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Letter from the Secretary of Agriculture, transmitting, in response to Senate resolution of December 13, 1890, a report on the progress of irrigation investigation under the Deficiency Appropriation Act of 1890

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LETTER

FROM

THE SECRETARY OF AGRICULTURE,

TRANSMITTING,

In response to Senate resolution of December 13, 1890, *a report on the progress of irrigation investigation under the deficiency appropriation act of* 1890.

FEBRUARY 13, 1891.—Referred to the Select Committee on Irrigation and Reclamation of Arid Lands, and ordered to be printed.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., February 10, 1891.

The Senate of the United States:

In pursuance of Senate resolution adopted December 13, 1890, as follows:

Resolved, That the Secretary of Agriculture be, and hereby is, directed to report to the Senate all information in his possession as to the progress made in the investigation for irrigation purposes of the regions lying between the ninety-seventh parallel west of Greenwich and the foothills of the Rocky Mountains, as provided in the act of September thirtieth, eighteen hundred and ninety, known as the deficiency appropriation act; and also to inform the Senate whether, in his opinion, under the limitations as to time provided in said act the said investigation can be carried out so as best to secure the information sought and with the greatest economy, and that he show by his report what amount of the money heretofore appropriated for this purpose has been expended in each State and Territory in which expenditures have been made.

I have the honor to forward herewith a progress report of the irrigation survey, which, in connection with that submitted to the Senate on the 20th of August, 1890, brings down to date the information, so far as it has yet been compiled, sought for by the Senate.

I am firmly of the opinion that the investigation provided for in the act of September 30, 1890, known as the deficiency appropriation act, can not be brought to a successful end within the time fixed in said act. In this connection I respectfully call attention to the following paragraph of my last annual report to the President:

The brief preliminary reports made to Congress of the artesian wells investigation resulted in the passage of the following provision of the general deficiency act, approved September 30, 1890:

"IRRIGATION INVESTIGATIONS.—To enable the Secretary of Agriculture to continue to completion his investigations for the purpose of determining the extent and availability for irrigation of the underflow and artesian waters within the region between the ninety-seventh degree of longitude and the eastern foot-hills of the Rocky Mountains, and to collect and publish information as to the best methods of cultivating the soil by irrigation, forty thousand dollars: *Provided,* That no part of said sum shall be expended unless the entire investigation, collection, and publication contemplated herein, including the report thereon, can be fully and finally completed and finished before July first, eighteen hundred and ninety-one, without any additional expense, cost, or charge being incurred."

The extraordinary nature of the above proviso made the formulation of plans for carrying out the investigations enjoined upon me under the act a matter of very serious difficulty. Indeed, a too literal adhesion to the language of the act, embarrassed as it is with this provision, would make it well-nigh impossible to undertake the work at all. Assuming, however, after due consideration, that the intention of Congress was that these investigations should be continued, I at once proceeded to organize an irrigation inquiry, and to prepare to carry on the work of artesian and underflow investigation as far along towards completion as was possible by the exercise of the utmost diligence within the period provided. At the same time I felt called upon to instruct the gentlemen in charge that all reports must be completed and handed in on or before the 30th April, 1891. The date at which the act was approved, and the early period at which I am obliged to call in the reports, necessarily curtail the time available for field service to a few weeks of field activity, and hence curtail the usefulness of this investigation.

Experience has confirmed me in the opinions then entertained with respect to the advisability of arbitrarily limiting the time to the first of July, 1891, within which the work should be completed and the report thereon should be published.

With the greatest diligence compatible with thoroughness of preparations, arrangements for field work were not completed until the 20th of October, too late in the season to enter upon that part of the investigation which must be performed in the Dakotas, Montana, and Wyoming. This portion of our task can not be undertaken before the 15th of March, and to insure the publication of the results by the 1st of July the material must be in the hands of the printer by the 1st of May; thus limiting us to the short period of six weeks for field studies, and for tabulation and compilation of results.

Our first efforts were directed to the States of Nebraska, Kansas, and Colorado; and the force was kept in this region until December, when, field work being no longer possible there, it was transferred to New Mexico, the Indian Territory, and Texas for the winter. Arrangements have been made to throw the entire force into the northern field as soon as the season is far enough advanced; and we shall submit our completed report in time for publication by the first of July, in the absence of further legislation extending the limit of time. I beg, however, most respectfully, to repeat my opinion that it is inadvisable, in a work so broad and so essentially one of exploration and discovery, to limit the Department arbitrarily to the short time fixed in the original act.

I append hereto a statement of the salaries paid from the appropriations for the irrigation, underflow, and artesian inquiry (acts of April 4, 1890, and September 30, 1890), showing, as far as possible, the distribution of the expenditures among the States and Territories interested.

I have the honor to remain, very respectfully,

J. M. RUSK,
Secretary.

The SENATE OF THE UNITED STATES.

List of office employés, their compensation, etc., in artesian wells investigation under urgency deficiency appropriation act of April 4, 1890.

Name.	Whence appointed.	Date of appointment.	Nature of service.	Where employed.	Length of service.	Compensation.	Remarks.
Richard J. Hinton	New York	Apr. 16, 1890	Special agent in charge	Washington, D. C.	146 days	$10 per day	Ex-irrigation engineer U. S. Geological Survey, author of report on "Irrigation in United States." Senate No. 15, second session Forty-ninth Congress.
Frank Blaisdell	Massachusetts	May 15, 1890	Civil engineer	do	122 days	$1,800 per annum	
W. Berton Nassau	New York	June 12, 1890	Compiler	do	95 days	$6 per day	
William A. Wansleben	Dist. of Columbia	May 1, 1890	Draftsman	do	69 days	$50 per week	
John T. Lucey	California	Apr. 21, 1890	Amanuensis and compiler.	do	88 days	$3 per day	
J. I. Christiancy	Michigan	June 11, 1890	Statistical expert	do	38 days	$5 per day	
Robert H. Partridge	Virginia	May 22, 1890	do	do	55 days	$150 per month	
Nathan B. Payne	New York	May 26, 1890	do	do	71 days	$100 per month	
Charles D. Poston	Arizona	May 1, 1890	do	do	52 days	$5 per day	
J. P. B. Littell	Dist. of Columbia	July 17, 1890	Tabulator	do	10 days	$3 per day	
M. R. Hampson	do	do	do	do	do	do	
Gustave Thielkuhl	do	July 7, 1890	Photographer	do	14 days	$5 per day	
Mortimer A. Downing	Missouri	July 8, 1890	Stenographer	do	11 days	$6 per day	
J. W. Barker	Dist. of Columbia	Apr. 18, 1890	Messenger	do	5 months 19 days.	$660 per annum	

List of field employés, their compensation, etc., in artesian wells investigation under urgency deficiency appropriation act of April 4, 1890.

Name.	Whence appointed.	Date of appointment.	Nature of service.	Where employed.	Length of service.	Compensation.	Remarks.
Edwin S. Nettleton, C. E.	Colorado	Apr. 15, 1890	Supervising engineer	The field	3½ months	$4,000 per annum	Assigned from Interior Department. Supervising Engineer U. S. Geological Survey.
Robert Hay	Kansas	Apr. 14, 1890	Chief field geologist	do	94 days	$8 per day	Geologist, Kansas State Board of Agriculture.
Louis G. Carpenter	Colorado	Apr. 16, 1890	Field agent and assistant geologist.	For Colorado from 105° to foothills and for New Mexico from east line to foothills.	78 days	do	Professor Irrigation Engineering, Colorado State Agricultural College.
Garry E. Culver	South Dakota	do	Geologist	Dakotas and east Montana to foothills.	60 days	do	Professor, University, Vermillion, S. Dak.
Louis E. Hicks	Nebraska	Apr. 14, 1890	do	Nebraska and Wyoming west to foothills.	do	do	Professor State University, Nebraska.
E. T. Dumble	Texas	Apr. 16, 1890	do	Texas	do	do	State geologist, Texas.

List of office employés, their compensation, etc., in artesian wells investigation under urgent deficiency appropriation act of April 4, 1890—Continued.

Name.	Whence appointed.	Date of appointment.	Nature of service.	Where employed.	Length of service.	Compensation.	Remarks.
P. H. Van Diest*	Colorado		Geologist	Colorado and New Mexico east from foothills to border of State and Territory.			Employed in making monograph on geology of Colorado and New Mexico from foothills to border of State and Territory.
T. E. Underhill	North Dakota	Apr. 16, 1890	Field agent (statistical)	North Dakota	60 days	$6 per day	State railroad commissioner.
Stephen G. Updyke	South Dakota	....do	....do	South Dakota (eastern division) from 98° west to Missouri River.	....do	....do	Professor in State Agricultural College.
J. W. Gregory	Kansas	Apr. 14, 1890	....do	Kansas, Nebraska, public land strip, Colorado to 103° west longitude.	80 days	....do	Editor Sentinel, Garden City, Kans.
F. E. Roesler	Texas	Apr. 15, 1890	....do	Texas from 97° to 105° west longitude.	68 days	....do	Civil engineer, Dallas, Tex.
Horace Beach	Wisconsin	May 5, 1890	....do	South Dakota	50 days	$5 per day	Well expert, Prairie du Chien, Wis.
F. F. B. Coffin	South Dakota	....do	....do	Western division South Dakota.	28 days	$8 per day	State irrigation engineer.
George E. Bailey	....do	Apr. 26, 1890	Division field agent and assistant engineer.	South Dakota	60 days	....do	Professor, State School of Mines, Rapids City.
J. B. Greenwell	District of Columbia.	Apr. 16, 1890	Stenographer to supervising engineer.	In field	2½ months	$100 per month.	

*The accounting officers have not settled the question as to whether Mr. Van Diest is entitled, without action by Congress, to compensation for his valuable monograph, as he holds the position of chief clerk of the U. S. Surveyor-General's Office of Colorado.

List of office employés, their compensation, etc., in irrigation, underflow, and artesian inquiry under general deficiency appropriation act of September 30, 1890.

Richard J. Hinton	New York	Oct. 1, 1890	Special agent in charge	Washington, D. C	Continuous	$10 per day	
Frank Blaisdell	Massachusetts	Oct. 17, 1890	Civil engineer	....do	... do	$150 per month	
W. Berton Nassau	New York	Oct. 6, 1890	Compiler	....do	48 days	$6 per day	
J. M. Hines	District of Columbia.	Nov. 8, 1890	....do	....do	Until 4th of Mar., 1890.	$5 per day	
Mrs. A. F. Wood	California	Oct. 7, 1890	Files' clerk and typewriter.	....do	Continuous	$1,400 per annum	
James I. Christiancy	Michigan	Nov. 1, 1890	Compiler	....do	....do	$100 per month	
Robert H. Partridge	Virginia	Nov. 24, 1890	....do	....do	1 month	....do	
Joseph Harper	Dist. of Columbia.	.. do	Stenographer	....do	17 days	$6 per day	
Mortimer A. Downing	Missouri	Dec. 23, 1890	....do	....do	Continuous	$5 per day	
Thomas Mackey	South Carolina	Nov. 10, 1890	Assistant compiler	....do		$75 per month	
J. W. Barker	Dist. of Columbia.	Oct. 6, 1890	Messenger	....do	Continuous	$660 per annum	
R. A. Baker	....do	Nov. 24, 1890	Indexer	....do	30 days	$5 per day	

List of field employés, their compensation, etc., in irrigation, underflow, and artesian inquiry under general deficiency appropriation act of September 30, 1890.

Edwin S. Nettleton	Colorado	Oct. 16, 1890	Chief engineer	Artesian and underflow, North and South Dakota, and Kansas, Nebraska, eastern Colorado and New Mexico, and western Texas.	Continuous	$4,000 per annum
W. W. Follett	do	Nov. 1, 1890	Civil engineer	Nebraska (Platte Valley), Kansas (Arkansas Valley).	do	$200 per month
Robert Hay	Kansas	Oct. 16, 1890	Chief geologist	Artesian and underflow, Nebraska and Kansas, New Mexico, Texas, Texas (Pan Handle, etc).	do	$250 per month
R. T. Hill	Texas	do	Geologist	Oklahoma (Pan Handle, Texas), Rio Grande, Texas, and eastern New Mexico.	do	$200 per month
J. W. Gregory	Kansas	do	Special field agent	Nebraska and Kansas, or central division of Great Plains.	do	$8 per day
Joseph Nimmo, jr	New York	Oct. 25, 1890	do	Irrigation inquiry, Montana, Idaho, eastern Washington and Oregon.	58 days	do

NOTE.—The name of a rodman employé or his compensation has not yet been forwarded to this Department by the Chief Engineer.

LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., February 5, 1891.

SIR: The provision of the general deficiency bill, approved September 30, 1890, directs the Secretary of Agriculture to continue to completion the investigation begun under a similar provision, approved April 4, 1890, "for the purpose of determining the extent and availability for irrigation of the underflow and artesian waters in the region between the ninety-seventh degree of west longitude and the eastern foothills of the Rocky Mountains." It also directs the collection and publication of "information as to the best methods of cultivating the soil by irrigation."

The Office of Irrigation Inquiry has been formed by the Secretary's orders, in order to fulfill the duty thus imposed upon the Department, the undersigned being in charge. A field of inquiry has also been organized by the appointment of Edwin S. Nettleton, C. E., as chief engineer, and Prof. Robert Hay as chief geologist of the Department of Agriculture. These officers report directly to the Secretary. Progress reports of the work accomplished and observations made by the Secretary's order accompany this report.

The brief time between the passage of the appropriation in the general deficiency bill and the reassembling of the second session of the Fifty-first Congress, making a period of but 61 days, precluded the possibility of doing anything with the irrigation inquiry beyond the preparation of a progress report, in which an endeavor will be made to show the conditions and development of irrigation as applied to the soil for the purposes of cultivation. It has been impossible to make those field observations by which the most accurate data could alone be obtained. The office has, therefore, been obliged to depend upon extensive correspondence covering all parts of the areas of the United States in which irrigation is required. It has also supplemented this correspondence with an extensive distribution of circulars, sent to land colonies, canal and ditch companies, engineers, practical irrigators, State and county officers, railroad companies, and others who might be in the way of obtaining information and giving intelligent account of the same. Copies of these circulars are annexed to this report. The percentage of replies to such inquiries has been quite large. They show a growing and widely extended interest in the whole subject and the serious questions involved therein. This correspondence has not been confined to what is generally termed the arid region, but has come from the great centers of commercial and industrial activity as well as from those of agricultural enterprise. From the extent and nature of this correspondence it is quite certain that the office of Irrigation Inquiry will soon be equipped with a complete record of every irrigation enterprise and land colony project, of the nature, character and extent of all works, the vast amount of territory, with accurate opinions bearing directly upon the multifarious questions of soil, climate, productions, engineering, and economic life, which are involved in the great problem of reclaiming to the uses of man the arable portions at least of two-fifths of our national domain.

I am, sir, very respectfully,

RICHARD J. HINTON,
Special Agent in Charge.

The SECRETARY OF AGRICULTURE.

IRRIGATION IN THE UNITED STATES.

PROGRESS REPORT FOR 1890.

BY

RICHARD J. HINTON

SPECIAL AGENT IN CHARGE,

DEPARTMENT OF AGRICULTURE.

IRRIGATION IN THE UNITED STATES.

PROGRESS REPORT FOR 1890.

By RICHARD J. HINTON,

pecial Agent in charge of the Office of Irrigation Inquiry, Department of Agriculture.

Irrigation, by English-speaking Americans, begins for all practical purposes with the Mormon settlement and occupancy of the Great Salt Lake Basin in Utah. The same people also exemplified the value of irrigation by their settlement at San Bernardino, in Southern California. These first and important efforts began about 1854. Very little or nothing was known of the nature and possibilities of farming by irrigation until the United States troops sent to suppress disorder in Utah had reached the neighborhood of Salt Lake City, early in 1858. In California, before and at that period, the value of irrigation was individually understood by a few pioneers, and meant success to those citizens, while here and there in the southern part of the State small and large ranches were being so cultivated with great success. Before the American occupancy of California and the Mormon settlement of Utah, irrigation within the boundaries of what is now the United States was confined to that portion of the Rio Grande Valley found within the present Territory of New Mexico, and to isolated points in southwestern Texas; to a few Indian tribes and pueblos in the Territory of Arizona; to a score or more of Catholic missions, with Indian villages attached thereto, and to the Spanish settlers found in the province of Upper California. All such efforts were of the most rudimentary character, giving results, however, sufficient to prove the possibility of enormous development and progress in that direction. Unmistakably the oldest irrigation is that produced by the Indian dwellers of the 18 pueblos found in New Mexico, and by the Moquis, Sapori, Pimas, Maricopas, and Papagoes, resident in the present Territory of Arizona. Evidence exists in our Southwest region of larger works and wider fields, made by a people long since extinct.

The value of irrigation as a fertilizer of the soil may be seen in the fact that the Pima Indians of Arizona have cultivated the same land—a portion of which they now occupy—for at least 500 years. Their cultivation, though rude, has been extensive and well conducted. Nothing has ever been applied to the land but the water, which quickens and fructifies it. As large crops are now raised as any of which the traditions of these Indians bear record. Besides the Indian Pueblo settlements, the valley of the Rio Grande for nearly 400 years has been the seat, as far north as southwest Colorado and as far south as Eagle Pass in Texas, of settlements the members of which have cultivated the soil by irrigation. This population when we first came into contact with it was known to consist of not less than 100,000 persons. They were organized into village communities, each member of which cultivated small areas along the valleys of the streams from which the water was obtained, and held in common the forest and timber land. Their descendants still form a considerable part of the population, and their methods have helped to shape the economic life of a portion of southern Colorado, New Mexico, and a large part of southwestern Texas. From the period of our acquisition of the Mexican Territory up to 1870 no definite interest was felt in the question of irrigation beyond that already referred to.

General irrigation really began in the United States with the founding of the Union Colony, in 1870, of Cache la Poudre, in northern Colorado. Fruit culture by means of irrigation began in the same year at Riverside and Fresno, in southern California. Horace Greeley's journey across the continent 12 years before and the reference he then made to irrigation fields seen in Utah and at isolated points in California were the initiatives of the discussion which increased in importance up to 1869. Several papers were printed in the annual reports of the Department of Agriculture. Mr. M. C. Meeker, then agricultural editor of the New York Tribune, began an agitation for the organization of a complete colony to be located in Colorado. As the result of this discussion the Union Colony was formed and the town of Greeley established. Ex-Governor Benjamin H. Eaton, who was one of the original colonists though a resident before its founding in the State, says that the colony was located on a barren plain of cactus in the very dry spring of 1870. There was not then a house or building or anything of that kind at Greeley, nor upon the land now occupied by the people tributary to that place. The first season was a very unpromising one. At that time no one thought there was any good land except along the river, supplied by capillary attraction from the soakage or seepage stream In the 10 years preceding the founding of the Union Colony there had been enough small farming by means of irrigation in Colorado to warrant belief, however, that in valley or bottom lands the soil was rich and the yield would be abundant. Indeed, as early as 1858 and 1859 one sagacious settler in the Cherry Creek Valley was able to supply the miners with vegetables and other products in quantities sufficient to make, at the prices paid, a very large return for his industry. The Union or Greeley Colony, as it was commonly called, was, in fact, the first body of American agriculturists to undertake irrigation on a large scale and on the bench or mesa land. The Mormons in Utah had confined their labors to the broad valley lands of the Jordan and to other points along the Salt and Utah Lakes. Mexican irrigators seldom carry the water on to bench lands.

It is but just, therefore, to consider the foundation of the Colorado Colony as the true beginning of American irrigation. Its first year was a very bad one; the second was but little better, while in the third year all the available land was cultivated. Enough of the original colony remained to keep the enterprise in active existence. The first year, by ditches, water sufficient was taken to irrigate 4,500 acres. This ditch was some 24 miles in length, generally 4 feet deep, and 2 feet wide at the head. It is now 20 feet wide and 6 feet deep and conveys about 14 times as much water as it did when first constructed. Considering the practical knowledge shown the Greeley-Union Colony was a bold enterprise. Four canals were to be constructed, costing $5,000 each. Only 2 were so constructed by the colony proper. Actually, they cost more than the first calculation called for. Ditch number 3, as it is termed, has cost in all $25,000, and now irrigates 4,000 acres of land. Ditch number 2, which was to have been made for $5,000, has cost at least $27,000. With its three enlargements its total cost has been $112,000, and it serves at present 25,000 acres of land. Ditch number 1 was never built. The fourth proposed main ditch has since been constructed by private capital. The total cost of these canals, colony and company works, which it was estimated would cost $20,000, have actually required $400,000. In the district served by the Cache la Poudre, which is known in Colorado as water district number 3, the total of irrigated land is estimated at 108,000 acres, of which the Union Colony proper and the subsequent settlers within its area claim 52,000 acres. There are some 50 ditches in the district. The largest amount of water flowing over the cañon weir at the head of the stream is reported at 7,000 cubic feet per second. In 1888 the greatest amount of water reported was 1,700 cubic feet per second. The maximum discharge in June, 1889, was 1,804 cubic feet per second. The lowest volumes named will give a service of water of 1 cubic foot per second for 60 acres. In spite of all the economy now practised in the use of water in the region under consideration, it is very evident that as much more runs to waste by reason of loss at the sources of the streams and by seepage from the ditches while being conveyed to the field, than is consumed in the actual process of irrigating the same. The important crop in this portion of Colorado is that of potatoes, the freight shipments of Greeley being from 1,500 to 2,000 carloads per year.

