

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 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 Chausees. In all cases the works are periodically inspected by engineers of this corps.

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 second 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.

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SAN FRANCISCO, CAL.,
 February 20, 1874.

APPENDIX 1.

A large portion of the water in 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[s] 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