water going through the Alamo to Sharps Heading is straining the waste gates at that point to their utmost capacity, and causing great anxiety lest they be washed away. Should this occur the valley would be out of water until the gates could be rebuilt and normal conditions restored - an occurrence which would be disastrous to all concerned - the people as well as the

Company. Thus far the only real damage to the irrigated lands which has been caused by the break at the river is the flooding of some 5000 acres of crops by the overflow of New River channel on either side of the International boundary.

PROBLEM SOLVED.

Looking at the system broadly and in perspective after an intimate inspection of its details the writer has been impressed with the fact that many discouraging and doubtful problems have been solved by the experience which has been had to date, some of which were new, and looked upon with pessimism by many.

These problems were advanced in about the following order:

First, the problem of disposal of silt.

Second, the alkali question.

Third, the question as to whether the people could be induced to take up lands and buy water rights under the system, promptly and in sufficient numbers to make a success of the project.

Fourth, the problem as to whether the climatic conditions would admit of continuous residence on the lands.

Fifth, The problem of the productiveness of the soil under irrigation, and the crops that might ne grown profitably.

Sixth, the feasibility of establishing sufficient drainage not only for storm waters, but for surplus water of irrigation, and seepage or return water due to irrigation.

Seventh, the problem as to the size of canals required to deliver water, the probable amount of influence of friction in the

soils of that section upon their capacity and the probable losses to be anticipated from seepage and evaporation.

Eighth, Transportation.

Ninth, The attitude of the U. S. Govt. and the Govt. of Mexico toward any project for absorbing a so-called navigable stream.

DISCUSSION OF PROBLEMS.

First, the silt problem. The disposal of silt on this river has caused more discussion among engineers and laymen and given rise to more impracticable suggestions and wild ideas than any other feature of the irrigation of land on the Colorado river. The Govt. Reclamation Service Engineers have given great weight to the problem in designing the Yuma Irrigation System, and the Laguna dam, which is to cost over a million dollars, was apparently designed quite as much for the purpose of forming a settling basin for silt, and giving opportunity to make scouring sluices and skim clear water from the surface of the stream, as to divert water into the canals.

In the Imperial Valley, however, the silt problem has been solved by the fact that the slope of the valley is everywhere greater than the grade of the river and it has been demonstrated that so long as the water is unchecked in velocity it will carry its load and deposit it upon the land. There are no deposits of silt to be found in the main canals or any of the laterals where the tules and cat tails are not allowed to grow in the margins, and where the velocity is not checked to less than about two feet per second.

In some of the small laterals, when carrying stock water or minimum heads for irrigation, silt has deposited rapidly and choked them, if neglected too long. In general, however, it is

universally conceded that by keeping the checks out of the laterals, except during the time of their actual use to divert water upon adjacent land, and by keeping down aquatic growth by timely attention, the silt can be kept moving, and no greater difficulty experienced with it than in other systems where the water carries only a moderate amount of sediment. The situation in this valley is unique, and without parallel, for in no other valley of a silt-bearing stream is it possible to carry the water on steeper grades than the river supplying the water. The valley of the Nile presents no such advantage as this. In Imperial Valley the maintenance of canals must always be cheaper and more practicable than in the Yuma Irrigation District, where the land has no greater fall than the river, which is about 1 foot per mile, and where the deposit of silt in the canals will always be very much greater for that reason. The value of the Colorado river silt when placed upon the fields as a fertilizer has been estimated by the Agricultural Experiment Station, University of Arizona, at $3 per acre-foot of water applied, giving to each constituent, phosphoric acid, potash, nitrogen and lime - its market value.

Second - The Alkali Problem. The fear of the salts in the soil having a killing effect upon crops after irrigation has been great and wide spread since the publication of an adverse report on this subject by the U. S. Dept. of Agriculture in 1901. This report was intended as a warning, and prevent loss of capital outlay in lands in that region. It was an official blunder. Actual crop production year after year without the appearance of alkali in noticeable quantity upon the surface has effectually allayed this fear, and

demonstrated that the report was in error. Determinations of total salt contents in the soil were made by the electrical resistance test, but analysis does not appear to have been made to show that a large portion of these salts which were thus indicated are not of a harmful nature. The soil is found to contain a quantity of minute shells of the periwinkle, the disintegration of which yields lime, acting as a neutralizer of some of the harmful salts. This is a most important question whose solution by experience gives the lands of the valley a much higher value than they had ever possessed prior to the four years of practical experience in irrigating them.