The success of the Greeley Union Colony was soon reported and widely apprehended. Its founders and some of its members were well known as journalists, and interest was concentrated and maintained upon the efforts they were making. At the same time, in California, more interest was being aroused in the intensive cultivation of the soil by the aid of irrigation. The lower foothills region of central California had already produced fruit of such degree and quality as to attract considerable notice. In the valley of the Sacramento, and the counties formed out of the San Francisco Bay region, the culture of the grape had already succeeded it to a large degree. The valley of the San Joaquin was then, to a limited extent, being made available for wheat-growing purposes. In Southern California proper, fruit culture had already begun, but stock raising remained the main industry of that section and of the San Joaquin Valley. The extensive introduction of alfalfa as a forage plant was, without doubt, a chief cause of the irrigation enterprise inaugurated by Messrs. Haggin and Carr in Kern County, which is formed out of the lower portion of the San Joaquin Valley, and bounded on the west by the coast range, on the east by the Sierras, with Mount Whitney as its culminating center, and southward by the range which separates the San Joaquin Valley from Los Angeles, San Bernardino, Orange, and San Diego Counties. The construction of the Southern Pacific Railroad during the seventies unquestionably stimulated the interest of large land owners in the possible reclaimability, by means of irrigation, of the vast San Joaquin Valley. In 1874 Congress authorized the appointment of a commission to investigate the possibilities of reclamation in the valley proper, and also to inquire into the character and the progress of irrigation in India. Elsewhere in California, individual farmers, fruit growers, and viticulturists, were steadily enlarging the area of their irrigated fields and orchards. The wheat ranches of the central portion of the San Joaquin and Sacramento Valleys were rapidly encroaching upon the stock and sheep ranges. This also brought about the formation of a number of water companies. In the lower counties of the State there was a marked change from grain and alfalfa to orchards and vineyards, but for want of a sufficient market the movement made but slow progress. In all cases the use of water for artificial distribution on the soil was shown to be an absolute necessity.

Two colony movements occurring in California during the first half of the decade from 1870 to 1880 may be taken as the initial points of the present wonderful industrial and horticultural development now in progress in California and elsewhere west of the 100th meridian of longitude. The first of these movements was that by which the town and colony of Riverside, the greatest single center of orange culture within the United States, was founded. The other movement was the establishment of the original raisin-grape and fruit-growing colony at what is now the city of Fresno. The Riverside colonists were generally Eastern people who were desirous of escaping the rigors of the Atlantic climate, and who were urged also to the step by the interest aroused by the success of the Union Colony at Greeley, Colo. Fresno Colony was organized by Californians, several of the founders being school teachers employed by the city of San Francisco. Both enterprises have achieved marvelous success. The foundations of success at both Fresno and Riverside has primarily been the cultivation of the rich soil under almost perpetual sunshine and equable temperature, and the use of artificial application of water to the land through irrigation works.

The general progress of irrigation was slow, however, throughout the arid west between 1870 and 1880. In Utah the direction given to farm settlers by reason of the Mormon organization and its economic skill, enabled them to make a steady advance throughout the decade. The striking growth at Riverside in San Bernardino County, of Fresno and Los Angeles Counties, yearly attracted more attention in the State of California. In the foothills region, through the decision of the courts not to allow the emptying of the débris or "slickens" into the rivers, hydraulic mining received a permanent check, and considerable impetus was also added to both agriculture and horticulture. This has been especially the case in the lower counties or outlets of the San Joaquin River. In Colorado there had grown up large irrigation enterprises in Arapahoe and Weld Counties, marking the advent of successful agriculture in that State. Wheat growing became a prominent feature of its production. In New Mexico the advance of railroad enterprise made larger demand upon its primitive agricultural methods. The change arising in California from the new fiscal conditions put in operation by the constitution of 1880, compelled the investment of capital in irrigation works in order to make the land with which the owners were weighted more valuable. The general condition in 1880 of the arid region was such as to give warrant in some degree to the declaration that its chief use must be that of stock raising. Railroad enterprise has had much to do with changing this view. In the new northwest section a considerable portion of the area so rapidly developed was blessed for several years with sufficient rainfall for agricultural security. Large settlements began in the more favorable portion of a region affected climatically by the topography of mountain lines and ranges. On the Pacific coast the increase also of its trunk line railroad facilities began to create a market and enlarge the demand for the more valuable products of its soil. Somewhat slowly, but assuredly, interest increased, as the necessity of irrigation to maintain successful cultivation became yearly more obvious.

SETTLEMENT ON THE GREAT PLAINS.

In the first part of the present decade population poured in upon the Great Plains region. The earlier years of sufficient rainfall were followed by periods of drought, in which a large percentage of the success previously achieved was destroyed. Reaction set in, and for a time it appeared as if the entire Plains region would have to be given over to cattlemen; but slowly, however, the cattle range business is changing as the pressure of population continues with more or less vigor, and ranchmen are becoming unable, east of the basins of the Rocky Mountains at least, to command large areas of natural grass land. This pressure is also driving out inferior cattle. This slow change from large ranch to smaller cattle farm, brings with it an increased understanding of the needed water supplies for the purpose of raising forage plants and grasses sufficient for the new form of pasturage and management. Isolated irrigation enterprises of considerable importance, however, began to grow in valleys like the Arkansas and North Platte, east of the Rockies; in the Yellowstone and its tributaries in the Northwest; in the Snake and Salmon Valleys of Idaho, and elsewhere on a smaller scale throughout the arid region. By 1885–'86 irrigation as a mode of cultivating the soil had begun to assume regional proportions and to impress itself upon national opinion and polity. This effect was seen in the adoption of action by Congress looking to the reservation of sites for reservoir and storage basins. For the past four years discussion on this subject has become a matter of familiarity to the whole country, and does not need to be dwelt upon in this report. Attention is called to it only to show the importance of the problems involved and the methods to be pursued in the cultivation of the soil by irrigation.

The visit of a Senate Special Committee on Irrigation in 1889 to the arid portion of the country and the subsequent conflict that arose over its report and recommendations, has had the effect of crystallizing to a very large extent public interest in this subject. Accompanying that discussion, there has also arisen a remarkable debate over the limits of the productive powers and agricultural possibilities of our arable areas. It is affirmed with great positiveness that a comparatively short time will see the limit not only of our power to export agricultural products, but even to supply the rapid increase of our own population. Irrigation, then, as a mode of cultivating the soil and still more as a means of fertilizing it and thereby largely increasing its productive capacity, is bound to become a considerable factor. This will be true without relation to the correctness of the position assumed in regard to future ability to supply our own people. The evidence taken everywhere shows that the production of grain can be doubled by means of irrigation within the arid region over equal areas within humid States; that the production of root crops and garden vegetables can be increased from five to ten fold over the same crops elsewhere, and that in the production of special products over large areas where the climatic conditions are favorable to them, aridity aside, the sections possessing constant sunshine, and soils laden with mineral elements, will have through irrigation an advantage and security no other region on the continent can possess. This will prove to be true, not in horticulture alone, but also in the raising of enormous crops of sugar, tobacco, hemp, and other articles of value in the markets of the world.

CHARACTERISTICS OF IRRIGATION PROGRESS.

At the present time the position of irrigation enterprises, development and cultivation thereby, show certain marked characteristics. Among these the first in importance is a decided tendency towards a division of large holdings of land and its more or less rapid disposal in quite small bodies. Throughout the Southwest and the Pacific coast region within the past three years the owners and holders of large areas of land, obtained usually through the Spanish land grant system, or by purchase from railroad land grant owners, or in some instances by the workings of the desert land act, are all exhibiting a desire to subdivide their property. In proof of this we have but to recognize the facts found in Merced, Fresno, Kern, Tulare, Los Angeles, San Bernardino, and San Diego Counties, in California. We can see the same desire at work in New Mexico and Colorado, where large holdings of land have heretofore been sought. In western Texas also the same feeling prevails. Something of this is owing to the development of Mormon settlement in Utah, where the largest arable farm is only 200 acres in extent, while only a dozen or so are found in the Territory of that size. Among Mormon farmers proper the holdings will range from 5 to 20, the average seldom exceeding 7 or 8 acres in extent. The continued increase of travel to Southern California and the proofs of the value of small farms under irrigation, has also had something to do with the general development, but the fact remains that irrigation distinctly tends to establish the necessity and profitableness of small farms.

A close examination of the records of the General Land Office points strongly in the same direction. Attention has elsewhere been called to the fact that the returns of entries made during the past two years will show that the average homestead taken up on the public lands, within the arid regions, ranges, according to different localities, from 140 acres down to 50. The reason for this is obvious. Irrigation in its more primitive form compels the settlers to hold possession at points where arable land can easily be reached by water taken from a natural stream or spring and distributed by gravity through the rude ditches or other means at their command. The care and attention required, which is amply repaid by the results of irrigation, is such as to forbid the pioneer farmer from holding large bodies of land unprofitable to him. One cause of depression in the region east of the foothills has arisen from the desire of occupants to hold more land than they could manage with profit. Settlers have taken up homesteads, filed on a preëmption quarter, and added thereto a timber culture claim, thus making as a rule in the Great Plains region three-quarters of a section of land to one occupant. With a few head of stock, a small amount of money, and two or three favorable seasons the majority of them succeeded in mortgaging these claims in the hope and with the desire of farming on a large scale. The summer drought has prevented growth, the hot winds have burned their growing grain, and in the course of a short period such men, overloaded with land, have become bankrupt and abandoned their settlement. Millions of acres in this way have been thrown back upon the mortgage, loan, and trust companies, by whom money is usually advanced to pay the preëmption fees and other needed farm capital. Other settlers have followed and learned the same lesson. Each retiring wave leaves behind it, however, the hardier elements of population, though consisting very often of those who have not the means to get away.

Along the railroad lines and in the river valleys these settlers are learning the value of smaller farms. As the artesian wells investigation has shown, they are seeking water by every means possible and sinking wells in all directions. The necessity as well as the aptitude of these Americans will force for them a road out of their difficulties; one sure way will be for them to moderate desire for a large acreage.

An incident was told to the members of the Senate Committee on Irrigation in 1889 which illustrates this position. At the junction of the North and South Platte, in Nebraska, a body of land has been placed under ditch, forming thereby the most easterly example of irrigation on the continent. One of the promoters told this circumstance: A young man employed at North Platte in a store had bought and made the first payment on 80 acres of the land to be reclaimed. He was not a farmer by occupation and had no further money wherewith to begin life or to till the land. Seeking the advice of the narrator it was suggested to him that he might cultivate (by planting cabbage) 2 acres favorably situated from the percolation of the main ditch. Out of his wages as a store clerk he bought seed and hired help, placing his 2 acres under cultivation. At the time the committee was in Nebraska the young man had just sold, in the ground, the product of his 2 acres of cabbages for $500 per acre. All over the region the ordinary farmer had failed miserably to obtain a decent harvest, yet a large majority of them had attempted to cultivate many acres, usually, too, with seed bought on trust. The young irrigator secured money enough to complete the payment for his 80 acres and to start in business, while learning a lesson in utilization of his land to the best purpose that he will never be likely to forget.

It is a self-evident result of the interest now being taken in irrigation throughout the Great Plains that the pioneer farmer will have his attention turned from extensive attempts at indifferent cultivation of large grain fields to a more intensive cultivation on his homestead of land favorably affected by water supply. Small areas will feed his family, support his stock, and leave him some surplus without debt, thus tending steadily toward securing independence for himself and them. It is not improbable also, as current developments show, that there will be more cattle, horses, and sheep of finer grades upon the plains region in a few years than is at present the case. In proportion to both population and stock, under the development of a steadier water supply and of its artificial distribution there will be equally as marked an increase of cultivation and production. Irrigation works and supplies will be largely localized; they will be a necessary adjunct rather an indispensable requirement.

Everywhere in the past year an increased tendency of irrigation enterprise has been that of the subdivision of the land. Those interested in the loaning of money on land are among the most energetic in their conviction that the small farm, well irrigated and made secure by a needed storage of water, is a much better risk for capital than large and shabbily cultivated farms that are subject to sporadic droughts. A notable feature of the past year is that which is seen in the interest taken by the mortgage companies doing business east of the foothills. In North and South Dakota these large operators have made it clearly known that they are prepared to invest to a considerable extent in the development of artesian and other water supplies for farming purposes if only they can be made, as is suggested, reasonably sure of the extent, permanency, and power of the water supplies they desire to aid in developing. Individual farmers are also energetically pursuing the same end.

A great number of artesian well projects are now under way as community enterprises, being conducted under authority of law which gives the counties in South Dakota the power to issue bonds for the purpose. A State board of irrigation has been organized to act with the State engineer of South Dakota, in order to insure the purchase of machinery at reduced rates and their transportation over the railroads at merely nominal rates. In western Nebraska, in which public interest has been but lately aroused, great local activity is being displayed, and under the presence of the Department's chief geologist, Prof. Robert Hay, and the able special agent, J. W. Gregory, for the division of Kansas and Nebraska, this interest is being well directed. There is a large region south from the Niobrara to the Republican River in northern Kansas, wherein the phreatic waters are known to be abundant and with their plane quite near to the surface. A regular fall to the eastward will enable the distribution of water to be made with comparative ease in that direction. No great amount of mechanical power will be required to lift such phreatic waters to points whence they may be more readily distributed. A very remarkable development is sure to be seen within the next year or two in the basin formed by the Republican, the Frenchman, and the tributaries of the North and South Platte. This area covers a large section of contiguous territory in Nebraska, Kansas, and Colorado.

In the valley of the Arkansas and south thereof, in Kansas, a much more hopeful feeling has recently arisen. The State census of 1888, and the recent national census, show a considerable decrease of population in the counties of Kansas lying west of the ninety-seventh meridian. The development of the undersheet water in the valley of the Upper Arkansas now in progress has greatly encouraged the people of that fertile section. In the extreme southwestern counties of the State lying between the Upper Arkansas and Cimarron, the facilities found for obtaining water by drilled and bored wells at very moderate depths has greatly animated the hopes and aroused the courage of those who have remained there in spite of the droughts. The wheat crop is always the prime crop of our newer western region, and that, too, in spite of the failure of rain. The yield in southwest Kansas, even with the past severe season, has ranged from 15 to 30 bushels per acre. The fall sowing shows an area nearly double that of 1889.

A striking feature of the situation in western and southwestern Kansas is seen in the formation, through the various land, mortgage, and trust companies of a great land syndicate for the purpose of developing the water supply of that country, and thereby giving permanent return for capital they have invested. These loan companies have already had thrown on their hands 1,000,000 acres. It does not appear to be their policy to foreclose mortgages, but in many cases they have been compelled to buy titles from mortgagors who have deserted their places. Plans for insuring a water supply sufficient to make the grain crops secure are now, it is stated, being perfected by competent engineers. The syndicate will endeavor to put one-fourth, or 250,000 acres, of the area under wheat in the ensuing spring. They will divide the farms to be thus cultivated among the several counties in western Kansas and eastern Colorado in which their lands lie. They will drill for water, construct underflow works, establish storage basins, make ditches, experiment with pumps, and dig the necessary distributaries. Agents will be appointed for each farm. In this way it is expected that settlers will be encouraged and stimulated to new exertions, while the rise in value of the syndicate lands will also increase, it is urged, that held by the individual farmer. The intention is not, it is assumed, to hold these lands in large bodies, but, on the contrary, to invite immigration. Having pointed the way to security by means of their investment in irrigation works, the syndicate expects to make rapid sales of the lands they are now weighted with. This at least is the view presented by their friends.

The tendency to divide irrigable lands into small holdings is also seen in Colorado and throughout the Northwest. It is becoming manifest in a marked degree in New Mexico, where among other tracts the well known Maxwell grant is being subdivided into small farms. The railroad lands in that Territory are to be brought into market in the same way. A very remarkable development of irrigation enterprise has taken place in the Pecos Valley, southeastern New Mexico, a fuller account of which will be found in the statement of the developments in that territory. This whole region until three years since was given over to the cattle ranchmen. From Roswell south the valley of the Pecos is being rapidly settled. Irrigation works of large extent are already in existence and more are being constructed. Projectors and promoters are earnest, it appears, in their efforts to subdivide the land, and they are wise therein as a business policy. None of it is valuable for varied farming or for horticulture without irrigation. On the "staked plains" and in southwest Texas, at the many points in which irrigation is now being tried, the same tendency to small holdings is seen. It is also the case in Arizona, where the policy of the desert-land act has been for years most stoutly maintained. In the valley of the Salt River especially, now developing most rapidly into one of the most remarkable fruit regions, the decrease in size of the farms has been quite marked in the past few years.

SMALL FARMS AND COLONY LIFE.

The most astonishin g development of the small farm and colony life which irrigation so rapidly tends to produce, has been seen in California during the past 10 years. What the effect may be on the average holding of that State under the present census can not now be estimated. In 1880 500 acres was the amount per capita for California. Two years since it was estimated at 300 acres. This development is not confined to southern California, but has, within the past 4 years or less, manifested itself strongly throughout the State, except in some of the wheat-growing counties. It has reached its largest development so far, within the most favored fruit section. A land sale that took place quite recently in San Bernardino County illustrates the progress of the small farm. At this sale, conducted by a company which has constructed irrigation works in a field heretofore regarded as unpromising, over 8,000 acres of land were disposed of at an average rate of $66.34 per acre. Of this land 2,000 acres was disposed of in 10-acre lots; nearly 1,400 acres were sold in 20-acre parcels; a few other sales were made at 40, 50, 60, 70, and 80 acre divisions. Two bodies of 700 acres each and one of 170 were sold to speculative parties. Nearly all the lots sold above 20 acres each were purchased by Eastern people. The California purchasers, who know the advantages of compact village life and horticultural settlement, contented themselves with smaller purchases. This is an example, on a little larger scale as to one enterprise, of a great many that are going on all over southern California and in the San Joaquin Valley. These fruit-growing settlements are advertised by their promoters as colony enterprises. They are seldom, however, coöperative in character.

The great ranch system which grew up in that State out of the Spanish and Mexican plan of land holding, and of the railroad land-grant system, by which the Southern and Central Pacific roads have been created, has broken down of its own weight. Over 12,000,000 acres were, till quite recently, held almost unbroken under Mexican grants within the southern counties alone. Disintegration and division is in very rapid progress just now. During the past year in the counties of Merced and Kern, for example, the owners of great bodies of land and costly water systems have been actively engaged in promoting irrigation and in the sale of their land in small bodies for fruit farm purposes. In Merced County one of the principal holders of such land and water privileges asserted in 1889 that it was the owners' intention to hold on to the land in large bodies and cultivate it, either directly or by tenants, for wheat and other field crops. Since then the same interest has organized colonies in Holland, and brought a considerable number of settlers therefrom, selling parcels of land to them of from 20 to 100 acres in extent. In that county alone there are now some 10 of these community or colony enterprises under way. In Kern County, where the first California irrigation operations upon an extensive scale were begun and carried forward, the land and water owners interested have been for the last year actively promoting the sale and subdivision of their great estates. Four fruit colony settlements are already under way through their efforts. Three other colonies have been inaugurated in another portion of the county, whose water supplies are obtained from an artesian basin of the most remarkable character. This basin is fed by the drainage of the Sierras, the culminating point of which, Mount Whitney, lies directly to the east of its location.

In Tulare County, still the most extensive wheat-growing section of the San Joaquin Valley and the State, a region in which but a few years since there appeared to be no room for horticulture or even agriculture upon a paying basis, there is now a growing and rapid division of the land into fruit-farm areas. The tendency throughout the whole region is in this direction—that of thickly settled communities, living in comfort and even in luxury upon very small bodies of highly cultivated land. In the western part, at Hanford, and along the eastern slope of the coast range, a section in which development has been heretofore very slow, there is now a rapidly growing increase of irrigation works and supplies. In San Luis Obispo, a coast county heretofore devoted mainly to cattle and grain, and which claims not to need surface irrigation in order to insure agricultural success, there is also a rapid growth in fruit farming, chiefly prune culture. At Hollister and some other points in that county, large irrigation works, however, are being established. Several land enterprises, divided into holdings of from 10 to 20 acres, are in operation. In Ventura County the same tendency is also seen. In Santa Barbara, to a certain degree, small orchard holdings have long existed; but not until recently has the organization of horticultural communities as such, obtained a foothold there. In the counties of Los Angeles, Orange, San Bernardino, and San Diego the growth of fruit-farming communities has been a most notable feature of the last few years. It began with the success of Riverside, Pasadena, Pomona, and other of the older settlements. There are about two hundred of these prosperous hives of comfort, fertility, and beauty of surrounding, within the boundaries of what is known as southern California. These are not boom towns, but places in which much work and high cultivation have already secured success. San Diego County is now being developed under this plan of operations. All of these settlements owe their existing prosperity to the water supply, which enables them to irrigate lands otherwise arid.

EFFECTS OF IRRIGATION IN CALIFORNIA.

