# REPORT

OF THE

# BOARD OF COMMISSIONERS

ON

# THE IRRIGATION

OF

## THE SAN JOAQUIN, TULARE, AND SACRAMENTO VALLEYS OF THE STATE OF CALIFORNIA.


Lieut. Col. B. S. ALEXANDER, Corps of Engineers, U. S. A.,
Maj. GEORGE H. MENDELL, Corps of Engineers, U. S. A.,
Prof. GEORGE DAVIDSON, United States Coast Survey,

COMMISSIONERS.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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43D CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. No. 290.

# IRRIGATION OF THE SAN JOAQUIN, TULARE, AND SACRAMENTO VALLEYS, CALIFORNIA.

## MESSAGE

FROM THE

## PRESIDENT OF THE UNITED STATES,

TRANSMITTING

*The report of the Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento Valleys, in the State of California.*

MARCH 24, 1874.—Referred to the Committee on the Public Lands and ordered to be printed.

*To the Senate and House of Representatives :*

I have the honor to transmit herewith the report of the Board of Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of the State of California, and also the original maps accompanying said report.

U. S. GRANT.

EXECUTIVE MANSION, *March* 23, 1874.

*Report of the Board of Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of the State of California.—Lieut. Col. B. S. Alexander, Corps of Engineers, U. S. A.; Major Geo. H. Mendell, Corps of Engineers, U. S. A.; Prof. George Davidson, United States Coast Survey, Commissioners.—February,* 1874.

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## INTRODUCTORY.

The following is the act of Congress authorizing the commission:

AN ACT to provide a board of commissioners to report a system of irrigation for the San Joaquin, Tulare, and Sacramento Valleys, in California.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the President be, and he is hereby, authorized to assign two engineers of the Army and one officer of the Coast Survey now stationed on the Pacific coast, for the purpose of examining and reporting on a system of irrigation in the San Joaquin, Tulare, and Sacramento Valleys of the State of California; and for that purpose the officers so assigned may associate with themselves the chief of the geological survey of California, and also one other civilian distinguished for his knowledge of the subject.

SEC. 2. That these five persons shall constitute a board, with power to fill vacancies, whose duty it shall be to make a full report to the President on the best system of irrigation for said valleys, with all necessary plans, details, engineering, statistical, and otherwise; which report the President shall transmit to Congress at its next session, with such recommendations as he shall think proper.

SEC. 3. That the Secretary of War shall furnish subsistence and transportation for the board while in the field, and the compensation of the members of the board who are not in the service of the United States shall not exceed two thousand dollars each, but the other members of the board shall receive no additional compensation for their services.

Approved March 3, 1873.

We insert here the following order of the Secretary of War, organizing the board of commissioners:

[Special Orders No. 75.]

WAR DEPARTMENT, ADJUTANT-GENERAL'S OFFICE,
*Washington, April* 9, 1873.

Under the act of Congress approved March 3, 1873, published in General Orders No. 56 of 1873 from this office, Lieut. Col. Barton S. Alexander and Maj. George H. Mendell, Corps of Engineers, are hereby appointed members of the commission, Lieut. Col. Alexander to be president thereof, for the purpose of examining and reporting on a system of irrigation in the San Joaquin, Tulare, and Sacramento Valleys of the State of California, and will hold themselves in readiness to proceed to the duties of the commission on receipt of further instructions from the Secretary of War.

By order of the President of the United States:

E. D. TOWNSEND,
*Adjutant-General.*

Official:
J. P. MARTIN,
*Assistant Adjutant-General.*

Also the further instructions of the Secretary of War:

OFFICE OF THE CHIEF OF ENGINEERS,
*Washington, D. C., April* 12, 1873.

SIR: A copy of the act of Congress approved March 3, 1873, published in General Orders No. 56, current series, Adjutant-General's Office, authorizing the assignment of two engineers of the Army and one officer of the Coast Survey now stationed on the Pacific coast, for the purpose of examining and reporting on a system of irrigation in the San Joaquin, Tulare, and Sacramento Valleys of the State of California, and for that purpose the officers so assigned may associate with themselves the chief of the geological survey of California, and also one other civilian distinguished for his knowledge of the subject, is herewith transmitted for your information and guidance.

The President has, in Special Orders No. 75, Adjutant-General's Office, Washington, April 9, 1873, a copy of which is inclosed herewith, appointed you and Major Mendell members of the board, and also Prof. George Davidson, assistant in the Coast Survey, as contemplated in the first section of the act.

The board so constituted are authorized to associate with themselves the chief of the geological survey of California, and also one other civilian distinguished for his knowledge of the subject.

As the president thereof, you will convene the board in San Francisco, or such other convenient place as you may select, and proceed to the business devolving upon it.

As soon as practicable, the board will proceed to the valleys mentioned, and make the investigations called for in the act, reporting progress monthly.

Having completed these investigations, the board will return to San Francisco and make up their report, and, if practicable, transmit it to this office in time to be handed to the Secretary of War before December 1, 1873.

Estimates will be made upon this office from the appropriation for "surveys for military defenses," for such sums as may be necessary to carry out the provisions of the act, not exceeding in amount five thousand dollars.

By order of the Secretary of War:

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
*Brigadier-General and Chief of Engineers.*

Lieut. Col. B. S. ALEXANDER,
*Corps of Engineers, San Francisco, Cal.*

Professor Davidson received the following instructions from Prof. Benjamin Peirce, the Superintendent of the Coast Survey:

CAMBRIDGE, MASS., *April* 25, 1873.

DEAR SIR: As already advised by telegraph, you have been appointed by the President of the United States as commissioner for examining and reporting on a system of irrigation in the San Joaquin, Tulare, and Sacramento Valleys of California, as by act of Congress approved March 3, 1873.

You are authorized to accept the appointment, and to proceed to the discharge of the duties specified in the act.

Yours, truly,

BENJAMIN PEIRCE,
*Superintendent United States Coast Survey.*

GEORGE DAVIDSON, Esq.,
*Assistant, Coast Survey, San Francisco, Cal.*

In accordance with these instructions the board, consisting of Lieut. Col. B. S. Alexander, Corps of Engineers; Maj. George H. Mendell, Corps of Engineers; and Prof. George Davidson, of the Coast Survey, met in San Francisco, April 23, 1873, organized, and elected Professor Davidson its secretary and Major Mendell its treasurer.

A letter signed by the members of the board was forwarded to Prof. Joseph D. Whitney, State geologist of California, but then at Cambridge, Mass., inviting him, in accordance with the first section of the act of Congress, authorizing the commission, to become a member of the same.

At the same time a telegram was sent to Professor Whitney asking him to join the commission as a member.

In answer to the telegram, Professor Whitney replied that he could not join the commission.

On the 6th of May, 1873, it was unanimously resolved that the president of the commission be instructed to invite Mr. R. M. Brereton, of San Francisco, to join the board as a member, in accordance with the terms of the act of Congress.

In answer to the letter of the president of the commission, Mr. Brereton declined to become a member in consequence of professional engagements.

Having thus exhausted the requirements of the law creating the Board of Commissioners on Irrigation in reference to its organization, it was determined to proceed to the duties before us, under our present organization, and without any further addition to our numbers.

We may add that we were driven to this course by the want of funds at the disposal of the commission for the purpose of making the necessary reconnaissance and report.

Only $5,000 were allotted to us for carrying out the provisions of the act of Congress in reference to this subject.

If two civilians had been associated with the board, they would each, by the terms of the law, have been entitled to $2,000 as compensation for their services. This would have left us only $1,000 for making the necessary maps to illustrate our report, and for the transportation and subsistence of five members instead of the present organization of only three members without salaries.

With only $1,000 for these purposes, we feared that the object to be attained in creating the commission would have been defeated.

## PRELIMINARY RECONNAISSANCE.

On the 13th of May the board proceeded to make an examination of the Merced, San Joaquin, King's, Kaweah, and Kern Rivers, from the plains to the mountains. They also examined the eastern side of Tulare Valley as far as Kern Lake, and inspected the systems of irrigation that have been introduced at Centreville, Visalia, and Bakersfield.

Returning, the board examined the west side of the San Joaquin Valley, between Watson's ferry and Banta's, observing particularly the works of the San Joaquin and King's River Canal and Irrigation Company, and the system of irrigation which this company is introducing on the west side of that valley.

In the month of June, the board examined the Tuolumne, Stanislaus, Calaveras, Mokelumne, and Cosumnes Rivers, on the east side of the San Joaquin Valley, from the points where they escape from the foot-hills to the plains. This completed our examination of the San Joaquin and Tulare Valleys.

The Sacramento Valley was also thoroughly examined at various times during the summer and fall.

On the east side, we examined the American River, the different branches of the Yuba and Feather Rivers, and the various small streams emptying into the Sacramento River between the Feather River and Tehama; and on the west side of the valley we examined the Sacramento River itself as high up as the town of Shasta; also Stony Creek, Cache Creek, (including Clear Lake,) and Puta Creek.

Having thus examined the three valleys mentioned in the act of Congress, the San Joaquin, Tulare, and Sacramento, which, taken together, we have designated "the Great Valley of California," and having seen the lands which may be irrigated, and ascertained from observation the necessity for its irrigation, and having seen the principal lakes, rivers, and creeks from which the water for irrigation must be obtained, we proceed, in accordance with our instructions, to present our views on the subject of the irrigation of these valleys.

## THE MAP.

For the purpose of illustrating this report we have had a topographical map of the great "Valley of California" prepared. This map embraces the San Joaquin, Tulare, and Sacramento Valleys, and shows the Sierra Nevada Mountains on the east side of the valley, and the Coast Range of Mountains on the west side, to the summits of the respective ranges. We refer to this map in all subsequent discussions. The map shows the "Great Valley of California," and the foot-hills and mountains by which it is surrounded, all the lakes, rivers, and principal creeks, with their catchment-areas; the overflowed or swamped lands, of which there are about 1,225,000 acres; the division into counties, and the township-lines of the United States surveys; the railroads and principal towns. On this map the canals that have already been constructed are laid down in heavy, full, red lines; the canals that have been projected, and actually surveyed, on the southern end and west side of the valley, in light, full, red lines; and we have also indicated a hypothetical system of irrigating canals on the eastern side of the valley in dotted red lines.

On the eastern side of the Great Valley, all the way from the southern end of Tulare Valley, south of Kern Lake to Red Bluff, the ground rises from the lowest depressions or central lines of drainage in a gentle inclined plain, swelling then into undulations, and then into foot-hills, which, as we proceed eastward, rise into mountains, culminating in the Sierra Nevada.

On the western side of the valley the ground first rises in a plain of gentle slope, then swells into foot-hills, then mountains, culminating in the Monte Diablo range on the west side of the San Joaquin and Tulare Valleys, and in the Coast Range on the west side of the Sacramento Valley.

The ascent from the foot-hills to the summit of the mountains is much steeper on the western side of the Great Valley than it is on the eastern side, and the drainage-area is much smaller on the western side than it is on the eastern.

Again, the Sierra Nevada being much higher than the Coast Range or the Monte Diablo range of mountains, the condensation of moisture, or the amount of rain-fall and snow in a year, is far greater on the Sierra Nevada than on the lower mountains to the westward.

An inspection of the map shows a marked contrast as regards the water-supply of the eastern and western sides of the valley.

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# CHAPTER II.

1. Necessity for irrigation in California—The subject a novel one to the United States—Reasons why irrigation is necessary.
2. The climatic conditions of the Pacific coast—The wet and dry seasons described—Tabular statements.
3. The orographical features of California—The mountain-ranges and their effect upon the law of precipitation of rain.
4. The average yearly rain-fall sufficient to insure good crops—The amount of rain-fall necessary for a crop—The rain-fall at different localities throughout the Valley of California.
5. The variability of the average yearly rain-fall, and the irregularity of rain-fall in each year—Tabular statement of extremes of rain-fall—Seasons of drought.
6. Annual crops may be secured by a proper system of controlling and delivering the waters of precipitation—Visit to irrigated lands—Crude methods adopted for irrigation.
7. Mildness of the climate especially well adapted for agricultural pursuits—Appearance of the face of the country in the wet season—The weather in the dry season—Matured crops standing all summer—Tables of temperature.
8. The Great Valley of California is admirably adapted for irrigation—It is the marked geographical feature of the Pacific coast in the United States—Detailed description of the Great Valley—Map to show its relation to California and Nevada—Soil of the Great Valley—Average product per acre—Volunteer crops—Permanent effects of irrigation—Prospective population.

## THE NECESSITY FOR IRRIGATION IN CALIFORNIA.

The subject of irrigation is a novel one to the inhabitants of the States lying east of the one hundredth meridian, where the harvests are so uniformly assured that a season of five or six weeks of continuous drought during the growing of the crops would be looked upon as a great national calamity, and prayers would doubtless, as heretofore, be offered in the churches for rain. There the average yearly rain-fall is 39 inches, somewhat regularly distributed through the different months; but on the Pacific coast there are two very marked seasons, one long, dry, and almost cloudless, embracing part of the spring-months, all of the summer, and part of the autumn, the other comparatively short and wet.

Some of the peculiarities of the climate and of the rain-fall have been frequently stated throughout the United States and abroad, but their effects upon our agricultural industry have been very rarely considered. The subject, however, has been practically brought home to the people of this coast; and all painfully realize the fact that if the country bordering the Pacific and that lying between the Rocky Mountains and the Sierra Nevada are to be developed and the crops assured for the support of their inhabitants and for exportation, some system of controlling the available waters and delivering them to the land must be devised and executed.

The extent of the Great Valley of California is hardly appreciated by the inhabitants of the State itself, certainly not throughout the United States or in Europe, and yet it contains in one body an area of almost level plains equal in the aggregate to the States of Massachusetts, Connecticut, and Rhode Island, and greater than that of Maryland, or of New Jersey and Delaware. If the area of the rolling foot-hills be added to the plains, the total arable land of the Great Valley is equal to the area of Massachusetts and Maryland, or nearly equal to half the entire State of Ohio.

The soil of this great valley is capitally adapted for the cultivation of grain, cotton, tobacco, the vine, and many of the subtropical fruits. The exportation of wheat, &c., after seasons of good rain-fall, is ample confirmation of this fact if the personal knowledge of the commissioners did not certify to it.

Under circumstances so anomalous in the experience of the United States, it therefore appears necessary to state, in consecutive order, the reasons that render irrigation necessary; then, to add short explanations to these reasons; and, subsequently, to give more extended exemplifications and illustrations.

## STATEMENT OF REASONS WHY IRRIGATION IS NECESSARY ON THE PACIFIC COAST.

A. The climatic conditions of the Pacific coast are such that crops are uncertain south of latitude 42°.

B. The orographical features of the country conspire with the climatic conditions to render crops especially uncertain in certain localities.

C. The average yearly rain-fall over the basin of the Great Valley is sufficient to insure good crops annually.

D. The rain-fall in different years is very variable, and seasons of drought and of great floods occur; and in any one season it is very unequally distributed in different sections.

E. With a proper system of controlling the waters of precipitation, and delivering them to cultivated lands when needed, annual crops may be assured.

F. The climate is mild throughout the wet or winter season, and especially well suited for all agricultural pursuits.

G. The Great Valley of California is admirably adapted for irrigation.

### A.—*The climatic conditions of the Pacific coast are such that crops are uncertain south of latitude* 42°.

The climate of the Pacific coast west of the Sierra Nevada and Cascade Mountains is altogether different from that of the Atlantic coast, and differs also from that of the country included between the eastern slope of the Rocky Mountains and the Sierra Nevada. The ordinary form of rain-fall tables fails to exhibit its characteristic, so that upon this coast tabulated results of precipitation of rain and snow are made out for the rainy season, which extends from about October 15 to

April 1. No rain, in the ordinary acceptation of the term, falls during the dry season, between April 1 and October 15, in the latitude of 38°. Northward of that latitude, and especially northward of latitude 40°, there is frequently a small rain-fall during the summer and a heavy rain-fall during the winter.

Southward of 38° the rainy season is shortened and the dry season lengthened, so that at San Diego, in latitude 32½°, the rain-fall on the immediate coast averaged only 9.2 inches during twenty-three years.

On the coast, about latitude 28°, is the region of the "doldrums," where little rain falls, but where a cloudy region exists. South of that latitude, the seasons are changed, and our rainy season is the dry season of the southern part of Lower California, and our dry season their wet season.

At the extremity of the peninsula of Lower California only 3½ inches fell last summer. The rain-fall at San Francisco, which may be taken as a type, averages 23.5 inches annually, distributed as follows:

| | Inches. | | Inches. |
|---|---|---|---|
| June | 0.04 | | |
| July | 0.01 | Total for the summer | 0.07 |
| August | 0.02 | | |
| September | 0.10 | | |
| October | 0.64 | Total for the autumn | 3.57 |
| November | 2.83 | | |
| December | 5.42 | | |
| January | 5.30 | Total for the winter | 14.32 |
| February | 3.60 | | |
| March | 3.18 | | |
| April | 1.74 | Total for the spring | 5.56 |
| May | 0.64 | | |
| Yearly average | | | 23.5 |

The tabulated results of rain-fall upon the western coast of the United States, from San Diego to Puget Sound, given by the Smithsonian Contributions, No. 222,* confirm this example as a type, having the following characteristics:

A most decided minimum during the summer-months, amounting, at some places, to an absence of rain, and a well-marked maximum late in December. Range excessive.

But, perhaps, the marked conditions of the wet and dry seasons of the Pacific coast, as compared with the rain-fall in the Atlantic States, can be best illustrated in the two charts annexed, wherein is graphically shown the peculiarity of the summer and winter rain-falls over the whole United States.*

Other tables and other more extended charts could be produced to illustrate a characteristic in the winter rain-fall, namely, that during that season there is a marked cessation of rain, ranging from one to four weeks.

This cessation does not occur at any regular epoch, so that its effect is not seen in a chart constructed only upon average quantities, but it has occurred nine years out of ten. Very frequently during this cessation of rain, the cold winds from the north, accompanied by a clear sky,

* Tables and Results of the Precipitation of Rain and Snow in the United States, Smithsonian Contributions to Knowledge, No. 222, by Chas. A. Schott, U. S. C. S., 1872, p. 133.

blow fiercely, and blast the young growing crops; or when this dry interval is prolonged, even without these cold northers, the weather is usually clear and fine, perhaps hot, and the young grain withers and may be wholly lost, even for fodder, if the last rains of the season come late.

In some years the rains cease suddenly in February, and the crop is lost. This was notably so in the Great Valley in the spring of 1873, where a most promising harvest was blighted by the ceasing of the rains, and only those few fields that were irrigated yielded a crop; those that had been summer-fallowed yielded about half an average crop; the remainder, especially in the southern half of the valley, yielded probably an average of six or eight bushels.

Southward of the Great Valley, to the Mexican boundary, the necessity for irrigation increases, and the problem becomes more intricate, because the extensive arable sections have a limited supply of water, and the country is not so easily watered. In the San Diego River no water flowed through its lower parts for about five years ending November, 1873.

Although the commission has not been required to examine any other than the Great Valley, the foregoing fact is stated in confirmation of the peculiar climatic conditions of the coast.

B.—*The orographical features of the country conspire with the climatic conditions to render crops uncertain in particular sections.*

The orographical features of the Pacific slope are such that, were other conditions equal, the uniformity of rain-fall can nowhere take place.

Speaking generally, the Coast Range of Mountains and the Sierra Nevada run parallel with the coast-line, and the Great Valley lies between them.

The Coast Range of Mountains maintains an average elevation of over 2,000 feet, reaching as much as 6,200 a few miles south of Monterey; and 3,800 on the peninsula of San Francisco.

The southerly storms of winter bring up rain north of latitude 28° to 30°, and drive the moisture-laden air against the southwestly or seaward flanks of these mountain-ranges, and the precipitation of rain amounts to two and a half times the quantity that falls upon the eastern flanks. This has been established by measurement at the reservoirs of the Spring Valley Water Company, and confirms the reports of the farmers and stockmen.

Nine years' observations at Pillarcitos Dam give an average of 58 inches of rain, while San Francisco, distant only fourteen miles, has 23.5 inches.

The same law holds good along the western flank of the Sierra Nevada, which chain averages 9,500 feet elevation. From several years' observations on the line of the Central Pacific Railroad, the fall of rain at Summit station is three times that between Rocklin and Auburn, and many times greater than on the eastern flank of the Sierra, where the rain-fall is very limited.

The same law is well known along the southernmost part of Lower California.

At the head of the Sacramento Valley, in latitude 41°, where the Coast Range of Mountains crowds upon the Sierra Nevada, the clouds are banked up heavily, and it is safe to say that four times, and in some seasons perhaps ten times, as much rain falls at Shasta as in the region of Kern Lake at the southwestern extremity of the valley. This latter section is the driest region in the whole valley, and probably only half the rain falls there that falls about the vicinity of Bakersfield.

On the Coast Range of Mountains snow very rarely falls, and never lies over twenty-four hours; but on the Sierra Nevada it falls to a depth of 60 or 70 feet, (observations at Summit station, 1866–'67,) and lies throughout the winter with an average depth of 14 feet. This snow forms a great natural store-house of water. It supplies the streams throughout the year. If the greater body of it is melted during the winter by warm rains it causes disastrous floods; but in ordinary seasons the main body of it is melted about June and causes the summer-rise in the rivers.

The law of the greater precipitation of rain upon the western flanks of the mountains is well exhibited in the number, size, and volume of the streams which have their sources in these mountain-ranges. The streams of the west, or seaward, flank of the peninsula of San Francisco and of the Coast Range northward are greater than those on the eastern flank; and especially marked is this in the case of the Sierra Nevada, where it may be also noted that the streams of the west flank exceed in aggregate volume those of both flanks of the Coast Range.

The figures to establish this well-known law are not produced in this place, as they will be used in the remarks upon the unequal fall of rain over the country.

C.—*The average yearly rain-fall over the basin of the Great Valley is sufficient to insure good crops annually.*

This proposition embraces two vital questions:

1st. What amount of rain-fall, if properly distributed, will insure a crop?

2d. What amount of rain-fall is there over the entire basin? Because if the amount of water is insufficient to insure crops over the entire valley, the whole subject of irrigation becomes limited and restricted, and also more complicated in every aspect.

We are satisfied that the proposition is correct.

We can best determine what amount of rain-fall will guarantee a crop by a good practical example, and fortunately that is at hand. During the rainy seasons of 1870–'71, 1871–'72, 1872–'73, a record of the rain-fall at Visalia, in the southeastern part of the Great Valley, was kept by Dr. James W. Blake, and is so instructive that we introduce the daily rain-fall for the year, upon which good crops were obtained in that section.

In 1870–'71 the total rain-fall was about 6.8 inches; in 1871–'72, 10.3 inches; in 1872–'73, 7.2 inches. In the first and third of these years the crops were failures; in the second year the harvest was an abundant one. In 1872–'73 the distribution of the rain-fall was very equable and adequate to the end of February; after that only one-quarter of an inch of rain fell upon one day in March and one in April, and the crops were virtually lost.

The critical period in the growing crops appears, in this as in other districts, to be about the middle or end of February, when the grain is several inches high, and another rain-fall of one or two inches would give good crops, whilst a cessation of rain leaves them blighted.

*Rain-fall at Visalia,* 1871–'72, *when a full crop was secured.*

| | | | Inches. |
|---|---|---|---|
| 1870. | November | 26 | 0. 50 |
| | | 27 | 0. 24 |
| | | 28 | 0. 44 |
| | December | 17 | 0. 10 |
| | | 18 | 0. 12 |
| | | 19 | 0. 33 |
| | | 20 | 0. 06 |
| | | 21 | 0. 28 |
| | | 22 | 0. 68 |
| | | 23 | 0. 15 |
| | | 27 | 0. 20 |
| | | 28 | 0. 98 |
| | | 29 | 0. 62 |
| | | 31 | 0. 40 |
| 1871. | January | 9 | 1. 05 |
| | February | 4 | 0. 30 |
| | | 5 | 0. 16 |
| | | 9 | 0. 17 |
| | | 22 | 0. 45 |
| | | 23 | 0. 50 |
| | | 24 | 0. 38 |
| | | 27 | 0. 40 |
| | March | 28 | 0. 91 |
| | | 29 | 0. 05 |
| | April | 13 | 0. 08 |
| | | 16 | 0. 48 |
| | | 17 | 0. 07 |
| | | 27 | 0. 13 |
| | | 28 | 0. 11 |
| Total inches | | | 10. 34 |

Throughout the southern sections of California crops have been secured when 12 inches of rain have fallen in the wet season; but the precipitation is not so reliably uniform as farther north. Farmers and stockmen claim good crops with 15 inches of rain, if it has fallen somewhat evenly throughout the season. This amount would not be necessary to mature the crops if, at the beginning of the rainy season, the earth had not been parched several feet deep by the excessive dryness and heat of summer.

The land cannot be plowed until the first rains have moistened the earth to a sufficient depth. During May we experienced a temperature of 130° in the sun between Bakersfield and San Emedio Cañon, and for months the temperature in the sun ranges over 100°. This great heat, accompanied by excessive dryness of the atmosphere and months of cloudless sky, evaporates every particle of moisture from the ground, and produces conditions which the farmers of the Atlantic States can hardly comprehend. It also demands a larger supply of water for maturing a crop than would be the case if the ground were moist when the proper season of plowing and sowing arrived.

The second question under this proposition now arises, What is the amount of rain-fall over the basin of the Great Valley?

Although the statistics are not as numerous as could be desired, yet they are sufficient to enable us to affirm with certainty that the average yearly rain-fall is not less than 20 inches, and may be much larger. This, it must be understood, is over the whole basin, from the crest of the Sierra Nevada to the crest-line of the Coast Range.

Commencing at the northward, we gather the following statistics from the Smithsonian publication already noticed, and from other sources:

At Fort Crook, on the Upper Sacramento River, elevation 3,390 feet, in eight years, from January, 1858, to October, 1867, an average of 23.7 inches of rain-fall.

At Fort Reading, on the Sacramento River, near Redding, in three and three-quarter years, from April, 1852, to March, 1856, 29.1 inches

At Clear Lake, head of Cache Creek, in six years, from 1867 to 1873, 34.4 inches.

At Sacramento, in twenty-four years, from September, 1849, to August, 1872, 19.6 inches.

At Benicia, in thirteen and a half years, from November, 1849, to December, 1864, 15.1 inches.

At Stockton, in three and one-half years, from January, 1854, to December, 1857, 13.7 inches.

At Millerton, on the San Joaquin River, in six and three-quarter years, from July, 1851, to June, 1858, 19.0 inches.

Thence, through the broadest part of the valley to Fort Tejon, we have no observations except those at Visalia during the three dry winters of 1870–'71–'72–'73, as already detailed, and averaging 8.1 inches.

At Fort Tejon, 3,240 feet above the sea and 3,000 feet above the valley, in four and two-third years, from March, 1855, to August, 1864, 19.5 inches.

From the mouth of the Sacramento southward along the west side of the valley, to its extremity, there are no records by which we can approximate the rain-fall.

The averages of the foregoing results, giving them weights proportionate to the number of years of observations, give the following results:

Average yearly rain-fall in the valley, or foot-hills of the Valley of California, north of the mouth of the Sacramento River, equals 23 inches; average in the valley south of the Sacramento River, 16 inches.

In the southern part of the valley, the average rain-fall over the valley proper is barely sufficient for maturing a crop if we consider that at Fort Tejon, in the mountains, the rain-fall is heavier than in the valley, and therefore that the derived average of 16 inches, which was obtained for a short period and few stations, is too great.

This is confirmed by the experience of the country where the usual estimate is that one crop in three years or two crops in five years is all that can be raised.

But both in the northern and southern parts of the valley, the flanks of the mountains, where, as we have shown, the largest rain-fall takes place, have a greater area than the plains of the valley, and therefore throughout the northern and southern parts of the basin there *falls, on the average, a superabundance of water for all the purposes of maturing crops.*

D.—*The rain-fall in different years is very variable, and seasons of drought and of great floods occur, and in any one season it is very unequally distributed in different sections.*

A glance at the annexed charts of rain-fall will show to what a narrow belt of coast the rain-fall upon the Pacific slope is restricted, in fact, embracing but the State of California, part of Oregon, and Washington Territory, while the region for which irrigation is required embraces but a fraction of California.

Hence it is very evident that any slight modification in the immediate causes which occasion the precipitation of rain along the coast will lead to large variations in the rain-fall of different localities and of different seasons.

A deflection of the oceanic current which bathes the western coast of the United States, or the decrease of the temperature of this stream by a few degrees, and the absence of the vapor-laden air which hangs over it, or the absence or moderate character of the "southeasters" during the winter months, or all combined, will be accompanied by months of beautifully clear skies, mild weather, and a very small amount of rain-fall.

But no matter what the causes are, we have to deal with the facts as we find them, and can best illustrate our proposition by some examples in California from the Smithsonian tables collated to 1867.