Third - Problem of securing people to occupy these lands. The rapidity with which settlers have come into the valley prepared to take up lands by desert or homestead entry and purchase water-rights wherever there was a hope of getting water has solved this question affirmatively, and to the degree that it is now apparent that as fast as the system is put inot good order and condition and the canals are given their proper supply of water with reliable certainty, the lands will be entered upon and improved, and water-rights purchased for every tillable acre that can be supplied. This is a question which every irrigation enterprise has to meet, and one which has wrecked a great many, where the long period of waiting for a market for the water, with interest account growing, has often been fatal.

Fourth. The Climatic Problem. The fourth problem in regard to the probable effect of the hot summer climate upon the inhabitants has been solved by the continuous residence of many people throughout the year, in comparative comfort even in the hottest portion of the summer. The only really hot months are June, July,

and August. The present population of the valley is estimated at 8000 to 10,000, more than 90% of whom remain all the year round. The winter climate is ideal, and delightful. All animals appear to enjoy good health the year through. Hogs fatten and thrive particularly well, even in the hottest weather. The valley is in fact making a specialty of hog raising, and dairying. This was one of the questions which had to be met at the outset, and the cause of much of the difficulty in enlisting capital in the enterprise.

Fifth - The soil productiveness problem. The productiveness of the soil has been demonstrated to be vastly greater than any other similar area in any portion of California. Alfalfa has been cut no less than 8 times a year, and each crop from 1 to 1-1/2 tons per acre. It remains green and growing throughout the winter, and affords fresh pasturage the year through. Crops of grain are large and profitable. Grapes have been experimented with successfully, and the valley appears to have a great future as a producer of raisins and early table grapes. Cantaloupes are grown which surpass the famous Rocky Ford melons of Colorado, and at least two months earlier. It also appears to be a most promising section for the production of dates, as the date palm trees thus far planted are making phenomenal growth. These various demonstrations of the productiveness of the soil are sufficient to excite the liveliest interest and enthusiasm among those who are familiar with the facts, and effectually solve that particular problem.

Sixth - The Drainage Problem. The drainage problem has been solved to a great extent by the deep erosion of the Alamo and New River channels through the Imperial Valley as the result of the long

continued flow of water into Salton Sink. In 1905 this amounted to over 4,000,000 acre-feet in all. The Alamo River is now a well defined gorge cut down through the alluvial plain, 100 to 500 feet wide, with vertical sides from 20 to 40 feet deep, all the way from Sharps Heading in Mexico to Salton Sink. New River has cut back a similar but wider gorge from the Sink to a point southwest of Imperial within a few miles of Calexico, with a prospect of further progression southward to or beyond the boundary line. If this erosion should continue until the channel is lowered to 10 to 30 feet all the way back to Beltran Slough, southeast of Sharps, or to Volcano Lake, it would be of incalculable benefit to the entire valley, particularly to that portion west and northwest of Calexico in the U. S. and to the lands south of the boundary in Mexico. Before the break in the river is closed much of this erosion will have occurred possibly, although it is retarded by a zone of still clay in which the river retrogrades slowly. If this drainage channel is not naturally deepened by erosion, it will have to be opened out subsequently by artificial excavation to promote the rapid drainage of the flatter lands now partially submerged. Barring the damage to the Southern Pacific R. R., the net result of the break and overflow of the river for a year or so into Salton Sink will be of such marked benefit to the valley and the California Development Company as to more than offset all that it has cost. The Main Canal as far as Sharps Heading certainly has all the capacity it will ever need to have to irrigate the entire delta, and more than could be given it with years of constant dredging.

The problem of the care of the storm water drainage is one

which is particularly urgent in District No. 5, where much damage has been done by washing of the fields and destruction of ditches. This has not been entirely solved, but is a question involving some outlay of money in drainage ditches, bridges, strengthening of canal banks, etc. The cultivation of greater areas of the district, especially the extension of the area in alfalfa, will tend to greatly modify the rush of water over the plains, and lessen its destructive power. As to the probable amount of seepage and return water that may be expected to leach from the soil experience is yet lacking for any determinations or indications whatever. The movement of all ground water is exceedingly slow, and particularly in soil containing so little coarse sand, and devoid of gravelly or sandy subsoil.