The growth of population in California during the past decade will illustrate, not alone the economic importance of the cultivation of the soil by irrigation, but the social significance of the changes which such methods of cultivation tend rapidly to produce in farm life and habits. Under its influence striking changes are going on in the character of that State. During the past 10 years California has gained at the rate of 39 per cent. in population. The cause of that gain can be seen when it is known that thirteen counties of the State have lost in population from 1 to 73 per cent., while fifteen, including the most important irrigated areas, have grown more rapidly than the State at large. In the counties that have fallen back, mining, stock-raising, and lumber industries have been the principal support. In the fifteen counties that have increased so largely, farming pursuits under irrigation have become the chief feature of their development. The total population of the State in 1880 was 864,552. In 1890 it was 1,203,969. The gain in the eleven counties most deeply interested in irrigation has been over 753 per cent. The percentage is as follows:

County of—	Per cent.
Fresno	228
Kern	79
Los Angeles	234
Merced	36
Orange	244
San Bernardino	227
San Diego	295
San Luis Obispo	77
Santa Barbara	66
Tulare	120
Ventura	98

These counties comprise those affected directly and indirectly by the growth of irrigation enterprises and horticultural progress. Taking the six counties of southern California proper, to wit, Santa Barbara, Los Angeles, Orange, San Diego, Ventura, and San Bernardino, and the increase of population will be—

In 1880	64,378
In 1890	202,974
An increase for the last decade of	138,596

The counties in northern and central California which have maintained and increased their population will also be found to have been favorably affected by the tendency that irrigation has so developed. Another evidence of the value of this form of farm life may be found in the banking statistics of California. There are 232 banks in the State. Of these 28 are in San Francisco and 63 in the southern counties. Putting aside the San Francisco bank statement, it appears that the 63 banks had on the 1st of July, 1890, of cash on hand, $6,264,000; the remaining 141 banks, scattered over the State, held as cash in hand only $9,265,000. The State at large shows $26 in cash to each inhabitant. Southern California, however, shows $31 to each one of its population. Leaving San Francisco and southern California out of account, the average cash per capita elsewhere would be $11. The deposits of the San Bernardino banks show an average of $93 to each man, woman, and child within the county. It is claimed that the property of the State will give an average of $9,000 to each family. These figures are presented in illustration only of the remarkable tendency towards small farming which irrigation produces everywhere, and of the still more remarkable results as to security and prosperity which, under favorable circumstances as now developed, has followed its progress.

VALUE AND ECONOMY OF IRRIGATION OVER RAINFALL.

The difference between irrigation and rainfall as economic factors in production was forcibly illustrated at the California State Horticultural Society's meeting in 1889, in a paper read by L. N. Holt, of San Bernardino. Some writer has said recently:

> Too much attention has hitherto been given to the chemical conditions of soils and too little to the physical conditions by which moisture and air are supplied to the roots.

Some propositions made by Mr. Holt seem to illustrate this statement quite forcibly, as, for example, when he called attention to the fact that in Florida the rainfall annually exceeds 50 inches, or over 4 inches per month. In San Bernardino County the average for 19 years of the month of January, which is the wettest month of the year in southern California, has been but 3.36 inches. At the first blush it will be suggested that the remedy, if any were needed, would be to apply, if possible, the Florida rainfall to the conditions of San Bernardino. On the contrary, however, the horticulturists of Florida are considering the necessity of constructing works and applying irrigation to their orchards. They assign as a reason for this the fact they are unable to obtain their rainfall at the period when it is most needed. The irrigationist in California or elsewhere commands water, if in control of a sufficient supply, just at the time when his crops require the same. The value of irrigation, whether in dry or humid sections, for fruit, garden vegetables, and meadow lands, at least, can not be doubted. The illustrations already given of the value of fruit crops in California, the success of which is dependent upon the artificial application of water to the soil, can not be disputed. A wheat field in Iowa or Illinois would probably not pay the expense of irrigation. Indeed, grain crops hardly pay the cost of irrigation within an arid region. They may pay because the product is necessary for the community, but as a business, unless in regions affected by natural subirrigation and with soils of a porous character, grain will soon be left for other and more paying crops. With regard to fruit, vegetables, or other special products the examples of Colorado, New Mexico, central Utah, portions of Idaho, and eastern Washington, and the Salt River Valley, in Arizona, combined with the great results already achieved in California, there can be no doubt. Mr. Holt says that the "superior orange is not the result of superior soil, but the result of superior climate, of which the rainless dry summer is the principal factor."

The semi-aridity of the Great Plains region, which has been a marked feature of the last 3 years, has caused a loss of 20 per cent. on its productions. If the fruit crops, then, of the arid States, especially California, were entirely dependent, as are the wheat crops of the Plains region, upon the irregular natural water supply, the enormous loss that would follow can be easily appreciated when it is remembered that peach and apricot orchards, etc., return a net profit of at least $100 per acre; the wine grape and the table grape one of $150; the raisin grape from $200 to $250; and oranges at least $300 per acre. The loss of 20 per cent. on such crops would reach a very large sum. Irrigation with such soils and under such circumstances makes production as certain as that of the weaver, the iron-molder, or the shoemaker. The sunshine is there, the soils are filled with fertile elements, and the water, when stored above or below ground, made rich by nitrogen, microscopic fungi, and other fertilizers drawn from earth and atmosphere, will, combined with the skill of the cultivator, rob agriculture of the uncertainty that has heretofore belonged to it as a pursuit.

Mr. Holt asserts that the water supply in southern California has been in many places largely increased during the past few years. In some it has been more than doubled by artificial means and this development is going on rapidly. The artificial progress is thus conclusively stated by one whose valuable experiences enforce his conclusions.

The water supply during the past few years has been materially increased and in many places more than doubled by artificial means, and this development is going on to-day at a rapid rate.

First. The natural flow is being saved by the construction of conduits (pipes and cement canals), which save all the water in the streams and put it where it will do the most good.

Second. The natural flow of our streams is being increased by running tunnels under the bed of the streams to take the underflow which otherwise is lost.

Third. Artesian wells are being sunk in large numbers and large irrigation systems are being formed and an abundance of water is being obtained from this one source alone, which is adding millions to our wealth and thousands to our population.

Fourth. Storage reservoirs are being successfully built. There are at present 3 large reservoirs completed and filled with water. The first attempt was the Bear Valley Reservoir in San Bernardino County. It is a grand success, and no one can look into the future far enough to see the vast acreage that reservoir will eventually irrigate. The Guyamaca and the Sweetwater Reservoir in San Diego County were next completed, both of which are more than meeting the expectations of their promoters. The Hemet Lake Reservoir near San Jacinto and the San Luis Rey Reservoir are both in process of construction, and others will follow. This shows the artificial increase of irrigating water.

But the increase of which Mr. Holt speaks is not alone found in the artificial methods of conservation. He indorses the claim made in the eastern Great Plains region to the effect that the cultivation of the soil on a large scale has had striking results in increasing the rainfall. It is a question whether this statement, taken by itself, can be considered in any large degree correct, but the general drift of weather records where the period has been long enough to warrant their division into periods of equal years, seems to support Mr. Holt's position. Along the center from north to south of the Plains region this presumed increase has been assumed by some authorities to be fully equal to 3 inches per annum during the latter half of periods ranging from 10 to 15 years each. It must be borne in mind, however, that everywhere the records have been better and more carefully taken during later years. Local rainfall has, it is probable, been favorably affected by cultivation. Changes in the temperature of the earth through moisture drawn from both below and above and retained in the veins and fibers of the plants, to be afterwards shed forth again, has greatly affected the temperature of the atmosphere lying nearest to the earth. In this way the low-lying local rain clouds that are affected by regional topography and other conditions will necessarily be more evenly and equally distributed over the drainage areas in which they fall. It is such phenomena as this which justly give rise to the idea of the local increase of rainfall in regions recently brought under cultivation.

Mr. Holt averages the rainfall of San Bernardino for the past 19 years, a careful record having been kept for that period. Dividing it into sections of 9 years each and leaving out of count an incomplete season, Mr. Holt states the result as follows:

During the first 9 years of the 19-year period the rainfall averaged 15.20 inches each year, and during the next period of 9 years the average annual rainfall was 17.44, an increase of 2.24 inches per annum.

The increase is not very much, but it reaches 15 per cent. of the annual average, sufficient at times to turn failure into success. Mr. Holt continues:

This increased rainfall becomes more valuable when we show that it is found in the spring of the year when most needed. During the first 9 years we find the average rainfall in March 1.07 inches, while in the second 9 years it is 3.15 inches. The rainfall for April also increases from 0.67 of an inch to 2.64 inches; and in May the increase has been from 0.23 of an inch to 0.68 of an inch.

It is well enough to note also in this connection that the rainfall of October has not increased, while that of November has been somewhat less. The principal increase of rainfall appears to have been during the months of March, April, and May.

While Mr. Holt acknowledges that this period of observation is too short to make these deductions certain, he still feels himself safe in calling attention to them and in declaring that, in his opinion:

The time is not far distant when practically every foot of arable land in southern California will be brought under successful cultivation by using water for irrigation where irrigation is necessary.

What has held true in southern California will most certainly prove true in some degree throughout the whole of the arid region.

AREAS OF LAND RECLAIMABLE IN SOUTHERN CALIFORNIA.

How important such a conclusion must be if the facts shall warrant the same, may be seen in the statement that the area available in the five counties of southern California, not including what is known as the desert region, that may be cultivated for fruit by means of irrigation is not less than 2,000,000 acres. Mr. T. S. Van Dyke, of San Diego, divides these acres as follows:

County of—	Acres.
San Bernardino	300,000
San Diego	550,000
Los Angeles and Orange	600,000
Ventura	300,000
Santa Barbara	300,000
Total	2,050,000

Against Mr. Van Dyke's estimate Los Angeles claims a much larger area and credits San Diego with less, but between the authorities 3,000,000 acres may be taken as the total reclaimable area. At an average profit of $200 per acre for fruit and other special crops—which is rather below than above the yield of fruit lands in that section—the reclamation of the 3,000,000 acres alluded to would within 5 years make an annual return of $600,000,000 to the income of the community. Mr. Van Dyke declares:

The amount of land available in southern California for the production of all kinds of fruit is a thing that few even of its oldest residents have any idea of. Every year sees thousands of acres of vineyard and orchard shining upon land that the year before everyone supposed nature had designed only for brush or cactus. Every year sees thousands of vines and trees come into the full bearing of abundant and perfect fruit upon gravel and bowlder washes, wastes of cobble stones, etc., that but 3 or 4 years ago the poorest seeker for a home on the public lands would not touch. So every year sees water brought higher and higher over the country, and thousands of acres which must have irrigation, and which with water are the most valuable parts of the whole, are being yearly reclaimed. Southern California is getting more water than ever before, is entering upon an era of water development that will cast the past into the shade. This is of far greater importance than the discovery of new land, for it is the irrigated sections that will produce the greatest amount of wealth, and maintain upon the market the highest standard of products.

HORTICULTURE AND IRRIGATION.

The farm value of the fruit trees raised in the United States is not less than $180,000,000. Our annual imports of fruits and nuts may be estimated at a value of $20,000,000; just about the amount that France spends annually in aid of her agricultural development. Our total exports will not exceed one-tenth of our fruit imports. Of oranges we import not less than 1,750,000 boxes; of lemons, 2,275,000; of raisins, more than 2,000,000 boxes of 20 pounds each, and of figs, 8,000,000 pounds at least; the value of prunes imported can not be less than $800,000. The 3,000,000 acres of land, which Mr. Van Dyke claims can be reclaimed in Southern California alone will produce of the finest of fruits enough to wipe out the difference between our present exports and imports of such production. This fact alone is a sufficient warrant for the practical interest manifested in the progress of irrigation. It is evident that California alone could supply all of the temperate and semi-tropical fruits and nuts that are now consumed in this country. Recent reports claim a commercial shipment for 1890 equal in value to $10,000,000. Of prunes, 15,000,000 pounds; raisins, 40,000,000 pounds, and of oranges 40,000 car loads, have been shipped out of the State. Nor is this all of the benefit arising from special culture and intensive farming by means of irrigation. Our wine imports exceed in value $7,000,000 annually; yet California has about 225,000 acres under wine-grape culture, and exports wine to Europe to be brought back and sold in our own markets as of French origin. The product for 1890 is estimated at 15,000,000 gallons. We can not only supply our own tables, but we can vastly increase that market by an increase of the fruit area. We can export and compete with the best fruit countries of the world, and ere long we shall probably be found doing this successfully. Our fruit area under irrigation is not confined by any means to California, either central or southern, coast range, or foothills. Colorado, for example, is now one of, if not the chief of apple-growing States of the Union, area being considered. In other fruits of the temperate zone its production is still advancing.

In the great empire growing up in the Northwest the most valuable fruit land is now being developed in areas requiring the artificial application of water to the soil. In eastern Washington, along the river valleys and foothills that separate that State from Idaho, a great stretch of semi-humid lands exist, in which the culture of temperate fruits, small berries, and valuable garden products is already being brought to a high degree of perfection. At Boisé City, Idaho, the display of fruits in the orchards already existing there is, simply astonishing as to size, quantity, and quality. At Missoula, Mont., in the Bitter Root Valley, as the peach, pear, plum, and apple trees ripen, it is a common sight to see the branches propped up by heavy timbers in order to prevent their breaking with the weight of fruit. Table grapes of the finest quality are also produced there. In the valleys of Salt River, Santa Cruz, and the Lower Gila, semi-tropical fruits are being brought to a degree of early perfection and ripening that is simply surprising to the horticulturist. And our capacity for special culture of this character has but just begun to be understood. In the neighboring Republic of Mexico some sixty varieties of delicious fruit are grown. One-half of these or more are unknown to our palates, and they can all be raised to perfection in the southwest section of the Union. In Texas the Rio Grande Valley for 100 miles below El Paso, under Mexican settlement and rule, was found to be an excellent fruit country, producing, as the western side in Chihuahua now does, the finest of Mission grapes and other fruits. The Mesilla Valley, in southern New Mexico, has been a land of fruit trees and vines for the past 200 years. Its yield is now increasing yearly and the market is abundant. In the Pecos Valley, to the east of the Rio Grande, the cultivation of fruit has just begun. It is claimed for this region, as also for a large portion of the Staked Plains in Texas, that special crops of this character, and of garden products also, ripen earlier than in California, and have at present a nearer market.

Of the 100,000,000 or more acres of land that may be reclaimed within the arid region it can fairly be assumed that one-fourth at least, or 25,000,000 acres, can be utilized for the production of specialized commercial crops. All of this land is to be reclaimed by the artificial storage and distribution of atmospheric and phreatic waters. Surely it is worth something to the whole country to know where these waters can be found and to show where and how they may be utilized. Whatever may be held as to the advisability of special surveys and public construction, the need of gathering and presenting this important information can hardly be denied. It is in this direction chiefly that the value of irrigated land within the boundaries of our present public domain will be most largely seen.

The question of general farm competition is settling itself. Take California, for example, as a wheat-growing State. Three years since California had nearly 2,800,000 acres, producing over 30,400,000 bushels. The past year the cereal crop has been about 27,000,000 centals. The average value of the wheat product per acre was about $7.50. The difference in favor of the Eastern farmer's contiguity to markets, etc., is estimated at about 30 cents per bushel. In an address before the State Horticultural Society the Hon. M. P. Chipman declares that the yield per acre in California has fallen off at least 28 per cent. within eighteen years. He estimates its average as below that of the United States as a whole. It is claimed therefore that to raise wheat for the world's market is comparatively unprofitable farming, and that fertility and production are alike diminishing. Forage plants, especially alfalfa, is much more valuable when combined with the raising of fine stock. But a very large proportion of the area devoted to wheat in California can profitably be transferred to fruit culture, with a difference in favor of the grower in net profits of from $100 to $300 per acre. In 1874 Vaca Valley contained 4,500 acres devoted to wheat and alfalfa. It is now planted to trees and produces an annual profit of nearly or quite $200 per acre. Land worth $60 in 1874 sold for $600 in 1888. At Newcastle, Placer County, Cal., among the foot-hills, wheat land worth five years since from $5 to $10 per acre is now selling for fruit-growing purposes at from $100 to $200 per acre. Wheat lands in Merced County, under ditch two years since, selling at from $25 to $40 per acre and renting for half these figures, are selling now for fruit purposes at from $60 to $150 per acre. At Bakersville, Kern County, a similar change from alfalfa and wheat to vines and fruit trees has trebled the value of the land. In the whole San Joaquin Valley, the vineyards average but 23 acres each.

One of the most striking evidences of all this change under the magic touch of irrigation is that exhibited by Fresno County, in the centre of the San Joaquin Valley, California, especially that portion of it lying adjacent to Fresno City. In 1871 a colony of 500 persons settled there and laid out 5,000 acres in small vineyards, for the purpose mainly of cultivating the muscat or raisin grape. This colony, begun on the 16th of February, 1871, is the most prosperous, with the exception perhaps of Riverside, now existing in California. The same settlers that bought and planted 5,000 acres of land, paying $2.50 per acre, became the supporters of the Fresno Canal and Irrigation Company, which then had a length of about 40 miles of main and lateral ditches. In 1870 there were less than 5,000 people; in 1890 there were over 100,000. There are 25,000 residents in and around Fresno City. More than 20 colonies, large and small, are located there, and 20,000 acres of vineyards are directly tributary to that place. In 1890 there were 16 main canals in existence with a length of 750 miles. The laterals had about the same mileage, or 1,500 miles in all. About 360,000 acres are under cultivation in the county. The entire area would be worthless except for occasional crops of wheat and sparse cropping for cattle, without the advantage of the systems of irrigation in vogue. Their cost is estimated in 1890 at $1,500,000. The acreage in cereals is given at 300,000, in grapes 30,000, in orchards 3,000, in alfalfa 20,000; the remaining 7,000 acres being utilized for small products. In 1870 the cultivated area would have been sold at a high figure if $1,000,000 had been paid for it. It is probably worth $30,000,000 at this time. The raisin grape began to bear in 1873, and 6,000 boxes of 20 pounds each were shipped that year. In 1883 2,800,000 pounds or 140,000 boxes were shipped from Fresno City. In 1890 the crop was at least 18,000,000 pounds or nearly 900,000 boxes. Land unimproved with water sells at the present time at from $50 to $100 per acre; improved and "under ditch" at from $100 to $300 per acre. The cost of water-royalty is included in the land, which remains, therefore, inalienable from it. The annual cost of maintenance averages 62½ cents per acre. Within the year 1890 irrigation districts have been formed in Fresno county under the Wright laws, the bonds for the construction of which works are about to be issued. Under these laws the company and private works now in existence will be assessed or condemned, and be paid for out of the proceeds of the bonds. This system will result in a large increase of irrigable area.

In California horticulture is in great part the result of irrigation. This is especially true of the culture of citrus fruits, raisin grapes; to a large extent also of wine grapes and of the deciduous trees throughout southern California. The fruits of the temperate zone and the culture of the prune—one of the largest fruit projects of the State—is accomplished, as a rule, without the direct application of water to the land on which the trees are grown. Natural sub-irrigation is but just being understood within the irrigable region as necessary for the successful cultivation of these fruits.

RIVERSIDE AS AN ILLUSTRATION.

The commercial value as well as other social and economic facts of crops grown under irrigation are forcibly illustrated by the results of fruit culture. In California it may be broadly declared that horticulture is practically impossible without natural or artificial irrigation. The former is mainly by means of the underflow or drainage waters. In the northern and central portions of the State the fruits of the temperate zone mature with but little application on the surface of water from ditches, or other means of irrigation. The prune, one of the great crops of California, grows to it greatest perfection in the coast section, where the surface is everywhere underlaid with water and the rainfall is more abundant than elsewhere, though evaporation and seepage is quite as active as in the semi-tropical part of the State. New products of commercial value, such as the olive, fig, English walnut, and other deciduous fruit trees, are found to flourish well and yield abundantly, being irrigated only in the earlier period of the tree's growth.

The two California fruit crops which forcibly illustrate the special value of irrigation are the raisin grape* and the orange. The history of the latter culture in southern and central California, especially the former, is of greatest significance. That California could grow oranges to perfection has been demonstrated for more than 100 years. The Padres and ranchmen of Spanish or Mexican times cultivated it successfully, but the actual production as a commercial factor began in southern California, with the settlement of Riverside in 1870 as a colony by Eastern people under the management of the late Judge North. At that time the site of Riverside was occupied by an Indian village. The largest owner of land thereabout pleaded with the board of equalization for a reduction of land taxes to 75 cents per acre. Some of the same land is now held as high as $15 per acre. Without artificial conservation and distribution of water, Riverside, like other prosperous settlements of San Bernardino County, would have no real value for farm purposes. It would have taken 800 acres of its area to support a ranchman or hunter, and 25 to poorly feed 1 broad-horned steer. About 6,000 people now live in the greatest comfort, even luxuriously, on 6,000 acres of land. Within the range of cultivated land in America there will be found no settlement more closely worked and subjected to more intensive farming, presenting no more striking features of beauty in landscape both natural and artificial to the acre, and returning a larger result for labor, skill, and enterprise. Of this cultivated area, 3,000 acres are in oranges, the oldest trees being 15 years of age, while thousands are but just fruiting. During the year 1889 there was shipped to market as the product of these 3,000 acres, 1,480 car-loads of oranges and lemons. The value on the track per car is given at $800, making a total return for the shipments of $1,184,000. These figures give the net return per acre of $395. Since 1880 several additions have been made to Riverside, and the area of all is now about 12,000 acres. The entire population is not less than 8,000. There are 750,000 citrus trees owned and cultivated by 660 persons. The cultivation of the muscat or raisin grape occupies a large area, and gave a return during the past year, with other fruits, of about $700,000. A moderate estimate of the fruit shipped from the Riverside settlements and sold in the markets of the country and of the world will give for the past year a return of $1,800,000. The larger estimate made puts the total at $2,500,000, which will give an average value of over $2,200,000. With 8,000 acres, estimated as bearing commercial fruit, the return will average $300 per acre.