*Table showing the extremes of rain-fall at various localities in California.*

| | Inches. | | Inches. |
|---|---|---|---|
| At Fort Reading, (3 years,) range | 37.4 | to | 15.9 |
| At Sacramento, (17 years,) range | 27.5 | to | 11.2 |
| At Millerton, (6 years,) range | 49.3 | to | 9.7 |
| At Stockton, (3 years,) range | 20.3 | to | 11.6 |
| At Fort Tejon, (5 years,) range | 34.2 | to | 9.8 |
| At Monterey, (5 years,) range | 21.6 | to | 8.2 |
| At San Diego, (12 years,) range | 13.4 | to | 6.9 |
| At Benicia, (12 years,) range | 20.0 | to | 11.8 |

These results* do not, however, fairly represent the ranges, because the yearly averages of the tables are computed from January 1 to December 31 of each year, as is done in the Atlantic States, but they are the best available.

From other sources we have the following results reckoned by wet seasons.

| | Inches. | | Inches. |
|---|---|---|---|
| At Clear Lake, (1,300 feet elevation, 6 years,) range | 66.7 | to | 16.2 |
| At Visalia, (3 years,) range | 10.3 | to | 6.7 |
| At San Francisco, (22 years,) range | 49.3 | to | 7.0 |
| At Pillarcitos, (9 years,) range | 82.0 | to | 39.0 |
| At Sacramento, (24 years,) range | 36.4 | to | 4.7 |
| At San Diego, (22 years,) range | 14.8 | to | 4.5 |
| At Modesto, (1870–'71) | | | 2.4 |
| At Stockton, (1870–'71) | | | 5.0 |
| At Marysville, (1870–'71) | | | 6.7 |

† These minima clearly indicate that there must exist years of drought when the crops cannot mature, and we have shown that a few inches more of water from rain-fall or from irrigation would have saved the produce of large areas of land.

In some seasons the greater volume of rain falls early in the season, and if the seed is sown before that the crops seem assured; but a following dry spring, as in 1873, cuts off one-half the crop throughout the moister parts of the valley, and totally destroys the crops in the southern part, except those isolated places blessed with the waters of irrigation, which we visited at localities on the east and west sides of the southern part of the valley.

The rain-fall of the years 1868–'69, 1869–'70, 1870–'71, was marked as not only below the average over the whole extent of the country, but throughout the southern section south of Monterey, and in the southern part of the Great Valley the rain-fall was so limited that neither grain nor grass grew. Hundreds of farms were abandoned, and stock-men were compelled to drive their cattle, horses, and sheep to the gulches of the mountains not only for food but for water.

* Smithsonian Contributions to Knowledge No. 222, already cited.

† At Shasta it is reported that 94 inches of rain fell in 1870–'71, which was a dry winter over the rest of the State, and 32 inches in 1872–'73, which was a wet winter with moderately dry spring.

In February, 1870, not a blade of grass was to be seen over the extensive valley of the Santa Clara; and the broad plains of Los Angeles, covering over one million of acres of arable land, were nearly desolate even to the borders of the streams. From Tulare Lake to San Diego, the country was nearly desolate; and in March, 1871, the usual season when the crops should be luxuriant, not a blade of grass was to be seen over the great plains and through the valleys, which are richly covered after favorable rains. Hundreds of thousands of sheep, horses, and cattle were lost by starvation.

The practical deduction of the farmers in the southern part of the Great Valley is that they can secure about two crops in five seasons; but this is still reduced in the extreme southern section, where we traversed ten and twenty miles at a time without a cabin to indicate a claim, yet where the land was remarkably good. The great drought of the seasons 1862–'63, 1863–'64, when only 13.6 and 10.1 inches of rain fell at San Francisco, was not so severely felt by the State, because the population was much smaller, and grain-crops were not then so largely cultivated; but a recurrence of such years at the present time or in the future would be accompanied by the most disastrous results to the prosperity of the country, unless artificial means be adopted to secure the use of the waters from the streams.

In 1850 only 7.0 inches of rain fell at San Francisco; such a season now without irrigation would produce a famine.

E.—*With a proper system of controlling the waters of precipitation and delivering them to cultivated lands when needed, annual crops may be assured.*

The statistics of rain-fall which we have presented and our personal knowledge of the country satisfy us that the average rain-fall is sufficient to secure an annual crop if the water be properly distributed; but a still more important question arises, whether in seasons of insufficient rain-fall enough water can be gathered from the streams draining the flanks of the mountain-range and applied to the cultivated lands, in addition to the rain-fall, to mature the crop. The statistics of rain-fall and crops at Visalia, already given, though limited, are valuable in this connection; but the experience last spring of the farmers on and beyond the line of the San Joaquin and King's River Canal is particularly interesting.

In this section we examined about twenty thousand acres of nearly matured crops at the end of May, and received from the farmers themselves their statement of the effects of irrigation.

Up to the time when the rains ceased, in February, the prospects of the farmers were particularly bright, and they would not take the waters of irrigation.

The grain was about six inches high, and very strong; but the dry weather, clear skies, and north winds soon parched up the earth, and the wheat began to grow yellow and sickly.

About the beginning of March every exertion was made to use the waters of the canal for irrigation; secondary ditches were hurriedly cut, and the water conveyed to the lands in a very crude manner.

One good flooding was given to saturate the soil; the grain revived, the crop was saved, and when we visited it the farmers claimed from thirty to as high as fifty-five bushels of wheat per acre.

They were earnest and enthusiastic in their praise of irrigation, as well they might be, for it was simply the difference of a total loss of their year's labor and grain that would yield them $1.20 per bushel.

Much of this land had previously failed to secure purchasers at $2.50 per acre, and many farmers had debated whether to abandon their farms or wait for another rainy season to make up for previous losses.

These crops raised the value of all lands capable of irrigation from $2.50 and less to $25 and $30 per acre. Many farmers from the western side of the valley visited these growing crops to compare them with their own parched fields, and there was a unanimous expression of opinion of the value of irrigation.

We examined similar effects at other points on the western side of the valley, and throughout the whole of the flanks of the Sierra Nevada where the water from the mining-ditches is used for irrigating the hill-sides for grain, grass, alfalfa, and fruit.

But all the irrigation that has been effected so far has, with one or two notable exceptions, been done with little or no system, and with a lavish waste of water that could never be permitted in any well-arranged system where the minimum of water would necessarily have to be husbanded to accomplish a maximum of results.

So-called canals and ditches have been constructed without regard to permanency or regimen, or the least foresight. And the "dog-in-the-manger" policy has been carried out by those claiming the water-rights, some of which are of the most extravagant character, and if fully persisted in must prevent the full development of which irrigation is capable.

Our examination has taken us over the entire valley and foot-hills, and we have visited all the principal and most of the small streams of the eastern and western sides. From rough measurements we became satisfied that with well-constructed main irrigating-canals to receive and conduct the waters of the streams and lakes, with the secondary, tertiary, and other ditches leading therefrom, and with a proper system of distribution of water, there was ample water to irrigate a large part of the whole valley; and, moreover, that if the waters were properly stored in those localities where large areas of good land exist with the smallest amount of rain-fall, there would be sufficient water to irrigate the whole area of the valley. But the system of irrigation would require to be of the highest character to attain this end; with some exceptions, the disjointed canals now constructed could not be made to approximate such a result; and when others are added in similar defiance of sound engineering, the result will be a partial and temporary good for only a part of the valley, and will lead to an intricacy of endless legal troubles. Those canals that have been properly constructed can be readily consolidated with an extensive system.

F.—*The climate is mild throughout the wet or winter season, and especially well suited for all agricultural pursuits.*

Throughout the whole of the Great Valley a slight fall of snow, such as occurred in December, 1873, is looked upon as strange and unusual. It then fell to a depth of a few inches and lasted but a few hours; but many years intervene without the occurrence of snow.

Ice is very seldom seen, and only in the early morning of some day far below the usual temperature, which averages nearly 50° Fahrenheit throughout the winter.

During this season, all agricultural pursuits are steadily carried on without a thought or care of a cold period sufficient to injure the crops; the stock roam the pastures and hill-sides without protection from the weather, and by the first of February the whole valley and mountain-flanks are clad in the brightest and richest green.

Delicate flowers that thrive only in hot-houses in the Atlantic and Western States are cultivated in the open-air and grow to great size. If the rains have been late, plowing is carried on to the end of December, and even later; or if the early rains have been very heavy and have inundated the lowlands so that the seed is destroyed, the land is again plowed and another crop planted. In fact, open-air pursuits are here carried on during the winter-months as comfortably as during May in the Middle States.

The exceptional "northers" that blow strongly and cold with a dry wind are apt to blight the young crops; but toward the end of a moderately dry season they have a good effect if without much force.

After the last rains in March, the warm weather increases rapidly; the clear, sunny weather, and the dryness of the atmosphere aid in maturing the grain very rapidly. Then follows a remarkable feature in the agriculture of this country: the crops when ripened need not be cut for months; in some cases they are not cut until the next wet season approaches, or if cut and thrashed the grain is sacked, piled up, and if necessary allowed to remain upon the dry earth until the rains of October.

The effect of this dry weather is seen in the quality of the wheat, which produces a flour with much less moisture than any in the Atlantic States.

During this dry season the heat is very excessive, but unaccompanied by the enervation and lassitude which an equally-heated and humid atmosphere would certainly cause.

Throughout the valley at midday, in the middle of summer, the temperature very closely approximates 100° in the shade, and is frequently above that.

While we were in the vicinity of Kern Lake, the temperature at the end of May was 130° in the sun, yet we were able to drive in an uncovered wagon, forty miles per day, without much discomfort; even with this high day-temperature, the nights were pleasant.

Along the foot-hills of the Sierra, the heat of last July was very great, reaching from 100° to 116° in the shade for seventeen consecutive days in some localities.

But before this excessively-heated season of the year has been reached, the crops have been matured and are safe, because the hot, dry weather and the parched surface of the ground prevent the standing grain from being mildewed, and it is not even shriveled.

It has been difficult to collect observations for temperature in connected series; but the following tables have been compiled to exhibit the yearly mean temperature at various localities, together with the maxima and the minima temperatures.

They fully confirm the mildness of the winter-season and the equable temperature of all seasons.

*Table of temperatures in and adjacent to the Great Valley.*

| Places. | Altitude above the sea. | Geographical position. | | Period of observation. | Temperature. | | | | Rain and snow. | Authorities and remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Latitude. | Longitude. | | Mean of hottest day. | Mean of coldest day. | Range. | Mean. | | |
| In the Great Valley: | *Feet.* | ° ′ | ° ′ | | ° | ° | ° | ° | *Inches.* | |
| Fort Reading | 674 | 40 31 | 122 05 | 4 years | 83. 0 | 44. 0 | 39. 0 | 62. 1 | 29. 1 | Army Meteorological Register, 1855. |
| Chico | 150 | 39 46 | 121 50 | 1½ years | 92. 3 | 37. 0 | 55. 3 | 64. 7 | 17. 7 | Engineer department Central Pacific Railroad, 1870–'71. |
| Colfax | 2, 421 | 39 03 | 120 55 | 1½ years | 91. 7 | 33. 3 | 58. 4 | 62. 7 | 30. 8 | Do. |
| Auburn | 1, 363 | 38 57 | 121 02 | 1½ years | 91. 0 | 34. 3 | 56. 7 | 62. 8 | 17. 6 | Do. |
| Marysville | 76 | 39 12 | 121 42 | 1 year | 90. 0 | 38. 0 | 52. 0 | 63. 3 | ........ | W. C. Belcher, 1858. |
| Sacramento | 54 | 38 31 | 121 20 | 24 years | 94. 0 | 32. 0 | 62. 0 | 60. 3 | 19. 6 | Thomas M. Logan, M. D. |
| Vacaville, Solano | 100 | 38 20 | 122 00 | 1 year | 86. 0 | 37. 0 | 49. 0 | 53. 3 | 24. 2 | Prof. J. C. Simmon. |
| Stockton | 23 | 37 37 | 121 14 | 1½ years | 91. 0 | 41. 0 | 50. 0 | 66. 0 | 4. 8 | Engineer department Central Pacific Railroad. |
| Fort Miller, (Millerton) | 402 | 37 00 | 119 40 | 5 years | 90. 0 | 47. 0 | 43. 0 | 66. 0 | 24. 5 | Army Meteorological Register. |
| Benicia | 183 | 38 08 | 122 14 | 18 years | 80. 0 | 44. 0 | 36. 0 | 59. 1 | 22. 9 | W. W. Hays, surgeon U. S. A. |
| San Francisco | 22 | 37 48 | 122 27 | 19 years | 78. 0 | 37. 0 | 41. 0 | 56. 4 | 21. 5 | Henry Gibbons, M. D. |
| Monterey | 140 | 36 36 | 121 52 | 6 years | 59. 0 | 50. 0 | 9. 0 | 55. 0 | 12. 2 | Army Meteorological Register. |
| Santa Barbara | 300 | 34 31 | 119 38 | 1 year | 92. 0 | 42. 0 | 50. 0 | 60. 2 | 15. 0 | J. A. Johnson. |
| San Diego | 150 | 32 42 | 117 14 | 7 years | 74. 0 | 52. 0 | 22. 0 | 62. 0 | 10. 4 | Army Meteorological Register. |
| Fort Yuma | 120 | 32 43 | 114 36 | 6 years | 92. 0 | 56. 0 | 36. 0 | 74. 0 | 3. 2 | Do. |
| Port Orford, Oreg | 50 | 42 44 | 124 29 | 4 years | 61. 0 | 46. 0 | 15. 0 | 53. 6 | 71. 6 | Do. |

The foregoing tabular statement gives a mean temperature of 61°.4 throughout the valley, giving weights to the different results in proportion to the years of observation; the average of the maxima, 91°.8; and the average of the minima, 35°.4; and the extreme range observed, 58°.4.

The following table exhibits the monthly temperature of one station, Sacramento, in the valley, and of three upon the coast; the latter introduced to exhibit the relation between them.

| Months. | Sacramento, 10 years. | | Fort Point, 11 years. | | San Diego, 20 10-12 years. | | Astoria, Oregon, 11¼ years. | |
|---|---|---|---|---|---|---|---|---|
| | Thermometer. | | Thermometer. | | Thermometer. | | Thermometer. | |
| | ° | | ° | | ° | | ° | |
| December | 46. 79 | | 52. 22 | | 54. 11 | | 40. 83 | |
| January | 45. 59 | Winter, 47°.75. | 50. 59 | Winter, 51°.54. | 53. 55 | Winter, 54°.09. | 38. 44 | Winter, 39°.35. |
| February | 50. 86 | | 51. 81 | | 54. 60 | | 38. 78 | |
| March | 54. 02 | | 53. 15 | | 57. 11 | | 44. 24 | |
| April | 59. 45 | Spring, 58°.86. | 55. 52 | Spring, 55°.43. | 60. 72 | Spring, 60°.14. | 48. 75 | Spring, 48°.72. |
| May | 63. 12 | | 57. 61 | | 62. 59 | | 53. 16 | |
| June | 70. 35 | | 58. 93 | | 66. 68 | | 57. 50 | |
| July | 73. 45 | Summer, 71°.61. | 59. 86 | Summer, 59°.21. | 70. 32 | Summer, 69°.67. | 60. 29 | Summer, 59°.52. |
| August | 71. 03 | | 58. 84 | | 72. 02 | | 60. 77 | |
| September | 68. 84 | | 59. 31 | | 69. 38 | | 58. 30 | |
| October | 62. 56 | Fall, 61°.56. | 58. 36 | Fall, 58°.04. | 65. 18 | Fall, 64°.53. | 52. 69 | Fall, 52°.41. |
| November | 53. 28 | | 56. 44 | | 59. 04 | | 46. 23 | |
| Yearly average | 59. 91 | .......... | 56. 05 | .......... | 62. 11 | .......... | 50. 00 | .......... |

The observations at Sacramento are by Dr. Thomas M. Logan; those at Fort Point, San Diego, and Astoria, by the United States Coast Survey.

G.—*The Great Valley of California is admirably adapted for irrigation.*

This great valley is a marked geographical feature of the Pacific coast of the United States.

To show its relation to the State of California and of Nevada, we append the map of the State geological surveys; and to exhibit it in greater detail, we append the map of the valley on a larger scale as drawn in the office of the geological survey, with additions under the direction of the commission. It lies between latitudes 34° 50′ near Fort Tejon, and 40° 40′ near Shasta, giving an extreme length of four hundred and fifty miles, and an average width of forty miles, including the foot-hills of the mountains. The general trend of its longer axis is north-northwest and south-southeast, lying parallel to the Pacific coast line, from which the middle line averages a distance of eighty-five miles.

It lies between the great range of the Sierra Nevada on the east and the Coast Mountains on the west, the crest-lines of these ranges being nearly parallel.

The average elevation of the former is perhaps 9,500 feet; that of the latter over 2,000; while the valley ranges from 30 feet at Sacramento, to 282 feet at Kern Lake at the south, and to 556 feet at Redding at the north. These ranges of mountains are separated by an average breadth of one hundred and ten miles; and from Mount Shasta at the headwaters of the Sacramento River to the Tejon Pass, the length is five hundred and twenty miles. This gives an area of 57,200 square miles, equal to that of Illinois, or Wisconsin, or Michigan, or Iowa, or Ohio and half of Indiana combined, or of half the area of all the Middle States.

The drainage of this large area is effected through the Sacramento and San Joaquin Rivers, the former being one of the few great rivers of North America emptying into the Pacific.

This great basin is hemmed in on all sides by mountains, except at the great rupture in the Coast Range occupied by San Francisco, San Pablo, and Suisun Bays, into which the Sacramento River empties.

The only direct communication with the Pacific Ocean is through the Golden Gate, which is one mile wide at its narrowest part.

The northern part of the valley is more contracted than the southern part, and the extent of the low flat lands much less. It is drained by the Sacramento River and its tributaries through the center of the valley proper.

This river presents a striking peculiarity, in that, with mountains on either side, it does not receive a tributary of note for two hundred miles of its course northward from the confluence of the Feather River.

Like all rivers flowing through broad valleys, it presents the phenomenon of running on a ridge down the middle line of the valley; on either side, at a distance of three or four miles, the valley is lower than the river-banks, reaching 20 feet in the vicinity of Colusa; and in seasons of continuous heavy rains, the river discharges part of its volume through sloughs into the parallel depressions, which also receive the discharge of the mountain-streams, and large areas thus become overflowed.

On the western side from the mouth of the Sacramento northward the flanks of the mountains are narrow and nearly treeless, the rain-fall comparatively small, and the streams very short and generally dry in summer.

The only streams that carry water in summer are Puta Creek, Cache and Stony Creeks, but in summer these lose their waters beneath their beds soon after leaving the hills. On the western side, north of Knight's landing, the plains are destitute of trees.

On the eastern side, north of the mouth of the Sacramento River, the distance from the river to the crest of the Sierra Nevada is nearly twice that of the western side. The flanks receive the winter-clouds driven against them by the southerly gales, and condense the vapor into rain or snow, and the rain-fall over given areas is three or four times that on the west side of the valley. There are consequently more and larger streams tributary to the Sacramento, the Mokelumne, Consumnes, American, Yuba, Feather, and numerous smaller streams, each equal, or nearly so, to the Puta, Cache, or Stony Creeks.

The mountains are well timbered; the foot-hills moderately so. The lowlands and plains have a narrow belt of wood along the streams, and scattered trees and groves are found over the greater part of the plains.

South of the mouth of the Sacramento River the valley gradually increases in width to the vicinity of the Kaweah River, where it reaches a breadth of seventy miles.

Through the middle or rather west of the middle line of the valley runs the San Joaquin River and the connecting line of sloughs and lakes from the southern extremity of the valley.

As on the Sacramento River, the banks of the San Joaquin River are higher than the land two or three miles on either side, but in a much less marked degree than in the former case; and the same general feature holds good for all the streams.

On the western side the flanks of the mountains are narrow and treeless, and the rain-fall upon them probably not over one-third or one-fourth that of the eastern side; consequently the streams are all very short, the courses small, and in summer the beds dry at the base of the foot-hills, while the plains are treeless, except a narrow fringe along the banks of the streams.

On the eastern side of the valley, the flanks of the mountains are very broad, averaging over fifty miles in width, well timbered in many places, but the quantity of the timber decreasing to the southward, while the foot-hills are sparsely wooded and in very many localities treeless.

The number of the streams and their relative volumes decrease to the southward, but they drain large areas, as we have elsewhere shown.

The Calaveras, Stanislaus, Tuolumne, Merced, San Joaquin, King's, Kaweah, and Kern Rivers are all good streams, and some of them quite large. The plains and most of the foot-hills are treeless, except along the valleys of the streams; and toward the southern extremity many miles are passed without seeing a tree.

One of the features of this part of the valley is the large lakes, Kern, Buena Vista, and Tulare, which receive the drainage of the streams at the southward, King's, Kaweah, and Kern.

Tulare Lake has an area of seven hundred square miles, equal to half the area of the State of Rhode Island. It is about 40 feet deep, and has very low marshy banks, which are subject to overflow in wet seasons, when the area of the lake becomes very much increased.

The lakes Kern and Buena Vista have an aggregate area of about forty-four square miles; the former we sounded across, and at the end of May, 1873, it had a maximum depth of $16\frac{2}{3}$ feet. The water was then very green, warm, and unfit for domestic use.

As a general proposition, the whole valley may be considered as formed of four plains, two north of the mouth of the Sacramento River and two south of it. The two northern plains slope toward each other along the line of the Sacramento River, and at the same time slope toward the south. The two southern plains slope toward each other along the line of the lakes and San Joaquin River, and at the same time toward the northward.

So flat and level do these plains appear that the eye is constantly deceived by them and the judgment undetermined which way they slope until instrumental means are applied.

From Redding to the mouth of the Sacramento River, the fall of the valley is 556 feet in one hundred and ninety-two miles; from Kern Lake to the mouth of the San Joaquin, it is 282 feet in two hundred and sixty miles; while cross-sections indicate that the slope of the east and west plains toward the line of greatest depression is quite moderate.

In the southwestern section of the valley, between Firebaugh's and Hill's ferries, the levelings show that the ground falls from the foot-hills to within four and a half miles of the river at the rate of 6 feet per mile, thence it is nearly level to within a half mile of the river, which it then approaches with an ascent of $1\frac{1}{2}$ feet per mile.

At Banta's the plains are contracted, and the fall reaches 18 feet per mile toward the river. In the southeastern section of the valley the fall of the land from the vicinity of Bakersfield to Tulare Lake is about $5\frac{1}{2}$ feet per mile for thirty-eight miles; Tulare River, from the crossing of the Southern Pacific Railroad, falls at the rate of 3 feet per mile to the lake in eighteen miles; and the fall from Visalia to the north point of Tulare Lake is $4\frac{1}{2}$ feet per mile for twenty-nine miles.

For the northeastern and northwestern sections of the valley the commission has no data available to exhibit the cross-section.

We have mentioned in general terms the two main rivers which drain the valley; but it appears necessary to state more in detail that their tributaries are generally well distributed for controlling and delivering water, and that they divide the valley into natural irrigation-districts. This is notably so on the eastern side of the valley from its northern extremity to the Kaweah River at Visalia. In the southeastern part the main reliance is upon Kern River, which is a good-sized stream, flowing probably 2,500 cubic feet a second, (May 23, 1873,) where it leaves the cañon, and losing comparatively little in volume where it leaves the foot-hills near Bakersfield. But the area to be irrigated from this source, aided by the small streams in the extreme southeastern part of the valley, is very large, and the water must be economically distributed.

This river drains the highest and wildest part of the Sierra Nevada, and its course is said to be marked by deep cañons, above each of which there may doubtless be opportunities to establish large reservoirs, while advantage can be taken of forming reservoirs in the hills to hold the water of all the minor streams. These are, of course, propositions for the future.

North of the Kaweah the streams are well distributed, and there is an ample supply to supplement the ordinary rain-fall on the plains, except possibly, in a long series of years of drought.

The principal streams on the eastern side of the valley, commencing at the southward, with their area of catchment above the points where dams should be constructed, as taken from the map herewith appended, are the following:

| | Square miles. |
|---|---|
| San Emedio and other small streams | 650 |
| Agua Caliente, Tehatchipi, &c | 461 |
| Kern River | 2,382 |
| Posa Creek | 278 |
| Tule River | 446 |
| Kaweah River | 608 |
| King's River | 1,853 |
| San Joaquin River | 1,630 |
| Fresno Creek | 258 |
| Chowchilla Creek | 303 |
| Mariposa and Bear Creeks | 248 |
| Merced River | 1,072 |
| Tuolumne River | 1,513 |
| Stanislaus River | 971 |
| Calaveras River | 389 |
| Mokelumne River | 573 |
| The branches of Dry Creek | 208 |
| Consumnes River | 589 |
| American River | 1,889 |
| Coon and Bear Creek and branches | 484 |
| Yuba River | 1,329 |
| Feather River | 3,393 |
| Small streams hence to Redding, about | 1,600 |

Several small streams lying between some of those enumerated have not been mentioned as having less than one hundred miles area each. The total of those enumerated is 22,127 square miles of catchment; but without surveys it is impracticable to estimate the ratio of area of each catchment to the area to be irrigated in the different districts.

On the southwestern side of the valley the streams are, as already related, short, small, and drain small areas where the rain-fall is a minimum. There the main reliance for the waters of irrigation must be upon Kern and Buena Vista Lakes, with an aggregate of forty square miles, upon Tulare Lake with an area of seven hundred square miles, and upon the waters of the San Joaquin, as already used by the San Joaquin and King's River Canal and Irrigation Company.

Although the small streams of the southwestern side lose themselves as soon as they leave the foot-hills, yet they drain a total area of two thousand square miles, and in the future the waters may be retained in hill-reservoirs for the uses of irrigation. In this section the following are the areas of catchment of streams having each over a hundred square miles, the areas reckoned above the positions of the necessary dams:

| | Square miles. |
|---|---|
| Los Gatos | 420 |
| Cantua | 164 |
| Big Panoche | 319 |
| Little Panoche | 136 |

Thence to the northward as far as Corral Hollow Creek the total area of catchment is five hundred and thirty-three square miles.

On the northwestern side of the Great Valley the streams are larger than on the southwestern. Some of them drain large areas, and are capable of affording a good supply of water for comparatively broad tracts of land. Clear Lake, with an area of eighty square miles, and 1,350 feet above the sea, forms a great natural reservoir, discharged through Cache Creek; and for a very trifling sum its surface may be raised 15 or 25 feet by the construction of a dam a few miles below the head of the creek.

The waters of this creek have already been dammed for irrigation, as elsewhere related. But the main source of supply for this northwestern section is from the Sacramento River at a point near Red Bluff. A canal from this vicinity will irrigate the lands skirting the foot-hills and reaching to the bottom of the trough described as running about three miles from and parallel with the Sacramento River and as much as 20 feet below its bank, while another canal may follow the right bank of the river to irrigate westward to the lowest line of the valley.

The rain-fall in this region averages larger than throughout the whole southern or San Joaquin part of the valley, but it is probably less than one-half what falls on the northeastern side.

For the irrigation of the comparatively small belt of flat land lying between the foot-hills and the canal, leaving the Sacramento River at Red Bluff, there are numerous small streams available, but the following are the principal streams, naming them from the mouth of the Sacramento River northward, with their areas of catchment above the proper location of the necessary dams:

| | Square miles. |
|---|---|
| Putah Creek | 584 |
| Cache Creek, (Clear Lake) | 1,024 |
| Stony Creek | 591 |
| Arroyo de los Sancos | 212 |
| Reed's Creek | 219 |
| Cottonwood, near Redding, about | 700 |
| Or, a total of | 2,330 |

We elsewhere state that the area of the lands which may be readily irrigated is about 7,650,000 acres, and, if we include what are called swamp or overflowed lands, this area is increased to 13,300 square miles, or 8,500,000 acres; but if the low foot-hills are included, it is estimated that 18,750 square miles, or 12,000,000 acres, are capable of irrigation.

In the former case, the area of catchment outside of the lands to be irrigated is between three and three and a half square miles to each square mile to be irrigated, while in the latter case it is about three square miles to one.

Now, if a monthly average of 3 inches of the rain-fall over the whole area of catchment was delivered during the rainy season by all the streams, they would furnish a supply equal to a monthly average depth of 10 inches of water over the whole of the first-mentioned area. Of course, in consecutive seasons of drought this amount would be much decreased.

From rough observations of the actual discharge of Kern River near the end of May, 1873, it was found to be equal to a depth of 1½ inches per month from the whole area of catchment of 2,400 square miles. This would give a depth of 3 inches for irrigation over 1,200 square miles, or 768,000 acres, which is larger than its natural irrigation-district; or, to express the foregoing quantity in other terms, the Kern River in May was daily discharging a body of water equal to a stratum 3 inches deep over an area of 25,600 acres. The discharge was doubtless much larger from the middle of February to the end of March, when the waters of irrigation are most needed. These partial results are very suggestive and satisfactory, and we are convinced that the whole eastern side of the valley northward of the Kern River will yield more ample supplies of water.

