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1885.

VICTORIA.

ROYAL COMMISSION ON WATER SUPPLY.

FIRST PROGRESS REPORT.

IRRIGATION IN WESTERN AMERICA,

SO FAR AS IT HAS RELATION TO THE CIRCUMSTANCES OF VICTORIA.

A MEMORANDUM FOR THE MEMBERS OF THE ROYAL COMMISSION ON WATER SUPPLY,

BY

THE HONORABLE A. DEAKIN, M.P.

PRESENTED TO BOTH HOUSES OF PARLIAMENT BY HIS EXCELLENCY'S COMMAND.

By Authority:
JOHN FERRES, GOVERNMENT PRINTER, MELBOURNE.

NOTE.

The Report of the Engineer will be issued immediately upon the completion of the Plans of Works and Implements.

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FIRST PROGRESS REPORT OF THE ROYAL COMMISSION ON WATER SUPPLY, 1884.

To His Excellency Sir Henry Brougham Loch, *Knight Commander of the Most Honorable Order of the Bath, Governor and Commander-in-Chief in and over the Colony of Victoria and its Dependencies, &c., &c., &c.*

May it please Your Excellency:

We, your Commissioners, appointed on the 23rd December, 1884, "to inquire into the question of Water Supply, and into other matters relating thereto," beg to submit this our first Progress Report.

We have held a number of meetings in Melbourne, and have also visited and examined a large number of works of Water Supply in various parts of the colony, and have taken evidence of the Chairmen and Officers of Water Trusts constituted under the *Victorian Water Conservation Act* 1881; of the Mayors and Public Officers of towns artificially supplied with water; and of other persons able to afford us information on the subject of inquiry remitted to us by Your Excellency.

We have also received from the Hon. Alfred Deakin, M.P., President of this Commission, a Memorandum of certain valuable information collected by him in the course of a visit to the United States of America, undertaken with the purpose of forwarding the objects of this Commission; a copy of which document we have now the honour to lay before Your Excellency.

We have the honour to be,

Your Excellency's most obedient servants,

ALFRED DEAKIN, President.

JAMES CAMPBELL, Vice-President.

CHARLES YOUNG,
WALTER MADDEN,
JAMES SHACKELL,
GEORGE GRAHAM,
A. BLACK,
WILLIAM H. STEEL,
ROB. L. J. ELLERY,
W. W. CULCHETH,
THOS. B. MUNTZ,
THOMPSON MOORE,
JAMES BALFOUR,
} Members.

Stuart Murray, Secretary,
Public Offices, Melbourne.

IRRIGATION IN WESTERN AMERICA SO FAR AS IT HAS RELATION TO THE CIRCUMSTANCES OF VICTORIA.

A Memorandum for the Members of the Royal Commission on Water Supply.

Preliminary

Since I had the honour of presiding over your opening meeting at the close of last year, I have visited America for the purpose of obtaining such a knowledge of the system of irrigation in that country as might throw light upon the possibilities of its application in Victoria, and thus assist you in the solution of the all-important problems of water supply into which your Commission was appointed to inquire. By a rapid tour through Colorado, California, Arizona, New and Old Mexico, Nevada, and Kansas, and, by the kind assistance of State officials, and of a large number of private persons, I was enabled to make a satisfactory inspection of the works and methods employed so far as they appear to have relation to the present circumstances of Victoria. The necessity for leaving Australia to obtain evidence of a practical order relating to agricultural production by means of an artificial water supply needs no remark. What experiment there has been among us in this direction is of so recent a date, of so limited an extent, and of so rudimentary a character that, to find a practical base for those recommendations which Parliament will expect to receive from the Commission, it seemed imperative that experiences of a much more varied nature should be laid before you.

Irrigation area of the United States.

What Major Powell, chief of the Geographical and Geological Survey Department of the United States, aptly entitles its "arid region"—that is, the portion in which irrigation is essential to all agriculture—begins about midway in the great plains of the central States, and extends across the Rocky Mountains to the coast range bordering upon the Pacific Ocean. It is an area of enormous extent, since it comprehends more than two-fifths of the whole territory of the Republic, excluding Alaska. Between this region and the "humid region" in which irrigation is unnecessary, stretches what he denominates the "sub-humid region," in which irrigation, though not essential and not yet introduced, is, in his opinion, certain to be adopted in course of time to meet the fluctuations of its rainfall. In this last division is included one-tenth of the whole country. Consequently, according to this competent judge, irrigation, now a matter of the most vital interest to more than one-third of the United States, is likely to become in the future a mainstay of the agriculture of more than one-half of its vast domain. It is scarcely possible, therefore, to exaggerate the importance to the States of a study of its progress and promise. So far, however, it has not obtained that complete scientific investigation which the knowledge of such a fact would lead one to anticipate.* At present, what practical experience there is has been attained in the arid area of the south-west,

* I am indebted to the Hon. E. A. Carman, Acting Commissioner of Agriculture, and to his able assistant in the Irrigation Branch, Colonel Hinton, for a very valuable and comprehensive description of the irrigable area of the United States, and the chief facts concerning it, compiled from the yet unpublished records of the Agricultural Bureau at Washington, D.C., expressly for the benefit of this Commission. It unfortunately arrived too late for me to make use of its important information in the preparation of this Memorandum, but will be found *in extenso* in Appendix L.

1,000,000 square miles in extent, of which not one-half has yet been surveyed. For the eastern boundary of this region Major Powell takes the isohyetal (or mean annual rainfall) line of 20 inches, which runs for the most part somewhat east of the one-hundredth meridian, and includes all the country west of this, with the exception of the strip of northern California, Oregon, and Washington territory receiving the mists and rains of the Pacific Ocean. Out of this enormous tract, containing one-third as much land as the whole of Australasia, only some 3 or 4 per cent. is irrigable at any price. There is not water enough to supply more, and doubtless it could not be profitably supplied to nearly so much. The proportion actually irrigated so far can only be approximately estimated. The State engineer of Colorado reckons over 1,000,000 acres within his jurisdiction; the Congressional delegate for Utah adds 650,000 acres for that territory; the State engineer of California has supervision over an area of about the same extent; while in Arizona, New Mexico, and Kansas, though the totals are small in comparison, they are increasing steadily, and already works are constructed to supply a much greater acreage than is actually watered. Probably the water supply of this year will be able to cover 2,500,000 acres. This is more than are supplied in Italy, and far more than in France and Spain together. The area in Mexico is very great, but can only be guessed at. From what can be learned, it would, if added to that of the States, give as large an irrigated area to North America as to Europe.

Irrigation era.

The extent of the area irrigated in the West is the more surprising since the practice, as compared with that of Europe, is a thing of yesterday. In Mexico, irrigation was practised before the Spanish conquest, and there are a few spots in its old provinces, now forming the south-western States of the Union, where, either at Indian villages or at the missions, plots can be seen which have been cultivated for a century by its means. In Utah, Americans began irrigating in a primitive way forty years ago, and their example was followed in that fashion, especially near the Mexican border, and under Mexican tutelage, for a score of years. But the real development of American irrigation, now so wide-spread, has taken place entirely during the last quarter of a century, and mainly during the last fifteen years. During that period it has been lifted out of its early rudeness and carelessness into something like science and skill. Its traditions date no farther than this; its records do not date so far. The strides it has taken may be judged from the now current estimate that, as against 4,500 miles of canal in Lombardy, there are 12,000 miles of main canals in the West, and that the capital invested in and about them is expressed in millions sterling.

The visible fruits of irrigation.

Though in area American irrigation to-day may be compared with that of Europe, there is no comparison in age. As yet, indeed, there has been no comparison of the two systems, nor is there any work of which I am aware dealing with the irrigation of the West as a whole, or presenting its peculiar features. A few papers have been written upon particular instances, but these have little more than a local interest. If one seeks for an explanation of the reason why American irrigation is so famous, one finds that it is not owing in any degree to the completeness of the information published concerning it, but to the impression made upon every tourist through the arid area. A very vivid impression he cannot fail to receive, no matter how careless or indifferent he may be, for the glimpses obtained from a railway carriage window are a constant illustration of the wonder-working powers of an element, the need of which is so painfully evident for scores of miles along his route. The irrigated lands of America, though widely various, may be divided into two great

classes. The rolling prairies of Kansas and sloping uplands of Colorado belong to one division. Poor and brown in ordinary seasons, their buffalo and bunch grasses are often green after favorable spring rains, and it seems but natural that, when a constant supply of water is secured, these treeless expanses should be gradually conquered by the march of settlement from thickly inhabited and closely cultivated districts. Not so with the sandy wastes stretching in a broad belt from the north to the south and south-west of the arid region. Here there is no prospect of any early invasion due to pressure of population or overflow from crowded towns. Here there is nothing to attract, and everything to repel. Here even the rich red mesa lands that lie under the shadow of the foot-hills are desolate at all times and in all seasons—so desolate that it seems impossible they should ever sustain a living thing. From them the illimitable desert, bare and blinding in its glaring barrenness, stretches far away to the mirage towers that shift along a dull and undefined horizon. Much of the soil is so powdery even in winter that it follows in a lazy trail of cloud the horse of the solitary rider, or is sucked up in whirlwinds under the scorching summer sun. Elsewhere its gravelly and gritty surfaces, strewn with splintered boulders, are seamed into gaping gulches and fissures of inappeasable thirst. There is no grass, the only vegetation being a withered-looking brush resembling saltbush, the thirsty-looking cactus, a juiceless scrub like our ti-tree, or a thorny variety of stunted palm. Such is the Mapimi desert in Mexico, the Maricopa desert in Arizona, or the Mojave desert in California, and such, without water, they must remain. As it is, these wastes of sandy aridity and grey innutritious herbage, surrendered by nature to solitude, surround oases created and sustained by irrigation. In the distance the track of a canal, pleasantly breaking the dull level of the dried-up plain, is marked, sometimes for miles, by a line of green bushes following its sinuous course. By-and-by this line broadens as if into a great green plantation dotted with houses, divided into gardens, and decked with flowers. Its little fields, fringed with flourishing trees, are bright with fresh-springing pasture, upon which stock are grazing, or else crowded with dark orange groves and clustering vines. In the centre of it is a tiny township, busy with teams and traders where the train stops for a moment or two. When it starts again the houses and trees vanish as if by enchantment, and the engine rushes on through the dreary desert once more. It is thus that the eye bears testimony to the fruits of irrigation in the south, and in the north, though in a less striking way, the lesson is the same. The unpretentious ditches that wind along the hill-sides or prairie ridges are not notable themselves until it is perceived that, where they are not, a scattered herd of rough cattle, a small party of roving Indians, or a burly rancher, are the only objects of interest, while, where they multiply, are the buildings, the barns, and the business. A stretch of open country broken by long ridges of canals, its paddocks plotted off into little checks, with a barefooted Chinaman or high-booted European, spade in hand, directing the water from one to the other, are common features of the landscape, where one beholds industry and intelligence transmuting barren surfaces into orchards and fields of waving grain. Familiar, too, are the knots of active men, the little camp of tents, and toiling teams, that mark the progress of a new ditch into the wilderness, where it is to create a settlement and maintain it in the face of all seasons. The Indian village, the Mexican pueblo, the American township, all cluster about the natural stream, or the artificial stream which makes it serviceable. For in these parched regions its progress is everywhere a triumphal march. It is here veritably the water of life—life to the grass and flower, to the loaded tree, to man and to the city of men whose homesteads and harvests follow in its wake.

America as a field of inquiry.

Still the choice of America as a field of inquiry was not dictated by any mere consideration of area or pictorial impressiveness, but with a careful regard to our own local conditions. Indian irrigation is known to be carried on upon the greatest scale, and many of its works are acknowledged to be marvels of engineering skill. But they are designed to meet the needs of a dense imperfectly civilized population, whose habits and wants differ from those of our race, and whose climate, country, and water supply lead them to grow a class of products chiefly foreign to our farmers. In the valley of the Po, the practice of irrigation, by means of a culture of immemorial experience, has probably reached greater perfection; but here too, as in the south of France and in Spain, the conditions of existence are widely different from those which obtain in the new worlds. In Italy and parts of France there is a rainfall 75 per cent. greater than ours, feeding numerous streams of considerable magnitude, besides which there is a large population, cheap in hire, frugal in habit, and trained from childhood to the practice of employing water for agricultural purposes. These countries have been long settled, much divided, regularly cultivated, while their cultivators act under a body of traditional customs, and local as well as general laws, adapted to their peculiar circumstances. They have the markets of the continent at their doors, and steadily supply them. In many respects, therefore, the irrigating countries of Europe and Asia differ widely from our own. The western States of America, on the other hand, which can now claim to be ranked among irrigating countries, present many likenesses to Victoria. The climate of California resembles ours as much as that of the south of France or northern Italy, but with a further resemblance that the rainfall of its warmer districts is insufficient or irregular, so that, in more than two-thirds of this State, artificial additions to it are rendered necessary. It is like Victoria—a new country, settled by the pick of the Anglo-Saxon race, attracted in the first instance by gold discoveries, and remaining after that excitement passed away to build up a new nation under the freest institutions and most favorable conditions of life. California is almost exactly the same age as our colony, and in soil also the two countries are not unlike. In both, water was first employed by miners, and in both agriculture has been a later development. The price of labour bears about the same relation in each to the price of commodities. Their products are similar, and in both the chief markets are found at a great distance. California, with the same population as Victoria, has twice our area, and as the State is oblong in shape and has its greatest length from north to south, it possesses within its borders a greater diversity of climate. The "coast" range of mountains divides it into a valley and a slope, the valley bounded by the Sierra Nevada on the east, and the slope on the west by the Pacific Ocean. Its agricultural lands lie mainly in the former, which is 450 miles long by 50 miles broad, and as level as the valleys of the Goulburn and the Murray. Its likeness to Victoria is most marked in its central portion, which includes its richest area. Except in climate and fruit products, the neighbouring western States have many, though not so many, points of likeness to Victoria. In fine, the close resemblance of the peoples, their social and political conditions, and their natural surroundings, renders the parallel between southern Australia and the western States of America as complete as such parallels can well be. It is thither, therefore, that we should naturally look to learn with least difficulty the modes of successful irrigation.

State inaction.

There are, however, not only likenesses but unlikenesses, which present themselves in any contrast of the two countries; and among them one of the chief is the attitude of the State towards every form of enterprise, including the construction and management of railways, telegraphs, and water supply. In Victoria the water

supply of cities and towns is generally in the hands of municipal bodies, who have carried out the works with money lent to them by the Central Government. In western America the water supply is almost invariably provided by private companies. In one instance, that of Los Angeles, Cal., where this rule obtains, a water supply has been undertaken by the municipal body; but it is not employed for domestic purposes, being applied, curiously enough, to irrigation only. The outlay incurred is recouped by sale of the water to the farmers, a great number of whom have their plots within the city boundaries. The local governing body of Salt Lake, Utah, has also undertaken a similar work, though this is maintained out of the ordinary rates, instead of by sales of water. Local governing bodies, however, do not, as a rule, go so far as this even where, as in Los Angeles and Salt Lake, water for irrigation is as essential to the maintenance of towns as is water for drinking purposes. The utmost they do is to permit, as in Carson City, Nevada, a canal 6 feet wide to run along a main road unfenced, or, as in Phœnix, Arizona, to permit ditches 3 feet and 4 feet deep to cross their roads without requiring them to be fenced or bridged. Beyond this, the municipalities do nothing. State Governments never have done anything in the way of undertaking or assisting in the construction of irrigation works. They are not expected to undertake them, and there does not appear any likelihood of their ever having any proprietary connexion with them. The Central Government maintains, if possible, an attidude of even greater indifference. All the irrigation works of western America, with the exceptions above named, have been constructed and maintained wholly and solely by private persons. Not only has the Government spent nothing upon them, but it has known nothing of them. They have been constructed outside the law, extra legally, if not illegally. Even now only two States and one territory have attempted to deal legislatively with any of the problems raised, and it is not claimed that in more than one of these has anything substantial been achieved. In Colorado the State engineer has issued one report, which includes a register of water rights. In California the State engineer has issued one report specially dealing with irrigation, but there is no register of water rights. In no other State or territory is there either report or register. These two reports are of great intrinsic merit, but have a further interest, inasmuch as they are the only official papers published by any State bearing upon irrigation. The authors have done the best that could be done with the means afforded them, but none can be more keenly conscious than they are of the magnitude of the work still undone. Major Powell's work is of the highest value, but consists of only a few pages of a general nature, dealing with the conditions precedent to irrigation.

Difficulties of the inquiry.

Only the fringe of the subject having been touched officially, the visitor who desires to study irrigation finds that the data upon which he must build his conclusions are not to be obtained ready garnered in a State office, but that they are virtually uncollected, and must be sought for in the fields of practical farmers. The officials of the Central Government and of the State Governments exhibit the most considerate courtesy, but can only regret that they have been so hampered by want of means and authority that they have not been able to carry on their work in this direction, so as to place the matter upon a scientific basis. This condition of things is doubtless largely due to the newness of the country, and will tend to disappear as these regions attain to the age, population, and organization of the eastern States. All that could be done to urge the Legislature of California to action has been done by the State engineer, who, with his colleague in Colorado, has managed at last to partially educate public opinion as to the duty of the State in this

relation. But their best endeavours at present can only point to the sources in which knowledge must be looked for. Obliged, as an investigator must be, to have resort at every turn to private persons, it is but right that he should acknowledge the frankness and kindness everywhere extended to the stranger. I cannot recall without surprise how courteously and cordially, even at the sacrifice of time and personal convenience, numbers of engineers, projectors, capitalists and their agents, vignerons, farmers, stock-raisers, orchard-growers, millers, and business people, bestirred themselves to furnish the best information procurable, and assist my inspection of works. Even with all this aid, it has been difficult to secure such precise data ranging over certain periods of time as would allow of definite conclusions being drawn. The paper of questions to be put to irrigators prepared under my direction on the outward voyage (Appendix A) was only partially filled. A shorter and simpler series, circulated by the State engineer of California some time back, proved equally unfruitful, and from the same causes. The farmers of America compare favorably with those of any country in method, quickness, and caution, but they are not given to recording exact quantities of water, nor the special conditions of its use, nor yet the results obtained with the exactness required for professional investigation. Many of them have been their own engineers or have employed engineers who either used no plans or have mislaid them. The many law suits as to the use of water now pending in California naturally render capitalists who have engaged in great irrigation enterprises within its boundaries somewhat chary of giving their private records for publication. Again, partly because of the neglect of the various States to collate facts and figures relating to irrigation, each district has grown up with its own theories, prejudices, and customs, differing often to a noteworthy degree from those of its neighbours.

Differences of various States.

The circumstances of the several States also naturally lead to great differences in their irrigation works. The mountain torrents of Colorado require to be grappled with by large and powerful weirs before they can be raised so as to cover their high rolling uplands, while the shallow rivers of Southern California call for light structures only capable of elevating water a few feet so as to lead it across sandy plains. Farming in the bottom lands of Arizona has led to the use of wing-dams which can direct the flood waters of spring along the ridges, and thence command the flats beneath, and a somewhat similar class serve for the low levels of Kansas, while its bench or mesa lands (the secondary flats or table lands running up to foot-hills) call for larger ditches and stronger works, drawing their supply from the turbid Arkansas. In Utah and New Mexico we touch upon primitive works supplying small plots of land with little driblets of the precious fluid, out of which, with care and economy, thriving settlements are built up. The parent source of this system, and indeed of American irrigation, is Old Mexico, where irrigation, from the simplicity of the Egyptian water-lifter to the masonry weir and solid stone aqueduct of centuries ago, spreads its sway over the whole of the territory classed in its temperate and tropic zones. If it is difficult to arrive at accurate information in the United States, in Mexico it is impossible. There is no trustworthy measurement of water, and but the loosest measure of products; a majority of those who till are too ignorant, and the minority who own the soil too indifferent to record their experience; the State does nothing to assist, and has no bureau to take cognizance of this most important factor of its chief source of wealth. What knowledge exists is in the shape of oral tradition; what works there are, are either of the rudest kind or else all knowledge of their cost is lost in the past. Everywhere in the States or in Mexico private enterprise is supreme, and one learns only from private persons. The general condition is scanty collections of

facts, and often opposite conclusions drawn from them. This diversity of local opinions casts upon the investigator the serious responsibility of deciding between them, and thus renders his task the more arduous. It is by contrast, therefore, of varying bodies of evidence, and by the aid of much expert opinion freely tendered, that the conclusions here put forward with this qualification have been obtained. It has been essential not only to see for oneself, but to travel far and see much in order to discover what was worth seeing.

Mexican irrigation law.

Remembering the immense extent of the arid area, and the magnitude of the irrigation already undertaken in it, one cannot but be surprised at the nature of the legislation under which it has been developed. Still the omissions and mistakes made in the States furnish some valuable material; in Mexico there is little bearing upon the Victorian situation. The Aztecs were expert in the art of irrigation when Cortez landed upon their shores, and the Spaniards who conquered them brought their "Law of Waters" into force in their possessions. Under the Montezumas, water was the property of the commune; under the Spaniards it became the property of the king. In both the public interest was thus permanently recognised. Private acquisition was permitted for domestic purposes, but not for irrigation or industrial uses, except upon an authority derived from the Crown or its delegates as representing the public interest. Property in water, however, can be acquired by uncontested possession for twenty years, and is superior to property on land, since its owner has the right to carry it over any land which may lie between his source of supply and the farm to which he wishes to apply it, on payment of compensation and justification of the route. There are a great variety of enactments relating to water in the several provinces and municipal districts; but as the water available for private use has been almost all appropriated, there is now little ground for litigation as to new diversions. Public rights are jealously guarded; a landowner near the head of a stream may not deprive a landowner lower down of his share. Unless he can obtain an official authority, he can use no water that is not derived from springs upon his own property. The chief measures of water are the Surco, which is equivalent to a flow of 0·23 cubic feet per second; the Naranja, which is one-third of a Surco; and the Paja, which is equal to 0·00053 cubic feet per second. In the city of Mexico and other important municipalities the Paja is the unit of measurement nominally employed. Law suits relating to the use of water are not uncommon; but nevertheless the law, with all its defects, appears to be fairly comprehended and obeyed. In what were Mexican provinces, California, Arizona, and New Mexico, the practice of irrigation was established, though on a very small scale, before its annexation to the United States, and has since developed to a considerable degree on the same lines, the only cardinal principle recognised being that of one appropriator over another in the order of priority of use. The issue of Mexican grants, and the wholesale incorporation of English common law, have combined to confuse the legal position of irrigation so much in the south, that it would demand an undue space to enter into all its phases. Still there are points which have a meaning for us, and these will be briefly alluded to.

Irrigation law in Colorado.

In all matters relating to irrigation the knowledge of what is to be avoided is of equal value with the knowledge of what is worthy of imitation, and this is particularly the case in regard to irrigation law. The enactments which have proved advantageous, and their particular deficiencies, are both worthy of close attention. The Central Government having no jurisdiction in the matter of irrigation, it is dealt with by each State in accordance with its own conditions. As the laws of Colorado are by far

the most successful, they may be fairly allotted the first place. By the constitution of this State, granted as late as 1876, and framed doubtless in this way, because it had the experience of California to act upon, all streams within its boundaries were declared to be public property. By this one declaration a thousand and one sources of contention as to riparian rights were altogether closed. By special enactment, it next provided for the proving and registry of every water claim. These were allowed by the courts in their order of priority, and to the amount of water which had been actually used. When these points had been adjudicated upon, the claims were then published as rights. The consent of the State engineer was required before the issue of any further rights. Under a further provision the national value of irrigation was recognised as in Mexico by the granting of a general power to any person to obtain an easement for his canal over his neighbour's land upon payment of compensation. Twenty-six water districts were defined according to the natural areas of drainage and supply, and a water master for each was appointed, whose duty it is to decide disputes between appropriators, and supervise the general distribution from a particular stream. By these simple means a host of difficulties and complexities were escaped, permanence was given to existing works, and encouragement offered for the construction of new works. It is not surprising, therefore, that, in mileage of canals or acreage irrigated, Colorado more than doubles any other State, or that its works are the greatest and most permanent, and are most rapidly extending. The territory of Utah has shown its appreciation of such results by copying as closely as convenient the legislation of Colorado. Its powerful church government has proved an invaluable administrative, judicial, and organizing agency.

Irrigation law in California.

In California more has been attempted, and much less achieved. In that State there is no constitutional or statutory provision that the waters shall be public property, but the common law of England has been incorporated in the Civil Code of the State "so far as it is not repugnant to or inconsistent with the constitution of the United States, or the constitution or laws of this State" (sec. 4468). As a consequence, the doctrine of the right of a riparian proprietor to receive from the riparian proprietor above, and his obligation to deliver to the riparian proprietor below, the water of the stream upon which his land abuts undiminished in quantity and unimpaired in quality, has been revived, and is now being contested in the Supreme Court of the United States. The case stated is but the precursor of a cloud of litigation. If this doctrine be maintained on the appeal now pending, all diversion of water for irrigation purposes would be rendered illegal—a consummation which could only be regarded as a national disaster. One effort has been made to mitigate the threatened catastrophe, but it is of limited aim and questionable efficacy. To protect those who have already made appropriations, an Act was passed in the recent session of the State Legislature declaring that the use of water for irrigation purposes is a public use, and that its distribution and price may be regulated by the supervisors (shire councillors) of each county. This offers no opportunity whatever for future appropriations, and it is yet somewhat uncertain how far it will operate in favour of the present appropriators, as its interpretation is likely to remain in doubt until tested in the Courts. In the United States, Acts of the Legislature may be reviewed by the Supreme Court, which has the power conferred upon it by the constitution to declare whether an Act of the Legislature is *inter vires* or *ultra vires*. For instance, there is already upon the statute-book of California a very valuable Act for the encouragement of irrigation, providing for the establishment of districts, the raising of funds, and the construction of works. This Act has been declared by the Supreme Court to be

contrary to the constitution of the State, inasmuch as it leaves the establishment of the proposed district in the hands of its residents, instead of providing for its declaration by some representative body recognised by the law; hence it has remained a dead letter. The very valuable "Reclamation Act" passed in the same State has escaped this danger, because it is brought into operation in each district by the local governing board of supervisors. It has been suggested that the "District Irrigation Act" had another vulnerable point, since it provided that the minority of landowners in any proposed district might be compelled to contribute towards the scheme adopted by the majority, in spite of them and against their wishes; but as a recent decision has validated a "Drainage Act," rendering contributions compulsory, even from owners who have not consented to the creation of a drainage district under that Act, it is now considered that no danger need be apprehended on this score. It is probable, therefore, that the former Act will be revived by a future amendment empowering the declaration of irrigation districts by the supervisors, in which case, even though dissenting owners are compelled to contribute, it is anticipated that the Courts will not raise any constitutional objection. Meanwhile, the measure is without force or effect. Even if the "District Irrigation Act" were valid, the riparian owner might still stop the way, or, if he were appeased, the various claimants might be unable to come to a settlement among themselves. Consequently, the irrigation representatives in California have set themselves three things to accomplish: to obtain the abolition of riparian rights; the registration and measurement of all claims to water, with provision for the granting of further rights of diversion; and lastly the constitution of irrigation districts. A Bill to accomplish the last purpose understood to have the approval of the State engineer, Mr. Hall, who is certainly the most competent judge of such questions in the West, as it deals with exactly the same plan which has been accepted by our own Legislature, is given in Appendix B.

Consequences of imperfect legislation.

According to the last message of the Governor of California to its Legislature, "rights to use water under the Civil Code are undefined and unproven claims, the extent and dates of which are known only to their holders or claimants," a state of affairs which necessarily involves all parties interested in doubt and loss. How serious the loss is, owing to this unsatisfactory condition of legislation, may be better judged when it is recollected that almost the whole of the 150,000 people who inhabit southern California are directly or indirectly dependent upon irrigation for their support. The value of the property in irrigation lands and works threatened in this State is publicly stated at £40,000,000. The injurious results of the uncertainty as to the position of appropriators are discovering themselves on every hand. The splendid fruits of irrigation upon desert lands have all sprung from schemes commenced before this issue was raised. From that hour all projects for new works or the enlargement of works in existence have been paralysed. Canals which have a capacity for supplying 40,000 acres, with but little addition, continue to supply only 20,000 acres, as they did when the doubt was first raised. Only under most exceptional circumstances or on the smallest scale are any new projects being carried out in California. Where, as at Ontario or Redlands, extensive expenditure is being incurred, it is because the question of riparian rights cannot be raised. The proprietors of existing canals are, many of them, involved in a web of litigation, the legal expenses on one canal alone, which is not a special subject of contention, having added £4,000 a year to its cost of maintenance. The urgency of the situation has been so far recognised that the chief work of last session was a series of unsuccessful attempts to find a remedy agreeable to both riparian owners and irrigators. A special session

was proposed to compel a settlement, but it was apparently considered that the interested parties were not ripe for a compromise. Neither party desires the final triumph of the riparian principle, even the riparian owners only seeking to gain this in order to obtain more favorable terms for themselves in future legislation. If that principle were adopted, it would mean the abandonment of irrigation. The contention at present really is for the possession of water for purposes of irrigation. The solution sought is how to distribute the water among the landowners upon the banks and those at a distance. The settlement of this difficulty, whatever it may be, must be such as to lead to an extension of irrigation by providing for the utilization of all the waters of the State under conditions that will protect alike the public interest and the private appropriator. The crippled condition of irrigation enterprise still remains an impressive warning as to the necessity for providing against these complications in a new State before vested interests become too deeply involved. In every country in which the practice of irrigation is grafted upon agriculture for the first time, the same difficulties must be met or avoided. The proprietorship of streams, the rights of riparian owners and appropriators, the extent of State control of the distribution of water, and whether special encouragement of the use of water should be given by entrusting the irrigator, under certain conditions, with a right-of-way over private property, are questions which have all to be determined. Outside of the laws already noted, there is no legislation of value to us in Western America. Outside of Colorado and Utah, Government has done nothing even to secure to the appropriator of water the fruit of his labours, or enable him to take a position in the Courts. In fact, legislative interference is only desired by the people of the States to untie the knots which the Legislature has either tied or neglected to untie. The utmost political aspiration of the American irrigator is that the Government will leave him severely alone.

Victoria and Western America.

In comparing the laws of America with our own, it is only necessary to place them side by side, but, in order to judge of the facilities for following American precedents in irrigation work, a general analysis of the physical conditions of each country is essential. The climate, soil, rainfall, and water supply must be first noted; after which the nature of the works, the method of applying water, and the character of the products obtained need to be taken into account. A glance at the means adopted for carrying out the enterprises, and special mention of any significant collateral circumstances will then enable conclusions to be arrived at as precise, perhaps, as such a complex collocation of facts will permit.

Climates compared.

To commence, then, with the climate. The irrigation area in America stretches from the snows of Colorado to the perpetual sunshine of Mexico, and from the shores of the Pacific to the valley of the Mississippi, embracing as great a variety of climate as is to be found in the whole of Australia. Over the whole of this great surface are scattered patches of irrigated land, and nowhere, north or south, east or west, does there appear to be any relinquishment of irrigation on account of climatic conditions. According to American experience, the climate of Warrnambool is not too cold, nor that of Swan Hill too hot, for irrigation. It is needless to add that, compared with the whole extent of this territory, the irrigated area is infinitesimal, and must always remain infinitesimal; but the fact stands that the high plains of Colorado, 5,000 feet above the sea, the bleak prairies of Kansas, the sandy waste of California at the sea level, or the arid valleys of the Mexican plateau, 7,000 feet above it and within the tropical zone, are all susceptible of irrigation. The only want is want of water. Climate limits the Colorado farmer to a short season of 100 days, while in Los Angeles or Leon cultivation is carried on all the year round. Climate

determines the class of products that can be profitably raised, and the temperature, of course, affects the quantity of water necessary to be used; but it is plain, from the extremes of heat and cold met with in the irrigating districts of America, that the climate of Victoria offers no obstacle to irrigation in any part.

Soils compared.

The soils of the western States are, as a rule, of a lighter character than our own, varying from sand of an apparently worthless order to a pale sandy loam found in the river bottoms, and a darker heavier loam of better quality upon the uplands. In Kansas the subsoil is of tough, impervious clay in the bottoms, which in the bench lands, where the soil is heavier, becomes light and porous, with often a stratum of pure sand 4 feet to 6 feet from the surface, much of it over a limestone formation. In the south the soil is friable and hopelessly dry, not simply silicious, but consisting of comminuted granite and eruptive rocks, with an admixture of schists. It frequently is distinctly calcareous and alkaline, of a greyish-yellow colour, with black particles in it; its depth, from 6 feet to 10 feet, together with its extreme penetrability, compensating in some degree for its poverty. Its quality may be best judged, however, from the analysis of Professor E. W. Hilgard, of the Agricultural College of the University of California (Appendix C). Upon this unpromising soil, agriculture, by means of irrigation, is carried on with such great success that it gives excellent crops of grain, lucerne, grapes, and orchard fruit. Upon the uplands a heavier loam, with a greater admixture of clay, is found; it is often of a yellowish or reddish colour, sometimes assumes a blackish hue, and has been found over 60 feet in depth above the gravel. It has high percentages of lime and potash, these substances ranging from 4/10ths per cent. to $1\frac{1}{4}$ per cent. each. The phosphates are higher than in the sandier lowlands, and sometimes as much as 7 per cent. to 12 per cent. of iron can be detected. This class of soil may be more accurately judged from the two analyses annexed (Appendix D), both of which have the same authority as that from Fresno. While these represent the best soils of California, the analysis of Professor Jamieson, of Aberdeen, will give an idea of the best northern soils as found in Colorado and Kansas (Appendix E). The former class represents land upon which splendid orchard yields are obtained, while the latter is that from which, in 1879, by means of irrigation, was produced the greatest yield of wheat per acre of any State in the Union. To compare these accurately with Victorian soils, it would be necessary to quote analyses of the latter, and enter upon a close contrast of the constituents of each, which would be here somewhat superfluous. Suffice it to say that the rich sandy loam of our mallee country offers a close parallel to the best Californian soils, while there are large areas of the Wimmera and the Goulburn valley, where irrigation is most needed, pronounced to be equal in fertility to the best soils of Western America.

Water supply: 1. Rainfall.

The arid area of the United States, by the terms of Major Powell's definition, includes only lands where the rainfall is under 20 inches per annum. Over the great belt in which irrigation has so far had its chief development the record for a series of years gives but little more than half that quantity, so that 10 to 12 inches may be taken as a fair average, though the extremes show a much wider variation. In Northern California, and among the mountains to the east, the rainfall rises to 40 inches, while in the deserts of Southern California it falls to 4 inches. In Western Kansas the fall not infrequently reaches 20 inches, but there, as with us, this is so irregular, that the farmer who relies solely upon a natural supply loses more by the dry seasons than he can make in those which are more propitious. The question as to whether settlement increases the rainfall in the West, as it has increased it in the Mississippi valley, is still undetermined, for, though popular opinion is decidedly

in the affirmative, the State engineer of Colorado points out that official records so far do not support the assertion. The exceptions to this are that Salt Lake, Utah, appears to be steadily gaining in depth, and that dew is now observed at Greeley, in Northern Colorado, a phenomenon quite unknown until irrigation had been practised for some years. Nor does the mere amount of rainfall indicate sufficiently the necessity for an artificial supply of water unless also the seasons in which it falls are taken into account. In parts of Dakota and Minnesota, where the rainfall only averages about 20 inches, dry farming is carried on, while in districts of Texas, where the figures are as high, it would be impossible to obtain the same results without irrigation. The explanation is that in Dakota nearly 75 per cent. of the rain falls in the season when the farmer needs it, as against about 50 per cent. in Texas. Indeed a gradation may be observed in this scale from north to south, since in Kansas some 65 per cent. of the rain falls in the spring and summer, while in the extreme south, as at San Diego, only half of the whole rainfall of 9 inches falls in the spring, and is consequently useless for agriculture. There is some irrigation in Dakota, as also in Iowa and Wyoming, but not nearly so much as in the States to the southward, where, even if the rainfall were as high, its distribution would render it insufficient. A glance at the rainfall statistics of Victoria will show that, roughly speaking, one-half of it might be included in the arid area, or in that portion of the sub-humid area in which irrigation is little less essential. The valleys of the north, and the great plains of the north-west, as well as the belt of level country immediately to the north and west of Port Phillip, and the eastern coast of Gippsland, all feel the need of a regular rainfall. Still, there is little of what would be called in America desert land. The irrigated districts of southern California are hotter and drier than any portion of our colony, resembling indeed, in parts, the climate of Algiers rather than that of southern Europe. There it is always grassless and almost rainless in many seasons, while in the country beyond Swan Hill though the rainfall drops to 10 inches and even less, there are still numerous seasons in which a fair crop of grass can be obtained. In Victoria, the difficulty for the most part is that the supply is sometimes insufficient, often irregular, or distributed so as to leave the crops unsupplied at a particular period. The critical season is generally that in which the crop is ripening, towards the end of spring and beginning of summer. A glance at our rainfall statistics for the last four years gives Horsham an average fall of about 16 inches, and Kerang of about 10 inches, of which at the first rather more, and at the second rather less than 25 per cent. falls in the three months, September, October, and November. If an emergency watering could always be obtained during this period, our northern farmers would be sure of a harvest, while as it is they run the risk of a complete failure every two or three years. So far as rainfall is concerned, then, Victoria appears to be in as good a position as any of the irrigated States except Western Kansas. Enough rain can be calculated upon to materially decrease the quantity of water required to be artificially supplied, and in exceptional years to render irrigation unessential. Though there have been at long intervals years in which this state of things has been reached in South-western America, yet they are so few as to but little affect the average. To make the comparison perfect, the fall in the various seasons in Victoria would need to be tabulated for a number of years. The soil of its several districts would also have to be carefully analysed, for it is to be remembered that one lesson of American experience is that soils which to the "dry farmer" gave but faint promise of any productiveness have proved extremely fertile when exposed to frequent saturation and continuous cultivation. The quantity of water needed is also affected by temperature, for, the

higher it reaches, the more water is demanded. The loss by evaporation has not yet been determined for the several States, but it is stated that in very arid tracts it rises to over 60 inches per annum. As favoured in rainfall as America, Victoria is less favoured than India, Italy, or France, where the precipitation is often twice as great. The fact that irrigation is resorted to under such conditions should be borne in mind when we consider the wisdom of securing an artificial supply in places where the yearly fall is often sufficient.