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* See appendix for paper on raisin growing.

The county assessor's returns give the following areas actually occupied, with the number of trees found thereon:

Citrus acreage.

	Trees.	Acres.
Oranges 4 years and over	287,301	310.3
Oranges 3 years and under	171,185	201.6
Lemons 4 years and over	12,012	132.3
Lemons 3 years and under	263	3.5
Total fruit bearing	470,761	647.7

Orange trees—	
Planted in 1890	187,491
In nursery for future planting	312,683
Seedling plants	713,000
Total	1,213,174

Deciduous fruit trees.

	Trees.	Acres.
Apricots	35,287	342.5
Pears	13,500	128.5
Peaches	11,655	111.3
Olives	3,396	38.4
Apples	1,645	10.5
Walnuts	1,037	16.0
Figs	737	4.0
Prunes	52,526	4.0
Total	67,783	655.2

	Acres.
Vines:	
Raisin grapes	1,667.7
Wine grapes	517.0
Berries	5.3
Total	2,190.0

The original cost of the land upon which these valuable crops are raised it will be very difficult to estimate. It certainly does not exceed from first to last over $100 per acre, or $1,200,000 in all. This does not include the cost of improvements by way of dwellings, etc., which must nearly double the value. The total cost of the works for the original settlement of Riverside will be about $80 per acre, or, in round figures, $500,000. For other works, pipes, pumps, canals, and artesian wells, the total cost will be about $1,100,000, making in all $1,600,000 or a fraction over for the whole 12,000 acres embraced in the five Riverdale settlements of $100 per acre. The maintenance of the system is a comparatively small item. It may be seen by these statements, which are rather above than below the mark as to the cost of land and works, that 2 years' production at Riverside would return a profit of 15 per cent. at least, on the average totality of outlay. Of course the present values of land to the later purchasers and occupants give an entirely different balance sheet. Even with these high figures a large return is secured, as, for example, a purchase was made in the winter of 1889–'90 of a 10-acre orange orchard, all of which was in bearing; the cost of the land and trees to the purchaser was $1,000 per acre. The crops sold divided between two grades of oranges, one for $1,750 and the other for $1,250, making a return of $300 per acre. Under this percentage of returns the purchaser of these 10 acres would inside of 4 years receive $2,000 more than his original outlay. During the past year the yield per acre from citrus orchards at Riverside ranged from $1,000 per acre down to $261.80. These figures cover the net and not the gross profits, as the cost of cultivation, etc., are all deducted before the amounts are given. All these results are from the primary application of water by artificial means to the soil. Blessed by unremittent sunshine, by the clear dry atmosphere common to the arid country, with land that has gathered for untold centuries, the fertilizing qualities of the rocks and soils around about, and manipulated also by an intelligent cultivation rarely to be found, the student of the new agriculture finds at Riverside abundant evidences of the benefits to be derived from irrigation, and striking proofs of the fine social life that is being created by such conditions.

SPANISH AND MEXICAN LAND METHODS.

The Spanish conquerors of Mexico, coming as they did from a land in which irrigation had been practiced from time immemorial, brought with them an appreciation of the relations of water, land, and cultivation within regions that were arid in character. They were therefore prepared to understand the habits, customs, and laws of the Indian or indigenous population, which were of a similar character, only more communal in form. The rulers of Mexico incorporated the Spanish law of "servitude," and the same has been maintained by Mexico as an independent government. Under it water is the property of the King or government, subject to beneficial uses for the people. This includes both running and subterranean sources of natural water supply. When the Spanish forces had occupied what is now the northern states of Mexico, Lower California, Arizona, and New Mexico, a portion of southern Colorado, the whole of Texas, part of the Indian Territory, and a strip of land in southwest Kansas, Charles V, Emperor of Germany and King of Spain, issued a decree in which the following paragraph occurs:

> If in that which is already in the Indians there should be any places and districts so good that it may be proper to found settlement, and any person should make application to settle and reside in them, in order that with a greater will and profit they may do so, the viceroys and presidents may give them in our name lands, house lots, and waters, in conformity with the disposition of the land.

While large areas of land were granted away to leading Spaniards and Mexicans, an extensive system of colonization was also projected. Along the Rio Grande within the Territory of New Mexico, Colorado in the counties of Conejos and Costilla, as well as in portions of southwest Texas, these colony grants obtained a vigorous foothold. After the final establishment of the Republic of Mexico in the third decade of this century, the colonization laws and regulations were greatly improved, becoming a more complete system, exceedingly well adapted to the people for whose benefit they were intended, and also to the character of the country they occupied. Surveyor-General Hobert, of New Mexico, in discussing the land-grant system of that Territory, says as to the colony grants that the governing ideas always were that to any one without land lands should be given as long as the Government had unoccupied land, and that it was better for the nation that "the country should be settled and the land reduced to private ownership." Generally the lands and waters were assigned to each person "in conformity with the disposition of the land, by an inferior officer (alcalde) sent with them for the purpose."

The chief result of such community settlement would be the formation of a "placita" or village center with the land on either side. Usually the colony would be located in a narrow valley with a mountain range side. Generally, too, it would be where the mountains on one side come closer to the river or stream than on the other. The other requirement sought was to be land with a natural slope for drainage. Ditches would be taken out, say on the side of a stream and of the occupied lands, close to the bench or foothills—only the valley or "bottom areas" are thus occupied as a rule—so that the water would by gravity serve the fields. The river on the other or north side would be tapped directly by lateral as needed. The village or placita would be in the center of the selected area. On either side would be long narrow tracks running across the valley from one supply to the other. In the placita each colonist would have a home lot; in the settlement, a farm lot.

From the outset this system was recognized as a necessity, and that the water needed for the cultivation of the soil must be artificially stored and distributed. The surveyor general urges that these facts be now recognized in settlement of all such land titles. The water supply was carefully drawn from the river by means of an "acqueia" or main ditch of the colony. Each man had his turn; when the necessity for use arrived he would cut the bank with his hoe and the water poured forth. His plat of land having been previously prepared in squares, marked off by slight ridges that were raised with the spade, water was made to pass from square to square as each in turn became saturated, beginning with the upper and ending with the lower. Mr. Hobert says:

> From the nature of this cultivation his land must extend from the acqueia downward, as the land slopes; and so farms that look all out of shape to the Eastern man are the almost universal custom here. And they are more apt to grow narrower than wider; for if a man who owns a strip 200 yards wide and one-fourth of a mile long dies, leaving four children, then each of them, without will or deed, but simply because every one so understands it, becomes the owner of one fourth of it—that is, of a strip of the full length and 50 yards in width. Again, the owner of one lot may, on marriage, acquire another lot. Then he goes on cultivating the two without seeming to try to get his holdings consolidated.

This form of settlement was not only adapted to the soil and water supply, but served to aid and secure a defense necessary against Indian marauding. The irrigators living together about a plaza were enabled to rally quickly in case of an attack. Under the regulations of their grant every man was required to be supplied with arms and horses for use in protecting the community. A system of local laws and regulations has naturally grown up out of this system, as under it the colonists conduct and maintain "acqueias" by united labor and as common property. They provided for a "major domo" or watermaster for the supervision of ditches and distribution of water. In some instances the original colony grant includes also the land for 10 or 20 miles on either side of the colony or community. Such extended grants specify that the land given was for the common benefit of the settlers, to furnish them with pasture and wood, to give an opportunity for the increase of the settlement by offering land to newcomers and persons born therein. The Mexican idea has always been that such newcomers or additions to the population by birth should, under proper circumstances, be provided with land out of the public domain. The effect of this policy has been to make a considerable population, which, with special customs, small farms, and peculiar habits and environments, form a remarkable feature of our southwest region.

When General Kearney first occupied the valley of the Rio Grande there were not less than 100,000 persons residing in the valley from north to south, located in colonies such as have been described and successfully cultivating the soil by irrigation.

The Indian pueblos, 18 or 20 in number, also found in the same Territory, were made secure in their lands by the control as public property of all natural waters within the boundaries of their community. The salt springs and their supplies are also public property. As is the rule in all distinctively arid countries, access to natural waters for man and domestic animals can never be denied. Elsewhere in Arizona and in southern California, smaller communities of both Indians and Mexicans were found as the region passed under the control of the United States. The present area farmed by Indians under irrigation aggregates at least 26,000 acres. There is something to be learned from these facts. Reclaimable land within the arid region can hardly be secured in the rectangular shape which our system of surveys has elsewhere found so admirable. Small mountain basins along narrow valleys, broad mesa lands, and that of the higher plateaus, require a mode of subdivision different from that of rectangular townships and sections. The controlling feature of any system of equitable and economic survey therein must be the water supply. Experience has determined that as a rule subdivisions of land must be much smaller than those now in use under our homestead and other public-land laws.

CONSERVATION OF LAND AND WATER REQUIRED.

In the valley of the Rio Grande, that of the Salt River, Arizona, in southern California, Nevada, Utah, and elsewhere, 40, 20, or even 10 acres of public land may form a far more valuable homestead that 160 acres of open prairie might do in the humid sections of our national domain. The pastoral character necessarily requires the strictest consideration of the scant water supply which is still found appropriated therein. The absorption of such water supply upon the public domain by means of preëmption and homestead filings upon that portion of the land which may hold a few springs or a large water hole, and thereby securing a monopoly of the only water for many square miles, has become a fruitful means of monopoly, enabling, it is affirmed, the wealthier and more enterprising cattle raisers to control without purchase and for their own private advantage the exclusive use of great areas of public land. Naturally cattle farmers elsewhere, who buy and pay for their lands, are indignant at such unfair competitions. A conservation of the pastoral water supply as public property, so as to maintain control of the grass lands, seems to be the first step towards a remedy. The experience of the citizens of our neighboring Republic of Mexico, of the wealthy colonies that have grown up on the Australian continent, of foreign states that are largely engaged in cattle growing and sheep raising, as well also as the universal experience of all communities, ancient and modern, within arid regions, point to the necessity of maintaining public control and careful conservation of the natural waters found within pastoral areas.

The most successful utilization and reclamation of irrigable areas within our public domain has grown out of the establishment of colony and coöperative life in some modified form. It is quite certain, then, that more rapid progress in reclamation will be secured through a system of land laws which will subdivide the irrigable areas by homestead divisions of from 20 up to 160 acres, according to location and adaptation to fruit, vegetables, cereals, and forage plants. Encouragement might, with profit to the nation and to the settlers, be given to land colony projects having a coöperative basis of action. The irrigation district system already referred to and now in vogue in California, could within the remaining Territories of the United States be enacted under a general law. In this wise the public land would become, as now only in smaller divisions, the property and prize of the homestead settler. The patents for such lands should be held until the settler had repaid the cost of providing the water needed for irrigation, without regard to the source from which came such cost or credit. The selection of irrigable areas could be then made in accordance with the natural water supplies and the facilities for obtaining the same. The surveys required could be made under the administration of the General Land Office, whose deputy United States surveyors might also be required, but at little additional outlay, to do a great deal of the primary hydrographic topography required within the arid region, by taking notes and recording on the township plats the width, depth, etc., of all natural water sources, with the elevation and volume of all springs or other supplies in sight. The great mass of facts that can be obtained, a knowledge of which is necessary after determining the availability of an area for irrigation, may be acquired and published at a little cost and largely in advance of settlement. The more important data relating to climatology are also attainable under administrative machinery now in existence, or which, if necessary, could be slightly enlarged to meet the requirements of reclamation. The weather service bureau with its official and volunteer observers can readily be made to meet the duties of extended irrigation observations. Related services and experiences can readily be obtained from those divisions of the Department of Agriculture which are charged with such work of observation and experiments as relate to propagation, botany, pomology, forestry, mammalogy, and other departments of agronomy. In this wise, and by other simple and economical extensions of existing service, the needed work of irrigation inquiry and information could go forward steadily, aiding the settlers and advancing the common progress of the whole people.

THE PHREATIC OR DRAINAGE SUPPLY.

Owing to the demand made by the people of the plains region for some legislation that might favorably affect their knowledge of the extent and capacity of the artesian basins and their waters with which a large portion of their States are known to be endowed, a great interest has been aroused during the past year in the matter of subterranean supply for irrigation purposes. But considerable antagonism has been manifested and continued against any action favorable to these demands. This opposition was found not alone among those who are always in doubt as to the value of any new suggestion, but it came also with organized activity and a large degree of force from other sources. That which arose from fear was due to the misapprehension felt among older farming communities that a low rate market already overstocked would be unfavorably influenced by such competition as the security to be obtained through irrigation by the farmers of the Great Plains might create. It had its effect on legislative action as well as upon public opinion. It is, however, rapidly disappearing. But the chief antagonisms to which the artesian and underflow inquiry has been subject are founded on feelings not so worthy of consideration. One set of views belongs to the region of learned prejudices. It speaks as if with authority by the mouths of those whom we have regarded as teachers. For example, an expert declaration was made in 1880 to the effect that forest trees could not be successfully cultivated upon the trans-Missouri prairies and plains, yet 4 years later about 30,000,000 such trees were growing upon the plains of western Kansas and Nebraska. It is now reported that about ten times as many are growing in the region west of the Missouri River and east of the foothills. Again, it was asserted "by authority" that out of the public lands remaining in 1880 not over 11,000,000 acres were arable or fit for farming purposes; certainly not without the use of water artificially applied. That area would, it was asserted, be exhausted in three years thereafter.

Since that statement was made at least 25,000,000 acres have been brought under plow and sown to grain, whose harvest results add greatly to settlement, trade, and wealth. And about 30,000,000 more acres have been occupied and much of it cultivated since the report referred to was made public in 1880–'81. It is the assumption that what is not known to us can not possibly be known at all; that is the greatest of stumbling blocks. It has been also assumed that the arid region, or as much of our public domain as lies beyond the one hundredth meridian of longitude west from Greenwich, was only fit, to a large extent, for the use of the cattle raiser and the sheep rancher. It was proposed to effect the division and sale or leasing of this arid region in considerable portions to the ranchmen for cattle ranges. Yet the years are dividing the large ranges, and smaller cattle ranches and forage farms are rapidly taking their place. In the same period, over the same region, 25,000 additional miles of railroad have been constructed; to the population at least 1,500,000 persons have been added; six of the feeble Territories existing in 1880 are now young but vigorous States of our Union. Not less than a billion of dollars has been placed to the credit side of the nation's ledger. Another assertion has been made to the effect that large bodies of public lands have been or may be fraudulently occupied within the arid region because of a desire to secure possession of water storage sites. An examination of the records show that land entries therein average much smaller for each area, counting even the desert land filings, than the average of entries on public lands within the humid States. It is also seen that the average of entries in the arid region since October, 1888, has not exceeded 75 acres per settler or entryman; while if the desert land entries are excluded, and they are not over one-fifth of the whole acreage entered, there would be an average of less than 50 acres to each homestead, prëemption, or timber-culture claim. This is important as illustrating a marked tendency. In arid regions and irrigable areas the holdings will necessarily be small. But the negative decrying has not been the most noticeable of the criticisms made.

Another misleading influence has been at work. Elaborate propositions looking to alleged schemes of reclamation have angered the settler by attempting a long prohibition of his presence on the public lands, and aroused the bitter opposition of the tax-paying farmers by the endeavors to secure large sums of money annually in order to prepare against them a vast amount of competition. At least that is the way it looks to the agriculturist. Far different from the effort to withhold from homestead settlement our public domain, to deforest or reforest in advance our mountain summits and slopes, to checkerboard before occupation the whole area with a vast array of artificially arranged drainage basins or a great projection of reservoir sites and high line canal routes, is the proposition of those who stand alike for the communities of the Great Plains and those to the west thereof. Out of the realization of the fact that the American settler goes where he will even if he go wrong, and that the pioneer "is always with us," comes the work placed under the care of this Department—that of investigating and presenting the facts in relation to the possibilities of an atmospheric and phreatic water supply, which properly developed will give security to the agriculturists of our semi-arid section, and bring aid and help without much cost to the enterprising Americans who are occupying, using, and reclaiming the more directly arid region. In the work as projected under your direction there is no effort to lay the arid west on a Procusteau bed of theory, and still less is there any purpose of presenting the costly spectacle of a regional system, articulated and jointed before use to suit the theories of projectors or administrators. The investigations ordered by Congress follow the plain American way of giving the facts and letting the people do both their own thinking and planning.

THE ARTESIAN WELLS INVESTIGATION.

It is this which brought about the artesian wells investigation of the past year. It has also sustained the wisdom of the legislation which ordered the inquiry continued. It is bringing to public knowledge by careful and thorough investigation and by study of the information obtained an astonishing array of facts as to the existence and availability of a great water supply, that can be readily made useful in irrigation and for the cultivation of the soil, outside of a permanent storage system, which without question will some day be created and maintained, to serve the needs and demands of human industry and progress.

The artesian wells investigation has in a comprehensive report recorded the existence from north to south across a considerable portion of the Great Plains region of some 1,400 flowing artesian wells, and of the presence of at least four times as many more of small domestic and farm wells showing artesian pressure and giving for domestic and stock purposes and to some extent for agriculture a very large supply; the value of the record made by this investigation consists even more largely in the conclusions to which it reasonably leads. Foremost of these must be that relationship of the great continental ranges to the plains and foot-hill sections within which the wells already examined have been found.

SOME OF THE PROBABILITIES.

It will be seen by an examination of the maps prepared for and published by the artesian wells investigation report* that from north to south a basin or basins of artesian water of great power and volume have been struck and are now operating, through 1,400 wells or more, in an area not to exceed in general 100 miles in width. There are wells on the plains and in the foot hills east and west of the belt defined, but they have distinct hydrographic and topographic features of their own. Within the developed artesian regions it will be found that the deepest and most permanent wells have, taking topographical "dip" and "trend" into consideration, an almost uniform depth from north to south, a considerable sameness of temperature, volume, pressure, chemical character, and flow. This argues that they come mainly from one general source and have about the same degree of hydrostatic pressure.

If the investigation of the past year had accomplished nothing more than to bring this encouraging series of facts to the attention of the struggling settlers and of all those interested in their maintenance and success, that would alone have been worth all it has cost. But this is by no means more than the beginning of a remarkable addition to our

*Senate Ex. Doc. No. 222, Fifty First Congress, first session.

knowledge of physical features and facts relating to our semi-arid and arid domain. The investigation has opened up a great vista of economic possibilities and engineering development. The engineer and the geologist engaged in the work are confident that the source of supply for the artesian wells now flowing will mainly be found in the drainage of our continental range—the Rocky Mountains. The same observations which governed their opinion of the Northwest hold equally good for similar conclusions as to the center and the Southwest, as far at least as concerns that portion north of the Rio Grande boundary.

UTILIZATIONS PROPOSED.

The practical business men as well as the home-seekers have not been slow to perceive the significance of the important facts brought together by the artesian investigations past and present. As the result of their understanding the irrigation progress of the past year on being summed up will have to make record of many projects of enterprises that are now under way for the utilization in agriculture of the artesian and other subterranean waters west of the ninety-seventh meridian.

In North Dakota interest is now centered upon the prospect of obtaining more deep wells and of storing water from the wells sunk in the glacial drift of the Red River Basin. Several hundred of these wells, all of a secondary character, are found in that section. Very little artificial application of water is necessary for the security of crops, but that little is needed very badly and during most years. Water has been found along the line of the Great Northern Railroad and at very moderate depths in the Milk River Valley. There is very little doubt felt that artesian water to a considerable extent, though at somewhat great depths, may be obtained from that vast reservoir, the Dakota sandstone, filled as it has been for unknown cycles from the vast precipitation falling on the Rocky Mountains and draining through the upturned edges of the stratum into the water-conserving rock below. Whether or not this artesian supply can be economically utilized as well as abundantly obtained in the northern and western portions of the State of North Dakota is a problem that yet has in it large elements of uncertainty. A system of surface supply upon a large scale, fed by the waters of the Upper Missouri, meets much attention and considerable favor in North Dakota.

OVER-DRAINAGE OF THE NORTHWEST.

One suggestion has been made of such significance as to command attention in a comprehensive consideration of the progress of the irrigation discussion and projection. It is found in the statement that the tendency is toward over-drainage in all the hydrographic basins of the arid West. The character of the upper soils and strata are such as to accelerate erosion. The treeless character of the region helps this. The deeper, therefore, the river channels are cut in their broad or narrow valley regions, the more certain is it that the drainage areas related thereto will be depleted of their waters and the more rapidly will the land become of a positively arid and irreclaimable character. It has been seriously suggested, and by intelligent observers, that under present conditions every mile of levee in the Lower Mississippi Valley becomes an added menace to the farmers and dwellers along the valleys and on the plains and table lands of the Upper Missouri region. The more freely, therefore, in this view of the case, that the Mississippi shall run unvexed to the Gulf, the more barriers are raised in the way of the permanent prosperity of the extreme Northwest. Those who present this view (and it is merely presented here as a part of the case) are mainly advocates of the establishment by the general Government and by their own States of a great system of storage reservoirs and canals. Some are even going so far as to talk of combining navigation with irrigation. The records of the Weather Service and of the Army engineers in charge of river work and its observations are all intimately related, so far as this region is concerned, to the problems thus slightly outlined. The volume of supply in the Upper Missouri waters has the most direct relations with the volume of discharge at the mouth of the Mississippi. A still more important series of facts are those which relate to the amount of precipitation over the hydrographic basins of the Upper Missouri, in connection with the volume of flow and the amount of discharge.