Seventh - The question of friction in canals, and losses by seepage and evaporation. The question as to the proper size to make the canals to carry the water needed, plus the inevitable losses by evaporation and seepage is one which must be determined by experience as to the total demand, and this must vary with the nature of the crops and the amount of natural loss in transportation of water through the canals. Some experiments made by J. B. Rosdhouse, C. E. in1903, for the U. S. Agriculture Department, on the Beech, Birch, Dahlia, Dogwood, Holt and Rose canals, indicated losses of 0.25 to 0.95 sec-ft. per mile of canal, averaging 0.52 sec-ft. per mile. With a total mileage of nearly 600 miles the system might be expected to lose 300 sec-ft. by evaporation and seepage, if this ratio were maintained. At the same ratio the 300 miles in No. 1 system would lose 150 second-

feet. The sum of the capacities of the laterals in this district, at their headgates is about 1000 sec-ft., while the main canal has a capacity below Sharps of 1250 sec-ft. It is to be expected that all canals in the system will need more or less enlargement as the land becomes more completely under cultivation and it would be unnecessary and unadvisable to construct them of ultimate required capacity at the outset. Excavation in the valley is easy and can be made at any time of the year it may be required, almost equally well.

Eighth- The Problem of Transportation. The transportation problem for the valley, which was one of the important questions in a new district, has been practically solved by the building of the branch of the Southern Pacific from Imperial Junction to Calexico, and a feeder by a private Company from this line to Holtville on the East side of the valley. The road is to be completed from Calexico to Yuma through Mexican territory, and the track has already been laid 10 miles beyond the border. Other steam or electric feeders in various directions will be needed, as the valley develops and a system of good highways, with bridges over the canals and natural waterways, must follow as rapidly as the wealth and population increase.

Ninth- The question of the attitude of the Government. The ninth problem which I have mentioned in the list of those either solved or in process of solution as affecting the interests of the valley is the doubtful one of the attitude of the U. S. and Mexican Governments toward the irrigation project by which the low-water flow of the Colorado will ultimately be entirely absorbed.

The U. S. Government has evidently become committed to the abandonment of the Navigability of the stream by the erection of the Laguna dam, 10 miles above Yuma, without locks for passage of boats, thus recognizing the superior value of the river for irrigation and agricultural production. The Mexican Government appears to be equally complacent and agreeable to the sacrifice of navigation during low water stages in the interests of the development and colinization of her territory. The stream has never been of much value for navigation, especially at low stages, and the traffic has not been of the slightest moment below Yuma for years past. The prospect appears to be decidedly favorable for absolute non-interference by Governmental authorities with the diversion and use of the water, as the Mexican Congress has granted to the "Socieded" the unrestricted right to divert 10,000 sec-feet, which exceeds the flow of the stream for a part of the year.

STRUCTURES. The plans for all the gates thus erected for the control of the water have been carefully examined, as well as many of the structures themselves. They are all constructed of Oregon pine and redwood lumber, without preservative of any kind to prevent decay. The life of wood of this sort of use in the valley is short. The conditions are severe - partially in the ground, and partially exposed to intense heat and drying winds, with elements in the soil which seem to promote decay. Some of the structures are already rotted and require replacement.

The policy of the future, in the judgment of the writer, should unquestionably be to build no more wooden structures without treating the wood in some effective manner to preserve it from decay. This treatment should be either to creosote it in a bath of hot

creosote oil, or apply a similar material, called Carbolimaum, which may be put on cold with a brush and will add greatly to the life of the wood. The latter is more convenient, as the material may be applied after the structure is erected, or while being built - in two or more coats, the more applications where the exposure is greatest. Another fairly effective method of preserving the wood would be to immerse it in hot coal tar, or asphaltum. This is only effective, however, when the wood is absolutely dry. Lime whitewash is also an excellent preservative and gives a pleasant appearance to a structure. It is particularly useful for flumes, not in contact with the soil.

The more important wooden structures whose location and use are so well established as to determine definitely the ultimate size and capacity needed, should be replaced by structures of reinforced concrete as they may require to be renewed. Plans are being prepared by a specialist in that line at the present time with this object in view. Gradually the entire system of gates can be made permanent by adopting this class of structure for all the principal ones thatare rebuilt.