The soil throughout the Great Valley is of the best and most readily-worked character, but the commission has not the data to enter into a detailed description of such an extensive region.

In some of the localities visited by us, more especially in the southern section of the valley, small areas of otherwise fine land showed the presence of "alkali;" and east of Kern Lake a rude manufacture of salt had been attempted by the evaporation of water obtained from shallow wells.

Broad belts of "adobe" are found throughout the southern section of the valley, while loam occupies the larger part of the main depression through which the rivers and lakes drain.

On the southwest side of the valley we found that on some of the irrigated lands near Los Baños Creek the adobe soil, dried hard to a depth of 2 inches after one complete flooding in March, prevented the evaporation of the moisture beneath, and the owners of one tract of three thousand acres claimed for the standing club-wheat (June 1) a probable yield of fifty-five bushels per acre. This crop would have been a total failure but for the waters of the San Joaquin and King's River Irrigation Company.

Along the eastern side of the valley, close under the foot-hills, there are considerable areas of good soil of small depth underlaid by what is locally known as "hard pan." Over other areas the soil is of moderate depth over gravel deposits. But throughout large areas of the valley and on the eastern side, extending in many places from the foot-hills to beyond the line of the Southern Pacific Railroad, the surface of the soil is peculiarly marked by innumerable and contiguous nearly circular mounds, locally known as "hog-wallows." These mounds, lying without perceptible symmetrical arrangement, are moderately uniform in shape and size; ranging from 6 inches in height to as much as 3 or 4 feet, although by far the greater number average about 1 to 1½ feet, as exhibited in the railroad-cuttings, and from 20 to 50 feet in diameter.

The largest we saw were on the Kaweah, above Visalia, and were composed of gravel, &c.

In many places the immediate substratum of these mounds is "hard pan;" but over large areas, where they abound, there appears to be no difference between their soil and the subsoil.

The mounds are mentioned because, where they occur on otherwise level plains, the waters of irrigation will not reach the tops of them, and it will require two or more seasons of plowing, conducted with special reference, to sufficiently reduce them for receiving irrigation. This we saw successfully done when crossing the valley from Millerton to Watson's Ferry. The farmers agree in saying that the summits of these mounds give a ranker growth of grass or grain than the low intervals between them. It is not our province to discuss their mode of formation, although it would appear to be the results of glacial action.

Notwithstanding these drawbacks, which are comparatively limited, it may be safely said that with water, the life-blood of this country, and with intelligent cultivation, the greater part of the plains of this great valley will annually yield an average of thirty bushels of wheat, or an equivalent of any other crop, to the acre.

The average in seasons of ample rains on fresh soil well cultivated is over that amount; but, unfortunately, there is little or no rotation of crops, no manure is supplied to the ground, and the cultivation is generally of the poorest character.

Where water has been available from rain-fall or irrigation, and the cultivation intelligently conducted, remarkable crops have been gathered, reaching from fifty to eighty bushels of wheat per acre, and as many as five crops of alfalfa, yielding an aggregate of fifteen tons an acre per year.

Throughout the country "volunteer crops" (that is, crops without cultivation, from dropped seed of the previous crop) are frequently relied upon for successive seasons, and reach as high as forty-five bushels of barley per acre under favorable circumstances.

The official reports of the State Agricultural Society abound with proof of the great fertility of these virgin plains, and of the salubrity of the climate for maturing and harvesting.

It is on record that in the San Joaquin Valley two crops of barley, each averaging over forty bushels per acre, were grown and harvested in two hundred and forty-five consecutive days.

Nevertheless, without a regular and certain supply of water to the land, the limit of cultivated land will soon be reached, and, consequently, the limits of population; but when five, eight, and twelve millions of acres are cultivated, and the regularity of good crops almost assured, it will be impossible to estimate the vast population and the varied industries which the valley will support.

But it will not be the Great Valley alone which will be filled with people; the valley of every stream, large and small, will be cultivated with part of the water which will subsequently reach the lower lands.

This great basin should in twenty years become the granary of the world.

The effects of irrigation will be permanently advantageous, because, when the soil once becomes moistened it will subsequently require the application of less water for each crop, and when once a thorough and comprehensive system is adopted the waters could readily be applied, if necessary, before the first rains to soften the ground and make it fit for the plow.

In fact, the whole method and season of cultivation would doubtless be modified, and it is within the range of probability to look forward to an average of two crops a year.

In the development of the irrigation of the valley another favorable feature would naturally be added in the cultivation of trees. These would not only be a remunerative source of investment, but would have a beneficial influence upon the soil and upon the young crops, because, if in sufficient bodies and numbers, they would protect the crops from the strong cold northers which have been mentioned as blighting the young and tender grain; and they would in a measure prevent the excessive rate of evaporation which now prevails during the hot summer-months in this comparatively treeless valley.

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# CHAPTER III.

1. Necessity of surveys—The funds at the disposal of the commission would not authorize surveys—Necessity of an instrumental reconnaissance and of detailed surveys.
2. System of irrigation—No continuous canal on the eastern side of the Great Valley—Each river may have one or more dams and canals—The San Joaquin and King's River Canal—Other canals—Some portion of the plain cannot be thoroughly irrigated—Canals on the western side of the Sacramento River—Main canal may be navigable—Clear Lake and its contents.
3. Influence of irrigation on the navigation of rivers—This influence is small—Experience in Italy and in India—Argument to show that this influence will be small on the navigation of the Sacramento and San Joaquin Rivers—Compensation by making some canals navigable.
4. What is irrigation?—Mistakes that have been made—Description as to how water is to be taken from a river and distributed over the land by dams, head-works, and canals—Examples taken from the San Joaquin and King's River Canal Company.
5. Existing and hypothetical canals—Existing canals at Bakersfield and Visalia—Canals from the King's River—The Chapman Canal—The Fresno Canal—Small canals—Hypothetical canals shown on the map.
6. General considerations—The irrigation of the foot-hills—Storage-reservoirs—Mining—Reclamation—Necessity of proper plans and location of works—Necessity of some authority—Farmers alone will never project and execute a comprehensive system—Connection between the irrigation of the foot-hills and mining and reclamation—Duty of Government.

## NECESSITY OF SURVEYS.

We remark that it was evident to us from the moment we commenced our examination of the Great Valley that it would be entirely impossible for us, on account of the limited time at our command, as well as the limited means at our disposal, to enter into details as regards the many problems in engineering which must present themselves for solution before a full report on the best system of irrigating these valleys could be perfected.

Such a report, as well as the first legislation on the subject of irrigating the Great Valley, should be founded on a careful instrumental reconnaissance, to embrace all the streams, and determine where a dam or dams on each of them can be best located; the amount of water that may be utilized; and the lines of main irrigating-canals. This would enable the valley to be divided into districts, and determine the amount of land that may be irrigated in each.

After such reconnaissances shall have established the extent and resources of the natural districts into which the valley is divided, then, when works of irrigation are contemplated in any given district, a minute survey should be made of that district, to determine the detailed location of the main canals and distributing-ditches.

The first reconnaissance specified could be made of a reasonable outlay, but the subsequent minute surveys, embracing specifications, plans, and estimates of the cost of works, will require a large expenditure.

It is not necessary, however, that the proposed instrumental reconnaissance shall be undertaken and carried through the entire valley at once, because the different districts are somewhat independent of each other, and are not in the same immediate need of irrigation.

## THE SYSTEM OF IRRIGATION.

We see from the topographical features of the eastern slope of the Great Valley that although water for irrigation is abundant, yet there cannot be any long line of continuous canal on that side, because all the rivers named above, and many smaller streams, flow down from the Sierra Nevada Mountains, and enter the plains in a direction more or less perpendicular to the Sacramento and San Joaquin Rivers, into which nearly all of these rivers finally empty.

No continuous canal can, therefore, be built, without great cost, along the foot-hills on the east side of the valley, because such a canal would cross the rivers escaping from the Sierra Nevada Mountains generally at right angles. The expense of bridging these streams with aqueducts or siphons to carry an irrigating-canal, in this country, with the present price of labor and material, would be enormous.

The system of irrigation on the eastern side of the Great Valley must, therefore, be by many short canals, so as to avoid crossing the different rivers and smaller streams by aqueducts.

Each river may have one or more dams thrown across it in the most favorable places.

All other considerations being the same, the higher up the streams the dams are placed the better, because it will always be desirable that the location and plan of the canals should be adapted to the irrigation of the largest area practicable at reasonable cost; and, besides, by keeping the canals which draw their supplies of water from the main rivers on a higher level, we will be enabled to draw water from them to supply those canals which are fed from the smaller streams, such as the Fresno, Chowchilla, Calaveras, Cosumnes, and Bear Rivers, as well as many others still smaller, which do not head in the high mountains, and whose water will, therefore, fail in the dry season. These dams across the larger rivers, as a general thing, will not be for the purpose of storing the river-water, however desirable such storage might be, but for the purpose of raising the surface of the water to such a height as will enable it to be carried out over or through the banks of the rivers, and get the canals into the plains which are to be irrigated at the least possible expense.

Each main river on the eastern side of the valley may thus have two canals, one on its right bank, the other on its left bank, and these main canals may be carried along on the proper grade so as to intersect the similar canals of the adjacent rivers to the right and left, supplying water, also, where it is wanted and where it can be made available to those smaller canals on a lower level which draw their supplies from the streams that do not head high enough in the mountains to have a perennial supply.

The proper location of the dams across the main rivers, and of the head-works and alignment of the main exterior canals, will present the most difficult and important problem which the hydraulic engineer undertaking the irrigation of the eastern side of the Great Valley will have to solve.

The dividing-line between a cost too great, in order to embrace more land, and the sacrifice of land that should be irrigated, will often have to be carefully determined by financial considerations.

It may be remarked that the banks of the rivers as well as of the smaller streams, as they flow through the lower plains, are, in many cases, higher than the plains to the right and left. The increased elevation of the banks of the rivers and creeks is usually discernible by the naked eye; but where instrumental levels have been taken the increased height of the banks, in some cases, appears to be very marked. Thus, on the Sacramento river, a few miles south of Colusa, the bank on the west side of the river was found by accurate levels to be twenty-one feet higher than the land at a distance of two and a half miles westward from the river. On the lower parts of the plains, where the river-banks are higher than the adjacent country, it will be necessary to carry the primary or secondary canals along on these banks in order that the adjacent plains may be irrigated.

It being impossible for us, on account of the limited time and means at our command, to enter upon such a minute reconnaissance of the Great Valley as must be made before a comprehensive and economical system of irrigation can be planned, we have availed ourselves of all attainable information bearing on the subject of irrigation of the valleys mentioned in the act of Congress.

The information thus obtained, mostly from surveys for proposed canals and from railroad-surveys, together with our own observations while traveling through and examining the country, furnish much of the data for this report.

Fortunately, our information about the west side of the San Joaquin and Sacramento Valleys is quite full, and is sufficient to enable us to lay down, with tolerable accuracy, the alignment, size, and slope of the main canals on that side of the Great Valley.

The San Joaquin and King's River Canal and Irrigating Company have already built a canal for irrigation from the great bend in the San Joaquin River (a few miles below Watson's Ferry) to Los Baños Creek, a distance of forty miles, and that company have caused an extensive system of experimental surveys to be made on the west side of the San Joaquin River, all the way from near the mouth of that river, to and around Kern Lake, to Kern River.

These surveys were made with the view of extending their present canal and also of ascertaining the practicability of constructing other canals on a higher level, drawing their supply of water from Tulare Lake and Kern River.

The company having kindly placed all the data in their office at our disposal, we are enabled to lay down the alignment of the canals for irrigation on the west side of the San Joaquin Valley.

These canals are:

1st. The canal already built from the great bend of the San Joaquin River to Los Baños Creek, a distance of forty miles. It is 28 feet wide on the bottom, is 6 feet deep, has a sectional area, when full, of 276 square feet, and with a grade of 1 foot per mile. The canal, when full, will therefore deliver 726 cubic feet of water per second, which would irrigate one hundred and forty-five thousand acres of land, allowing 1 cubic foot of water per second for two hundred acres.

2d. The proposed continuation of this canal, on a grade of 6 inches to the mile, to the Lower San Joaquin River, near Moore's landing.

3d. A proposed canal from Summit Lake, but actually drawing its supply of water from Tulare Lake, (which is fed by King's, Kaweah, Tule, and Kern Rivers,) and extending from Summit Lake to the Lower San Joaquin River at Antioch. This canal is laid down from actual surveys made by the company and is on a grade of 6 inches per mile.

4th. A proposed canal carried from Kern River, on a grade of 3 inches to the mile, beginning on the left bank of that river above Bakersfield and extending around and to the southward of Kern and Buena Vista Lakes. This canal would irrigate the country between it and Kern River and those lakes.

Here we may properly remark that the plain to the east and south of this latter canal, lying between it and the surrounding foot-hills, does not seem to be capable of irrigation, because it is higher than the proposed canal, even with its small grade.

Doubtless, some irrigation of portions of this plain can be effected by storing the water which now escapes through the small streams from the surrounding mountains during the winter-season. It may be possible, too, in the distant future, when the country becomes rich enough to stand the expense, to irrigate all of this land by taking the water out of Kern River high enough up that river to enable it to flow over the entire plain, but the expense of such a construction would be too great for many years to come.

The same remarks apply to the extensive plains southwest and northwest of Tulare Lake, between that lake and the line of the upper canal, (leading to Antioch,) and the foot-hills of the Coast Range. Except partial irrigation of small portions of these plains by storage-reservoirs, they must be considered as non-irrigable; for there is no large supply of water on this side of the valley that can be spread over them, and water cannot be brought from the large rivers on the eastern side of the valley except at a cost which would be disproportionate to the benefits to be derived from such enterprises.

We also have a very good preliminary survey of the alignment of a canal for irrigation and navigation on the west side of the Sacramento River, leading from a point just below Red Bluff to the navigable waters of Cache Slough. This survey was made under the auspices and by authority of the State of California in 1866.

We have laid down on our map the route of this canal as projected by its engineers. It leaves the Sacramento River just below Red Bluff, keeps close to the foot-hills, so as to irrigate all the lands below it, and finally terminates at the head of navigation at Cache Slough.

The quantity of land to be irrigated by this canal was estimated to be 782,000 acres, and the quantity of water necessary for the irrigation of this land and for navigation was supposed to be 6,571 cubic feet per second. This canal was projected for navigation as well as irrigation. In view of this fact, we think if a canal for irrigation alone were to be built here, important changes in the location, size, and slope of such canal could be made, whereby the cost would be greatly reduced.

But even if this canal be made for navigation, which it probably ought to be, its size may be greatly reduced if Stony, Cache, and Puta Creeks be used as feeders, which was not done in the original project.

A branch-canal leaves this main canal on the right bank of Stony Creek, and extends thence to the Sacramento River, and then down on the right bank of the river to Knight's landing, for the purpose of irrigating the land between the river-bank and the "trough," or lowest depression of the valley between the river and the foot-hills to the westward.

A private corporation, the Clear Lake Water-Works Company, has undertaken the appropriation of the waters of Cache Creek for purpose of irrigation.

A canal is now partially completed for the irrigation of sixteen thousand acres of land in Capay Valley, and a dam has been constructed at the lower end of this valley for the purpose of starting two canals, one on either side of Cache Creek, for the irrigition of the plains in Solano and Yolo Counties.

Clear Lake, which is drained by Cache Creek, is a fine natural reservoir, covering about eighty square miles; and as its drainage-area, together with that of Cache Creek, is one thousand square miles in extent, and as most of the water can be stored in the lake by inexpensive works, when it is not wanted for irrigation it follows that a large body of land, probably four hundred thousand acres, can be irrigated by the proposed canals, which are to draw their supply of water from Cache Creek This company has also kindly placed at our disposal all the information which their plans and surveys furnish, and we have laid down their finished canal as well as their proposed canals on our map.

## THE INFLUENCE OF IRRIGATION ON THE NAVIGATION OF RIVERS.

It has been supposed by some persons that the withdrawal of large quantities of water from the Sacramento and San Joaquin Rivers, and from their tributaries, and the appropriation of these waters to purposes of irrigation, would be inconsistent with the navigation of these rivers.

The supposition is natural; but, anomalous as it may seem, the experience of the extensive irrigation of the plains of India and of Italy would seem to contradict it.

Captain Baird Smith, in his "Italian Irrigation" says, pp. 171 and 172:

I may mention here that the singular and interesting phenomenon of percolation, which is so marked in the beds of the Himalayan rivers of India, is not less strikingly shown in those of Northern Italy. In seasons of great dryness the entire volumes of the Ticino and other irrigating rivers have at times been entirely exhausted to meet the demands of the cultivators. The results are thus adverted to by M. Lombardini, a minute and accurate observer, who has devoted himself especially to the study of river phenomena:

"The subterranean waters with which the plain is charged are also occasionally collected in the rivers, whose beds are below the level of the ground. These streams, exhausted in their upper portions by the channels of irrigation derived from them, are found to become gradually refilled at lower levels with new waters. The Ticino at Tornavento, the Adda at Cassano, and the Oglio at Torre Pallavicina, in times of great dryness, are entirely closed and exhausted. Yet, without the aid of any visible affluent whatever, the streams soon re-apppear, formed by new supplies derived from percolation through the banks and springs in the beds, so that they early again become navigable."

This is precisely the result observed in Northern India, and with which the main objection urged against the grand Ganges Canal, that it will ruin the navigation of the river, has hitherto been combated. I am glad to be able to bring Italian as well as Indian experience to the support of this work, besides which even the greatest of the Lombardian canals appear small.

In speaking of the effect of the canals on the navigation of the river Jumna in India, the same author says, (Baird Smith, p. 386:)

During four months it is occasionally necessary to abstract the entire visible stream for the supply of the canals, and for eight or ten miles below the bunds or embankments employed for the purpose, the bed is dry. Beyond this distance water appears;

and by the time the river has reached the latitude of Saharunpûr, it has become a deep unfordable stream, with a considerable velocity of current. The explanation of this singular result, observed in greater or less degree in all streams which traverse the tract of country under the Siwalic Hills, both east and west of the Ganges, is not difficult. From sections exposed by wells sunk in the vicinity of the Jumna, it is evident that the bed of the river is composed of a porous, readily permeable stratum of shingle resting upon clay or clay sand, which is comparatively impervious. The upper or shingle stratum is thoroughly saturated with water to a depth which, from sections we have observed, may be estimated at from 60 to 80 feet. The slope of the bed for the first ten miles from the lower hills is excessive, and there is consequently a considerable under-current through the shingle bed. The volume of the river may therefore be regarded as consisting of two separate parts: 1st. The visible stream, over the shingle bed; and, 2d, the invisible or under-stream through the shingle bed. The canal bunds affect only the former; and it is the latter which makes its appearance when, at the lower levels of the river's course, the sub-stratum of clay outcrops, and the porous shingle bed terminates. The under-current is thus thrown to the surface, and constitutes the main body of the river, and, with the additions it receives from affluents, is the volume available for navigation during the months of minimum supply.

From our observations, we believe that if a general system of irrigation of the San Joaquin, Tulare, and Sacramento Valleys is carried out, the effect of such irrigation will have very little influence on the navigation of the Sacramento and San Joaquin Rivers, which are the only navigable rivers in the Great Valley of California.

It should be observed that the quantity of water that will be used for the irrigation of the valleys mentioned above will be only a portion of the flow of these two rivers at and below the points at which they are now navigable; and of this portion a certain quantity will find its way back into the rivers again by percolation and underground drainage after it has done its work of irrigation. This will be particularly true of the San Joaquin River, where the greatest amount of irrigation is required.

This river is navigable for steamboats in its high stage only as high as the mouth of Fresno Slough, where the head-works of the San Joaquin and King's River Canal are located, and in its lowest stage only as high as Stockton Slough, which is below the influence of the tides. Now, during its high stages when water is always abundant in the rivers flowing from the Sierra Nevada, the San Joaquin River receives the drainage of the whole Tulare Valley through Fresno Slough, a few miles below Watson's ferry.

The irrigation of the Great Valley above this point can therefore have very little influence on the navigation below it; for it is only the quantity of water which is taken up by the increased evaporation due to irrigation, and that going to form a component part of the increased vegetation of the country that is lost to navigation.

After once wetting the soil down to the water-bearing strata, all the remainder of the water of irrigation will be carried off by underground-drainage, and will find its way into the river at or above the point where winter-navigation ceases. Indeed, it may well be questioned whether the irrigation of the southern end of the Great Valley will not tend rather to improve than to injure the navigation of the river; for the water of irrigation will be held back during floods, when it is not wanted for navigation, and that portion of it which finds its way again into the river by underground-drainage will do so in a great measure when the river is falling, and at the time, therefore, when it is wanted for navigation.

In considering the effect of the abstraction of water for the irrigation of the San Joaquin Valley from that river, and from its tributaries below the mouth of Fresno Slough on the navigation of the river, we have on the west side the San Joaquin and King's River Canal, with a maximum discharge of 726 cubic feet per second, which is only about one-tenth the actual flow of the river at that point in the summer-season. It is said that the effect of this canal in lowering the water in the river has been tested by the experiment of closing the head-gates in the canal so as to exclude all water from the canal. The effect was to raise the water in the river below the head-works one inch and a half, from which we may conclude that the withdrawal of the quantity of water which the canal carries from the river lowers the water in the river one inch and a half.

To this extent, therefore, this canal may at certain stages of water injure its navigation.

The effect of canals of irrigation drawing their supply of water from the tributaries of the San Joaquin River on its eastern side, say from the right bank of the Upper San Joaquin River itself, from the Fresno, the Merced, the Tuolumne, and the Stanislaus, on the navigation of the river between Stockton and the head of high-water navigation, we believe will not be injurious, and, in fact, may be beneficial.

The effect of drawing water for irrigation from the tributaries of the San Joaquin below Stockton, from the Calaveras, the Mokelumne, and the Cosumnes, can scarcely be felt on the navigation of the San Joaquin below that point, for here the depth of the water in the river is influenced by the ebb and flow of the tides.

The west side of the Sacramento Valley, as we have seen, must be irrigated by water drawn from the Sacramento River at, or a short distance below, Red Bluff, and from Stony, Cache, and Puta Creeks.

The Sacramento River is navigable during the season of high water as far as Red Bluff; though since the consolidation of the railroad company with the California Steam Navigation Company it is rare that steamers are sent up the river higher than Princeton.

During the low stage of water, Colusa may be regarded as the head of navigation.

The effect of withdrawing a large quantity of water by a canal for irrigation, leaving the river in the vicinity of Red Bluff, would be to decrease the depth of water in the river at and immediately below that point.

At the time, however, when irrigation will be most needed—during the winter and spring—the river is always high, and the withdrawal of the quantity of water that will be required for irrigation would scarcely be felt.

During the late summer and early fall, when the river is low, but little water will be wanted for irrigation, and the withdrawal of what would be required could have but little effect on the navigation of the river at Colusa or Princeton, the head of navigation at that season of the year, for these places are one hundred miles by the river below the head of the proposed canal.

Of course, there will be a certain stage of the river when it is falling, and again when it is rising, when, without the withdrawal of any water from the river for irrigation, it would just be navigable for small steamers between Colusa and Red Bluff. If, at this stage, a large quantity of water be withdrawn from the river, the depth of water would be decreased, and the river would not be navigable.

How much the influence of such a canal on the navigation of the upper part of the river at these stages would be felt, it will be impossible to state with certainty without knowing the discharge of the river at such times and the quantity of water that would be taken from it by the canal.

We may remark, however, that it is only the falling phase of the river that need be considered in this connection. In the months of July and August the river falls very slowly; and if it is just navigable at a certain stage, the withdrawal of a large quantity of water from it at that time might affect the navigation for some weeks; but in the fall, when the river rises, after the first rains, it rises suddenly, and the effect of the cause we are considering could only be felt for a few days, and generally only for a few hours.

The effect of withdrawing a portion of the waters of Stony Creek for irrigation could have but little, if any, influence on the navigation of the river; for the greater portion of this water would find its way back again into the river above Princeton, which is the practical head of navigation, unless the river above be improved. And the appropriation of the waters of Cache and Puta Creeks to irrigating-purposes cannot affect the navigation of the river; for both of these streams find their escape into the river through Cache Slough, a tidal arm of the Lower Sacramento.

On the east side of the Sacramento River, between Red Bluff and the city of Sacramento, the principal tributaries are the Feather, the Yuba, Bear and American Rivers. Besides these rivers, there are numerous smaller streams, escaping from the foot-hills of the Sierra Nevada, and emptying into the Sacramento River above the mouth of the Feather, the largest of which are Butte and Chico Creeks, which are living streams all the year round, in the vicinity of the town of Chico.

We do not think that the appropriation of all the water that will be wanted for the irrigation of the eastern side of the Sacramento will have any injurious effect on the navigation of that river, and for the reasons already stated in speaking of the tributaries of the San Joaquin on its eastern side.

On the whole, therefore, we conclude this subject by stating it as our belief that the irrigation of the Great Valley of California, in the manner we have sketched on our map, will have no injurious effect on the navigation of the San Joaquin and Sacramento Rivers except for a short time, at a certain stage of their waters, and for a short distance below the points where the proposed canals leave them, viz, the mouth of Fresno Slough on the San Joaquin, and Red Bluff on the Sacramento. Even here we do not think that the injury to navigation will be at all serious.

The canals for irrigation on the western side of the valley, owing to the necessity of giving them a gentle slope, may easily be made navigable. The San Joaquin and King's River Canal as far as constructed is navigable, and its continuation as projected will furnish a more certain and cheap navigation than that of the Upper San Joaquin River.

A canal from the Sacramento River, leaving it at Red Bluff, on its western side, may readily be made navigable. Thus, these two navigable canals would afford compensation to any supposed or real injury they might do to the navigation of the rivers.

When we reflect that no canal for navigation could be proposed in this or any part of the United States without the possible or supposed injury of some railroad, and, in fact, that no great public work of any kind can be carried into execution without injuriously affecting some existing interests, we think, if a comprehensive scheme for the irrigation of the Great Valley of California is ever undertaken, the effect of such irrigation on the navigation of its rivers may be disregarded.

## WHAT IS IRRIGATION?

It may be well to state here, in general terms, in what the works of irrigation for these plains must consist; or, in other words, how the water is to be taken out of the rivers and spread over the land. This appears to us to be necessary to a proper comprehension of the subject, because the irrigation of the land has been practiced but very little by the farmers of the United States. With the exception of rice-culture along the sea-coast of a few of the Southern States, agricultural irrigation may be said to be almost unknown in this country.

Even in California it is yet in its infancy, although it was practiced for many years in some places by the old Spaniards, particularly in the southern portion of the State.

The profession of the hydraulic engineer for agricultural purposes is almost unknown, and the farmers, as a general thing, do not understand how to use the water when it is delivered alongside their lands.

We have noticed that in some of the new canals which have been built, many mistakes as to their alignment and slope have been committed. In fact, the very first principles of hydraulic engineering, as applicable to agriculture, have been violated.

This is particularly the case in relation to the canals, or irrigating-ditches, at Visalia and Bakersfield. The irrigating-ditches at these places have too great a slope. The consequence is that the banks are washed away and the bottoms of the ditches scoured out, so that the water cannot be elevated sufficiently in many places to flow over the surface of the land which was intended to be irrigated.

Again, no attention, apparently, has been paid to drainage. The consequence is that the surplus water of irrigation, and that which escapes at low places through the banks of the ditches and sloughs, settles in pools in the lowest ground, becomes stagnant, and, under the influence of a sun which may be called tropical, renders the vicinity of these two towns unhealthful in the summer-season.

A main canal for irrigation must be taken from a river or lake. The quantity of land to be irrigated, the nature of the soil, the minimum rain-fall on this land during the year, and the kind of cultivation, or the amount of water which the land will require in a given period, are the elements which determine the size of the canal or the quantity of water it must deliver in a given time.

The first thing to be done is to raise the surface of the water in the river to such a height as will enable it to flow out through a canal on to the plain to be irrigated at the least possible expense. This is usually done by a dam across the river, though sometimes water can be taken from a river without a dam. The dams, as a general thing, will not require to be built to the full height of the banks of the rivers, but only high enough to command the highest land to be irrigated.

The canal will then be carried from the water above the dam, through the river-bank, in more or less deep cutting, on to the irrigable land.

These works, by which the water is taken from the river out to the land to be irrigated and its quantity regulated, are usually called "The head-works of the canal." It would be useless to enter into a detailed description concerning them, because they will differ in every river.

In looking over the "head-works" of the canals for irrigation in India and in Italy, we find great numbers of these works, but no two of them alike.