According to Lieutenant Maury, the precipitation of the Mississippi River Basin amounts annually to 620 cubic miles of water. A considerable proportion of this vast supply comes from the great northwestern mountain system through the Missouri River and its tributaries. The amount of loss, according to Maury, is equal to 1 in 6. His estimate of the discharge in the Gulf is but 107 cubic miles. This leaves 513 such miles to be accounted for. If we allow one-half of this huge volume to the western portion of the drainage basin we shall open a great field of speculation. The ratio of drainage or outflow to rainfall is given by other authorities as follows: The Missouri, upper and lower, gives at its outlets but 15 per cent. of the precipitation which falls over its drainage basin. The Upper Mississippi is rated at the same figure; the Arkansas and White Rivers give a similar per cent. of outflow; the Ohio River presents 34 per cent.; the Red River of the South is credited with 20 per cent. outflow; while the Yazoo gives 90 per cent. at its mouth. The Darling River in New South Wales gives but 8 per cent.; the Thames 32 per cent.; the Seine 33; the Elbe 25; the Murray, the largest river on the Australian continent, gives only 24 per cent. outflow from its total precipitation. Still another proof of the loss of precipitation and river flow by sources other than evaporation may be seen in the fact that the Upper Missouri Valley, from Fort Buford, Dak., to Omaha, Nebr., embraces an area of 160,760 square miles. The annual average of normal rainfall in cubic miles will be 39.34, as shown by the records of 18 years. The maximum discharge into the Central Missouri Valley has been estimated at 27 cubic miles annually. This would leave 12 such miles to be accounted for. A comparison made in another form will give for a period of 24 months a mean of 22.32 inches. During the same period the observed outflow was but 4.1 inches and the computed outflow was but 5.9.

ENORMOUS PROPORTIONS OF THE VOLUME OF RAINFALL.

It would be worth while to calculate for a few moments what is embraced by the volume of rainfall.

Volume of rainfall per minute for given inches per 24 hours.

Rainfall.	Volume on 1 acre.	Volume on 1 sq. mile.	Rainfall.	Volume on 1 acre.	Volume on 1 sq. mile.
Inches.	*Cu. ft.*	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Cu. ft.*
.1	.252	161.33	1	2.521	1,613.31
.2	.504	322.67	2	5.042	3,226.62
.3	.756	484.01	3	7.563	4,840.00
.4	1.008	645.33	4	10.084	6,453.25
.5	1.264	806.67	5	12.605	8,066.56
.6	1.515	968.00	6	15.126	9,679.87
.7	1.765	1,122.73	7	17.647	11,293.18
.8	2.107	1,290.67	8	20.168	12,906.50
.9	2.269	1,450.00	9	22.689	14,529.81
			10	25.200	16,133.12

Four cubic inches in 24 hours will give 6,423.25 cubic feet to each square mile per minute. Eight inches so falling will give a volume of 12,906.50 cubic feet per square mile. To put it in another shape, one inch of rainfall will give to each square mile or to one section of the public lands a volume of water equal to 550,400 barrels. Estimating the average rainfall of the Upper Missouri Valley east of the foot-hills at about 20 inches per annum, we shall obtain 1,100,800 barrels of water to the square mile. It will be necessary to have for security in the ripening period of summer an artificial supply of water equal to about five inches of the rainfall, or 220,800 barrels to the square mile. An artesian well of the ordinary Dakota capacity will thus, if its annual supply were stored for irrigation purposes, furnish, at a flow of 100 barrels of water a minute, 52,560,000 barrels per year. It will require, therefore, according to Prof. Culver, upon whose authority these figures are given, but 7 such wells to fully irrigate one township or 36 square miles of land. Recalling, then, the figures of Maury and others that show the difference between precipitation and outflow over and from hydrographic areas, we may arrive at some conception of the extent of loss in percolation or evaporation of the rainfall and snow water that falls upon the mountain; foot-hills, and plains region. Within our own arid section, unless in such limited areas as the Colorado and Mojave Deserts, on the Paramint waste, or within the desolate bowl-formation of Death's Valley, the evaporation seldom exceeds one-third of the fall. Certainly not over 40 per cent. of the entire precipitation therein is lost through evaporation.

THE SOURCES OF PHREATIC SUPPLIES.

Let us take Maury's estimate of the Mississippi's precipitation and outflow and allow for the evaporation of 170 cubic miles of water per annum. With the output of 107 cubic miles we shall have as lost in the earth 343 such miles. This water must form the source of phreatic supply. The loss by percolation, seepage, or soakage can be made apparent by some mining ditch records in central California. The North Bloomfield, in Nevada County, delivering water a distance of 40 miles at a grade per mile of 16 feet, loses in that distance 300 of the 3,000 miner's inches that are delivered at its head. The Milton, flowing 19.4 miles with a grade of 19.2, loses 150 miner's inches out of 1,600 delivered at the head. The Eureka Ditch, traversing 30 miles and running 2,500 inches at the head, delivers but 2,000 inches below. The rate of transmission is too rapid for any great loss in evaporation. Therefore the major portion must disappear by percolation into the earth. Innumerable illustrations of the same phenomenon could be given, but these are sufficient for a generalization of the subject now being considered.

THE EARTH'S POWERS OF IMBIBITION.

The earth drinks in water by absorption directly from the air, by deposition at night, in the form of dew and condensation, by direct precipitation in the form of rain and snow, by huge percolation from the surface, and by the hidden channels which flow between oceans, seas, and lakes, making subterranean streams and filling the veins by which the fluid circulation of the globe is carried. The enormous importance of the absorption of the rainfall is illustrated by Engineer Van Diest, in reference to the loss thereby in Eastern Colorado. He gives the extent of that seepage as equal to 5 cubic inches over 32,000 square miles of surface, equal to 784,080 cubic feet of water per minute disappearing into the ground. This amount would be sufficient to irrigate 1,200,000 acres; that is, 1 acre in 17 of that portion of Colorado which is included in the artesian wells investigations.

Another illustration of the extent of this absorption is given by a railroad agent at Mojave Station on the Mojave Desert, who has kept a rain-gauge record. In the region where he is stationed the streams are few and small and swiftly disappear when they reach the desert table-land. There are no bodies of "still" water, and the whole region has been regarded as arid and almost worthless. His record for 7 months from July 1, 1889, to January 30, 1890, gives a precipitation equal to 12.47 inches. During this period the mean temperature was but 46° Fahrenheit, the thermometer usually ranging from 32° to 62°, and the conditions, therefore, were such as to make it apparent that 40 per cent. of evaporation would be an extravagant estimate. The balance of the rainfall disappears into the earth. In that region dews do not come, and from the surface all indications of moisture speedily vanish. Taking any reasonable given space and estimating 60 per cent. of the precipitation as percolating into the earth, and it will be found that over this so-called desert water had disappeared below the surface sufficient, if it could be reached and stored, to anywhere make an artificial lake deep enough to float a light-draught vessel; even the terrible Death Valley holds on its outer rims some 30 flowing wells. One sunk to a depth of 528 feet rises above the curb some 20 feet and gives a discharge of 20,000 gallons each 24 hours. A majority have a depth of less than 100 feet each, with flows rising to and above the surface. In the Mojave Desert a number of artesian bores have been successfully sunk, and water now rises above their curbs. In the Antelope Valley, further south, but still a desert region so called, within the past 2 years about 50 flowing wells have been bored and are now in operation. There are four times that number of driven wells of shallow depth, deriving their supplies from the drift and erosion strata. The elevation of all this region is from 5,500 to 7,000 feet. These supplies of phreatic waters are obtained entirely from the drainage of the great Sierras, by which the alleged deserts are surrounded. Below, an abundant rainfall would be 14 inches as the region goes; above, on the Sierra's summit, the precipitation will range from 50 to 100 inches per annum. No artificial storage reservoirs will ever be able to conserve even a considerable portion of this vast precipitation. Falling as it will and melting as it must with torrential force and rush, a large proportion of its volume under all conditions must disappear by crevice, rift, and chasm into the rock stratum below, and so pass to the gravel, bowlders, clays, and sands that underlie the alluvial.

SURFACE RESTORATION OF SUBTERRANEAN WATERS.

East and west of the great continental ranges, as well as within their borders, continued and systematic inquiry and observation, with careful notation and deduction, are already establishing that under favorable conditions for restoration to the surface this earth supply will now be found the most favorable and convenient, locally and regionally considered, of the waters needed for the cultivation of the arid soil by means of irrigation. The existence of this supply has been shown by the work of the artesian-well investigation, and by the inquiries made over the whole arid region. It is estimated that in California alone, and mainly along the foothills region, and within the San Joaquin

Valley, there are some 3,000 wells having artesian characteristics, either positive or negative in quality. In other parts of the State 1,000 or 1,200 more of such wells are to be found, and 10 per cent. of the entire number are now estimated to be in use for irrigation purposes. In the great basin embraced within the Territory of Utah there are over 1,800 flowing wells deriving their supply from lacustrine or drift deposit, the drainage of which gives them artesian character, but with a low pressure. Elsewhere, and under unpromising circumstances, the evidence obtained during the year past of underground waters is simply surprising. In the valley of the Salmon and Snake Rivers, of the Columbia and other streams in Idaho, eastern Washington, and Oregon, a large number of bores have been made at quite high altitudes, and during the year some thirty-five or forty artesian wells have been sunk for water, which rises with great pressure and flows with considerable volume. Artesian and underflow water has been struck and utilized by the railroad along the margins of the dead sea bed, known as the Colorado Desert. In the valley of Salt River, Arizona, at an altitude of about 5,000 feet, a considerable number of wells have in the last 2 years been dug and bored, their water having the negative artesian quality. It rises in the bores, but not with sufficient force to reach the surface.

Another evidence quite important in its way of the extent of the phreatic waters within the United States may be found in the records of the several waterworks for the supply of towns and cities. Of these works 68 per cent. derive their supply from rivers and streams, 6 per cent. from surface waters, such as lakes, ponds, etc., while fully 26 per cent. obtain a supply from underground sources by means of wells and springs. These statistics show also, as a source of farm and domestic supply, a very great excess of wells over other methods within the Northwestern States and Territories. Nearly one-half of similar works in the Southwest and Pacific States are also supplied from wells. The northwestern percentage of well supplies is stated at 75.1. Surface supplies, such as lakes and small streams, are of course extremely few throughout the arid West. There are mountain areas that will yet furnish a large lake supply for both town and farm pnrposes. The number of systems of water-works west of the 97th meridian, whose supply is derived wholly from underground sources, is as follows:

Arizona 2, California 50, Colorado 10, Idaho 4, Montana 5, New Mexico 15, North Dakota 6, South Dakota 2, Western Texas 13, Western Kansas 33, Western Nebraska 25, Utah 2, Eastern Oregon 4, Eastern Washington 4, Wyoming 5. There are a number of others projected.

PERMEABILITY AND RETAINING POWERS OF THE STRATA.

The porosity of the several strata in which underground waters are found form an important factor in the problems of underflow and artesian investigation. One cubic foot of sand will, it is estimated, hold 5 gallons of water; in coarse sand the amount will be 2½ gallons; in sand and fine gravel 3 gallons; in coarse gravel and small stones 3.06 gallons. Sand will contain, when saturated, 33 per cent. of water; marl will hold 15 per cent.; dry clay at least 12 per cent.; in strata, consisting of sandstones and limestones, chalk, etc., there is room for at least 15 per cent. of water. Beds of coarse gravel and small stones will hold 33 per cent. The sand underlying the alluvium alike in the North and South Platte Valleys will contain nearly 40 per cent. of its bulk in water. Sandy soils always porous in character respond like a barometer to the temperature, rising or falling with the humidity of the atmosphere. Prof. T. Sterry Hunt is authority for the statement that 1 square mile of sandstone 100 feet thick will contain water enough to flow continuously 1 cubic foot per minute for 13 years. The larger portion, embraced in the Upper Missouri basin between Fort Buford and Omaha, is believed to be underlaid with sandstone of this porous and water-conserving character; its thickness has not been anywhere ascertained, though the drill has penetrated it in parts to the depth of from 80 to 100 feet. There is reason to believe that the stratum is much deeper than the lowest point to which the drill has yet penetrated. It is doubtful if there is any geological substance wholly impervious to the action of water. The lowest percentage given of water held in rocks by complete saturation is found in the granites, and stated at from 0.06 to 0.12. The Devonian limestone holds but 0.08; Basalt is rated at 0.33; silurian slates at 0.19; coal shales at 2.85; carboniferous sandstone will hold 43.30; oölite (inferior) is rated at 23.98; and chalk at 24.10.

The older porous stratifications are found above archean rocks and as a rule below the drift and clays. These reservoirs, for such they are, filled to overflow by the constant accretions of the past, are also as constantly replenished from the atmosphere. The waters of percolation are gradually drawn downwards, moving steadily until they are met by an impervious stratum; they will then horizontally or as nearly so as the "dip" allows, move until an exit is found either by opening from above or the flowing into deeper channels, subterranean or surface. Springs appear usually where these subterranean channels or veins intercept the surface valley. The slow soakage from the earth's surface descends only as a rule through sand, gravel, sandstone, or bowlders to stratum below that are somewhat impervious in character. The flow from such deposits is always variable, generally quite weak, but possesses, as has been shown, great value if reached and collected, in regions where the rainfall is almost sufficient for industrial uses. A subterranean water basin, either deep or shallow, is always full at its outflow when first tapped. Its continued value depends upon the drainage area by which it is supplied, the amount of precipitation thereon, the altitude and consequent gravity and force with which the waters are pressed or sunk through the earth.

THE HYDROLOGY OF THE ARID REGION.

There is a somewhat striking resemblance in the continental features of all great arid regions. The interiors generally consist of high tablelands, plateaus, broken-mountain bowls, and great longitudinal valleys or plains or ranges, such as are seen in the San Joaquin and Owens valleys of California. The sea-plane sections of these arid areas are usually narrow and descend precipitously to the ocean, being traversed by but few rivers, which are generally narrow and precipitous, opening into broad alluvial valleys as they near the shore. The interior drainage basins will commonly be found marked by a few extensive river channels, having small tributaries in their upper and mountain courses, all descending torrentially to the open plains. Spreading as they reach it, they then flow over wide and porous channels. An illustration of this on the largest scale can be seen by a bird's-eye view of our trans-missouri region. The channels which deeply furrow its vast contours are but few in number. Looking eastward from the Rocky Mountains, we shall find not over a dozen important streams from the British line to the Gulf of Mexico. The Upper Missouri, with several important branches, chief of which is the Yellowstone, makes the most northerly drainage basin. The Niobrara, the North Platte, the South Platte, the Arkansas, the Cimarron, the Canadian and the Red River of the South are all tributary to the Mississippi Basin. The Pecos, Rio Colorado, Rio Brazos, and other smaller Texas streams feed the Rio Grande. That river, which rises also in the Rocky Mountains, flowing eastward and southward to the Gulf of Mexico, makes its way for at least 700 miles of its long course through a more or less stupendous cañon and gorge system. It is a characteristic of the open valleys (with the exception of perhaps the Niobrara and the Rio Grande) to make their way by widely meandering channels through broad deposits of sand and gravel. At the point at which most of them leave the mountain ranges there commences an enormous phreatic absorption of the volume of flow that has descended from the summit above. This absorption saturates a wide range of porous deposits. In the valley beds proper this water lies near to the surface, and may be reached on the uplands at about the point of difference between the saturated bed and the elevation of the prairie.

Experiments successfully conducted in the valley of the Upper Arkansas conclusively establish the existence of such undersheet water. The uniform upward grade of the valley westward, at least from Dodge City, Kansas, has encouraged the engineers interested in securing a constant supply of water for irrigation, and underground tanks and reservoirs have been constructed. From these reservoirs a fall of several feet on either side of the river presents abundant facility for the distribution of the waters thus obtained. It is also expected that large surface ditches, which during the past 4 years have been made in the valley counties of southwestern Kansas, can be fully supplied from the undersheet waters that are to be conserved in the works now in progress. A similar experiment is under way in the valley of the North Platte, Nebraska, and it is confidently expected that the water supply for Denver will be made permanent by works which aim to reach the underflow or undersheet of both the South Platte and Cherry Creek channels. If these operations are successful, as there is reason to believe they will be, the experience and results thus gained will be repeated in every valley and channel belonging to the eastern flanks and plains of the Rocky Mountains. Similar characteristics prevail in the valleys and channels of other important streams that flow through and drain the arid region. The construction begun in the Upper Arkansas marks the initial point of a great development in a water supply, relatively abundant in volume and possessed of valuable fertilizing qualities.

LOCATION OF AND SUPPLY FROM SPRINGS.

Without reference to the inquiry made into the existence and character of a great supply of springs, the discussion of a phreatic supply would be incomplete. It will be observed that in the Northwest section, east of the Rockies, the record is so far comparatively small. It is hardly worth while to hazard an opinion, as further investigation may demonstrate that there is no lack of such underground waters, but still it may be suggested that the apparent paucity may find its source in the tendency towards over-drainage. When the Black Hills region is reached, however, proofs are abundant of a supply of springs large in volume, frequent in number, and flowing with great force. The geologist in charge of that field, and the field agent for western Nebraska and Kansas, call attention to and present tabulations of a large number of them. Entering eastern New Mexico, however, we find a great increase in this supply, and with it must be remarked the hydrographic fact that the vast area in which they are found is marked but by a very few stream channels of importance. Within the region in which the springs are most abundant, the drainage of the mountains to the west, failing to flow in such channels as are sufficient for its volume, must necessarily find its way to the Gulf and the sea by underground courses which would necessarily break out at favorable topographical points and localities. A glance at the map of eastern and southeastern New Mexico, of the Panhandle regions of Texas, and the contiguous territory of that State, will illustrate what is here indicated. The entire region is one possessing abundant springs, many of which are very remarkable in character, as for example the great volumes of water that break out at Roswell, N. Mex., and an enormous spring at Lampasas, Tex.; one that yields over 4,000,000 gallons of water every 24 hours. Another evidence of the immense drainage volume of the region under consideration is seen in the readiness with which water is obtained at a short depth from the surface. On the western portion of the Staked Plains, where Capt. John Pope's failure to procure water in 1857 became a standard proof of the aridity of that region, but a short distance north and south of the point at which he failed the managers of great cattle ranges have obtained water at a depth of not over 40 feet through dug wells and over a large area.

It has long been a favorite theory in the Southwest that the Staked Plains region is underlaid by what, in effect, is a moving body of water. Some observers have suggested that such water not only percolates through the earth with considerable force and motion, but that there is in fact a subterranean river channel into which its larger volume freely flows. It has been pointed out that the wells of this region rise periodically and that the long and well defined line of springs from eastern New Mexico southward and eastward about the lower edges of the Staked Plains, which geologically speaking are reported to be a superimposed stratum on an older formation, have also their periodic rise and flow. The waters of the Sabine and Red Rivers flowing to the Gulf are also known to be affected at the same seasons, showing an enormous periodic increase of flow which is not accounted for by any seasonal increase of precipitation.

The value of springs in irrigation is well understood in all other arid countries. They are also largely used for meadow irrigations. Henry Stewart, in "Irrigation for Farm, Garden, and Orchard," says that the vast number of springs really furnish a much larger supply of water than is expected. He claims that a spring yielding only 2 quarts of water per second will properly serve an acre of land, if properly discharged during that length of time. The total amount of discharge for the day would be 43,200 gallons per day, giving 1 quart of water for every square foot. A reservoir to store such a body of water should contain 5,760 cubic feet; that is, an area 40 by 20 feet, having a depth of 7 feet. Springs are guarded and protected by law and custom in all arid regions. The French law provides that the ownership goes with the land; that of Spain, which follows the Roman and Moorish customs, makes them public property to a limited extent. In Mexico, for example, the owner of land upon which a spring breaks out is entitled to the undisturbed use of its waters for 60 hours per week. He may not fence it off from man or cattle, though entitled to compensation for the use of the space occupied by the land for the means of access. The Ottoman law of water makes all natural springs not privately appropriated the property of the community. The Pueblo Indians, as also the Mexican people, claim the public nature of all such waters and are protected by the treaty of Guadeloupe-Hidalgo in their claim. Important bodies of springs are found at many points in our basin and intra-mountain region. All through the arid region also, and especially west of the Rockies, streams are known that sink out of sight, flowing, as does the Santa Cruz in Arizona and the Humboldt in Nevada, through subterranean channels to a junction with other bodies of water. These streams can be recovered and distributed, and they will yet play a very important part in the reclamation of limited though valuable portions of our arid region.

RIVERS AND STREAMS OF THE PLAINS.