The earlier gates designed by Mr. Chaffey and built when funds were particularly scarce are extremely light in design, and although they serve the purpose thus far they have small factors of safety. These will be among the first to be substituted with concrete-steel structures. The more recently erected gates are decidedly more substantial, and in some cases even excessive in size and strength of timbers.

There are several types of gates used for lateral headgates

and checks. The most common are the inclined flash-board gate, where the water pours over the top, and loose boards, held in place by water pressure on an angle of about 60° are removed one at a time. The objection to this form of gate or any overpour structure is that it encourages silt deposit more than the solid gate, lifting straight up, leaving an orifice below, with bottom draft on the canal. A combination of lift gate and flash-board, consisting of a gate stem with one or two flash-boards nailed solidly to the bottom, and loose boards above, placed at an angle, have proven very satisfactory in other localities, and should be tried here. Plans of the principal types of gates in use in the system are appended hereto by way of illustration.

Powell type of pipe-outlet gates.

In Idaho and Colorado deliveries are made from the main canal to the laterals through vitrified clay pipes, embedded in the embankment level with the bottom of the canal. They are made from 10 to 36 inches diameter. At the upper end these pipes connect with a cast-iron section, having a rectangular opening closed with a gate of wrought iron set at an angle somewhat steeper than the side slope of the canal. The stem of the gate reaches up to the top of the canal bank, where a hand-wheel in an angle-iron frame, with locking device, gives definite control of the discharge. The farmer may shut off his water if he likes, but cannot increase the flow without application to the zanjero. Measurement of water through these gates is made by a rating flume at the lower end of the discharge pipe. They are no more expensive than the large wooden gates in ordinary use and are much more satisfactory in every way.

A list of the gates and other structures which have to be maintained by the California Development Company to comply with its obligations is appended hereto. They are comparatively few in number for so comprehensive a system, and their annual maintenance will be a small tax when they are all built in a permanent way.

The newer type of gate which is finding favor in the north west for large structures is the drum or radial gate, which lifts from the bottom, and turns on a center axle supported by piers. The new headgate at Hanlons is to be of this type, modified for the fluctuating height of water in the river. The plans being drawn for a permanent waste gate into the Alamo above Sharps, and for the new headgate of the Main Canal called "Sharps Heading", as well as the new group of gates contemplated at the head of the Eucalyptus lateral, contemplate the use of radial gates of steel, with reinforced concrete gate frame.

Works required to complete system for satisfactory delivery to lands now provided with water stock.

In considering the general improvement of the system, the lands for which water stock has been sold should be first provided with adequate facilities for securing a sufficient water supply, having in view at the same time the future extension of the system to other lands. As heretofore stated the area thus covered with water stock is approximately 200,000 acres in the U. S., and in these same districts commanded by canals there are approximately 97,000 acres additional which may be commanded without going into new territory

a total issue of 297,000 acres. Water stock for Mexican lands has also been issued to the extent of 18,200 acres. Adding No. 2, 13,000 acres, and the lands south of No. 8 west of New River, amounting to about 15,000 acres of what is considered to be lands of good quality for which water stock is certain to be required, the total area is 343,000 acres, which may be watered without material extension into new territory further than is really needed to perfect the present system. To water this area satisfactorily the main canal should deliver 4000 sec-ft. through the headgate at the river, which includes an allowance of about 10 sec-ft. per mile for seepage and evaporation in the main canal - and permits of the delivery of four acre-feet over the entire area in a period of six months. To deliver 4000 sec-ft. from the Upper Heading will necessitate the enlargement of the canal for four miles to about the following dimensions:-

Depth	10 feet.
Bottom width	115 "
Top "	155 "
Water area	1333 sq. ft.
Mean velocity	3.0 feet persecond.

This will require the dredging or removal by sluicing of about 900,000 cubic yards. The new clamshell dredge now building will have a capacity of 12,000 cubic yards in 24 hours, and may be able to do the work in three months at a cost of about $20,000. In case the lower heading gate is successfully maintained it can be utilized for diversion of the larger part of this supply, until the upper four miles of canal can be oblarged by sluicing, aided to some

extent by the dipper dredge. In this event the cost of enlargement of this section will be very small.