2. River supply.

So far as streams are concerned, the comparison is more unfavorable to Victoria. That great backbone of the North American continent—the Rocky Mountains—traverses, with its companion, the Sierra Nevada, the whole of the south-west, pouring from its snow fields permanent streams in greater profusion than Victoria possesses. They rush from rocky gorges out into the open country, running often bank high, and thus facilitating the diversion of their waters over the surrounding lands. But the majority of them are small; even rivers like the Arkansas are tapped for irrigation where they are no bigger than the Goulburn, and where the supply is best, as a rule the need of it is least. One peculiarity of theirs, of the utmost value in irrigation, is that they run along the ridges of the plain, while the country slopes away from their banks, and in this many of our own streams resemble them, notably those traversing the great tertiary plain of the Murray basin. In the south the rivers which supply the chief settlements are very shallow, and run in broad, sandy beds, often changing their course. The States have, as we have, streams which are a chain of pools for one-half the year, and often a torrent during the other half, while with them the melting of the snow supplies the water in volumes, as in the Murray, just when it is most required. In Colorado the San Luis and Saguache dissipate themselves in the plains, while in Southern California the Kern, in Utah the Jordan, and in Nevada the Carson, Truckee, and Humboldt, terminate in lakes which have no outlet, thus furnishing parallels to the Wimmera, Richardson, and Dunmunkle of our own colony. One feature of many American streams, especially of those in sandy beds, is that they lose a great quantity of their flow by soakage, which in some cases returns to them by the same means. It has been observed of some rivers in New Mexico, as in Italy of some tributaries of the Po, that the stream tapped by a large irrigating ditch, and robbed of a considerable share of its flood, regains it all again a few miles lower down. It has been found also that old river beds still carry a flow underground, and that some running rivers have but a fraction of their streams above ground. In California sometimes as much as two-thirds of a stream has been found below its bed, and consequently what are called submerged or sub-soil dams have been occasionally employed with great success, as in the Santiago valley and at Downey, Cal., to arrest these escapes and bring the whole body of water to the surface. Works of the kind merit special attention in a country like our own, where, judging from the testimony of most experienced bushmen, a large proportion of the rainfall never finds its way along known rivers or creeks, and must therefore discover for itself hidden channels. At the same time it must be remembered that in the districts of Victoria where such stores are supposed to exist the thickness of the drift-bed is measured by hundreds of feet. Another characteristic of American rivers is that, no matter how clear the water may appear, it almost invariably carries with it a sediment, which is, in the majority of cases, a valuable fertilizer. This is not invariably the case, as may be seen from the analyses of two samples of Californian water, one from an artesian well, the other from a spring (Appendix F). No excess of injurious constituents is suspected in Victorian waters, but, from

the amount of discolouration observable in most of our streams, it may fairly be anticipated that they will prove rich in fertilizing matter, and thus assist in redeeming poorer soils or maintaining richer soils, as some American waters have done. There are rivers, such as the King's River, Cal., which are said to carry no silt and yet to fertilize the land, in which case it is to be presumed that the water acts as a solvent, disintegrating the coarser particles of the soil and preparing the fertilizing elements for absorption in plant growth. Altogether there are many points of likeness between the rivers of Victoria and Western America, though the latter are in California more numerous, better distributed, and more easily tapped. The topography of this latter State has been specially favourable to small schemes, and has induced the farmer, by its opportunities of obtaining water when he most needs it at a minimum of labour and expense, to commence experiments on his own land. With us, higher banks would call for stronger head-works and dependence upon rain for storage reservoirs, while the small fall in our streams would demand longer canals, and those of larger section on account of the small velocity to be obtained. The quantity and quality of water available for irrigation in Victoria has yet to be learned, but it is at least plain that, from the Goulburn, the Loddon, the Ovens, and the Murray, a great extent of country can be irrigated by large schemes in addition to the more numerous spots in which smaller undertakings might be entered upon profitably.

3 Springs and wells.

In the matter of the supply obtained from underground, American experience is, on the whole, encouraging. In the Los Angeles and San Bernardino counties, Cal., there are springs or springy marshes called cienagas which irrigate from 20 to 400 acres each, and together supply an area of 7,000 acres of cultivated land. These springs, which are an important source of supply in Italy, where they are styled fontanili, are some of them so charged with mineral matter as to be unfit for use, and have usually so small a flow as to be employed for orchard irrigation only. At San Gabriel, Cal., a vineyard, 1,200 acres in extent, is supplied solely by springs or artesian wells, of which there are 21 on the estate, ranging from 75 to 100 feet deep. In southern California, altogether there are calculated to be 1,000 of those wells, varying in depth from 200 to 550 feet deep; some of them have a flow of 1·7 cubic foot per second, and suffice for the irrigation of small farms; on one estate there are fifteen, of an average depth of 200 feet, yielding water at the rate of 2·2 cubic feet per second. Artesian water has been, if anything, rather dearer than canal water in California, but has the advantage of being at a higher temperature than snow-fed streams. Many of the wells have a double casing of heavy sheet-iron, which brings up their cost from 10s. to 12s. 6d. per foot sunk. In Santa Clara county, Cal., there is an artesian tract yielding 2,000,000 gallons every 24 hours, but the greatest supply from such sources is at Denver, Colo., where a stream of 2,880,000 gallons per day is derived from 80 wells, which range from 300 feet to 900 feet deep. In sinking these, the "club churn" drills have been found cheaper and quicker than the diamond drill, sinking 45 feet in 12 hours, as against 15 feet with the diamond drill, or 90 feet in 24 hours, as against 35 feet. The cost of drilling averaged about 8s. per foot, while in easy ground the work has been done for less than half this price. The character of the strata passed through will be found in Appendix G, and also a description of the simple machine employed in boring in Appendix H. When artesian water is used the wells are, where possible, put down upon the highest part of the farm from which the water can be most easily distributed; when the water is raised by means of a windmill from an ordinary well, which is usually upon low ground, it is delivered into a light wooden flume, which conveys it into a

reservoir on some commanding spot. In the Leon district of Mexico may be seen small cultivation plots, with perhaps half-a-dozen wells to the acre, in which the water rises to within 4 feet or 5 feet of the surface, and is then dipped out by an Egyptian lifter, consisting of a rude bucket swung on a long pole, with a counterpoise, resting upon an upright, by means of which the water is ladled into little irrigating gutters. In California, and especially at Florin, water is raised from depths of 10 to 20 feet in a steady stream, by means of windmills, one of which, as a rule, can supply 2 to 3 acres of land with water; and as the machinery employed costs only about £25 complete, this is not grudged by fruit growers. Further south the water is raised from more than twice this depth by the same means. In most cases the water is bored for and struck, but does not rise to the surface, the windmill being employed to lift it the extra distance. If water were found without boring at 10 feet deep, irrigation for vines or lucerne would be considered superfluous. The utilization of such small quantities of water as can be obtained by these means attests the value set upon any supply, however minute. Though the streams of the West are considerable in number, they are small and far between in almost every district in which irrigation is necessary. There are most extensive areas without appreciable rainfall, without rivers, and without springs. The irrigable area is narrow and widely distributed, occurring, except in Colorado and Kansas, in comparatively small allotments. A general view of the water supply of Victoria, remembering that many of its sources are yet unexplored, does not forbid the forecast that we may some day be able to compare our irrigable area with the area irrigated in most sections of equal size in the west of America. There may be greater difficulties for us to overcome at the outset, owing to our less extensive field for small individual enterprises; but, on the other hand, we can perhaps acquire the necessary knowledge in this regard from California, so that our larger undertakings may not suffer in consequence. We have not the natural mountain storage of moisture, in the shape of snow, released by the heat of the sun in the season when it is most needed upon the plains, which is the prime source of American supply. We shall be obliged to depend in a greater degree upon artificial storage, and for this also our topographical conditions are not so promising. Our first outlay, therefore, is likely to be larger and our engineering more important. These are circumstances which may impose conditions upon our efforts, but need be no bar to success.

Population and wages.

An epitomized view of the natural conditions of Western America does not lead one to discern in those of Victoria the absence of any factor essential to success in irrigation. A smaller water supply means, of course, a smaller area irrigated; but, setting aside the question of area, upon which there are not data enough to found a comparison, the circumstances of the Pacific States, whether as regards climate, soil, or quality of water supply, do not appear more favorable to irrigation than those of Victoria. It has been feared that our present population is too small to allow of the establishment of schemes of any extent; but the experience of America supplies a practical contradiction. In 1870, when irrigation was making rapid headway in California, that State with twice our area, had but half our population; to-day, with its fifteen hundred miles of main canals, it scarcely exceeds us. We have in Victoria more than twice, the number of inhabitants of Utah and Colorado together, where there are 1,500,000 acres under irrigation. In the States it is found that irrigation attracts population and there is no reason why it should not do so here. Again, it has been argued that the rate of wages paid in Victoria virtually prohibits the construction of irrigation works. Here, again, the experience of the West is invaluable. Chinamen and Mexicans

are paid 4s. a day, but are only employed to a limited extent, and the wages of whites are as high as they are in Victoria; unskilled labour cannot be obtained under from 6s. to 8s. a day, while farm labourers receive £50 to £80 a year, and skilled labourers 10s. to 16s. per day. In remote districts the rates are still higher. Yet even with these wages, irrigation has paid, and is paying. Both apprehensions, therefore, are readily disposed of by a knowledge of the American situation. The social conditions, equally with the natural conditions, are found on examination to put no insurmountable obstacle in the way of the development of irrigation in Victoria.

Irrigation works.

It is next desirable to consider the means by which water is diverted, and the methods of its application, so as to share any knowledge which Americans possess in these directions. To comprehend the nature of their works, it is desirable to bear in mind their history, for they have rarely been the result of one foreseen plan, but have, as a rule, been brought into their present condition piecemeal. It must be remembered that they are not State works, and that, in many cases, they were not constructed by companies or capitalists, but by the farmers themselves, either singly or banded together. On the faith, perhaps, of a good season, the settler had taken up land, and, after his crop was in, had seen himself in danger of losing it, or else in sheer desperation he had settled without expecting a rainfall, and determined to try the Mexican custom of flooding his fields. In either case his necessity has been the same. He must have water, or be ruined. If it did not fall from the clouds, he has asked himself why it should not prove as efficient if obtained from the nearest stream. With this pressure upon him, he has not waited to inquire into his legal rights, or seek for engineering skill, or hold public meetings. He has hitched his team, and, with plough and spade, run a rough ditch to the river bank. By cutting this through, and, if necessary, throwing up a slight wing-dam to turn the water in, he has been able to soak his fields, save his crop, and, probably, get half as much again as an ordinary yield. Stirred by this gain, and by the strong sense of successful self-reliance, he has made his work permanent. A neighbour has joined him in enlarging the ditch, and then shared in its benefits. Others have been encouraged to face the same task. Where several were interested, they have joined their forces, apportioned the work, and each carried out his share, or paid for its being carried out for him. By these means a great number of so-called works have been constructed, and, learning from them, the small capitalist and the large capitalist have followed suit, and have built canals to supply water for use upon their own lands, or upon lands which they wish to let or sell, or upon the lands of others to whom they intend to dispose of the water they have secured.

How constructed.

Defects of works.

These works have been built often without engineers, almost always without plans, and their defects are patent. The weir, headgate, or wing-dam, as the case may be, has been carried away several times, and has probably cost more to replace than a substantial structure might have done. Then the easiest courses for the ditches have been chosen, so that, instead of running on high land, they have even followed old watercourses, and thus have commanded from the canal a much smaller area, and more imperfectly, than they should have done. There have sometimes been no surveys, and, as a consequence, curves have been too sharp and grades too steep, so that the ditches gradually destroy themselves, cutting out their own banks and filling in their beds. Or, perhaps, an opposite fault has been committed, and there has not been current enough to keep down the water weeds, which spring up in the channel and choke it. Then, again, the natural result of individual effort of this kind has been that several canals have been built where only one was necessary. For instance, there are five ditches supplying the Mussel Slough

district, Cal., where one would carry all the water with far less loss in the carriage. There are thirty-two canals taken out of the Kern River, where eight would have been abundant; and at Fresno half-a-dozen where two would have sufficed. What loss this involves may be estimated from a calculation of the State engineer, who, after a careful examination of two of these canals, finds that their combined stream could have been carried in one channel, at a saving of 20 per cent. of the water conveyed. The engineering defects of such works are palpable, and are not disputed or disguised. At the same time it would be a mistake to condemn them out of hand. At least, they have served their purpose for a time; it may be wastefully, but the waste could not have been prevented. Crop after crop has been saved, the farmer has kept his land, has built his house, and cultivated his plot comfortably by their means. If he now possesses the knowledge how to irrigate and how to build ditches, and has the money in his pocket to enable him to use his knowledge, he owes it all to these first rude efforts of his, by which he put the water upon his fields cheaply and without delay. The indolence of the Mexican leads him to be content with works of this kind from generation to generation, and though his practised hand succeeds better in managing water than the ordinary American farm hand, the structures from which he draws his supply are, as a rule, wasteful and without stability. Near the border even the energetic Californian seems to have partially succumbed to the same influence, where we find Riverside, probably the most famous settlement in Southern California, with its 8,000 acres of splendid orchards, taking 2,500 inches of water from the river by means of a rough brush weir and an open ditch, and, owing to losses by the way, only receiving 800 inches of it for actual use. In the same way the town of Los Angeles, the centre of a settled district, with 40,000 inhabitants, handsome buildings, street cars, and the electric light, derives its domestic and irrigating supply from the same class of work and in the same open ditches. But for the most part the tendency throughout the States is to improve existing works. In California the condition of the law has led to a paralysis of enterprise in quarters where law suits are dreaded; but where there is no such fear, and in Colorado, Kansas, and Arizona, the progress is very marked.

Irrigation finance.

Everywhere, however, engineering work is characterized by extreme simplicity and economy; it is rarely massive, and never ornamental. There is no attempt at finish, but only at efficiency. Waterworks in the West are like railways, often made to pay for their own construction. At first, just enough work is done to enable them to yield a return, and then additions are made from time to time, until at last they are brought into a condition of stability. Money is not allowed to lie idle in any investment, but is made to pay towards its own maintenance as early as possible. Interest is high, and is taken into account in even the smallest transaction. This leads to the adoption of another principle, which may be said to be universal. This is running a certain risk whenever it can be shown to be profitable. In places where it is cheaper to build a new weir or wing-dam of brush and sand every year than to pay interest upon the sum required for a permanent structure, the temporary work is invariably resorted to. It is rare also that any work is built strongly enough to endure all contingencies. The practice is to put up a weir that will stand in ordinary seasons, foreseeing that it will be swept away by the first of the heavy floods which occur periodically every few years. There are many ingenious engineering devices for decreasing expenses, but this principle of risk to save interest governs all. American engineers know that these works are not permanent when they build them. As a rule, they have the professional dislike of building temporary

works, and, not having to provide the funds, prefer structures that will prove a lasting credit to them; but shrewd capitalists have tested the principle in practice, and they find it pays to resort in many cases to these slighter works.

Among the illustrations of this combination of risk with very clever engineering there are none better than those to be found at Bakersfield, where Mr. James, as engineer for Messrs. Haggin and Carr, has had a large field for the display of his ability. A detailed description of the most typical of his designs will be found in the Engineer's report. Timber is cheap in America, and California is favored with the redwood, which is soft, easily worked, and yet durable; consequently, it is almost wholly employed by Mr. James upon his 250 miles of canal. His main gates cost from £40 to £60, while his head-gates, controlling a flow of 30 feet or 40 feet of water 3 feet or 4 feet deep, are erected for £600. A wooden weir in the Callaway Canal, costing only £2,600, is 700 feet long, can be put in place in a couple of hours, and is ingeniously arranged so that its superstructure is rapidly removable. Many of the contrivances employed on these ranches are well worthy of imitation wherever shallow streams are to be dealt with in a level country. The combination of weir and bridge in the same wooden structure is another feature of these works well worth the attention of local governing bodies, one of these, 360 feet long, 20 feet wide, raising the water 5 feet, and reckoned to have a life of at least 20 years, being built for less than £2,000. In the streams of Southern California, which are of no great depth as a rule, brushwork is generally used for weirs and dams, sometimes being loaded with sand-boxes or sand-bags, or protected with fascines, loaded down with cobble stones. Thus the San Joaquin and King's River Canal, Cal., has such a wing-dam, 350 feet long; as has the Larimer and Weld Canal, Colo., where the dam is 177 feet long and 5ft. 8in. high. Examples of this class of construction on a great scale, though not for irrigation, may be found in the Yuba and Bear Rivers, where two dams may be seen, one of them 8,900 feet long, and the other 5,875 feet long, ranging from 3 feet to 15 feet in height, and from 60 feet to 120 feet in width. Perhaps the largest irrigation headwork in this style is that of the Eureka Canal in Kansas, which is 1,500 feet long and 8 feet high, supported by a dyke a mile long on the south side of the river, and diverting 5 feet of water through a cut in the banks of the Arkansas, 16 feet deep, into a canal 28 feet broad at the bed and 80 miles in length. The dimensions of these works, together with the stability of such head-gates as that upon the 76 Canal, Fresno, Cal., which is also a bridge 100 feet long and 20 feet wide, and raises the water 5 feet, at a cost of £1,000, and the ingenuity of the head-gate of the Chowchilla Canal, resting upon a quicksand, as described in the Engineer's report, are evidence enough of the ability which is displayed in many works. In Northern California there are both dams and weirs, of great height and excellent simplicity of structure, erected for mining purposes, and now, in a few cases and on a small scale, utilized for irrigation as well as motive power. For the most substantial of all headworks, however, we must look to Colorado. There are some small stone weirs in the south, and some fine pieces of masonry work of great antiquity in Mexico, but none of these are liable to such an enormous strain as is met with in the wild canons of the Rocky Mountains. The South Platte weir, for instance, is 120 feet long from the cliff on the one side to its waste-gate of solid masonry, 24 feet wide, on the other, raising the water 14 feet by means of a framework of 12 x 12 timbers, bolted into the bed-rock, filled with stones, and planked on the face with 6-inch boards. The apron extends 54 feet up stream and 18 feet below the weir, the water having

Head-works.

a perpendicular fall. The waste-gate and offtake are both protected by substantial "booms" or "grids," the latter 72 feet long, built of 12 x 12 timbers. These admit the water through bars below the surface, and protect the work from the trunks of trees, which are carried down with great force when the stream is high. These "booms" are in frequent use in Colorado, and are worthy of note for application upon the many Australian streams in which heavy floods invariably whirl along with them great quantities of timber with a force that would destroy an unprotected structure as speedily as a battering-ram. The weir across the North Poudre endures even fiercer floods, and is more massive in structure, stretching 160 feet across a rugged canon, from wall to wall, in the form of an arch, bending up stream, and composed of strong cribs filled with stones; it raises the water 26 feet into its flumes. The lower face consists of three steps pitched with stones, which are so keyed into each other that the pressure upon them only serves to wedge them more firmly in. As it has stood two or three severe floods without incurring any damage, it may be considered a success, more especially as, though situated in an out-of-the-way district over twenty miles from the nearest station, and a mile up an almost inaccessible gorge, its cost was less than £2,000. It was considered worthy of being made the chief subject of a special paper read before the Institution of Civil Engineers in London. Enough has been said here to indicate the character of the chief classes of headworks, of which there are a great variety in each State. The minor works, such as drops, gates, or regulators, are usually of wood, and of simple design. In the South Platte Canal a much superior gate may be seen, the offtake from the main canal being by means of an earthenware pipe set in stones, beyond which is the usual gate and a measuring weir. Wherever these headworks or minor works are worthy of special note, they will be found professionally described and criticised in the Engineer's report. In the plans which accompany it, as in these pages, only typical illustrations are selected, which, while displaying the peculiar characteristics of American works or practices, are also considered likely to be of service in Victoria.

Other works.

The head-gates, however, include but a small part of the works undertaken in order to secure a supply of water. There is a prevalent idea that in America the streams only require to be touched with a spade to pour themselves upon the farmers' sown lands. That such is not always the case in Colorado may be seen from the fact that the South Platte weir referred to above, built at a cost of £4,000, serves to raise the water to the level of a tunnel 600 feet long, 20 feet wide, and 12 feet high, hewn through the solid rock, at an outlay of £12,000, emptying its tide into a wooden flume 2,640 feet long, 28 feet wide, and 7 feet deep, which cost nearly £20,000, and is supplemented further on by other wooden flumes along the 83 miles for which this artificial river has been excavated across the plains. The North Poudre Canal has about a mile of wooden flumes, and three tunnels, one of them 900 feet long, necessitating an outlay of £10,000 for its first mile, before it touches the open country, through which it flows for 50 miles. Nor is expenditure of this character limited to great canals supplying large areas. The price that can be paid for water may be better understood by noting what the outlay is upon small areas. At Pasadena, where there are but 1,500 acres to supply, the water is carried from the weir by a flume 700 feet long, into an iron pipe three miles long, from 13 inches to 11 inches in diameter, to a reservoir with a capacity of 3,000,000 gallons, partly rockwalled and partly cemented. From this another iron pipe conveys it to the land to be irrigated, while a lower portion is supplied from another source by a pump throwing 30,000 gallons an hour into another 500,000 gallon reservoir, from which it is distributed by a mile and a half more of

iron piping. The total cost of these works is given as £8,000. The Lake Vineyard Company to the east have a concrete ditch 17,000 feet long and a quantity of iron piping simply to water their own vines. The supply to the neighbouring colony of Anaheim is carried in a flume 6,970 feet in length. At Redlands there are six miles of iron piping 1 foot in diameter, carrying 5 cubic feet of water per second from the weir to the 2,400 acres which it is intended to irrigate, upon which there are stand-pipes and iron measuring weirs to every allotment. At Ontario, with its 8,000 acres, the arrangements are equally perfect, a large portion of its supply being obtained by a tunnel nearly 3,000 feet long, upon which £10,000 has been spent. An illustration of another class of waterworks on a great scale may be seen among the mountains of Nevada, where there are wooden flumes from 50 to 80 miles in length, down which sawn timber is floated from the forests among the hills. The distance which great streams of water have to be carried before they can be utilized may be judged from a few illustrations. The Dodge City Canal, Kan., is 90 miles long and 50 feet wide; the San Joaquin and King's River Canal, Cal., 78 miles long and 68 feet wide; the South Platte, Colo., is to stretch 160 miles when completed; while the Great Eastern, Kan.; the 76 Canal, Fresno, Cal.; the Larimer and Weld, Colo.; the Arizona Canal, Ariz.; all range from 40 to 60 miles in length, with a breadth of over 30 feet. In considering the length of these canals, it should be remembered that some of them have been carried much farther than the natural circumstances required, passing irrigable lands in their course just as rich as those they reach beyond, but which are unsupplied because they do not belong to the proprietor of the ditch. The area of irrigable land under canals of these dimensions amounts often to from 50,000 acres to 250,000 acres each, but from none as yet is more than the smaller quantity under cultivation. In Utah, settlements have been abandoned because they were located too far from the streams supplying them. The higher up stream an offtake of a canal is, and the shorter the distance water is carried to land, the less the loss by soakage. The more favorably situated flats, however, usually lie farther down stream, and as these are always the first to be irrigated, it becomes necessary for the later settler to take up higher ground, to water which he must go farther up the river. There is thus a tendency for the canals to become longer as the country is taken up. It is unnecessary to describe their construction, for they are merely ditches, of sizes and grades varying according to the soil in which they are cut and the water they have to carry, which is from 1 cubic foot to 2,000 cubic feet per second. The average cost of a 30ft. canal is reckoned in ordinary country at from £200 to £300 per mile by Colorado engineers. The average grades chosen are from 1 to 3 feet per mile; the banks, in most places, being on the slope of 4 or 5 to 1. The breadth is adjusted so as to equalize the discharge, being greatest where the grade is least. Whatever difficulty may be met with in irrigation engineering in Victoria will probably be chiefly in connexion with the head-works which it may be necessary to erect to make the water available; the excavation of canals is simple. The amount of money which private persons have invested in these works shows that the prospects of profit are tempting. The San Joaquin Canal represents in direct and indirect outlay £260,000; the Dodge City, £160,000; the South Platte, £150,000; the Arizona, £100,000; the North Poudre, £50,000; and the City Ditch, at Salt Lake, £45,000. Several of these are built by companies, which have other canals of considerable size and land purchases made in connexion with them in which even larger sums are sunk. Two companies in Colorado control between them nearly 500 miles of main canals, which, together with the land they were constructed to water, represent an outlay of more than half a million sterling. As far as can be judged, there are no

apprehensions entertained as to the future of such investments; their proprietors appear satisfied with their returns up to the present time, and not unwilling to enter upon extensions of their existing enterprises. Still, the figures even now should make it plain that irrigation in America is not the simple matter it has been supposed, but one that taxes the capital and enterprise of even a speculative people.

Reservoirs.

Next to headworks, the most important feature in which Victorians are interested, in consequence of our deficient water supply, is the provision of storage by means of which the surplus of winter rains or spring floods may be retained for use in time of need. The surveys made in California and Colorado so far have discovered many natural depressions of no great extent, but still valuable in connexion with irrigation schemes. In Los Angeles county are to be found a number of reservoirs already built, some of them cemented; others, such as those of the Lake Vineyard Association, composed of the natural soil. Most of these are small, the largest containing 21,000,000 gals. The cost of excavation here was from 7s. 6d. to 12s. 6d. per thousand cubic feet of storage. In Mexico, reservoirs are employed to a limited extent. Near Santa Maria is one which has a capacity of nearly 100,000,000 gals. behind a piece of masonry of the same class as the weir in the neighbourhood of the Taja of Nochistongo. In New Mexico, by means of a series of earthen dams, one farmer has created seven reservoirs, from which he can command, with a reserve supply, some 2,000 acres of his estate. In Colorado the mountainous character of the country has been favorable to the construction of similar works, the State engineer recording a number of them as 6 feet to 35 feet deep, and 10 acres to 500 acres in extent. The largest is that in connexion with the Big Thompson Canal, which covers 427·35 acres to a depth of 35·8 feet, of which 21·8 feet is available, and is expected to water 12,000 acres. A chain of such reservoirs is being added to the North Poudre works previously referred to. But by far the greatest of these reservoirs is situated in the Bear Valley, above Riverside and Redlands, Cala., where, by means of a wall of masonry 300 feet long and 60 feet high, 8,000,000,000 gals., or more than the contents of the Yan Yean when full, are preserved, owing to exceptional natural advantages, at a cost of £12,000. This will give a continuons stream of 150 cubic feet per second for 100 days, which, on the scale of supply adopted at Redlands, should water at least 50,000 acres. A still larger reservoir is projected in South-eastern Colorado where water sufficient to supply 100,000 acres is to be stored, in connexion with a canal 80 feet wide, 7 feet deep, and capable, with the reservoir, of irrigating twice that area. If it will pay to construct such storage works in California, one must seek for a reason why it should not pay in Victoria. The Waranga basin is known to present a holding ground for more than 3,600,000,000 cubic feet of water, which could be made available by the construction of an earthen embankment across its lower end. This has been estimated as likely to cost five times as much as the Bear Valley reservoir; but, on the other hand, it would contain twice and a half times the water. Probably in the future other favorable sites will be discovered; and, if we are guided by American experience, they will certainly be made use of to supplement canals wherever possible. In the ideal irrigation scheme every farmer would have his own reservoir, into which his water would be delivered at stated periods, to be used by him as he thought best. This would provide not only for accurate measurement, but for the greatest economy in the use of water. It is, however, too costly a scheme to be regarded as within the bounds of experiment in America, and would be impracticable in flat country such as our northern plains.

American engineering.

The engineering features of irrigation in the States need not detain us further at this stage. The specialties are the economy, simplicity, and, where necessary, the durability of their structures. In selecting the best means for attaining these qualities, the engineers act according to instructions. In America, a private capitalist takes the advice of his professional man, but only acts upon it according to his own judgment, or to the extent of his interest. The engineer has no hearing as to whether the soil is suitable, whether the crops will pay, or whether the financial prospect is promising. His business is to plan the necessary works in the most economical manner, and carry them out within the estimate. Should the plan be too dear, or the work fail to stand the strain prepared for, he runs the risk of losing his position, or more often a part of his business, since the practice of professional men is chiefly as consulting engineers. The exception to this rule is where the engineer would not be qualified to claim such a title in Australia. He is then simply a manager or foreman of a ranche, who has acquired sufficient knowledge of practical work to be able to construct head-works and excavate canals, and does what is necessary to secure a water supply as part of the ordinary operations of farming. There are many of these in the West, besides a number who, having some acquaintance with the theoretical principles of surveying and dam or ditch building, practise as engineers as well as land agents or colony managers. The class of professional men trained as engineers, and acting only as engineers, is small. But whatever be the standing of the engineer, it is always under the pressure of the private employer that the economical structures in use in the States have been built. The capitalist has taken care that they should be cheap, and the engineer has taken care that they are effective; a mutual check having been exercised, which it is probably not possible to obtain except in private enterprises.

Implements.

The cost of labour and material for works in the irrigating States is generally the same as in Victoria; where, for instance, as in timber there is a cheaper and easier material, it is less strong and less durable than our harder and heavier woods, and so the account balances itself. The only marked saving is effected by the use of implements specially adapted to the kind of work to be done in connexion with irrigation. The implements themselves are various, and a considerable portion of the saving is made in the knowledge when to use one and when to replace it by another. To begin with the simplest kind of construction, that of field ditching; the farmer does this, as a rule, with his plough, with which he can easily run a ditch of a few inches capacity across his field. If he intends to widen it while keeping it shallow, he employs the ditch plough, which consists of a blade suspended behind the share so as to push the earth which it cuts to one side. In many soils this is found to be an invaluable implement. When the work is more roughly done, what is known as a V scraper is brought into play. This varies from a mere log of wood with a couple of old spade heads nailed in front, forming a sharp prow, which is its rudest form, to a triangle some 6 feet wide at its wooden base, from which proceeds two long iron blades forming the acute angle. Its use is always the same. It is drawn by horses, and steadied by the driver's weight, so as to push the earth outwards from a simple plough furrow or series of furrows, and thus form a ditch. When this is over 6 feet in width, a "side wiper" is generally substituted, which is a long iron blade, lowered from a frame which rests upon four wheels, so that when drawn by a powerful team it slants the ploughed soil to one side. In light soils and for large ditches, an elaborate machine is used, which not only ploughs the earth, but takes it up and shoots it out upon the banks a distance of 10 or 12 feet to either side, at the rate of from 600 to 1,000 cubic

yards per day. But the implement most in use for operations of any extent is the iron "scraper," well known in Victoria as the "scoop," which is found in many forms, sometimes run sledgewise, sometimes upon wheels, and ingeniously fitted so as to be tilted without effort. For a long pull, wheels are considered best, and for steep banks runners have the preference, but scoops are preferred without either for sandy soil. The kind of soil to be moved and worked upon, and the length of haul, are always taken into account in determining the class of scoop used. In constructing a deep canal, a haul of 1 foot upward is reckoned the equivalent of 50 feet on the level, and with an experienced driver, and a team of two horses or mules, a scoop is expected to remove from 80 to 120 yards per day. Sometimes in railway work one man is told off to every four teams to fill the scoops, but in the majority of cases the driver does this himself. There is another implement known as the Buckscraper, which for ordinary farming use in light soils, and in practised hands, accomplishes remarkable results. It consists of a strong piece of 2-inch timber, from 6 feet to 9 feet long and 1 foot 3 inches high, with a 6-inch steel plate along its face projecting 2 inches below its lower edge, and is strengthened with cross pieces at the back, where there is a projecting arm, upon which the driver stands. Like the ordinary scraper, it is also found on wheels and runners, and in many patterns, and is drawn by a pair of horses. Instead of taking up the earth as the scoop does, it pushes the soil before it, and, when under good command, does such work as check making, ditch excavating, or field levelling, in sandy soils, with marvellous rapidity. Work with the scoop costs, as a rule, from fourpence to sixpence per cubic yard; when the cost reaches ninepence, it is considered time to set it aside. With the Buckscraper, work has been done in favorable localities as low as twopence and even a penny per cubic yard; and it is astonishing to note the number of uses to which this simple implement is successfully applied. Where the levelling of fields is difficult, a machine is sometimes used which cuts off the tops of mounds or ridges, and drops the stuff in the first hollow over which it passes. The windmills for raising water from wells have been already alluded to, as have the boring machines at Denver. Where the water is to be raised from a running stream, a wheel is employed turned by the current, raising little buckets full and pouring them into a wooden flume from 12 feet to 20 feet high. Many little contrivances, such as a movable iron gate or "Tapon" for diverting water at any point from field ditches, and shaped like a railway disc, are to be met with; and such of these as merit special notice, together with the implements above alluded to, and the larger machinery employed for boring or raising water, will be dealt with in the Engineer's report. Where the machinery or implements are already described and illustrated in business circulars, these will be open to the inspection of those interested at the office of the Secretary for Water Supply. The drills used in the oil-well regions appear to deserve careful examination, as they are guaranteed to penetrate to great depths at a very low cost. The chief expense is generally in the engine power, which absorbs seven-eighths of the £1,600 for which a drill capable of boring 3,000 feet can be obtained in Pennsylvania. The fact that there have been no opportunities for the employment of these and similar machines, no doubt accounts for the fact that hitherto they have not been supplied in the colony. As the demand occurs, it will certainly be met; and our experience with agricultural machinery encourages us to hope that local manufacturers will not only be ready to adopt improved contrivances from abroad, but that they will again prove themselves capable of adapting them to the particular circumstances of the colony. The necessity which has arisen of making

deep borings for water in many parts of the States, including New York city, and the development of the great oil resources of the east, have naturally led to the manufacture of powerful boring and lifting plants, which are well worthy of a closer scrutiny from colonial engineers, farmers, and stock-owners than the time at my disposal enabled me to give them. The total supply of the cities of Chicago (Illinois), Buffalo (New York), and Cleveland (Ohio), are raised by steam pumps, in the first city by two engines capable of lifting 75,000,000 gallons, and in the others by three and four engines respectively, in each case having a capacity of over 40,000,000 gallons per twenty-four hours.

Pipes.

In this connexion it may be well to notice the variety of pipes employed for water supply, and likely to be more employed as water becomes scarcer and fruit-raising increases. The waste in the open ditches commonly in use, as at Riverside, has already been incidentally referred to, yet, as in the growing of cereals and similar crops, no other system of conveying the water could pay, this system will probably have to be adopted in Victoria until the higher culture is pursued. Where suitable material is at hand, it is not uncommon to find ditches, as at Lugonia, Cal., roughly paved for six or seven miles, thus saving one-third of the water previously lost in this distance. Again, the South Fork ditch, from the Santa Ana, is made in a similar way, by neatly fitting cobble-stones together, and with an equally satisfactory result. Near Pasadena, as already mentioned, there is a concrete ditch more than five miles in length. This mode of ditching, however, is not always possible, and where such an outlay can be faced it is generally advisable to use pipes. The greater profits realized from fruit-growing encourage such an expenditure, by means of which a very small stream can be made to cover a comparatively large area. Pipes can either be employed to bring water to land upon which it is to be used, or they can also be carried on so as to distribute the supply throughout the cultivated area. This latter process, known as sub-irrigation, will be described at a later stage. When it is practised, a simple machine is generally used, by means of which a cement pipe is made in the ground and in position, thus saving the risk of transportation, and some cost of labour. The scale on which this has been attempted is not as yet sufficient to demonstrate its universal efficiency. For main channels a concrete pipe, cheaper than earthenware piping, is largely in use in the "colonies" of Southern California, as at Ontario and Pasadena, where it has proved durable and serviceable under low pressure. In the San Demas Canon there are three miles of this pipe, 5 inches in interior diameter, carried along the face of a cliff. Its most formidable rivals have been a riveted and asphalted pipe and a light laminated pipe, both of wrought iron, the latter made by telescoping one sheet-iron pipe into another, when submerged in asphalt and tar, and thus filling up the small space between them with the mixture. As a 4-inch pipe of this pattern is supplied for practically the same price as that in cement, and has proved itself capable of withstanding great pressure, the preference, on the whole, appears to be given to the iron. Where it is found, as in Utah, that a ditch, 3 feet deep, which is 20 feet wide for the first 23 miles of its course, can in the next two miles carry all that is left of its stream in a width of 12 feet, it becomes plain that, where water is valuable, there is a fair margin to pay for piping. For city works and deep hydraulic mining, a wrought-iron pipe is in use in the West, where, partly owing to the lesser cost of carriage, it has proved considerably cheaper than if the customary cast-iron had been adopted. Riveted together, boiler fashion, by means of machinery, the lengths of pipe are easily and rapidly laid, are jointed by rivets in the ditch, and, if necessary, a band of iron placed round the joint. But,

even without this, no break has ever occurred in San Francisco, where the whole supply has been carried for years in this piping. It is used up to 44 inches diameter, stands a pressure as great as that from the Yan Yean reservoir, and can be supplied at a much less cost, though being too thin for tapping it is not suitable for reticulation porposes. In the Engineer's report will be found full particulars with reference to these and other inventions, so as to admit of their manufacture in the colony should they prove suitable to our needs. It would be advisable, perhaps, to submit the wrought-iron pipe to experimental testing in view of the large extension of mains already contemplated for our metropolitan system. If it could have been adopted in the recently accepted contract for the 30-inch and 18-inch cast-iron mains, a saving of £10,000 could have been made to the Treasury. The one question concerning the pipes is as to their durability, and on this head we have testimony that they are in as good condition to-day as when laid fifteen years ago. There does not appear to be any other reason for questioning their success in California, or doubting that similar results will be obtained here; and if this should be the case, the reduction in the cost of large pipes for extending town supplies throughout the colony will be both great and permanent. They may also become of use in mining, as in the West, where they were first introduced in connexion with deep sinking by means of hydraulic machinery.

American enterprise.

In closing this curt reference to matters requiring professional criticism, it may be added that in the construction of all American works there is one factor which must be taken into account in every calculation. It is not only the design of an ingenious implement, or a clever piece of engineering, but the uses to which they are put and the rapidity with which they are improved and adapted to new conditions that commands one's admiration. The most potent factor in the achievement of American successes is the untiring energy and self-reliance of the people, many of whom, unfettered by tradition, independent of professional men, and original in idea, have conquered difficulty after difficulty, and added device to device in a way which it would be almost impossible to equal under any stereotyped system or by means of any one organization, no matter how well qualified its agents or inexhaustible its purse.

Method of irrigation.