The size and slope of the main canals will depend on the quantity of water which they must carry in a given time, and the tenacity of the soil forming their bottoms and sides.

Perhaps the easiest way of showing how the land in these plains should be irrigated will be by an example. But it must be understood that these examples, in practice, will be of almost infinite variety, and it is only by understanding the principles upon which the canals and ditches must be laid out and constructed that a proper system of irrigation can be successfully introduced.

Let it be borne in mind that the object to be accomplished is, at any given time, to put from two to four inches of water on the soil, and hold it there until it is absorbed; say, one irrigation in the fall of the year, to enable the land to be plowed and the grain to be sowed; and three or four irrigations in the winter and spring, depending in number and quantity on the kind of cultivation and the amount of rain-fall during that time.

In order to show in the clearest manner in what the works for spreading the water from a main canal over the land usually consist, we have taken a case from the actual practice of the San Joaquin and King's River Canal Company, in which a portion of the land represented is prepared for the irrigation of wheat or barley, and the remaining portion for grass-pasturage. The system is shown on the sheet herewith, marked A.

The main canal has a grade of 1 foot per mile, and the ground slopes from the canal toward the lowest depression of the valley, which in this case is the San Joaquin River, about 8 feet per mile. The slope is shown on the sketch by dotted contour-lines for each foot of elevation.

Water is not taken directly from the main canal to the ground to be irrigated. It is first drawn from the main canal into a series of smaller canals, called "primary ditches." These primary ditches leave the main canal where the slope of the ground is favorable, in a direction more or less at right angles to its course. They follow the highest part of the land to be irrigated.

The distance apart of these primary ditches will vary according to the circumstances of the ground. In the example we are considering this distance is one mile.

The section of these primary ditches, like that of the main canal, is usually made partly in excavation and partly in embankment. In the example before us, however, these primary ditches are entirely in embankment, the water running on the natural surface of the ground, the earth to form the embankment being taken from outside the ditch. As a general rule, the water should not be taken from them directly to the ground to be irrigated. They are feeders drawing the water from the main canal and distributing it through a series of secondary ditches of smaller size, in which the water is on the surface of the ground, and retained in a given channel by banks of earth from 1 to 2 feet high. It is from these secondary ditches that the water is drawn off into the plow-furrows, and distributed on to and over the land to be irrigated.

It will be noticed that in the example of practical irrigation shown on our map, the contour-lines show that the ground slopes in nearly a true plane away from the main canal at the rate of about 8 feet to the mile. We have seen how the water is first delivered from the main canal into primary ditches, running down this slope at distances of one mile apart, and how this water is again distributed from the primary into secondary ditches, located one quarter of a mile apart, and running parallel to each other, with a slope of from 4 to 5 feet per mile; each of the secondary ditches is to irrigate the land between it and the next one below it.

This piece of land in the example is eighty acres. We have now to show how the water is actually applied to the ground. For the sake of clearness we will confine our attention for the moment to the eighty acres shaded on the map, shown also in the sketch annexed marked B. The secondary ditch, marked A B, is to irrigate these eighty acres.

This land is first divided by plow-furrows parallel with the primary ditches and placed 40 yards apart. These are shown at 1-2, 3-4, 5-6, &c., up to 39-40. It is again divided by plow-furrows, called "checks," laid out parallel to the secondary ditch A B, at distances of fifty yards apart, measured along the line parallel with the secondary ditch. These are shown at 41-42, 43-44, up to 53-54.

The note on the drawing marked A shows that each secondary ditch has a capacity sufficient to fill ten of the little boxes leading from it at 1, 3, 5, 7, &c., into the plow-furrows.

To irrigate this land, then, we first close the gate at C in the middle of the secondary ditch A B, and open the gate at A, which communicates with the primary ditch, then the water will flow into the secondary ditch from A to C. Open the little gates at 1, 3, 5, 7, &c., and it will escape into the plow-furrows and run down to the first check-furrow, 41 41½, where its flow will be checked, and it will gradually flow over the belt of land between A C and 41 41½. This little belt can then be irrigated to any depth that may be required. When this is done, the plow-furrows at the intersection with the first check at 1 2, 3 4, &c., with 41 42, are opened with a hoe, and the water will then run down on to the next belt, included between 41 41½ and 43 43½, and so the process is continued until the forty acres included in the parallelogram A C D E has all been irrigated.

Now, if the gate at C be opened and those at 1, 3, 5, 7, &c., be closed, the water will flow into the lower part of the secondary ditch from C to B; and if the gates at 21, 23, &c., be opened, the other forty acres, C B F E, can be irrigated in the same manner.

As the ground slopes away from the secondary ditches and the parallel check-furrows at the rate of 8 feet to the mile, and as these checks are fifty yards apart, the slope between the adjacent checks will be 2.7 inches. When the water has backed up on the upper side of any given check-furrow to the depth of 2.7 inches, it follows that the ground on the lower side of the next check-furrow above will just be covered, and when it is 4 inches deep on the upper side of the lower check it will be only 1.3 inches deep on the lower side of the upper check. This does not give an entirely equal distribution of the water, but in porous soils there is a system of compensation for this unequal distribution by the percolation of the water standing in the secondary ditches and check-furrows finding its way to the belts of land immediately below them.

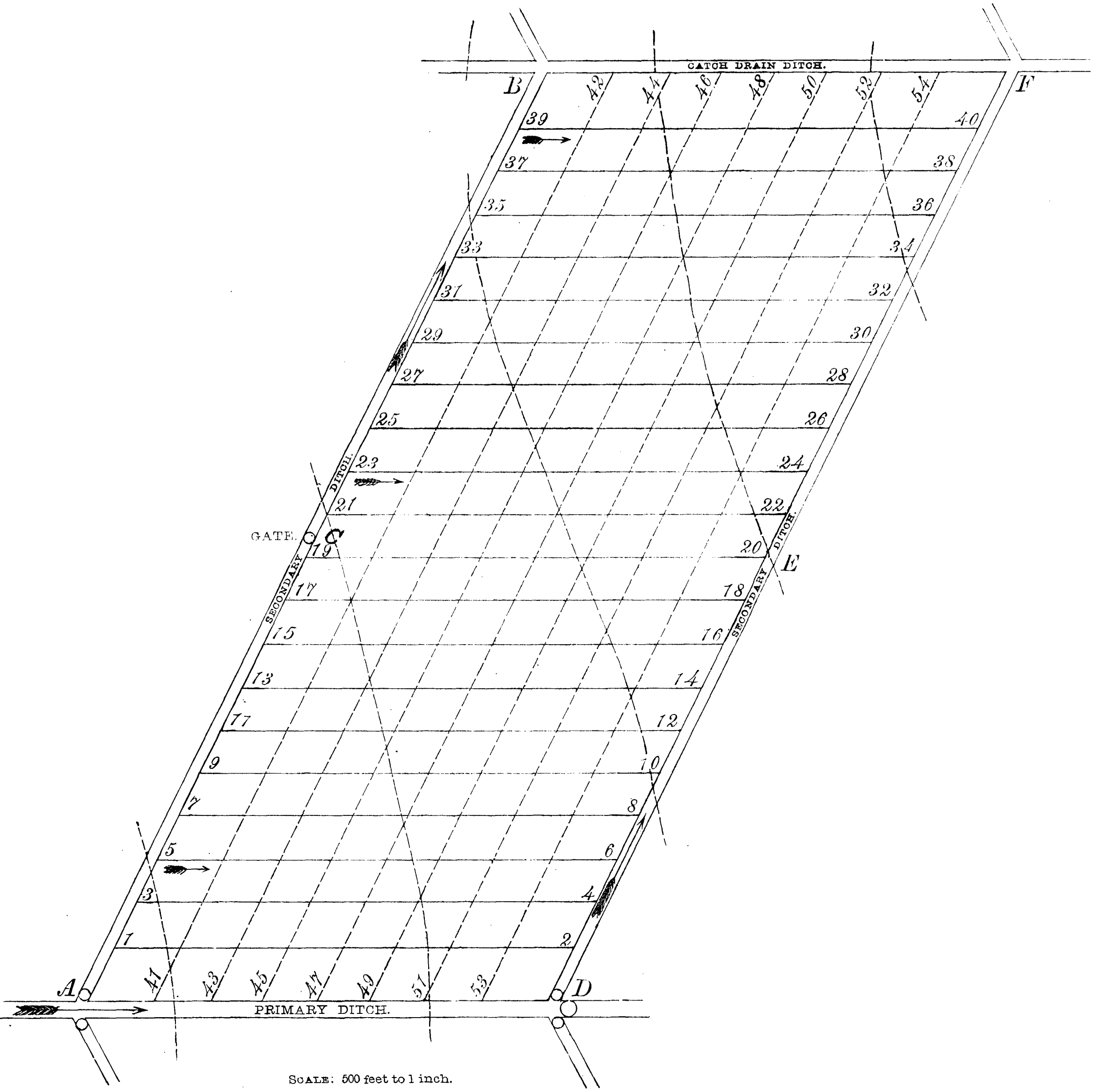
Thus, in the example we are considering, the water from the secondary ditch A B will irrigate the ground immediately below this ditch by percolation if the soil is porous, and the water on the upper side of the checks 41 42, 43 44, &c., will be absorbed and irrigate the soil immediately below them. Of course, where the soil is impervious to water, like clay or adobe, the check-furrows should be closer together, in order to insure a more equal irrigation.

In the example of irrigation for alfalfa or permanent pasturage, the little furrow-channels are multiplied, insuring a more equal distribution of water.

The water which is not absorbed by the ground is carried off by the catch-drains and utilized for irrigating lands at a lower level.

This whole system of the distribution of water on to the land, as

## Sketch B.




SCALE: 500 feet to 1 inch.

illustrated in our sketch, is in accordance with the principles which the experience of European countries as well as of India has established.

It should not be forgotten, however, that the quantity of water, as well as the details of its distribution, will vary according to the kind of cultivation. As the cultivation of wheat will require a difference in the times and details of irrigation from that of alfalfa or other grasses, so the cultivation of Indian corn will differ from wheat, and sugar-cane would differ from either of the others. In fact, each product will require a difference in the method of distributing and a difference in the quantity of water for each irrigation.

## EXISTING AND HYPOTHETICAL CANALS.

Although we have been enabled to lay down on our map, with some approach to accuracy, the canals for a comprehensive system of irrigation on the west side of the Great Valley of California, because we have had access to surveys which were made for that purpose, such is not the case on the eastern side of the valley. Here we have no detailed surveys of the country.

It is true there are several small canals and irrigating-ditches on the eastern side of the valley, some of which are completed and in operation; but, as a general thing, those canals have not been laid out on scientific principles; they have not been projected on a plan, so as to form a part of a comprehensive irrigation-system for this side of the valley, and the surveys of these canals, even if attainable, would furnish us with very little valuable information.

We may mention, among these small canals and irrigating-ditches, those at Bakersfield, where the water is taken from Kern River; the irrigation at Visalia, where the water is taken from Kaweah River; three small canals leading from King's River, now partially completed; the Chapman Canal, on the right bank of the San Joaquin River; and the Fresno Canal, on the left bank of the Fresno River, (both partially completed, and laid down on our map.) Of these, the Fresno Canal is the best.

Besides the foregoing, there are small systems of irrigation scattered at different points throughout the foot-hills, all the way from the Tuolumne River to the Feather, the water for irrigation being drawn from ditches that were originally constructed for mining-purposes.

Many of these ditches have been more or less abandoned for mining, and their water is now diverted to the irrigation of gardens, orchards, and vineyards, which betoken the permanent settlement and cultivation of these foot-hills.

It results from our lack of detailed topographical knowledge of the country on the eastern side of the Valley of California that we can now only sketch a hypothetical system of irrigating-canals on that side of the valley. This we have done on our map.

The location of the supposed canals are shown in broken red lines, and are laid down as near as may be in accordance with the principles heretofore mentioned in this report; that is, each main river has two canals, one on either bank, extending to the right and left just below the base of the foot-hills, until they meet similar canals from the adjacent rivers; the whole of them taken together forming, as it were, a main exterior canal of large size, extending from the Kern River, on the south, to the vicinity of Red Bluff on the east side of the Sacramento River. From these main exterior canals, hugging close to the foot-hills, the country below them and lying between them and the central lines of drainage of the Great Valley can be irrigated by branch-canals, which will be the service-canals for the distribution of water for irrigation. The branch-canals in their turn would have their system of primary and secondary ditches, as has been already explained.

The hypothetical system of exterior and branch canals for the eastern side of the valley shown on the map must be understood as being only hypothetical. Although we have examined all the rivers on the eastern side of the valley with great attention, we do not know that we have in any single case selected the proper point on any river from which a main exterior canal should leave it, and, of course, it follows that we do not know that we have laid down any canal in the position it ought to occupy.

No comprehensive system for the irrigation of this portion of the valley, nor in fact for the irrigation of any country, can be made without a complete instrumental survey made for that special purpose. Then, the proper location, size, and height of the dams across the different rivers and streams can be discovered; the alignment, size, and slope of the exterior and interior canals, as well as of distributing-ditches, determined, and the country divided into different irrigating-districts which would be more or less independent of each other.

Here it may be remarked that all such natural districts, because they are natural, cannot be altered by legislation, and their boundaries are independent of the artificial boundaries of a State, county, or township unless those boundaries follow the natural lines of drainage, or the divisions of drainage-areas into different water-sheds.

## GENERAL CONSIDERATIONS.

### THE IRRIGATION OF THE FOOT-HILLS, STORAGE-RESERVOIRS, MINING, RECLAMATION OF OVERFLOWED LANDS, ETC.

In the preceding discussion of this subject, we have confined ourselves entirely to the irrigation of the valleys mentioned in the act of Congress. We have endeavored to show the necessity of their irrigation, and some of the results that will flow from it.

That these plains will be extensively irrigated in the future, we have no doubt. But the works for a complete system of irrigation will be enormous and the cost too great for the present day.

A large increase of population in these valleys will be necessary before such works can be perfected. Time will bring this about, but probably fifty years will be necessary to complete it.

It is all-important that the works should be properly planned and located in the beginning, so that whatever is done to meet the present requirements of a sparse population may form a part of those that will be necessary to meet the demands of a population of millions by simply enlarging them.

Canals that may eventually cost $15,000 per mile need not at first cost more than $5,000 per mile, but they should be located on the right ground and so planned and built as to admit of enlargement without shifting the banks.

The works required, even at the present time, will be extensive and costly, and unity of action is absolutely necessary to their proper execution. If the Government of the United States lends any aid toward the accomplishment of this great scheme of irrigation, it should do so in full accord with the government of the State of California; and whatever action the State government may take in the matter should be taken in the interests of the people of the State, or otherwise the scheme of irrigation will be a failure.

Some authority must be exercised, in the first instance, in planning and locating any proper system for comprehensive irrigation. If left to themselves, the farmers in any country of large extent can never devise or execute such a system.

Constant conflicts would take place among them about the rights of water. The streams ought not to be left to the exclusive control of those living on their banks.

The main canal in many places will be miles away from where the water is most required; and if the location and construction of such canal and the distribution ditches be left to many different proprietors to carry out, each anxious for his own interests, and those interests in conflict or in apparent conflict with each other, and there be no authority to control their action, it is manifest that the system of irrigation will be begun in confusion and will end in financial disaster.

In future the foot-hills, particularly the foot-hills of the Sierra Nevada range, will also call for irrigation. In fact, as we have before stated, they are already irrigated in many places by water from mining-ditches.

The plains will furnish the large farms, but the homes of the well-to-do farmers will be found in the foot-hills or mountains. Their more healthful climate, more varied and picturesque scenery, finer fruits, and greater facilities of obtaining building-materials, as well as wood and water, mark them as places for the farmer's permanent home, and then they too will call for irrigation. This will be an irrigation different from that of the plains. The water will come from the Sierra Nevada Mountains. Large storage-reservoirs will then be constructed in the gorges and valleys of the mountains, and water will be brought down from them in ditches, pipes, and flumes, as water for hydraulic mining is now carried to the mines.

This system of irrigation for the foot-hills will doubtless be combined with obtaining water for mining those extensive gravel deposits of gold, which are yet almost untouched for want of water at sufficient elevation to work them profitably; many of which deposits could not be exhausted in a hundred years.

As the gold production of these mines will be immense, we may suppose that in the future the works for supplying them with water and for irrigating the foot-hills will be in like proportion.

The western flank of the Sierra Nevada will be dotted with reservoirs like some portions of India. Their water will first be used for mining-purposes, where it will be as valuable as for irrigation. Afterward it will be used for watering the foot-hills, and the waste water finally carried into the canals leading from the different rivers built for watering the plains.

We are aware that we are not called upon by the strict letter of our instructions to mention these considerations, and we allude to them only to show that in a complete and comprehensive consideration of the subject of irrigation in California they should not be forgotten.

And there is one other view of the subject which should be stated: we allude to the reclamation of the overflowed and swamp lands in the San Joaquin, Tulare, and Sacramento Valleys. Extensive irrigation will assist in their reclamation, for the water of irrigation, and particularly that stored for future use, will be held back during floods, when these lands are liable to damage, and will escape by percolation or be let into the rivers again through artificial channels after the floods are over, when it can do no injury.

It has been well said that "water is the wealth of California." If it has been so in the past, we believe it will be still more so in the future.

If the people of this State can be once convinced that the irrigation of the plains will be extended in time to the foot-hills, and their irrigation will be combined with the development of new and extensive mining-enterprises; that all irrigation will assist in the reclamation of more than one million acres of rich land, now almost valueless on account of being overflowed in wet winters; and that the water, after having been used for mining, will not be injured, but rather benefited for purposes of irrigation, we believe, after a complete system of irrigation is laid out for them, and proper laws and regulations in reference to the use and abuse of water established and enforced, that unity of action would be insured, and the people would take hold of the subject of irrigation with a will, and carry it out, except perhaps in particular instances, without much aid from Government.

But it is the duty of the Government to teach the value of irrigation, and lay out a comprehensive system, and enforce proper laws on the subject.

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## CHAPTER IV.

*History, description, and statistics of irrigation in foreign countries.*

*Introductory remarks:* Authorities—Irrigation in India; its necessity—Famines—Extent of proposed works—Price of labor—Description of Ganges Canal—Other canals in the Punjab and in the northwest provinces—Delta-systems of Southern India—Other canals in India—Tanks; their numbers and dimensions—Mudduk Masoor tank—Mode of construction—Inundation-canals—Wells—Superiority of channel-irrigation—Improvements by the English—Silt—Velocity of canals—Drainage; its relation to health—Measuring water; its necessity in California—Navigation of canals—Primary ditches—Administration of canals in India.

*Statistics:* Of Western Jumna Canal—Of Bari Doab Canal—Of other irrigation-canals in the Punjab—Of inundation-canals from the Sutlej and Indus Rivers—Of the Ganges Canal—Of Eastern Jumna Canal—Of Dhoon Canals.

*General remarks:* Financial aspect—Cost of maintenance; of repairs.

*Description and statistics:* Of Delta-irrigation in Madras—The Cauvery Delta—The Kistna Delta—The Godavery Delta—Official report for 1873—Financial statement—Prospects for the next five years—Private enterprises in India—Madras Irrigation Company; its agreement; embarrassments—The East India Irrigation Company; agreement; failure—Opinions of governor-general of India and of home office.

In the rainless regions of Egypt and in some portions of India, irrigation and systematic agriculture are of the same age, the latter being quite impossible separate from the former. The present purpose does not require an inquiry into the date of its origin and the circumstances attending the introduction of irrigation in ancient times. It is sufficient on this point for us to know that it has been used for thousands of years, and that in some countries it has been continuously applied throughout their historic existence. The wide distribution and range of this mode of cultivation under the most diverse climatic conditions deserves to be referred to.

This range is almost as long and as wide as that of civilization itself. It embraces countries where the rain-fall is high and the mean temperature that of the temperate zone, and others where the temperature is tropical and the rain-fall small or very unequally distributed. Within its limits are included England, France, Spain and Italy, Egypt and India, Java and the neighboring islands, the West India and the Sandwich Islands, Mexico and Peru. Even in our own country, irrigation exists in the rice-cultivation of the South and on a small scale in our acquired territory where it was introduced by the Spaniards, who, in their turn, derived it from the Moors. The vestiges of works found in Arizona and Mexico point to a time when this mode of cultivation existed to a much greater degree than it does at present, and when perhaps the rainfall was in excess of its present amount. It is also practiced to some extent in Utah.

In an investigation looking to the extensive introduction of irrigation into our imperfectly-watered plains, it is essential to inquire into the circumstances of its existence in other countries, in order to ascertain the proper principles of construction and of administration as they appear to have been established by the experience of other nations. The literature of irrigation is extensive, and the occasion is such that one might easily be tempted to collate historical and descriptive information, all interesting enough, on a scale that might defeat or interfere with the practical ends in view. It will be sufficient to give our attention chiefly to the modern phases of the subject, and to examine the conditions existing in countries whose civilization corresponds in some degree to our own; to ascertain the principles of administration; and to refer to those countries where it has long been established, or where it is being most widely extended, to learn its effects and its methods.

It is, then, the object of this chapter to take a cursory view of irrigation as it exists in some of the countries where it has long been established; to ascertain whether its influence is or has been favorable upon the prosperity, manners, and health of the people; to learn how works of this kind are provided and managed; to inquire into their financial condition, the cost of construction and of maintenance; and, generally, to inform ourselves as to what other nations have done or are now doing to introduce or extend this system of cultivation.

It may be remarked here that a sound financial basis is essential for the existence of irrigation; and if this basis be wanting, we ought not to permit the judgment to be carried away by beautiful pictures of trees and flowers and growing crops; these have in some cases been purchased at too dear a price. Irrigation may be desirable, but indiscriminate irrigation may be disastrous. The same conditions of care and prudence and judgment apply to this as to all other industrial enterprises.

Some of our points of inquiry could be better studied on the fields of practice than from the descriptions in books; but under existing circumstances we are compelled to draw our information from the researches of others. Fortunately, we have descriptions of most of the existing systems from the hands of intelligent observers, and, if we find diversity of opinions and inequality of mental vision when directed to the same circumstances, we only repeat a common experience. Irrigation has its panegyrists and its depreciators. The truth will most probably be found to lie between—in the middle way.

The principal authorities for what follows are these, namely: Col. Baird Smith, Irrigation in the Madras Provinces; Col. Baird Smith, Italian Irrigation; Lieut. Moncrieff, Irrigation in Southern Europe; M. Aymard, Irrigation du midi de l'Espagne; I. B. Roberts, Irrigation in Spain; papers and discussions by various civil engineers in England, published in Proceedings of Institution of Civil Engineers; various parliamentary and official reports in regard to Indian irrigation from 1848 to 1872.

## IRRIGATION IN INDIA.

India affords us the most conspicuous examples of irrigation on a grand scale, and it is here more than anywhere else in the world that a great systematic scheme is in progress of development. Irrigation in some other countries is merely an incident. It permits the cultivation of certain crops, which, indeed, add greatly to general and individual wealth, and if it were withdrawn the general prosperity would doubtless suffer, but the basis of future existence would remain. In many parts of India, irrigation is the very condition of existence, both of the government and of the people. More than half of the revenue of India comes directly from the products of the soil; and the country is so vast, and the communications have been so difficult, that a generally good harvest has not sufficed to preserve large districts not so favored from the most dreadful ravages of famine. The failure of the northeast monsoon in 1832 caused in the Madras presidency most severe and extended suffering; and in Guntoor, out of a population of 500,000, it is estimated that 200,000 persons died of famine and of the fevers resulting from scarcity of food. More recently, in Orissa, a severe famine, causing a great loss of life, occurred, (said to be 1,000,000 persons;) and now in Bengal a similar disaster is impending.

Hence, for double reasons, both for humanity and for the sake of its own revenue, the government is impelled to provide a remedy for these terrible evils. This remedy is irrigation, which is indispensable to insure a crop of rice, the main staple of food among the people. Under the influence of these powerful motives, the government has been, for some years, and is now, actively engaged in building canals and in extending irrigation on a scale that certainly appears, at first glance, large, but which, in comparison with the work to be done, is no more than reasonable. The works that are now in course of construction and that are now projected, it is estimated, will cost $175,000,000, and the rate of expenditure is now many millions of dollars each year. When we attempt to realize the possible results of so great expenditure, it is important to notice that prices of labor and of most materials are very much below those ruling in our own country. The wages of a skilled laborer are 50 cents per day, and of an ordinary laborer 12 cents per day. Earth-excavation may be done for 5 cents per cubic yard, and masonry from $1.50 to $3 per yard. On the other hand, it is well to remark that the constructions are of the most permanent character, and of a much more expensive kind than we would be likely to adopt in our western plains.

The great extent of the country, its topographical features, its enormous population, and the volume of its large rivers, permit and require canals of length and section surpassing beyond all comparison any to be found elsewhere, unless it be in the single instance of the Imperial Canal in China.

The Ganges Canal is, indeed, an artificial river. It is intended to carry nearly 7,000 cubic feet of water per second. Its depth is 10 feet, and its width 170 feet in its upper part. Including its principal branches, it is nine hundred miles in length, and it is intended to irrigate 1,500,000 acres of land, an extent equal to that watered by the whole system of canals in Lombardy and Piedmont. Its length much exceeds the aggregate of the irrigation-lines in Lombardy and Egypt combined. It is the unrivaled instance of modern times. Its original capital cost was about $12,000,000, not including interest or other charges. In the United States the same work would cost $100,000,000.

The Ganges Canal is arranged for navigation as well as for irrigation. This circumstance, and others, relating to the difficulties of the country, and to its populous condition, which rendered necessary a great number of bridges, account for its cost, which, with the low prices ruling in India, is, however, regarded as excessive. Its aqueducts and embankments are necessarily on a very large scale, and it presents many points of interesting study in an engineering point of view. Some of these are, the proper slope of the bed, which at first was, and, although improved, is still too great; the means for reducing this slope by overfalls; and the different arrangements to effect the result.

We learn from its history the prime necessity of giving the proper velocity to the water, and of the disastrous results that may follow from the velocity being too great or too small. Reference will be made to this point again in the statistics of the canal.

This canal is purely the work of the English; it was projected and built by the government.

The other canals of importance in the northwest provinces and of the Punjab are the Eastern Jumna, the Western Jumna, and the Bari Doab Canals, carrying from two to three thousand cubic feet of water per second, and each several hundred miles in length.

Passing from Northern to Southern India, we find in the deltas of the Cauvery, the Godavery, and the Kistna Rivers, a comprehensive system of canals, no one of which, indeed, can compare in length or in dimensions with those just named, but which, taken together, irrigate large areas in their respective deltas.

The map of the Cauvery Delta, herewith attached, will illustrate better than a verbal description the arrangement of the canals and the system of irrigation. These delta-systems were not the earliest of the works restored and extended by the English, but they have been the most successful. They have enriched people and state alike. They have placed declining districts in a condition of the highest prosperity, and they have produced this result in a remarkably short time.

The slow development of irrigation, so noticeable generally on other canals, is wanting here.

The flowing water was in demand and was brought into use at once. The reasons for this remarkable success were the facts that the people were familiar with irrigation, and that from the conditions of the climate there could be no successful cultivation without irrigation, and, further, that by a conjunction of fortunate circumstances the works were very cheaply provided.

These systems form the staple of the argument for the extension of this mode of cultivation in other parts of the country.

The limits of this meagre review of the Indian system will permit us only to refer by name to some of the other important canals recently completed or in course of construction. These are the Soonsekala and Bellairy Canals from the Toombuddra River, three hundred and fifty miles long; the Saone, just completed, from the river of the same name, to carry 4,500 cubic feet per second, with a capacity to irrigate about 1,000,000 acres; the Sirhind Canal, from the Sutlej River, to cost $15,000,000; the Lower Ganges Canal, to carry 6,000 cubic feet per second; the Orissa Canal, built by the East India Irrigation Company, all of which are very large enterprises, some of them rivaling the Ganges Canal in magnitude and importance. We may add to these the Agra Canal from the Jumna, and the Eastern Ganges Canal. There are other new works and extensions of existing systems to which it is not necessary to allude by name.

The government has built or restored, or is in the act of building, all of these canals but two, and it now owns all except one.

The history of private enterprise in this connection will be given elsewhere. Its efforts thus far have been unsuccessful, and there seems to be no prospect that it desires or that it will be permitted to undertake any further enterprise of this character.

This for the present may end our sketch of the channel-system, and we may pass to the notice of another conspicuous feature in Indian agriculture, namely, irrigation from tanks, or, to use our own more familiar term, from reservoirs.

One cannot restrain surprise when he first looks upon a map of the Madras provinces, and notices the number and distribution of these tanks. They appear to occupy nearly as much land as remains to be cultivated. In fourteen districts of the Madras presidency, the English found, in better or worse condition of preservation, fifty-three thousand tanks, estimated by Col. Baird Smith to have 30,000 miles of embankment and 300,000 separate masonry works, consisting of sluices and waste-weirs. These tanks afford a revenue of $7,500,000. How many more there are in India it is probable no one knows. We do know that the numbers above given are found in a relatively small area.