To comply with the requirements of the concession granted by the Mexican Government to the "Sociedad de Yrrigacion y Terrenos de la Baja California", it will be necessary to construct substantial controlling gates of reinforced concrete at the river, with waste or over-flow gates, and under the terms of a proposed contract which has been practically agreed upon with the Colorado River Land Company, an American Corporation owning several hundred thousand acres of irrigable land in Lower California, a substantial division gate will have to be built about the head of the Cusil River Cut, 12 miles below Hanlon's. This gate is to be designed and built by the California Development Co. or "La Socieded, etc" at the expense of the Colorado River Land Co. This gate must be of generous dimensions, each side of which will need to be large enough to carry water for about 500,000 acres, or about 6000 sec-ft. In connection with it there must be a capacious waste gate to return water from the canal to the river. These structures will have to be built on a heavy concrete floor founded on piles driven to a great depth in a soft formation, and will probably cost upwards of $50,000. The location selected for them may have to be changed to some point next to the hills to secure more stable foundations. The country has been so constantly submerged for some time past as to render a definite determination of location impossible.

A spillway to the south at Beltran Slough and possibly one or two others may ultimately found to be essential.

District No. 8. Delivery of water to this district was formerly

made by flume across New River, which was small and of insufficient capacity. It was never intended for a permanent delivery of full supply and was about to be replaced by a canal heading in New River when the flume was washed out and destroyed by a flood. The new canal was rushed to completion and is an excellent piece of earth work, of good alignment and regimen, 11.5 miles long from the flume up to the river, where a substantial headgate was built. The upper end of the canal above the Superstition Mountain Spur, around which it passes, was badly washed by severe rains and storm run-off from the mountains of San Diego to the west, in the Spring of 1905, and caused the District heavy expense for maintenance. This was followed by the flood from the Colorado River overflow, which eroded New River channel 8 feet deep below the flood of the headgate. The District authorities succeeded in maintaining a flow of 50 or 60 sec-ft. during the irrigation season of 1905 by extending the canal up to Pelican Lake, which is an enlargement of a side stream or branch from New River. Further retrogression of this branch has cut back sufficiently to drain Pelican Lake and the canal has again been extended around this Lake and has tapped Badger Lake, the next one of the chain of small lakes on the branch streams. It is questionable if this extension will be a sufficient reliance for the district for the coming season.

The plan for permanently supplying the district which appears to be most feasible is to extend the Main Canal of District No. 1 by flume across New River, and thence build a new canal on a grade line as far west as possible to cover good arable land, and on to a connection with the present main canal at its headgate, starting at the curve where the canal turns north. A waste gate into New River

can be conveniently placed in the flume. This new canal will be 84 miles in length, and command 18,000 acres not now supplied with irrigation, of which 15,000 acres are estimated to be good, arable land. This territory will either be joined to No. 8 District or formed into a new water company to be called No. 9. This canal will need to have an ultimate capacity of 1000 second-feet across New River, to the point where the laterals for No. 9 will be taken out, and thence to No. 8 heading its capacity will be 750 to 800 second-feet, if it is made to do duty for 75,000 acres in No. 8 proper.

The Main Canal No. 1 will have to be enlarged by dredging to a capacity of about 8000 second-feet gradually reduced as it passes the heads of the laterals in No. 1.

District No. 4 and its extension now known as No. 2, can best be supplied by a new canal taken out from the Alamo channel below the Holtville power house,-which will relieve Main Canal No. 1 to that extent. The main advantage is that it will give a greater discharge through the water wheels of the power house, than would otherwise be available without waste. It will necessitate the enlargement of the Main Canal No. 5 as far as the Holtville division gate to carry the increased supply needed for the No. 4 and No. 2 Districts, and the construction of a dam across the Alamo channel, with a waste gate of sufficient capacity to care for all water which might reach it in case of extreme emergency at Sharps. This wastegate will be an important and expensive structure, and should be of the best type of permanent work. A similar wastegate for main canal of District No. 5 will also have to be constructed.

A survey has been made for a new canal above the Rose, to supply water from the proposed dam on the Alamo below Holtville. It involves considerable culvert work in crossing deep cuts and washouts around a depression called Mesquite Lake, but is not necessarily expensive or impracticable on that account.

District No. 5 Improvements.