Just this same spirit of self-confidence and readiness of resource are carried into the methods adopted to utilize the water after it has been brought to the farm. There is nothing complicated about the process, though there is a good deal of judgment and practical knowledge brought into play at every turn. In this part of the work the patient Mexican often surpasses the impatient American, who is too anxious to rush the water over his land. There is a certain skill in the management of the fluid agent which is only acquired by experience, though the main duties of an irrigationist are simple in the extreme. Equally simple is the system by which the water is conveyed to him. From the main canal, fed by its head-work on the river, runs the secondary channel, which traverses a particular slope. Both of these are the property of the water owners. From the latter the farmer makes his own chief channel, or "lateral," which leads his supply to the highest point or points of his land. From this, again, his "sub-laterals" or field ditches intersect his farm, according to its situation.

The earliest, easiest, simplest, and cheapest method of irrigation is by flooding. The water is then directed so as to cover the whole area under cultivation to a depth varying according to the crop and the quality of the soil. This plan is the most

wasteful of water, but cannot be avoided in the cultivation of cereals. The only work it involves in the field is that necessary to permit an even flow of the water. With a regular slope, this work is sometimes trifling, but, as a rule, some preliminary outlay is required for levelling inequalities or else providing for the equal distribution of the stream from points of vantage. When the fall is slight, shallow ditches are run in Colorado from 50 feet to 100 feet apart in the direction of the fall; when the land is steeper, they are carried diagonally to the slope, or are made to wind around it, and from these, by throwing up little dams from point to point, the whole field is inexpensively flooded. When the fall is still greater, and the surface irregular, ridges are thrown up along the contour lines of the land, marking it off into plots, called "checks," on the whole of the interior of which water will readily and rapidly reach an equal depth. When one plot is covered, the check is broken, and the water admitted so as in the same way to cover the next plot. The ridges or "levees" must have rounded crests and easy slopes, or else they interfere with the use of farming machinery such as the stripper. By means of diagonal furrows and checks, remarkable results are obtained, even in very broken country. By their means it is claimed that in Colorado one man can irrigate 25 acres per day. Where checks have not been used upon ground with an acute incline, the water has soon worn deep channels through it, utterly ruining it for agricultural purposes; or again, where the water has been allowed to flow too freely, the consequence has been that all the fertilizing elements of the soil have been washed away. In flooding, the aim is therefore to put no more water upon the land than it will at once and equally absorb or can part with without creating a current sufficient to carry off sediment. The neglect of these precautions has caused the abandonment of several settlements made in Utah before the art of irrigation was properly understood. In Southern California checks are employed even more successfully than in Colorado, the levees being built by buckscrapers so as to prepare large areas for crop at 2d. per cubic yard of material moved, or 6s. per acre. The lands there are not so rolling as in the northern uplands, where the average cost of preparing land for irrigation is from 8s. to 16s. per acre. As much higher estimates have been given in Victoria, it should be noted that the higher price is for country more difficult than the average of our northern plains. It would be possible, by grading and terracing, to water very steep slopes, but the labour would not be paid for by any cereals that could be raised. Both the depth and number of floodings are varied according to soil and crop. With a clay soil the waterings are light and frequent, while with a sandier quality they are heavier and rarer. Much, too, depends upon the distance and nature of the subsoil. There is considerable uncertainty with regard to the measurements given for flooding. It is sometimes placed as low as will give a depth of 2 or 3 inches, and at other times as high as from 5 inches to 10 inches at a single watering. There are cases in which as many feet have been used. The number of waterings is best determined by the crop itself, and the most skilful irrigators are those who study its needs and take care to supply them without giving an excess of water. The quantity used alters, therefore, from season to season, so that only an average can be given. In Colorado, where water is used more lavishly than in any other State, some good judges have agreed that an average of 14 inches should be ample, and this is certainly not too low. Where the soil is liable to become hard, and will retain moisture, wheat is often grown with two floodings, one before the ground is ploughed, and the other when it is approaching the ear. When two waterings are given after sowing, one is when the wheat commences to "tiller," and the other when it reaches the milky stage. Where irrigation does not precede the ploughing, it is postponed as long after the appearance

of the crop as possible. Sometimes wheat has three, or even as many as four floodings; but this is unusual, as over-watering occasions "rust." Experience shows that it is easy to exceed the quantity required by the crop, and that every excess is injurious. Extravagance is the common fault, so much so that the most successful irrigators are invariably those who use the least water. The less water, indeed, with which grain can be brought to maturity, the finer the yield.

Peas and potatoes are not irrigated by flooding, but from furrows 4 feet to 10 feet apart, and this is found the more economical and more successful system for vines and fruit trees. Under the flooding system, the ground, if not protected from the sun, cakes quickly. When the water is run down furrows drawn by a plough between the plants, this caking is avoided, and the water soaks quietly to the roots. When flooding was practised in orchards, it was found to bring the roots to the surface and enfeeble the trees, so that they needed frequent waterings. Sometimes the furrows feed a small hole at the foot of the tree, from which the water soaks slowly in. When this is done, mulching is found desirable over the hole to reduce the loss by evaporation. The general rule is to protect the trees by small ridges, so that the water does not affect the surface within three or four feet of them. The simple furrow, however, is most generally in use. Oranges are watered three or at most four times in summer; vines once, twice, or often not at all after the first year or two; and other fruits according to the caprice of the owner, the necessities of the season, and the nature of the soil once to four times. It is impossible to be more exact. An even greater difference, comparatively, in the quantity of water used obtains in the furrow irrigation of fruit trees and vines than has been noted in regard to cereals. To such an extent does this prevail, that not only do districts differ, but, of two neighbours who cultivate the same fruits in contiguous orchards, having exactly the same slope and soil, one will use twice or thrice as much water as the other. Judging as far as possible from conflicting testimonies, the cardinal principle appears to be just the same. To attain the best results the trees must be carefully watched, and supplied with only just enough water to keep them in a vigorously healthy condition. Another all important principle, as to which there is no question, and which is testified to on every hand, is, that the more thoroughly the soil is cultivated, the less water it demands—a truth based partly, no doubt, upon the fact that the evaporation from hard unbroken soil is more rapid than from tilled ground, which retains the more thoroughly distributed moisture for a longer period. For the irrigation of cereals, works are required on a larger scale proportionately than for fruit, because in the first case the water is demanded in greater quantities at particular times, while in the latter the supply can be more evenly distributed throughout the year, though of course the irrigating season with both is much the same. In the northern States irrigation is limited to a hundred days, while in the South it can be employed at discretion all the year round. In both regions winter and autumn irrigations are growing steadily in favour. Land which receives its soaking then needs less in summer, and is found in better condition for ploughing. It is argued that moisture is more naturally absorbed in that season and with greater benefit. Everywhere the verdict of the experienced is that too much water is being used, and the outcry against over-saturation in summer is but one of its forms.

Irrigation from furrows.

Irrigation beneath the surface, if not excessive, is considered the most perfect method of supplying water to vegetable life, and it has been the aim of many to devise a scheme by which this can be done with the greatest economy. The idea is to replace

Sub-irrigation.

soakage from above, by either flooding or furrows, with what is called "seepage," that is, subterranean and lateral soakage which, to be perfect, should not wet the surface. The method adopted is described in the "Report of State Engineer of California, 1880," as follows:—"Pipes made of a combination of Portland cement, lime, sand, and gravel, with a small admixture of potash and linseed oil, the composition weighing 144 lbs. per cubic foot when dry, are laid at a depth of one and one-half foot to two feet below the surface, parallel to the rows of trees or vines in an orchard or vineyard. In these pipes, on the upper side, is inserted a wooden plug opposite each tree or vine, the plugs having tapering holes in the centre, one-fourth to three-eighths of an inch in diameter, through which the water finds exit. Each plug is surrounded by a larger stand-pipe, setting loosely on top of the distributing pipe, open at the bottom, and reaching to the surface of the ground, for the purpose of keeping the dirt away from the outlet and rendering it accessible at all times for inspection. The pipes are connected with mains leading from a reservoir. The process of irrigation is unattended by any labour beyond that of turning on the water and shutting it off. The water finds its way through all the outlets, filling the stand-pipes, and slowly percolating to the roots of the plant. No water appears on the surface, consequently the ground does not bake with the heat of the sun, but is kept mellow and moist, and no moisture is lost by evaporation. In the orchard of the inventor, where the system was first tried, three acres of young trees were thoroughly irrigated in half-an-hour with about 400 cubic feet of water, or less than 3,000 gallons. Such an application twice a month is sufficient to maintain a vigorous growth in the trees, which have attained twice the size of adjacent trees of the same age, on the same soil, with the same amount of cultivation, irrigated by the usual method of surface application. Could the same proportion in the use of water be carried out through the season, as that of the experiment mentioned, a cubic foot per second would irrigate 9,000 acres. The cost of the system for an orange orchard is but £6 to £10 per acre. The pipes are laid in the position they are to occupy by a simple machine, with which three men may lay 1,600 feet per day. They are, therefore, continuous and without joints." This appears to have been an unusual result, as the practice has not become general. It has been tried in England and elsewhere, but there is still room for careful experiment. The one advantage possessed by surface over sub-irrigation is that, when carefully managed, irrigation by soakage is a perennial source of fertilization, on account of the quantity of deposit which is obtained with the water from most streams in certain seasons. Irrigation by seepage cannot produce this beneficial effect, but it can avoid the dangers of excessive saturation or surface caking, or of washing out the richer elements of the soil, as well as accomplish an enormous saving in the water used. Two difficulties have presented themselves to its complete success. The first of these is the tendency of the apertures in the pipes to become choked by the roots, which tend to form a mat about it. This has been met, it is hoped, by an ingenious contrivance of Mr. L. M. Holt, of Riverside, which will be described in the Engineer's report; the main difficulty, however, so far rather feared than experienced, is that the constant seepage of water would have such a solidifying effect upon the soil, closing its pores, and converting it into an almost impenetrable mass, that it would become necessary after some years to break it up to a considerable depth by cultivation. Of this it is too early to pronounce, but it certainly appears that sub-irrigation is the hope of most intelligent irrigators, because it promises a great economy of water, and the most direct application of it to the thirsty tree that it is possible to devise. The average cost of making and laying pipes for sub-irrigation is given by an authority at £7 per acre, a sum which the owners of land under intense culture could afford to pay, particularly if there are any cases in

which, as Professor Hilgard suggests, the same pipes could, when not used for supply be used for draining surplus water away. The employment of these so-called "asbestine" pipes, which are more properly named hydraulic cement pipes, would certainly effect an enormous saving of water, and this in many districts would more than cover the cost of laying them.

Waste of water.

The present practice is the most wasteful that could be devised. There is waste along all the miles of open canals, both main and secondary, with a consequent loss to the owners of from 25 per cent. to 50 per cent. of the stream they take in. Sometimes it is even greater, a canal in the San Joaquin valley, which took in 90 cubic feet per second at its head, only delivering 14 cubic feet per second on the farms 28 miles away. Where the canal owner's loss ends, that of the farmer begins. He loses all along his laterals tapping the secondary canal, all along his sub-laterals intersecting his farm, and, again, all that is not absorbed by the crop over which he pours his periodic flood; besides which has to be added the loss from evaporation. As a matter of fact, therefore, he only receives the benefit of a very small proportion of what he pays for. Some put the loss of farmer and canal proprietor together as high as 9-10ths of the water diverted, others at 3-4ths, and it is rarely calculated at less than the latter figure. There is certainly ample room for saving at every turn. In Utah, as in Italy, another economy is effected by requiring those entitled to water to take it at night as well as by day, so that, instead of the supply running to waste for eight to ten hours out of the twenty-four, the whole capacity of the ditch is utilized every minute during the irrigating season. This custom has the further advantage, that the water is thought to act more favorably upon the soil by night than if it were under the burning rays of the sun. The manual labour or skill required for controlling water is not great, and it calls for patience and attention rather than activity. In Southern California, Mexicans and Chinamen prove specially fitted for work of this kind, which involves no tax upon their energies. To see the irrigator, spade in hand, engaged, in a leisurely way, directing the stream gushing from his ditch, it would scarcely be suspected that upon so unimpressive a proceeding the whole future of the orchard in which he is engaged entirely depended. There seems an incompatibility between causes and effects which asserts itself in many ways, so that it becomes an effort to realize that the rude ditches which wind their rugged banks across trim fields, or among regular rows of vines or orange-trees, are actually the generous source from which all the profusion of foliage and fruit is being invisibly fed.

Irrigation as fertilization.

Part of this incompatibility no doubt arises from the fact that there is something more than water conveyed in canals, and that this something more is extremely valuable, though usually left out of the calculation. Water of itself can work wonders, but when allied with sediment, which, in nine cases out of ten, appears to consist either of decayed vegetable matter or to contain elements that replenish the soils by which it is absorbed, the results become multiplied. Reference has been made to the fact that all American streams appear to leave some deposit of a fertilizing character, and that, judging from appearances, Victorian rivers and creeks should be at least equally well laden. In France the practice of pouring large bodies of water heavily charged with sediment upon inferior lands for the purpose of reclaiming and enriching them is extensively adopted. This is not systematically attempted to the same extent in America, though the sandy sage brush lands of Utah and Nevada have been turned into rich meadows in the same way; but it is generally recognised that where irrigation is so controlled as to admit of just as much water being placed upon the land as

it can drink at a draught, without allowing it either to stand or run away, then the consequence is invariably a maintained or an increased production. Not only is the crop secured, but whether it be grain, root crop, or fruit, the yield is often largely enhanced so as to reach, in arid regions or upon poor soils, a yield equal to that obtained upon fertile lands enjoying a plentiful rainfall. Farmers' estimates of what this gain actually is differ considerably, ranging from 30 to 100 per cent. That there is a gain, and a great gain in many instances, no one thinks of disputing, though there may be some looseness in the figures quoted concerning it. There seem to be no products of which the crop may not be increased by irrigation, and there are none that will not suffer from over-irrigation. The richest silty water, instead of having a fertilizing influence, will be fatal if allowed either to stagnate, or to rush too rapidly through a field. But with this danger provided against, irrigation may mean fertilization to such an extent as to render any further artificial enrichment of the soil unnecessary. In most parts of the West this has been the only fertilization which has maintained land under years of cropping.

Drainage.

One of the objections raised in Victoria to the prosecution of systematic irrigation has been the difficulty and expensiveness of the drainage works which would be required. As the entire absence in the foregoing remarks upon the engineering aspect of American irrigation of any reference to drainage works has already indicated, the matter has not presented itself in that light in the experience which is here cited. As a matter of fact there are no drainage works worthy of the name in America, the farmer having quietly left the water to settle this problem for itself. Water is always valuable in these regions, and what one farmer allows to flow by another is only too eager to acquire. Canal proprietors have not found any necessity to spend money in making provision for the surplus water which passes their area of supply, as it is generally extremely easy to let it find its way into the natural watercourses which run at lower levels than the artificial stream. How to get water is the one question of importance ; how to get rid of it has been found in nineteen cases out of twenty only too easy. With a deep subsoil or a good fall, it seems as if drainage may always be unnecessary, and these are conditions very frequently met with. There are, however, lands comparatively level in which, sooner or later, it will be required, and there are one or two localities in which the need of drainage works is rapidly becoming an imperative necessity. Among these, by far the most striking illustration is furnished at Fresno, Cal., a district in which the same facts are also extremely valuable as indicating the change in character of an arid plain, submitted to years of extravagant irrigation. Fifteen years ago its sandy soil, sparsely covered by struggling herbage, grassless and treeless for scores of square miles, maintained only a few herds of cattle. There was no sign of cultivation within its borders, water could only be obtained by sinking from 40 feet to 80 feet, and the rainfall was both irregular and insufficient. The King River, which was its one available stream, sometimes carried no more than 500 cubic feet per second, and when the first "colony" was established it was stoutly maintained that the whole of its waters would not suffice to supply this little plot marked out in the midst of the wild. For some time, indeed, even after the canal to supply this colony had been constructed, so rapidly did the open ditch absorb the intake, that it was thought that the water would never reach the settlement at all. Week by week the tiny thread of fluid trickled and wound its way along; at last it entered the fields prepared for it, and, the flow steadily strengthening, crept farther and farther on, feeding an ever-widening district, until to-day there are fifteen canals drawing their waters from this river, irrigating 55,000 acres of land, which form a chain of

settlement all around the central Californian colony, and extending 16 miles beyond it. Water can now be struck anywhere across the whole plain at 10 feet, and often at 6 feet. The seepage from the canals has been great indeed, for it seems to have filled the whole subsoil, which has sucked it up like a sponge until it can hold no more. One important consequence is that irrigation by flooding or furrows is being abandoned at Fresno, as the irrigation by seepage maintains a constant supply within easy reach of the roots of vines and trees. The once arid region has become thoroughly moistened. Where till lately the contention for water was keen and ceaseless, one hears now of suits against canals on account of their supersaturation of adjoining vineyards. Nor is this to be wondered at, seeing that, in the midst of the once parched plain, there are now patches of artificial morass created, as in the Poudre Valley, Colo., by over-irrigation, and continued for want of drainage. For in Fresno, and Fresno alone, has drainage become a vital question. The largest vineyard in the district, that of Mr. Barton, has not been watered for two years, and the enterprising proprietor has actually excavated ditches around his property so as to drain it to a depth of 6 feet. The Eisen vineyard, close by, one of the oldest and best known in the district, is now involved in a suit, which its proprietor is bringing, in self-defence, against the canal proprietors for flooding his land. It is not only excess in flooding that has to be avoided, for excess of seepage is just as bad. Not only is the creation of a morass on the surface fatal, but the morass condition below is proportionately injurious. Roots, of course, will not penetrate below the perpetual water-line, and thus, if the water rises in the soil, the depth from which they draw their nourishment is liable to be greatly diminished. It has been suggested that, if the pipe method of sub-irrigation were adopted, the same pipes might be made available for drainage. If this could be accomplished without materially increasing the cost, it should contain a solution of the difficulty in a few cases, but, as a rule, where drainage is needed, sub-irrigation in any season would be superfluous if not injurious. A remarkable evidence of the rate of seepage in sandy soils is notable in the Fresno district, and that is, two little ditches, a foot or so apart, each of them carrying a swift stream of water, which is soaking through the bank of a small canal, and which they divert from the field beyond. A few ditches of this description compose the whole of the drainage work yet done in Western America. Even here the drainage problem does not appear to threaten the requirement of works any more expensive than those already in use, and, except in localities as peculiarly situated as Fresno, it is improbable that any outlay to provide them will be needed, at all events for many years to come. We may hope, therefore, that such escapements will only be demanded in parts of Victoria, and that even there they need only be gradually constructed some years after irrigation on an extensive scale shall have been in operation.

Capillary attraction.

For a complete comprehension of these facts, however, it is necessary to read them by the light of a knowledge of a peculiar property possessed by many soils, and which forms a most important factor in all calculations as to the limits of irrigation. It has been found, by experiment in California, that water rises rapidly in coarse sandy soils, but only to a moderate height, while in finer soils, whether clayey or of silty formation, the rise is slower, but higher, so that, in a few weeks or months, as the case may be, the water attains twice or thrice the height that it climbs to in the former. This has been said to be accomplished by means of a "capillary attraction," in which heat may, perhaps, be an important agent, seeing that the phenomenon is not observed in Colorado to anything like the same extent as in California. The table given in Appendix I is taken from the report of a scientific expert appointed by the Commissioner of Agriculture to inquire into the agricultural conditions of the Pacific

Slope, and presents the results of experiments made upon different soils, to test their capacity in this direction. A consideration of these results points to the superior value in suitable soils of sub-irrigation or irrigation by seepage from below, over all methods of surface application, because it is thus possible to avoid caking the soil and loss by evaporation.

The irrigable area naturally extending.

Taking together the facts as to seepage of water from rivers or ditches, and those relating to the rising of water by means of what is called capillary attraction, one is furnished with the key to the gradual diminution of the water necessary for irrigation of the same land, which has been noted in almost every part of the West. In Colorado alone, in situations like that of Greeley, upon a deep porous soil, with a rapid fall and quick drainage, as much water is said to be used to-day as in the initiation of the practice of artificial watering twelve years ago. Everywhere else the verdict of experience is that the water goes farther every year. The ranch owner, who doubted if his spring or brook would suffice for 20 acres, extends the area of his cultivation bit by bit until it reaches 80 or 100 acres, and he still has some to spare. Bishop Musser, of Salt Lake, who has made an especial study of irrigation in Utah and abroad, states that, when the city was first founded, there was only water enough from a particular source for 800 or 900 acres, while now the same amount supplies more than 5,000 acres. In another Mormon settlement, named Bountiful, where at first it was supposed that only a few families could be placed, on account of the smallness of the stream of water available for irrigation, there are now between 4,000 and 5,000 people, all maintained by means of the same supply. The whole of Utah has been peopled and all its cultivation based upon little driblets of water in this way. Yet the sandy aridity, which is absolutely worthless without water, may be soon over-wet, and it is found that, where a piece of ground is fed by good seepage, to irrigate it as well kills the crop. Here, as at Fresno, Riverside, Mussel Slough, and in Tulare county, California, may be seen farms and vineyards, up to 160 acres in size, irrigated solely by seepage from ditches which run along the upper edges of their fields. The distance that water will penetrate, even without any discoverable dip in the land, has been partially indicated by experiments in sub-irrigation, when the pipes and orifices, though 50 feet apart, have saturated the whole soil between them. With a fall in the country, the seepage extends for far greater distances, and, curiously enough, an instance is reported in the San Joaquin valley, where, upon the construction of a canal, a well a mile or two on the upper side increased several feet in depth after the canal had been some time running. Another most instructive fact is that, as the water supplied diminishes, the crops tend to increase. They now raise more grain in Utah with half the water than they did when they concentrated double the supply upon a smaller area. For the first year or so of irrigation, the soil becomes soppy, but afterwards, while seeming drier, it is not nearly so thirsty ; when it is very shallow, flooding ceases and seepage alone is relied upon. Irrigation is said to close the pores of the soil with an infiltration of rich impalpable silt, so that it absorbs more slowly and retains what is absorbed much longer. Under good cultivation the soil thus enriched becomes far more fruitful than it originally was ; but too much water makes the land cold, and eventually turns it into a quagmire. When soakage, as from flooding, is accompanied by soakage upwards by "capillary attraction," the consequence in California is the formation of what is termed "hard pan," an impenetrable layer which resists the entrance of roots, and yields them no nourishment. Where this is feared, flooding is suspended, and the subterranean supply depended upon. Such is the rapidity with which roots push for water that, even where moisture can be found 15 or 20 feet from the surface, no flooding is needed

after the first year or two. The roots of vines have been known to penetrate nearly 30 feet in a little over three years, while even lucerne roots travel 15 and 20 feet downwards to moisture. But the catalogue of facts, proving in a variety of ways the injurious effects of over-irrigation, and the marvellous results to be accomplished in time by small streams of water, might be multiplied indefinitely. It should be extremely encouraging to Australians to note that their deficient water supply may come in course of time to satisfy the wants of a much larger area than has been calculated upon, and to know that where seepage occurs at any moderate depth irrigation may be altogether abandoned on certain crops after the first year or two.

Duty of water

A review of the facts just cited is also of value here as giving some preliminary idea of the difficulties surrounding a question perpetually put, but never capable of an entirely definite answer. The question is as to the "duty of water," or, in other words, what area of land a given quantity of water should irrigate. At first sight, this seems not only a vital query, but one that should admit of a complete reply from experience. It does admit of a reply in each case, but, as the slightest variation in any of the numerous conditions under which irrigation takes place makes a marked difference in the answer, the inquiry, though of the utmost moment, can only be met by a lengthy statement, complicated by continual qualifications.

Water measures.

A preliminary doubt as to water measurements has to be taken into account, for, until recently, different standards have been in use; and still there is, even in flourishing districts, the greatest laxity in applying what standards they have. In Los Angeles, for instance, the zanjero, or water-master, has relied solely upon his eye to judge of the stream a farmer was entitled to receive; and though practice, no doubt, had enabled him to allot something like an equal share to each person concerned, it is plain that any attempt to define the quantity in recognised measures could only be an uncertain approximation. In every State the use of water for mining purposes has preceded, or, in the first instance, overshadowed, that for irrigation; and, consequently, what estimates have been the quantity of water flowing through an aperture an inch square, but, as in some parts made in the past have been expressed in "miners' inches." This was supposed to define the pressure adopted was that of a 4-inch head, while in other places the head was 6 inches, there was evidently abundant room for variation, even in the determination of the capacity of a single inch. When, again, a number of inches came to be measured at once, it became possible either to adopt an aperture one inch high and the specified number of inches in length, or to take the square of the whole number of inches as giving the dimensions of the orifice, in which case again there was another great cause of variation. The State engineer of Colorado has calculated that the miner's inch in that State has been ·026 cubic feet, or, roughly speaking, a fortieth of a cubic foot, and this is now generally adopted as its equivalent, though as a matter of fact, in more southerly States, where water has been scarce, the miner's inch has only meant a fiftieth of the cubic foot.

Conditions determining water duty.

Taking into account this initial cause of confusion in the measurement of water, we next find that the quantity of land which any given unit of water will irrigate is governed, first, by the kind of soil, subsoil, the rainfall, temperature, and evaporation of the particular area irrigated; next by the kind of crop grown, and the method of watering it, as well as by the length of time which that land or neighbouring land has been irrigated; and lastly by its position with regard to seepage and its capacity of capillary attraction. It is plainly no easy matter, even

when all the terms of the special instance are known, to fix the duty of water under these circumstances. But in almost every instance the records of American experience are wanting in respect to one or more particulars, and hence again there is only room for the vaguest conclusions. Instances can be quoted in which a flow of one cubic foot per second has supplied 9,000 acres, while in others it only supplies 50 acres. It is vain to attempt to arrive at accuracy in the face of such extremes as these. The manner in which water is sold in the States puts another barrier in the way. A water right there does not mean a right to any given quantity of water, but a right to have a stream of a certain capacity turned into the purchaser's lateral for as often and as long as he pleases. Each farmer accordingly draws upon the supply just according to his fancy in each season. As yet, as there is water in plenty, the Colorado companies do not restrict their customers to the stream they have purchased, but give them whatever flow they happen to have. The farmer, for his part, does not measure the quantity he receives, nor yet the quantity which flows away from him, so that on neither side is there any opportunity of obtaining exactitude as to the quantity actually absorbed by the land. Where measurements have taken place, as in Southern California, it has usually been at the farmer's receiving point, from which there is more or less loss, according to the nature of his soil, the make of his ditch, and the distance to be travelled before the field is reached, which renders these almost equally unreliable. In the face of this array of disturbing causes, it is utterly impossible to do more than notice a number of rough generalizations, which have some force in special localities. The more sandy the soil, the more readily it receives and parts with water, while, as the soil becomes heavier, it absorbs less and retains it longer; the deeper the soil the more water is required in the first instance, while with a retentive subsoil succeeding waterings can be greatly diminished. The heavier the rainfall, the greater the duty of water in equal temperatures, and, when evaporation comes into play, the duty has to be correspondingly reduced. Where the land is in a position to receive seepage from higher irrigations or is so porous as to draw a sufficient supply from its own laterals, or is so saturated as to need for a time no water even in its canals, which are perhaps, as at Fresno, turned into drainage ditches, the duty, of course, tends to become nominally enormous. Then, again, small grains as a rule take twice as much water as corn or potatoes, and many times as much per acre as orchards, which are watered on an economical method. Even the waterings given to one grain, such as wheat, vary according to locality from one to four, oats requiring more, and barley a little ess. In Riverside the orchards are often only watered once from furrows in winter, and once, twice, or thrice, according to the idea of the owner, in summer. Where flooding takes thousands of gallons, the furrow system only requires hundreds, and sub-irrigation tens of gallons for a similar area, though, of course, under different crops.

Comparison of water duties

Setting aside the question of the actual quantity of water used or needed for irrigation, we find that, even comparing the flow of water allotted to farmers for as long as they like, there are the widest differences. Taking the flow of one cubic foot to the second (available during the season for the cereals of Colorado, and all the year round for the orchards of California), without making allowance for differing rainfalls, this supplies, in Colorado, 53 acres; Italy, 70·2 acres (Col. Baird Smith); Utah, San Bernardino, Cal., and France, 80 to 100 acres; San Gabriel, Cal., 120 acres; Fresno, Cal., 160 acres; India, 150 to 200 acres (Sir A. Cotton); Los Angeles and Anaheim, Cal., rather over 200 acres; Riverside, Cal., nearly 300 acres; Ontario and Redlands, Cal., Algeria, and parts of India, 400 acres; Sierra Madre, Cal., 580 acres; Spain, as high as 1,000 acres; Pasadena, Cal., 1,665 acres; and by sub-irrigation

according, to one or two experiments, from 1,500 to 9,000 acres. In Kansas, Arizona, and Mexico, the figures given are too conflicting to be quotable. There are the same contrasts as to the depth of water which should be put upon land. In Colorado two or three waterings are given of from 3 to 5 inches in depth; in some parts of southern California waterings of 12 inches in depth have been given, and in other parts a total sufficient in the year to make a depth of several feet. On the other hand, there are farmers in these districts who, according to their own testimony, employ less than half the quantity used by their neighbours, and with equal if not superior results. If the Colorado farmer were to use all the water at his disposal, he would cover his fields nearly 4 feet deep. The practice appears to be, on the average, to use about one-fourth of this, but there is such a difference in soils that this is but a poor guide. Where a coarse sandy soil, with porous subsoil, can take ten feet in the season, a fine compact alluvial, with clay subsoil, would be injured with one foot; hence ten acres of the latter can be irrigated to one of the former by the same quantity of water. A natural measure of the duty of water in many places may be supplied by the rainfall of good harvest years, making allowance for the time of fall. In Central California, 13 inches during a frostless winter and spring have proved sufficient, and probably if 12 inches could be secured from rainfall and ditch together during the spring it would prove more than ample for flooding cereals either there or in Victoria. Messrs. Gordon and Black's calculations, it should be noted, fixed the same quantity for this class of cultivation.

Duty of water in Victoria.

It may be impossible to name anything like a trustworthy duty of water from American experience; it may even be impossible as yet to fix upon a scale of duty which should apply to all crops in all cases; but one thing is echoed on every hand in every State of America. All who have studied the question unite in condemning the extravagance in the use of water common to every class of irrigators. One competent critic has declared that four times too much water is used in California, and six times too much in Colorado. In any case, the admission should be encouraging to Victorians, whose soil, as a rule, is not nearly so thirsty as much of that irrigated in America, and whose loss by evaporation would probably be rather less than in Southern California or Arizona. It would be idle to attempt more than a guess at what the duty of water would be in Victoria, but, judging from the opinion of experienced canal proprietors in the West, even with rude methods, it should be possible after the first year or so to make a flow of one cubic foot per second at the field cover 200 acres of cereals, and 400 acres of vineyard or orchard. It would be infinitely preferable to state the amount put on the land in gallons, instead of the amount available in flow, as in the latter case the quantity actually used is left a matter of guesswork. This exactness in measurement should be studied from the first, to promote economy and a more scientific knowledge of the actual requirements of each kind of crop. If our soils were tested as to their qualities and powers of capillary attraction, and our waters as to their sedimentary deposits, we should then be in a position to utilize what streams we have to their fullest extent. Remembering that our subterranean sources of supply are still unexplored, that old river beds have not been tested, nor the scattered flow through porous strata collected at suitable spots, we may yet hope for an increase in the quantity of water capable of being used for irrigation. The teachings of American experience, with scarcely an exception, are that the quantity of water needed per acre is a steadily decreasing quantity, and that the area irrigated, therefore, is likely to progressively increase, at all events a long way beyond the area which can be commanded at first. The limit of water duty is not for years

an iron limit, but possesses an elasticity which enables it in many localities to widen its region of supply two or three hundred per cent.; in Utah it has been increased two or three thousand per cent. All calculations that may be made as to the limit of the irrigable area of Victoria will require to be made with this principle in view, so that, while it may be properly said that at first a certain stream can only water 10,000 acres efficiently, it must not be forgotten that, in most instances in Southern California, which so closely resembles our own colony, such a supply, in the course of five or ten years of continuous irrigation, would, in all likelihood, be able to supply that area, and another containing as many acres more.

Price of water.

The prices paid for water are so complicated by the conditions under which it is sold, that it is almost impossible to do more than quote the rates in different localities. The water itself costs the appropriators nothing beyond the expense of putting it upon the land, which differs, of course, in every State and every district. This first outlay for works furnishes one clue of an uncertain character to the price of water. Where farmers unite for the purpose of securing a joint supply, they work or pay their share of the construction, and afterwards their proportion of the sum necessary to keep the works in repair, so that it is difficult in many instances to determine exactly what their water costs them. In Colorado it is considered that an irrigable area should be supplied with an outlay upon main works of £1 or 25s. per acre, an estimate which appears to agree on the whole with experience elsewhere. Occasionally, as at Kansas, where very large canals run through very favorably-situated country, main works of a temporary character can be built for as low as 10s. per acre, while on the other hand, where special difficulties intervene, as at Salt Lake, in the price to be paid for easements over private lands, one finds the canal costing 50s. per acre to build. This is by no means the maximum of first expenditure. With extra works, such as fluming or tunnelling as in Colorado, or wooden channelling as in the City Ditch at Salt Lake, Utah, or expensive piping as at Pasadena, or the Highlands Canal in Los Angeles county, Cal., the cost may rise as in the last two instances to £8 and £10 12s. per acre. Here, of course, the supply is for small areas under intense culture. The greater the scale of the undertaking the less the cost per acre. The 150,000 acres at Bakersfield, Cal., can be watered by one proprietary for 10s. 8d. per acre, whereas if divided into a number of different schemes, adapted here and there to the conditions of ownership rather than to the natural surface of the land, it would probably have cost twice as much; or, take the 76 canal beyond Fresno, Cal., which now supplies only 20,000 acres, at a first cost of about 25s. per acre. With an extension of its secondary canals, so as to allow it to supply the 40,000 acres lying under them, the outlay per acre would be reduced to 20s., while if the complete plan, which is for the irrigation of 180,000 acres, were carried out, this would be still further brought down to 15s. per acre. Water, therefore, is dearest where the schemes are smallest, that is, where the works are relatively most costly. The same fact is again illustrated by the price asked for water-rights, which are almost invariably highest in small schemes. Thus, in such "colonies" as Ontario, Etiwanda, or Pomona, Cal., where land is sold in 10-acre blocks, a water-right costs from £15 to £20 per acre, while upon 80-acre blocks it can be purchased in Colorado for £3, in Utah for about 50s., and in Kansas for half that sum. Having a water-right, the farmer is then liable only to a yearly assessment for maintenance. This, on the other hand, is highest as a rule where the water-right is cheapest, ranging from 8s. per acre in Kansas, and 4s. an acre in Utah, to 2s. 6d. in Fresno, and 2s. in several colonies in Los Angeles County. In Colorado, the maximum rate of 6s. per acre per annum is rarely charged, the

water-right owners only paying the sixpence or ninepence per acre which is actually spent on repairs, and the same custom prevails in some parts of Utah; but in both of these instances the schemes are large. The prices of water-rights vary from a variety of causes, such as whether the water-owner has land of his own to sell or not, so that particular instances offer but little guide to an exact estimate of their value; nor do they furnish any clue to the quantity of water actually sold. In Kansas, water is paid for according to the acreage of the purchaser, who takes as much as he likes in return for his yearly rental. This most wasteful of practices was tried and abandoned in Southern California, as it will be abandoned in Kansas when water becomes more valuable. Meanwhile, its steady increase in price is everywhere noticeable. Thus, at the foundation of Greeley, Colo., 80 acres with water could be purchased for £60; a few years later the water alone became worth £100; to-day the same water-right is bringing £200, and with the land is worth £600. In all the "colonies" of California there has been as great a rise in the price of water, though there it is to be found in almost every instance linked to the land. This puts another difficulty in the way of estimating the exact price of water, for though the water is really that for which the money is paid, some deduction has to be made for the area upon which it is to be utilized. Land which in the arid state brings only £1 per acre, is sold at £10 or £15 per acre when under a ditch, and something like this proportion is maintained even for higher-priced dry lands, which rise from £5 to £40, and from £15 to £100, when artificially watered. When the land and the water-right are sold apart the canal owner makes two profits, one in the tripling or quadrupling of the price paid for the land, which is his chief profit, and the other upon the water-right, the price of which represents his outlay upon works, with liberal interest added. The first profit, made nominally upon the land, which is often greater than here stated, is of course really another profit upon the water, and as the cost per acre of the works is, as a rule, less than the cost per acre of the land, the gain upon the investment in water is much larger than appears. Where there is no sale of land, that is where the water has been brought to land already sold, or for sale by persons other than the canal owners, the price of the water is much higher, reaching sometimes as much as 20s. or 25s. per acre per annum. At Los Angeles, Cal., water is sold by what is called a "head," which, under their loose measurement, varies from two cubic feet to four cubic feet per second, at 8s. per day or 6s. per night in summer within the city, twice that price outside of its boundaries, and half the price in winter. At Orange and its neighbouring settlements the price for a flow of about two cubic feet per second is 10s., for twenty-four hours, or 6s. per day and 4s. per night, and in winter 6s. for the twenty-four hours. At Riverside the cost is about 7s. 6d. per day, or 5s. per night, for a cubic foot per second, or 12s. for the twenty-four hours. These prices varying indefinitely as the conditions of sale vary furnish but an insecure basis for any generalisation. Possibly a better idea of the importance of water than can be derived from any list of purchases and rentals in particular places may be obtained by a glance at its capital value. It has been calculated that the flow of a cubic foot per second for the irrigating season of all future years is worth from £15 to £25 per acre in grain or grazing country, to £30 in fruit lands. This is the price paid to apply such a stream to a special piece of land for as long as the farmer may think necessary, the knowledge that an excess of water will ruin his crops being the only limit. But if a flow of a cubic foot per second were bought in perpetuity without any limit as to the acreage to which it might be applied, or the time or circumstances of applying it, the capital value of such a stream in Southern California to-day would be at least £8,000. The value of the thousands of cubic feet which run to waste in Victoria would make a formidable total if calculated on this basis.

Comparison of water prices.