These tanks are, it is believed, all, or nearly all, of native origin, and the dates of their construction remain in uncertainty. It is known that some have been in existence for many hundred years.

The English have repaired many of these works, but so far as is known they have not built them, at least to any great extent.

Recently there have been plans for building new or restoring old tanks on a large scale.

Tanks are necessary adjuncts to a system of irrigation which aspires to use a very large portion of the water in a country where heavy freshets prevail, or where the rains fall in a short interval, for they store the surplus waters.

In size tanks vary greatly. The Ponairy tank in Trichinipoly had an embankment of thirty miles in length and a storage-area of about seventy square miles. The Veevanum tank, which is shown on the map of the Cauvery Delta, has an embankment of twelve miles in length and an area of over thirty square miles.

A reference to the details of the Mudduk Masoor tank on the river Choardy may serve to give us some sort of conception of the labors undertaken by the natives four hundred years ago to secure a supply of water for cultivation.

It is interesting, too, in an engineering point of view, to notice the height of the dam; for it has been claimed by high authority that it is impossible to build safely earthen dams approaching this one in height.

The dam, or *bund*, as it is called in India, bridges a narrow gorge, its extremities resting on high mountains on either side. Its length on top is 550 yards. Its interior slope varies from 2½ to 3 base for 1 in altitude. This slope was revetted with large stones laid dry. The greatest height of the dam is 108 feet and the base in its broadest part is 1,100 feet; it is made of red earth containing considerable gravel. It possessed no waste-weir, and this fact is supposed to account for its ruin. The depth of water in the tank is believed to have been from 90 to 95 feet, which would give a storage-area of forty square miles, and contents of

1,400,000,000 cubic yards of water. Its drainage-basin is about five hundred square miles.

Most of these tanks are, of course, not nearly so large, and those on the plains are generally shallow, having a depth of 6 feet and up to 10 feet. They were generally placed where the accidents of the ground favored an economical storage. In some cases they were supplied directly from the natural drainage; in other cases they were filled by artificial channels which brought to them the flood-waters of the rivers to be stored for times of need.

The dam is usually of earth and built in the native way, that is, the earth was carried in baskets and distributed in layers of 6 to 8 inches in thickness, which were packed by the feet of the carriers passing to and fro; no clay puddling was used, the silt, carried by the infiltrating water, serving to render the dam finally water-tight. They were provided with masonry sluices to deliver water into the chanels which irrigated the land below.

The interior slope was usually revetted with stones. They were generally provided with masonry waste-weirs, which stopped several feet short of the height of the earthen dam. In the crest of the weir were placed stone posts 4 or 5 feet high, which permitted the easy construction of a light dam of brush or straw to hold the water up as high as possible. If a flood came, this temporary dam, when not previously removed, gave way easily and the flood-water took its course over the weir.

From various causes, their numbers are becoming less; some are filled by silt; others are breached from want of attention and repair.

The extension of the channel-system through the tank-districts supersedes the tank-irrigation by degrees.

The fertilizing silt, brought from the mountains, gives the running water a value superior to that stored in tanks, where the matter in suspension is deposited. On the other hand, by reason of this deposit in tank-beds, they are classed, where dry, as among the most fertile lands of India.

A map of a small district in the Madras presidency is attached which may serve to give some conception of the numbers and average areas of these reservoirs.

Among the irrigation-facilities not yet noticed are what are termed inundation-canals. These differ from the class first noticed, which may, with some allowance, be called perennial, in the fact that they only carry water from the rivers in seasons of high freshets. The beds are on a higher level than those of the perennial canals. The season of freshets is so unequal, and the supply of water is so precarious, that irrigation by inundation-canals becomes peculiarly uncertain, even when the water carried by them is stored in reservoirs. The irrigation in Egypt is of this character.

These canals are of native origin. As a rule, they have no head-works, and they are peculiarly liable to injury from breaches, by floods, and by silt deposit.

Some of the principal canals of this character are taken from the Indus and the Sutlej Rivers.

Wells afford another source of supply, from which an unknown acreage of very large extent is watered. These wells are generally square pits lined with masonry, from a few feet to 60 feet in depth, and from each three to ten acres are irrigated.

The details of the raising and distribution of the water are very curious and interesting, but for our purposes we may dismiss them with the remark that they indicate a patient, painstaking population of which the people of our own western country afford few examples. This system may impress us with the value of water, but otherwise it has no lesson for us.

The water in these wells rises to a higher level where the canal passes near them, a fact which may be noticed in California.

The cost of irrigation from wells in some cases is stated to be as much as $7.50 per acre each season.

The canals afford better water so much more cheaply that the well-supply loses its importance. The change to channel irrigation is, however, slow, as the history of the various canals hereafter to be alluded to will show.

This completes the outline of the modes of irrigation-supply existing in India. We do not find any statement of land irrigated nor of the relative proportions irrigated from the various sources. Nor is it important that we should be able to state this amount with even an approach to accuracy.

The main conclusions are plain that canal-irrigation is considered to be the most economical and the most valuable, and that every effort is made to replace the old methods by the new, and that as yet the work has only been begun.

British India contains 800,000 square miles and a population of 200,000,000, and but a small proportion of the land is yet under this mode of cultivation.

The English appear as restorers and promoters of irrigation, and not as its originators.

The service they render is to place the system under sound principles of construction. The native system, like all the earlier systems of the world, was defective in alignment and expensive in repairs.

The English are introducing proper slopes and proper velocities, and are making the arrangements permanent, where before they were temporary. The construction of permanent dams in the sandy beds of the rivers was beyond the native skill. They were compelled to rely upon temporary structures, generally banks of sand, which were swept away by the annually recurring floods. To protect the canals from the destructive action of floods, the natives closed the head by a temporary bank, to be removed when the flood had passed. The English have provided permanent head-works, arranged with sluices, by which the floods may be controlled. The drainage, which was little considered by the natives and which yet remains in need of correction in some places, is now attended to, and regulations are provided to guard against the sanitary evils which follow upon the presence of stagnant pools in hot countries.

Silt is a formidable enemy in India. The rivers in floods come down aden with particles of soil in suspension. The Ganges in flood has in lsuspension one fifteen-hundredth of its bulk. The Ganges Canal, flowing 6,000 cubic feet, therefore receives for a time 4 cubic feet a second, or nearly 13,000 cubic yards of silt in a day.

The great problem is to dispose of these large quantities. When the velocity is slackened, as it must be in a canal, for generally the banks and beds cannot sustain so great a velocity as the river maintains, the silt begins to make deposits. Then, again, if the silt is of a fertilizing character, it is very desirable to transport it in suspension to the irrigated land to assure its fertility.

Again, the water of the river in its lower stages may contain very little silt, and a velocity which silt-laden water may carry with safety through earthen beds and slopes becomes under the changed condition erosive and produces great injury. So the conditions may contradict themselves, as, indeed, they actually do in the Ganges Canal.

The question of the proper velocity to be given may thus not admit of positive solution in some cases; but when the solution is possible, its importance cannot be overestimated. Upon this point may hinge the success or failure of the canal.

If the velocity be too great, it may involve heavy expenditures for repairs, which finally may become so burdensome that the canal has to be lined with masonry, as is the case on the canal of Caluso and others in Italy; or, if the velocity be too low, the canal-section has to be increased to carry the requisite quantity of water, thus entailing increased expense, and perhaps the canal must be closed once or twice a year for clearance, at a large outlay.

The canals in India show great differences in the cost of repairs.

In some cases the canal-section at its head for a mile or so is made wider than the general section to insure the deposit in this part, so that when clearance has to be made it is done at one place rather than all along the line. Then, too, the river at the head of the canal may silt up to the level of the crest of the dam, and the canal-supply may thus be cut off. This is generally provided for by placing a number of sluices in the dam or adjoining it, so arranged as to scour out a channel above and leave the canal-head clear.

For clearance of flood-water in the canal, waste weirs are sometimes placed in its banks connecting with natural channels, which shall carry off the surplus water.

### DRAINAGE.

Standing pools of water as connected with irrigation are, of course, the result of defective drainage, but they may be produced in different ways or proceed from different causes. In India these cases occur when an embankment is carried across a natural channel, leaving no exit for the water collected above. Such a construction, it is plain, endangers the safety of the canal. Again, there is leakage through the pervious beds and banks, and when the canal is carried 20 or 30 feet above the ground, as is the case in the Ganges Canal, this leakage may be considerable.

Another source is careless practice in distributing the water, and in not providing for its escape after it has done its duty. There is plain loss to the canal in all of these cases, and, worse than this, the sanitary condition of the neighborhood becomes unfavorable.

The rice-cultivation, which, in a certain sense, involves the opposite of drainage, is too well known to be productive of miasmatic diseases, in all parts of the world, to deserve more than a reference here.

We know what to expect of rice-fields, but there is danger that wheat-fields may prove no mean rivals of rice-fields in unhealthfulness. It costs money to secure good drainage; and if this fact is no reason why there ought not to be good drainage, it certainly accounts, in common with ignorance, for its absence in many cases.

It has been thought by many that the introductien of a system of selling water by the cubic foot instead of making a definite charge per acre irrigated would, by making it to the interest of the cultivator to use the water economically, put an end both to waste and to part of the evils of bad drainage.

The same crop on different soils requires different quantities of water, while there is equal variety in the amount required by different crops on the same soil. This latter difference is recognized in India, the charges depending on the character of the crop; the sugar-cane, for instance, pays about $3, while cereals pay about one-fourth as much, but no discrimination is made either for the receptiveness of the soil or for care and economy on the part of the irrigator.

It certainly seems to be a reasonable proposition that water should be sold, as all other articles of commerce are sold, by measure; but the difficulties attending its measurement under different and ever-varying heads, and through varying dimensions and shapes of outlets, and more than this, the ignorance and suspicious character of the cultivators, have thus far been able to defeat the establishment of such a system.

It may well be considered whether such a system ought not to be ingrafted upon the irrigation of California in its infancy, where the people are in some degree familiar with the measurement of water by the miner's inch, and where their superior intelligence ought to be equal to the comprehension of its justice, and of the favorable sanitary results it promises to secure. If, however, this mode of measurement cannot be established at once, we may be doubtful of its later success.

The new canals in India generally combine navigation with irrigation. It may be remarked that in the abstract those objects conflict. The irrigation-canal ought to carry water at a high velocity, as high as its bed and banks will permit. The navigation-canal ought to have little or no velocity. Where the soil is light, the velocity of the irrigation-canals may of necessity be so low as to permit navigation at little or no additional expense. The case is one to be determined by attendant circumstances of facility of communication and expense, and no absolute rule can be laid down.

A canal from Tulare Lake, for instance, to irrigate the west side of the valley, would necessarily have a low grade in order to insure a command over the maximum quantity of land. The velocity would be small, and navigation would be practicable as well as desirable.

### PRIMARY DITCHES.

It is important for the success of the canal that the primary ditches should be laid out on the proper lines. This line may not be the one desired by any particular cultivator. The considerations that should govern its location are mainly topographical and general.

To insure a good location and an economical distribution of the water, it seems essential that the owners of the canal should mark them out even if they do not build them.

It is also regarded as conducive to economy and good drainage that irrigation should not be allowed directly from the canal, but only from the primary or secondary ditches.

It is to other countries more nearly assimilated to our own in institutions and modes of civilization than is India that we must look for an administration-system that shall fit our condition, if, indeed, any such system can be found. In India, the government does everything and the people do nothing in the management of the canal-system. On the other hand, in our country we expect the people to do everything and the Government nothing. There, all power and authority are in the hands of the officials, whose range extends to the merest details. This state of affairs is much lamented by intelligent observers, but in the present condition of the people any other system is impossible. We shall find in Italy and Spain that the principles of self-administration, and, in some degree, of self-government, have existed in irrigation-associations for years, and in some cases for ages.

Americans will doubtless find in this kind of administration something congenial with their opinions, and perhaps they may discover in it the germ of their own modified system of the future.

We may terminate this review of Indian systems with the following observations from the pen of an intelligent observer and critic, well informed in the history and experience of irrigation:

Statistical details and magisterial experience show clearly that where irrigation, with its pleasant train of consequences, is introduced, crime diminishes, plenty and security prove the best policemen, lawless habits yield to their genial influences, and men who were the Ishmaelites of society fall without force or constraint into the ranks of the great army of industry.

## STATISTICS OF CANALS IN INDIA.

### CANALS IN THE PUNJAB.

#### *Western Jumna Canal.*

This canal was built in the fourteenth century by the Mogul Emperor and was restored by the English about 1820. In 1871 the capital account stood at $1,381,000, leaving out the interest and charges which had accumulated against the enterprise during the years when its receipts did not defray its expenses. It required fourteen years to work up to its expenses. It irrigated, in 1871, 444,385 acres; the capital cost per acre being something over $3. Its length is over four hundred miles. It carries from 1,800 to 2,200 cubic feet of water per second. The maximum water-rate per acre is $2.50; the minimum 67 cents, the average being $1.22 per acre. The cost of maintenance in 1871 was 46 cents per acre. The profit for the year was 26 per cent. The government reaps additional profit from increased tax on lands. The principal crops are sugar, rice, cotton, and wheat. One cubic foot per second irrigates in the summer 102 acres and in the winter 114, making a total of 216 acres. The rain-fall near head of canal in 1871 was 70 inches and at the lower end about 11 inches.

#### *The Bari Doab Canal.*

This canal was built by the English, and opened about 1860. To 1871 it had cost $6,297,600, to which should be added for interest and deficit, in paying expenses, $1,388,672, making a total cost of $7,686,272. It irrigated, in 1871, 287,070 acres. The canal has carried 2,300 cubic feet per second, but in low water it may come to 1,300 feet, and has capacity to irrigate about 500,000 acres. When it attains this extent of irrigation, the capital cost per acre will be about $15; the maximum charge for water per acre, $2.94; the minimum charge for water per acre, 75 cents; the average gross income per acre irrigated, $1.17; cost of maintenance, 65 cents per acre, being 56 per cent. profit on original capital in 1871; and in 1872, 2.68 per cent., and, including land-tax, 4⅔ per cent., which rates are the same for the next preceding year; repairs of principal distributing-ditches about $8 per acre. It irrigates in hot weather 41 acres per foot a second; in cold weather, 111 acres per foot a second; total, 152 acres.

## OTHER IRRIGATION-WORKS IN THE PUNJAB.

### *Delhi and Gargaon Works.*

These works have cost $92,000, and they irrigated in 1871 about 8,000 acres. They were worked at a loss of over $3,000, and in the previous year the loss was about $7,000. If the enhancement of the land-revenue be included, the profit is said to be about 10 per cent.

### *Lower Sutlej and Chenab Inundation-Canals.*

These are old Mohammedan works, which carry water only during the prevalence of freshets. The period of freshet fluctuates very much, and irrigation is peculiarly uncertain. Capital expended, $56,000. Expenses exceed direct revenue to the extent of 33 per cent. of capital; acres irrigated, 188,000.

### *Upper Sutlej Canals.*

These canals are of the same character as those last mentioned. They have cost $282,000. Deficit, 1871 and 1872, $50,000, 16 per cent. of capital; 87,000 acres irrigated. These inundation-canals in all are six hundred and fifty miles in length. The repairs upon them are enormous. In the last year 2,300,000 cubic yards of silt had to be taken from them.

### *Indus Inundation-Canals.*

These are old native works over five hundred miles in length; cost, $192,569; loss in 1871 and 1872 about $50,000, over 25 per cent. of capital; loss previous year, 6 per cent.; irrigate 144,000 acres.

## CANALS IN THE NORTHWEST PROVINCES.

### *The Ganges Canal.*

This canal was begun in 1842 and opened in 1856. In the year 1860–'61 it first paid its expenses; 1862–'63, deficit of $50,000; 1863–'64, paid 1 per cent. profit; 1864–'65, paid less than 1 per cent.; 1865–'66, paid 2.83 per cent.; 1866–'67, paid 3½ per cent.; 1867–'68, paid 2.44 per cent.; 1868–'69, paid 7.29 per cent.; 1869–'70, paid 4.69 per cent. At the end of 1870 this canal had cost $12,038,305. The deficit of revenue and the interest on the capital had accumulated a further charge, variously stated, the minimum being $4,000,000, the maximum more than $5,000,000. This added makes the cost of the canal in 1871 from $16,000,000 to $17,000,000, and as the profits above given are calculated only on the paid-up capital, the rates should be diminished in a corresponding ratio.

### *Progress of irrigation.*

In 1861–'62, irrigated 372,322 acres; 1862–'63, irrigated 205,605 acres; 1833–'64, irrigated 449,788 acres; 1864–'65, irrigated 566,517 acres; 1865–'66, irrigated 573,129 acres; 1866–'67, irrigated 634,734 acres; 1868–'69, irrigated 1,441,918 acres; 1869–'70, irrigated 1,089,673 acres.

*Rates of water per acre irrigated in 1864 by Ganges Canal.*

Sugar-cane, $2.20 per acre; 12 per cent. of land pays this rate.
Gardens, rice, $1.25 per acre; 20 per cent. of land pays this rate.
Indigo, cotton, &c., 80 cents per acre; 51 per cent. of land pays this rate.
Grains, 60 cents per acre; 17 per cent. of land pays this rate.
Giving mean rate of $1.02 per acre.

In 1866 and 1867 average gross revenue per acre irrigated, $1.21; cost of maintenance per acre, 50 per cent., or 61 cents. It required ten years for this canal to reach 30 per cent. of its probable ultimate irrigation. The Eastern Jumna, which now pays a handsome profit, took thirty years to reach the same condition.

### EASTERN JUMNA CANAL.

This is a canal taken from the river Jumna. It was an old native work, which had fallen out of repair, and it was restored by the English and opened in January, 1830. It did not pay its expenses until the year 1838; the deficit up to that time being about $130,000. In 1839, 1841, and 1844 it ran largely behind its expenses. In 1845, 1846, and 1847 its income was insignificant; including 1847, and counting from its opening, it was behind its working expenses $141,000, to say nothing of interest on its capital cost and of previous deficits. In 1856 it was again behind $20,000. In 1857 and 1858 deficit were $3,230, and it was not until 1865 that its profits caught up with charges of interest and maintenance. In 1867 its capital was $876,030, and it irrigated 239,555 acres. The capital cost was at this time $3.70 per acre. It paid this year a revenue of 25 per cent., and the state was further benefited, indirectly, by increase of land-assessment. The average income per acre irrigated was $1.12; cost of maintenance, 25 cents, being 22 per cent.

### DHOON CANALS.

Capital expended to end of 1865, $266,850. Worked at a loss ever since 1841. Accumulation of charges and interest to 1865, $129,770. In 1866 and 1867 Dhoon paid a profit of 2¾ per cent. on original capital, and irrigated 8,852 acres. *Capital* cost per acre irrigated, about $30.

The Rohilcund Canals irrigate about 100,000 acres; in some years, often very much less. The cost of these canals, without interest, is about $170,000. They have generally been worked at a loss. The water-tax is only about 25 cents per acre.

Agra Irrigation Works cost over $100,000, and have in some years not paid their expenses, while in other years they have returned an insignificant income. Since 1864 they have been closed for sanitary reasons.

## GENERAL REMARKS.

The canals and irrigation works in the northwest provinces, comprising Ganges, Eastern Jumna, Dhoon, and minor works, had cost, at the end of 1869, $13,503,525; add interest and charges, $4,589,000, giving a total of $18,092,525; net revenue 1869–'70, $683,515, being about 5 per cent. on the capital alone, and less than 4 per cent., including capital, accumulated interest, and charges. If we include the enhanced land-tax due to irrigation, the revenue is considerably increased. The amount of increased tax to be estimated as due to irrigation cannot be ascertained with precision, but it is probably sufficient, when added to the direct revenue' to make a fair return on the capital invested. Nevertheless, the financial aspect of these enterprises, taken as a whole, is not at present satisfactory. The slow development of irrigation is certainly a remarkable feature in their history; it is sufficient alone to ruin financially an enterprise of this character. No joint-stock company could exist on such a basis; none could be formed to build a canal which, when finished, could not for five or ten years pay its expenses, and from which no profitable return could be expected for twenty or thirty years. Yet it deserves to be remarked that the value of these properties increases from year to year, and that the time must come when they will be very valuable. It may also be noticed that an enterprise of this kind may, by reason of increase in land-tax, be profitable to the government when it would be disastrous to a joint-stock company.

In India the government is really the landlord, a circumstance which makes the obligation of irrigating the country peculiarly strong, and which, at the same time, insures a share of profit which could not inure to a private company. The cost of maintenance of the canals when built and in full operation deserves to be remarked. This ranges from 56 per cent. of gross receipts on the Bari Doab, 50 per cent. on the Ganges, 37 per cent. on the Western Jumna, to 22 per cent. on the Eastern Jumna. In this item are included all expenses of salaries, of repairs, and of contingencies. It is the item of repairs which it is important to notice, for the repairs may alone eat up all the profits, as indeed they actually do in the inundation-canals of the Sutlej and Indus. The repairs on the Bari Doab Canal are 33 per cent. of the whole expense of maintenance, whereas they are but 15 per cent. on the Western Jumna.

In the Ganges Canal the expenses on this account have been enormous, amounting almost to a remodeling of the work. Both in the Bari Doab and the Ganges Canals these repairs are stated to be necessary, on account of the faulty original construction, owing to which great erosion of the beds and banks occurs in some places and large deposits are made in other places. This is alluded to here merely to show that a correct adjustment of dimensions, slope, and mode of construction has a direct relation to the financial state of these enterprises.

## CHANNEL-IRRIGATION IN THE DELTAS OF RIVERS IN THE MADRAS PROVINCES.

The works in the deltas of the Cauvery, Godavery, and the Kistna Rivers have been the most remunerative in India; but some explanation of the circumstances attending the development of irrigation is necessary for even an incomplete comprehension of the case. Different authorities estimate returns from these works so variously that we may well despair of getting any clear knowledge.

First, in the Cauvery delta there have been irrigation-works from the dawn of history. A dam made of stones of moderate dimensions, set in clay, is still in existence, which has stood sixteen hundred years, and which is yet an important part of the system. Many channels were cut from the river-bank, which were supplied by the aid of temporary dams, and an extensive system of channel-irrigation has existed for ages.

The English came into possession of Tanjore in 1801, and about thirty years afterward attempts were made to correct some evils which had been growing in magnitude, and which affected the prosperity of the district and even threatened to destroy it.

The Cauvery River on entering the delta is divided into two channels one called the Cauvery, and the other the Coleroon. From the Cauvery 505,000 acres of rice-land were irrigated, which required a supply of 12,600 cubic feet per second; while from the Coleroon 165,000 acres were watered, requiring 4,125 cubic feet per second. Now, the trouble was this, namely, that the Cauvery in 1833 could supply but 9,375 feet, while the Coleroon had 7,500 feet. The Coleroon had too much water, the Cauvery, too little, the gross amount, however, being equal to the duty required of both channels. Moreover, there was considerable danger that the whole river would go to the Coleroon, and leave the Cauvery district without water.

The English began to regulate the rivers, first, by building a dam across the Coleroon adjusted in height to give the Cauvery the needed increment of supply. After a time, the Cauvery, instead of not getting enough water, got too much, and there was danger that the whole river would go to the Cauvery, to the destruction of the lands depending on both streams. This danger was averted by a dam across the Cauvery, and after eight or ten years the engineers were able to control both rivers, and to distribute the water as was required. This was accomplished in 1845.

The whole story is very interesting and instructive, and it is well told by Col. Baird Smith.

The English, therefore, did not build the system of canals shown on the map of the Cauvery Delta. They, however, saved them from ruin, and improved them, and thereby assured the prosperity of the district. When, therefore, we hear of the profits of irrigation in this delta being so great, we should reflect that the profits paid are on the capital expended to save, and in some cases to restore, old works, and not to build them. This district is termed the Lombardy of India.

Col. Baird Smith estimates the profits in 1853 to be 23 per cent.; others place them much higher. The fluctuations of the crops, which, before these operations, were as much as 50 per cent., have since been quite insignificant. In these provinces the government-tax is in the form of a percentage of the products. The rate in this district is two-fifths of the gross products, which includes land and water tax, and which certainly appears very high.

We cannot avoid having respect for the ancient rulers of India when we reflect upon the intelligence displayed in the arrangement of the system of canals in the Cauvery Delta.

### *The Kistna Delta.*

The irrigation of the Kistna Delta was effected by the English, who were moved to undertake it by the terrible famine in Guntoor, already referred to. These works are comparatively recent, having been commenced in 1852. The profits are estimated at 15 per cent.

### *The Godavery Delta.*

The Godavery Irrigation Works are intended to irrigate about 800,000 acres. They were constructed by the English, beginning in 1847; and in 1862 and 1863 the returns were estimated to be 47 per cent. on the capital expended.

It has already been stated that the circumstances of these delta-works were peculiarly favorable. The rivers run on the crest of the alluvial deposits they have themselves made, and their banks are from 6 to 20 feet above the land to be irrigated. This circumstance gives the canals command of the land at once. There were many old channels in these deltas, which were used to convey the water, which saved the construction of new works; and when new channels were needed they were easily excavated in the alluvial soil.

The delta-works on these three rivers, in all, irrigate about 1,500,000 acres of land. The cultivation is generally in rice, 40 acres of which require a cubic foot per second. The quantity of water used would be sufficient to irrigate fully five times as much land in cereals.

Among the projects sanctioned by the government, which are now in course of execution, are large extensions of irrigation-works in each of these deltas.

From the official report of the government of India for 1873, which has just been received, we make the following extracts, showing the present financial condition of the irrigation-works as estimated from the "best information available:"

| | Capital account to the end of 1871-'72. | Net income as per latest information. |
|---|---|---|
| Madras, (30 works only) | *$6, 535, 000 | $1, 835, 000 |
| Bombay, including Sindh | *3, 990, 000 | 7, 500 |
| Bengal | 10, 815, 000 | †112, 500 |
| Northwestern provinces | 16, 655, 000 | ‡830, 000 |
| Punjab | 11, 300, 000 | §940, 000 |
| Sindh | *4, 000, 000 | 950, 000 |
| Total‖ | 53, 295, 000 | 4, 450, 000 |

* Amounts not known; these are approximate sums.
† Loss. A capital of $10,000,000 in Bengal nets a loss of $112,500.
‡ Includes increase of land-revenue due to the canals of $220,000.
§ Includes increase of land-revenue due to the canals of $490,000.
‖ Pounds sterling converted at $5.

This report states—

That so far as existing information goes, the net results of the entire outlay on irrigation-works, up to the year 1872-'73, is a return of $2,068,200 per annum above the interest, at 4 per cent., on the first cost of the works.

We may remark, in regard to this claim, first, that the government is receiving a very large portion of this revenue from works which it never built, but to which it fell heir, and of which the cost does not enter the capital account; secondly, the deficits of working expenses on many of these works for years, and the interest on these deficits, are not included in these capital accounts.

In further considering the prospects of works of this character for six years in advance, the report states:

No profits have been calculated from any of the new works within the period embraced in the forecast.

It is found by experience that, as a rule, the growth of irrigation from new canals is slow, and in the first few years the canals hardly pay working expenses.

The only source of increased income to be reckoned, therefore, is the growth of the returns from the canals already working.

It has been found from experience that returns continue to grow long after the works are apparently in full use.

This growth is largely due to increasing economy in the use and management of the water, which permits the cultivation of a larger area with the same amount of water.

The increase of net revenue for the next five years it is estimated will be $100,000 for each year.

The new works sanctioned by the government, which are now in progress, are estimated to cost $115,000,000, and the estimated yearly expenditure from loans on this account runs from $5,000,000 to $8,000,000 for the next six years.

Other works are contemplated, and are in course of survey and examination, which are not included in the statement given above.

It further appears from this report that the Ganges Canal irrigated in the last year but 684,139 acres; that its capital account is now $13,000,000; and that the direct returns for the past year were 2⅓ per cent. on this expenditure; that the capital account of the Eastern Jumna Canal is now $1,030,000; that its acreage last year was 184,153, and its direct returns were 16¾ per cent. on the invested capital. These returns are less favorable than those which we have already given for the preceding year. No explanation for this difference is known to us, but it is probable that the rain-fall was more favorable to the cultivators than was the case in the two preceding years, and hence that there was not so great a necessity for irrigation.

A large portion of the cultivation in these districts is devoted to cereals, and in some seasons the rain-fall is such that these crops do not require irrigation.

The facts contained in this last official report add further evidence in support of the conclusions, resulting from our previous inquiry, and confirm the opinion that, except in particular and favorable instances, the irrigation-works of India are not such investments of capital as private companies would desire to make. It does not follow from this proposition that it is not good financial policy for the government to extend these works. The government has indirect sources of revenue depending upon the production of the country, which may more than make up for direct deficits. This, at least, is the opinion of the government of India.