Another source of supply is found in streams that take their rise from open plains and basins at considerable distances from mountain ranges or from other than local drainage areas. The chief geologist and his assistants have been actively engaged in an examination of such a system. The Republican and Frenchman Rivers, in northwest Kansas, southwest Nebraska, and northeast Colorado rise in the plains region, nearly 150 miles from the foothills of the Rockies. They have no surface or objective connection with the mountain precipitation and drainage. Yet their sources must be, it is evident, in the first place the drainage of the mountain area, next they are fed by local or basin precipitation; the latter is a point of considerable importance. The progress report of Professor Hay deals with this question.

The Republican River in northeastern Colorado, the headwaters of its branches being from 120 miles to 140 miles east of the foothills, offers the more notable illustration. Apparently its branches, the Delaware or South Fork, the Arickaree or Middle Fork, and the Frenchman or North Fork, rise in the open plains and without any direct connection with the mountain range to the west and its great drainage supply. There is an area of about 150 miles square which possesses an abundant supply of water just beneath the surface and recoverable by ready and simple means. At some period in its later geologic history this basin was the seat of a large but probably shallow lake. It possesses many characteristics of such a formation, not the least notable of which is the existence on its central and southern section of a large bed of quicksand.

An accident occurred some years since on the Kansas Division of the Union Pacific Railroad, and across a marshy or wet stretch, such as in the Southwest are termed *cienagas*, a train was derailed and the locomotive overturned. Engineer and fireman with engine are reported to have sunk out of sight. The two bodies were recovered 10 miles to the east, and the locomotive was engulphed in the sand, being lost entirely. No trace of it has ever been found. Accounts are given to show the existence of underground streams and channels, of wells along the valley of the Frenchman or North Fork, which are known as "roaring," because of the blowing noise that arises from them, as of the air passing from a higher elevation underground, and finally escaping through these wells, using them as vent-holes. It is also stated that their water freezes in winter at considerable depths below the surface—another proof of their being influenced by atmospheric condition.

It is quite certain, therefore, that some source of supply other than the local precipitation over this basin must be accessible. The rainfall from east to west will range between 17 and 14 inches per annum. This fall is helpful to increase, but can not be sufficient to create the great body of water found within the upper basin of the Republican and its branches. Taking two convenient foot-hill points and ascertaining their elevation we shall begin to perceive where the source must necessarily be. Denver to the south is 6,105 feet, and Cheyenne to the north is 5,281 feet above sea level. North Platte, Nebr., to the east a short distance of the area under consideration, has an altitude of but 2,841 feet.

The Upper Republican basin then will have a general fall from west to east of at least 10 feet to the mile, while the fall from its western limit to the foothills will range from 17 to 10 feet per mile, or an average of over 13 feet, making an aggregate decrease of altitude of about 1,900 feet at the western line and another of over 3,000 feet at the east line of the basin under consideration. This gives ample gravity for drainage waters to supply such a basin, more especially if the stratigraphy of the area is favorable, as seems to be the case from such facts as are now known.

THE UNDERSHEET WATER OF THE VALLEYS.

The managers of the Great Eastern Irrigation Ditch, at Garden City, Kansas, have successfully brought to a head the first portion of their experimenting with the underflow supply. The Great Eastern Ditch near Hartland was constructed to be supplied by the Arkansas River direct. The use of the water above in Colorado and the aridity of several past seasons reduced the volume in the channel to such an extent as to make the ditch nearly useless. The main ditch was continued westwardly parallel with the bank of the river. At a point 1 mile west of Hartland, on the Arkansas, the company begun to deepen the ditch, so that while the bottom has a fall sufficient to secure the ready flow of the water its depth below the surface of the ground is made to increase as it extends westward. In the progress of 1 mile the depth has been so increased that it is now 10 feet below the surface. Into the ditch thus formed, so as to tap the saturated sand at 10 feet below, a body of water is flowing 14 feet wide and 11 inches deep. Some distance below the stream is 20 feet wide with an average depth of 6 inches. The water plane, which is found in firm, close sand fully saturated, begins to flow or discharge water into the channel at the point of excavation. The head of the ditch has the appearance of a large spring, the supply of which is oozing out at every point. The Great Eastern Company intend to carry the head of the ditch still further westward and deeper, so as to secure the full advantage of the seepage and fill the reservoir thus formed as completely as it is possible. The quantity of water and the steadiness of its percolation seem to meet the most sanguine hopes of those who have interested themselves in this experiment. The fall below the head of the new subditch being an average of 7 feet to the mile directly east and west, with a larger fall north and south, gives ample opportunity for ready distribution of the water thus obtained.

The irrigation engineers in Colorado are interesting themselves quite actively in the obtaining of supplies by the sinking of galleries below the surface of streams in a manner similar to that begun in the Arkansas Valley within the State of Kansas. They have also just begun to apprehend the importance of the phreatic supply that it has been demonstrated can be found in the gravel beds, so that the water found in them can percolate into underground tanks and wells and be lifted by machines to the surface, a method of supply which will be shown to have a great impetus. The use of pumps of great power in lifting underground currents to the surface from bedrock is also proposed, and works of that character in several instances are projected and begun.

Mr. John Goodwine, of Dodge City, Kansas, in a paper read before the State board of agriculture at its annual meeting, gives a description of his personal efforts to utilize the Arkansas Valley underflow. His farm was inaccessible to the sub-canal service provided by the enterprise of Gilbert Bros. Mr. Goodwine sought refuge in a farm reservoir supplied from the sand-stratum storage and lifted for distribution by a windmill. He says:

I began about 1 year ago to try my experiment by building a reservoir 100 by 150 feet, 7 feet deep, locating it on high land near orchard and vineyard. By the side of this reservoir a well was dug, 5 feet at the top and widened to 6 feet at the bottom. The underflow was reached at the depth of 53 feet, and the well sunk 3 feet in the water, giving a basin in the underflow of six feet wide by 3 feet deep. The ground being sandy the well was curbed from top to bottom with 2-inch lumber. A 6 by 24 inch cylinder was placed about 4 feet from the water, and 3 inch suction and discharge pipes used. To get the water into the reservoir it had to be raised 5 feet above the top of the well. A 22-foot windmill was put up and started about July 1, 1890, but the mill was a poor one. It broke several times. While idle the water was discharged into the reservoir, but on account of the sandy soil it failed to hold it. Loam was then hauled into the reservoir at leisure times and the sandy portion of the bottom covered about 6 inches thick. The mill was again started about the middle of November, and the water run directly where it was wanted. Since then 2 acres of grape vines have been well watered and some trees besides. The mill has an 8-inch stroke and throws about one gallon of water to the stroke, and makes from 18 to 30 strokes per minute. Recently I put on the Zerbe adjustable stroke attachment and lengthened it to 12 inches, giving 1¼ gallons per stroke. With the short stroke I think I can irrigate 10 acres the driest year we have had, and with the lengthened stroke can thoroughly water 15. With a bunch of cattle to eat the buffalo grass and forage crops we can grow, and 15 acres well watered, we need not run from the drought, but partially at least run the drought from us.

Two of Mr. Goodwine's neighbors are at work on similar lines. Others are investigating. A vapor engine is coming into use which it is claimed costs only 1½ cents per hour for each horse-power used. Mr. Goodwine says:

With this new power we can raise water in sufficient quantity to produce the ordinary farm crops if we prefer. We will be enabled to view with pleasure our crops of alfalfa, corn, and wheat. Indeed, I shall not be surprised if in a very few years vapor engines are used to tap the underflow to supply the canals. I believe it will be cheaper and more reliable than the reservoir system now in use.

THE SAN LUIS ARTESIAN BASIN.

The enlargement of cultivation in the San Luis Valley, Colorado, by the use of the wells that have been bored therein, has brought into remarkable relief the value of tillage by seepage irrigation. In the discussion of phreatic waters, this is a matter of importance. This great mountain basin or park, with its uniform elevation of about 6,000 feet, is surrounded by mountain ranges of from 4,000 to 7,000 feet elevation. The sides inward to the valley are quite precipitous. It follows, then, as matter of course, that the stratum beneath the soil within the borders of the San Luis Park is kept constantly saturated with a vast supply of water. Cultivation has gone on until the water-plane has moved nearer to the surface. The wells which have been dug and bored, to the number of many hundreds, have also had their effect in this direction. There has always existed a large area of surface water, not deep, and sometimes only perceptible by the moisture of the ground and the luxuriance of the marshy grasses existing there. During the past harvest season the benefit of what may be termed natural subirrigation was made very apparent. The small grain on the whole averaged better than anywhere in the United States, while the subirrigated lands gave invariably the maximum crops. The ordinary explanation of the theory of percolation, whether from above or below, is, that directly under the top soil will be found a clayey or other stratum that does not allow the water to sink, and that the loose earth, well broken up by cultivation, acts as a sort of sponge that contains the water that has percolated from the ditch surrounding the field. This is the explanation given by those who suppose artificial seepage to be the only cause of such irrigation.

CAPILLARY ATTRACTION.

This theory of artificial sub-irrigation will, however, serve to illustrate that of the natural and normal process. Plant life not only affects very materially the surface of the earth, and, by condensation, the humidity of the night, thereby also influencing the atmospheric temperature in its lower stratum at least; but by means of its roots penetrating deeply for moisture and by the influence of the air passing through the opened and pulverized earth, the whole supply of earth waters nearest the alluvium are drawn by capillary attraction closer to the surface. The present situation in Fresno County, California, illustrates these statements as well as the situation in San Luis Valley, Colorado. The first fruit colony that was formed and commenced cultivating the soil in San Joaquin Valley, at Fresno, found themselves obliged to dig at least 50 feet before reaching water for a well supply. Further from the center of the valley they had to dig deeper. At present the average plane of water is below the surface from 8 to 12 feet. In less than 20 years, then, by cultivation and surface irrigation the supply has risen some 40 feet. The alluvium is saturated to so great an extent that alkali is again appearing upon the surface and the necessity of drainage is becoming apparent. The practice in Fresno vineyards now is to fill the small ditches that bound their fields once or twice in a season, and then to allow the supply to percolate through the adjacent soil. It has been found in practice there that the area of percolation extends for 500 feet on each side of the ditch. By having fields or vineyards, therefore 1,000 feet square a sufficient supply of water can be obtained from the ditches by percolation to sub-irrigate the whole area. In the case of the San Luis Valley, however, the areas embraced are very much larger.

It is stated by Colorado agricultural journals that in what are known as the Streator and Stanley settlements of the San Luis Valley tracts of from 100 to 400 acres are irrigated as the needs of the growing crops require without spreading any water on the surface. Boundary ditches, often inclosing 60 acres, are filed with water and their contents allowed to percolate through the porous earth. The roots of the plants are, it is claimed, supplied with sufficient moisture to secure an abundant harvest. Unless such ditch percolation was greatly reinforced by the steady rise of the underflow nearer to the surface, the fields would be found altogether too large for effectual irrigation.

Portions of the arid region in which the questions of phreatic waters may yet prove to be of supreme importance is found within the States where "bad lands" and "desert" areas are acknowledged to exist.

RECLAIMABILITY OF DESERT AREAS.

Half a century since General Fremont found the border of the Great American Desert nearly 1,000 miles eastward of its present location, and many hundred miles to the north. Under the advance of civilization, however, the desert has been gradually circumscribed, and the waste lands are being made fertile, so that now this desert region is almost wholly confined to the southern counties of California and the lower half of Nye County, Nev. Within the borders of this region are inclosed such well-known tracts as Armagosa and Death Valleys and Mojave, Colorado, and Panamint Deserts; in all not less than 30,000 square miles. In San Diego County the desert is bounded on the east by the Colorado River and on the west by the San Jacinto Range. It is traversed southeastwardly by the San Bernardino Mountains, and widens as it enters Lower California. The reclaimable desert area of San Bernardino County alone is estimated as larger than the States of Maryland and Delaware.

The average rainfall on this region ranges from 2 to 6 inches. In the more depressed area there is barely a trace of precipitation. Throughout the growing and ripening months even this dwindles away, and the sands and scant herbage are burnt in the fierce sunlight. The mountain streams, fed from the enormous masses of constantly melting snow, are soon absorbed in the friable soil and sink to the lower gravelly levels, from which the artesian bore can alone restore their supply.

The Colorado Desert is, undoubtedly, the dry trough of the old Gulf of California, the head of which once flowed a long distance farther inland. Saline shells and deposits with the well-defined beach lines plainly show this in many parts of its circumference. The mountain valleys once supported quite a numerous population of natives. To day many streams rise in the surrounding mountains and are lost in the thirsty sands and detritus below. Precipitation must be stored in natural reservoirs, and the seepage or imbibed waters of its many "lost rivers" must be restored by a system of wells and tanks, or underflow canals.

A short but striking account of the lower part of this desert is given by Mr. H. W. McFadden, of Anaheim, Orange County, Cal., one of the most respected of citizens there, who writes the office of irrigation inquiry, in reply to a request for information relative to the Colorado region, and especially that portion of it known as "The New River Country," as follows:

THE DRY BED OF A DEAD SEA.

The New River Country borders on the northern line of Lower California, and is about 60 miles west of the Colorado River at Yuma. I am not personally interested in this section of the country, but being intimately acquainted with ex-Surveyor-General Shanklin, he has repeatedly spoken to me of this section as being capable of being made wonderfully productive if water could be obtained. He received most of his information from data filed in the State land office. In September, 1887, General Shanklin and myself drove from here overland about 200 miles to see the country and judge for ourselves if the truth had been told. After a hasty inspection, which we were compelled to make on account of not having water for our animals and ourselves, we retraced our steps. Not being satisfied we again organized a party of five with plenty of food for ourselves and feed for animals, also instruments and tools to bore for water, etc.

In October of the same year (1887) we again set out and made a thorough inspection, and with such statements as we were able to glean from cattlemen and the proverbial oldest settler we obtained much of the information we were seeking. Some of it may be of interest to the Government; if so, I shall be amply repaid. We learned by observation that the Gulf of California once extended up into the great sink in the Colorado Desert. This is now 261 feet below sea level; that the annual floods of the Colorado (or Red or Muddy River), being backed in by the high tides, had deposited annually from 2 to 4 inches, until the entrance was filled up to 12 feet above sea level. The gulf being dammed off, as it were, the inland sea or lake evaporated and became a bed of salt, the mining of which is now a profitable industry, whose headquarters are at Salton, on the Southern Pacific Railroad. The winds drifted up a border of sand, which has stopped all subequent overflows from running back into the lake or inland sea.

The New River channel is without water at its head. Unlike most other streams, the water runs in at its mouth, when it has water, which occurs but once in 7 or 8 years. That is only when the extreme floods of the Colorado River (which occur in June) meet the new or full moon tides of the gulf. The Colorado is backed up then over the elevation of 12 feet. There is a fall to the north. The channel is about 200 to 300 feet wide and from 6 to 8 feet deep. The water will run north till about 350,000 acres are entirely submerged, being covered from a few inches to several feet deep. The water stays till it sinks and evaporates; it never returns to the river or gulf. As this water is full of sediment, the deposits are very great, so that the country is being gradually raised, and a few more floods will probably be the last. It has been covered with water this year (1890) for the first time in 9 years, and thousands of tons of wild grass could have been cut. As soon as the water begins to disappear by evaporation, the Indians flock in from their mountain fastnesses for the distance of 160 miles, and by the crudest kind of cultivation follow up the receding water, planting melons, squash, beans, wheat, corn, red peppers, etc. In a very short time they gather an abundant harvest and return to their mountain homes.

In January, 1888, Gen. J. W. Shanklin and a surveying party went to Yuma and examined the Colorado River till they found a good place to take out a ditch, about 6 miles below Yuma. They made their starting point 3 feet below low-water mark. In 12 miles their levels came to the surface. With a cut of 20 feet at the river it ran out gradually. In 12 miles, allowing 2 feet fall to the mile, the country becomes level and open, with about 5 feet fall westward to the mile. In 30 miles they struck the overflowed lands, which fell off toward the north from 8 to 10 feet to the mile. They did not run their survey beyond 30 miles, but took levels to satisfy themselves that the whole overflowed territory could be irrigated.

On account of a range of sand hills that approach the river near Yuma and extend below some distance, if ever such a ditch is constructed it will have to be made through Lower California for at least 30 miles. Had it not been for the difficulties that presented themselves in regard to the right of way over foreign soil, that section of country would now be irrigated. Nothing is being done by private parties towards the reclamation of the arid section. We estimated that a ditch 100 feet wide, 5 feet deep, 60 miles long, would cost $350,000 or perhaps over $1 an acre. Other parties have been there since, looking over the country, and about 35 miles to the northwest of the Lower California line from Indian Wells they report a large stream of water flowing in a deep channel apparently coming from under this overflowed land. The stream had about 1,000 miner's inches of water flowing towards the inland dry sea; following it for some distance in a northwesterly direction, they report it lost in the alkali swamp on the margin of this dry sea or lake, it being so soft that a horse could not cross it. That fact and the high mountains on the west where 36 inches of rainfall annually occurs, would indicate an undercurrent. The Colorado River directly due east 60 miles, is about 80 feet higher than the New River country. This would make altitude sufficient for pressure on any underflow waters. We found surface water—by boring in a channel about 6 feet deep—at a depth of 22 feet in a stratum of 8 inches of sand. The deposit is 29 feet deep where we bored; the water rose 6 feet above where we found it, or within 16 feet of the surface. The water was slightly brackish, but both man and beast could live on it.

The climate is about 100 degrees in the months of July and August during the heat of the day, but almost daily a breeze comes up from the Gulf. By building houses, to guard against the heat with double roofs, and sheds and porches all around to protect the walls of the house, it can be made habitable. During the balance of the year it is delightful. Occasionally wind storms occur which carry more or less sand or dirt, but with cultivation and tree-planting that will not be noticed so much. The production, in my opinion, would be of the finest of oranges, bananas, cotton, sugar-cane, lemons, raisin grapes that would ripen by the middle of June; alfalfa, sorghum, wheat and all sorts of vegetables in a most prolific yield; also, all the beans and medicinal plants of Mexico.

The good land is capable of sustaining a very dense population. The Government could not spend money where it would do the same good as there; and by passing a law adding the cost of the reclamation works to the land, they would get it all back, sell the land, and provide homes for thousands of people. I have been hoping to see this great enterprise consummated during my lifetime and still hope to see it done.

It is too big a move for private capital, which has no interest in the land. If the land was owned by private parties it would soon be reclaimed. The Government can do it and ought to do it. I think of nothing else now that would be of importance or interest, but trust that some of this may be of use to you and of benefit to the Government.

POSSIBLE MEANS OF RECLAMATION.

The discoveries and utilizations already made give good reason to hope that springs and artesian water may be found in considerable volume throughout the Mojave and over a considerable portion of the old beach lines and other portions of the Colorado trough or basin.

The reclamation of the Algerian Desert offers lessons of value in this direction. There, waters are restored to the surface after percolating for an immense distance; here the stream beds are numerous, and the courses of their buried waters within the area to be reclaimed are easily ascertainable. Railroads have crossed the barren waste without experiencing great difficulty in obtaining water, and indeed in many places the water is so near the surface that the coyotes, as at Coyote Wells, are known to have reached it. The chief difficulty in the way of a copious supply of phreatic water in the Colorado desert is found in the fact that quicksand is liable to choke the well bores or other appliances.

Antelope Valley is a part of the region known as the Mojave Desert. In 1882, the Southern Pacific Railroad Company bored an artesian well at Lancaster, in the northern part of Los Angeles County, and obtained a good supply of water. Flowing water was no sooner found than settlement began, wells were bored, cultivation and improvements put under way; and from this section of the Mojave Desert, whose aridity has been so notorious, the wheat was harvested in the summer of 1890 that took the prize at the county fair over the competition of all southern California.

In this valley, which is rather a portion of a wide intra-mountain plain, forming part of the vast drainage basin which once fed a great inland gulf that now heads into a shallow delta some 300 miles below and is slowly but steadily receding, as well as in the upper and narrow portion of the Colorado desert, irrigation has already created the beginning of large and prosperous fruit-growing settlements. In the Antelope Valley proper, since April, 1889, some 10,000 acres have been brought under cultivation; this area can be readily increased to 25,000 acres. It is estimated that in all 50,000 acres are now under ditch. The surface supply is obtained from mountain streams, stored in three reservoirs, with a total capacity of 30,000,000 gallons. The works include 5 dams, 5 headways, 7 weirs, and 6 tunnels driven into the foothills. The main ditches are 50 miles in length, 5 feet wide at the top. There is an equal mileage of distributing and lateral ditches. Five artesian wells, besides that of the railroad at Lancaster, have been sunk at depths of from 180 to 500 feet, with a flow for each ranging from 50,000 to 200,000 gallons per 24 hours. The economic service of their waters is equal to a duty of 7,000 acres. Over 100 wells are in use. They range from 20 to 100 feet in depth. They draw their supplies from the glacial drift of gravel and bowlders.

SOME OF PRODUCTS ADAPTED TO THE REGION.