In counting the cost of water, allowance must always be made for the fertilizing material that may be obtained from it, so as to enhance the productive power of the soil. On this ground, as is the case in the south of France, one water supply might easily be much more valuable than another. There are other elements of variation too numerous to catalogue, but the effect of which may be judged from the contrast in the charges made in the same country. The prices of water in Europe differ as widely as those in America, the cost per acre in parts of Spain being much greater than any figures quoted above. If allowance be made for the capital expended upon water-rights, the average cost of rented water per acre per annum in the West is probably from 10s. to 25s. as against the 20s. to 28s. of France and Spain, and the 8s. to 12s. of the valley of the Po. When land and water are sold together, the price ranges from £10 per acre in Colorado, with a flow attached of about a miner's inch per acre, to £40 per acre in Southern California, with a supply of a miner's inch to ten acres. Judged by any of these scales, the present price of land without water in the northern districts of Victoria leaves a considerable margin for the construction of irrigation works. Taking the estimate of Mr. Culcheth, M. Inst. C.E., for the Tragowel Plains scheme at 14s. per acre for capital cost of works, and 4s. per acre per annum for maintenance, there is room for not unfavorable comparison with the figures just given, even doubling them to allow for the greater quantity of water provided by most American schemes. Where possible, up-country townships might take a hint from Los Angeles, where the whole sewerage of the city, amounting to a flow of over $3\frac{1}{2}$ cubic feet per second, which even there is sufficient to supply over 700 acres, is carried two miles in a 22-inch pipe to be used for irrigation, though this would require rigorous conditions of use and close supervision for the protection of health. One main lesson of water values is the necessity for having matured schemes prepared in the first instance, so as to prevent the establishment of small areas of supply, where they would render the later undertaking of a greater scheme unprofitable. For instance, if the available lands along the upper course of the Provo were watered, one-third of the valley of Utah would be deprived of a supply which, with its more genial temperature, would yield much better results to husbandry. Under Victorian conditions it is far more imperative than in America that our chief sources of supply should be tapped, so as to cover the largest possible area in the first instance, and thus reduce the cost per acre for construction and maintenance to the lowest possible point. If this be accomplished, it should be feasible to allow of the construction of supplementary storage works in favorable districts, without unduly increasing the rates to be paid by farmers.

Products.

What price can be paid for water, or land and water together, depends upon the products raised, and the price of those products at the homestead, by taking which as a guide consideration of complicated questions as to markets and freights may be avoided. So far as American experience goes, there appears to be no limit to the scope of irrigation, which embraces the fruits and cereals of the temperate zone, as well as the products that are raised only under a tropical sun. Apples, blackberries, and barley are irrigated in Colorado or Northern California, as are rice, cotton, and sugar in the hot lowlands of Mexico. Over a large area of the West it may almost be said that, as nothing can be grown without irrigation, anything can be grown by irrigation. One opinion current in Victoria has been that, whatever might be the water available, grain could not pay for irrigation; another has been that, if it did pay for a time, the soil would rapidly become impoverished, with the yet further fear that, failing these results, the quality of the grain would be deteriorated. As these dangers have been prominently put forward in Victoria, it is satisfactory to learn that, so far as American

experience goes, there is no ground for regarding any one of them, providing that proper precautions be taken.

Grain-growing under irrigation.

Wherever water has been plentiful, and the ground fairly level, it has paid to grow irrigated grain. There are thousands of acres in Colorado and Utah which have never grown any other crop, and are still growing it. The irrigated area under grain in Mexico is very large, and the yield heavy, while it is a moderate estimate that in the States 5,000,000 bushels of wheat are raised by its means. It is generally calculated that grain can be grown at a profit under irrigation for 2s. 6d. per bushel, and even where, as in Arizona, the crop has to be teamed twelve or fourteen miles across the desert, at a cost of 7d. per bushel to railways, upon which the rating is all against the local grower, grain is found to pay. Of course, the chief prosperity in the wheat districts was when 4s. and 5s. a bushel were regularly realized, and a profit of at least 50s. per acre was counted upon. All this has changed since the fall in prices, which has brought profits down to 20s. per acre, with a yield of 25 bushels. Grain pays still, but very poorly, and, even in better times, it is generally considered the poorest paying crop that can be raised. Still, it does pay for irrigation, and this is an important fact to the farmer who cannot afford to wait for the higher returns from intense culture. Nor does grain-growing noticeably impoverish the land where proper precautions are taken against the washing out of the fertilizing matter in the soil, and for the utilization of any sediment there may be in the irrigating water. In Utah, a rotation of crops is adopted; but in Colorado are to be found instances where grain has been grown every season for ten or fifteen years without perceptibly injuring the land. In Arizona and Mexico, the native population have raised their wheat and Indian corn from the same plots for scores, if not hundreds, of years; and to them the idea of manuring is quite unknown. Here and there a farmer may be found who takes the pains to use the droppings of his stock upon his fields, but this is the exception; as a practice, systematic fertilization is unthought of; and, so far, no serious injury appears to have resulted from its neglect, where any falling off in yield has been followed by change of crop. This is of interest, as showing, at all events, that the need of expensive restoration of the soil is not likely to assert itself in our richer lands until after some, or perhaps many, years of irrigation. Neither does the grain itself suffer if the seed be carefully selected. In Southern California, irrigated wheat has a slightly thicker skin, makes more bran, and, to the practised eye, is slightly darker in hue than that from the wet northern region, but it is said, even there, to be fully equal in quality to unirrigated wheat, a testimony which was repeated by millers in Mexico, Arizona, and Colorado. It is not from any such fallacious anticipations that grain-growing by irrigation is condemned in the States. Though all kinds of grain can be grown well, and at a profit, the growing is considered a mistake, because the profit is too small. Land and water that will grow grain will yield crops which are much more remunerative. Grain may be taken in rotation with potatoes, which flourish, under irrigation, in a sandy loam, or with peas, or lucerne, which act as restoratives to the soil. All kinds of root crops, and all kinds of vegetables, can be grown, and are grown, usually at a somewhat higher profit than grain; these again have, as a rule, a smaller profit than can be obtained from stock, which, in its turn, yields to the profits derivable from grapes and fruit. The average rates in the States, in 1883, was, for oats, 2s. 2d. per bushel; for wheat, 2s. 6½d. per bushel; and for maize, 1s. 6½d. per bushel. In 1884, they were even lower still, wheat selling as low as 1s. 8d. per bushel in Dakota, the average of the whole of the States being little over 2s. While prices such as these reign, grain-growing will not pay well anywhere under irrigation, and it is not likely

to be attractive at any time while the northern territories of the Union can raise it at a profit, and in enormous quantities, without irrigation, for 2s. per bushel on the farm.

Stock-raising on irrigated land.

It is a far more remunerative occupation to grow beef and mutton, or bacon, for which there is just as steady a demand. Two-thirds of the 50,000 acres irrigated at Phœnix is under grain, but this little valley also raises its one hundred thousand hogs. Dairy produce is successfully raised in Northern California by means of irrigation, where, indeed, it is applied to little else on account of the regular and sufficient rainfall which can there be counted upon. Even in Australia, many towns owe a considerable proportion of their vegetable supply to the Chinese irrigator. It would be a mistake to ignore these minor ways in which irrigation can be very profitably employed, especially in the neighbourhood of centres of population, but it would be an equally great mistake to suppose that irrigation is only practised on this scale. A prevailing misconception as to irrigation is that it is employed only for small areas under high culture. The fact that great stock-growers in California, such as Messrs. Haggin and Carr, or Messrs. Miller and Lux, irrigate thousands of acres for stock purposes appears to be lost sight of. Much Mexican irrigation is carried on upon the same plan. Where the great landowners have their immense estates, one can see not hundreds but thousands of acres artificially watered; and where smaller proprietors enjoy a share of the coveted irrigable area, they cultivate so closely to each others borders that the fenceless area as far as the eye can reach appears one gigantic irrigated field. The great valleys of the Ortiz, the Concho, the Florido, and the Nazas, the wide sloping plains of the Laguna country, in the neighbourhood of Lerdo, and in the province of Leon, exhibit the patient industry of the peasants and a marvellous fertility, secured by means of an artificial water supply of the rudest character. On the great cattle and sheep ranches of New Mexico, the proprietors, some of them Australians, are enlisting the same invaluable ally in order to protect themselves against the occasional ravages made in their flocks and herds by bad seasons. It pays, as a rule, to irrigate natural grasses, for by this means the carrying capacity of land is increased 33 per cent. The Chowchilla Canal, in Fresno county, Cal., 30 miles long, 30 feet wide at its mouth, and 2½ feet deep, is used almost solely for this purpose, and there are 20,000 acres of natural grass land irrigated in one property in Kern county.

Lucerne.

But the mainstay of the American stock farmer, large and small, is lucerne, there styled alfalfa, which, though unsuccessful in England, is highly prized in France. In every western state this is grown to profusion. There are 35,000 acres of it grown by irrigation at Bakersfield. In Yolo county, Cal., almost the whole of the 13,000 acres watered from the Woodland Canal is under lucerne; it is to be found upon almost every colony plot in Southern California, and is the surest source of revenue in Utah and New Mexico. The area planted with this crop is increasing with marvellous rapidity. It is said to carry 10 sheep or even 20 sheep to the acre, if it be cut for them. It is not a new growth in Victoria, but without irrigation its marvellous qualities have only partially developed themselves. At Dookie, with only the natural rainfall, it can be cut but once a year, yielding about three-quarters of a ton to the acre; while at Bacchus Marsh, with irrigation, or water within reach of its roots, it can be cut five or six times, yields seven or eight tons, and lasts fifteen to twenty years. There are some 300 acres of it in this locality, thriving upon a natural seepage, and though rather delicate in its earlier stages, owing to the lack of irrigation, when once firmly rooted, it raises the value of the land to from £50 to £75 per acre.

It is sown broadcast and freely, with a little wheat, oats, or barley mixed in it; is rarely manured, though better for an occasional scarifying and top-dressing; is never fed down, but cut early and often, and found to possess splendid fattening qualities. It has succeeded just as well, but upon a much larger area, on stations south of Ballarat. It is said that it has been grown on the flats of the Hunter, N.S.W., for many years without replanting, yielding a regular and heavy crop, and that in parts of Queensland it is employed for fattening store stock with excellent success. This latter practice has been reduced to a system at Watrous, N. Mex., where not only are the cattle sustained upon it during the few times in the year when the ground is covered with snow, but store stock are fattened for market at any season by stall-feeding them with 40 or 45 lbs. of lucerne per diem, the average gain in weight per beast being set down at 3 lbs. per day. It pays well, therefore, to buy stores at from £4 to £6 apiece, and sell them again in three months at £14 or £15. Under irrigation, lucerne seems to flourish everywhere, particularly in sandy loam, and in a warm climate free from frost, and, though the yields given vary, they are all great. Three cuttings are sometimes obtained in the first year, making a total crop of four tons to the acre, but the general thing is, as in Utah, to obtain only one crop in this period. After this six tons is expected in the second year, and eight to twelve tons in the third year. There are poor soils where it is cut only twice or three times, and other soils on which its quality does not keep pace with the quantity, but on those that most resemble our own plains the cutting is rarely less than four times, and the yield generally over ten tons per acre in the course of the year. It can be sold, at 28s. a ton, at a profit of from £5 to £10 per acre per annum. Much higher profits than this have been made from lucerne in Victoria, but even under competition the net returns should be at least as high. The lucerne field is said to be green a week after it is cut, and knee-deep five weeks later. The crop presses well, and improves by keeping, lasting for three years, though losing a large percentage of its weight when turned into hay. One of its advantages is that it thoroughly cleanses and restores exhausted soils without manure, and thus is of special value as a rotation crop. Some authorities in America consider it difficult of eradication, while others maintain that with a thorough cutting of the roots about three inches below the surface it can be entirely destroyed. In some districts it is considered judicious to plough it in about every seven years. It can absorb a large amount of water, and will send its roots many feet in search of moisture. In Utah it is found best to sow as much as 30 lbs. of seed to the acre, but the average is from 8 lbs. to 16 lbs. elsewhere. At present there is an excellent market for it on every hand, as many farmers consider one acre of it better than any two acres of the best blue grass land of the famed Ohio valley. It is claimed for irrigated lucerne that it will carry one or even two beasts to the acre on land which, without the water, would not carry a beast to twenty acres, and that with fertilization its capacity is doubled. It stands first in the popular esteem, but is not by any means the only grass irrigated, red top, timothy, and clover giving excellent results as well, while, in the opinion of some, Arabian millet surpasses all. A natural grass known as alfileria (Spanish alfilerilla) is so very highly prized for its nutritious and drought-resisting qualities that a supply of the seed is being secured for the Experimental Farm, in order to admit of its acclimatisation upon our own arid lands, on which artificial waterings cannot be looked for. It should lend an impetus to the great stock interests of Australia to be reminded that their rivals in America are making almost as much use of irrigation as the agriculturists.

Fruit-raising by irrigation.

But the products for which irrigation is most necessary, and in which it yields the largest profits, are grapes and fruit. The great landowner in America not only plants his thousands of acres of lucerne and perhaps his ten thousand acres of grain, but, with incessant enterprise, plants his hundreds of acres of vines and fruit trees. When irrigation is employed, however, the production is almost wholly in the hands of small proprietors, men often of some education and some capital, who have found an attractive field for the exercise of their intelligence in bringing small allotments into a condition of the highest productiveness. Judging by the results obtained in Southern California, to which this class of cultivation is as yet chiefly confined, it has not proved an unprofitable speculation. Others have been quick to learn the lesson conveyed by the steadily lowering prices of cereals, and have concluded that, though their growth may be a necessity for some who have no means to carry them on longer than from season to season, they should never be grown except under such a necessity. It is safe to predict that, in a short time, grain-growing will be given up on all smaller areas of irrigation, and that a commencement will have been made upon the larger tracts to follow the same example. It pays better to grow fresh vegetables for towns, or can them for export, to establish chicken farms or bee ranches, rather than raise grain for export. Already in Northern California the great farms, so famous a few years ago for their yields and extent, are being cut up into vineyards and orchards, and where, along the old mining ditches, any vintage ground can be secured it is being put to the same uses. Twenty acres under vines or fruit trees are preferred to 160 acres under grain. There is more regular employment and more regular leisure, with less stress at a particular season for adult male labour. An acre in raisins was reckoned as valuable as five acres of wheat when the price of wheat was nearly twice what it is now. The fruits grown are oranges, lemons, limes, apricots, pears, figs, peaches, pomegranates, nectarines, apples, plums, quinces, cherries, olives, almonds, walnuts, and chestnuts. From some of these two crops a year are obtained, but, of course, none of them bear for some time after planting. This is not all lost time to the American farmer, who grows great crops of vegetables between his fruit trees until they are ready for bearing. The period during which no return is expected, even under irrigation, is considerable, as, for instance, it is for peaches, apricots, almonds, and vines four years; for oranges, ten years from the seed, five years from the bud; olives, from seven to ten years, unless the Spanish practice of planting branches is followed, in which case it takes only two years; and walnuts seven years. When the profits do come, however, they are proportionately large. An orangery should be brought into bearing at a cost of about £50 per acre, or, with hired labour, £80; when in bearing it is always reckoned to return £120 per acre per annum; single trees have been known to yield a profit of £10; in good seasons a net return of £300 per acre has been obtained, while £200 per acre is said to be not infrequently earned. The profits of fruit-growing as stated vary greatly; but, taking moderate estimates, orchards in full bearing should give on small fruits a yearly average of £15 to £20 per acre; peaches and apricots, £40 to £60 per acre; almonds, £50 to £80; vines, £40 to £80 per acre; and olives, £100 to £150 per acre; and this upon retail prices ranging about the same as ours. Taking a general average for all these products on small farms, the profits appear to be calculated at from £40 to £50 per acre per annum. The price paid for fruit at the canneries averages from 1½d. to 2d. per lb., all round, and dried fruit about twice

as much, though there is but a limited market for the latter. Nearly 50 per cent. of the fruit grown in California is canned, but only 5 per cent. is dried. The production is increasing enormously every year. Vineyards are utilized not only for the supply of grapes, but of raisins and wine; and there is no branch of production into which great capitalists and small farmers are now entering upon a greater scale or with more confidence than that of vine-growing. The clearest heads in California consider the over-production of wine or raisins an impossibility, and experience is teaching them that at existing prices the investment is remunerative, although wine making is developed in the face of a prejudice quite as unreasoning as that which has till lately faced colonial vintages. For other fruits, though drying is occasionally adopted, the chief reliance is upon the canning process practised in every fruit-growing centre.* The taste for fruit, whether fresh, dried, or canned, is one that appears to grow by what it feeds on, for the demand in America seems to increase almost as fast as the production. The markets of the East are, of course, open to the irrigating West, but rates of transport are relatively high, and competition from the West Indies and the Mediterranean is keen, so that it can scarcely be said to be a home market in the ordinary sense of the term. The injurious effects of over-irrigation are just as patent in fruit-growing as in every other crop. It is claimed, on the authority of a commission of experts appointed by the French Government to inquire into the remedies for phylloxera, that regular furrow irrigation in summer keeps the disease in check, but it has been proved in Fresno that an excess of water injures both the wine and raisin qualities of the grape. There is a special disease to which orange trees are subject, which strips the tree of its leaves, prevents the fruit from coming to maturity, and finally kills the tree, which a special committee of the Southern Californian Horticultural Society, after an exhaustive inquiry, has declared to be wholly due to over-irrigation and deficient cultivation. The citrus family can endure more water than any other class of fruit tree, but it is clear that the limit of the water consumption of any of them is soon reached, and that to go beyond it is injurious if not fatal.

Eucalyptus in California.

Among the products raised it may startle the Australian to find his native eucalyptus, the various members of which, particularly the Eucalyptus globulus, E. viminalis, and, most prized of all, the Eucalyptus rostrata or red gum, are planted on extensive areas. From 700 to 1,000 trees are set to the acre, and, with good cultivation, excellent supplies of firewood are obtained. Land worth £2 to £5 per acre when planted with eucalyptus becomes worth from £20 to £80 in six or eight years. Official returns show a net profit of £3 10s. per acre upon plantations which raised the value of a property from £20 to £120 per acre in eleven years. It is rare that irrigation is needed for their growth. On the plains they are in great favour as break-winds, and are planted also as posts for wire fences, yielding a supply of firewood every year or so as they are "pollarded." Were irrigation established upon our treeless plains, a valuable supply of firewood might be secured by planting along the canals, though there is a difference of opinion as to the wisdom of such a practice. Notwithstanding the fact that the eucalyptus does not propagate itself in California without cultivation, there were, in 1883, 5,000,000 trees planted in that State alone. The readiness with which its valuable qualities have been tested and taken advantage of is characteristic of the American farmer or of the business

* For a detailed description of the processes, see "*The Australian in America*," by J. L. Dow, Esq., M.P., and "*A Tour in America*," by T. K. Dow, Esq.

men who use farming as one means out of many for money-making. Enterprise like this has made the fruit-growing industry, and will yet by its aid wring stores of wealth from much apparently worthless territory.

Prospects of Irrigation in America.

We have now taken a rapid glance at the products of 2,500,000 acres of Western America, watered by 12,000 miles of main canals and 120,000 miles of subsidiary ditches at an expense of many hundreds of millions of dollars. The estimates of the value of the yield from irrigated vineyards and orchards are not official, but those engaged in supplying the markets put the production of Californian vineyards, this year, at £1,000,000, and of the orangeries and orchards of the same State at half as much again. A good deal of fruit is grown for home consumption in neighbouring irrigating States, but prohibitive railway rates have prevented the full expansion of this and other classes of production. Utah and Colorado, entirely dependent upon irrigation, draw their revenue from other classes of products; the latter, in 1883, raising in value £1,100,000 of grain and root crops; the former £700,000. To assess the total value of the products raised by means of irrigation, many of which could not be raised without it, would be no easy undertaking, but it is clear from the statistics to hand that it must be expressed in millions sterling. Adding the enhanced stock-bearing capacity of the country, and the value of industries not directly productive which are dependent upon the irrigating settlements, would make up a grand total that would probably surprise the Americans themselves. There is no reason to suppose that the list of products capable of being profitably grown under irrigation is yet exhausted. Experiments are continually being made with fresh crops, and the result is generally favorable where climatic and soil conditions are studied. Great as the produce of the artificially-watered West now is, the prospects are that it will become very much greater; and the opinion of those qualified to form a judgment is that irrigation, marked as have been its successes, is yet in its infancy, and has given no more than a promise of what it is destined to achieve. There, as in Victoria, the yield from mining decreases, and the yield from agriculture increases, year by year. At the same time, the proportion of the latter raised by means of irrigation is increasing in a greater ratio. It will in all probability, before many years, overshadow all other sources of production; and, if Victoria is to keep pace with this development, it can only be by the employment of the same means of reclaiming and populating her arid lands to the fullest extent which her water supply can accomplish under the most improved system of scientific irrigation.

Healthfulness of irrigated lands.

Before summing up the lessons to be learned from a study of American irrigation, there remain a few collateral matters of great importance calling for prior consideration. The first of these relates to the healthfulness of irrigated country. A little experience makes it plain that no unqualified generalization regarding it could be justified. There are irrigated lands in which health seems entirely unaffected; there are others where the influence of malaria is but too patent; and the task is to discriminate between them. The river bottoms, as they are termed, flats but little raised above the level of streams, are, throughout the southern parts of the United States, recognised as malarious, whether irrigation is practised or not. Fever, ague, and chills are prevalent in such localities in Missouri, in Louisiana, or in the south-western area. From their position, these lands are easily irrigable, and hence settlers are tempted upon them, and become subject to the same complaints. Whether irrigation, as is probable, increases the danger in such

spots is not known, but in places similarly situated, though not malarious previous to irrigation, it seems that the practice has acted injuriously. Thus the State engineer of California, in his report for the year 1880, says that "neighbourhoods formerly noted for their salubrious climate have been rendered unhealthful in a marked degree, not only by the accumulation of water in the low ravines and flat places on the hill-sides, and in the valleys, but by saturation of the soils irrigated," so that "all along the foot-hills, where the streams emerge from the mountains, and irrigation is practised, malarious fevers are present in a greater or less degree," which injurious conditions are directly traceable, in his opinion, to "deficient drainage and careless use of water." The inference is only what might be anticipated—that, on the flat lands adjoining moors or swamps, malaria can only be avoided by efficient drainage. Where the soil is saturated, and artificial morasses are formed, as at Fresno, fever is naturally found in the immediate neighbourhood. Along the lower lines of this district, the miasma rises to a height of 10 feet, and here, as in the counties further south, the sleeping rooms are always placed in a second storey in consequence. Much of this region was malarious before irrigation was practised, and in parts the formation of channels is said to have actually reduced the danger. This, however, in such circumstances, can only be entirely removed by complete drainage. Much importance is attached to the source of the water drunk, and wells are sunk to great depths so as to avoid all seepage and secure a pure supply. On the bench or mesa lands of California or Kansas; in those of Colorado, with their rapid natural drainage; or in the porous lands of Arizona and New Mexico, malaria is as yet unknown; nor does there seem much prospect of its appearing. It is feared only in lands naturally swampy, or readily made so. It is not regarded as a fatal complaint, though the repeated attacks to which its victims are subject necessarily have a permanently weakening and depressing effect. There are many who seem to escape even in these localities, but there are others whose sallow and sickly looks only too plainly indicate the presence of malaria. As this is a question of the utmost moment, the testimony of a number of medical men residing in irrigated districts is attached (Appendix J). Rice cultivation in Italy has been legislated against repeatedly on account of its marked unhealthiness; but there does not appear to be any kind of crop raised in Western America which is specially injurious, and there would seem to be few places where the construction of drainage channels would not banish the miasma which now makes its appearance in the summer of every year. Knowing the risk to be run in those parts of Victoria where such consequences of neglect might be feared, it should be easy, in the initiation of irrigation schemes, to make ample provision against them.

Land and water to be united.

Another matter arising out of American experiences which it is desirable to notice, is the relation between the ownership of land and that of water. Where a farmer has his own canal to his own land, no question arises. Where a number of farmers excavate a ditch, and parcel the water out between them, the only question is as to whether the water used by each can be applied where he pleases, or whether it must be applied to particular acres specified in the contract. If he can sell his water to another, or turn it upon new land, the business of the company becomes more complicated, and the value of the lands first irrigated is not so well maintained. If, however, as is often the case, the farmers have been unable to make the ditch without assistance, and have called in a capitalist to join them, he frequently arranges to take up a certain amount of unoccupied land, which can be served by the canal, and from the sale of which he looks to derive a considerable share of his profit. To prevent competition, therefore, he generally stipulates that the water-rights which the farmers

receive in return for their investment of labour or capital shall attach to their particular acreage, and cannot be transferred to any other land. By this means he secures for himself the market for all irrigated land outside of these acreages. When he sells what land can be irrigated by his share of the water, his interest in the canal determines, and the works become the property of those who own the various ear-marked acreages which it is confined to supplying, unless by common consent the proprietors then decree otherwise. Capitalists often construct canals into unoccupied country as a speculation, and sell so much land with a right to so much water attached, until rights covering the whole flow of the canal are parted with, and the new owners of the land become joint proprietors of the work which feeds it. In this way land and water are bought and sold together, the area of the land being measured by the quantity of water; for, in the West, all value may be said to inhere in the water. Land is plentiful, and almost worthless. The owner of the water really owns the land, for it is useless without his supply. The quantity of available water, and not the area of a territory, defines its agricultural extent; consequently, where capitalists have built canals to lands which they do not own, and have secured the water, they have really acquired the land too. They have the farmers absolutely at their mercy, and enjoy a monopoly of the most arbitrary kind. A landowner who obtains a water-right can carry a stream to his own property at a distance through land as good as his, which never can be cultivated except with his consent, and which will fetch only one-tenth of what his irrigated land will fetch, though the two are only divided by a fence. A recognition of the danger of allowing water to be monopolized without regard to the land has led a commission appointed to inquire into Californian irrigation to declare that, "as a matter of public policy, it is desirable that the land and water be joined never to be cut asunder; that the farmers would 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 shall be sold separately." Major Powell, in his careful draft of a land system adapted to the arid region, most emphatically recommends that "The right to use water should inhere in the land to be irrigated, and water-rights should go with land titles." In Colorado, the feeling has gone so far that a proposal has been made in the Legislature to compel all canal owners to supply any persons with water, which they are not themselves using, at fixed rates; but as this would simply mean transferring to landowners who had invested nothing in canals part of the profit to be made by those who had so invested, the proposal was not entertained. Indeed, where the companies, as at Denver, sell the water-right with the land, and then contract to maintain a water supply in perpetuity for a fixed sum per annum, the system is unobjectionable, providing that, as in these cases, the water-right has been properly obtained. In Colorado and Utah, notwithstanding their peculiar situation, the water is given to the first applicant, though he has to purchase the land to use it upon, which, without the water, would be worthless. It would have been more economical and more simple to have sold the water and given the land. Be this as it may, it is essential that they should always go together. The practice of tying water-rights to the land has another argument beside that of avoiding monopoly, and this is that it tends to a more careful use of the water by its concentration upon a smaller area. Whether the farmers by a committee maintain the works and supervise the distribution, or whether this is done for them under contract by a canal company at fixed rates, is not a matter of so much moment, as in the latter case they are likely to be built substantially at the outset. When built by a capitalist, whose only object is to get rid of his land, poor works are often constructed, he being

indifferent as to their permanence, so long as they last until he has sold out. After this, the obligation of maintaining or reconstructing them will be thrown upon those who have purchased from him. In Utah, the despotic authority of the Church furnishes a basis for communal organization peculiar to that territory, and proved to be of the highest value in settling new country. The one lesson to be learned in this connexion is then, that in any introduction of irrigation into Victoria it will be necessary to provide against the separate ownership of land and water, except where the water may belong to the State or is sold under its regulations. All applications for water will require to be very carefully considered, and the grant of water-rights even for fixed periods jealously guarded. Though water with us may not be the vital necessity that it is in most of the irrigated districts of America, it is at least the means by which land can be greatly increased in value, in production, and in its capacity of sustaining population, and is, therefore, a treasure which no State can afford to give carelessly away.

Irrigation enterprises

The irrigation enterprises now proceeding in America or these recently carried out upon the larger scale have usually a considerable capital behind them. The farmers who were able by construction or agreement to irrigate have taken advantage of their opportunities, and it is necessary for those who wish to accomplish irrigation now to go farther afield. This the new settler can rarely do, and consequently he must purchase his land and water from a company which will ask him anything from £1 to £40 an acre for land with a water-right, and charge from 25s. to 2s. per acre per annum for water. The lower price is that of the outlying prairie land of Kansas, suitable for grain, while the higher price is for the best mesa lands of California, suitable for fruit. The average price for good grain land under a ditch and near a railway cannot be reckoned under £3, and will probably be nearer £6, while good orchard land will average about £30 per acre. These prices appear high, but the limit of available water even in America will probably send them still higher. There is little irrigable State land now unoccupied near either a railway or a settlement. The new settler buys from the capitalist or the company, who in their turn bought either railway grants or else private estates, paying from 6s. to £2 per acre. Some took up large areas of what were termed in California desert lands, offered to the public at merely nominal sums, and by means of irrigation have made them very valuable. But, as a rule, the lands open to small settlers were bought by their present owners at second hand, and are re-offered with water rights attached. Even under these circumstances they yield large profits to the speculator. Not seldom the large estate-owner retains all the land he can acquire, irrigating it for his own purposes, so that it may already be said of parts of California that wherever irrigation is possible it is undertaken. The great estate is irrigated that it may raise more stock; lucerne and other grasses are planted, and the carrying capacity of the whole multiplied many times over; or else part of the estate is leased to farmers who irrigate, and who pay the owner a proportion of the crop. If the land is to be parted with altogether, the universal practice is to adopt what is known as the "colony" system.

The colony system

At first, as at Greeley, "colonies" were established upon something of a communal basis beyond the joint ownership of waterworks, but this is now very rare. It is still frequently the case to find them organized upon a temperance basis, or by the union of those of the same nationality, as in the Scandinavian and German colonies. The joint

interest in the sources of their irrigation supply remain, but all other kind of community has disappeared. Under the most favored plan, a piece of irrigable land is marked out into small holdings; either the landowner or a company construct works to supply these with water, and the lots are then sold to any purchaser with water-rights attached. By liberal advertising and easy terms of sale, new centres of population and production are created in this way in a very short time, so that the barren plain, in the course of a few years, becomes dotted over with these oases until one joins another, and, at last, they enclose and support a thriving and well-built city such as Fresno is to-day. Altogether there are some fifty of these colonies in California, some of them planned upon a large scale, such as Riverside, and containing their township within themselves. It becomes the interest of the original owners to make the advantages which their lands offer widely known, and, consequently, they turn themselves into emigration agents of the most energetic kind. The eastern States are deluged with pamphlets; even the old world is reached by means of the printing office and by correspondence through the relations of those already settled. The aim is to make the place attractive, and no expense is spared to ensure success. In one such enterprise at Ontario the proprietors have laid out nearly £100,000 upon 8,000 acres of land, bought at 28s. per acre; of this sum about £10,000 was spent upon head-works for the water supply, which is conducted in 26½ miles of cement pipes to the corner of each ten-acre allotment, and in 3½ miles of iron pipes to the township for domestic purposes, at a cost of over £10,000. More than £20,000 in land was given to establish an agricultural college now built in the centre of the settlement, nearly £4,000 spent in planting trees and making streets, and £700 in securing a railway station. There is a double avenue running through the colony seven miles long in a straight line and 200 feet wide, planted with eucalyptus trees, and intended to contain a cable tramway, and the masts from which will be suspended electric lights run by hydraulic power. Over £7,000 was spent in advertising this colony, and the result is confidently awaited. Many persons, weary of city life, are drawn from the New England States, while numbers are attracted from the old world by the inducements held out to them. The colony enterprise has many advantages for those who engage in it, To join in it does not imply so great a trial as that of facing the wilderness with no neighbour less than miles away. It permits of society, of the establishments of schools. churches, and libraries, and the enjoyment of comforts which cannot be secured in isolation. It furnishes in fine a framework for commercial organization and the beginnings of local government. It appeals too to a larger class than that usually drawn to agriculture. The physical labour required is not so severe, there is more scope for intelligence, and it offers remunerative employment for a small capital.

Small holdings under intense culture.

This is due not to the colony organization but to the fact that by means of irrigation small holdings under intense culture are proved to be profitable. The land and water which will produce 25 to 35 bushels of wheat at 2s. 6d. per bushel will produce, under fruit trees, a crop worth twenty or thirty times as much. One-twentieth or one-thirtieth of the area under fruit instead of grain will yield as great a return and a larger percentage of profit. It has been found in parts of Europe where the water is the property of one owner and the land of many others, that the tendency of irrigation is to establish a monopoly in land. This is the case whenever the water is not attached to the land, and owing to a defective code law suits are frequent. But where water is attached to land, and rights are indisputable, there is exactly the opposite tendency—to cut up the land into small farms. It needs

both men and money to prepare and plant 20 acres of fruit trees at once. It is as much as a hard-working man can do to attend to 20 acres of oranges or 25 acres of vines himself, and then he needs light assistance in the picking season. It is calculated that he can, by frugality, maintain himself and family upon half as much. Hence in the colonies 40 acres is a large estate; it requires hired labour and yields a considerable revenue. Whether colony life yields large profits or not, the visible evidences are all of prosperity. The little holdings are neatly tilled, with an air of perfect security, owing to their being often unfenced or fenced only by a row of trees; the houses are neat, well finished, well furnished, and of some architectural pretension; the people are comfortably dressed and well nourished, and their cattle in capital condition. Many of them brought their savings with them, and they are apparently content with their investment. The poorest places in these colonies have a far greater air of comfort than grain farms of two or three hundred acres in extent. Whole colonies have been settled direct from Europe by a peasantry trained to the most frugal and industrious habits, and with these success is immediate. The much more extravagant American has a harder time of it, if he starts upon his ten acres with less than £500, as he must maintain himself by laboring for others the greater part of his first three or four years. Still there are numbers who enter upon their little plots without even the money to pay for them, or build a house, or buy their tools. Many of these are dependent upon advances from the land companies, and, though interest is charged, the general result is that in a few years the hardy colonist has his homestead clear, and a profit from it which, in a few years more, suffices to maintain him, and employ him always upon his own land. Ten-acre blocks are gaining in favour in some districts, and nowhere can one observe deserted colonies, or parts of a colony, which show signs of the total failure of effort. The chief secret of the success of small holdings is the practice of the principle so long preached in Victoria of variety of products. On a ten-acre farm there will be a plot of lucerne, maintaining a horse and a head or two of stock; an acre or so of vines, another acre or two of mixed fruit trees, with perhaps an acre of some special kind of orange or apricot, an acre of grain or root crops, and a great brood of chickens. From these sources a family largely supplies its own wants in the way of food, and by the sale of its products provides clothing and comforts, and still lays something by, or more probably invests it in permanent improvements. With irrigation there are no bad seasons; with such diverse products no fluctuation of prices is feared; and in the proximity of schools and settlement the settler himself has no sense of exile from civilization, and need not fear that his children being left to run wild will grow up unfit for any change of life. Another very important consideration is that the labour of women and children can be utilized to a very large degree in the picking, packing, drying, and canning of fruit, to the advantage of the producer and of the employé provided with a thoroughly healthy and often attractive means of earning a livelihood away from the crowded town.

What has been accomplished upon small holdings.

The success of small settlement in Utah is evidence of what can be accomplished in the face of the greatest difficulties. The tide of immigration constantly pouring into Salt Lake City consists of families often entirely destitute, and who have, as a rule, to become indebted to the church for their start. They have nothing but small plots of bare land, barren by nature, and are obliged from the very start to yield tithes yearly of all they produce; to give their labour to make the ditch which brings them water, and pay back their debts to the church with interest. Yet these

peasants are enabled to make homes for themselves, which, though plain, are not uncomfortable, and to steadily improve their credit, though trading at the store established in the church interest, which is not obliged to offer the lowest prices. What has been achieved under these unfavorable conditions, where a sterile sand waste has been raised in value from 6s. to £20 an acre, for agricultural purposes only, can be secured anywhere in America or out of it by industry and thrift, if the water can be cheaply placed upon the land, and climatic conditions are not prohibitive. With these lessons in the value of intense culture, it is not surprising that the most intelligent and most enterprising irrigators desert grain growing for either stock raising or fruit growing as quickly as possible, nor that the newspapers and authorities of weight are persistently bringing before the eyes of others the relatively unprofitable character of wheat growing, and urging them to attempt higher culture. For its increase means the increase of population and of natural wealth. Railway accountants in California calculate that an acre in vines gives as much freight as nine acres of grain. A 640-acre grain farm can be managed by a farmer with two grown-up sons, except in harvest time, and at all other seasons the broad, bare fields and rude homestead are not indicative of permanent improvements. On the Barton vineyard, at Fresno, which has 540 acres under vines, 30 men are employed all the year round, without pickers. The winery, which is to receive the 600,000 gallons upon which the proprietor calculates, is a great building, 330 feet long by 96 feet wide; besides which there is a distillery and office in addition to the usual farm buildings surrounding a handsome residence and garden. The capital invested is £60,000, and the amount spent annually upon the 330,000 vines nearly £5,000. Thus under intense culture the same area as the grain farm is made to produce a hundredfold. With 640 acres under grain a farmer's position is precarious without irrigation, and but poorly profitable with it. Under fruit or vines it is a great estate, and its owner a wealthy man. The Barton vines are used to produce wine, while on small holdings they are usually employed to make raisins. It is calculated that the value of the products of Riverside will, in the course of a few years, be £200,000 per annum, and though the oldest it is not the best managed colony in California. It is hard to see why similar results should not be obtained in Victoria. There must be spots on which it would be comparatively easy to establish a colony of 8,000 or 10,000 acres, supplied with water by means of gravitation, and with a soil suitable to vine or fruit culture; there must be many places in which the rich soils of the northern plains and their splendid climate could be utilised so as to rival the finest Californian yields; all that is needed is the capital and enterprise on the part of the purchaser of the site, and the small capital or persistent energy of the settlers upon 20-acre lots to illustrate the wealth of Victoria under a system of intense culture.

Victorian water supply equal to that of the arid region.

There are certain difficulties in the way of agriculture in California which do not exist in Victoria. Though free from the rabbit pest, a small ground-rat, called the gopher, is a constant source of loss and annoyance in many districts; in many more the ground squirrels are almost as destructive; and in others the soil or water or both are so alkaline as to require the most careful handling in order to make them produce at all. Nor is the water supply of Western America, as a whole, so superior to our own as has been assumed. The coast to the north of California enjoys a rainfall as great as that which visits the belt along the central ranges of Victoria, and parts of the south of this State, and of the east of the arid region in Kansas and Colorado, are well supplied by snow-fed streams. These, however, are exceptional tracts, and outside of

them there are conditions more unpromising than our own. The territory of Utah is almost as large as Victoria, and is chosen by Major Powell as typical in the extent of its irrigable area of the whole arid region. It has been carefully surveyed, especially with reference to its facilities in this respect, and the result given is that out of its 80,000 square miles, 2,262 square miles, or 2·8 per cent., have been declared capable of being artificially watered. This is said by Major Powell to be probably the average ratio of the irrigable lands of Western America to those which cannot be irrigated. Adopting the reports of Messrs. Gordon and Black and Mr. Culcheth upon the Goulburn and Tragowel schemes as a guide, it seems certain that Victoria will be able to show at least an equal percentage.