### PRIVATE CANALS IN INDIA.

Under the English supremacy, the native works of irrigation remained, as before, the property of the government, which undertook to keep them in repair, to administer them, and to receive their revenues. The results of irrigation have always appeared so favorable to the Indian government that it has endeavored in every way to extend their range and increase their facilities. In order to hasten the work, after very full discussion, it was decided to call in the aid of private capital. To this course there were many objections. It was generally held that the property in water could not safely be intrusted to private hands; that the ignorant cultivators would, without the intervention of the government, be helpless against a powerful corporation; and that any supervision by the government, to be effectual in protecting the cultivators, would interfere with the freedom of the enterprise, and, therefore, with its prosperity and success. At this time it was thought by the government that the profits of irrigation were great and immediate, and that they should inure to the government and not to a corporation. On the other hand, the demands upon India for railways and other improvements were so great, and its resources so inadequate, that it appeared indispensable to call in private aid, if the development of irrigation was to be undertaken on an extensive scale. So it was determined to make the experiment of private irrigation; and in 1858 an agreement was entered into with the Madras Irrigation Company to build a canal, estimated to cost $5,000,000, and upon this sum the government guaranteed an income of 5 per cent. The system of guarantee had been the rule with the government for some years in constructing the lines of railways. The government was to divide all profits above 12 per cent. The other conditions of the agreement were substantially the same as those yet to be mentioned in the contract with the East India Irrigation Company for the construction of a canal in Orissa. The history of the Madras Company's enterprise is briefly this: The company raised and expended $5,000,000. They found that a considerable sum would yet be required to complete their works. They applied to the government for guarantee on an increase of capital. The government declined to grant further guarantee, and the company was unable to raise any more funds. The government under these circumstances felt obliged to give further assistance, which it did by lending the company $3,000,000, to be repaid from the profits of irrigation. In 1872 the government had paid $2,559,260 in interest, and had expended in all $5,559,260. The company had expended $5,000,000, making the total expenditure $10,559,260, to which should be added, for five years' interest on $3,000,000 at 5 per cent., $750,000; total cost, $11,309,260. The works were commenced in 1859 and completed in 1871. The prospect of immediate returns is quite unfavorable. The company expected to irrigate in 1872 at least 40,000 acres and perhaps as much as 100,000 acres. The rate is $3 per acre. The estimate by the government is not as favorable as that entertained by the company. It is worthy of remark that the system of guarantee of interest on the capital removes from the company a great motive for economy. The operations of this company have been considered extravagant, and the cost unnecessarily large.

### THE EAST INDIA IRRIGATION COMPANY.

The Madras Company had hardly made a beginning before the East India Company undertook to build a canal in the delta country of Orissa under the following conditions: No guarantee of interest by the government; the government to give, free of charge, all land required for permanent works; when the works are completed, the company shall sell to the government all the water that irrigators shall desire to use; that the government shall distribute the water, and shall return to the company the net amount received from cultivators, full expenses of distribution and collection of water-rates to be deducted from gross receipts; the price of water shall be fixed by the government and the company, by arbitrators, two chosen by each party, and an umpire selected by the arbitrators in case they fail to agree; the government to have the right to purchase for six months after the expiration of the twentieth, thirtieth, fortieth, and fiftieth years of occupation, paying the mean market-value of the stock in London for three years preceding purchase; the company shall keep their works in good repair, and if they fail so to do the government may make the necessary repairs, re-imbursing itself from the water-revenue; when the net profits exceed 25 per cent., the excess shall be equally shared by the company and the government; the works shall be executed under inspection of the government, and the company shall reconstruct any part not approved by the government.

It appears, from this statement, that the company builds the works and keeps them in order. The government acts as the agent of the company, and reserves to itself the right to protect the cultivators from inordinate charges on the part of the company.

The company proceeded under this contract to execute an extensive system of irrigation, but before long they fell into embarrassment, and were unable to raise the means to carry on the work. The government gave them assistance from time to time, and finally purchased the works from the company before they were completed.

The famine which occurred in Orissa during the progress of these works, by which many hundred thousand persons perished, demanded the speedy construction of the canal, and this added to a growing conviction, now become settled, that under the peculiar circumstances in India it was undesirable that irrigation-works should be intrusted to private parties, induced the government to make propositions of purchase to the company, which were accepted and the works passed out of its hands. This transfer leaves the Madras Company, before mentioned, the only private corporation engaged in selling water for irrigation, at least on a large scale.

All the principal works now in progress or that have been undertaken for the past ten years are in the hands of the government. Private enterprise, never heartily engaged in this kind of work, appears now to have been compelled to abandon the field. The opinions of the government are made clear by the following extracts, viz:

*Minute by his excellency Sir William Denison, governor-general of India,* January, 1864, *and dispatch of the home government to the government of India, dated August* 8, 1864.

These extracts give a fair statement of the views of all the government council of India, and it does not, therefore, seem necessary to quote further from the official correspondence on the subject.

*Minute by his excellency Sir William Denison, governor-general of India.*

My experience of the working of the Irrigation Company in Madras justifies me in asserting that the system which has been adopted in dealing with this company is essentially faulty, and will lead to every kind of complication; disputes will arise, as indeed they have already arisen, as to the value of the water, the mode of distribution, the quantity to be given per acre, whether the occupier of land under the level of the supply-channel is to be compelled to take water, &c., *ad infinitum.* I see no means of framing the clauses of a contract in such a manner as will reconcile the rights of the government as proprietor of the water, as landlord of the estate, and as protector of the rights of its subjects, with the claims of a company whose only object is to make as large a profit as it can upon the capital it expends.

In our anxiety a few years ago to introduce capital and to hasten the completion of certain works of acknowledged utility, we overlooked the difficulties which we were warned would arise out of the conjoint action of the government and the company in dealing with questions relating to assessment of land. I think our experience now is sufficient to justify a statement on our part that the system upon which we have dealt with the company is not likely to be to our advantage, and that we decline altogether to extend it beyond the projects which have already been undertaken and commenced, viz, that of the Madras Irrigation Company under a partial guarantee and the Orissa project; and I should propose to word this communication to the company in such a manner as to exclude any proposed extension of their undertakings under existing contracts.

There are two modes in which this or similar companies should be dealt with. They may act either as contractors for the execution of the works, in which case they would not be responsible for the plans; or, they may agree to carry out a given work for the supply of water to a given district, such water to be delivered at points determined by the government, and to be paid at a fixed price per 100 cubic yards, or for any selected amount of measurement; it will then be for the government to determine the quantity it can profitably employ at each issue from the canal, and to state the maximum it will pay for under any circumstances, and the minimum which the company must be bound to deliver. The company should have nothing to do with the profits of the application of the water.

*Public works.—Dispatch from the secretary of state to the government of India, dated 8th August,* (*No.* 39,) 1864.

* * * * * * *

2. The plan of intrusting the execution of irrigation-works to the agency of private companies was, as you are aware, introduced in 1858 as an experiment. The arguments

for and against the system were fully considered; and it was during the period of financial difficulties, when doubts were entertained of the government being able to raise funds for the execution, on a grand scale, of works of this character, that it was determined by the home government to avail itself of the offer of a private company as an experimental measure.

3. It is now for consideration whether, under a different state of financial affairs, the system then introduced should be continued, or whether works of irrigation should, as a general rule, in future be carried out under the direct control of the government.

4. The experience that has already been had of the working of irrigation companies tends to show the correctness of the objections to the employment of this agency which those opposed to the system entertained, and which have been now so forcibly put forward, as well by the late governor-general, Lord Elgin, and by Sir William Denison, when temporarily acting as governor-general, as by Mr. Maine, in his minute of the 30th September last; and it appears that however desirable it may be for the government to avail itself of the agency of companies in carrying on railways and other similar works of public utility, the close connection between the interests of the government which receives and those of the rigot (farmer) who pays the rent of the land, and the intimate relations which are thereby created between them, render it very undesirable that works of irrigation, and the arrangements connected with the return from them, by which those interests and relations may be so materially affected, should be in other hands than those of the government.

* * * * * * *

7. After carefully considering this important subject in all its bearings, and the able minutes recorded by the several members of your government, I have to signify to you my concurrence in the conclusions at which you have arrived: that the state should undertake directly all the irrigation-works that it can practically manage in preference to intrusting them to private companies; and that when the surplus revenues and available balances prove insufficient to supply the requirements of the country, funds, by means of loans, should be raised; and I shall be prepared to give favorable attention to the practical steps you may propose to adopt to give to these conclusions.

8. In the mean time it would seem to be premature to inquire what concessions it might in certain contingencies be proper to make to private irrigation-companies.

Undoubtedly, it would be better that such companies should be encouraged than that important irrigation-works should either not be undertaken at all or should be indefinitely postponed.

But since it has been determined that your government shall at once make arrangements for prosecuting such works to the extent of its means, it will be advisable to wait to see whether those means may not suffice of themselves before considering on what terms extraneous aid might be obtained. The objections to irrigation-companies in India may not be insuperable, but they are sufficiently strong to make it desirable that resort should not be had to such companies.

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## IRRIGATION IN ITALY.

Rain-fall and temperature—Mean and maximum temperature—Comparison with California—Historical sketch—Canals in Lombardy—Tabulations—Canals in Piedmont—Tabulations—Area irrigated in Piedmont; in Lombardy; cost—The Cavour Canal; agreement; history; details of canal—Ownership of canals—Administration—Associations—Marcite meadows—Measurement of water.

If California possessed a rain-fall equal in amount, and distributed in the same way as it is in Italy, she would not require artificial means of water-supply, at least for the staples she now produces.

The mean annual rain-fall of Lombardy and Piedmont differ little, and may be taken at 37 to 38 inches.

In Piedmont 28½ inches fall in the irrigating-months, from March to September inclusive, giving an average of seventy-one rainy days.

The meteorological facts are contained in the following table, viz:

*Tabl showing temperature, rain-fall, and weather during the season of irrigation in Piedmont.*

| | Mean temperature, Fahrenheit, deg. | Rain-fall, in inches. | Clear days. | Cloudy days. | Rainy days. |
|---|---|---|---|---|---|
| March | 45 | 2.84 | 13 | 10 | 8 |
| April | 52 | 4.14 | 9 | 10 | 11 |
| May | 61.5 | 6.33 | 8 | 9 | 14 |
| June | 74.8 | 3.71 | 9 | 11 | 10 |
| July | 74.6 | 3.37 | 12 | 10 | 9 |
| August | 71.5 | 4.80 | 11 | 10 | 10 |
| September | 63 | 3.37 | 12 | 9 | 9 |

For Lombardy we have the following table, viz:

*Statement of the rain-fall and weather in the irrigated region of Lombardy during the season of irrigation.*

| | Rain-fall, in inches. | Clear days. | Cloudy days. | Rainy days. |
|---|---|---|---|---|
| March | 2.3 | 17.5 | 10.1 | 3.4 |
| April | 3.1 | 15.9 | 7.8 | 6.3 |
| May | 3.8 | 14.1 | 15.1 | 1.8 |
| June | 3.1 | 19.4 | 8.8 | 0.9 |
| July | 2.8 | 21.7 | 7.5 | 0.9 |
| August | 3.2 | 21.3 | 8.2 | 1.5 |
| September | 3.4 | 17.8 | 9.3 | 2.9 |
| Winter | 8 | 42.2 | 31.5 | 13.3 |
| Spring | 9.3 | 47.5 | 34.7 | 9.8 |
| Summer | 9.2 | 62.4 | 26.3 | 3.3 |
| Autumn | 11.8 | 46.8 | 32.5 | 11.7 |
| | 38.3 | 198.9 | 128 | 38.1 |

Including the statistics for other parts of Lombardy, we have about 22 inches of rain-fall in the irrigating-season and about eighteen rainy days.

*Table of temperature in Milan from March to September.*

| | Mean. | Maximum. | Minimum. |
|---|---|---|---|
| March | 44.6 | 62.4 | 33.2 |
| April | 54.8 | 67.6 | 40.3 |
| May | 64 | 78.1 | 49.6 |
| June | 70.5 | 84 | 56.5 |
| July | 74.8 | 87.2 | 61 |
| August | 71.4 | 86.5 | 59.5 |
| September | 66.4 | 80 | 53.4 |
| Winter | 36.1 | 53.8 | 18.3 |
| Spring | 55 | 78.1 | 33.1 |
| Summer | 72.8 | 88.5 | 56.1 |
| Autumn | 56.3 | 82.6 | 32.5 |

The mean temperature in the irrigated region of Lombardy from May to August ranges from 70° to 75°, and the maximum from 85° to 90°.

If Italy, with a meteorology like this, requires irrigation, what shall we say of the necessities of California?

We are without data for complete tables of our own meteorology, but something like the following will not be an inexact statement for a large section of our principal valley: Mean annual rain-fall, 10 inches or less; minimum annual rain-fall, 5 inches; number of clear days in the year, 275; maximum summer-temperature in shade, 110° to 115°, with periods of several weeks in which the thermometer every day passes 100° and sometimes 200 days in succession in which no rain falls.

It is not so much the amount of rain-fall as its distribution which affects the prosperity of agriculture.

In Orissa, (India,) with a rain-fall of 60 inches, there was a terrible famine. In California, with 15 inches well distributed, we often have fine crops.

There are traditions of irrigation in Italy in earlier ages, but the first authentic instance of a canal for this purpose is one taken from the Vettabbia River by the Cistercian monks of Chiaravalle in the twelfth century.

In the twelfth and thirteenth centuries the Naviglio Grande, from the Ticino, was built; and in 1220 the large canal Muzza was commenced. In the fourteenth century no work of importance was executed. In the fifteenth century the canal Martesana, one of the earliest provided with locks, was built. In the interval, from the end of the sixteenth century to the nineteenth century, very few canals were constructed. The canal of Pavia belongs to the nineteenth century. It was first opened in the fourteenth century, but, falling into disuse, it was ordered to be rebuilt by Napoleon I in 1805, and was completed in 1819.

The above enumeration relates to Lombardy.

In Piedmont the canal-system dates from a later age, the first works having been executed in the fourteenth century. In the fifteenth century there was considerable activity in this kind of enterprise, while in the sixteenth, seventeenth, and eighteenth centuries there was but little extension of irrigation. In the nineteenth century we have the canal of Charles Albert and the Cavour Canal from the Po, the last the greatest and perhaps the most unfortunate of all.

The following tables, taken from Col. Baird Smith's work on Italian irrigation, places before us in condensed form the principal facts which we are now concerned to know.

## CANALS IN LOMBARDY.

*Data in regard to the canals from the Ticino River.*

| Name. | Date of construction. | Length, in miles. | Discharge per second, in cubic feet. | Area in acres irrigated. | Price of water per foot per second. | Annual expenditure. | Income. | Area irrigated per cubic foot. | Annual indirect returns. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Naviglio Grande | 1178 | 30. 5 | 1, 851 | 93, 440 | $35 to $65 | $8, 500 | $8, 980 | 61. 8 | $300, 000 |
| 2. Berequardo | 1460 | 11. 5 | 156 | 10, 400 | | ........ | ........ | 66. 6 | 31, 200 |
| 3. Pavia | 1359 / 1847 | 20 | 213 | 9, 550 | | 6, 960 | 9, 375 | 69. 2 | 28, 650 |

From other small streams, viz, the Lambro, Olena, &c., canals containing 240 cubic feet irrigate 20,181 acres, giving 84 acres per foot, and furnishing indirect returns of $60,540.

*Data in regard to the canals from the Adda River.*

| Name. | Date of construction. | Length, in miles. | Volume per second, in cubic feet. | Area in acres irrigated in summer. | Price of water per foot per second. | Annual expenditure. | Annual income. | Irrigation in acres per foot per second. | Indirect returns. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Canal Muzza | 1220 | 43.5 | 2,652 | 182,500 | $4.12 | $3,970 | $7,380 | 83.9 | $522,500 |
| 2. Canal Martesanae Naviglio Interno of Milan. | 1457 / 1440 | 27.5 | 981 | 58,900 | $55 to $65 | 6,000 | 7,000 | 67.2 | 176,700 |
| Three small canals | ..... | ..... | 414 | 38,000 | ..... | ..... | ..... | ..... | ..... |

Canals from Brembo, five in number, which carry 298 cubic feet per second, and irrigate 27,425 acres.

Canals from Serio, fourteen in number, carry 501 cubic feet, and irrigate 44,200 acres.

Canals from the right bank of the Oglio, carry 1,372 cubic feet, and irrigate 142,500 acres.

Canals from the left bank of the Oglio, ten in number, carry 1,522 cubic feet, and irrigate 136,432 acres.

Canals from the Mella, six in number, carry 429 cubic feet, and irrigate 36,300 acres.

Canals from the Clisio, four in number, carry 828 cubic feet, and irrigate 74,500 acres.

A canal carrying an average of 510 cubic feet per second is taken from the Mincio, which irrigates 20,500 acres, principally of rice. In addition, this river supplies five small canals, which irrigate a few thousand acres.

## CANALS IN PIEDMONT.

### *Canals from the Dora Stura and Orco Rivers.*

Seven canals are taken from these streams. They were built at various periods between 1556 and 1790. Their aggregate length is fifty miles. They carry 770 cubic feet of water per second, and irrigate 19,855 acres. The price per acre irrigated is from 62 to 75 cents. The net income is $6,855.

*Statistics of canals from the Dora Baltea.*

| Name. | Date of construction. | Length in miles. | Discharge in cubic feet per second. | Price per foot. | Net income. | Indirect returns. |
|---|---|---|---|---|---|---|
| 1. Canal of Ivrea — main line | 1468 | 44 | 700 | $80 to $105 | $22,100 | $90,000 |
| 1. Canal of Ivrea — branches | ...... | 55 | ........ | | | |
| 2. Cigliano Canal — main line | 1725 | 20 | 650 | | 26,025 | 100,000 |
| 2. Cigliano Canal — branches | ...... | 10 | ........ | | | |
| 3. Canal del Rolto — main line | 1450 | 8 | 600 | | 21,875 | 75,000 |
| 3. Canal del Rolto — branches | ...... | 40.5 | ........ | | | |

*Statistics of canals from the Sesia, &c.*

| Name. | Date of construction. | Length of channel, in miles. | Discharge per second, in cubic feet. | Area irrigated, in acres. | Price per cubic foot per second. | Net income. | Indirect returns. |
|---|---|---|---|---|---|---|---|
| 1. Gattinara | 1320 | 23¾ | 100 | 4,500 | $40 to $50 | $6,000 | $13,500 |
| 2. Gattinara | 1482 | 2½ | 22.5 | 1,250 | 40 to 50 | 1,250 | 3,750 |
| 3. Mora | 1481 | 32½ | 130 | 7,000 | 157.50 | 5,000 | 21,000 |
| 4. Busca | 1380 | 39¼ | 65 | 6,915 | 140 | ........ | 20,145 |
| 5. Rizzo Biraga | 1488 | 88¾ | 90 | 9,059 | 140 | ........ | 27,175 |
| 6. Sartirana | 1380 | 60½ | 220 | 13,860 | 210 | 17,500 | 41,580 |
| 7. Sundry canals from Agogna | Var... | 78 | 222 | 20,112 | 175 | ........ | 60,335 |
| 8. Sundry canals from Arbogna | Var... | 13¼ | 18 | 906 | 175 | ........ | 2,720 |
| 9. Sundry canals from Terdoppio | Var... | 35 | 136 | 7,488 | 175 | ........ | 23,465 |

*Statistics of canals from the Ticino, &c.*

| Name. | Discharge per second, in cubic feet. | Area irrigated, in acres. | Price of water per foot per second. | Net income. | Indirect returns. |
|---|---|---|---|---|---|
| 1. Langosco | 249 | 19,142 | $210 | ........ | $56,925 |
| 2. Sforzesca | 216 | 14,878 | 159 | $7,500 | 44,635 |
| 3. Molinara | 25.4 | 2,483 | 113 | ........ | 7,450 |
| 4. Castellana | 114 | 9,125 | 98 | ........ | 27,375 |
| 5. Magna | 25 | 2,040 | 98 | ........ | 6,120 |
| 6. Canals from springs | 788 | 52,500 | ........ | ........ | 157,500 |

The Cavour Canal taken from the Po at Chivasso is intended to carry 3,885 feet per second.

This completes the enumeration of the principal works in Lombardy and Piedmont.

To gather the main facts in a summary form, it may be stated, first, for Piedmont, that the total quantity of water applied to irrigation is 8,290 cubic feet per second, not counting the supply of the Cavour Canal.

The total area of irrigable land commanded by these canals is stated to be 1,335,680 acres. If we deduct one-third for roads, villages, marshes, &c., the net irrigable land will be about 900,000 acres, of which 306,600 are actually irrigated.

If we add the scattered irrigation in the upper valleys of Piedmont not before included, amounting to 180,000 acres, the total area irrigated is 486,600 acres.

In particular districts the area actually irrigated is about half of the irrigable area.

In Lombardy the area actually irrigated at the date of Col. Baird Smith's report, 1851, was 1,074,129 acres, which is about one-fifth of the productive area.

Between the rivers Ticino and Adda nearly nine-tenths of the surface, between the Adda and the Oglio two-tenths, and between the Oglio and the Adige one-seventh of the plain are irrigated. It is estimated that the aggregate length of the canals and their principal branches in Lombardy exceeds 4,500 miles.

To sum up, we may state that Italy employs for irrigation more than 24,000 cubic feet of water per second, supplying 1,600,000 acres of land.

It is estimated that there have been expended for the irrigation of

1,000,000 acres in Lombardy not less than $200,000,000. This expenditure has been spread over seven hundred years, and has made Lombardy a garden. This estimate, however, is made from very incomplete and uncertain data, and is supposed to cover outlay made for every purpose connected with irrigation, not only the construction of the channels, large and small, the aqueducts and siphons, but also the adaptation of the ground for the special irrigation required. This expenditure, therefore, includes not only that made by the owners of the canals, but also that incurred by the cultivators. The returns from this large investment of capital are to be sought in the indirect revenues accruing to the government from the increased production and the general prosperity of the country.

The canals are chiefly owned by the government; some, however, are in private hands. The same lesson is to be learned here as in India; *as a financial investment for private parties, irrigation-works have not generally been favorable.*

So far as the government is concerned, it is to be said that on the old canals the many private grants of water, made ages ago for services rendered to the state or from caprice, detract largely from the revenue, and they should be considered in estimating the financial character of this kind of enterprise.

The Cavour Canal, before mentioned, is the most important work of the kind in Italy; and, inasmuch as it is a recent construction, and as it was made by a joint-stock company, it will be of interest to inquire what conditions were considered necessary by the government in the light of its extended experience of the working and requirements of irrigation. It was the intention of the government to construct this canal; but on account of its financial difficulties, arising from the wars with Austria and Russia, it was prevented from carrying out the project, and was induced to intrust it to a corporation.

The principal points of the contract between the government and the English company, made in 1862, are as follows, viz:

The company were to construct and work a canal from the river Po, to contain 3,885 cubic feet per second, to irrigate the Novarese and Lorvellino districts, and to combine with this the waters of the Dora Baltea, to be used also in the Vercellese. The company was to commence the work in six months, and to complete it within four years, in spite of all circumstances of every kind.

The government granted a reduction of 50 per cent. of the customs-duties on all material introduced for the construction and maintenance, a complete remission of duties on all instruments and tools, and a partial remission of registration-duties on all deeds and contracts.

The government sold to the company the royal canals from the Dora Baltea, with every appurtenance of factories, mills, &c., for the sum of $4,060,000, to be paid in installments.

The company is to have the use of the irrigation for fifty consecutive irrigating-years, after which time it shall revert to the state, without any compensation whatever to be made to the company.

The company is to raise a capital of $16,000,000, of which $10,680,000 is to be devoted to the construction of the new works, and the remainder to be applied to the purchase of the crown canals above mentioned, and other canals or volumes of water.

The government guarantees interest to the amount of 6 per cent. annually on the capital of $16,000,000.

The company is authorized to issue 6 per cent. bonds to the extent of $11,000,000, the shares to be issued for $5,000,000. The sum raised by bonds is to be deposited in the public treasury, to be issued to the company as required. The government must approve of the works to be constructed; and it has the right to superintend their execution, and to inspect the management of the canal.

The amount of the water-rate and the price of water-power "shall be fixed by the government in consultation with the society, an approximation to the average of current prices being agreed on, and the society shall not vary the prices without the approval of the government."

The company is obliged to lease the water carried beyond the Sesia to an association of proprietors at a price to be fixed in the way just stated.

The obligation of the government to pay the 6 per cent. interest is conditional, and shall only apply when the net income of the canals shall be insufficient to meet the expense.

The canal-rates shall be collected by the proper officer of the government in the same way that public taxes are collected.

The company shall deposit in the treasury, as security, $200,000 in Italian bonds at their nominal value, to be refunded when the company shall have expended $2,000,000.

The state shall have the right to purchase the works after twenty years' occupation, paying the capital corresponding to the mean annual net income for the preceding three years at 5 per cent., deducting the sum previously paid by the government on account of its guarantee.

These are the important points of the agreement, and it must be confessed that the government made a good bargain.

The history of the enterprise is melancholy. In the first place, the Po, instead of carrying 4,000 feet a second in its lowest stage, falls to 1,500 feet. It is simply impossible to understand how such an error could have been committed in Italy.

The Dora Baltea has, however, water in sufficient excess of its requirements, and it is possible to remedy the error by a comparatively small expenditure.

Then there was extravagance and bad management on the part of the company, and the government declined to pay interest on the capital because the works were not absolutely completed within the specified time.

By decision of the courts, however, the government was required to pay the interest. Under all these disadvantages, the company failed, and the enterprise passed into the hands of its creditors.

The character of the works on this canal may perhaps be in some degree realized by an enumeration of its principal features.

The canal is 55 miles long, and at its head it is 131 feet wide on the bottom, and 6 feet in depth. The general slope of the bed is 1 in 4,000; in places it is as much as 1 in 2,800. The side-slopes are one upon one; but on the curves and on the embanked portions, the slopes are revetted with masonry. These dimensions give a velocity varying from 4½ to 5 feet a second. The soil, however, is gravelly.

The canal crosses five streams of torrential character by aqueducts and siphons of considerable length; the aqueducts being approached by long embankments.

There are 345 bridges, or passages, for water over and under the canal, being more than six for each mile. These constructions are of the most substantial character.

The cost of the work, however, is largely due to the fact that the canal is carried across the drainage of the country. Its alignment would have its counterpart in California in a canal skirting the base of the foot-hills of the Sierra Nevada, and crossing, by aqueducts or by siphons, the successive parallel streams which discharge into the Sacramento or into the San Joaquin River. Indeed, the resemblance between the topography of the southern flank of the Alps and the eastern side of the valley of California is complete. The Sierra corresponds to the Alps, the Po to the San Joaquin, and the feature of parallel drainage-lines is common to both.

The canals are quite generally owned by the state. They are under the control of the finance department of the government, which has a staff of engineers to superintend the repairs and to see that the works are kept in efficient order.

The usual practice is for the government to farm out the canals to contractors for a period of nine years. The contractors arrange with the cultivators for the distribution and measurement of the water, and fix the rate of payment under some restrictions.

Disputes between the contractors and cultivators are decided by the civil tribunals.

Each canal forms a district for administration; it may, however, include more than one district.

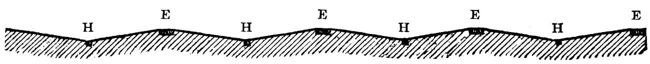
In each district, under regulations prescribed by the government, the irrigators form associations, which administer the affairs connected with the distribution and use of the water.

We need make no further reference here to the description of these associations, for the reason that we attach to this report, as an appendix, a full account of one established by Count Cavour about twenty years ago, for the irrigation of the Vercellese district. This association may be regarded as the most recent result of Italian experience. It embodies the principles which are believed in Italy to be most conducive to the interests of all concerned in irrigation.

This description is taken from a book by Lieut. G. C. S. Moncrieff, Royal Engineers, entitled "Irrigation in Southern Europe."

We should infer, from the meteorological details already given, that cereals and most other products scarcely need irrigation in Italy. Indian corn and flax are irrigated to some extent, but irrigation is mainly confined to rice-cultivation in the summer, and to meadows in the winter. These meadows are devoted to the cultivation of a grass called marcite. This crop requires that a thin film of water shall pass continuously or almost without intermission, except at the periods of cutting, over the grass. This is secured by shaping the land in planes about 30 feet wide, with a slope of 1 in 12 or 15. On the crest of the planes there is an irrigating-channel, from which the water is spread over the land; the surplus being carried off by drainage-channels.

The accompanying section of the land will convey an idea of the arrangement for the distribution of the water.