In view of the extension of reclamation by irrigation over large portions of the desert region, now arid and unproductive, it may be as well to suggest in outline some of the products which, by the aid of unfailing sunshine, a tonic atmosphere and water intelligently applied can be as surely *manufactured* from the arid soils as the wool from the sheep can be sheared, washed, carded, spun, and woven into cloth. Not only can the grains and sugar cane, roots and other vegetables, with the trees and shrubs of the semitropics be brought to maturity in great abundance, but all of the citrus and deciduous fruits and berries of the same regions. Not these only, but the commercial, leguminous and medicinal products of Mexico, etc., may be successfully cultivated. The date, as a fruit, will require careful study in the more elevated portions. But the indigenous date palm of the Colorado desert and lower river valley yield a fruit which, in spite of entire neglect, is still palatable, and may yet, by hybridization, become of commercial value. A great industry that can be created is that of the cultivation of the olive, with the preparation also of its various merchantable products.

It is not the purpose of this report to deal with more than climate and possible water supplies. To favor the olive, the mean annual temperature must not be below 57 degrees; the mean for the coldest month not below 41 degrees, and the minimum not below 14 degrees. The olive will grow in a soil even too dry for the grape vine, and too rocky for any other fruit tree. On low, moist lands it has made but indifferent progress; but it is not therefore to be concluded that it will grow on sterile land. The warm soil of the desert region, from its calcareous nature, offers great inducement for the production of this fruit. A flinty, clayey, limy soil is, according to M. Grandeau's experiments in France, the best for olives. The desert soil possesses this qualification. The physico-chemical analysis of good olive soil is as follows:

	Parts.
Water	2.000
Sand	72.000
Limestone	12.037
Clay	12.050
Humus	0.140
Organic débris	1.773
Total	100.000

Professor Hilgard's analysis of the soil of the Mojave shows a great similarity of composition:

The analysis of the soil from the neighborhood of Mojave shows clearly that it is not inferior in productive capacity to some of the best soil of the great valley, which it greatly resembles, save in the scarcity of humus or vegetable matter. Its supply of lime and potash is high, that of phosphoric acid low, but not more so than in some very productive soils of the valley. The scarcity of humus is the defect which it would be most needful to remedy; probably best by turning in a crop of alfalfa, which there could be no difficulty in growing when irrigation was available. There are doubtless many many tracts where this defect does not exist, since they are covered with a dense growth of small shrubs. The soil of the Colorado River bottom is a highly productive one, easily worked, and not liable to suffer from wet in case of overflow being quite light. It is highly calcareous, containing 16 per cent. of carbonate of lime. Its potash percentage is very high, yet there seems to be no trouble from alkali, as the soda percentage is very small. Its supply of phosphoric acid is fair, though not large for a bottom soil; the humus percentage is likewise small for a lowland soil, yet adequate.

The olive seems to be quite sensible to variations of altitude; but the climate of this region, especially under cultivation, is so agreeable and so near that of many old world olive plantations, that this fact is merely mentioned as a factor to be considered, and not as a barrier to the cultivation of this plant. The olive blooms early in May and ripens from November to January. It bears at 2 years, and at 4 years there is a good crop. There are now 16 or more varieties of this berry cultivated throughout California. There is frequently found an indigenous date palm, which in spite of drought, utter neglect and exposure, has survived and grows to the height of 80 feet. This fact alone, aside from the favorable soil should be an inducement to the irrigated cultivation of this fruit on these rainless tracts. The fig tree grows in earth too dry for other fruits to mature; and the warm arid soil and dry atmosphere of the desert section offer peculiar advantages for its culture. Water sufficient may yet be supplied to support this hardy tree. There is no more profitable crop for the fruit grower; and in the Mojave and Colorado deserts, shielded from unfavorable coast winds, the crop under irrigation is certain. Mr. James Stewart, of Downey, Los Angeles County, says he has fig trees "growing on high dry, sandy soil, where it is 20 feet down to water; also some on rich sandy loam, where it is about 10 feet to water. Again, I have them growing on stiff adobe, not more than 5 or 6 feet to water; and they all grew vigorously and well."

Below Yuma, in the Colorado Valley, and, indeed, within the whole area affected by the Gulf overflow, as described by Mr. McFadden, cotton, rice, tobacco, and sugar cane can be grown profusely. In wild hemp 50,000 acres are reported; there is as much more to be worked for fibrous. This in the hot rich valley lands. Back of these acres is found a great body of alluvial land, adapted for all fruits and products of a semitropical character. The live oak can be grafted with the chestnut, the castor bean on the mesquite tree, which can also be made of value for its gum, which is nearly as important as the gum arabic of commerce. Even the sterile and rockier foothills will grow the many varieties of the cactus plants which our Mexican neighbors utilize in many ways.

PRESENT AREAS OF IRRIGATION.

It will be difficult to state in figures and acres the actual amount of irrigation progress accomplished in the semiarid and arid States during the year 1890. The conflicting discussion of this subject has had, of course, to some extent, the effect of delaying investment. It had, however, one more beneficial, in that it has created a great interest in the whole subject. This has been manifested in a large variety of ways, causing, wherever there was no land policy to intervene, a very considerable degree of preparatory activity, whose effect will be seen during the ensuing year. The report of the Senate Committee on Irrigation presented the following tabulated estimate of the actual and approximate areas under ditch (1889) within the region of its investigation:

	Under ditch.	Irrigated.
	Acres.	*Acres.*
Arizona	455,000	225,000
California	4,000,000	3,300,000
Colorado	3,000,000	1,600,000
Idaho	715,000	500,000
Kansas	300,000	75,000
Montana	986,000	350,000
Nebraska	50,000	5,000
Nevada	142,000	70,000
New Mexico	800,000	625,000
Oregon	191,000	150,000
South Dakota (Black Hills)	100,000	15,000
Texas	200,000	125,000
Utah	700,000	413,000
Washington	75,000	50,000
Wyoming	1,947,000	75,000
Total	13,661,000	7,578,000

The estimates for 1889, made by the U. S. Geological Survey, were as follows:

	Acres.
Area under ditch, constructed and projected	*9,974,419
Area under ditch and irrigated	8,307,000

The largest activity has prevailed during the past year in the States of California, Colorado, Idaho, and Montana. In the Territories of Arizona and New Mexico there has been some considerable progress made. In portions of South Dakota and in western Nebraska and Kansas the necessities of the people, as well as the discussion that has arisen, have crystallized into practical channels various projects and forms of enterprise that are likely to be of great service in the near future. The beginning of great activity has already been indicated in Washington and Oregon east of the Cascade range, while in Nevada there is a growing feeling that the security and maintenance of their State organization depends upon the efforts that are to be made in the direction of reclamation.

IN CALIFORNIA.

As has already been stated, the chief development of this State in irrigation has been in the subdivision of the areas under ditch, and of the steady growth in the organization of irrigation districts. The abolition of the State engineer's office now leaves California without any official channel for the publication of information; in fact, no attempt has heretofore been made to present the irrigation statistics of that State as whole, important though they are. Under the head of California this report will give a great deal of local information relative to the progress of works and the increase of acreage. By the report of the Senate it was estimated that at the time of their visit (1889) the following acreage was under cultivation:

Estimates made from testimony taken by the Senate committee, 1889.

Miles of ditches in State	3,835
Cost per mile	$640 to $5,400
Total cost	10,375,289
Acres of irrigated areas:	
In farm crops	3,080,000
In vines	83,000
In fruit	131,000
Total estimated	3,294,000

NOTE.—The difficulty of obtaining definite data is very great, and it is most probable a more correct estimate would cover at least 4,000,000 acres.

It is difficult to estimate the new areas brought under ditch, and largely, too, under irrigation during the past year within the State, but it is not less than 150,000 acres for the Southern California and San Joaquin Valley sections, and 50,000 for the remainder of the State. Under ditch in the works now in progress, the increase will not be less than 750,000 acres.

The most important works in connection with irrigation that have been undertaken and are now in progress are found in San Diego and San Bernardino Counties, as well as on the American River in central California, where dams and other works are being constructed for a

* This estimate only includes Arizona (1889), California (1885), Idaho, New Mexico, Oregon, and Wyoming (1889).

large reservoir. The Bear Valley reservoir in San Bernardino is elsewhere briefly described. When in full operation it will add at least 250,000 acres to the acreage under cultivation in that region. During the past year works have been constructed in the Antelope Valley—an elevated intra-mountain section in Los Angeles County—one which has been considered heretofore as almost irreclaimable. One large and several small reservoirs, with 50 miles of distributing ditches, have been constructed. A considerable number of acres have been brought under cultivation, and the production of grain, forage, and fruit has already commenced on a large scale. No doubt of success is now felt. The area of irrigated land has increased quite largely in the whole of Southern California and the lower counties of the San Joaquin Valley. In Fresno County some 10,000 additional acres have been brought under use. Twice that amount, it is claimed, will be cultivated during the coming year.

In Tulare County the activity has been very great, the additions to cultivation there being more widely scattered than in Fresno, but the total is even larger. In Kern County a remarkable degree of development is in progress, and the fruit colonies under way in the neighborhood of Bakersfield, Poso, and Laerdo have laid out a large acreage for future cultivation. One most striking enterprise is in the northeastern section of Kern County, where three fruit colonies have been established, the water supply for which is found in the powerful artesian basin now being developed therein. In San Diego County there has been a steady increase in the area and service of several great enterprises established therein during the last two years. The acreage of fruit as well also as of grain farming has largely increased. Small areas have been brought under irrigation by wells and small phreatic supplies. In both San Bernardino and Los Angeles Counties there has been a steady growth during the past years of numerous small irrigation areas served by local supplies, chiefly underground. One of the most interesting developments is being made in Inyo County—a region of high altitude, lying between parallel ranges of the Sierras. In other mountain counties, as Lassen and Sierra for example, considerable progress has been made. In Lassen it is seen in utilization as reservoirs of natural storage basins. In Sierra County the development of an artesian supply of water is referred to. In Shasta, in the extreme northern part of the State, irrigation enterprises for fruit cultivation are under way, while elsewhere in the foothills region considerable activity and interest have been manifested; progress to a considerable extent is reported.

In further illustration of the effects of irrigation are presented the following summaries of the "taxable values" of California for 1879 and 1889, as summarized from the Senate committee's report:

	1879.	1889.	Increase.
13 southern counties enriched by irrigation	$102,516,281	$350,981,695	$248,405,414
11 other counties, wherein irrigation increases	47,791,104	99,336,095	51,544,991
8 foothills counties, partially irrigated	23,739,268	36,397,142	12,657,874
Total	174,046,653	486,714,932	312,608,279

The increase in the balance of the State, 21 counties, amounted in 1889 over 1879 to $192,125,578, or $56,297,836 less than in the first division given.

IN COLORADO.

This State has shown a great deal of activity in the construction of ditches and by an increase of the acreage to be served. This increase was especially manifested in southeastern Colorado, in the Valley of San Luis and in the western and the northwestern portions of the State. The estimates made by the Senate committee in 1889 of the area under water and cultivated are as follows:

Statements furnished Senate committee by Prof. L. G. Carpenter and State Agricultural College, 1889.

Number of water divisions	6
Number of water districts	44
Acres under ditch	2,913,273

Statement furnished by State Engineer Maxwell, 1889.

Divisions east of and in the Rockies	3
Water districts	35
Acres under ditch	2,522,073
Acres actually irrigated	*997,346
Number of reservoirs	162
Number of ditches	2,000
Mileage of ditches	5,000

Estimate of U. S. Geological Survey, 699,539 acres irrigated.

Since that date about 750,000 acres have been added to the area under water. The totals according to the admirable summing up of Prof. L. G. Carpenter, whose statement is given in this report, is as follows:

Square miles	6,256.89
Acres under ditch	4,004,009
Acres irrigated	1,585,000

The mileage of canals reported to the State Engineer's office is 6,316.89. This does not include a considerable mileage of small ditches within the mountain valleys which are not reported nor recorded; the total within the State of mileage, adding these, is estimated at 8,000. The total cost of the reported works is given by Prof. L. G. Carpenter at $10,950,000. This does not include a number of reservoirs constructed during the past year nor the cost of the 2,000 and more wells that have been sunk in the valley of the San Luis. The total in the whole State of irrigation works can not therefore be less than $13,000,000. There is an increase of interest in the economy of water, a growing public opinion in regard to legal measures for the protection of water users, and much activity displayed in regard to the feasibility and availability of underground supplies. The use of pumping machinery has also increased in Colorado, a fact due largely to the comparative cheapness of cost with which this want has been supplied through the use of pumps manufactured at Greely, in that State.

IN IDAHO.

Great activity has been displayed in portions of the new State. The Senate Committee on Irrigation and the governor of the late Territory, in his last annual report, made a statement as to irrigation works,

*Estimated acreage under ditch and cultivated west of the Rocky Mountains, 291,000, making in all for Mr. Maxwell's report a total of 2,813,273 acres.

areas under water and cultivation, mileage of canals, etc. The totals are given for the thirteen counties in which irrigation prevails:

Number of completed ditches	1,311
Miles of completed ditches	2,418
Acres irrigated and under ditch in 1889	715,500
Acres that can be reclaimed, estimated	7,141,400

Less than one-half of the area under ditch is actually cultivated. Governor (now United States Senator) George L. Shoup, in his last report as executive of the Territory, presents a statement and table from A. D. Foote, C. E., of Boisé City—a most competent authority—which gives the following totals for 1890:

	Acres.
Area now irrigated (that is cultivated)	327,000
Area to be irrigated when projected works now constructing are completed	1,181,500
Area irrigable with proper water supply	5,046,500
Reservoir sites, capacity in acre-feet of water	4,780,000

The estimate of the U. S. Geological Survey for 1889 is as follows:

	Acres.
Area irrigated and under ditch	400,000
Area under ditches, constructed and projected	740,000

During the past year it may be fairly estimated that 100,000 additional acres have been brought under ditch, 35,000 of which have been brought under cultivation, while new works in progress in southern Idaho, in Bingham County, and in the Boisé Valley will soon add several hundred thousand acres to the area under ditch.

THE CENTRAL DIVISION OF THE PLAINS.

Western Kansas and Nebraska, with a considerable portion of eastern Colorado and Wyoming, belong to the area of wells and underflow development. In Nebraska (1889) one irrigation enterprise on the North Platte projected a service for about 10,000 acres. Enterprises now commencing and covering portions of Nebraska, and southern, western, and northwestern Colorado and Kansas, propose to provide a service of water sufficient to insure security for 150,000 acres of land. Several small areas in western Kansas are also active in organizing irrigation works. In the valley of the Upper Arkansas about 500 miles of ditches had been constructed by the close of 1889, by which it had been proposed to serve about 350,000 acres of arable land, as well as to place under ditch a large grazing area. This system of surface supply has to a considerable extent proved a failure. Works of importance to be fed by the underflow of the Arkansas Valley have been under way during the past year with every promise of success. In southeastern Colorado the area of land to be served by ditches, constructed during the past year and supplied by the Arkansas River below Pueblo, is about 68,000 acres. The canals in progress in the same region will have a length of 350 miles when completed.

IN NEW MEXICO.

The Territory is developing quite rapidly. The principal direction of settlement is to the Maxwell grant, in the northern section, along the central portion of the Rio Grande Valley, into the Mesilla Valley, and especially in that of the Rio Pecos. Large works are under way at different points in the Rio Grande and in the lower part of the Pecos, where, especially, a railroad is just finished, and other reservoirs and additional canals are rapidly approaching completion. There is a population there in all of about 20,000. Two years since there was not one-fourth of that number. All of the works projected and constructing in New Mexico promise to be of the most substantial character. The following were the estimates presented for 1889 in the Senate committee's report:

Summary of census, Federal and Territorial, 1880 *and* 1885, *presented to the Senate committee with estimate.*

Year.	No. of farms.	No. of acres improved.	Average acres per farm.
1880	5,053	237,392	47
1885	10,511	525,550	50
1889	13,000	650,000	50

According to estimate of T. B. Mills, presented by the U. S. Geological Survey, the acres under ditch in 1889 were 638,455.

Under recent inquiry made by various Government agents, the following are presented as the best figures obtainable for 1890:

	Acres.
Total arable area of Territory	36,185,000
Total reclaimable area of Territory with present works	1,962,342
Total acreage under ditch and irrigated	593,315
For Eddy, Chaves, and Lincoln Counties, at least, may be added as now "under ditch"	184,000
Or a total under ditch and irrigated of	677,315

IN ARIZONA.

In this Territory the actual increase of acreage by irrigation has been moderate. The Senate committee's report presented the following table of areas under ditch and cultivated:

Estimated by the Senate committee from testimonies given in 1889.

Number of counties reported	*8
Number of canals reported and estimated	203
Number of miles	740½
Acres under ditch	529,200

Report of the United States Geological Survey estimated by Mr. F. H. Newell, C. E.

Number of counties	10
Acres under ditch	455,600
Acres under irrigation	175,000
Acres cultivated	203,080

The acting governor, in his annual report to the Secretary of the Interior, under date of September, 1890, gives the following totals:

Areas under ditches, in acres	587,460
Areas actually irrigated, in acres	295,200
Miles of canals	845½

These are estimates made in the acting governor's report for 1890. The governor estimates the total area reclaimable at 5,550,000. Lieutenant Glassford, U. S. Signal Service, and others, estimate it as high

* Ten counties not reporting.

as 10,000,000 acres. Capt. George M. Wheeler, E. C., put the possible area at 25 per cent., or over 26,000,000 acres. The latest estimates given, gathered by Government agents, are as follows:

Acres under ditch	669,440
Acres to be reclaimed by works in progress	245,000
Miles of ditches	1,064¼
Miles of ditches in construction	300

The development has mainly been in the slow progress of enterprises that were already under way when the year begun; in the reorganization or consolidation of enterprises; in the establishment of several colony movements—one of which is described elsewhere in this report; and in the growing evidence of the capacity of large areas within this Territory adapted to the production of the finest variety of semi-tropical fruits and vines. There is no doubt that the ensuing year will see a more definite policy and a more determined effort in southern and central Arizona, at least, to inaugurate irrigation for the cultivation of the soil on a large scale. The prosperity of the Salt River Valley is an ample inducement to that end and an argument for its success.

IN OTHER STATES AND IN UTAH.

The changes in Wyoming, Utah, eastern Oregon and Washington, and Montana have not been in 1890, in actual results, of a very marked character. In projected constructions, however, work of great importance is under way. The Bear Lake enterprise in Utah is making some progress. Activity prevails elsewhere, as is shown by the incorporation of several companies. There can be no great increase in irrigable area under the present Mormon policy, but larger works on a more scientific basis of storage and distribution.

The following estimate is made from the testimony taken by the United States Senate committee in 1889:

Number of counties reported	23
Number of acres under ditch	700,000
Number of acres irrigated	413,000
Number of canals	1,079
Number of miles in ditches	3,903

The following estimate is presented by U. S. Geological Survey on authority of Mormon Church officials:

Counties reported	23
Acres under ditch	802,456
Acres irrigated	371,437

In addition to these totals the Mormon authorities reported 1,794 flowing wells with a total irrigation of 1,193 acres. Marcus E. Jones, of the Deseret University, reported to Governor Thomas, 1889, 2,000 wells, and at least 8,000 acres irrigated by them.

In Montana the Senate committee report for 1889 gives an area under ditch of 986,000 acres; actually about 350,000. Considerable activity has prevailed, and with the increased area of cultivation the total will reach at least 400,000 acres. Work in progress and partly constructed will make 1,100,000 acres, a not unreasonable estimate for the area under ditch.

The area reported (1889) in Wyoming under ditch, by the Territorial engineers was as follows:

Number of recorded ditches	2,349
Number of unrecorded ditches	466
Number of miles in ditches	4,249
Total carrying capacity in miner's inches	33,475
Total of acres served	1,946,876

The area cultivated may be estimated at 8 per cent., or about 160,000 acres. The increase in 1890 in cultivated area (beyond forage plants and pasture) will not be less than 15,000 acres; making in all 175,000. No increase in ditches or mileage is reported.

The irrigation estimates in eastern Washington and Oregon, made to the Senate committee in 1889, were as follows:

EASTERN OREGON.

		Acres.
1889.	Under ditch (estimated)	75,000
	Actually cultivated	35,000
1890.	Under ditch (estimated)	100,000
	Actually cultivated	45,000

EASTERN WASHINGTON.

		Acres.
1889.	Under ditch (estimated)	75,000
	Actually cultivated	50,000
1890.	Under ditch (estimated)	150,000
	Actually cultivated	60,000

Nevada has made some progress during the past year. It may fairly be estimated as follows:

		Acres.
1889.	Under ditch	75,000
	Under cultivation	50,000
1890.	Under cultivation	75,000

An awakened interest is felt throughout the State, as will be seen by reading the review elsewhere presented in summaries of State progress. The next legislative session will not adjourn without taking some definite action for a generous attempt at fostering large reclamation efforts.

The Black Hills in South Dakota is at present the only section irrigated by surface works; the area under ditch is estimated at 100,000 acres, and that under cultivation at about 20,000 acres. Elsewhere small experiments by artesian wells reached an area of about 2,000 acres, and have clearly demonstrated the possibilities of that supply. In Western Kansas, Nebraska, and Texas, some increase in area of cultivation and a large addition to that "under ditch" has been noted. The estimates are as follows:

	Under ditch.		Cultivated 1890.
	1889.	1890.	
	Acres.	*Acres.*	*Acres.*
Western Kansas	300,000	350,000	120,000
Western Nebraska	50,000	65,000	10,000
Western Texas	210,000	340,000	160,000

The area indicated as cultivated is of course largely used for forage plants, as well as cereals and roots.

THE TOTAL RESULTS PRESENTED.