Negative conclusions

With this suggestive fact, which is after all the key-stone of the position, it may be well to close these notes upon the American development of irrigation. Such brief and superficial comparisons as could be instituted between the States and the colony have been given from time to time as they occurred, and require little recapitulation here. The difficulties of the inquiry, its incompleteness, its dependence upon conflicting evidences, and its strictly limited character, were stated at the outset, and may be here taken as stated again. If it had resulted in nothing but a series of refutations, it could not be considered by any means unfruitful. It may be as well, before indicating the positive conclusions arrived at, to recapitulate the negative results. A knowledge of the circumstances under which American irrigation has been crowned with success rebuts the presumption that there is anything in our soil or climate which forbids the profitable introduction of irrigation, or that the limited nature of our water supply renders the field of its application so minute as to be unworthy of attention, disposes of the theory that our population is too small and our wages are too high to admit of extensive operations, contradicts the assertion that expensive drainage works are essentials at the outset of any scheme, and that artificial fertilization must be at once resorted to in order to secure remunerative crops, exposes the fallacy that irrigation deteriorates the quality of the produce and rapidly exhausts the land, dismisses the suppositions that grain will not pay for flooding, that the cost of canals is necessarily enormous, that works must in every case be constructed so as to endure for all time, or that irrigated areas are invariably pestilential, and at the same time puts to flight the fears that the State alone can undertake irrigation on a great scale, that private enterprise is unequal to the task of dealing with it, and that only a poverty-stricken population can be maintained by its means. The first irrigators in California were met by just such warnings and just such predictions of inevitable failure as have been sometimes given currency to in Victoria. The settlers of Fresno, in referring to their early struggles, quote word for word the same despondent prophecies which have been current in this colony. They, however, have lived to see them falsified by their own inexhaustible energy, patience, and self-confidence, and with similar qualities, so may we.

Summary.

In conclusion, then, so far as the evidence goes, the writer can discover no irremovable obstacle to the achievement in Victoria by means of irrigation, and in proportion to its irrigable area, of all that has been achieved in the Western States of America. Our climate is equal to the most favored of all their climates, and, as far as known, our soil is not inferior. A smaller water supply in proportion to territory may render the area to be irrigated in this colony less than in the most favored parts of the West, but there is reason to believe that it will not fall below the average of the

arid region. There is also room for hope that the steady extension of area which can be irrigated from a given stream will be found a feature of Australian experience as encouraging as it is in America, and a possibility that our supply may be augmented in the same way from what are as yet unsuspected sources. The cheapness of American works, the ingenuity of their machinery, and the art of applying water to the land, we may hope to learn from them and from their teachers in older lands. Private enterprise with us can adopt the methods which have been so remunerative to private enterprise with them. Our products are the same, the rate of wages about equal, and the available population equal also, so that in these respects there is nothing to prevent intense culture securing the same results with us as with them. In their nearness to great fruit markets they have the advantage of us, an advantage which they take care to make the most of. As regards their facilities of transportation for fresh fruit there seems to be some slight misapprehension. So far from being satisfied with their railway systems, there is not a producing interest or centre in the West but is loud in complaint against them. The farmers of Utah and of Arizona declare that they are crippled by heavy freight rates on their produce, while that of more easterly States is brought long distances at low rates to compete with them. The fruit-growers of California, though of course enabled to command the market in their own State, and recently promised a concession upon the transport of green fruit eastwards, have maintained that the charges levied almost closed the Chicago market against them. The seven days' railway journey between San Francisco and New York, though relatively very cheap, proves more expensive than the slightly longer sea voyage from the south of Europe, and hence the great markets of the east are not at the command of the western fruit producer, as has sometimes been supposed. The home market of the West for fresh fruit is a good market; but that of the East, like the wheat market, is regulated by foreign competition. The great reliance of the Californian "colonist" is upon canned or dried fruit, for which he finds a large and growing home market, in which it would be impossible to compete with him, and a smaller market abroad, where it might be possible for Victorians also to obtain a footing, as such products could be sent almost as cheaply by ship from Melbourne as from San Francisco to European or Asiatic consumers. Here, however, the demand is not great as yet, or else the trade is not established. The total exports of canned and preserved fruit from the States amounted in value, for the year ending June, 1884, to £110,000, out of a total export of fruit valued at £350,000.

American competition in fruit.

And in grain.

As the United States is regarded as a formidable exporter of agricultural produce, it is interesting to notice that, even so late as 1883, she imported one-seventh of her barley consumption and £48,000,000 worth of food products, reckoning only at sea-board prices, from which it appears that her farmers have still a large home market to supply before they can turn all their attention abroad. In her export of wheat it is the opinion of many of the well informed that within the next ten years there will be a great decline. The area sown in wheat fell nearly half a million acres between 1880 and 1884. In Minnesota, where it can be grown at a profit for 2s. per bushel, the increase in wheat production was only 10 per cent. between 1875 and 1880, as against 70 per cent. for the preceding five years. The verdict of American experts is that grain can never be a profitable crop for export at anything like present prices, and that there are many kinds of agricultural products which will always pay much better. The certainty is that sooner or later these views will materially decrease this particular class of product.

But whether or not the American fruit-grower will remain without a rival in foreign ports, our farmers need not look far to find a market for the best paying crops which can be raised by irrigation. In 1884 Victoria imported in value a balance over our exports of £2,000 in olive oil, £2,500 in nuts, £4,000 in almonds, £10,000 in dried and bottled fruits, £23,000 in raisins and jam, and £80,000 in fresh fruit, or a total of £121,500 worth of the products of intense culture, which could be all produced in a few years from a single irrigation colony of 10,000 acres. The Australian market is still larger, its imports of those products from abroad for 1884 making up a total value of £385,000, in supplying which demand Victorian irrigators should find a good field for a long time to come (see Appendix K). Prices may be regulated by imports; but with the rapid growth of the colonies our producers have at least an enlarging home market, which it will tax all their efforts to control in the next decade or two. Our markets.

Nor need the outlay upon irrigation be feared by the practical farmer. If, as is likely, he could obtain a water-right giving him 12 inches in two or three floodings, whenever needed, for 20s., or even 25s. per acre, and a rental of 5s. or 10s. per acre per annum, it would possibly pay him even to grow grain. But it will pay him much better to grow beef or mutton upon lucerne, and to enter gradually into fruit-raising. Even Mr. Gordon's estimate of £5 14s. per acre for the irrigation, which would render the farmer secure against bad harvests, is nothing to the £10, or even £20 an acre, which has been expended, either in labour or in wages, in clearing many parts of Gippsland. Private enterprise has accomplished this without hesitation. Often it has been achieved by men without resources, who have earned by their labour elsewhere enough to live upon, while they gradually prepared their own selections for cultivation. And clearing, after all, does not ensure the regular crop promised to careful irrigation. The energy of the men who have already planted homesteads in the most heavily timbered and inaccessible parts of the colony, if applied to the irrigation of country which needs no clearing, as upon the northern plains, would have won even greater rewards. Irrigation not a costly improvement.

Not that it should be assumed that irrigation is a sure means to affluence and ease. In America, it has made large profits for those who had large sums to invest in starting colonies or watering their own great estates. To the farmer already upon the land, it offers a means of doubling or trebling the value of his land, if he can unite with his fellows in launching a scheme for mutual supply, as by means of an irrigation area under the present Act; but to him, apart from this, and to the new settler, it simply offers the prospect of regular employment and a regular income, which, with frugality and industry, will enable him to rear his family and make a home for himself, the value of which should rise steadily as he permanently improves it under careful cultivation. Irrigation is in fact the best possible insurance for the agriculturist, since, in many years, it prevents disaster, and, in all years, should more than repay its cost. Besides the confidence it gives, which enables him to undertake extended operations in any season, there is the gain in fertilization, and the increase in yield, which a professor at the Agricultural College of Colorado puts down at more than a hundred per cent. above what could be expected in a region with a defective rainfall. Irrigation, employed with foresight and skill in the raising of a variety of products, relieves the life of the agriculturist, always attractive in so many aspects, of its one danger, by removing the element of risk, which robs it in bad seasons of most of its charms. With proper Irrigation profits sure.

provision for drainage on low-lying lands, the pursuit should be perfectly healthful to the individual, and, under wise direction, should multiply, not by fits and starts, but by slow and steady accretion, his wealth, and the wealth of the community. Irrigation means immigration, if cheap passages from Europe and wide advertisement in the mother country are employed. A settlement of even the million acres of irrigable land which lie in the northern watershed of Victoria, if undertaken under judicious legislative and administrative control, should be the means of establishing there a prosperous and an intelligent class of farming citizens nearly as large as the whole population of the colony at the present time.

The policy of the State towards irrigation.

Though there are lessons in American experience, already referred to, which have convinced the leading politicians of the States interested that certain legislative and administrative duties should be undertaken by the Government, there is nothing either in their policy nor in their experience which casts any direct light upon the problem whether the State should assume any other attitude towards the man who increases the natural production and his own wealth by irrigating than it assumes towards the man who accomplishes the same results by reclaiming or clearing his land. The conclusions as to State action which have been accepted among so self-reliant a people would be worthy of attention if it were only because of the national tendency to which, in a measure, they run counter. Though they have been alluded to before, they are of so much moment that they will bear repetition, more especially as, if now called upon to offer suggestions as to the duty of the State towards irrigation, I could find firm foothold in American precedent for just the recommendations which would be made by the irrigators of Colorado or California. Their verdict, based in the first five instances upon a practical trial in one or other of the irrigating States of the course advised is, that—

Recommendations based upon American experience.

(1.) It is essential that the State should exercise the supreme control of ownership over all rivers, lakes, streams, and sources of water supply, except springs rising upon private lands.

(2.) That it should dispose of the water to those desiring to irrigate, on such terms and conditions and to such an extent as may be determined by professional or qualified officers of its own, its object being to encourage the greatest possible utilization of the water on the largest possible area.

(3.) To ensure this, it should establish a scale of water measurement, and insist upon its employment in all transactions relating to water.

(4.) The State should appoint local water-masters to supervise the distribution of water, settle disputes, and exercise such a jurisdiction under a central office as shall guarantee the preservation of water-courses and other sources of supply.

(5.) Power should be given to holders of water-rights to obtain easements over private lands on payment of compensation and proof that the route asked for by them has been selected for sufficient reasons.

(6.) The State should furnish the fullest information as to the natural capacities of its territory for irrigation. The United States has already recognised its obligation in this direction. In addition to the work done by the Bureau of Agriculture, as summarised in

Appendix L, the Central Government is having prepared, under Major Powell's direction, a most elaborate series of maps, based upon careful surveys, showing the irrigable areas, the area suitable for pasture, the area of growing forest, and the forest where burned; while the State engineer of California has commenced such a close examination of that State, as, if completed, would give the most complete picture of its irrigation possibilities, works, and practices. A similar course is being pursued in Colorado. Victoria, which has done something in this way, might very properly do a great deal more.

(7.) In California it is also held that, to prevent all irrigation from necessarily falling into the hands of capitalists, or any scheme for the general benefit from being negatived by one or two refractory landowners, there should be a means of organizing irrigation areas and creating corporations for them, who should be capable, at the bidding of a majority of those interested, of doing all things necessary to the construction of works and distribution of water, by means of funds borrowed upon the common security. Here, again, the State officers would be employed in protecting the public interest and testing the plans of projectors. This has been provided for in Victoria.

It seems to me, however, that without departing from methods approved elsewhere, we might go farther and adopt some of the minor forms of State encouragement already in operation in Europe. Even in America, judging from what is sometimes done in other ways, there would be little opposition to proposals for holding out inducements to the study of irrigation, theoretically and practically, as best adapted to local conditions. Such means of encouragement are used in France, in which country may be found a precedent for the despatch of the writer to Western America, where, some two years ago, a similar visit, with exactly the same objects, was paid by an official representative of the French Government.

Further recommendations.

To understand the Victorian position we must note what has been done and what remains to be done, if we are to be guided by American evidence. In a more or less definite way, Victorian legislation has already recognised the power of the State over all sources of water supply (*Mining Statute* 1865, section 36; *Land Act* 1869, sections 46, 55, 56; *Water Conservation Act*, No. 716, sections 38, 41, 42, 46, 48, 78), the duties of a State department as to surveys (No. 716, section 15; No. 778, section 5), with provision for the constitution of districts (Part I., No. 778), and the issue of water-rights. It remains to provide (1) an unit of measurement, and (2) require the measurement of all water used. Were (3) our newly founded agricultural colleges made use of to train up a young generation of irrigators, (4) conferences organized among practical irrigators, (5) bonuses awarded for the most successful farming by irrigation, and (6) prizes offered for the most fruitful studies of the best methods of utilizing our water supply, the development of a scientific system of irrigation might be greatly advanced. Our experimental farms (7) might be made actively experimental in irrigation, and (8) steps taken to put within the reach of those interested a knowledge of the latest successes in economical engineering, or in

the art of artificial watering obtained from America or elsewhere. There might even be found a suggestion in the visit of the State engineer of Colorado to California and Utah for the purpose of inquiring into the progress in irrigation in those States, of the advantages likely to accrue to us from (9) a visit of inquiry to the colony paid by some such irrigation expert as Mr. Ham Hall, State engineer of California, one of the highest authorities in the States, previously engaged in the construction and management of irrigation works, and author of "The Problems of Irrigation," now appearing. This would unquestionably afford a very satisfactory means of settling some of the questions as to the extent and value of our water supply, and the nature of the works calculated to distribute it most economically.

Should the State construct head-works.

Whether we should cast upon the State the responsibility of the construction of head-works for irrigation, is a question upon which American experience gives no answer. That experience makes it plain that the State cannot afford to ignore the questions relating to irrigation. It must regulate the diversion and sale of water and generally supervise all sources of supply. For it is clear that, if the sole control of any sources were to be conferred without restriction upon private persons or ncorporated companies, there would be a possibility of creating a most injurious monopoly. The one motive of the private person or company, in controlling the supply, would be to obtain the largest profits or dividends. And, if these were the only objects sought, the tiller of the land, being entirely at the mercy of the owner of the water, would either be compelled to yield to exorbitant demands or allow his land to go out of cultivation. This, however, is a different issue to that raised by the question whether the State should itself construct irrigation works. There is no precedent in this direction, and only one expression of opinion. This is from Mr. Ham Hall, C.E., who, on theoretical grounds, was at first in favour of State assistance, but, on further research, has seen reason to greatly modify his views. He now says that:—"The State could not with safety enter upon the construction of irrigation canals, or materially encourage the building of such works, upon any other basis than that of the entire burden of the cost being borne by the property benefited, for the following reasons, viz.:—With such encouragement, works of irrigation would inevitably be pushed beyond the capacity of the water supply to fill the demand, and beyond the ability of the people to use the diverted water profitably. Thus irrigation would fail of a fair measure of success from one or both of these causes, and the State would have to make good towards the payment of debts incurred what could not be derived from the projects in a legitimate manner." It is in other and older lands than the United States that those seeking to extend the responsibility of Governments must look for illustrations of its advantages. But whether the verdict as to the actual construction of works be given for State action or private enterprise, one thing is clear, and this is that the works ought to be constructed. If Victoria is to continue to progress in the settlement of her people upon the lands and the multiplication of her resources by the conquest of those areas hitherto regarded as worthless; if she is to utilize her abundant natural advantages, bring her productiveness to the highest point, and secure to the agricultural population of her arid districts a permanent prosperity, it must be by means of irrigation. No price, it may be said, is too high for such a promise of progress. No price is too high, unless, indeed, it implies the sapping of that spirit of independence and of that self-reliant energy and enterprise which have won her present position; for by these, and these alone, can she maintain it.

In addition to the descriptions of works and machinery specially relating to irrigation given in the Engineer's report, a heterogeneous mass of information upon the water supplies of the chief cities of the United States, such as Chicago, Buffalo, Cleveland, Philadelphia, and San Francisco, has been placed at the disposal of the Engineer of the Melbourne Water Supply; plans and specifications of improved dredging plants have been forwarded to the Public Works Department; and copies of official papers relating to Railways, Agriculture, Forestry, and Health, distributed to the various offices interested. Additional results of the tour.

It remains for me to acknowledge the letters of introduction to the representatives of the British Government in America considerately presented to me by His Excellency the Governor, and those to high officials of the State and Central Governments furnished by the kindness of Mr. O. M. Spencer, United States Consul of this city. Acknowledgments.

I have to express my indebtedness to the Hon. James Lorimer, M.L.C., for letters of introduction, which proved of the greatest value; to one of his correspondents, Mr. Dempster, of Messrs. Dempster and Keys, San Francisco, I owe many of the best opportunities which were afforded me of obtaining expert opinion and a practical insight into the problems of irrigation, as well as other information, attention, and courtesy, extended without stint in the most generous manner; to Messrs. Haggin and Carr, of San Francisco, for the hospitality of their various ranches; and to Mr. James, C.E., and Captain Taylor, their representatives at Bakersfield, special thanks are due for assistance cheerfully rendered at the very outset of the tour.

Mr. C. H. Livingston, formerly of Melbourne, and now of San Francisco, readily bestirred himself to further the object of my labours. For introductions to him and to Mr. Senator Stanford I have to thank Mr. Thomas W. Stanford, of this city. My warmest acknowledgments are due to Mr. T. D. McKay, of San Francisco, agent for the Chicago, Burlington, and Quincy Railway, for the indefatigable zeal and thoughtfulness which he displayed in facilitating my movements and increasing my opportunities of personal investigation, and also to Mr. Lowell, general manager, and Mr. Lomax, assistant general manager, of the same company, for the consideration extended by them to our party. To my companions on the journey, Mr. J. L. Dow, M.P., whose agricultural knowledge and previous acquaintance with the United States were extremely valuable, and to Mr. E. S. Cunningham, who courteously placed his practised pen at my disposal in order that Mr. Derry, M. Inst. C.E., might devote the whole of his attention to professional inquiries, I am under obligation for numerous kindnesses. To Mr. Howard, President of the Spring Valley Water Supply Company, and Mr. Schossler, director and chief engineer, I owe valuable information as to city waterworks, which was afterwards supplemented by a number of other municipal officers, in various States, to whom I desire to tender my acknowledgments for their response to my circulars. Mr. Carter Cotton, of Fort Collins, Colo., exhibited a lively interest in my mission, and lent his assistance under circumstances involving a sacrifice of his time and personal convenience. Major Powell, of the United States Survey Department, Colonel Hinton, of the Agricultural Bureau, Mr. N. H. Egleston, of the Forestry Bureau, and Mr. Dodge, of the Bureau of Statistics, with other departmental chiefs at Washington, exhibited the greatest

willingness to aid me with all the resources of information at their command; I am specially indebted to Colonel Hinton for the exhaustive paper on American irrigation.* Mr. Hall, State engineer of California, and Mr. Nettleton, State engineer of Colorado, contributed much valuable evidence—the former not only placing many of his manuscript returns at my service, but accompanying me upon a visit to one of the chief centres of irrigation for the purpose of exhibiting it in all its phases.

Messrs. Miller and Lux, of San Francisco; Mr. Spence, mayor of Los Angeles; Mr. De Barth Shorb, of the same place; Mr. L. M. Holt, of Riverside; Mr. G. Chaffey, of Ontario; Messrs. Watrous, Wilderstein, and Kroënig, of Watrous, New Mexico; Mr. Holmes, of Garden City, Kansas; Messrs. Duff and Gilmour, of Denver, Colo.; Mr. Dwyre, of Fort Collins, Colo.; Mr. G. G. Anderson, C.E., engineer to the South Platte Company; Mr. Irvine, C.E., of Santa Fe; Bishop Musser and Mr. Winder, of Salt Lake City, Utah; Mr. Barton, Mr. B. Marks, and Mr. F. Baber, of Fresno, Cal.; Mr. J. D. Buckley, C.E., and Mr. La Grange, Water Commissioner, of Greeley, Colo.; Mr. A. Selman, of New York; Mr. F. Eaton, C.E., Mr. Knox, C.E., and Mr. Jenkins, Zanjero, of Los Angeles; the Comte de Prez and Senor Josè Rincon, of Mexico, are gentlemen to whom I am under great obligation for courtesies and information.

It would be a pleasant but an almost endless task to mention all the private individuals at whose hands I so continually received unexpected kindness. During the whole period of my stay, though engaged upon a task that necessitated inquisitorial researches into private affairs, and under circumstances that forbade delay or formal introduction, I cannot recall a single instance in which I was not treated with courtesy. Though without a claim on those upon whom I was compelled to intrude, I have to record a list of unvarying attentions and kindnesses, only limited by the very short time at my disposal and my unwillingness to trespass upon the frank and generous cordiality which appear to be characteristics of the American people.

ALFRED DEAKIN,

President of the Royal Commission on Water Supply.

June 15th, 1885.

* Referred to in the note upon page 1 and published in Appendix L.

APPENDICES.

APPENDIX A.

ROYAL COMMISSION ON WATER SUPPLY, VICTORIA, AUSTRALIA.

Subdivision III. Subject 4. *Irrigation.*

INFORMATION REQUIRED.

GENERAL.

1. In what year did irrigation commence ?
2. Was cultivation possible without irrigation ?
3. What is the rainfall and evaporation over the irrigated area ? What is the area ?
4. What led to the adoption of irrigation ?
5. What is the source of supply ?
6. What quantity of water is available in the irrigating season ?
7. What is the maximum discharge, and in what month ?
8. What is the quantity of water available throughout the year ?
9. What is the minimum discharge, and in what month ?
10. If the supply is by pumping, what quantity, and to what height and distance is the water delivered ?
11. If from wells, supply similar particulars ?
12. Is it found that less water is used now than when irrigation commenced ?
13. Is there a weir, or other means of raising the surface level of the water of the river ?
14. What works of construction are there in the scheme ?
15. How is the supply to the canal or off-take (main channel) regulated ?
16. How is the supply to the minor channels regulated ?
17. How far from the head is the first minor channel ?
18. How far from the head is the last minor channel ?
19. How many minor channels are there ?
20. What is the maximum discharge of the off-take ?
21. What means of escape is provided for the water that is in excess of the irrigation requirements ?
22. How is the supply to the cultivator or distributory regulated ?
23. Is drainage of excess water considered of importance, and how provided for ?
24. What have drainage works cost, as compared with irrigation ?
25. What has been the total cost of works ? (See Appendix.)
26. What is the cross-section of the main channel ?
27. What is the cross-section of the minor channel ?
28. What is the cross-section of the distributories ?
29. What are the depths of water and inclination of beds of the main, minor, and distributory channels ?
30. If commencing again, would any modification be made in the designs of the channels and works ?
31. What are the average size of holdings, irrigated and unirrigated ?
32. What has the effect of irrigation been on the health of the districts within its influence ?
33. If any modification or remodelling of the works should be required to be carried out, have the companies reserved any rights to make these on a valuation by jury or arbitration ?
34. Has the growth of weeds in channels been found troublesome ? If so, what means are adopted for their removal ?
35. Has the level of water in wells been affected by irrigation ? If so, to what extent ?
36. Have wind-mills been used to any extent ? What form is preferred ? Also what kind of pumps ?
37. Has travelling sand been found troublesome ? How is it dealt with ? What vegetation is most effective in protecting it from the action of the wind ?
38. Where irrigation is partial, what area or proportion of the cultivated land is irrigated ?
39. Where is the market for sale of produce from the irrigated lands ?
40. What is the average income of the farmers ? Is it more than that of the laboring man in regular employment ?
41. Is there much more land available for cultivation by irrigation ?
42. What is the average cost of wheat, &c., raising per bushel, irrigated and unirrigated ?
43. What is the cost of maintenance of the irrigation channels and works ?
44. What is the irrigator charged, and how is the water measured ?

TILLAGE.

45. What is the nature of the soil irrigated ?
46. To what depth does the water penetrate ?
47. What is the usual mode of irrigating—by grading, furrows, seepage, or checks ?
48. What is the cost per acre of preparing the land for being irrigated by grading, furrows, seepage, checks, &c. ?
49. How is your system most economically effected ?
50. Is much land irrigated before ploughing and the crop allowed to depend on this only ?
51. What is the duty per cubic foot of discharge per second ?
52. What depth of watering is given to the different crops ?
53. How many waterings for each kind, and at what seasons ?

54. What labour is required for watering?
55. What is the cost of irrigating one acre of different crops by the various methods named?
56. What is the production from land thus irrigated?
57. What is the production from similar crops unirrigated?
58. What is the value of produce delivered at railway station?
59. What rotation of crops is adopted?
60. What period of fallowing is allowed?
61. Is manure extensively used?
62. Is the land impoverished rapidly by irrigation, and when exhausted what steps are taken to restore it?
63. What are the respective values of irrigated and unirrigated land?
64. Has irrigation been found to pay for the production of wheat on a large scale?

PASTURAGE.

65. Is pasturage (meadow land) irrigated?
66. What depth and number of waterings is given?
67. Is lucerne (alfalfa) cultivated? If so, what area to each holding?
68. How many crops are taken annually?
69. What depth and number of waterings are given?
70. What number of sheep or cattle can be carried to the acre on lucerne?
71. What number of sheep or cattle can be carried on irrigated natural pasturage, and what is the kind of grass?
72. What areas are sheep or cattle depastured on, and how retained to these areas?
73. Are the sheep raised for their wool or flesh chiefly?
74. What is the nature of soil? What depth? Analysis?
75. What is the situation of the land in relation to the hills from which your water flows? Mean temperature?

COST OF WORKS.

TIMBER WORK.	Labour.	Material.
Piles (driven) per lineal foot		
Timber (framed) per cubic foot		
Planking (fixed) per superficial foot		
IRON WORK.		
Bolts and nuts, per lb.		
Straps, plates, &c., per lb.		
Spikes, per lb.		
EARTH WORK.		
Excavation, per cubic yard		
Filling, „ „		
GRAVEL FILLING.	Labour.	Material.
Per cubic yard		
SUNDRIES.		
TOTAL.		
MAINTENANCE.		

APPENDIX B.

AN ACT TO PROVIDE FOR THE ORGANIZATION AND CONTROL OF WATER AND IRRIGATION DISTRICTS.

The People of the State of California, represented in Senate and Assembly, do enact as follows:—

SECTION 1. Any number of landowners interested in the waters of any stream or streams, lake or lakes, reservoir or reservoirs, from which there are two or more diversions of water, for the purpose of irrigation, may petition the board of supervisors of the county in which the larger portion of the lands that may be irrigated from the source or sources of supply are situate, for the formation of a water district, which petition shall show the name of the stream or streams, lake or lakes, reservoir or reservoirs, from which the

diversions have been made to irrigate the proposed district, the points of diversion of the several appropriations, the name of the county or counties through which the waters naturally flow, and the names, so far as known, of the present appropriators of water.

SECTION 2. Upon the filing of the petition, the board of supervisors to whom it is addressed shall ask the advice of the State engineer in relation to the exterior boundaries of the proposed district, so that it may embrace, as nearly as practicable, all the lands that may be economically irrigated from the source or sources named. The State engineer shall immediately suggest boundaries for the proposed district, supplying the board with a map of the same. The board shall, as soon as practicable, proceed to consider the matter, making such investigation as it shall deem advisable, and shall make an order to establish the district and describe its boundaries, and shall give it a name suitable to its locality. The clerk of the board shall keep a correct record of the proceedings of the board, and shall send a certified copy of the order establishing the district to the recorder of each county in which the district may be wholly or in part situate, and the recorder shall record the same in the book of water-rights of the county. The expenses of the proceedings necessary to and including the formation of a water district shall be borne by the county or counties in which it may be located.

SECTION 3. The said board mentioned in the preceding section shall issue a proclamation, to be published once a week for four consecutive weeks in some newspaper of general circulation in the district, calling an election, designating the hours the polls will be open and closed, to be held on a day not less than four weeks from the date of the proclamation, for the election of three water commissioners for the district. Every qualified voter residing in the water district who would be entitled to vote if it were a general election shall be entitled to vote at such election. The board of supervisors shall provide convenient polling places and election officers, and the election shall be conducted and returns thereof made and canvassed, and the result declared and certified in all respects as provided in the State Election Laws. In case of a tie vote, a new election shall be had, as provided by law for such cases.

SECTION 4. The commissioners shall hold office for the term of four years from and after their election, and until their successors are elected and qualified.

SECTION 5. A water district shall be a body politic and corporate, with the general powers of a corporation and the powers specified in this Act, and its board of commissioners shall have jurisdiction, and its powers and duties are as follows:—

1. To have perpetual succession, and to adopt and use a corporate seal.

2. To appoint some convenient place within the district as its place of business, of which notice must be published for three successive weeks in some newspaper of general circulation in the district.

3. To appoint a secretary, and, when required, to employ engineers and attorneys.

4. To hold regular sessions on the second Mondays in January, April, July, and October of each year, and special meetings whenever necessary, on five days' notice, by mail, to be given at the request of any member, by their secretary.

5. To appoint a water superintendent, who, under their supervision and instructions, shall be the executive officer of the board, and who may appoint one or more assistants to assist, when necessary, in the performance of his duties.

6. To protect the sources of water supply of the streams and their tributaries which supply the district, and the channels thereof, so as that the greatest amount of water possible shall flow therein, and especially to prevent any acts which might diminish the supply of water.

7. To inspect the channels and canals within their district at least once yearly, and report to the State engineer, when directed by him, the condition of said channels and canals and water supply, and all other matters of interest concerning irrigation in their district.

8. Generally to have supervision over the channels and waters of their district, and of the diversion of waters therefrom; to see to the proper distribution of all waters used by any and all irrigation districts, corporations, or persons, from the streams in their district, according, so far as practicable, to priority of right as settled by law, and to prevent useless waste thereof.

9. To establish, by orders published in a newspaper of general circulation in their district once a week for four weeks before they go into effect, and to enforce, by action or otherwise, such police regulations as to the diversion, use, waste, and distribution of the waters of the districts as they deem proper: Provided such regulations be not contrary to the laws of this State.

10. To require all divertors and users of water within the district to make to them an annual accounting of the amount of all waters diverted and used by them, and the number of acres irrigated thereby.

11. To establish upon all streams supplying the district, above the highest point of diversion of the waters in the district, a water-gauge, at which point the waters of such stream shall be measured, to guide in the distribution of the waters among the appropriators.

12. To do all other things necessary, properly to care for, distribute, and utilize the waters of their district for irrigation.

SECTION 6. The water commissioners shall, from time to time, make estimates of the necessary expenses of the district, and apportion the same among the appropriators of water in the district.

SECTION 7. Whenever a vacancy shall occur in the board of water commissioners, the board of supervisors of the county which established the district shall fill the vacancy by appointment for the unexpired term.

SECTION 8. Irrigation districts may be formed within the exterior boundaries of any water district. An irrigation district may include the whole of the water district, or such portion thereof as may be most economically irrigated from one system of canals or other works, or it may include a smaller portion on showing that the landowners of one portion desire to proceed with works of irrigation, while those of other portions do not; or be made to embrace lands already irrigated at the date of the passage of this Act, when it can be shown that the works constructed or the supply of water will not supply a larger area than the district proposed to be formed; or an irrigation district may be formed where the circumstances as described in Section 1 of this Act requiring a water district do not exist, and where, from the state of facts existing, the formation of a water district may be deemed unadvisable or unnecessary.

SECTION 9. Whenever any number of persons owning lands in a water district may desire to have an irrigation district organized, they may petition the board of supervisors of the county in which the

proposed district, or the largest part thereof, is situate, to inquire into and determine the feasibility of such organization. The petition shall contain a description of the boundaries of such proposed district, to be accompanied with a map of such district showing its exterior boundaries and the lands embraced therein with sufficient accuracy for identification, and to be accompanied with a good and sufficient undertaking, guaranteeing the payment of all costs and expenses in the matter of the organization of such district. The board of supervisors shall be the judges of the sufficiency of the undertaking.

SECTION 10. Upon the filing of the petition, map, and undertaking, as provided in the preceding section, the board of supervisors, at their next regular meeting, shall, upon the approval of the undertaking, fix a time for the hearing of such petition, giving at least three weeks' notice thereof in such newspaper as the board may deem most likely to give notice to the parties interested.

SECTION 11. The board of supervisors, upon such hearing, shall have power to reform the boundaries of the districts by including such land as may be equitably included, and excluding such as may be equitably excluded. If any change shall be made, a new description shall be made of the exterior boundaries of the district, which shall be signed by the supervisors, and the new boundary shall be marked on the map and the same approved by the supervisors. If no changes shall be found necessary, then the supervisors shall mark their approval on the petition and on the map. No land not described in the petition shall be included without notice, either personal or as provided for in section 10, to the owners thereof, with opportunity given them to be heard; nor shall any land described in the petition be excluded from the district without such notice or opportunity to be heard. And no such irrigation district can be formed without the written consent of the owners of more than one-half in value of the lands in the district, held in private proprietorship, as the same was valued on the then last preceding annual assessment roll of the county, has been filed with the clerk of said board. It shall be the duty of the board of supervisors, before making its final order establishing said district, to ascertain whether notice has been given as by this section provided, and whether the requisite petition of landowners has been filed, and if it so finds, it shall, in its order establishing the district, so declare, and its decision in that behalf shall be conclusive upon all persons whomsoever. Said order shall also contain a particular description of the boundary of the district by metes and bounds. Land within the exterior boundaries of the district may be excluded from the district upon showing that its irrigation from any of the works or proposed works is impracticable, in which case such excluded land must be described and marked upon the map as excluded. Said order and decree of the board of supervisors establishing said district, together with the map, shall be recorded in the book of water-rights of each county in which the district, or any part thereof, is situate. A traced copy of the map on vellum, securely fastened in the record book, shall be a legal record of such map. The board may, from time to time, change the boundaries of the district, by and with the consent of the landowners of the district representing a majority of the acreage of the district.

SECTION 12. The board of supervisors shall make an itemized account of all the expenses incurred in organizing the district. If the district shall be finally organized, all preliminary expenses herein authorized shall become a legitimate charge against the district, and the trustees thereof shall pay the same out of the first money collected in the district, but if the district shall not be so finally organized, the expense must be paid by the petitioners, and may be collected on the undertaking.

SECTION 13. An irrigation district shall be a body politic and corporate, with the general powers of a corporation, and the powers specified in this Act; and its board of trustees shall have jurisdiction, and its powers and duties shall be:—

1. To have perpetual succession, and to adopt and use a corporate seal.

2. To appoint some convenient place within the district as its place of business, of which notice must be published once a week, for two successive weeks, in some newspaper of general circulation in the district.

3. To appoint a secretary, and, when required, to employ engineers, attorneys, and labourers.

4. To hold regular sessions on the first Mondays in January, April, July, and October of each year, and special sessions whenever necessary, on five days' notice, by mail, to each member, by the secretary, on request of any member.

5. To appoint a water overseer, who, under their supervision and instruction, shall be their executive officer.

6. To look after the water supply to the canals and ditches by which the lands in their district are irrigated.

7. To see that all canals, ditches, and other waterworks which belong to the district are kept in good order and repair.

8. To establish, by orders published in a newspaper of general circulation in the district once a week for four successive weeks before they go into effect, and to enforce, by action or otherwise, such police regulations as to the reception, use, waste, distribution, and general management of the waters of the district as they deem proper: Provided such regulations be not contrary to those of the water district, if the irrigation district is within a water district, or the laws of this State: And provided further that if and while there be any canals, ditches, or other waterworks or water-rights in the district, not the property thereof, no regulations shall be made affecting the same, otherwise than to regulate the distribution of water to the owners thereof, according to priority of right, and to prevent useless waste of water by them and all persons.

9. To have the general and particular management of the affairs of the district, and all water and waterworks belonging to the same; the reception of the water therein from the stream, and the diversion of water therefrom, and the just distribution thereof to the irrigators of the district.

10. To purchase and construct canals, ditches, aqueducts, headgates, dams, tunnels, reservoirs, and all other works, and to purchase all other property which the proper irrigation of the lands of the district may require, and to secure the right of way over lands.

11. To authorize the issuance and sale of bonds, as hereinafter provided, for the purpose of raising money to be used in the purchase of works already constructed or in constructing new works, and to authorize the issuance of bonds to be used in payment of works already constructed, or in payment of the cost of constructing new works: Provided, however, that no bonds shall ever be authorized for any purpose, by said board of trustees, without there has been filed with said board a written request for the issuance thereof for such purpose of the owners of at least one-half the value of all the lands in said district held in private proprietorship as the same was valued in the then last preceding assessment roll.

12. To exercise, in behalf of the district, the power of eminent domain, as the agent of the State in the condemnation, in the manner provided by Title VII., Part III., of the Code of Civil Procedure of this State, of lands for waterworks of all descriptions, rights of way for canals and ditches, canals, ditches, and other waterworks, and all water-rights and water claims of whatsoever nature, and also any other private property, or private rights of property, however existing or acquired, or by whatever name designated, which may be necessary or useful for the appropriation or use of water for the irrigation of the lands in the district: Provided that in condemning the right to any property in water appropriated for some beneficial purpose at the time of the commencement of the action to condemn the same, a manifest greater public use shall be shown.

13. To levy a tax on all lands in the district benefited, or which can be benefited, by the irrigation thereof, for the general purposes of the district; to defray the expenses of the district, and to pay for the construction of canals, ditches, and other irrigation works, and to puchase those already constructed, by condemnation, or otherwise: Provided that no lands shall be taxed for the construction of works of irrigation except lands actually to be irrigated by works of such system.

14. To acquire water-rights of every description, by appropriation, purchase, or condemnation, for the benefit of the landowners of the district: Provided that waters already appropriated shall, after the organization of the district, be utilized, as at present, through existing works, or extensions of the same, so far as may be necessary for the irrigation of the lands dependent thereon. And provided further, and that all water-rights, and the right to the use of all water so acquired, shall be the property of the landowners of the district in equal parts *pro rata*, according to the acreage of irrigable lands owned by them; and the right to such water and the use thereof shall be attached to such lands *pro rata*, as aforesaid, as a perpetual appurtenance thereto and part thereof, transferable only with the land, designating the quantity; but the trustees must provide that, notwithstanding the quantity named, no more water shall at any time be furnished than can, by the owner of the land, be applied to some useful purpose of irrigation economically applied.