To provide irrigation facilities of the best and most permanent character for District No. 5 it appears to be desirable to reconstruct the Main Canal from a point near the Holtville division gate on a grade line which will follow closely along and below the old sea beach, some two or three miles east of the present canal. This location will embrace a large area of good land, and afford greater security against injury to the canal from storm-water.

This will also involve the building of new lateral headgates in the main canal and the extension of all the laterals to the main. A system of ditches for storm water, parallel with the laterals in an east and west direction every half mile, from the main canal to Alamo river, will also have to be devised and constructed. Part of the system has already been commenced.

A rough estimate of these various works for the entire Imperial Valley indicates that an expenditure of $500,000 to $600,000 will probably suffice, and serve to place the entire system in first class condition for the irrigation of 500,000 acres in the U. S. and for the irrigation of some 250,000 acres of the Mexican lands.

Power Development.

The development of power at Holtville has already been referred to. A contract has been entered into with Mr. W. F. Holt, by which

the latter agrees to pay a monthly rental of $2 per H. P. for all power developed and sold. There is likely to be a demand for all power that can be developed at this drop. A fall of forty-five feel from the penstock at the end of the power canal built by Mr. Holt to the floor of the power house is available for power development, with ten to fifteen feet additional head to be secured by extension of draft tubes down to the level of Alamo channel. The power house has been built and machinery installed for 600 H.P. with floor space provided for 2000 H.P. in all. A drop of 55 feet net fall will require a flow of 500 sec-ft. to develop 3000 H.P. gross, or 2000 H.P. net, delivered to customers. With this power developed and sold to the extent of 2000 H.P. the revenue to be derived by the California Development Co. will be $48,000 per annum. This is sufficient inducement to make the changes in delivery to the irrigation districts which is required to supply the water needed to produce this power. There are other opportunities on the system for producing power of considerable amount.

The drop at Sharps Heading can be increased to 18 feet by cutting back the 4-ft. drop at the next wastegate below, called Station 134, and all the water for Districts 1, 8 and 9 can be utilized for power. The flow for a considerable part of the year will ultimately have to be about 2000 sec-ft. and may average 1000 sec-ft. throughout the year. The latter amount would yield about 1350 gross H.P. or 900 H.P. net. This plant is in Mexico.

A third drop of about 30 feet in U. S. territory may be utilized by carrying water to a new district of about 30,000 acres, northwest of the present cultivated area of No. 8 District. This water would be taken through the Holt power house, thence through

the proposed new canal for District No. 4 and dropped into New River channel. The water used would amount to about 350 sec-ft. and furnish about 800 H.P. net. The location of the drop would be near the North line of District No. 4.

On the Main Canal of No. 8 District there are two drops of 14 feet each, at which power may be developed to the extent of about 400 to 450 H.P. net, at each place,-the "net" power being reckoned two-thirds the theoretical, and is the approximate amount which may be delivered to consumers. A drop of about 10 feet in the Main Canal of District No. 1 can be developed at Structure No. 10, three miles N. E. of Calexico. When carrying 2000 sec-ft. in the canal this drop may develop 1500 H. P. net. These various possibilities are of value in a country where fuel is scarce and industrial activity may soon create a market for all electric power that can be developed. The total estimated power at the five drops here described amounts to 6000 H.P. net, and all belongs to the California Development Company. When fully developed it should yield a net revenue of $100,000 to $140,000 per annum, if the rental rate of $2 per month per H.P. is maintained.

PROBABLE RETURNS.

The result of completing the system in the manner heretofore outlines should be about as follows:-

Sale of new water rights on 125,000 acres to $20	$2,500,000
Value given to securities now held by C.D.Co. in No. 8 District	300,000
Total negotiable assets made available	$2,800,000

The minimum income on 343,000 acres at 50 cents per acre-foot would be $171,500 per annum. When fully irrigated a mean consumption of 3 acre-feet per annum would give a yearly revenue of $500,000 in round figures. Estimating the annual cost of maintenance at $75,000, which is thought to be quite an extravagant figure, the annual profit of $425,000 would seem to be within reasonable reach. This would be over six per cent on a capital of $7,000,000.