E, minor irrigating channels, generally 12 inches wide and 6 or 7 deep.
H, minor drainage channels, about half the above dimensions.

The amount of water necessary for these meadows exceeds, beyond comparison, that required for any other cultivation. A cubic foot per second, if economized, may irrigate as much as three acres. The production is very great. The meadows near Milan are cut seven times a year. An ordinary result is 50 tons a year, with exceptional yields of 75 tons, per acre. These meadows are, however, fertilized by the sewerage of Milan, which is distributed over the land directly by the irrigating-channels. In less-favored localities, the yield falls as low as

24 tons per acre. This production cannot, however, be sustained unless the land is richly manured.

On the crown-canals, water is measured as it leaves the principal channels by an apparatus known as a module. There are various examples in different provinces, but the best known and most reliable is that used in the Milanese.

It seems scarcely necessary here to give a description of the arrangements made for this purpose, inasmuch as the information is readily accessible. We may, however, mention that the principle of the measurement is that the head of water is kept constant, whatever may be the changes in the level of the canal. After the water leaves the main channels, there does not seem to be a uniform practice of measuring it on its distribution into the secondary ditches. There are so many usages in this country, sanctioned by long periods of time, that it has hitherto been impracticable to introduce complete and thorough measurement.

There are always some persons who profit by the absence of regulations on this point, and their influence exerted against change has proved sufficient to defeat the purpose of the government.

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## IRRIGATION IN SPAIN.

Rain-fall and temperature—Comparison with California—Value of irrigated land in various parts of Spain—Irrigation introduced by the Moors—Water annexed to land in Valencia—Variety in ownership of water—Value of water in different provinces—Spanish law—Method of obtaining a grant of water—Privileges to irrigation-enterprises—Exemption from taxation—Minority compelled to pay their part for canals—Subsidies; how given—Position of government of Spain—Irrigating-associations—Subsidies to canals—Area of irrigation—Huerta of Valencia—Administration of irrigation—General assembly—Syndic—Kinds of cultivation—Drought—Tribunal for deciding disputes—Its composition and modes of procedure—The canal of Mencade.

In some parts of Spain we seem to be near home. There is something familiar in a rain-fall of 7 inches and a temperature of 111°.

*The mean annual rain-fall for different parts of Spain for four years, from 1858 to 1861.*

| | Inches. |
|---|---|
| Granada | 33.4 |
| Seville | 22.5 |
| Valadolid | 20.9 |
| Saragossa | 17.0 |
| Valencia | 15.9 |
| Alicante | 13.6 |
| Madrid | 12.0 |

In 1859, at Alicante, there were only 7.1 inches of rain.

*Table of rain-fall and temperature for the irrigating-months, from March to September.*

| | Mean rain-fall, in inches. | Mean temperature, in degrees, Fahrenheit. | Maximum temperature, in degrees, Fahrenheit. |
|---|---|---|---|
| Madrid | 5.31 | 64.69 | 98 |
| Alicante | 7.66 | 69.41 | 94 |
| Valadolid | 8.98 | 62.51 | 90 |
| Seville | 5.45 | 77.98 | 111 |

A comparison of the meteorology of these parts of Spain and of the irrigated portions of Italy, will show for Spain both a higher temperature and a smaller rain-fall.

The climate in our interior valleys differs from that of Spain, in the fact that the latter country has a summer rain-fall ranging from 5 to 9 inches, whereas in California we often have no rain worth measuring from April to December; and generally from the beginning of May to the end of October not a rain-cloud obscures the sun.

Spain, by common consent, needs irrigation, and perhaps of all the countries in the world it best repays irrigating.

We might establish the remunerative character of this mode of cultivation in other ways, but it is probable that no way can be more satisfactory than to give the values of land as established by sales, both of irrigated and of unirrigated land.

Near the city of Valencia, irrigated land is sold at prices running from $700 to $900 per acre, and at a distance from the city from $400 to $500 per acre, while land of the same quality not irrigated is sold at $80 or less per acre.

Don Juan Ribera, a Spanish engineer, states that land near Madrid is increased in value by irrigation from four to ten fold, land of the lowest price being most appreciated in value.

From sales made at Castellon in 1859, it appears that the average price of irrigated land was $700 per acre, while unirrigated land in the same neighborhood was sold for $50 per acre.

Parts of the *huerta* of Murcia have been sold at $2,500 per acre, dry land close by being worth $150.

At San Fernando, near Madrid, the rental of irrigated land is $25 per acre, which is the price in fee of dry land in the vicinity.

In the valley of the Esla River irrigated land is worth $600 per acre, and dry land $50.

In the valley of the Tagus it is said the produce from irrigated land is twelve times that from unirrigated land. In parts of France where irrigation is not nearly so much needed, irrigated land is only appreciated 50 per cent. by irrigating.

Spain may be described as a country where the water is more valuable than the land in a ratio of from 5 to 20, and we feel assured that the same proposition is equally true of large parts of California.

Spain is, from the value attached to water, an interesting study. It is interesting to know what steps have in recent years been taken to extend the use of water, and what systems have been adopted.

The Spaniards have an experience of a thousand years behind them, and they ought to be convinced of the value of this mode of cultivation.

There is probably no part of the world where water is more carefully applied, and there certainly is no country where the legislation is more clear and precise.

Irrigation in Spain is a legacy left by the Moors. All or nearly all of the old systems were the work of this wonderful people. Not only the works but the customs of the Moors remain in some provinces almost untouched since their departure. These customs may be said to be imbedded in the hearts and minds of the people of certain provinces, and we must regard it as a tribute to the intelligence of the conquered race that their regulations, adopted by their enemies, have been able to exercise a sway so complete that the efforts of rulers and the progress of events have alike failed to change them in their essential features.

We find in Spain every variety in administrative systems for using water. In Valencia, in the lands irrigated from the Jucar River, and in Murviedro, the water and the land are, so to speak, married, without a possibility of divorce. When the land is sold, the water that irrigates it goes with it; neither can be sold separately. The irrigator cannot even dispose of his turn or privilege of water. The same is true in the province of Murcia, and at Almansa.

As Elche, on the other hand, the water belongs to parties who do not own the land. The land has no rights. When the farmer needs water, he buys it as he buys any other article. There is a daily water exchange, where one may buy the use of water in an irrigating channel for twenty-four hours, beginning at six in the evening. The prices that are stated to have been paid in times of scarcity, tax our credulity very much.

In 1861 it is said that water was sold at more than $11,000 per cubic foot a second.

At Lorca there is an auction of water held daily.

These are all old works, where the customs of past ages prevail. The new canals are generally built and owned by capitalists, under conditions which will hereafter be explained. On the Heuares Canal, just built, it appears that the company owning the works made agreements with the farmers before building as to the price to be paid for irrigation. The government fixed the value of water on this canal to be $1,875 for one cubic foot a second for one year.

It will be remembered that in Italy the annual value of the same quantity is about $75 to $80.

The different meteorologies of the two countries make the basis of this difference of value.

On the Heuares Canal to cover an acre with twelve inches of water costs $2.88; on the Esla Canal, $1.70.

At Alicante the price of 16,000 cubic feet of water, which is about 4¼ inches over an acre, has varied, according to scarcity, from 50 cents to $13.

At Larca the average price of 17,500 cubic feet of water, nearly 5 inches over an acre, is $6.25.

The canal Llobregat charges on an average $2.75 per acre, and as high as $4.25.

The canal of Urgel charges $4.75 per acre. In Malaga the price is about the same.

On the old Moorish works, which are now the property of the irrigators, the price is only what is necessary to pay the expenses of the works and keep them in repair.

The farmers have agreed to take water from a new canal in Navarra, and to pay $3 per acre for four irrigations in a season. An irrigation in Spain is generally from 2½ to 3 inches in depth.

### SPANISH LAW IN REGARD TO CANALS, AND CONDITIONS OF AGREEMENTS MADE WITH PRIVATE COMPANIES.

The latest enactment, which seems to be most complete and detailed, and which contains three hundred paragraphs, is dated August 3, 1866. Although all the provisions would doubtless be of interest to those called upon to legislate upon the subject of water, we cannot do more than refer to those points which bear immediately upon our subject.

Article 236 states that all grants of water made to owners of land for its irrigation shall be in perpetuity. All grants made to parties to irrigate the lands of others shall be for a period not exceeding ninety-nine years, which period expired, the works shall become the property of the irrigators. An application for a grant of water shall be accompanied by proof that the applicant owns the land he proposes to irrigate; or if not, the rates of payment proposed to be paid by the parties who own the land or who are to buy the water; or if a particular district is to be irrigated by the owners thereof, that the agreement made by the majority of the owners reckoned by the area owned. The project is then to be advertised, and objections may be made for a month. The project is referred to various authorities, to ascertain whether it is desirable, whether it interferes with any vested rights, whether it promises to endanger the public health, or whether the constructions proposed are suitable. Any grant of water is subject to rights of other parties previously established.

Certain privileges are granted to undertakings of this class, as follow, viz:

1st. To quarry on the public land. Sites for the necessary works, shops, kilns, &c., on the public lands are given free.

2d. Exemption from certain charges required in transfer of property.

3d. The capital invested is exempted from tax of every kind; and all foreign capital invested in these enterprises will be under the protection of the government, and it shall never be confiscated in time of war.

4th. Employés have certain local privileges. If the company allows the works to fall into bad repair, and does not restore them within the period assigned by the government, or if the new works shall not be finished in the stipulated time, they may be sold at public auction to the highest bidder.

All the land included in any project which is called for by the majority of the proprietors shall pay the approved rate, whether the owners wish to take water or not; and those who refuse to pay are obliged to sell their lands to the company at a price equal to the assessed value of the land, for taxation, increased by 50 per cent. If the company declines to purchase the lands at this price, the proprietor shall be exempt from any payment.

The law of April 22, 1849, provides, that for ten years after the works are completed all products of irrigation shall be free from taxation.

All land brought under irrigation is taxed as unirrigated land for ten years.

The law of July 11, 1865, appropriated $5,000,000 to be given as subsidy or as loans, without interest, to irrigating enterprises, in sums not to exceed $100,000 for each enterprise. The special authority of the Cortes is necessary to permit a larger grant. This subsidy is generally given to the amount of 15 per cent. of the estimated cost, as certified by the government engineers, and it is paid in three installments:

1st. When the earth-work is finished.

2d. When the bridges and culverts are finished.

3d. When the work is completed and the irrigating is begun.

The attitude of the government toward the administration of these enterprises is commended by M. Aymard in the following terms:

> We may inquire, What is the nature of the action of the government in regard to enterprises of irrigation? What is the character of its intervention or supervision? Does it lead or does it follow the people?
>
> The government is in advance of the people, but it does not exercise an injudicious pressure. Where customs sanctioned by antiquity prevail, it does not seek to overthrow them merely for the purpose of securing unity of administration.
>
> Itis in advance of the people in this sense, namely, that it lays down with clearness and precision in the laws the modern principles of the administration, so that the moment that the necessity for a reform is felt, the people are at once informed in what direction that reform is to be sought.

In regard to the terms on which new concessions are granted, the same author says:

> In the activity which has recently prevailed in the extension of enterprises of irrigation, the problem was to guard the rights and interests of future generations, while

making such concessions to the commercial spirit of the present as would induce the extension of these necessary works. In its decrees the government lays down with great wisdom the general terms of all concessions of water-franchises, and defines the respective rights of the proprietors, and of the users; so that enterprises of this character may be undertaken without hesitation or embarrassment. The outline of every possible enterprise is defined in the statutes, and in each particular case it is only necessary to fill in the details.

One clause in these statutes provides that in every irrigating-district or community there ought to be established a syndicate or association, and a system of regulations fixing the details in every respect concerning the use of the water; which regulations must be approved by the government or by the provincial authorities, as the case may be.

The general principle which forms the base of the syndicate is this, namely, that the administration of the water-supply and use shall be in the hands and under the control of the irrigators.

We see that the Spanish systems of a thousand years' duration lead to the same general conclusion that the experience in Italy has established and exemplified in the association for the irrigation of the Vercellese, an account of which is given elsewhere.

This conclusion may be stated in these terms: that where the irrigators do not own the irrigating-works, they ought nevertheless to have the control of the distribution of the water, and of the details of irrigation.

A conclusion which is fortified by the experience of hundreds of years in Italy and Spain, where the people cannot be supposed to be more familiar with the principles of self-government than are our own people, which is supported by the wisdom of a man like Cavour, which promises relief from the difficulties attending the administration of water by capitalists having no direct interest in the land, but looking for the best return for their money invested, and which, moreover, is congenial to the habits and feelings of people like our own, must, perhaps, with modifications, prove the solution of our own vexed problem.

It is worthy of remark, and it is confirmatory of the general conclusions derived from the experience elsewhere, that in a country where irrigation is so desirable, and where its effect is to increase in so striking a manner the value of the lands, the government feels obliged to aid works of this kind by subsidy and by exemption from taxes.

According to the official reports, the area of irrigated land in Spain is four thousand four hundred and thirty-nine square miles.

The principal canals, however, irrigate only 500,000 acres. There are many small canals and a few tanks or reservoirs, which increase this area considerably. If we accept the official reports, the greater part of the land must be irrigated by wheels or *norias*. These wheels have buckets or jars attached to the circumferences, by means of which the water is raised. The motive power may be the current of the river, or it may be animal power.

We close this review of Spanish irrigation by a brief description of the agriculture and system of administration in the highly-cultivated *huerta* of Valencia.

This district extends for eight or nine miles along the river Guadalaviar, from which the canals which irrigate it are derived.

It has been under this kind of cultivation for perhaps a thousand years. The Moors introduced irrigation, and the executive and judicial system established by them retains to this day its essential characteristics.

The water in this district is, as has already been stated, annexed to the land, and when land is sold the right to water goes with it. A person cannot even give to another the water to which he has a right; if he does not use it, it reverts to the common benefit.

The plain of Valencia is irrigated by eight small canals, four of which are on each side of the river. Each canal is entitled to an aliquot part of the river-supply, and the proportions are established by the levels of the sills of the head-works. which are of masonry, and which have remained unchanged since the days of the Moors. It is, however, only in the low stages of the river that it becomes essential to observe the prescribed division of water, for at other periods there is an abundance for all.

The aggregate length of these canals is but forty-two miles. The longest is but twelve miles in length. The dams are of masonry.

The administration of these canals is at least curious, and it will be interesting to recount it briefly.

Each canal forms a district, the irrigators of which meet once in two years to elect a permanent committee of administration, to assess the expenses or taxes, and to elect the officers of the district. The principal officer is called the syndic; we should probably call him the superintendent. He must be an actual cultivator; not a proprietor merely, but one who actually holds the plow. He must have a good character and be owner of a certain quantity of land in his own zone or district. He is elected by a majority of votes, and he may be re-elected. His term of office varies between two and four years. He is chief administrator; he expends the funds, and in time of drought he is an absolute dictator in regard to the distribution of the water. The other employés are appointed by the syndic, or by the permanent committee, or sometimes they are elected by the general assembly.

Usually the taxes are assessed by the general assembly. Generally each irrigator pays according to the land under cultivation, but not always so. In some cases he pays in a measure proportionately to the quantity of water used. The taxes are collected in a summary manner. If any one fail to pay his taxes, he is deprived of the use of the water, and if he take it he is liable to a severe fine; or if any official shall allow him to take water, the latter is exposed to the same fine.

There is no regulating machinery for the distribution of water. The arrangements are at the discretion of the officials, who keep themselves informed as to the condition of the crops, and who supply water to those which seem to need it most. No cultivator can claim a definite quantity of water.

The cultivation is various; hemp, corn, wheat, beans, pears, melons, artichokes, and peppers are among the products of the soil. Hemp is regarded as the most valuable crop. It is cut in July, before the water gets very low, and therefore it seldom suffers from scarcity of water.

In times of drought the syndic gives water to the crop that needs it most, keeping in view, however, the value of the crop. Hemp being the most valuable crop, receives attention first if it needs it, which is seldom the case; next come artichokes, the order being established by long custom. If all of a given crop cannot be saved, the water is applied to half of each field, the other half being allowed to suffer. The decision is in the hands of the officials, none of the cultivators being permitted to take water without permission.

This is certainly a very rigorous kind of administration. It is democratic so far as its deliberations and constitution are concerned, but in its action it is essentially autocratic. Doubtless the long line of customs descending from a thousand years serves in practice as a guide for the action of the syndic, and divests it, in a measure, of its arbitrary appearance. The responsibility is, however, not divided. In times of drought some responsibility must be taken, and one man can take it better than a number. The working of the system must be favorable, or it would long since have fallen under the opposition of its enemies.

These canals have a curious tribunal, which has come down from the Moors, and which is as simple and untechnical in its constitution and in its modes of procedure as can be desired. Its proceedings are not recorded, unless at the request of one or both of the parties concerned. It enforces its decrees in a summary manner, and there is no appeal from its decisions.

This tribunal of the canals is composed of the syndics of the canals of the plains. It meets every Thursday at 11 o'clock in the public square in front of the Cathedral in Valencia. The judges are seated, while the parties concerned and the spectators stand respectfully a few paces distant. The syndic in whose district the grievance or offense was committed brings the case before the court. He questions the witnesses and presents the case, but he does not vote. When the case is heard, the judges discuss in a low tone for a few minutes, and announce their decision. No expense is incurred by the parties to the case, if the fines or damages assessed are paid at once. If they are not so paid, the tribunal has power to enforce its decisions by processes which entail expense upon the recusant party. The fines attached to particular offenses are stated in a code of laws. The jurisdiction of the court is absolute in matters of fact and police over those who appear before it. Any person may decline to appear before the tribunal. If, having been twice summoned, any person shall fail to appear, the matter is turned over to the ordinary courts, where its adjudication is attended with considerable expense. It is said that cultivators rarely fail to appear before this tribunal when summoned.

It may well be supposed that this institution has often been assailed. A court of peasant judges, whose proceedings are not recorded and whose decisions admit of no appeal, could not fail to attract criticism and invite intervention. The government has more than once attempted to make changes in harmony with the usual course of procedure, but the steadfast attachment of the people interested in the tribunal has sufficed to maintain it substantially as it descended from the Moors. Whatever may be its defects, we cannot doubt that it has dispensed even-handed justice; otherwise it could not have existed so long.

The canal of Moncade, which is also taken from the Guadalaviar River, has some differences in administration which indicate the character of the changes which the government has wished to make in the case just described. This association has a code of regulations which prescribes fines for the various offenses. The superintendent or syndic of the canal is invested with authority to impose fines in accordance with the code. The parties concerned have the right of appeal to a court elected by the irrigators, which resembles in many respects the tribunal of the canals, and there is a further right of appeal to one of the ordinary civil courts. On this canal each irrigator has a right to water on fixed days for a certain number of hours.

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## IRRIGATION IN FRANCE.

Government owns canals—How canals are built and how managed.

Irrigation is quite extensively practiced in France, and several new canals have been built in the past few years.

There is nothing so specially distinctive in French irrigation as to require detailed description. The principle of management of works by the irrigators applies here as well as in Spain and Italy. There is, however, more interference by the government.

The government owns no canals. They are generally built by the land-owners. The government encourages the construction of canals.

In the charter of the *Carpentras* Canal, built in 1854, the irrigators were guaranteed that no increase of the land-assessment should be made for twenty-five years after the completion of the works.

There is no provision in the French law corresponding to the Spanish statute which permits a majority of proprietors to carry on an irrigation enterprise and compels the minority to bear their share of the expense.

When a charter for a canal is given it states the quantity of water which is granted. The plans for the works must be approved by the government. In some cases the canals are built under direction of engineers of the Corps of Ponts et Chausées. In all cases the works are periodically inspected by engineers of this corps.

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## CHAPTER V.

1. Cost of irrigation—Quantity of water required—Secondary and tertiary ditches to be made by cultivators—Canals and primary ditches will cost about $10 per acre irrigated.
2. Conclusions—Large bodies of land in "the great Valley of California" require irrigation; abundance of water; irrigation much needed—Cost—Ignorance of the subject—A comprehensive system cannot be devised by the farmers—Duty of government—Proper laws depend on reconnaissance and surveys—Irrigation will be the work of time—Land and water should be joined together—State and counties benefitted—Private capital—Relation of the United States to irrigation—Supervision.

### COST OF IRRIGATION.

Before making an estimate of the cost of canals, it is necessary to inquire how much water is required to irrigate an acre of land. It will readily be understood that the quantity will depend upon a number of considerations. In the first place, it will depend upon the character of the soil, whether sandy or clayey; upon the character of the substratum, whether pervious or impervious, and upon the depth and inclination of an impervious stratum. It will depend upon the character of the cultivation. Rice and sugar fields, vegetable-gardens, orchards, and meadows require more water than cereals.

The present staples of this country are cereals. There is some cotton-cultivation, which will probably be extended; and, with abundance of water, we shall doubtless have a good deal of Alfalfa or Lucerne grass. Every farmer will have a little orchard, and will raise the vegetables required for home consumption.

The evaporation is high in the interior valleys of the State, quite equal to that in Madrid, where it is about 13 inches in July.

The amount of water lost by absorption in the bed and banks of the canal, is an unknown and variable quantity, depending on the dimensions of the canals and on the character of the soil. In the absence of exact data upon these points, we may for the present adopt the rule laid down by engineers for other countries of similar climate, and estimate the loss of water from these causes at 15 per cent.

The rivers of California generally run full for about seven months.

The rains of the winter increase their discharge, and the melting of the snows keeps it up, so that we may say that the streams from the Sierra Nevadas are well supplied with water from December to August. The streams from the coast range have no snow reservoirs of much extent, and they are generally dry in summer.

Let us assume that the streams on the east side of the valley are well supplied with water for two hundred days in the year, and, to make up for any overestimate on this point, let us neglect their flow for the remainder of the year.

How much land ought a cubic foot of water, supplied every second for two hundred days, to irrigate?

We will make a further supposition that the water is used for fourteen hours out of the twenty-four. Irrigation at night is practiced in other counties, and we may be assured that in seasons of scarcity it will be practiced here if it shall prove to be necessary to save the crops.

In fourteen hours there are fifty thousand four hundred seconds, and hence one day's supply, at one cubic foot per second, will give us the same number of feet. Deducting 15 per cent. for loss by absorption and evaporation, we shall have remaining 42,840 cubic feet, which number, although a little less, we may take to be the same as the number of square feet in an acre. Hence, one day's supply will put 12 inches of water over an acre, or 2 inches of water over six acres, and in two hundred days a supply of a cubic foot per second will cover two hundred acres with 12 inches of water.

Wheat planted in October or November on summer-fallowed land, well watered when the rivers are high, will probably make a good crop without further watering, except what it gets from the winter rains, even when they prove scanty.

Wheat planted in January or February will probably need one or two irrigations of 3 inches each to make a crop. Wheat or barley planted later, and with irrigating facilities, (there seems to be no reason why, in these hot valleys, the sowing-time may not be extended to April,) will probably ripen with 12 inches of water judiciously applied. We know that good crops of wheat are raised without irrigation when there is a rain-fall of 12 inches, or even less, which comes at the required times.

On the Tule or reclaimed lands, barley sowed after wheat-harvest has been gathered comes to maturity.

The water required for cotton will probably not exceed that necessary for wheat. Rice-cultivation is so unhealthful that its introduction into California will hardly be looked upon with favor.

Alfalfa, if cut five times for hay, will require 12 inches of water or more, depending on the nature of the soil; this in addition to the usual rain-fall.

There is another point to be considered. The whole of the land commanded by the canal will not be irrigated; some of it will be waste or unsuitable for cultivation; some will be fallow, and if we add the areas taken up by the roads, fences, buildings, farm-yards, &c., we ought, according to experience elsewhere, to deduct one-fourth, at least, from the irrigable lands. This deduction of one-fourth, we assume, will make up for any kind of cultivation, such as gardens, orchards, &c., requiring larger supplies of water.

Our opinion is, therefore, that a reasonable allowance for the land commanded by the canals is one cubic foot a second for each two hundred acres.

In seasons when there is a great surplus of water there can be no objection to a more liberal use of it, but it seems to us indispensable that the State should lay down a general rule. There ought to be an established allotment, which may vary in different districts. The cultivators who come first ought not to be allowed to appropriate more water than they require, because, if they do, those who come after will not be able to procure a fair supply.

There are probably exceptional places where the lower average of rain-fall and porosity of the soil may combine to require a larger allotment of water than we have assigned. Such places are about Tulare Lake, on the west side of the valley. There is no cultivation in these portions, and before the occasion may arise to irrigate them further information will probably be available to enable a proper conclusion to be reached.

As the population of the irrigated districts increases there will be an increased demand for water, and it will probably result that the allowance which is sufficient in this generation, may prove entirely inadequate fifty years in the future.

When the state makes the survey elsewhere recommended in this report, we will learn both how much water and how much land there is, and will be enabled to proportion the supply to be granted.

It may then be a question, in seasons of scarcity, whether a smaller supply of water will be given to the whole land or a larger supply to a portion of it.

There is so much variety on this point, in the circumstances of climate, soil, and cultivation, and so much difference in the statements of different authorities, that we cannot derive, from the experience of other countries, any definite conclusions applicable to our own; but as a matter of interest it will not be amiss to mention the duty of water in other irrigating districts.

In North India a cubic foot of water per second irrigates five acres per day.

Taking the interval of irrigation at forty days, we have the duty of two hundred acres for one foot a second for cereals.

In Granada a canal from the Genil irrigates, of wheat, barley, and vines, two hundred and forty acres per cubic foot.

In Valencia, where it is very hot, wheat is watered four or five times, giving about two hundred acres per foot.

In Elche, where water is very scarce, a cubic foot goes as far as to irrigate one thousand acres. Wheat here in some years scarcely requires artificial watering.

Rice-fields in different parts of the world vary from thirty to sixty, and even eighty acres, to the cubic foot.

In the heavy monsoons of India ninety acres per foot are irrigated.

In some of the *huertas* or gardens in Valencia, only from thirteen to twenty acres per foot are irrigated. Here, however, there are at least two crops a year, and a part is devoted to rice.

The grants for six recent canals in Spain run from seventy acres per foot to two hundred and sixty acres per foot.

Assuming, then, that a cubic foot per second will water two hundred acres of land, we proceed to give some considerations in regard to the probable cost of construction of the canals and their primary ditches.

The secondary and tertiary ditches will, it is supposed, be made by the cultivators. They can be made by the farmer in seasons of leisure, and in the general case their cost will hardly be felt. The case will be somewhat different with the cultivator who farms on a large scale, and who is obliged to hire laborers.

It is plain, on the slightest consideration, that the cost of a canal will be so dependent on local and special circumstances that it is impossible to deduce a perfectly satisfactory conclusion from a given or hypothetical case.

The dam, the character of the soil, the quantity of land to be irrigated, the manner in which it is disposed, the relative remoteness, and the resources and population along the line, are all elements which vary from case to case, and either of which may affect the cost by a very considerable percentage.

Still it seems essential to know within some limits the probable cost.

If a canal is to cost $100 per acre irrigated, the subject may be dismissed without any further consideration.

It is plain that we cannot afford to pay that price. If, on the other hand, canals may be built for five or twice five dollars per acre, it is equally plain that now or before many years we shall be able to afford them, and shall have a fair prospect of return from such investment.

The value of the estimate which we proceed to give, will be understood from what precedes.

Let us take the most favorable case that can happen, namely, when the excavation equals the embankment.

We assume a canal to carry 315 cubic feet of water per second, having the dimensions given in the figure. Deducting from this 15 per cent. for loss, the water available for irrigation is 268 cubic feet, which will irrigate 53,600 acres.

If we suppose the irrigable land to lie on one side of the canal in a strip five miles wide, and that the ground permits straight parallel primary ditches spaced one mile apart, it follows that for each mile of canal there must be five miles of primary ditches, and that the quantity of irrigable land for each mile of canal will be 3,200 acres. Deducting one-fourth for land not actually watered, we shall have 2,400 acres of irrigated land for each mile of canal.

Let us take a primary ditch of capacity to carry 50 feet of water per second. Allowing for loss, this size will be rather more than sufficient to cover the 2,400 acres with 3 inches of water in seven days and seven nights.

The canal can fill at the same time six of the primary ditches, so that in seven days 14,400 acres can be covered with 3 inches of water, only six of the primary being full at a time. And in twenty-six days 3 inches of water may be put over the whole amount of the land, namely, 53,600 acres.

If the water is used only for fourteen hours for each day, the time necessary to go over all the land with 3 inches of water will be forty-five days.

Under our hypothesis, in order to irrigate 2,400 acres, we must build one mile of main canal and five miles of primary ditches.

Placing the excavation at 30 cents per cubic yard, we find the cost per acre to be about $5.

The section of the main canal will diminish toward its lower end, but to be on the safe side, so far as cost is concerned, we keep it of uniform size. The price of excavation may be somewhat in excess of its actual cost in some places; but inasmuch as in it are included all incidental and contingent expenses, we believe it is not far from correct.