15. To contract with present canal owners for the use of water for the district, and to furnish surplus waters to owners outside of the district.

16. The board shall ascertain the assessed value of all the lands situate in the district, and the assessed value of the portion of such lands included in each county, and shall apportion the amount of money to be raised for expenditures to the different counties according to the value of the lands belonging to such district situate in each county, and shall make such apportionment a part of their estimate.

SECTION 14. Immediately after establishing the district the said board of supervisors shall issue a proclamation for an election, at which shall be elected three trustees for the district. Every qualified voter residing in the district, who would be entitled to vote if it were a general election, shall be entitled to vote for the three trustees at such election. The board of supervisors shall provide convenient polling places and election officers, and the election shall be conducted and returns thereof made and canvassed, and the result declared and certified in all respects as provided in the State election laws for county officers. In case of a tie vote, a new election shall be had as provided by law for such cases. The proclamation shall be published three weeks in such newspaper or newspapers as the board may deem most likely to give notice to the voters of the district. The proclamation must state the hours at which the polls will be opened and closed. The trustees shall hold office for the term of four years, and their successors shall be elected at a special election to be called by the board of trustees at least two months before the expiration of their terms, and for such election the trustees shall issue a proclamation as above provided. The trustees shall provide the polling places and election officers; the qualification of voters shall be the same as hereinbefore provided. The election shall be conducted, returns thereof be made to and canvassed, declared and certified by the board of trustees, substantially in the same manner that is provided by law with respect to county elections, and every four years thereafter the same course shall be pursued as to the election of trustees.

SECTION 15. The compensation of the boards of commissioners and trustees shall be five dollars per diem for each day actually employed in the discharge of their duties.

SECTION 16. It shall be the duty of the boards of supervisors of the counties in which irrigation district and parts thereof are situate, to levy upon the district lands within their respective counties their just proportion of the taxes to be raised, as herein provided, according to the assessed value of such lands, which taxes shall be levied and collected as other taxes, and, when so collected, shall be received and set aside by the county treasurer as an irrigation fund, to the credit of the district for which collected. The treasurer of the county in which a smaller portion of a district may be situate shall transfer the amount to the treasury of the county in which the greater portion of it is located. The trustees of the irrigation district shall audit and allow or reject all claims against the district, and shall certify all audited claims to the board of supervisors of the proper county, and the said supervisors shall order the same paid, unless on showing by some interested person they may deem the same illegal or unjust.

SECTION 17. If at any time the board of trustees deem it advisable to issue bonds and sell the same, or to use the bonds themselves to pay for works already constructed, or proposed works, or to pay for property condemned, and the necessary proportion of landowners consent thereto, as hereinbefore provided, the board of trustees shall pass an order directing the bonds to be issued, to an extent not exceeding the amount stated in the consent of the landowners, to be specified in the order, and the rate of interest and the minimum price at which the bonds may be sold shall be stated in the order. The bonds shall be in sums of not less than one hundred nor more than one thousand dollars each, having not more than twenty years to run, and bearing interest at not to exceed seven per cent. per annum, and shall not be sold for less than ninety cents on the dollar of par value.

SECTION 18. The board of trustees shall, immediately on the passage of any order to issue bonds, transmit a certified copy of the order with the required consent of the property owners therefor, filed with said board of trustees, to the board of supervisors of the county in which the district was formed, and it shall be the duty of said board of supervisors, without delay, to examine into the proceedings and ascertain, and by order determine whether the requisite consent of the landowners has been given, and whether the board of trustees have passed the necessary order, and whether all the proceedings necessary to the issuance of said bonds have been had and taken, and if it so finds, its order and judgment in that behalf, when entered, shall be conclusive upon all the world; and if its determination be that the requisite consent of the landowners has been given, that the board of trustees have passed the necessary order, and that all the

proceedings necessary to the issuance of said bonds have been had and taken, it shall order the bonds to be executed, numbered consecutively, and sealed.

SECTION 19. The said bonds shall be substantially in the following form: —

IRRIGATION DISTRICT BOND.

The county of , in the State of California, for value received, promises to pay , or order, at the office of the treasurer of said county, in , on the first day of or at any time before that date, at the pleasure of the county, the sum of dollars, gold coin of the United States, with interest at the rate of per cent. per annum, payable at the office of said treasurer annually, on the first day of in each year, on presentation and surrender of the interest coupons hereto attached. This bond is issued by the board of supervisors in the name of the said county, for and on behalf of irrigation district, in conformity with an order of said board, dated the day of , and in conformity with and after compliance with the provisions of an Act of the Legislature of the State of California entitled "An Act to provide for the organization and control of water and irrigation districts," approved (insert date of approval of this Act), and is payable only out of moneys to be raised by taxes levied upon the lands in said district as in said Act provided, and in no other way.

In testimony whereof, the said county, by its board of supervisors, has caused this bond to be signed by the chairman of the board and attested by the auditor, with the county seal attached, this day of .

Chairman of the Board of Supervisors.

Attest:

Auditor.

And the interest coupon shall be in the following form:—

The treasurer of county, California, will pay to the holder hereof, on the day of , at his office, dollars, gold coin, for interest on (name of district) Irrigation District Bond No. .

County Auditor.

The said bonds, when issued, shall be payable, principal and interest, only out of taxes levied upon the lands in the irrigation district, and the county shall never in any event be liable therefor.

SECTION 20. Whenever bonds issued under this law shall be duly executed, numbered consecutively and sealed, they shall be delivered to the county treasurer, and his receipt taken therefor, and he shall stand charged on his official bond with all bonds delivered to him and the proceeds thereof, and he shall sell the same or pay them out as directed for the purposes hereinbefore provided, as directed by the written resolutions of the board of trustees of the district, and the proceeds of all bonds sold shall be kept by the said treasurer in a separate fund and paid out upon the written resolutions of said board of trustees, and not otherwise.

SECTION 21. Whenever the amount in the hands of the treasurer belonging to the sinking fund is sufficient to pay one or more of said bonds, he shall advertise in one daily newspaper published in the city and county of San Francisco that he is ready to redeem such bonds, giving the numbers of the bonds he is ready to redeem, and, at the end of forty days from the first publication of said notice, interest on said bonds so advertised shall cease. All redemptions shall be made in the exact order of the issuance of the bonds, beginning at the lowest or first number.

SECTION 22. Before entering upon the duties of his office, each commissioner and trustee shall be required to take the oath of office, and file with the county clerk of the county in which he resides a good and sufficient bond in the sum of twenty-five hundred dollars, conditioned for the faithful performance of his duties, which bond shall be approved by the superior judge of the county where filed.

SECTION 23. The duties of the secretary shall be:—First, to record all the proceedings of the board; second, to make full entries of all their resolutions, decisions, and allowances; third, to record the vote of each member upon any question upon which there is a division; fourth, sign all orders made and warrants issued by the board for the payment of money, and certify the same to the supervisors of the county in which the same is to be paid; fifth, keep an account against the treasurer of each county in which any part of the district lies, preserve and file all accounts acted upon by the board; sixth, to prepare, under the direction of the board, an annual estimate of the amount of money required to meet the expenditures of the succeeding year, and apportion the amount thereof to be raised in each county, and file the same with the clerks of the boards of supervisors of the counties in which the lands of such district are situate, on or before the first day of July of each year; seventh, to perform all other duties required by law, or any rule or order of the board.

SECTION 24. The board of trustees of each district shall ascertain the assessed value of all the lands situate in the district, and the assessed value of the portion of such lands included in each county, and shall apportion the amount of money to be raised for expenditures, as provided in the last preceding section, to the different counties according to the value of the lands belonging to such district situate in each county, and shall make such apportionment a part of the estimate mentioned in the last preceding section.

SECTION 25. The board of trustees must cause to be kept:—First, a minute book, in which must be recorded all orders and decisions made by them, and the daily proceedings had at all regular and special meetings, and all police regulations, all orders for the allowance of money from the irrigation fund, which order must state to whom made, and on what account, dating and numbering the same consecutively each year; second, a record of warrants to be kept by the county auditor of the counties in which the lands of the district are situate, in which he must enter, in the order of drawing, all warrants certified to the supervisors, with the number on the minute book, with the date and amount, and on what account, and the name of the payee.

SECTION 26. Whenever bonds shall be issued, as in this Act provided, it shall be the duty of the boards of supervisors of each county in which any part of the land of such district is situate, in each year thereafter, at the time at which other taxes are levied, to levy upon the lands of the district a tax in addition to the taxes in this Act authorized to be levied, for the purpose of paying and sufficient to pay the annual interest on such bonds, and not less than five per cent. of the original principal, in order to create a

sinking fund. Such tax, when collected, shall be kept in a separate fund, and inviolably appropriated to the payment of such indebtedness. The board of trustees shall, in each year, ascertain the assessed valuation of all the irrigable lands of such district, and of the lands lying within such district situate in each county separately, and shall apportion the amount of such tax to be raised in each county, and shall communicate said apportionment to the clerks of the several boards of supervisors, not less than thirty days prior to the time of levying the annual taxes for State and county purposes.

SECTION 27. Whenever a vacancy shall occur in the board of trustees of any irrigation district, the vacancy shall be filled by appointment by the board of supervisors of the county which established the district, till the next annual election at which time his successor shall be elected for the unexpired term.

SECTION 28. In the measurement of all waters throughout this State, one cubic foot flowing per second shall be the unit of measurement.

SECTION 29. Any person violating any of the provisions of this Act, or of any of the police regulations of the water commissioners or district trustees, shall be guilty of a misdemeanor.

SECTION 30. Nothing contained in this Act shall be construed as a recognition that any law now does exist, or has ever existed in this State, which divested the right of this State to allow, or otherwise prevented the State from allowing, the appropriation of the waters of this State to any and all useful and beneficial purposes.

SECTION 31. This Act shall take effect from and after its passage.

APPENDIX C.

FRESNO SANDHILL SOIL.

	Fresno Sandhill Soil, California.	Homochitto Bottom Soil, Mississippi.
	Per cent.	Per cent.
Insoluble residue	86·58	
Soluble silica	3·53 } 90·11	91·97
Potash	·19	·15
Soda	·38	·04
Lime	·99	·12
Magnesia	·78	·21
Br. oxide of manganese	·06	·28
Peroxide of iron	3·20	1·18
Alumina	3·13	3·27
Phosphoric acid	·02	·08
Sulphuric acid	·04	·05
Water and organic matter	1·53	2·70
	100·43	100·05
Humus	·43	...
Available inorganic	·50	...
Hygroscopic moisture	1·21	4·05
Absorbed at	12° C.	8° C.

NOTE.—This poor soil produces well on account of its depth, the roots easily penetrating from 3 to 8 feet, which in richer soils need only from 12 to 20 inches.

APPENDIX D.

SOIL OF ONTARIO COLONY, SAN BERNARDINO CO.

Unlike the usual mesa soils of the southern region, this soil is of a blackish grey tint, due, as will be seen, to an unusually high percentage of humus. The surface soil to the depth of six inches is quite sandy and full of herbaceous roots, denoting a vigorous vegetation, and glistens with mica scales. Lower down it becomes more compact, and at the same time shows an increasing amount of rock fragments, and so continues until at the depth of five feet the latter form quite half or more of its mass, the finer portion remaining, however, of nearly the same dark greyish tint as at one foot depth. The rock fragments, all angular, consist mostly of schistose material, largely gneissoid. The analysis of the soil, taken to 12 inches depth, resulted as follows:—

	Per cent.
Fine earth	53·2
Stones and coarse sand	46·8

Analysis of Fine Earth.

Insoluble matter	43·50	66·54
Soluble silica	23·04	
Potash		1·58
Soda		·43
Lime		2·77
Magnesia		2·87
Br. oxide of manganese		·06
Peroxide of iron		5·58
Alumina		14·20
Phosphoric acid		·09
Sulphuric acid		·04
Water and organic matter		5·53
		99·68

Humus	1·29
Available inorganic	·42
Hygroscopic moisture	4·44
Absorbed at	12° C.

From its composition this soil would naturally be conjectured to be that of a cienaga (artesian swamp). Its potash percentage is extraordinary, exceeding that of any other California soil thus far examined; and, with its relatively high amount of soda, would arouse a suspicion of "alkali," if that were possible in a location and soil naturally so well drained. The extraordinary percentage of "soluble silica" explains the seeming anomaly, in suggesting the innocuous combination in which these substances doubtless exist.

The lime and magnesia percentages are very high, as is, for that region, the item of humus; and that of phosphoric acid, while it would not generally be considered high, is so, at least in comparison with other mesa soils of the southern region. Considering, in addition, its depth, this soil should be extremely productive—almost too much so for the production of high quality wine grapes, but well adapted to that of raisins, as well as of olives, and doubtless, from its location, to that of citrus fruits; all of which should in such a soil require only one or two good winter irrigations to secure both quantity and quality.

SOIL OF REDLANDS COLONY, SAN BERNARDINO CO.

The prevailing soil of this region is a reddish brown sandy loam, containing a good deal of coarse angular sand. This material changes but slightly to the depth of from three to four feet, where it is mostly underlaid by an orange yellow hardpan, flecked with white, the white spots being grains of coarse angular sand, or rather granitic débris, consisting mainly of quartz and felspar, with a little black hornblende and magnetic iron ore (black sand). This hardpan appears in gullies and ditches everywhere, being usually many feet in thickness. It is quite porous, and its cement is a red clay, which softens in water with little difficulty. Dry lumps can also be crushed between the fingers, so that this subsoil may be considered as fairly penetrable by roots. Occasionally this hardpan approaches the surface so closely as to take direct part in the formation of the soil. The analysis of the soil and subsoil hardpan resulted as follows:—

	Red Soil. 12 inches deep.	Hardpan Subsoil. 3 to 4 feet deep.
	Per cent.	Per cent.
Fine earth	·9	81.2
Coarse sand	42·1	108
Analysis of Fine Earth.		
Insoluble matter	69·56	67·14
Soluble silica	11·82	10·81
	81·38	77·95
Potash	·85	·32
Soda	·11	·40
Lime	1·34	1·44
Magnesia	1·11	2·58
Br. oxide of manganese	·08	·07
Peroxide of iron	3·46	4·86
Alumina	8·87	10·08
Phosphoric acid	·06	·06
Sulphuric acid	·01	·03
Water and organic matter	2·69	3·00
	99·96	100·79
Humus	·37	...
Available inorganic	·27	...
Hygroscopic moisture	3·37	5·86
Absorbed at	12° C.	12·5° C.

As regards, first, the mechanical nature of these materials, it is striking that the hardpan subsoil contains so much less of inert sand than the surface soil, although its aspect would lead to the contrary conclusion. The hardpan is considerably more retentive of moisture than the surface soil, albeit the latter contains some humus to increase this factor. The humus percentage of this soil is, however, very small, and constitutes its chief defect, as in nearly all the mesa soils of the southern region. The hardpan stratum secures the land against waste of irrigation water and against drought by its high retentiveness of moisture.

Chemically the surface soil is rich in potash (so heavily drawn upon by the vines), while the hardpan is relatively poor in that substance. The lime percentage is the same in both, and is ample. In phosphoric acid, both alike are above the limit of deficiency, but the supply is not large, and will probably be the first needing to be replenished when the soil becomes "tired." Still, in view of the depth and perviousness of the subsoil, it may be long before this condition will make itself felt in the case of deep-rooted plants, such as vines and fruit trees.

APPENDIX E.

ANALYSES OF COLORADO SOILS, BY S. JAMIESON, ABERDEEN.

—	Larimer County.		Arapahoe County.					Pueblo County.
	Adobe.	Upland Clay Loam.	Platte Land Co's. Land, Sampled 1879.	Clay Loam — S. 29, T. 2, S. 66, W.	Sandy Clay Loam from Sand Creek. — S. 33, T. 3, S. 66, W.		Sandy. — S. 21, T. 3, S. 66, W.	Osage Avenue.
					Surface.	Subsoil.	Surface and Subsoil.	
Volatile matter	2·49	1·31	10·10	3·90	4·23	4·18	1·87	6·83
Matter soluble in strong acid	11·40	5·33	2·58	3·82	3·98	4·30	2·08	3·11
Matter insoluble in strong acid	86·11	93·36	87·32	92·28	91·79	91·52	96·05	90·06
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
The volatile matter contained nitrogen ...	·14	·13	·07	·088	·083	·022	·005	·10
The soluble portion contained—								
Lime	2·27	·26	·55	·17	·14	·43	·16	·38
Magnesia	·54	·44	·13	·25	·29	·57	·16	·28
Potash	·39	·43	·23	·13	·11	·10	·06	·22
Iron oxide	1·04	1·25	1·28	3·14	3·35	·08	1·61	1·79
Alumina	2·39	1·20						
Phosphoric acid (anhydride)	·12	·10	·11	·13	·09	·12	·09	·14
Sulphuric acid „	·23	·20	·11	trace	·00	·00	·00	·13
Nitric acid „	trace	trace	...	...	...	...	...	...
Carbonic acid „	1·80	·20	...	...	...	...	...	...
Chlorine „	·10	·03	·17	...	...	...	...	·17
Soda, carbon, matter, &c.	2·43	1·22	...	...	...	...	...	...
	11·40	5·33	2·58	3·82	3·98	1·30	2·08	3·11

The distinctive characteristics of these soils are, the large proportion of potash; the form in which the phosphates exist; nearly the whole is soluble in weak acid, and hence can be readily assimilated by plants; the low percentage of organic matter, and the high proportion of nitrogen the organic matter contains; the large proportion of lime in the adobe soil; generally the ready available form of all the onstituents.

APPENDIX F.

WATER FROM AN ARTESIAN WELL IN THE CROSS CREEK REGION, TULARE COUNTY.

The sample examined was supplied by Mr. Cutler Paige, who states that the well from which it was taken is of large bore. The water is clear, and possesses no obvious peculiarity of taste. It, however, shows a slightly alkaline reaction on delicate test-paper. On evaporation it leaves a whitish residue,

amounting to 11·8 grains per gallon, of which water re-dissolves only a little over 10 grains, leaving about 2 grains of insoluble residue. These portions are constituted as follows :—

—	Grains per Gallon.	Per cent. of Residue.
SOLUBLE PART		
Sulphate of potash	·745	6·31
Carbonate of potassium	·380	3·22
Carbonate of soda	8·559	72·54
Chloride of sodium	·405	3·43
Total soluble salts	10·079	85·50
INSOLUBLE PART.		
Carbonate of lime	·457	3·88
Carbonate of magnesia	·708	5·97
Silica	·808	6·85
Total insoluble matter	1·973	16·70

It will be seen that, while the total residue contained in this water is not unusually large, over two-thirds—eight and a half grains—consist of carbonate of soda, or "black alkali." At the same time, nearly one grain per gallon consists of salts of potassium, of high manurial value; so that irrigation to the extent of 10 inches over all would supply about 53 pounds of these substances per acre.

On land entirely free from alkali this water might be used for irrigation for a number of years without injurious effects, although with surface irrigation the accumulation of carbonate of soda would after a while become detrimental to plant growth. On land already more or less impregnated, the addition made by the annual irrigation would soon become perceptible, unless counteracted by the use of plaster for the neutralization of the carbonate of soda by gypsum.

WATERS FROM SOUTHERN CALIFORNIA.

Water from San Fernando Tunnel, Los Angelos County.

The result of the analysis is given in the following table. The water leaves on evaporation a saline residue amounting to 67·6 grains per gallon. (Ordinary river and well waters contain from 6 to 12 grains.) Treatment with water resolves this residue into an easily soluble and a difficultly soluble or "insoluble" portion as separately given below :—

—	Grains per Gallon.		Per cent. of Total Residue.
SOLUBLE PART.			
Sulphate of potassium	·853		1·262
Sulphate of magnesium (Epsom salts)	14·175		20·974
Sulphate of calcium (gypsum)	·137		·203
Sulphate of sodium (Glauber's salt)	3·578		5·294
Chloride of sodium (common salt)	1·344		1·989
Carbonate of sodium (common soda)	2·069		3·062
Organic matter (by diff.)	4·372		6·470
INSOLUBLE PART.			
Carbonate of magnesia	1·80		2·677
Carbonate of calcium (lime)	6·18		9·138
Sulphate of lime (gypsum)	30·60	40·76	45·276
Silica	2·10		3·076
Iron oxide and alumina	·07		·103
Total	67·258		99·254

The total amount of mineral ingredients in this water is far greater than is admissible in waters intended for domestic use of any kind. But even if the quantity were much less, the quality of the ingredients—including so large a proportion of gypsum and Epsom salts—renders it highly objectionable for drinking purposes, and it is only by the addition of a considerable amount of soda that it could be made to answer for washing.

As regards its fitness for irrigation, it should be noted that out of the (in round numbers) 68 grains of solid contents, nearly 41 belong to the "insoluble" class, and are in quality not only unobjectionable from the irrigator's point of view, but the bulk being gypsum is actually a benefit to most lands, especially those afflicted with "black alkali." It is only the 27 grains of soluble matter that remain to be dealt with. Of these the four grains of "organic matter" need not be considered; and of the remainder, the mainly objectionable portion is the 14 grains of sulphate of magnesium, or Epsom salts, an accumulation of which

in the soil would soon become very injurious, although small dressings of it in the guise of "kieserite" are used for fertilization in Europe and the East. But in the lower San Joaquin Valley it renders considerable tracts uncultivatable until it is removed. This can be done by the use of quicklime, of which about one-half of the amount of sulphate of magnesia present is needed for complete removal. The outcome of the mutual action of these substances is gypsum and inert magnesia; applying, therefore, seven grains of lime per gallon of the San Fernando water, or say three barrels of lime to every million of gallons, the alkaline salts remaining (about nine grains) would not exceed what is found in many of the natural irrigation waters of the State.

Whether or not such a correction of the water in question would pay, will have to be determined by local circumstances. Where land now uncultivatable can be made to produce high returns in fruit or grape culture, and from $10 per acre can be made worth $150 or more, the expenditure required may not be at all unreasonable. One million gallons will cover nearly 40 acres to the depth of one inch, and by eking out the natural rainfall with the needful amount of this water, wholly or partially corrected by means of lime, all that is needed for successful culture may, in many cases, be cheaply realized.

There is, however, one class of land upon which this water would be an unmixed benefit just as it is. This is the alkali lands, such as those of Westminster, Anaheim, and Orange. Here the use of gypsum supplies the natural antidote to the carbonate of soda which is the chiefly injurious ingredient of the alkali, but which would be active first of all in decomposing the objectionable Epsom salts, leaving the gypsum in the soil to counteract any excess or additional rise of the alkali from below. If then it be feasible, financially, to convey the San Fernando water to these lands, it could be utilized, for a long time at least, without any correction.

In using it on non-alkaline lands, also it would probably remain harmless for some years on those soils naturally rich in lime. Whenever any injurious action is noted, the use of lime on the land, or in a reservoir furnishing the water, can be made to correct it. It should not be forgotten that the large supply of gypsum and lime thus put on the land acts as an efficient fertilizer, and is, therefore, not an altogether unremunerative expense in itself.

APPENDIX G.

ARTESIAN WELLS.

TYPICAL WELL OF THE DENVER BASIN, ILLUSTRATING THE PRINCIPAL FEATURES OF THE LARIMIE FORMATION.

	Feet.
A seam of gravel and surface wash	12
Clay	17
Sandstone	1
Hard clay	94
Hard sandstone	8
Clay slate	22
	154
Sandstone (first flow of water)	14
Hard clay	24
Sandstone	2
Very tough hard clay	50
	244
Sandstone (second flow of water)	16
Hard clay	30
	290
Sandstone (third flow of water)	10
Blue clay	8
Sandstone (fourth flow of water)	12
	320
Soft clay	15
Dark hard clay	15
Loose white sandstone (fifth and greatest flow)	25
Total depth of old well	375

The well was cased with 3in. pipe to a depth of nearly 300 feet. Pressure, 25 lbs. Discharge not given, probably 150,000 gallons. Other wells gave pressure of 70 lbs., and decreased to 20 only. The electric light works well. Three hundred and seventy-five feet is well cased, and the flow has not varied during ten months on account of unusual care being taken to make tight joints. Rainfall per year, 14½ inches. Denver lies in a horse-shoe basin valley. (Seed bag packing acts apparently by the swelling of the seed.)

APPENDIX H.

MACHINERY USED IN BORING, COLORADO.

The tools and machinery used in sinking artesian wells in the Denver basin are usually of a very simple description. A boiler of about 20 horse-power, and a reversible link motion steam-engine of about 15 horse-power, furnish power sufficient to sink to any depth necessary there. The engine is directly connected with a band wheel, which oscillates the walking beam. At the further end of the walking beam is attached a short rope terminating with a temper-screw. At the lower part of the temper-screw the sinking cable is attached by means of an adjustable clamp. The drilling portion of the machinery weighs about 2,600 lbs., and consists first of a bit of the kind usually called a club bit, which is screwed into the lower end of the "augur stem." This augur stem is a rod of iron about 32 feet long, and $3\frac{1}{4}$ inches in diameter, and upon its upper end are screwed the jars or links, and to them the "sinker-bar," which is usually a $3\frac{1}{4}$in. bar of round iron, about 14 feet long. To its upper portion is attached by screwing a rope socket, by which the whole is united with the cable. The bit is a solid mass of steel, and is dressed out at its lower or cutting end to a width of from $5\frac{1}{2}$ to 10 inches, according to the diameter of the hole. The part played by the jars is very important. When the entire drilling apparatus is lifted, these jars are extended to their full length, but when the mass is lowered, the drill meets the rock through which it is advancing, stops, and is struck upon the top by the sinker-bar which plays through the jars.

To enlarge the bore or smooth its sides before inserting casing, a rimmer of steel, weighing about 125 lbs., is attached to the lower part of the augur stem in place of the bit. The drilling rope is of manilla, from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter, and of a length necessary to complete the boring. This rope, after passing through the temper-screw clamp, is attached to the "bull-wheel," which is connected with the hand wheel by a "bull-rope." Above the well is a derrick of lumber, and usually about 64 feet high, which is used for lifting the tools and drill. The stroke of the walking beam is adjustable, and varies from 15 inches at the upper part of the work to about 36 inches at the lower portion of the well. After three or four feet are drilled, the drill is lifted out and the "sand-pump" lowered. This "sand-pump" is a tube of light iron, 12 feet long, with a valve at its lower extremity. The sand-pump is attached to a manilla rope, $\frac{3}{4}$ in. in diameter, and is lifted by a friction pulley on the band wheel. Two shifts of two men each—a driller and a tool-dresser—are employed. Much skill is necessary in the driller, who regulates the play of the sinker-bar upon the drill by means of the temper-screw, and the success or failure of an attempt to sink depends largely upon the driller's practical knowledge or experience.

When trouble is experienced from caving, the bore is cased to its lowest point, and a drill of less width substituted.

Cost of sinking about Denver is about 2 dollars per foot.

APPENDIX I.

The following table of results was obtained by placing in a vessel containing water, kept at a constant level, wide glass tubes filled with the different soils, and recording, from hour to hour at first, then from day to day, the heights reached by the ascending moisture.

No. 1.—Coarse, sandy soil, from Morano Station, Stanislaus county, may be considered as representing the more "open" plains soils of Kern and Tulare counties.

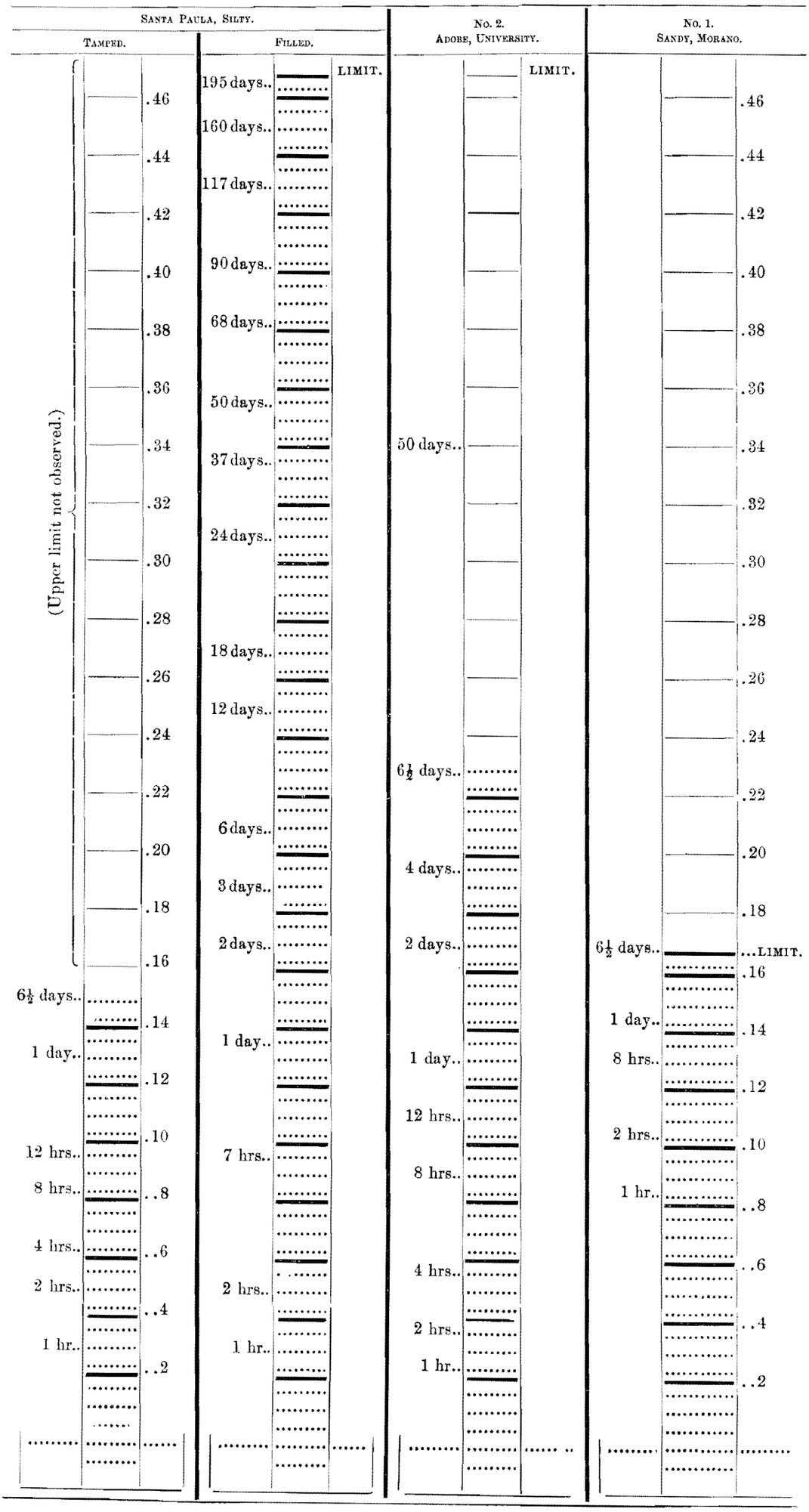
No. 2.—Hill adobe soil, from the campus of the University. A very refractory clay soil, very tenacious when wet, and when dry, untilled, opening into wide, gaping cracks to 18 inches depth.

No. 3.—Light sediment soil, from Mr. Blanchard's orange orchard, on the first bench of the Santa Clara River Valley, at Santa Paula, Ventura county. Is remarkable for remaining moist within 20 inches of the surface throughout the season, the water table being at 15 to 20 feet below the surface; very easily worked at all times.

No. 4.—Same as the last, but somewhat compacted by light ramming or tamping in the tube, as it would be if left untilled.

With the exception of No 4. the above soils were in a condition of perfect tilth.

TABLE SHOWING RAPIDITY OF ASCENT OF WATER IN DIFFERENT SOILS, AND LIMIT OF SAME.



This table illustrates forcibly some important points in the management as well as in the natural peculiarities of soils. The coarse sandy soil represents not only its kind, but also any well-tilled soil; while, on the other hand, the adobe soil illustrates the case of any compact soil, whether naturally so, or rendered so by imperfect tillage or the prevalence of carbonate of soda. The extreme slowness of the ascent of the water toward the end of its possible rise shows why a poorly-tilled adobe soil will open into gaping cracks a short time after the cessation of rains, while a well-tilled soil, maintaining both a quicker supply from below and a slower rate of surface evaporation, may maintain moisture throughout the dry season. At the same time, it informs us that sandy soils stand in especial need of a more dense subsoil, capable of drawing up moisture from greater depths than it is possible for a sandier mass to do, and thus supplying moisture to the roots of plants, while allowing but little surface evaporation.

In the case even of the light sediment soil from Santa Paula the difference between the rate of ascent in the tilled and the compacted soil is very apparent, and, in the case of the adobe, subsequent experiments showed that, when in the compacted state, the rate of ascent may be less than half of what it is in the lower portion of the column representing the tilled adobe.

Water applied to a soil like No. 1, at the depth of 24 inches, cannot reach the surface at all, and can therefore evaporate but very slowly. It does not, therefore, follow that, in order to produce the same result in the adobe or silt soils, the water has to be applied at the maximum depth of 50 inches. For, in a field planted with any growing crop, the leaves of the latter evaporate a very large amount of moisture, thus intercepting that which would otherwise rise to the surface and evaporate there. This is a matter of every-day experience. The inference is that ditches or pipes designed for sub-irrigation would not in such soils require to be laid to any unreasonable depth in order to prevent the rise of alkali resulting from surface evaporation.

APPENDIX J.

APPENDIX TO THE EIGHTH BIENNIAL REPORT OF THE STATE BOARD OF HEALTH, CALIFORNIA.

Irrigation—Its Influence on Health, etc.

By H. S. Orme, M.D., Member of State Board of Health.

The question of the effect of the irrigation of agricultural lands, particularly in California, upon public health is one of growing importance, and, inasmuch as the available evidence bearing upon the subject is somewhat contradictory, it is necessary to note the conditions of locality, with respect to soil, temperature, humidity, and drainage wherever irrigation is practised.

Although irrigation has been carried on in California since the first establishment of the early missions by the Franciscan Fathers, more than a century ago, very little progress has been made in the scientific application of the system, the object of the cultivator being apparently only to get the water upon his land, without regard to the method employed.

The application of the water used in irrigation varies greatly in manner, but may be described as two different methods, viz.: first, by flooding the whole surface of the land from open (*zanjas*) ditches; and second, by sub-irrigation—that is, a conveyance of the water through pipes beneath the surface of the ground, which have openings at intervals protected by upright pipes.

So far as the effect on health is concerned, the latter method will not be considered, because of the very limited extent to which sub-irrigation is being applied.

In the case of the application of water by *flooding* the land from open ditches, the various reports, though made by impartial authorities, are in some respects conflicting. For instance, in Los Angeles, Ventura, Santa Barbara, San Bernardino, and San Diego counties, where irrigation has been carried on for over a hundred years, the testimony is strong to the point that there is no striking difference in the amount of malarial diseases, whether irrigation is practised or not. On the other hand, if we consult the records of some other portions of California, we find an increase of malarial fevers with the increase of irrigation, too intimately connected to be overlooked. The reasons for this are not difficult to discover. In the Los Angeles and other valleys in extreme Southern California, where the soil is, as a rule, sandy or gravelly loam of unknown depth, the water used in irrigation either sinks into the ground, or, if there is much surface slope, immediately drains off. The soil does not remain saturated unless there is a stratum of clay (hard-pan) at or near to the surface. In such sections of country there is great freedom from malarial diseases. Along the bottom lands of rivers where the slope is insufficient to ensure good drainage, or where the soil is constantly saturated, the case is different. Here there is more or less intermittent and remittent fever during the warmer season of the year. In the case of swamp or overflowed lands, especially those having a heavy adobe soil, as well as those which remain wet and boggy from the winter rains, and are in summer kept in a saturated condition by artificial means, containing also an excess of decomposing vegetable matter and many stagnant pools, malarial diseases of the most pronounced type are very prevalent. In such localities all zymotic diseases are much worse in summer than in winter—a consequence which naturally results from the high temperature and increased evaporation. The fact that the people living in these low, wet adobe sections of country are dependent upon impure or surface water for drinking and domestic purposes greatly aggravates the difficulty. Indeed, it has been more than once demonstrated that people living in a "fever and ague" country are tolerably exempt from the fever if they drink only pure water.

Concerning this view of the subject I make use of a report made in May, 1884, by Will S. Green, editor of the *Colusa Sun,* to the State Irrigation Convention. He states, in substance, as follows:—

"During a residence of 34 years in the Sacramento Valley I have had an opportunity to observe the effects of irrigation on health, and have been led to reject the theory of infection by malaria in the atmosphere. All along the margins of the tules people are living, some of whom are attacked by chills, while the occupants of other adjacent places are never so attacked. All these people breathe the same air, coming to them from the same hot stagnant water and decaying vegetation.

"There are clay or hard-pan banks to the Upper Sacramento River, which are from a quarter of a mile to a mile apart. There is, in consequence of the action of the river current, a clay formation, and a new alluvial formation. I began to notice that those people who built their houses and *dug their wells* on a newer formation generally had chills, while the others, as a rule, had none. Sometimes these sickly and healthy places would be but a few feet apart. They all breathed the same air, but they *did not drink the same water.* The town of Colusa is built upon the old clay formation, and the inhabitants are almost entirely free from chills, typhoid fever, diphtheria, &c., but just at the lower end of the town there is a new formation, and upon this an extension to the town was located; and among other buildings the County Hospital was placed there. The patients and employés of the hospital all had chills for several years, until the physician in charge, Dr. W. H. Belton, noticed that the people generally who used water from wells on this newly-made land had chills, while the others had not, and caused pipes from the town waterworks, into which river water was pumped, to be laid to the hospital. There was an *immediate* change. At the commencement of the use of river water there were some forty persons in the hospital, all with chills, but since the building has been almost entirely free from it. There could be no more conclusive evidence that these people *drank* the germ of the disease, and *did not breathe it.*

"It is claimed that after a wet season there is more malaria in the air, and that hence people are more subject to disease. I have investigated this, and my observations, extending over a number of years, have convinced me that the water in the wells is simply raised to a newer strata—one not thoroughly washed, as it were, and that people there drink the germ of disease, and do not breathe it.