Those figures neglect the income derivable from power, and the assets in Mexico, where the Mexican Company owns many thousand acres of land on the 100,000 acre tract that may be made salable and irrigable. The Mexican lands are generally of superior quality to those north of the border. The sale of water to the California-Mexico Cattle Co., which owns a large tract of land in Lower Mexico amounting to several hundred thousand acres, much of which is susceptible of reclamation, under a contract whose terms have been practically agreed upon, although not absolutely formulated, is a future asset which should be of great value to the Mexican Company. The writer does not attempt in this report to estimate it, or do more than suggest its large possibilities.

Extension of the System by building of the high-line canal.

Lying East and North of No. 5 District is an extensive tract of bench land, covering some 200,000 acres, as estimated by Mr. Rockwood, and all can be covered by a high line canal from the Alamo River. Much of this land is thought to lie in a frostless belt, and

upper heading at Hanlons, and cross the boundary a
of Monument 216, which is 14 miles east of Calexic
the border line. The survey of the canal was made
and no definite location has since been attempted.
however, is the last large extension which the Cal
Co. can make to its system. It appears to offer
wisely managed in the light of past experience.
not be undertaken, however, until all water-rights
other canals are sold, and the distributing system
this canal, water-rights for lands susceptible of
and other citrus fruits should command $40 per acre
tract be made to yield from $5,000,000 to $7,000,0
It may be questionable if the water supply can be
this entire tract after the Mexican lands are
project is provided for. The latter will doubtless
to 800,000 acre-feet per annum, when fully
extensions, various possibilities for this system
as capable of being realized in U. S. territory
devoted to paying off present indebtedness and
extensions and betterments. When these are
cured by a continuance of the present system
Water Companies extending over the entire area
the property must be enhanced so as to
the most desirable character.

-45-

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Respectfully submitted,

are referred to as constituting a part thereof:-

No. 1. A general map of the territory including the Imperial Valley from Salton Sink to the Gulf.

No. 2. Detail contour map of Imperial Valley, showing canal systems, and irrigation districts.

No. 3. Plan of headgate of Main Canal, No. 1.

No. 4. Lifting device for Main Canal Headgates.

No. 5. Checkgate plan for vertical lift-gates, used on Encina and Alamitos laterals.

No. 6. Headgate plan, Alamitos lateral relocation.

No. 7. 3.5' Drop at Station 134 Main Canal No. 1

No. 8. Plan of 2'8" Drop on Alamitos Laterals

No. 9. Plan of flume on Ash lateral over old Alamo channel

No. 10. Combination chute and check used principally in Nos. 7 & 8

No. 11. Type of Delivery Box.

No. 12. Flume over New River on line of Encina Canal.

No. 13. A set of 62 photographs taken by the writer during various visits to the works, inserted to illustrate some of the features of the system.

List of Structures which must be maintained by

The California Development Company.

(All other gates and structures are kept in repair by the Mutual Water Companies.)

Compiled from notes of C.N.Berry,Res't Engr.,Feby.1906.

1. Waste gate at Beltram Slough, and check gate across Alamo River. The check gate was built in 1902, to turn excess water down the Slough to New River. The gate across the Slough was never completed, but piles were driven across it as a temporary expedient, to hold brush thrown against them. This temporary barrier washed out in the summer flood of 1903 and has not since been replaced, and there is now no control of the outflow.

2. a. Headgate for Hemlock ditch, District No. 7.

b. " " Holt " " " " " main.

c. " " New No. 5 canal.

These gates are in a group together at the boundary line in the Mexican side. All in good repair, and good for 3 or 4 years. The No. 5 headgate is of insufficient size to serve the purpose for longer than about two years. It was formerly the heading for the Holt ditch. Lumber was ordered for the larger gate, but it has not yet been erected.

3. A check gate in No. 5 Main Canal, to divide water with the Holtville Power Canal, is to be constructed as soon as its location can be decided upon, and will be maintained by the C. D.Co. The directors of Imperial Canal No. 5 are considering a high level location for their main, to the east of the present main canal, and in that event will want the division to be made at a point higher up the canal than would otherwise be

necessary. Its capacity will have to be large enough for all of the water of No. 5 District which will ultimately need 1000 sec-feet.

4. Waste gate for No. 5 Canal into Alamo channel. The present check in main is to be utilized for this purpose, near the head of the power canal, with the addition of a chute to drop the water over the bank.

5. Waste gate of New Rose canal, near head. This gate will be an important structure, as the entire water of the Alamo channel will at times have to pass over it, in case of a closure of Sharps heading, and other headings of Nos. 5 & 7. It will have to be designed to carry about 4000 sec-ft. Until the flood subsides and the bottom of the channle can be examined the depth of drop required to be provided for cannot be determined.