We have omitted from this calculation all estimates for inequality of the ground, by reason of which the amount of excavation may be considerably increased; all expense due to the fact that generally one or several miles of canal have to be made at its head before the water is high enough relatively to the adjoining land to irrigate it, and we do not include the cost of a dam, which generally will be indispensable. Neither do we include the cost of head-works or of the bridges and sluices which will be required, or of the measures that may be necessary to pass the drainage of the country into, over, or under the canal. We do not estimate for these points, for the reason that no estimate can be made, the circumstances in no two cases being the same.

Speaking generally, we are of the opinion that the omitted points will cost as much as the excavation, and hence that the rate per acre just given should be double.

This brings us to the conclusion that it will cost about $10 per acre to irrigate these valleys.

It is, however, to be remarked, that large portions of the eastern side of the San Joaquin Valley are underlaid 2 or 3 feet from the surface by a hard stratum, which it will be necessary to blast, or, if not blasted, the canals must be very shallow. This fact leads us to believe that the cost per acre in these sections will be increased 25 to 33 per cent. above the estimate already given.

The irrigation of the foot-hills will of course cost more. Here the problem will be more similar to that presented in other countries. So far as we are able to judge from descriptions given by writers, we are inclined to believe that the physical conditions in these valleys are exceptionally favorable for irrigation. This fact accounts in a great measure for the smallness of our estimates as compared with the actual cost of canals in Spain; for instance, where the price of labor is so much cheaper than it is in California.

A further reason for this difference lies in the character of the constructions. The dams, head-works, and sluices of foreign works are made of masonry, and in the most thorough manner. In California all of these constructions will for many years be of wood. It is cheaper, with the present rates of interest, to build of wood, and to rebuild when the works decay, than to construct once for all of masonry.

The cheapest canal that we find in Spain is that from the Esla, which cost $15 per acre. The other modern canals in Spain have cost more than twice as much. There are no longer in these old countries any lands which admit of easy irrigation, and on all these lines there is a great deal of heavy work in excavation, tunneling, aqueducts, and in revetment-walls, which the valley works in California will not require.

## CONCLUSIONS.

1st. That there are large bodies of fertile land in the great valley of California—extensive plains, in fact—that require irrigation to make them productive, and that the natural features of these plains are favorable to artificial irrigation.

2d. That there is an abundance of water for the irrigation of all land on the eastern side of the valley by canals from the rivers.

3d. While there is a scarcity of water on the western side of the valley, at the necessary elevation, particularly on the western side of the San Joaquin and Tulare Valleys, yet there is sufficient water attainable there, and at a sufficient elevation, to irrigate large areas of land on that side.

4th. That irrigation is much needed, particularly in the San Joaquin and Tulare Valleys. The productions of these valleys could be increased many fold by a comprehensive system of irrigation. The value of the irrigable land and of the revenue derived from it, both by the State and by the people, will be increased in the same ratio.

5th. The cost of a comprehensive system of irrigation for these valleys will be great, but as the different portions are not equally in want of irrigation, the complete system may be the work of time.

6th. Irrigation is but little understood in this country, either by our engineers, who must design, plan, lay out, and execute the works for that purpose, or by the farmers who are to use the water when it is brought alongside their farms.

7th. That the experience of other countries appears to prove that no extensive system of irrigation can ever be devised or executed by the farmers themselves, in consequence of the impossibility of forming proper combinations or associations for that purpose. That while small enterprises may be undertaken by the farmers in particular cases, it would not be in accordance with the experience of the world to expect of them the means or inclination to that co-operation which would be necessary to construct irrigating-works involving large expenditures. That enterprises of this character, if built at all, must be built by the State or by private capital.

8th. That it is the duty of government, both State and national, to encourage irrigation, and the first step in that direction ought to be to make a complete instrumental reconnaissance of the country to be irrigated, embracing the sources from whence the irrigating-canals ought to commence, gauging the flow of the rivers and streams, and defining the boundaries of the natural districts of irrigation into which the country is divided.

9th. Then, when it is proposed to irrigate any particular district, an accurate topographical survey of that district should be made, so that the canal and other necessary works for its irrigation may be designed on an intelligent and comprehensive system, and in harmony with the neighboring canals, and these works executed in the most economical manner. In this way every farmer will be informed, before he will be called upon to contribute to the works of irrigation, whether or not his land is irrigable; and if it is, of the quantity of water he will obtain; the exact place or places where it will be delivered to him, and of its probable cost.

10th. While these surveys are being made, we think it would be a step in the right direction if the Government of the United States, as well as of the State of California, would inaugurate measures for obtaining from foreign countries all possible information relating to the more modern systems of irrigation in these countries, and for disseminating this information throughout this country.

11th. After the necessary reconnaissance shall have been made, and a knowledge of the most improved systems of irrigation in other countries has been obtained, the general system of irrigation can be properly planned and the outline of the principal works determined, the laws under which a proper system of irrigation for the great valley can then be decided upon intelligently, the country divided into those natural districts which its topographical features require, and all, or nearly all, the land-owners will then know what benefits they are to derive from irrigation. Light will be thrown on a subject which is now in comparative darkness; unnecessary clashing of private interests can be avoided or harmonized. The rights of water which have given so much trouble in other countries where the laws regulating these rights have grown up with their systems of irrigation, and, as history teaches us, have often been made for the benefit of private parties or particular districts of country, can be established beforehand, if not for all time, at least on the principle of "the greatest good for the greatest number."

12th. That while the irrigation of these plains would probably be effected in the cheapest and most thorough manner by a comprehensive system of canals, such as we have sketched, we by no means recommend that all irrigation should await the development of such a system. We are taught by the experience of other countries to expect such development to be the work of many years. In the mean time, ten or twenty or fifty farmers, having lands so situated as to be irrigable from a neighboring stream, may desire to construct the works necessary for that purpose, to be operated for their benefit, or they may desire to enter into an agreement with other parties, who shall build the required works. In either case, if the proposed works do not conflict with the general system of irrigation, we believe that such an enterprise should be permitted and encouraged by the State.

13th. As a matter of public policy, it is desirable that the land and water should be joined together, never to be cut asunder; that the farmers should enjoy in perpetuity the use of the water necessary for the irrigation of their respective lands; that when the land is sold the right to water shall also be sold with it, and that neither should be sold separately.

14th. That the parties chiefly benefited by irrigation are the farmers or land-owners. That there is every reason to believe that the value of land in the driest districts will be appreciated many fold; that it results from this that the lands should, as far as possible, pay for the construction of the necessary works.

15th. That the State and counties will be directly benefited by the appreciation of land and by the increase of wealth in their revenues from taxation. That, consequently, it may be good policy for them to aid such enterprises.

16th. That there is this difficulty in the way of the proposition that the lands shall pay for the canals, namely, that in many places the lands at present are not worth more than $5 per acre, if so much, and that the irrigation-works may cost $10 per acre.

17th. That whatever aid is given by the State or county should be extended in a cautious way. That in many parts of the country where irrigation will ultimately best repay expenditure there are now no people; that the population must be imported, the houses, barns, and equipments of the farms must be created before returns can follow the investment. That for these reasons we must look for a comparatively slow development of the country.

18th. That while we believe, as we have already stated, that the best policy is for farmers to build and own the canals, we also believe that where the farmers are unable to build, and where the State is unable or unwilling to build, it may be, and it probably will be, the best policy to invite the aid of private enterprise. We refer to numerous instances in Spain and Italy, where this system is now in successful operation, in support of our opinion.

19th. That private companies undertaking such enterprises should be subjected to certain conditions, some of which are as follows:

That after a stated period the franchise shall lapse in favor of the State or of the irrigators; or that, after a certain period, the State shall have the right to purchase on certain previously-defined conditions. That the price of water shall be fixed by agreement, each party in interest being represented by arbiters. That the State shall have the right to charter an association of irrigators to administer the works, the company merely selling the water, and having nothing to do with it after it leaves their channels, the association making all arrangements for its distribution and for the collection of the water-rates. This latter provision has several advantages: It relieves the company from the odious duty of discriminating in times of scarcity, and from the endless disputes which attend the distribution of water, and puts the responsibility where it belongs, on the irrigators. It favors each irrigator; for he becomes a member of a company, which is strong enough to stand up for its rights in any contest with the capitalists.

For a successful system of this kind, we refer to the "Association for Irrigation in the Vercelles, Italy," given elsewhere in this report. That we see no reason why the rights of farmers and the rights of capitalists may not be adjusted by some such plan, on the basis of justice and of mutual interest.

We observe that the conditions just referred to place a company of capitalists in the light of temporary owners, and that they contemplate a period when the works shall be owned by the State or by the farmers.

20th. That there is no reason to suppose that for a long time capital will look upon this kind of investment with favor. The financial history of most irrigating enterprises in other countries is not favorable, so far as the interests of shareholders are concerned. It may be a question for the State to consider whether it is good policy to offer any special inducements in aid of such enterprises.

21st. That the relation of the United States to the irrigation of California is for the most part indirect, but that—in the southern end of the valley, between Visalia and Bakersfield, and south of this town—it is believed that the United States own many thousand acres of land which are capable of irrigation; that most of this land cannot be cultivated under existing circumstances; that it has no value, except for pasturage, during part of the year; that, if irrigated, its value would be increased many fold; that under these circumstances it may be a question whether the United States ought not in some way to encourage the irrigation of these lands.

22d. That when any canals are built, the State should establish a system of inspection by which a proper construction shall be assured; that the quantity of water to be taken from a river at its mean stage, for the irrigation of a definite quantity of land, should be fixed by a reasonable rule, so that those who come later shall not find all the water taken up, and so that proper drainage shall be secured.

23d. That such supervision will probably be distasteful to the parties concerned; that, nevertheless, we believe it is essential to future prosperity, and that its neglect now will bring a fruitful crop of contentions in the future, will delay the development of the country, and that by making irrigation unhealthful it may make it odious.

24th. That the water-rights of the streams now taken up for mining-purposes in the mountains do not conflict with the irrigation of the plains, the water being returned to the natural channels above the points where it will be taken out for irrigation, at least for many years to come.

Respectfully submitted.

B. S. ALEXANDER,
*Lieut. Col. of Engineers, U. S. A., Pres't Board of Commissioners.*
GEORGE DAVIDSON,
*Assistant U. S. Coast Survey.*
G. H. MENDELL,
*Major of Engineers.*

SAN FRANCISCO, CAL.,
*February* 20, 1874.

## APPENDIX 1.

A large portion of the water of the Cavour Canal is sold to a species of co-operative society at Vercelli, known as the "General Association of Irrigation west of Sesia."

This society was founded by government under an act of 3d of July, 1853, and owes it origin to Count Cavour. It had for its object, at starting, to lease, administer, and employ in general, according to an economical and matured system of irrigated cultivation, the waters of the Crown Canals derived from the Dora Baltea, in terms of the grant made with the state finance for the irrigation of the respective properties of the shareholders, with the power of extending successively the benefits of the association, even to the mutual assurance against losses by hail, fire, and such like, and to other social objects of mutual profit.

By the terms of the agreement made between the society and government, the society were thereby granted a thirty years' lease of all the waters of the Crown Canals of the Dora Baltea with certain exceptions in favor of the owners of old hereditary rights, entitling them to a free use of a portion of their waters.

The volume thus reserved amounts to no less than 793 cubic feet per second.

When the Cavour Canal Company was formed it was obliged to abide by this agreement with the irrigation society, and in 1867 there was supplied to the latter from the waters of the Po 900 cubic feet, and from those of the Dora Baltea Canals, after the deduction above alluded to, 537 cubic feet per second, while this year (1868) they have sent in an application for 971 cubic feet of the former and for 659 cubic feet per second of the latter waters.

The regulations and statutes of this Irrigation Society are too long to give in detail, for they consist of 379 articles, in 76 pages octavo; but the system possesses sufficient interest to be described minutely.

In each *commune* or parish irrigated by these canals, there is a society termed a *consorzio agrario*, composed of all the proprietors within the parish who take water for their lands; or, in certain cases, a *consorzio* may be composed of proprietors of adjoining small parishes. Each *consorzio* elects by universal suffrage one or two deputies, according as it uses a discharge of less or more than 30 module (61.4 cubic feet per second) on its irrigation. These deputies form an assembly for the general administration of affairs. They must be themselves members of the society, over twenty-five years of age, "sufficiently acquainted with agriculture," and men of good character. They receive no salary as deputies, nor are they allowed to hold any paid office under the society. They are elected for three years, and may be re-elected. They meet regularly twice a year, on the 15th of March and the 15th of November, and half their number form a quorum. They elect from among themselves a president and vice-president, whose functions last for three years, and each year they choose also an honorary secretary and two assistants. They pass the accounts of the year, settle how much is to be paid by each *consorzio*, what salaries their employés are to have, listen to suggestions for the benefit of the society, and, in short, generally direct and control the whole of its business. The rules passed by the assembly are binding on all the members of the society. To help them in forming decisions, they have a legal and an engineering adviser.

From among themselves the assembly elect three committees: the direction-general, the committee of surveillance, and the council of arbitration.

The first is the committee of management of the affairs of the society. It consists of a director-general, three members, a secretary, and an assistant secretary. If the director-general likes, he may appoint a colleague, with the approval of the assembly, to take his place in case of illness or absence.

The director-general may call on the assembly to dismiss any of the members of his committee, or he himself may suspend them for not doing their duty. He has in every way to watch over the interests of the society, to see to the conduct of its servants, and to give them rules for their guidance, to direct any works, to disburse expenses, to arrange with the government (or with the canal company) for the amount of water required at each point, to see generally to the distribution of the water over the irrigated district, to carry on all communications with the government—in short, to be general manager. The director-general receives an allowance of $1,800 a year, from which he is expected to pay a number of small charges, and each member of his committee receives a certain salary. This committee has its headquarters at Vercelli, and renders an account of its proceedings at each meeting of the general assembly.

The committee of surveillance is "the eye of the assembly over the direction-general," and has to see that it carries out faithfully its duties toward the society. It consists of three members, of whom the oldest presides. They meet once a week, and each time receive a ticket which entitles them to a small allowance, as fixed at each general assembly; in 1866 the whole amount being only $152. Should they think necessary, they may call an extraordinary meeting of the assembly, and at each ordinary meeting they make a report of their proceedings.

The council of arbitration has for its object, "1st, to settle all disputes regarding affairs of the society which may arise between the members and the society, or between the society and its servants; 2d, to decide cases of breaches of the rules and discipline of the society; 3d, to assist the society in actions before the courts; 4th, to give their advice on whatever may be referred to them by the director-general; 5th, to fix and settle, in case of dispute, the compensation for the passage-outlet, or any other obligation or damage occasioned by the flowing distribution, employment, recovery in drains, and escape of the waters of the society, whether affecting the interests of the society with its members or among the *consorzios* or members with each other."

This council is composed of three members of the assembly, who must be resident in Vercelli, and are elected annually. They receive no regular pay, but get certificates of attendance at meetings like the committee of surveillance, and these certificates entitle them to a small remuneration, of which the whole amount in 1866 was $223. Their decisions are settled by the opinion of the majority. There is always the power of appeal from them to the ordinary courts of justice; and, to admit of this appeal, the execution of their sentences is deferred for fifteen days after being promulgated, unless in cases where, for the sake of the crops, it must be carried out at once. After fifteen days, if no appeal has been made, the decisions of the council are looked on as final. When necessary, the council summon a lawyer or engineer to their assistance. All charges of this council are paid by whoever loses the case. The director-general is not allowed to carry on any lawsuit on the part of the society without the previous sanction of the council of arbitration.

The money transactions of the society are under a cashier, who has to give a security for $4,000, and who is responsible for all connected with their cash. His chest has three keys, of which he keeps one, the director-general another, and the third is held by the largest shareholder of the society, who is a member of the general assembly, and happens to live in Vercelli. Money is issued on the checks of the director-general, and once a month he and the member who keeps the third key of the cash-box count the cash and audit the cashier's books.

To effect the distribution of the water, the area irrigated is divided into a certain number of districts, (at first only four, but increased since,) in each of which there is an overseer in charge of the irrigation, termed the *delegato*, who receives his orders from the direction-general, and several guards or water-bailiffs, termed *acquainolo*. These officers patrol the water-courses, see that the modules are discharging their proper amount, that the water that passes off the fields is not running to waste, but is caught in catch-water drains, from which at a lower level it can be again utilized, (a point attended to with admirable care in the Piedmontese irrigation,) and do all the other ordinary duties connected with their position. Neglect of duty or disobedience of orders subjects them to fines, reduction of salary, or dismissal.

It may be seen by the agreement between the society and government that, while the latter became responsible for the entire maintenance of the main canals, the irrigation society has to pay for all current repairs, &c., of the minor canals, which repairs the government (or now the Italian Canal Company) executes for them, and that all further operations of distributing water, &c., are entirely carried out by the irrigation society's agents, and at their cost. This society, then, has in its employ no engineers, but a number of irrigators. Their executive operations are divided into those of interest to all, and those affecting merely single *consorzii*. To the former belong the general maintenance of the branch canals, the formation of new ones, the catch-water drains, &c., which are paid for from the funds of the society at large. To the latter belong the maintenance of small water-courses and minor works, which are charged to those *consorzii* alone who are benefited by them.

The cost of executing such works is paid for at the time by the society and recovered from the *consorzii* afterward, who tax each individual according to the extent and species of his irrigated crops, which is supposed to give a fair approximation to the proportionate share of water which he has consumed.

This is a point to be noted. Previously to visiting these canals, I understood that water was universally issued by module, and that the administration of the canal had no monetary interest in the question of whether a cultivator made an economical use or not of the discharge allotted to him. I believe this is nearly the case in Lombardy, but by no means in Piedmont.

The Piedmontese module of 2.047 cubic feet per second is too large a unit to apply to small properties, and in most cases the cultivator may be said to pay, according to the area he waters, just as much as with us in India.

Article 16 of the statutes of the irrigation society runs as follows: "All payments for irrigation are to be made in money at the rate of so much per hectare." The society, it is true, buys its water from the canal company by module. It distributes it by module among its districts, and the irrigation overseers supply it by module to the various *consorzii*. But there the measurement ceases.

In November of each year each *consorzio* makes out an indent of the number of acres of each description of crop that is desired to be irrigated within its limits during the summer of the year following, and each December this ought to be sent in to the director-general; and on these indents are settled how many modules are to be issued to each.

At the end of the season each *consorzio* is called on to pay for a certain discharge of water received by it, as well as for the maintenance, repairs, &c., of the works particularly connected with it, and for its share in the general expenses of the whole society. The *proper* system, then, is to make out a calculation for each irrigator, which is done in each *consorzio*, allowing at the rate of one cubic foot a second for 43¾ acres of rice, one cubic foot a second for 100 acres of meadow, and one cubic foot a second for 304 acres of Indian corn.

Supposing, then, that an irrigator had watered 10 hectares of rice, 20 of meadow and 20 of maize, he would be charged for 60 modules, or 1.23 cubic feet per second; and if the whole consumption of the *consorzio* had been 24 modules, and the whole cost $6,000, he would have to pay one-fortieth, or $150, for the irrigation of his 50 hectares, or 123,5 acres. But the next year he might find he would have to pay considerably more or less, according as the working-expenses of the year had increased or diminished.

Should any cultivator have used great economy of water, and irrigated fields which he had not entered in the annual indent, he would be charged for all this irrigation, although by so doing he might help to cheapen the water issued to the *consorzio;* that is, the *consorzio* as a whole would pay for its 24 modules; and if, by any means, some of its members make these 24 go as far as 30 modules that had been calculated for, the effect would be to reduce the rate on every hectare within the *consorzio.* This, however, is not a case that is likely to occur. The certainty of getting a fixed supply and having to pay a fixed rate for it, irrigating year after year precisely the same lands, is preferred to the chances connected with any system by which a man's endeavors to economize water might be rewarded by having to pay less for it. Nor do I believe there is much waste, so carefully is the water collected in drains round the fields and passed off to other distribution-channels.

In North India the case is totally different. There a man's irrigable area, as a rule, far exceeds that for which in any one year he will have sufficient water. Here the whole irrigable area may be watered; and if it is not, it is because in the rotation of crops irrigation is not required for it all, not because there is any lack of water.

While, then, the Italian irrigator is enabled every year to get the fields watered which he wishes, and is contented to pay a fixed moderate sum for it, the more intelligent and industrious of the North Indian peasantry consider the more water they can get the more the area they will irrigate. The system of supplying water by module to them, which has been so highly extolled, and which as yet has never succeeded, would doubtless be an inducement for the more indolent classes to use the precious element with economy; but I think my brother canal-officers who have most experience in the matter will agree with me that among the villages inhabited by the hard-working castes (I instance especially the Jâts in the districts of Delhi, Meerut, and Kurnal, with whom I am personally best acquainted) there will be very little saving of water effected by introducing the module system. Its other advantages in restricting the canal establishment to their own works and removing the interference with the villages caused by the yearly measuring parties, with their concomitant amount of rascality and bribery, I think are undeniable.

The system above described has been called the proper system, for it is the one which the society has laid down in its statutes. In the case of the water-rate for rice, however, the old system is still in vogue, to some extent, of paying in kind.

Before the cultivator is allowed to reap his rice-crops he is obliged to give due notice to the *acquainolo*, in order that one of the society's agents may inspect the field. When the rice is cut it must be conveyed to a thrashing-floor provided in each *consorzio* by the society, and there its agent takes as payment for the irrigation one-sixth of the crop, which is thereupon conveyed at the expense of the irrigator to the great central granary which the society possesses at Salasco.

Why this system should be still allowed to exist seems strange. In Col. B. Smith's time he found it unpopular, and the society in their statutes provide for doing away with it and receiving payment in money for rice as for the other crops; but still it goes on, although only to a small extent.

The rice irrigation is generally continuous, any one taking just what he requires, and when he requires it. The other irrigation is conducted by a rotation, or *ruota*, as it is termed, of fifteen days, beginning each year on the first of April.

The marcite fields or meadows, arranged in succession of ridges and furrows, receive their waters in summer in the same way as the regular crops by a regular rotation; but in winter the system is quite different. This is the only species of irrigation that goes on at all during these months, and the waters of the *fontanili* (springs) having a higher temperature in winter than that of the canals, is generally preferred for this kind of irrigation, which must go on continuously, or the frost sets in about the grass and checks its growth.

The irrigation society has the lease of all the *fontanili* belonging to the crown and of many others within the limits of its irrigation, and these are put up to auction, for periods not exceeding nine years, to be used for *marcite* irrigation from the middle of September to the middle of March. For the rest of the year these *fontanili* are used for general irrigation, and do not belong to the winter tenants.

For the local management of the *consorzii*, the members in each elect, along with their deputy who represents them at the general assembly, six others, (or, if there be over 200 electors, nine others,) and these, with the deputy as president, form an administrative committee. They have the whole management of the irrigation with their own *consorzio*. They correspond with the direction-general, arrange what works requir erepair, and in fact are the mouth-piece and representative of their parish.

The society undertakes, when it has enough of water, to supply lands with irrigation which do not properly come within its area, as, for instance, when they only require an occasional watering, and are so situated as not to be able to receive it continuously. These lands are charged at the same rate as those belonging to the society.

The water-power is let to millers, the rates being fixed by the number of stones driven, rather than by the head of water disposable.

Article 244 of the statutes lays down that "every member of the society is obliged to place, without any return of identification, at the full disposal of the society all the trenches, channels of *fontanili*, ditches, and water-courses, with the buildings pertaining to and connected with them, and all the works of all kinds without exception, which exist on his property, in order that the same may be made use of for the passage, distribution, and employment of fresh waters, as well as for those recovered by the drains, and for the transit of drains."

The proprietor, too, is obliged to keep these channels in working-order at his own expense, or, if he neglects to do it, the direction-general will do it for him, and charge him with the amount. All the water that passes off the irrigated fields into the society's drains becomes again the property of the society, so that the irrigator has only a right to the use of the water while it passes over his lands, and he must not prevent its escape into the drains provided for it.

If any member of the society possesses a *fontanile*, or has a hereditary right to a certain discharge of water beforehand, he may make this over to the society at a valuation, which they will give him for it by way of yearly rental.

The statutes provide a number of fines for breach of canal laws. Any one interfering with the channels or water-courses may be fined from $4 to $12. Any one tampering with the canal-buildings or altering the sluices may be fined from $6 to $18. There is a fine of $3 for hindering the water from going into the drains, and one of from $20 to $60 for wasting the society's water. Any member caught selling the water is fined double the sum he is believed to have got for it.

Whoever tries to cheat in paying his rice contribution is fined double the amount he tried to escape paying, and whoever conceals fields he has irrigated is charged $10 for every hectare he has concealed. The amount of fines goes one-half to the funds of the society and the other half to the charitable support of old *acquainoli* who are unfit for work. The half that accrued to the society's fund in 1866 was only; $68 double of that, $136, represents the whole fines of the year. They are certainly very low.

There remains to describe not the least important part of the society's administration, namely, the financial. By its agreement with government, the irrigation society was bound to raise and maintain a reserve fund of $60,000, as a security for its proper management. It was permitted, however, to borrow from this fund capital to carry on its expenses the first year, and in any other year when there should be extraordinary charges to meet. It was further allowed to raise this capital by a loan to be paid off in four installments, so as not to press too heavily the first year on the society. Each irrigator then, from the government canals, was called on to become a member of the society, and to send in a statement of the area and description of crops which he was in the habit of watering and wished to continue to water. The same calculation was then gone through as given, allowing per hectare .028 module for rice, .012 module for meadow irrigation, and .004 module for Indian corn, and, according to the number of modules thus required by any irrigator, he became a shareholder in the society.

Supposing his whole area required .60 module, and that all the original shareholders together require 300 modules, he would be considered as the owner of one five-hundredth of the concern, and would have to pay that fraction of the fund of $60,000, or $120. The original shares thus formed are liable, like any others, to rise or sink in value, and may be divided, sold, and bought, &c., along with the lands to the irrigation of which they refer. Any irrigating proprietor not entering the society when he might have done so, and wishing to do so afterward, is bound to pay for the shares according to their market-value at the time, and, in addition, an entrance subscription equal to half the original value of his shares.

Those, however, joining afterward, on account of the society having brought them irrigation they had not before, (the new irrigators, for instance, on the Cavour Canal,) are not obliged to pay this entrance subscription, but merely to buy their shares at their value at the time.

I have before me the detailed accounts for the year 1866, from which I have made the following abstract:

ASSOCIATION-GENERAL OF IRRIGATION WEST OF THE SESIA.

*Abstract of expenditures and receipts for the year* 1866.

Expenditure, (neglecting the decimals:)

| | |
|---|---|
| Salaries for establishment for the year | $12,350 |
| Price of water purchased, Italian Canal Company | 135,505 |
| Price of water purchased from various private sources | 7,200 |
| Maintenance and supervision of secondary channels | 8,355 |
| Maintenance and supervision of water-courses, &c., from fountains | 7,360 |
| Hire of buildings | 315 |
| Compensation for land occupied | 400 |
| General expenses of office and direction | 5,290 |
| Expenses of society's rice-granary at Salasco | 1,125 |
| Allowance to members of committee of surveillance for their sittings | 150 |
| Allowance to members of council of arbitration | 225 |
| Legal expenses | 1,480 |
| Interest at 5 per cent. of the capital of society | 5,380 |
| House of refuge for old servants | 760 |
| Advances to *consorzii* for carrying on works | 38,775 |
| Sundry ordinary charges | 1,355 |
| Construction of various new works | 7,325 |
| Various extraordinary charges—purchase of land, &c | 2,940 |
| Balance of receipts paid as bonus to shareholders | 11,770 |
| Grand total | 248,060 |

Receipts:

| | |
|---|---|
| For 1,559 cubic feet per second of water sold for irrigation | $152,480 |
| Price agreed on for watering about 4,750 acres of rice in various places | 20,955 |
| Value of 1,043 sacks of rice of sorts, paid in kind as water-rent | 5,745 |
| For sundry other detached portions of irrigation | 8,970 |
| Rent of rice and corn mills, with water-power | 7,270 |
| Advances, for carrying on works, to various *consorzii*, recovered | 38,775 |
| Interest received from capital of the society | 8,160 |
| Fines for breach of rules | 70 |
| Commission paid to council of arbitration for cases referred to them | 195 |
| Rent of houses and lands belonging to the society | 465 |
| Various sundry ordinary receipts | 965 |
| Sundry ordinary receipts, recovery of advances, &c | 2,370 |
| Refunded by Italian Canal Company for work done for them | 1,305 |
| Capital of society increased by purchase of shares | 335 |
| Grand total | 248,060 |

The chief item of expenditure of course is for the water brought from the Italian Canal Company. Of this, 714.4 cubic feet per second was water brought by the Cavour Canal from the river Po, and bought at