"My conclusions are, therefore, that irrigation will tend to bring on malarial disorders, as it raises the water in wells to a newer strata of earth, but no farther. When we irrigate so as to produce this effect we must *go down* after pure drinking water, or bring it to our houses in pipes. * * *

"In some localities, where the air is not in motion every day, as it is here, the air, like standing water, may become stagnant. I know of some hotels in this valley totally void of drainage, and where the accumulated filth of a quarter of a century stands in the yards in cesspools. In some countries this would kill ninety out of a hundred people who would stop in them a week, but here we feel no inconvenience from it, except in so far that the water may become impregnated. Air in motion, like water in motion, purifies itself, and hence I have come to the rejection of the theory of malaria in the air."

The same gentleman, writing further on this subject, under date of July 14th, 1884, remarks:—

"Stony Creek runs into the river through the plains. It once had its mouth below its present one, and has worked north. On the land that the creek has thus made there are settlers. Some of them have chills. At other places no such thing is known. Just off the made land there are no chills. There is, apparently, nothing to make a difference—no tree, no shrub of any kind—all an open plain, with the wind blowing from the south or north every day. Some of these people get water in a soil mixed with vegetable mould, rotted so as to appear to be all earth, but in reality it still retains the parasite of the chills called malaria, while the others get water not so impregnated. This is a large extent of country—some eighteen miles by three—and it gives the inquirer a good opportunity to make a rule.

"The hospital case, however, mentioned in my letter to the Riverside State Convention, is the most conclusive, and for this we have the evidence of Dr. Belton. He endorses my theory."

Further on I shall append to my own remarks quotations from correspondence addressed to me on this subject.

In many instances where diseases are attributed to malarial influences, I am convinced, in addition to the one of impure water for drinking purposes, that a serious cause of evil lies in the habitual disregard of all sanitary laws by the people. Improper food and clothing, reckless exposure, and personal uncleanliness, will dispose to diseases closely allied to those charged to malaria, and such conditions are too often found among the lower class of our people.

Without discussing the germ theory, as applied to zymotic diseases, it may safely be said that the application of water to the soil during hot weather has the effect of developing into activity many forms of organic germs, including minute algæ, confervoids, diatoms, bacteria, &c.

The germ spores of these organisms require both heat and moisture for their full development. Until then, they remain in a passive condition for weeks, months, and even years; but in the presence of heat and moisture, they develop and become prolific with the most wonderful rapidity.

In substantiation of this a recent Paris medical journal gave the results of a series of investigations continued for eight years into the composition of the Paris atmosphere:—"It was found to hold in suspension cotton, hemp, wool, hair, down, pollen, starch, particles of skin, carbon, silex and various salts, iron, dead insects, ova of infusoria, and especially spores of cryptogamia and bacteria. The spores vary from 3,000 in March to 54,000 in June, and moisture increases their number. The mortality from infectious diseases increases with the number of bacteria."

A microscopist, living in Los Angeles (Professor J. W. Redway), in answer to certain queries, informed me that, after going through an orchard which had been recently irrigated, he always found present, in his saliva, not only those particular species of bacteria which are peculiar to moist soil, but also the spores of that organic growth variously known as green scum, green mould, fever and ague plant, &c. Not only were these found in the mucous secretions, but they were also present in the perspiration.

Fortunately, the exceeding dryness of the atmosphere in those sections of our state where irrigation is most generally used, and our daily ocean winds, prove our best safeguards against the dangers of malarial infection, excepting in the few localities where the ground is kept saturated for lengthened periods.

It is barely possible that intermittent and remittent fevers are more prevalent in well-drained orchard lands, where irrigation is carried on, than where none is practised, but it will require long and careful observation and experiment to establish this fully.

The fact, however, that bacteria and other organic growths are more abundant in the neighbourhood of irrigated than of dry lands is an important point, and should be studied closely with the aid of microscopic research.

The same dangers arising from irrigation are likewise great in the case of street sprinkling, and is it not possible that some of those troubles of the throat and nasal passages, so closely resembling "hay fever," are caused by inhaling the dust of the streets, which is always alternating between saturation and dryness?

The prevention of zymotic diseases in irrigated districts has of late received considerable attention. Of the methods employed, the removal of the surface water, and, where possible, the provision for systematic drainage, has been the most successful. For *irrigation in order to be innocuous must go hand in hand with drainage.* This fact has been demonstrated, time after time, by the drainage and cultivation of marshes whose noxious exhalations had previously rendered their vicinity uninhabitable, but which, after drainage and cultivation, became healthy and fertile lands. These results are due to the removal of the superabundant moisture and the conversion of the decomposing organic matter into plant food. It may also be said here that while the dangers from standing water are serious, those arising from running water are in our climate comparatively slight, for has it not been often asserted, and believed by many, that running water, like air in motion, does much to purify itself?

Where drainage cannot be accomplished, the removal of the products of decomposition by absorptive plants bids fair to be successful to a large extent. The planting of the helianthus (sunflower) in the Potomac flats, and the culture of rapidly-growing plants in the bayous of Louisiana, have certainly modified the prevalence of fevers in the localities where they have been grown. The planting of the eucalyptus in the Campagna of Italy is a more remarkable case, for there districts which had been wholly depopulated were made not only habitable, but even healthy, by the growth and influence of eucalyptus groves. In parts of California the cultivation of the cinchona tree might be successfully carried out. Not only does the cinchona possess all the virtues of the eucalyptus, but it also commends itself as a source of revenue and profit. In Southern California there exists every condition requisite to its successful culture.

By systematic removal of the surface water by drainage, together with the intelligent and careful cultivation of the soil, and the planting of those trees which help to bring about salubrity, it is confidently expected that much good may be looked for in the future.

There is also another imperative necessity, namely, that people must be taught how to live. The study of physiology must include the elements of hygiene, or sanitary science, and the lesson must be taught that sound health can no more exist in the same house with foul water, foul air, and foul persons, than can moral virtue be contained in a phosphoric nimbus of filth. For, has it not been truly said, "That the health of the people is really the foundation upon which all their happiness and all their power as a State depends."

The following communications from reliable and prominent physicians, and others, have been received within the past few weeks, in reply to requests for opinions and observations on this subject. They will be read with interest, as showing a remarkable unanimity of opinion to the effect that irrigation, under the conditions of system, soil, and climate that obtain generally throughout this state, has not, as yet, especially in Southern California, been productive of malarial disease to any such extent as to cause alarm. At the same time it is sufficiently apparent that all those who have the general health of the public at heart should not fail, whenever practicable, to point out the advantages of thorough systems of land drainage, and the necessity of drinking only pure water.

[From M. M. CHIPMAN, M.D., San Francisco.]

"Irrigation produces a tendency to malaria, if carelessly managed, but if the engineering and levelling of the land is such as not to allow the water to stand in stagnant pools, if the ditches are kept properly cleaned out, and if wholesome water, not open ditch water, is provided for domestic uses, the prejudicial effects of irrigation may be nearly, if not altogether, averted. And, on the other hand, the increased vegetation, the covering of the surface of the country with orchards, shrubbery, and trees, must lessen and modulate the extremes of summer heat, and, in that respect, render the climate more tolerable and salubrious. The circumstance should not be overlooked that the air of malarious regions in drifting through forests is purified of its noxious principles, and we may, therefore, anticipate that the development of a considerable tree growth over an irrigated district will have a favorable influence, and especially by devoting a part of the surface to forest tree culture, giving preference, when practicable, to such varieties of the eucalyptus tree as are adapted to the different localities. And, on the whole, the apprehension of malaria from irrigation should have very little influence with an intelligent people, as compared with the benefits of the enterprise."

[From Dr. H. N. RUCKER, Merced.]

"In the county of Merced there are only two localities where irrigation is practised up to the present time. One is on the west side of the San Joaquin and the other on what is known as the 'Merced River Bottom.' Here, for many years past, portions of the bottom land have been irrigated with water from the river, and form a regular hotbed, so to speak, for malarial diseases. The bottom varies in width from perhaps one to three miles; is bounded on either side by high bluffs, and, in most places, is covered by trees and shrubs. It will thus be seen that the bottom is shielded to a very great extent from the prevailing winds. As far as I have been able to learn, this was a healthy locality till the water of the river was turned out of its proper channel. The soil is a rich black alluvium, and, when watered, produces abundantly. At other points on the river, more or less remote from irrigation, with like conditions, malaria is not present.

"In regard to the planting of trees, there seems to be a difference of opinion among those who have given attention to the subject, as to whether the effect is salutary or otherwise. It would seem that in temperate latitudes the cultivation of forest trees would contribute to health by protecting the soil from the rays of the sun, and thus moderating the temperature, besides the consumption of miasmatic exhalation by absorption through the leaves. To the eucalyptus globulus has been attributed especial merits in this particular, for the reason that to their great absorbing power is mainly due the rapidity of their growth. It is claimed for them that they will absorb ten times their weight in water, and that if planted in marshy

soil they will dry it up in a short time. According to the *Medical Times and Gazette* of 1873, the English were the first to make experiments with them at the Cape of Good Hope, and it is said that 'within two or three years they succeeded in entirely changing the climatic conditions of the unhealthy part of the colony.' At Pardock, a town twenty miles from Algiers, situated on the Hamyze, and known for its infected air, were raised in the spring of 1876 about 13,000 plants of eucalyptus globulus. In July of this year, at which time the fever had in former years usually begun, there was not a case, although the trees were only nine feet high. Since that time the place has maintained a complete immunity from disease.

"A farm is spoken of in the neighbourhood of Constantine, which was a marsh summer and winter, and was made dry in five years by 14,000 trees; the inhabitants enjoying excellent health. Many other instances are also mentioned of the same marvellous success. But, flattering as these reports may seem, we are confronted with instances which seem to set at naught both theory and practice in relation to this matter. One particular instance may be mentioned, of a large farm on the open plains in Merced county, which has been under a system of irrigation for a number of years. Quite a dense grove of eucalyptus trees has grown up around the farm-house, and for the past two or three years the effects of malaria have become quite apparent. On other portions of the farm, where farm hands are domiciled, and where quite as much water is used, with an absence of timber, the effects are not noticeable.

"In latitudes where the temperature runs high, it has been argued that forests, or the planting of trees, do harm, for there, even in the shade, the temperature is abundantly sufficient for the development of these effluvia 'by the material which these trees supply for decomposition, the dampness which they promote, and the impediment which they offer to the diffusion of the poison, far more than they can do good by their consuming power.' At a temperature under 60° F. the peculiar morbid effects ascribed to miasm seldom arise, while, on the other hand, a temperature of 80° or 85° renders it very active. Experience demonstrates that this activity increases with still further elevations of temperature, for the nearer we approach to the equator the more violent, as a general rule, do we find them, implying a greater intensity of the cause. Throughout the larger portion of the great San Joaquin Valley, where the thermometer ranges from 80° to 110° and more, in the shade, for months, it will not be surprising that, with the other conditions favorable, malarial disease eventually may become a matter of serious moment. In fact, the essentials to production of miasmatic diseases appear to be heat, moisture, and vegetable decomposition."

[From Judge B. BRUNDAGE, Bakersfield, Kern County.]

"In reference to the sanitary effects of irrigation, I settled here in January, 1872. At that time there was but little improvement made in the now irrigated portion of the adjacent country, the land being covered with quite a dense growth of brush, trees, and other vegetation. Numerous sloughs meandered through the valley below the river bluffs, the banks and beds of which were befouled with dense vegetable growths, causing the water to stagnate; the people residing near the sloughs and streams using the water for drinking and other domestic purposes, all of which caused almost universal sickness during the months of June, July, August, and September, from malarial fevers.

"Since then the country has rapidly improved, the lands (sloughs and swamps) have been cleared up, the waters taken from the sloughs and river and diverted into large irrigation canals, carrying flowing water, comparatively free from vegetable growths, and used extensively for irrigating purposes. The people have better habitations and use water for drinking purposes from bored wells. Hence the general health of the country has vastly improved, and the doctors complain of its being 'distressingly healthy.' Although there is annually a large increase of irrigated acreage, yet the general health of the community steadily improves. The clearing and cultivation of the land, and the annual cleaning of the canals and irrigating ditches, cause the general health of the people to improve. On the west side of the river, out on the desert plain, where an extensive system of irrigation and cultivation of the soil has been carried on during the past six years, the residents are as healthy as anywhere else in the state. Seven years ago it was a barren plain, now there are farms all along the canal for a distance of twenty-six miles, producing large crops annually by means of irrigation, and no sickness occasioned by it to my knowledge."

[From W. M. MCFADDEN, Anaheim.]

"I have resided in a district in Los Angeles county nearly sixteen years, in which, for the last seven years only, the whole district has been under irrigation supplied from a ditch, which was constructed for the purpose. I have had excellent opportunities for observing the effects of irrigation upon the health of the people within the irrigated district. I have noticed no change effected by irrigation. The health of the people is good. No malarial epidemics, fevers, or rheumatism. There are no stagnant pools, nor decayed vegetable matter, as the dryness of the climate evaporates all superfluous water and cures or matures all vegetable growth. In as dry a country as Southern California, I am satisfied that irrigation does not affect the health of the community."

[From Capt. J. Q. A. STANLEY, Los Angeles.]

"I can state, from personal knowledge and experience of over 30 years, that I have never known of any cases of malarial fevers, or other diseases, caused by irrigation in Los Angeles county, and I am satisfied that, under ordinary circumstances, and with a proper regard to the rules of health, there is nothing in connexion with irrigation that would necessarily produce disease."

[From Dr. W. R. FOX, San Bernardino.]

"In regard to the production of malaria by irrigation, I would say that, during the ten years I have practised medicine in San Bernardino and vicinity, I have seen a few cases of mild malarial fever that I attributed to the action of water and heat upon recently disturbed virgin soil. I do not think that sufficient irrigation, with proper cultivation, upon well-drained land, will produce malaria to any appreciable extent, especially when there is a daily trade wind during the season of irrigation."

[From Dr. A. H. WOODILL, Riverside, San Bernardino county.]

"I have to say, as the result of my own observation and from information from others, that irrigation does not produce malaria in this part of the state. Not one case of well-marked disease, of malarial origin,

has ever occurred here. In fact we have no endemic disease of any kind at Riverside. Irrigation, therefore, has no injurious influence on the public health. We have had some few cases of fever of a mild character, lasting from two to three weeks.

"We have had a few cases, certainly not more than six, of typhoid, in a year, that originated here.

"All of these cases undoubtedly had their origin in local insanitary conditions, and occurred for the most part in the more thickly settled portions of the town proper.

"Many cases of typhoid fever, well developed, have come from abroad. We get the credit of these, hence the report that fever was epidemic at Riverside.

"We certainly have heat enough to promote fever, and in some places plenty of moisture, but the *materies morbi* is wanting. The Santa Ana River runs on the windward side of the valley throughout its whole length.

"If malaria originated from it, it would be blown directly upon the settlement. People live along its banks, and there has never been a case of malarial fever. Our water ditches run through the entire valley, and they are all open ditches. The soil through which they pass is completely soaked at times, and, other things being equal, offer favorable conditions for fever.

"I am satisfied that if the common sanitary precautions were strictly practised by the people, that all cases of fever would be prevented.

"The worst being said, I am still of the opinion that this is one of the most healthy communities in California. Our cool nights induce sleep, which precludes the possibility of much or any miasmatic disease.

"As regards the benefit to be derived from tree-planting on the rainfall, I will say, however popular the idea may be, I have failed to recognise any good to be derived from it. The illimitable vastness of the plains is such that it would require many years of planting to produce any visible effect. I think, also, that the influences that bring about increased rainfall do little good in this valley, even if every inch were planted in trees, because of the everlasting hills."

[From Dr. F. S. HILLARD, San Gabriel, Los Angeles county.]

"The July number of the *Zeitschrift*, edited by Professor Klebs, contains some particulars of an investigation into the physical cause or poison to which marsh or intermittent fever is due. The inquiry was conducted by Professor Klebs, of Prague, in conjunction with Signor Tommasi, Professor of Pathological Anatomy at Rome. The two investigators spent several weeks during the spring season in the Agro Romano, which is notorious for the prevalence of this particular kind of fever. They examined minutely the lower strata of the atmosphere of the district in question, as well as its soil and stagnant waters, and in the two former they discovered a microscopic fungus, consisting of numerous movable shining spores of a longish oval shape. The fungus was found capable of being artificially generated in various kinds of soil. The fluid matter obtained was filtrated and repeatedly washed, and the residuum left was introduced under the skin of healthy dogs. The animals experimented on all had the fever with the regular typical course. After explaining minutely the results of their various investigations and experiments, these gentlemen are of the opinion that they have discovered the real cause of the disease in question. As the fungus grows into the shape of small rods, Tommasi and Klebs have given it the name of Bacillus Malarial.—[*Medical Times and Gazette*, October 18, 1874.]

"If the fact of the existence of fungus, the so-called Bacillus Malarial, is accepted as proved, it would explain much that hitherto has been mysterious in the nature of malaria. Why is it travelling and infesting districts hitherto free from it? If it is due to a distinct bacillus, the answer is now simple, for unless one accepts the doctrine of spontaneous generation, he must have a parent for his child. He must have bacilli to produce bacilli. Moisture and decaying vegetation alone are not enough, the bacilli must be present. If our premises are correct, our conclusion is as certain as in the case of variola or scarlatina.

"Hence, irrigation is perfectly safe, provided the soil was originally free from malaria, and the water put upon it is also free from it.

"My own observation here, in Southern California, leads me to believe that cases of malarial poisoning which have occurred were imported. I have seen nothing yet to cause alarm as to the evil effects of irrigation on health—granted that the air and soil are free from all miasms, we have only to examine the water, and, if that also is free, malaria is there impossible."

[From Dr. M. S. JONES, Santa Ana, Los Angeles county.]

"As to my observation of irrigation on malarial and zymotic fevers, I have this to say:

"I have been a practitioner for nine years in the Santa Ana Valley, and know the class of diseases above mentioned have not increased. I came here when irrigation, to any extent, was just being begun. Have seen the amount of irrigated land raised from three to 20,000 acres, and can say truthfully no increase of the above-named diseases has taken place.

"The Santa Ana Valley Irrigation Company has now 14,000 acres being irrigated from their canal, and a large percentage of the irrigators use the ditch water for domestic purposes, passing it through filters to cisterns. Such a one I have used for three years, my family enjoying good health all the time.

"I am sure there has been scarlet fever in but one family east of the Santa Ana River in the nine years, and in that family, five out of six children died, caused by want of drainage and using water where filth from a sheep corral had access.

"As to tree planting on the rainfall, health, &c., I know nothing from experience, but would advise it on common sense principles."

[From Mr. A. F. KERCHEVAL.]

"After a residence of fifteen years in Southern California, I am of the opinion that irrigation has caused no increase of malarial diseases. Although the area of irrigated land has increased more than one hundred fold within the last ten years, there has been no increase of malarial disease, excepting in proportion as our population has increased. The reason for this is obvious. All our lands requiring irrigation are of a peculiarly porous or sandy character, underlying which are strata of gravel, boulders, and sand of unknown depth, thus giving the most thorough under-drainage, and rendering it impossible for water to remain on the surface a sufficient length of time to become stagnant. Besides, water in the irrigated

colonies is so precious that no one could afford to let it run to waste and form lakes or pools. Usually only about one-thirtieth of each irrigated district is allowed water on any given day, and during the balance of the month the ground becomes drier and drier as the moisture sinks from the surface, or is evaporated by our peculiarly absorbent and drying atmosphere."

[From Dr. W. C. SMITH, Downey.]

"I have been for ten years in regular practice in the Los Nietos Valley, in Los Angeles county, perhaps the most abundantly watered region in Southern California, and where irrigation is more extensively practised than in any other region of the same extent. Cereals grow in winter without any irrigation. During the last ten years, thousands of acres have been added to the vine and tree interests of this locality. There are thousands of acres under irrigation now more than ten years ago, yet I cannot see that the diseases of the country have been affected by it. The type has not changed nor sickness increased disproportionately to the increase of population. Intermittent and remittent fevers are almost never seen, unless imported.

"It would seem that a legitimate effect of irrigation would be malaria to some extent, but there has been no such result, perhaps owing to the fact that we have a strong ocean breeze about one-half of every day, and besides there is no stagnant water, nor decaying vegetation. There seem to be no local nor climatic diseases peculiar to this locality. My opinion in general is that there is no healthier location anywhere in the state."

[From Dr. O. H. CONGAR, Pasadena, Los Angeles county.]

"Marsh miasm can scarcely be expected to arise from soils, free from all vegetation, that may be periodically irrigated for the purpose of promoting tree or vine development. The conditions are so widely different from those obtaining in the marshy lands that it is not reasonable to anticipate analogous effects. The use of pure water in irrigating soils devoted to vine or tree culture cannot be regarded as conducive to the development of malarial poison, but in the application of sewage, or waters bringing down decomposing vegetable matter, if used for irrigating purposes, it is not otherwise than reasonable that more or less malarial poison will be set free to the surrounding atmosphere. Waters brought down from the mountain streams in iron or cement pipes must reach their destination in as pure and wholesome a condition as when taken up, but if conveyed in open ditches, cemented or otherwise, the growth of vegetation will be found profuse, not only along its borders and high up on their embankments, but also in all shallow places in their channels. Here are favorable conditions for the development of malarial poison, and such waters used either for domestic or irrigating purposes are necessarily more or less unwholesome, carrying the germs of disease directly into the blood of those who use the water or inhale the atmosphere of the irrigated district. Such ditches are also but little less than open sewers receiving filth of all descriptions, animal as well as vegetable, and statistics warrant the statement that infections and contagious diseases not only linger in such districts, but presumably prepare the system of susceptible individuals for the reception and rapid propagation of these germs of disease and death.

"Typhoid fever, scarlatina, measles, diphtheritic affections, &c., are known to first prevail along such water-courses and those using the water for domestic purposes in certain districts, and not a case appearing among the inhabitants using the same water at its fountain source, but brought out by iron pipes instead of the open ditch. The two communities breathe the same atmosphere, live upon the same soil, and in short the same environment is identical in all respects, save in the mode of bringing out and storing their domestic and irrigating waters. It is, therefore, apparent *primâ facie* that the water is the source of contamination. It must be observed, also, that in all warm climates the growth of vegetation and decomposition is often much more rapid than in the more temperate latitudes, and if the hypothesis be accepted that none but decaying or dead organic matter is infectious, the sources of malarial poison at least will be more easily traced."

[From CHESTER ROWELL, M.D., Fresno City.]

"One of the first questions asked by a newcomer into an irrigated section of country is: What is the condition of the health of this community, and do malarial fevers prevail here? Speaking for the irrigated portion of the San Joaquin Valley, in which I have had a continuous residence of nearly ten years, I have generally been able to answer these questions favorably, though it cannot be said that malarial fevers do not sometimes prevail.

"The complete transformation of a country that is absolutely dry, treeless, and often barren of vegetation, into almost a marsh with rank weeds growing wherever allowed, and vegetation remaining green the entire year, cannot be otherwise than productive of some sickness and of a character new to the locality. This transformation has already taken place in many parts of the San Joaquin Valley. When settlement with irrigation first began here the surface was as dry as powder for seven months of the year. The water level was from 30 to 100 feet from the surface. Population consisted of the owners and herders of a few bands of sheep, and was supplied with none of the luxuries of living. Sickness was very rare. A tract of country was surveyed into twenty-acre lots; a large canal built to the border of the settlement, where it was divided into a large number of small canals and distributing ditches. The lots were ploughed, checked, or levelled off into one to three-acre sections, and these sections ploughed and scraped down to a water level. When water was turned into the canals and on to the land it soaked into the ground as into an enormous sponge, and the entire surface settled from four to fifteen inches. Whatever of vegetable or animal matter was in the soil began to decompose and gaseous poisons were liberated. Vegetation sprang up as by magic. Houses were built on each twenty-acre lot, and almost from the beginning everything in the shape of vegetable or fruit was raised and consumed without limit. As the soil became saturated the water-level gradually rose higher till, instead of thirty or a hundred, it became from two to ten feet from the surface. Surface irrigation, which was a necessity at first, became unnecessary after a few years, and in all low lands the question of drainage became of more importance than irrigation. Wells which were originally deep filled up to the water-level, and the water in them which had been good became salty or mouldy as the soil through which it had percolated had been alkaline or vegetable mould. It would seem that these conditions here, in this climate of long-continued summer, would produce an appalling amount of sickness, but such has not been the case. There has been some sickness, but it has not been malignant nor intractable, nor, as a rule, from climatic causes.

"After ten years of careful observation and active medical practice, during which time the changes described have taken place over a vast tract of territory, I have arrived at these general conclusions: Irrigation, of itself, need not and does not make a sickly country. Irrigation on a large scale, where water is used to such an extent as to saturate and fill up the soil, and continued during the summer months, will produce a general malarial influence. It will be most active where the soil is hard or clayey, and where the locality is protected by trees, hills, or otherwise from the summer winds which sweep up the San Joaquin Valley nearly every afternoon. This malarial influence is but a small factor among the causes of disease. Sickness is most prevalent during the first three years of settlement, and decreases with a better knowledge and observance of the rules of living applicable here. Most of the causes of sickness in an irrigated country are visible and can be overcome, and the tendency to sickness decreases as the settlements grow older. Among causes are: Impure water, excessive and indiscreet drinking of water, careless use of fruits, and malaria. The water under most of this valley before irrigation was practised was reasonably good, as a rule containing more of the potash and soda salts than palatable, and but little lime, but not unwholesome. As water for irrigation is brought upon the plains, the wells fill up and the water partakes of the character of the soil through which it has percolated. In some localities it becomes strongly alkaline, and in others impregnated with vegetable matter, and where the roots of poplar and willow trees are abundant near the well the water becomes bitter. In any case, it is unwholesome. The continued use of the alkaline water deteriorates the blood, weakens digestion, and prepares the system for the development of disease. When strongly impregnated with vegetable matter, as is the case in the black loam and clayey lands, there is no question but its use is one of the most prolific causes of fevers. There are few localities in the valley where good water cannot be obtained by boring down to the original good water levels and casing the wells with impervious iron cases, which should be firmly landed in one of the stratas of clay which underlie the valley. In this way the surface water is cut off and a possible cause of sickness obviated.

"The excessive drinking of water and the indiscriminate use of fruit are matters wholly within the control of people themselves, and while, next to impure water, the causes of a great deal of sickness, no remedy can be here suggested.

"As has been stated, where irrigation is practised extensively, a general malarial influence will be developed, but experience seems to demonstrate that except under very unfavorable conditions the malarial influence will not be active, and has a tendency to decrease rather than increase with time. Where the soil is loose and porous, whiteash or sandy, with a rapid under-drainage, as is the case on the plains west and south of Fresno, with moderate care it is doubtful whether malaria will ever be seriously felt. The summer northerly winds exert a purifying influence, and localities receiving the full benefit of them are less affected than localities cut off from them by the contour of mountain ranges or by timber. The effect of tree-planting can scarcely be estimated as yet, though it is certain that the growth of willows and cottonwoods already allowed on some of our farms, by shutting out the winds, has already brought a harvest of fevers. The prophylactic properties of the Australian gum tree in malarious sections remains to be demonstrated, few here having planted these trees in sufficient numbers to have any appreciable influence. In one case on a large ranch that has been irrigated for nearly ten years, the buildings are situated immediately adjoining a large eucalyptus grove, and malarial fevers have never prevailed there. As they have prevailed on adjoining ranches, it would seem that the gum trees have served as protectors. The tree is clean, free from insect pests, purifying and health giving, and its cultivation ought to be encouraged. Satisfied of its beneficial influence, as well as of its value as timber, I have urged its planting in every part of the county, and believe it will yet prove one of the most valuable adjuncts to the health and the wealth of our community. It is a remarkable fact that diphtheria has never prevailed to any considerable extent upon the irrigated lands of this part of the state, though it has prevailed in a most malignant form on the dry lands of the plains and in the foothills and mountains. I can give no satisfactory explanation of the fact, and have heard none given. Likewise pneumonia is rarely ever seen in our colony settlements, and typhoid fever is rarely met with in these localities. As almost the entire state of California must eventually be irrigated, the health changes likely to occur become a matter of great interest, and I would urge that it receive the attention of physicians in every part of the state."

APPENDIX K.

IMPORTS of Bottled, Dried, and Preserved Fruit, Jams, &c., in Australasian Colonies 1883, exclusive of Intercolonial Imports.

Articles.	Colony.							Total.
	Victoria.	New South Wales.	Queensland.	South Australia.	Western Australia.	Tasmania.	New Zealand.	
	£	£	£	£	£	£	£	£
Fruit, bottled ...	2,730	2,516	1,920	2,248	...	...	523*	9,937
„ dried—Currants	40,519	93,650	8,011	14,682	1,950†	5,265	22,015	285,107
„ „ Raisins...	36,297		5,700	7,049			14,976	
„ „ other ...	11,208		4,962	10,958			7,865	
Jams and Preserves ...	9,051	39,015	9,594	2,270	944‡	...	8,330	69,204
Almonds	3,540	8,197	915	377	...	433	3,005	21,166
Nuts	2,750		393		...	260	1,109	
Walnuts	125		53	9	...			
Total ...	106,220	143,378	31,548	37,593	2,894	5,958	57,823	385,414

* Including preserved fruit. † Excluding dates. ‡ Including bottled fruit.

Office of the Government Statist,
Melbourne, 27th May, 1885.

H. H. HAYTER,
Government Statist.

APPENDIX L.

DEPARTMENT OF AGRICULTURE,
Washington, D. C., April 7, 1885.

The Hon. Alfred Deakin, M.P.,
Solicitor-General and Minister of Public Works,
President of the Royal Commission on Water Supply,
from Victoria, Australia.

SIR,

In response to your verbal inquiry as to the facts and conditions surrounded and connected with the question of irrigation within the United States, the Department of Agriculture, which for some time past has been engaged in a partial inquiry into the subject, through one of its staff, Mr. Richard J. Hinton, a gentleman specially well-informed and acquainted with the section of the Union more directly interested, takes great pleasure and interest in forwarding to you the following summary of facts and results so far obtained.

The scope of the inquiry has been directed to what is known, and as to what has been practically accomplished, in the following directions :—

1. As to the extent and character of the area within which, broadly stated, the humidity and precipitation is insufficient for full industrial uses, and wherein the same is often so irregular in character as to make the insufficient average rainfall still more unreliable.
2. As to the extent of the rain and snow-fall within the area to be indicated; also the evidences obtained as to increase or decrease of precipitation, in connexion with agricultural settlement, the increase of travel, pastoral occupation, the destruction of the timber mainly by its use for settlement purposes, the effect of the destruction of the native grasses and the substitution of other and cultivated varieties.
3. The sources of water supply, their character, uses, conservation, and the means employed, natural and artificial, for their distribution.
4. What has been and is being accomplished in the way of artificial methods of water distribution and economy, and the laws and customs pertaining thereto, as well as to the progress of tree-planting, and the effects that are known to have resulted.

As to the extent and prevalence of aridity within the United States, inquiry develops grounds for the statement that there is, comparatively speaking, but a moderate proportion of this country which can properly be termed an arid region; there is, however, a very large area, embracing at least one-third of our total land surface, wherein the water supply, whether surface or subterranean, and in the form of precipitation, is both inadequate and irregular in character. This great area may be defined as to its eastern boundary by the 98th meridian of west longitude. The western boundary may be in part placed at the Pacific Ocean, though more accurately the coast range of California would be the line. The northern boundary is the British territorial line west from the 98th degree to the summit of the Sierras, or the 120th meridian. Following the summits of the main range, the north-west line would deflect to the central portion of Oregon, following the south-westerly bend of the mountains down to the northern boundary of California.

The southern limit of this dry area would be the northern line of Mexico, and thence south by east, along the valley of the Rio Grande, down to the Gulf of Mexico. The area then, east and west, through its central and larger portion, runs from the 98th to the 124th meridians of west longitude, and in its greatest prolongation from the 43rd to the 27th degree of latitude north and south.

In its more northern portion it runs east and west from the 98th to the 120th degree of west longitude. The larger portion from north to south is embraced by the 32nd and 43rd degrees. These lines cover one-half of the States of Kansas and Nebraska, the whole of the States of Colorado and Nevada, with three-fifths of that of California, one-third of Texas, and about the same of Oregon, also the whole of the territories of Dakota, Wyoming, New Mexico, Utah, Montana, Idaho, and Arizona, with at least one-third (east of the mountains) of Washington territory. This makes an area of about one-third of our whole territorial surface, inclusive of Alaska. How much of the latter-named territory may be wholly or partially arid and desert in character cannot yet be estimated, as but little besides the coast section has been explored.

The east and west lines of the dry region are, in its widest section, over 1,500 miles apart, and in its greatest length north and south about 1,000 miles. If the whole region was compactly arranged, it would make a block of about 1,000 miles square. The area thus indicated may be subdivided again into three broad divisions, as follows:—

1. The plains region, running north and south from the British American line to the lower portion of the Rio Grande valley in Texas, and east and west from the 98th to the 105th degree of west longitude. This division may be broadly declared to have a general rise and altitude of from 1,500 to 5,000 feet, though it will fall below that at either end of the area. It is but sparingly supplied with streams, which are mainly fed from mountain sources; the annual precipitation is nearly everywhere below what is considered to be a reliable amount for economic uses. In the central portion this will not exceed, under favorable conditions, as to the central or main portion, 18 inches per annum in the eastern part, diminishing as it moves westward to an average of about 14 or 15 inches per annum. In the southern or Texas portion of this area the rainfall will somewhat exceed 20 inches on the east, decreasing until, on the north-western extremities, it will reach only 8 or 10 inches in the most favorable seasons. In the northern, or Dakota portion,

the average is more evenly maintained. This division will include the western half of Kansas and Nebraska, one-third or the eastern foothills and plains region of Colorado, the major portion of Dakota, the eastern half of Wyoming territory, and one-third or more of the Indian territory and Texas, with about one-fourth or the eastern part of New Mexico. It is drained by a number of streams, some of them of importance, and it is bounded on the east and north by the Missouri River and its affluents, and by the Pecos and Cimmaron Rivers on the west and south-west. Its soil is almost uniformly fertile. Natural grasses of most nutritious quality are found throughout its area. It is now one of the most important grazing sections of the west, and large farming settlements are moving steadily and compactly westward from the eastern line, while at various points in its western limits there are important farming communities, created mainly by the use of water, as applied through irrigation ditches and other means of storage and distribution. The valley of the Upper Rio Grande region, from its sources in the San Juan range, or the west limit of the San Luis Parc, in Southern Colorado, to where the Rio Grande Bravo del Norte debouches from New Mexico into Texas, and becomes the boundary-line between this and the republic of Mexico, has for many generations been the seat of extensive, if local and unsystematized, modes of irrigation. The Pueblo, or town-dwelling Indians, have for centuries practised it. Since the Spanish conquest in the 16th century, the mixed Mexican people who have inhabited it have always been obliged to irrigate in order to cultivate. In these latter days our own more enterprising people are inaugurating and carrying on larger enterprises and projects, whose advantages are already perceivable.

2. The second great division can be most distinctly characterized, if any portion may, as the *arid* section of the United States. It lies between the 105th and the 120th meridians, east and west, and from the British American line as far west as the 120th meridian, going southward by the summits of the continental range to the northern line of California. The southern boundary will be the northern line of Mexico, and a portion of north-west Texas. This will take in the whole of our intra-mountain region from the foothills of the Rockies to the lower slopes and foothills of the Sierra Nevada in California. To the north, therefore, it is limited by the east flank of the Sierras. Within this area, except on the higher and arid heights of the ranges, principal or secondary, there is almost generally good pasturage for cattle to be found. The natural grasses are sun-cured, and with the comparatively mild winter climate which characterizes this intra-mountain region, in its westwardly flow, afford ample food and range for many million head of cattle.

The only limit seems to be the water supply. This problem is now becoming one for serious consideration. There are desert tracts and areas within this great region which are undoubtedly arid and desolate to the extent of irreclaimability; but, taken in connexion with the whole extent, the space they occupy is but small.

The defined outlines of this second division cover the great Basin section, of which Utah and its water reservoir—the great Salt Lake—are the dominating physical and geologic features; the Colorado plateau region, which occupies the larger portion of Southern Nevada and Northern Arizona; the beautiful parcs of the Rocky Mountains, or the eastern flank and ranges of the Northern American Cordillera system; the table lands of Southern Arizona; and of the great valleys and basin made on the north by the Columbia River and its important affluents in Eastern Oregon, Idaho, and Montana. Arid and desert as such a stupendous mountain system must seem to be, it will be found, on examination, to have large sections capable of agricultural uses, and also to hold within its borders such sources and supplies of water as, properly conserved, protected, and distributed, by proper engineering and competent skill, under the wise and conservative direction of national and State Governments, will be found of ample utility for the purposes—1st, of larger pastoral uses; 2nd, of more limited and localized, but still extensive, agricultural purposes; and 3rd, as storage and reservoir sources, from which, at no distant day, the life-giving waters may be conveyed to and distributed over vast areas, which our present, though limited, experiences already prove can be converted into fertile farms.

A glance at a good topographical map will indicate to the observant eye the areas under reference.

For example, the central section of the Rockies (in Colorado, Wyoming, and a portion of New Mexico) contain the sources of important rivers. This hydrological area is extensive, as there are a number of lakes, some of considerable size, while the snow precipitation is also quite heavy. There is sufficient achieved already in Colorado, under the stimulation of private need and profit, to indicate what may be accomplished under larger direction.

The entire foothills region, a considerable portion of the plains rolling eastward to the 98th meridian and beyond the important valleys of the Rio Grande, Plate, and Arkansas, with many small valley areas related thereto, might all be reclaimed from the water supplies and precipitation to be found in the frontal range of the Rocky Mountains. Taking the extreme west, and even brief inquiry and examination will satisfy the inquirer that the higher Sierras, under proper engineering conservation and wise plans of distribution, to be carried out for the interest of the common weal rather than of corporate profit, contain a supply of water, from the snow precipitation alone, sufficient to supply the whole of the great valley and foothills regions of Central and Southern California, now being so vastly developed as a wheat and fruit-growing region.

In the northern portion of our intra-mountain area, the hydrological system, covered by the Columbia and Snake Rivers and their affluents, will give for pasture and agriculture a sufficient water supply.

Taking the southern portion, where the Colorado Plateau descends to the valleys of the Gila and Colorado, and forms the *mesa* or table-lands of Southern Arizona and New Mexico, there has already been utilized a water supply sufficient for cattle, and in several extended portions, as in the valleys of the Gila, Rio Verdi, Salt, Colorado, Chiquito, San Pedro, and Santa Cruz, enough almost for the present general agricultural and horticultural purposes. The inquiries of the Commissioners, as made in Arizona, will give illustrations of this sufficient to prove the general statement.