6. Heading for Rositas Lateral. This gate will have to pass 120 second-feet, unless it should be decided that the Canal will irrigate the country lying between the two ruvers north of No. 4 District, in which event both gate and canal will have to be enlarged to correspond.

7. Headgate of Hawthorne,-a small gate, in good condition, good for 6 or 7 years.

8. OriginalAlamo wasteway hear Sharps, built by Chaffey, and subsequently abandoned. Now used again as a wastegate auxiliary to the new waste gate built in 1905. The old gate has a flume extension to discharge water far away from gate to avoid washing it out.

9. New Alamo waste-gate. This is a fine, solid, substantial gate, finished in fall of 1905, with exception of lower apron

which is still to be added whenever the water is low enough to permit all waste to pass through the old gate.

10. Sharps Heading. Headgate for Main Canal No. 1, and check for all water supplying Encina, Aliso, Alamitos, Main No. 5, Holt, Hemlock, and Hawthorne Canals. The gate has a drop of 8 feet for Main No. 1 water. It is the most important structure in the valley, whose failure would be more serious than that of any other gate. Should be replaced by permanent structure.

11. Alamitos Headgate. Small gate, in good repair, with probable life of five years yet.

12. Encina Headgate. Mr. Perry has not much confidence in this gate, although it has never caused any trouble. It should be replaced by a more substantial structure.

13. Aliso Headgate. Small gate, in good order, should last five years.

14. Gate in Main Canal No. 1, with 3.3 feet drop. One of the earliest and lightest structures in the valley. Should be rebuilt.

15. Old Alamitos headgate,-which might be omitted from this list as it has been abandoned.

16. New River waste-gate, at Station 134. This structure has a total drop of 8 feet in two steps. A new structure not yet entirely finished and is lacking an apron below. It has carried 900 to 1000 sec-ft. for 14 months, but considerable back cutting has taken place next to the lower sheet piles. Will need repairs as soon as possible.

17. Chute with 3 feet drop in Alamitos Canal in Mexico. Small structure, good for five years more.

18. A vertical drop of 3 feet in Alamitos Canal in

Mexico, in good condition.

19. Ash lateral headgate. Same comment as No. 18.

20. " check. " " " " "

21. " delivery box. " " " " "

22. Wagon bridge over Main Canal, in good condition.

23. Birch lateral headgate, small structure, good for four years.

24. "Structure No. 10", with 10,5 ft. drop, provided in origina grade, but the canal has not cut back sufficiently to make more than five feet drop. There are diversion ditches heading on both sides of thisstructure, with vertical lift gates in the wings of the drop.

25. Weir. Known as "the Double "eir", across Main Canal No. 1. In bad condition, requires immediate reconstruction.

26. Date lateral headgate. Good for four years, small, in good order.

27. Dahlia lateral headgate. Same comment as No. 26.

28. Evergreen lateral headgate. A new, solidly built structure, in good condition.

29. Check-gate across Main Canal No. 1. at head of Evergreen lateral. An expensive and substantial gate, should last six years.

30. A group of five gates, viz:

Headgate of Main side ditch.

Checkgate for Main Canal.

Headgate for Eucalyptus lateral.

Headgate for Elder lateral.

Waste-gate into New River.

All of these five gates are in fairly good condition, and should last one or two years, except the waste-gate, which is flimsy and unsafe.

31. Daisy lateral headgate. Small structure, in good condition, should last five years.

32. Sixteen-foot drop in Main Canal, five miles from Imperial. In good condition but too light for the strain it may have when the canal has cut down to grade, if it ever does.

33. Check in Main Canal, at heading of New Side Ditch. This is a weak and flimsy structure, old and requiring early substitution with a better structure.

34. Headgate of Lilac Lateral, needs replacing at once.

35. Eight-foot drop in Main Canal. In fairly good condition. Will probably not require rebuilding for three years.

36. Original headgate for No. 8 District. Abandoned when flume washed out, but is to be used again as a waste-gate for No. 4 when the pipe is installed to carry the waste down to the bed of New River. Gate should last four years.

37. Encina flume, in Mexico, Length 400 feet; depth 6 feet; width 12 feet.