It may be estimated that, of our whole intra-mountain region below the timber line, as herein outlined, at least 60 per cent. affords fair pasturage, with sufficient watering places, though often at long intervals apart, and subject to various limitations, which are rapidly being in a degree overcome, and will hereafter largely disappear as more attention and skill is directed to the subject. The facts accessible in Utah and Nevada will show these possibilities. There can now be made no really accurate estimate of the amount of this intra-mountain area that may be utilized for arable and horticultural purposes; but it is within bounds to declare that one-fourth of its acreage (as already limited) as a whole may be so utilized when the accessible water sources shall be brought into use. In a very large portion the per cent. will be quite small; in others it will greatly exceed the general estimate here made. It must be borne in mind that in both estimates the higher mountain sections, embracing at least one-fifth of the whole region, is excluded. However, on the summit of the highest plateau region in Northern Arizona, for instance, cattle are successfully wintered at an altitude of from 7,000 to 10,000 feet above the sea.

3. The third division embraces the Pacific coast region from the western slopes of the Sierras Nevada (in California) to the ocean, and takes in the great transverse valley troughs or plains cradled between the Sierras foothills and the coast range—the great wheat granary of the Golden State, and also the fruit-growing section, yearly rising in importance. It is not necessary to amplify any reference to the physical aspects of this division, as they are already familiar to the President of the Australian Commission. Attention should, however, be drawn briefly to the uses of water within its boundaries. The first division then in order of interest will be that which has been placed third in physical sequence. This division embraces the State of California, lying between the 120th meridian of west longitude and the Pacific ocean, east and west, and between the 40th and 31st degrees of north latitude. The extent, character, and results of irrigation are similar questions of State polity. As the President of the Commission of the Colony of Victoria has doubtless made inquiry into the details of California irrigation practice and means, it is unnecessary herein to do more than point to some salient facts developed by the growth of irrigable cultivation:—

1. In the San Joaquin Valley, at Fresno, and at different points in Southern California, as Los Angeles, San Gabriel, Riverside, Anaheim, San Diego, it is being rapidly developed that water is obtainable at moderate depths, and, apparently, in all directions. This factor is reducing, wherever it has been reached and utilized, the need of surface irrigation, and that, too, in a striking degree. The fruit growers, viticulturists, and wheat farmers are uniting in the testimony that the seepage or percolation of the soil by means of surface irrigation has increased wherever it has been steadily practised in California to so great an extent the humidity thereof that there is a marked decrease in the use of surface water by means of irrigating channels. It is no longer a speculation to assert that cultivation, within the dry valleys and plains of Central and Southern California, is having the effect of drawing upwards by capillary attraction the sub-terrene supplies of water, and to a distinct and marked degree lessening the need of surface application. How much, if any, effect this increased humidity of the surface soil may have on the atmospheric humidity is not yet known. The increase of evaporation by means of cultivation, both of trees and plants, must ultimately produce a beneficial change in this regard.
2. The full industrial use of water in California must necessarily be governed by the larger topographical and other physical conditions. Those of climate, as to winds, humidity, and temperature, are somewhat uniform in character, and may easily be calculated upon. The precipitation seldom exceeds 22 inches annually, and over a greater portion of the State falls below that estimate. Hence, it is insufficient for full industrial uses. Broadly stated, the physical features are divided into what may be termed—

(*a.*) The natural area of sources, supply, and reservoirs; that is, the higher portions of the Sierras Nevada, upon the western flanks and summits of which the snow precipitation is heavy where physical formation creates the great catchment basins, and whose altitude is sufficient to break, deflect, and dessicate the great moisure—bearing currents from the Pacific Ocean.

(*b.*) The foothills region, extending from Mount Shasta to the San Bernardino Range. This is the seat, also, of the important mining operations, hydraulic and lode, of this State. It is, consequently, the area in which the water supply section has been drawn upon, and made most extensively available by means of catchment areas, dams, ditches, and flumes. It has, also, especially in what is designated as the lower foothills, where the altitude is below 2,500 feet, extensively utilized these supplies and distributing agencies, natural and artificial, for agricultural and horticultural purposes. Experience has developed that, in this subdivision of the State (which for all practical purposes embraces nearly all of Northern California), irrigation must, for such industrial purposes, be heavier and more continuous than elsewhere.

(*c.*) This subdivision embraces the great valley region of the State—its most important wheat and grain-growing section—and includes the extensive drainage basins of the Sacramento, San Joaquin, Feather, Bear, Yuba, American, Cosumnes, Mokelumne, Tuolumne, Merced, Kings, Fresno, Kern, and other streams, large and small. It covers an area of over 34,000 square miles, is divided into sixteen counties, and within this area every problem connected with the industrial use of water and its conservation, legal and practical, is in process of both application and discussion. The most extensive canal system, with the combination of farming interest in control of supply, or the application of capitalistic enterprise to induce land settlement primarily and water purchase subsequently, are to be found therein.

There are also well-developed artesian belts in the upper portions of the region. The lower portions are subject to tidal overflow and river inundations, while the existence of water at a moderate depth is being demonstrated in almost every portion of the great valley areas. This region embraces not only the

major portion of the wheat-producing area, but is also the seat of large viticultural and horticultural activity. In wheat alone, for fifteen of the valley region counties, was, in 1884, as follows:—

	Acres.
Colusa	450,000
Contra Costa	136,500
Fresno	32,501
Kern	14,322
Merced	186,200
Placer	32,728
Sacramento	94,370
San Joaquin	248,357
Solano	61,536
Stanislaus	453,412
Sutter	95,528
Tehama	130,553
Tulare	262,272
Yolo	140,000
Yuba	23,130
	2,361,499

The entire area laid down in wheat within the State of California was, in 1884, 3,267,109 acres, producing over 57,420,000 bushels, or for the valley region alone over 40,000,000 bushels. The importance of these figures, as connected with the supply of water, is perceived when it is remembered that much of the area made so productive has been reclaimed by the use of water, and that in doing this there has been developed some facts worthy the closest attention from those who have in hand the problem of water supply and conservation for the British Colonies of Australia. Perhaps the most gratifying, as well as significant, fact developed by the irrigation experiences of California, especially in the valley region, is that connected with the capillary quality of the soils, which are generally of great thickness and tenacity. Underlying these surface soils there are found almost everywhere, at moderate depths, impervious strata, by which the water drawn too rapidly from the over-drained surface has been happily preserved. Owing to this almost generally established condition of things, water throughout the central portions of the State is being obtained from ordinary wells. It is pumped to the surface and distributed by the agency of peculiar windmills, which are now known in all parts of the world. The altitude of the Californian valleys is nowhere great, and the lower portions are at but moderate heights above sea-level. That of the foothills region is from 2,500 to 4,000 feet.

The rivers themselves carry water enough to irrigate either side of their channels, and, now the *débris* created by the hydraulic mines is no longer poured into their channels, they may be more surely depended upon for agricultural service. It is being established at all the centres of farming, where irrigation has been, and yet remains, the supreme need for the successful consummation of agricultural activities, that the amount of surface water so required is yearly growing less. Inquiries made by the Commission will afford evidence sufficient for the careful consideration, at least, of the pregnant suggestion that Californian experience raises so strongly—as to whether the cultivation of the soil in surface-dry and wind-dessicated areas, such as the valleys and lower tablelands of that State were assumed to be but a few years since, does not in the first place and of itself tend directly to an increase of surface humidity by capillary attraction, or the drawing upon the sub-terrene water supplies that are unquestionably found in the underlying strata. In the second place, are there not seen reasonable grounds for presuming that there are bodies of such waters flowing below or underlying considerable areas of the valley plains and table-land regions of Central and Southern California? The precipitation of rain, and of snow with its annual melting, would be in itself sufficient to feed such subterranean bodies. It is evident that these aqueous supplies do not directly flow to the ocean within the hydrological channels and basins that have been worn through the surface and other stratum. The streams and rivers of California do not carry volume enough to account for the amount of deposition that could be calculated upon, if it be possible to utilize the same, within the subdivision designated as the source and supply area of the Sierras. If such bodies of water exist, they will be utilized (as in some instances has been the case) by borings that have reached, or may yet reach, waters that will flow to the surface, or will have the more distinct characteristics of artesian streams. The high altitudes at which waters disappear into the earth must give them, when arrested under the tablelands and plains below by impervious strata, a force ample to propel the same up and above the surface, and to give them the value of living perennial streams or springs. In other words, there are two sources of sub-terrene waters to be utilized in California for fullest industrial purposes. The first is the water arrested in its flow from the surface, at moderate depths, and which it is being widely established can be reached and drawn upward, by the loosening of the soil consequent upon cultivation, and by the hardy and penetrative qualities of the plant roots, drawing from below the life-sustaining moisture denied them from above by climatic conditions. The other source is to be found in the deeper bodies of waters, that are presumably the lost and sunken floods of the Sierras. That such bodies exist there is more than conjectural data to indicate. Both these suggestions are worthy the attention of the Commissioner in considering how far the physical aspect of California may prove of service in hints towards solving the problem of water conservation in the colony of Victoria.

3. Passing from these points, the third division, or Southern California, embodies the features of both the valley and foothills region. It is also affected in its western portion by the trade winds and other coast influences; and its extreme southern and eastern section is modified and moulded by the great Colorado plateau formation, of which the boundary mountains and *mesa*, or table lands, are in fact a part. There are great stretches of arid *mesa*, or secondary table-land, which must be counted as desert, though the major portion has native grasses sufficient to feed a large number of animals. There is also sufficient development, especially in Los Angeles and San Bernardino counties, for example, to

indicate the possible and profitable reclamation of considerable portions of these so-called deserts, provided the waters now available, explored and utilized, can be distributed over their surface. The Southern Californian division approaches, in many of its products, a semi-tropical fertility and luxuriance. It is the chief seat of the orange culture. The lemon, olive, date, fig, almond, pomegranate, nectarine, and other fruit-trees requiring warm and fecund soils and skies, grow in abundance there. The upper or northerly part of this subdivision forms a part of the great wheat-producing area of the State. The area under wheat was, in 1884, as follows :—

	Acres.
Los Angeles	255,000
San Bernardino	7,321
San Diego	27,351
Total	289,672

That is nearly one-third of the State's production outside of the valley region. The table land or *mesa* portions are extensively utilized for the pasturage of cattle and sheep.

In the southern section of California, then, the absence of any considerable hydrological basins with flowing waters in them makes the methods of conservation of great significance. The economic use of water therein has almost approached perfection. The conservation of the Los Angeles River, and of other similar but smaller streams, within the three great counties into which Southern California is legally divided, is in proof of this. The important facts in relation to irrigation are the existence, almost uniform, of an artesian water-belt, with force enough, when reached by borings at a depth almost uniformly of about 300 feet, to flow to the surface; and the other one already alluded to, that irrigation itself seems to uniformly lessen the need thereof by the loosening of the soil, as well as by the seepage from the canals and ditches, &c., until the increased humidity of the earth has become so marked that many viticulturists and other small fruit-growers are deciding against the use of surface waters at all, or in very limited quantities, in their vineyards, gardens, and orchards.

4. The practical legal issues involved in the conservation and distribution of water for economic uses within the State of California involve questions of the most serious character. There are distinct community methods of control, as seen in the laws and policy found operative within the State.

The first comes from the admixture of the Indian community, or pueblo life, with that of the Spanish conqueror, both being affected and shaped by the needs and customs of people to whom irrigation has always been a prime necessity. The Indian, with his tribal clan or village organization, has regarded land and water as common or communal property, in the use of which all had a right. The Spaniard regarded the land as his by conquest; but that the water, being necessary for its full utilization and profit, must be controlled by the king, *i.e.*, the State, and therefore should be for public use. The English common-law doctrine of riparian rights had no place in the economy of either people. The public charge of the water supply at Los Angeles and elsewhere in Southern California illustrates to what perfection the community may bring control and distribution.

The discovery of gold brought with it, in California, the rapid adoption of a miners' code, both as to the occupation of mineral "claims" and of water-rights. This code has become the foundation of nearly all our legislation, State and national, as to the disposition and use of the mineral lands, and, in a minor degree, it has also dominated and shaped the water usages, so far as mining is concerned. The public use of water is fairly established in that direction. But, as to the other and larger utilization in agriculture, the drift of events in California seems to be away from the controlling customs and ideas briefly referred to. This tendency began early in the construction of large works in the upper foot-hills and Sierra regions, for the purpose of obtaining a water supply large enough to carry on the great hydraulic enterprises which for a quarter of a century past have been so marked a feature of California gold mining. The corporate power came into existence at first to help the labour and energies of individuals, and later, as it would seem, to dominate them by the creation of artificial persons, whose only aim could be that of making dividends, under more or less wise direction and policy. The water ways and supplies of the State have thus been passing under the control, in forms more or less direct, of incorporated companies. Some of these are composed of those by whom both land and water are to be used in conjunction. Others are controlled by those who have obtained possession and ownership of great bodies of land, and, in order to either use or dispose of them, have been obliged, at large outlays, to bring water thereon. The tendency in all directions is to put the farmer at the disposal of chartered collectors of water taxes, for such must be the form of payment for the use of one of the great divisions or elements of natural property—water. This tax must be equitable or otherwise, according to the character of the State or local control over those who vend the same, and the needs thereof by those who pay. The different methods have ample illustration within the State of California, that of community control being seen in its best aspects at Los Angeles, while different and varying methods of association and corporation, construction, and control of such irrigation works, all more or less by the indulging necessity of the community, will be found in large form at such points as Riverside or Fresno, in Tulare and Kern counties, and elsewhere. The State has, by legislation and administrative control, done much, these later years, to correct the equilibrium, and has thus put the private enterprise to some extent, in this dealing with an elemental property and a natural source of wealth, under the sovereignty of the body politic. California is divided into irrigation districts, as the Commissioner is aware. A State engineer has been placed in a supervisory position over these, and encouragement is given to the landowners, occupants, and cultivators thereof to enter upon the work of irrigation—construction by means of corporative endeavour, in the form of joint-stock associations. Under these laws, the extent of conservation and distribution is in a large degree placed under control, and local rules are allowed, sanctioned by experience, to have the force of law. All this the Commissioner will have learned.

The reference made to these matters is for the purpose only of suggesting the lines upon which, in California at least, the interesting problems that are there in process of solution have been started and carried

on. The State Supreme Court has recently complicated the question of water use by a decision affirming and applying the common-law doctrine of riparian rights to the running waters of the State. The particular case that called this decision forth relates to a great irrigation enterprise carried out by large landowners, who have diverted a considerable portion of the waters of the Kern River, in Southern California, over the lands they own and are preparing for colony sale and occupation. The landowners on the same stream above the ones adversely affected by the decision have gained their point, but the questions involved in the decision are so serious as to affect the rights and necessities of many thousands of farmers and horticulturists all over the State, and may indirectly, perhaps, do so in the long run over the entire area within the United States, where the artificial conservation and distribution of water must become a prime necessity of land occupation and cultivation. There are modifying influences at work on the agitation felt in California. It is already suggested by some intelligent irrigationists that it would be easy for a wealthy corporation of waterholders and landowners to cripple all the farmers above them in any stream, unless there was some modifying legal right enforced, either by priority of ditch construction or water pre-emption, or by the enforcement of the common-law doctrine of riparian rights, modified as to the amount to be used by any such owners, and providing for the return of surplus of unused waters to the upper streams, so that landowners below may have their equities preserved.

Within the limits of the second great or intra-mountain division lying between the 105th and 120th degree of west longitude east and west, and the Mexican and British-American frontiers north and south, the Commissioners will have found irrigation works and experiments in progress, small in extent, perhaps, in most cases, but extensive when aggregated. The larger portion of Colorado, New Mexico, Wyoming, and all but a small portion of Eastern Montana, are within the limits assigned. The whole of Nevada, Utah, Idaho, and Arizona, and the eastern half of Oregon and of Washington Territory, are also included. The physical character of this vast region, comprising 15 degrees of longitude and nearly 17 of latitude, makes a total area of 1,100 by 900 miles square. In its northern portion very little worth mentioning has been attempted in the way of irrigation. In Utah, however, an extensive system is well under way, and a large area has been reclaimed. The evidence of its character and value are seen not only in the valleys near to Salt Lake City, but in all the Mormon settlements within the territory.

The influence of the Mormon polity in directing industrial activity has often been commented upon. In no one thing is it more apparent than in this great work of the conservation and distribution of the water supply. It exhibits several noteworthy features. They are—

(*a.*) The treatment of natural water supplies, under legislation, as public property, to be used for the common benefit.

(*b.*) The construction of all distributive agencies (artificial) at the cost necessarily of those to be benefited.

(*c.*) The incorporation of the expected beneficiaries by neighbourhood companies, under general law, and the assessing of such cost, co-operatively, by means of share purchasing and holding, according to the number of acres to be served by the water so utilized.

(*d*) The distribution of water under stated regulations, which have the effect of law, under the supervision of an officer specially chosen for the purpose.

(*e*) The payment for this authorized use by means of stated rates levied upon the volume of water used.

The records taken at Fort Douglas, a short distance outside the city, for twelve years, and those made by the Signal Service observers, in Salt Lake City itself, covering a period of eight years, show a mean temperature of nearly 52 degress, and an average precipitation of 17 inches and 68–100th. The first half of the period, that is from 1863 to 1872, the mean average is placed at 18·81 ; while from 1873 to 1882 inclusive, the mean precipitation is stated at over 16·65. It is noticeable throughout the entire mountain area that wherever the records have been kept long enough (this at some army posts has been the case) for comparison, that the latest years will show a marked diminution of the precipitation, while equally as marked is the increased humidity of the soil where settlement has, by irrigation, been enabled to cultivate the same.

The decrease in atmospheric humidity is believed to proceed from the destruction of the timber on the side of the ranges, and from the elevated foot-hills, valleys, and canyons thereof. This observed increased in terrene humidity is a factor of great importance. In dry areas like that portion of the United States whose characteristics are herein briefly outlined, and in similar regions, like those of Australia, South Africa, *et al.*, where cultivation under modern directiou is just beginning, there is every opportunity offered for systematic observations of so significant and valuable a series of facts—if such indeed they are, of which little doubt can be felt.

The extent of irrigation in the settlements of Utah cannot be accurately stated, as there have been no general official statistics published since 1875, a period of nine years. At that date there were in the twenty organized counties 2,095¼ miles of principal canals, costing $1,918,174 ; 4,888¾ miles of tributary canals, costing $503,320. This was a total coustruction of 6,984 miles of canals and ditches at a cost of $2,527,678. The total cultivated area within the district "under water" was 302,766 acres, of which 106,184 did not require the application of water at all.

The honorable delegate in Congress from Utah, Mr. Caine, under date of December, 1884, estimated that there were in the four most prosperous counties of that territory, in the way of irrigation (main) canals, as follows :—

Counties.	Miles of Main Canals.	Estimated Cost.
Weber	165	$300,000
Utah	150	250,000
Cache	175	550,000
Salt Lake	190	1,250,000
Total estimate	640	$2,350,000

As compared with 1875, the increase in tributary canals and their cost will, for the counties named, be 2,132 miles, and $216,596. The cultivated area "under water," or within the irrigation districts of these counties, in 1875, was over 102,000 acres, or one-third of the total. It has, unquestionably, doubled, as the estimated increase of main canals in 1884 over 1875 was 289 miles, or very nearly one-half more than the main mileage of 1875. It would not be fair, Mr. Caine suggests, to consider the increase as great in other counties of the territory. But there has been no retrogression. An estimate which adds one-fourth to the system of irrigation and the acreage affected by it would, in 1884, be within moderate bounds for the remaining sixteen counties. That would give a total cultivated area of over 656,000 acres, a main canal construction of 2,810 miles, and one of tributary works aggregating 7,750 miles.

Turning southward, Arizona is found to be making considerable progress. The southern part of the territory, and its smaller central valleys, offer a considerable area for the farmer when irrigation is applied. The difficulties of the problem are found not only in the newness of the region, as to settlement, but in the want of system, and the confusion of ideas as to the lawful use and control of water. The Mormon system would bring admirable results in both Arizona and New Mexico. There is a great deal of waste in such areas as the Salt River, the Gila, San Pedro, and Santa Cruz valleys. There has already been disputes over questions of priority, &c. Gradually order is being evolved, but at the expense, unnecessarily, of the farmers present and to come, who now or will be obliged to use water. There is in the Salt River Valley some 30,000 acres "under water." This is the oldest farming settlement in this territory, except the lands which for several centuries have been cultivated by the Pima and Papago Indians. The valley of the Gila, which contains not less than 1,000,000 acres easily irrigable, according to the analysis presented in the United States Exploration Reports, conducted by Capt. George M. Wheeler, possesses soils richer in constituent elements of fertility than the valley of the Salt River. At the present time there is a considerable number of irrigation enterprises under way. Some of them will reclaim large areas of secondary tablelands as well as cover the more available valley.

This department is possessed of information showing over 200 miles of main canals completed, or under rapid construction, during the years 1884 and at the present writing. With the tributary feeders and laterals, Southern and Central Arizona has finished, or very nearly so at least, 600 miles of irrigation works. As this territory has always been considered one of the most unpromising in the dry and mountain regions of this country, the facts are of a cheering character. The most astonishing reports are made of the fecundity and fertility of the areas "under water."

The annual precipitation of Arizona, as reported from five stations of the United States Signal Service, over an average observation period of six years, ranges from 2·04 inches at Yuma, on the Colorado, at an altitude of 200 feet above the sea level, to 15·76 at Fort Grant, an altitude of about 2,500 feet. The mean average for the territory during the six years ending June, 1883, will be only 9·34.

The physical configuration of Arizona shows it to be an over-drained region. This is in itself sufficient to account for the unquestioned aridity of a large portion of the territory; but settlement and time is providing there, as well as elsewhere within our mountain area, that the supplies of water, with proper conservation and distribution, will be found more important and available than has generally been considered probable. In the narrow and precipitous valleys of Central Arizona, there are natural reservoirs, of which, with but comparatively little artificial outlay, valuable storage basins may be created, and force enough obtained to raise the water high enough for reaching extensive portions of the *mesa* or tablelands adjoining the river valleys. Several of the minor streams are known to sink, and their recovery and use for industrial purposes will be found a task not difficult to engineering skill. In the south-eastern portion of this territory there are extensive grassy plains or broad intervals, known as *cienegas*, on account of the nearness of water to the service. The cattlemen have taken advantage of this fact. It would seem to argue the existence of subterranean waters—the consequence of over-drainage with its rapid disappearance of the precipitation. There are two rainy seasons—in our winter and summer months. In the latter they are often violent and torrential in character, disappearing almost as suddenly as they come. In April and May there are often neighbourhood showers, seeming to be limited in area, as if the currents in their passage from the Southern Pacific, coming through the Gulf of California, were broken by the higher peaks, and whirled in circular eddies over the sections visited. They are known by the Mexicans and Indians as "shepherd rains." No artesian wells have yet been sunk, but at several points the Southern Pacific Railroad has obtained water at comparatively moderate depths.

It may be worth suggesting that such artesian water belts as have been found within the mountain region herein outlined, are upon or below the east and west (foothills) flanks of the Sierras Nevada and Rocky Mountains. On the west flank of the first-named dorsal range, among the foothills of California, and on the other and physically related eastern side of the eastern and continental range—the Rocky Mountains—as at Laramie, Wyoming, Denver, Colorado; on the southern portion of the Staked Plains of North-Western Texas, upon the western division of the Texas Pacific Railroad, artesian wells are being successfully sank and utilized. The significance of this suggestion as to artesian water belts, and their topographical relation to the mountain ranges, and the possibilities of a system of conservation and distribution of water for industrial purposes, can easily be seen by a reference to any topographical map of this country.

The north-western part of the intra-mountain region or division embraces the State of Nevada and eastern half of the State of Oregon, and of the Territory of Washington. The latter sections run as far west as the 120th meridian of west longitude.

The State of Nevada presents the most forbidding aspect, so far as the water problem is concerned. The area north thereof offers but little, at this writing, of distinct interest. The average precipitation will range therein at about 14 inches per annum, falling a little below at points most exposed or distant from the hydrological system of the Columbia, and rising to about 22 inches where under its direct influence.

The indigenous grasses afford nutriment to large herds of cattle. Some irrigation enterprises are already underway, others are projected. The Columbia River and its affluents make an extensive basin, wherein concurrent testimony establishes the existence of an available water supply, large as to extent and volume. In illustration of this, there is a project now under way for utilizing the waters of the Snake River, the largest affluent of the Columbia, and turning it by means of irrigation canals, &c., over the Snake River Plateau, a great area embracing 12,000,000 acres, now almost rainless, and thus reclaiming the same. The project is a possibility, and indicates the attention that is being directed to these matters.

There is no doubt whatever of there being a sufficient and available body of water in their natural ways and channels, with the average precipitation and the storage of the snowfall in the higher canons and channels of the Sierras to provide for the reclamation of a considerable portion of Eastern Oregon and Washington Territory, while the rapid increase of pastoral use establishes the superior grazing value of the indicated region. The timber area, according to the Federal Census of 1880, will not exceed four per cent. of the whole, but that may be fairly set down as an under estimate, owing mainly to the insufficient data upon which it is based. The opening of the Northern Pacific Railroad, since 1880, has shown that this calculation falls short of the facts. The increase of land occupation and population which follows railroad construction is already being felt.

The entire area of Nevada is within the Basin region, and its average altitude is about 5,000 feet. The Carson and Humboldt Rivers form the only hydrological areas of any importance. The drainage basins of the Sierras afford valuable opportunities for water storage, natural and artificial. Lakes Tahoe and Pyramid are examples. The southern extremity of this portion is of an arid character. Yet there are some evidences of agricultural reclamation. In the Carson Valley there is some systematic effort at irrigation. The Surveyor-General of the State reported in 1883 and 1884 that within the counties named as the western half of the States there were twelve mining ditches in 1833, with a total length of 31 miles; in 1884 the length had increased to 34 miles. The irrigation ditches in 1883 were 518 in number, in 1884 there were 570; their length in 1883 was 1,040 miles, and in 1884 it was 1,091 miles. The area under water in 1883 was 77,910 acres, in 1884 it was 81,910 acres.

These figures do not cover the full consumption of water, industrially considered, within the area of this State. There are small irrigation enterprises not fully reported, and in some localities wells and springs are utilized. Water is also brought for mining purposes by flumes and ditches, sometimes for long distances, which incidentally serve, for limited areas, agricultural uses also. It is also shown, especially in Humboldt County, and elsewhere in the northern portion of the State, that water is obtained by wells sunk to but moderate depths. They Surveyor-General claims, also, that there are evidences seen of a climatic change in the direction of increased humidity. The "shepherd" rains from across the Sierras are said, on the eastern flanks, in the valleys and foothills thereof, to be more frequent, and the winters even are more mild. These statements are not yet demonstrated as facts, however.

The records of the Smithsonian and of the U. S. Signal Service observers, as well as observations taken by railroad employés, and at the military posts of the United States, irregularly though they are, run back for an average of twelve years. They indicate the annual precipitation of Nevada to be, in the northern portion, about 12 inches; in the central, along the line of the railroad and below, not over nine, under favorable circumstances; and in the southern it will run down to 6 or 7 inches per annum. Nevada is therefore to be regarded as the most unpromising portion, on the whole, of our dry area. Yet even there is evidence that water can be conserved and made largely to aid the work of land reclamation, Aa a grazing State, Nevada is slowly coming into prominence. The mildness of its winters, comparatively speaking, invites occupation for cattle and sheep. It has always been found that pastoral occupation is accompanied, after a short period, by a marked increase in agricultural utilization.

That portion of New Mexico which lies west of the 105th meridian embraces two-thirds of the territory and its most important agricultural region. The principal centres of irrigation enterprise are in the Rio Grande and Mimbras Valleys.

The former bisects the territory almost from north to south.

Irrigation has been practised therein, and in the smaller valleys, by the Indian town-dwellers, from a period long ante-dating the Spanish occupation in the middle of the sixteenth century. Water has been conveyed on to the same land for centuries by ditch and by hand, and the soil remains as fertile as when first turned by the hand of man. No reliable statistics are available as to the extent and importance of the irrigation works, within the territory, but as the population in 1880 numbered 119,565 souls, and at the present writing is estimated to be at least 140,000, raising within the territory a considerable proportion of the bread stuffs they use, besides fruit, cattle, sheep, &c., it follows that the means of water distribution must be quite extensive.

The number of farms is not less than 5,500; the yield is large, and the products of a varied character. The entire length of the irrigation canals and ditches will probably equal that of Utah.

The Indian and Mexican laws and customs as to community uses of water still continue. They were preserved to those inhabitants by treaty when Mexico ceded to the United States a large portion of its northern territory. The average annual precipitation ranges from 12 to 16 inches, according to the altitude and locality.

It will not be necessary to more than refer to the question of irrigation within that part of Colorado which lies west of the 105th meridian. A large proportion of the irrigated districts lie along or east of that imaginary line, but the southern portion of the State contains the oldest farming section. A portion of it was formerly under Mexican rule, and has the same agricultural and grazing characteristics as other portions of the Rio Grande Valley region.

The water system of the State is regarded as the best yet devised in its supervision of outflow and distribution, and its method of settling and adjudicating disputes.

The possession of water under law can be obtained by companies or by neighbourhood organizations for the purpose of distributing the same at certain rates, which are to be judicially decided upon, if disputed by the users and purchasers. The ownership of distributing and construction works is in the hands generally of large and wealthy joint-stock association. The older water companies were formed by and from the agricultural colonies, which begun over twenty-four years since the work of systematic land reclamation. The later constructions—those now operative and those in progress—are usually owned by great land companies. These works are planned on a large scale. The results are surprising, and will be more so in the near future, as a larger area is placed under water. The State is now divided into 26 water districts, in each of which a water commissioner has been appointed, to whom all questions of distribution are referred, with the right of appeal to the State District Courts. A State engineer's office has also been created, to which all engineering and other technical supervision belongs.

The discovery of an extensive belt of artesian water is likely to have an important influence on the problems herein considered. The heavy snow precipation, chiefly seen on the eastern flanks and the summits of the great ranges, which fact must be due to the influence of the Gulf of Mexico and the

Atlantic Oceans—from which the winds bear moisture over the interior of this continent—will sufficiently account for the subterranean water supply developed at Denver, and partially found elsewhere, as at Laramie Plains, Wyoming, and along the southern edge of the Staked Plains of North-West Texas. The questions to be solved in Eastern and Central Colorado and Wyoming, so far as the water supply is concerned, will be found to be of great future importance for the plains division, already referred to as lying between the 98th and 105th meridians of west longitude.

Passing then to this division, the first one in order of statement, the last in that of description, the observer is met with another aspect of the problems under review. From the foothills, north and south of the Rocky Mountains, the plains, generally treeless, of Texas, Kansas, Nebraska, and Dakota, roll eastward and downward, like a great grassy sea, to the valley of the Missouri, and the hydrological basin of the Mississippi.

It has already been suggested that within both the divisions named the imperfect meteorological records indicate during such period of contemporaneous observation as they cover, a diminution rather than an increase of atmospheric humidity and precipitation. This is not stated as a fact to be decisively accepted, but as indicative evidence only, and it seems to be accompanied also by other evidence to the effect that such diminution runs co-terminously with forest denudation and destruction of the timber. On the other hand is the striking statement, so suggestive of economic possibilities and utilities, that where settlement and cultivation has progressed to any marked degree, and especially where the latter has been aided by irrigation, there has been a decided increase of terrene humidity. Springs have increased in volume. The running waters are more regular in flow and quantity. The increase in some places is a very noticeable phenomenon, as that of Salt Lake, for instance. With all these and other details it is shown in California, Utah, and Colorado, that, wherever irrigation has been longest applied, the necessity for the use of water by its means has diminished, owing to seepage from the ditches, and that capillary attraction which has heretofore been referred to. Under cultivation, then, the soil everywhere shows an increase in humidity. But this is offset by the destruction of the forests, which is a marked feature of settlement within all the intra-mountain and Pacific coast divisions. On the other hand the destruction of the native grasses, and the substitution of other and cultivated varieties, have a marked effect favorable to the terrene increase of humidity. The eastern, or plains, division shows, however, a phenomenon of another character, and that is the movement westward with the movement of population, of an increased rainfall. This precipitation is likened by the State engineer of Colorado to a wall pressed westward. At Fort Leavenworth, Kansas, on the Missouri River, for example, the record of observation cover a period long enough in continuity and accuracy to be reliable for deduction. Prof. Snow, of the State University, Kansas, a recognised authority on these questions, states that the increase at Fort Leavenworth during the last nineteen years over a similar period just preceding, to be not less than five inches and twenty-one one-hundredths per annum. This makes an increase of nearly 25 per cent. per annum. During the first nineteen—the period preceding the white settlements, the average rainfall was 30·96 inches; during the second period it has been 36·21 inches. Fort Riley is a United States army post, located in the State of Kansas, 110 miles directly west of Fort Leavenworth. There are twenty-three years of recorded observation at Riley, and twenty-four at the State Agricultural College, a few miles north and east of the army post. At Fort Riley, the yearly increase has amounted to 3·05 inches per annum. At Manhattan, the average annual increase is stated at 5·61 inches. Going further west one degree and the 98th meridian is reached—the limit set for the eastern boundary of the dry region.

When settlement begun on this line and west thereof, the average annual precipitation did not exceed 14 inches. It now ranges as high as 18 inches in the eastern portion, of course far short of the full needs of industrial life. And yet the column of settlement is moving west in both Kansas and Nebraska in a slow but almost solid wall. In Dakota this western movement is now more rapid, but has not continued long enough for reliable deduction.

Within the western or "dry" half of Kansas no white population was in 1860 recorded by the Federal Census enumerators. In 1870 the total population in the same region was given by the ninth Federal Census as 5,169. In 1880 the tenth census records it at 165,000. The State Agricultural Report for 1884 gives the following figures. Returns from only 30 organized counties are given. The unorganized ones are also growing rapidly:—

Population	191,226
Acres under fence	2,840,979
Acres under cultivation (grain and tame grasses)	2,233,723
Number of cattle, sheep, &c.	1,239,662
Pounds of wool clipped (1883)...	1,726,443
Number of orchard trees	2,823,782
Number of acres in small fruit	1,660
Number of acres in forest trees (planted)	29,367
Value of all marketed meats, wool, and dairy products, also poultry, eggs, &c.	$5,338,825

In the extreme south-western portion of Kansas, forming part of the upper valley of the Arkansas River, and traversed by one of the great trunk railways—the Atchison, Topeka, and Santa Fé road—there are a number of rapidly growing colonies and farming centres. This growth is due to the inception and construction of the irrigation works on a large scale, supplied from the Arkansas, and serving a considerable area of fertile and tillable land heretofore used only for grazing purposes. The first of these enterprises was begun in 1880; the most extensive are not over two years old. The present canals and ditches have a length of over 300 miles, and for water service cover an area of about 600,000 acres. The capital invested aggregates over 500,000 dols.

The land thus irrigated now sells at from 4 dols. to 10 dols. per acre. The population of this valley, within the irrigable area not already included in the totals given, will be not less than 3,000 persons. The total population in the unorganized counties, not given, can be estimated at 5,000 persons.

The total population thereof in one State alone, of an area wherein it is asserted that the rainfall is insufficient for agricultural settlement, is not less than 196,000, all of whom live on, and cultivate, the land.

Western Nebraska, to the north of Kansas, equally shows, and perhaps in even a more marked way, the peculiar western movement of the rainfall to which attention has been called as characteristic of the Plains division. Professors Aughey and Wilbur, of the State University, with ex-Governor Furnas, of that State, recognised authorities, declare that Western Nebraska and Eastern Wyoming, therefore, will show a steady climatic change. Prof. Wilbur regards the rainfall as comparing favorably with European countries.

A soil that is not cultivated, he says, is dead, or arid in character. He holds that there is no such thing as a desert in any of the Plains region; that ordinary well water will be found in all directions, and that artesian water is also obtainable. The under soil, he declares, presents a saturated stratum of 8 feet in thickness, upon which capillary attraction acts. There may be, and probably are, areas in the colony of Victoria of which this description by Prof. Wilbur, of the State University of Nebraska, will prove true. It is given for the Commissioner's use :

" When a settler on the frontier builds his sod house, or roofs his dug-out with sod, he is sheltered from the rain. The thatch of sod throws off the rain which falls on it. Even so with the unbroken prairie. It is thatched ground. The rain falls, but penetrates not. It may come in ample abundance, but, as regards the land on which it falls, it is mostly wasted. It rushes off into the draws, through the draws into the creeks and rivers, and from the rivers to the sea. When the plough of the husbandman breaks the sod, the thatch is taken from the earth. Thenceforward the rain that falls largely stays. The absorbent soil of the prairie drinks up the moisture, and, for five or seven years of cultivation this absorbing process may go on, until the ground is thoroughly saturated, and has taken up its plenum of water for the uses of the farm. I have talked with hundreds of farmers on the frontier, and I have found this to be their experience—a gradual yet rapid development of the resources of the soil by the increase of moisture in its various forms, which follows upon cultivation. As cultivation extends, the characteristic growths of the prairie change. The stunted buffalo grass is displaced by grasses of a richer growth. Trees spread out from the river bottoms, and the land which was known to the traveller before the farmer settled upon it would be known by him no longer."

One of the most notable among the processes of reclamation is seen in the cultivation of timber. It is stated that since the passage of the Timber Culture Act (a law under which a settler receives 160 acres—additional to the homestead of the same extent—on condition of planting ten acres thereof in forest trees) a great area has been set out. The extent of this arbor-culture can be seen by remembering the fact that over 29,000 acres were reported, in 1884, as planted with growing timber in Western Kansas alone. In Nebraska, in 1884, there were set out 4,435,000 trees, and over 2,000 bushels of trees seeds were sown.

The area reclaimed under the Timber Culture Act, July 1st, 1884, within the States and Territories herein named, was 16,961,742 acres.

If the law is obeyed, there is now growing 4,240,433 acres of forest trees. If this is reduced, for fraudulent entries, by one-half, we shall still have an area of over two million acres.

The Commissioner for the Australian colony of Victoria is thus in possession of an extended outline of the report on irrigation and land reclamation within the United States, now being prepared by this department. It is respectfully transmitted to him in the hope that the facts and suggestions contained may prove useful, and for the purpose of responding to the inquiries propounded.

Very respectfully,

E. A. CARMAN,

Acting Commissioner of Agriculture.

By Authority : JOHN FERRES, Government Printer, Melbourne.