These figures, when summed up, present the totals that follow. This office has been scrupulous in its endeavors to obtain exact statistics. That it has not yet been as successful as is desirable is due to inability to send agents out, and to the fact that the States and Territories, with the exception of Colorado and Wyoming, have not as yet made any direct effort to secure a full account of the important interest under review. Probably from this date, however, this difficulty may not be met with, as in addition to the systematic efforts making under law by the Department through this office, the United States Census Office has also made a minute inquiry. The Treasury Bureau of Statistics, in dealing with internal commerce, is publishing considerable information. The U. S. Geological Survey is also reported to have been active while carrying forward topographical work within the arid region in gathering irrigation statistics, and a most important inquiry into climatology has also been completed under a resolution of the House of Representatives by the United States Weather Service, under Brigadier-General Greely's direction. All of these reports will largely extend our knowledge of the arid region and of the possibilities of reclamation therein, even if there is a loss of energy and a waste of money in pursuing such a diffused system of inquiry.

Lands under ditch in the arid and semi-arid region..

States.	Acreage under ditch.		Cultivation, 1890.
	1889.	1890.	
Arizona*	529,200	643,450	310,100
California	3,294,000	4,044,000	3,444,000
Colorado	2,813,273	4,004,0[illegible]9	1,585,000
Idaho	715,500	1.181,500	327,000
Kansas (western)	500,000	860,010	100,000
Montana	986,000	1,100,000	400,000
Nebraska (western)	50,000	65,000	10,000
Nevada	142,000	150,000	75,000
New Mexico	638,455	677,315	450,000
Oregon (eastern)	75,000	100,000	45,000
South Dakota (Black Hills)	100,000	100,000	20,000
Elsewhere in Dakotas	....	2,000	2,000
Texas	200,000	340,000	160,000
Utah	700,000	700,000	413,000
Wyoming	1,946,876	1,946,876	175,000
Wyoming (eastern)	75,000	150,000	60,000
Totals	12,764,304	16,064,160	7,576,100

*In Arizona for 1890 two estimates were sent in, one of 587,460 acres under ditch, and 295,200 cultivated acres, by the Acting Governor; the other, by Government officers, of 699,440 acres under ditch and 325,000 cultivated. The figures above are the mean of the two estimates.

It may safely be assumed that there are very many small irrigated areas scattered throughout the arid region, which are not included in these estimates. There are also larger areas, not many in number, perhaps, in which the use of water for irrigating natural and cultivated grasses is of considerable importance. No estimate is attempted of the small irrigations of house gardens, lawns, and fruit trees, which prevail in every city, town, and village west of the ninety-seventh meridian. Altogether it will not be unreasonable that the area actually cultivated in 1890 reaches at least 8,000,000 acres.

CROPS OF THE ARID REGION.

The following carefully summarized table presents objectively, and it is hoped effectively also, the latest data as to agricultural production within the region affected by arid conditions of climate and precipitation:

Estimated amount of crops, etc., named for 1890 within the States and Territories affected by aridity.

[Based on Crop Report, December, 1890, Department of Agriculture.]

Divisions.	Corn.	Wheat.	Oats.	Acreage.	Value.
	Bushels.	*Bushels.*	*Bushels.*		
United States	1,489,970,000	399,262,000	523,621,000	134,489,286	$1,311,255,615
Arid and semiarid regions west of 97th meridian	193,602,000	146,133,000	109,542,000	29,353,119	266,500,988
Arizona		311,000		25,000	280,044
California	4,396,000	29,121,000	1,943,000	2,657,256	26,077,559
Colorado	767,000	1,777,000	2,498,000	238,888	3,171,097
The Dakotas	12,030,000	40,411,000	24,846,000	6,277,232	42,253,767
Idaho		1,370,000	1,093,000	119,496	1,702,989
Kansas	55,269,000	28,195,000	31,269,000	6,903,775	61,779,385
Montana		1,488,000	2,797,000	177,785	2,841,078
Nebraska	55,310,000	15,315,000	22,430,000	5,543,918	46,936,181
Nevada		250,000		18,489	214,658
New Mexico	1,126,000	1,105,000	392,000	163,229	2,095,383
Oregon (eastern)	173,000	12,865,000	6,658,000	1,117,201	13,092,149
Texas	63,802,000	3,575,000	11,059,000	5,266,266	55,416,616
Utah	739,000	2,279,000	1,059,000	203,917	2,862,403
Washington		8,071,000	3,497,000	540,667	7,777,679

It must be borne in mind in considering the figures of the above table that portions only of Texas, Kansas, and Nebraska lie west of the ninety-seventh meridian; while in the northwest those portions of Washington and Oregon which are east of the Cascade Range are properly classified as within the arid and semi-arid regions. For the States named east of the Rocky Mountains only one-third of the areas are to be considered. A fair estimate will take from the totals given in each case about two-thirds of the whole. In Washington one-half of the total product at least will be east of the Cascade Range. In the case of Oregon it will be only one-third. With these explanations the table will stand. Following this estimate while making the deductions required by it and we shall have for the region west of the ninety-seventh meridian these figures for the year 1890:

	Bushels.
Corn	80,592,666
Wheat	102,130,392
Oats	60,546,664
Total acreage is estimated at	17,418,146
Total value of crops named	$144,464,643

On the basis of the crop reports for 1889, and making allowances for changes, the following figures for other farm crops within the same area are estimated as for 1890:

	Bushels.
Barley	22,000,000
Rye	3,000,000
Potatoes	26,000,000
Buckwheat	1,100,000

The crop area thus covered will not be less than 1,800,000 acres. The area required for the hay crop of the region under review will not be less than 5,500,000 acres, and at an average of 1.25 tons per acre, the yield will be about 6,840,000 tons.

A valuable comparison will be found in the following table showing the—

Percentages of farm areas, population, value of land tenures, yield and acres in corn, wheat, oats, and the average value of stock in the United States and in the arid and semi-arid regions thereof.

[Adapted for this report from the Album of Agricultural Statistics, Department of Agriculture, 1889.]

States and Territories.	Farm lands.					Rural population.		Lands in arid States.	
	Total areas.	Tillage.	Grass land.	Wood land.	Unproductive.	In agriculture.	Relation to United States (average).	Average value.	Relation to United States (average).
	Acres.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*
United States	2,295,043,840	41.6	11.5	35.5	11.4	44	....	$19.02	....
Arizona	72,906,240	36.6	4.8	9.9	48.7	15	—65.9	8.32	—56.3
California	100,992,640	39.8	24.5	10.1	25.6	21	—52.3	15.70	—17.0
Colorado	66,880,000	23.8	29	3.8	43.4	13	—70.5	21.55	+13.3
Dakota, North and South	96,596,480	21.7	8.6	2.1	67.6	49	+11.4	5.89	—69
Idaho	55,228,160	37	23.2	3.6	36.2	25	—43.2	8.64	—54.6
Kansas*	51,776,240	40.6	9.6	4.6	45.2	64	+45.5	10.98	—42.3
Montana	92,016,640	32.9	31.8	.9	34.4	20	—54.5	7.97	—58.1
Nebraska †	48,636,800	47.4	8	3.3	41.3	59	+34.1	10.65	—44
Nevada	71,737,600	33.4	31.5	3.5	31.6	13	—70.5	10.19	—46.4
New Mexico	77,568,640	30.2	7.4	34.7	27.7	35	—20.5	8.74	—54
Oregon †	60,975,360	29	23.2	33.8	14	40	— 9.1	13.50	—29
Texas †	175,587,840	21	13.8	43.7	21.5	69	+56.8	4.70	—75.3
Utah	54,064,640	45.5	18	.3	36.2	36	—18.2	21.38	+12.4
Washington †	44,796,160	23	11.4	31	34.6	42	— 4.5	9.82	—48.4
Wyoming	62,645,120	19.4	47.4	.4	32.8	.18	—59.1	6.7[illegible]	—64.7

States and Territories.	Farm tenures in United States.				Corn.		Wheat.	
	Total.	Cultivated by—			Total.	To each 1,000 acres of total land surface.	Total.	To each 1,000 acres of total land surface.
		Owner.	Tenant, money rental.	Tenant, on shares.				
		Per cent	*Per cent*	*Per cent*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
United States	....	....	....	....	75,672,763	41	37,336,138	20
Arizona	767	86	5.5	7.7	....	....	24,695	1
California	35,934	80.2	8.9	10.9	154,184	2	2,351,300	24
Colorado	4,506	87	3.7	9.3	34,394	1	134,074	2
Dakota, North and South	17,435	96.1	.4	3.5	737,899	8	3,921,269	41
Idaho	1,885	95.3	1.7	3	....	....	76,818	1
Kansas*	138,561	83.7	3.2	13.1	5,924,566	113	1,050,000	20
Montana	1,519	94.7	1.1	4.2	....	....	121,255	1
Nebraska †	63,387	82	3.1	14.9	4,097,067	84	1,560,021	32
Nevada	1,404	90.3	4.5	5.2	....	....	12,500	1
New Mexico	5,053	91.9	.4	7.7	53,609	1	82,186	1
Oregon †	16,217	85.9	4.6	9.5	7,140	1	892,425	15
Texas †	174,184	62.4	6.9	30.7	4,814,363	29	572,226	3
Utah	9,452	95.4	.6	4	33,500	1	119,299	2
Washington †	6,529	92.8	3.2	4	6,100	1	486,791	11
Wyoming	457	97.1	1.1	1.8	....	....	....	....

* Only one-third or thereabouts of this State is included in the semi-arid region.
† One-half or more of these States are embraced within the region under review.

Percentages of farm areas, population, value of land tenures, etc.—Continued.

States and Teritories.	Oats.		Average value per head.			
	Average yield.	Relation to United States (average).	Horses.	Cattle (excluding milch cows.)	Sheep.	Swine.
	Per cent.	*Per cent.*				
United States	27.0	....	$66.11	$19.87	$2.21	$4.97
Arizona	25.0	— 7.4	52.82	19.31	1.84	5.70
California	28.2	+ 4.4	56.14	22.90	1.77	5.15
Colorado	31.7	+17.4	59.57	24.36	1.94	8,06
Dakota, North and South	31.5	+16.7	76.49	23.64	2.52	5.84
Idaho	32.1	+18.9	54.74	22.58	2.25	7.43
Kansas*	29.3	+ 8.5	63.82	22.94	2.04	5.98
Montana	34.2	+26.7	54.89	23.55	2.38	7.98
Nebraska†	30.4	+12.6	72.92	24.20	2.24	5.96
Nevada	30.4	+12.6	55.75	22.46	1.87	6.69
New Mexico	22.6	—16.3	38.08	17.78	1.52	7.26
Oregon†	29.1	+ 7.8	54.54	21.63	1.65	3.63
Texas†	24 3	—10.0	32.17	12.20	1.97	3.16
Utah	26.3	— 2.6	44.38	20.67	2.09	8.66
Washington†	37.3	+38.1	47.49	23.46	2.23	6.86
Wyoming	30.2	+11.9	64.65	24.90	2.22	5.63

* Only one-third or thereabouts of this State is included in the semiarid region.
† One-half or more of these States are embraced within the region under review.

THE LEGAL ASPECTS OF IRRIGATION.

It has been deemed important to offer a brief review of recent legislation and of matters discussed or pending. In an article published in 1888, and since adopted by Appleton's Cyclopedia, the special agent laid down the governing law in arid regions as to the disposition of water for economic uses. As these principles and habits are universal where aridity prevails they must govern. They are stated as follows:

*(1) The maintenance of a general sovereignty among all civilized nations over all navigable waters. *(2) The Anglo-Saxon or common law jurisprudence recognizes riparian rights or control over running water or other natural supplies of the owners of the land bordering thereon. *(3) The Latin jurisprudence, and all codes founded thereon, as well as all the Oriental codes, customs, and systems, place all natural waters as subject to "servitude," therefore public property subject to economic individual use through community rules or legislative enactments.

In this country the Spanish and Mexican codes and customs in this direction govern in large portions of our western and southwest territory.

IN SOUTH DAKOTA

Legislation has been adopted looking to the encouragement of irrigation by means of the construction of artesian wells through public taxation, the waters of which are thereafter to be stored and used for irrigation purposes. The first acts were passed by the Territorial legislature, and remain upon the statute books of both North and South Dakota. The sections relative to water rights, adopted in 1887, provide that persons owning land also have a proprietary right to the use of the water thereof. The right of way is given to ditches, flumes, and other works. Damages may be assessed where such works cross different bodies of land. The waters running were made available for ben-

* Harper's Weekly, Sept.21, 1888, "Irrigation" by R. J. Hinton; Appleton Annual Cyclopedia 1889, title "Irrigation."

eficial uses "without regard to deterioration in quality or diminution of quantity, so that the same do not materially affect the order or rights of the prior appropriator." One year's failure to use forfeits rights in ditches or other works. Provisions exist requiring the rapid construction of all works needed, having the use of any prior appropriation of water. Failure to commence construction within 60 days after location, appropriation being required, shall forfeit the same.

By sections 2760 and 2771 of the "Political Code" of the Territory, now in force in both States, it is provided that—

The following land burdens or servitudes upon land may be attached to other land as incidents or appurtenances, and are then called easements:

* * * * * * *

4. The right of way.
5. The right of taking water, etc.

* * * * * * *

9. The right of receiving water from or discharging the same upon land.
10. The right of flooding land.
11. The right of having water flow without diminution or disturbance of any kind.

Also that the owner of land owns water standing thereon or flowing over or under its surface, but not forming a definite stream. Water running in a definite stream, formed by nature over or under the surface, may be used by him as long as it remains there; but he may not prevent the natural flow of the stream, or of the natural spring from which it commences its course, nor pursue nor pollute the same."

By an act passed at the last session of the Territorial legislature, 1889, "to provide for the sinking of artesian wells and construction of water courses therefrom," the probate judge of each county is made *ex officio* county artesian-well commissioner.

On the filing of an application by ten freeholders for the sinking of a public well, and giving a description of the land, etc., upon which it is to be sunk, the same commissioner shall, within 20 days, appoint three persons as viewers, who shall examine the said site and report the route thereof. If any one object to the location and route of said well and water course, and claiming damages because thereof, the viewers shall make a report of the said damages and the amount of assessment therefor. If the board of county commissioners confirm the report in favor of locating the proposed well and with regard to the damages claimed, the costs, etc., shall be paid out of the county treasury. Unreasonable assessments may be set aside and a new one ordered. After the report made by the viewers is accepted the county surveyor shall make a survey and file a plat thereof in the county office. Railroad companies are required to construct and maintain necessary openings and culverts for the passages of water ways across the road-beds of said railroad. All water ways crossed by public roads are under the jurisdiction of the road overseer. The wells shall be named by the county commissioner. He shall advertise for bids for contracts for the sinking or making of such wells and for the construction indicated therein. The contracts are to be approved before becoming valid by the board of county commissioners.

After making the order for locating said public wells, the artesian-well commissioner is required to notify the chairman of the county board and the county treasurer, who, with the well commissioner, shall constitute a board of assessment. They shall proceed to make an estimate of the costs of constructing the said wells and ways, and the funds for that purpose shall be apportioned as follows: An assessment upon taxable property, not to exceed 2 mills on the dollar, shall be made and known as the artesian-well fund. One-tenth of the cost of the well and water ways is to be paid out of the State funds. The board of assessment shall then determine the proportions of cost to be borne by each of the organized townships in which said well or water ways are to be located and served. The amount to be paid by any one township shall not exceed one-fourth of the estimated cost of said well and works. An estimate shall then be made upon the property of said township for the purposes of "general township tax for artesian-well purposes," which shall be held as a distinct fund for the payment of said construction. The board of assessment shall also make a special assessment against the land directly benefited by said well and water-ways, adjusting this assessment by a careful understanding of the relative distance of each parcel of land to be assessed from the well itself. The said assessment shall be levied as a special tax and placed in the tax list under the head of "direct tax for artesian well." It shall be kept separate as a special fund to pay for the cost of construction, etc. Such amount of tax may be collected in one year, or divided into two, three, four, or five equal installments, each collectible in pro rata annual payments. The board of assessment may act as a board of review for the raising or lowering any special tax assessment, upon the application of the assessed land owner. All assessments of benefits shall be upon the principle of benefits derived. The balance of the provision consists of the usual safeguards for the collection and disbursements of the public money.

The State of South Dakota, on the 8th day of March, 1890, passed "An act to encourage the construction of artesian wells." This act makes it lawful "for any person or persons, corporation or corporations, company or companies, to construct artesian wells upon any lands owned or leased by such person, company, or corporation, for the purpose of power and the irrigation of lands for agricultural purposes, and for any and all purposes for which said water from such wells may be utilized. The right to survey is given to any such parties and they are made liable for actual damages by reason of such entrance and examination. Water ways may not be located, without written consent, within 15 rods of any dwelling house or any other buildings on the premises, or across any orchard or garden. No land shall be burdened with two ditches when one is sufficient. Any person engaged in the business of supplying water for irrigation purposes shall have the right to sublet the most direct and shortest route practicable upon which their works and wells can be constructed. They shall have the right also to cross any public highway or railroad, the same to be done under public supervision. The estimate of damages is provided for by a jury appeal. Penalties for interfering, for injuring, and the unlawful use of water (from $50 to $300 and by imprisonment for not more than 90 days) are put in force. The plat of the route selected and surveyed is to be recorded in the office of the county register of deeds. The right acquired by location shall serve as an easement, "running with the land so long as the water way, thereon constructed, shall be used for the water flowing" from any well belonging to the carriers of water. All of said well ditches and water ways are required to be kept in good repair. The cost of construction to be borne by the proprietors in proportion to their interests therein. Any person over whose land such water ways shall be carried may have the right to use the surplus water flowing from said ditch or water way, by paying for the same a just rental to be fixed, if necessary, by the board of county commissioners. Whenever said water ways or ditches are located along any public highway "the water which may be flowing therein shall be for the use of the public," under the same terms required in the use of surplus water flowing across private land. Permission also is given, under due notice and rules, to construct necessary ditches and works across the school lands of the State.

By another act the office of State engineer of irrigation was created. The appointment of such Engineer was made contingent upon the passage by Congress of an appropriation for irrigation development within the State of South Dakota. The appointment was consequently made at a time after the passage of the organic division act of April 4, 1890. The salary is $1,000 per year with $500 for expenses. The engineer is placed in supervisory charge of the system of irrigation within the State "by means of artesian wells, dams, reservoirs, basins, or other methods that may be found practicable." He is to recommend the enactment of such measures "as he may deem necessary to perfect a system of irrigation." He is required, also, to coöperate with the officers of the United States in any survey or investigation relating to irrigation problems in South Dakota. Experimental and observation stations are to be established. The volunteer observers appointed are to note carefully "the time and manner of applying water artificially to the soil and its effects on vegetation." They are to collect all other data that may be beneficial and make a report thereof to the State engineer. Analysis of soil and water from different sections of the State are to be procured, the same to be made by the State Agricultural College. The State engineer is empowered to negotiate with the manufacturers of well and other irrigation machinery, in order to secure the lowest possible prices, and also to negotiate with transportation companies for the bringing of the same within the State. He is required to make an annual report.

IN WASHINGTON.

No copy of the act has been received by this office, but newspaper summaries indicate that the irrigation law recently passed has provisions somewhat similar to those of the California laws known as the "Wright District Code," by which the citizens of any area that can be served with water from a common source for irrigation purposes may form, under conditions provided for, a municipal district, with power to issue bonds, pay interest, levy rates, construct works, distribute water, and empower the collection of rental and other dues for the use of the same.

No additional legislation is reported from any of the irrigated States or Territories during the year 1890, except that at the last session of the Colorado State legislature a commission was appointed to modify the numerous and somewhat contradictory irrigation laws of that State. This report will be made during the present session of the State legislature.

WATER CARRIERS OR WATER OWNERS.

Considerable excitement has arisen among the farmers and other water users of the State with regard to this report. It is charged by the water users that the commission was formed in the interests of the incorporated carriers of water. Practically both the farmers' organizations and the newspapers that represent them are a unit in demanding that the legislation to be adopted shall provide for some form of permanent control and public ownership, either by the State direct or by a corporate subdivision thereof, whether the same be a water division or district or by counties.

In the main the controversy is directly tending to the advocacy and adoption of laws similar to those which already exist in California.

THE "WRIGHT" DISTRICT SYSTEM OF CALIFORNIA.

The district irrigation of that State has unquestionably caused a cessation of litigation over water rights and prior appropriations. It is also giving a great impetus to the systematic and economic enlargement of water systems and of the usage thereunder. Objections have been urged in California against the provisions of the Wright irrigation laws upon the ground that they give undue advantage to holders of large areas of unimproved land for speculation, and thereby discriminate against holders of well-improved farms, vineyards, orchards, etc. It is also charged that they generally clean out farmers having small means by requiring the compulsory payment of construction taxes before they can be in a position to utilize the water, thus, in a measure, thrust peremptorily upon them by the majority vote of the more prosperous irrigation districts. To the first statement it is practically certain that, under the tax provisions of the State constitution and laws of California, the owners of large areas of land will find it impossible to bear the burden of any single irrigation district with the view of securing to them a monopoly in the way of water supply. Land is taxed in California separately from its improvements. This provision of the constitution of 1880, so vigorously denounced at the time, has, it is claimed by sagacious observers, in its application, turned out to be of the greatest benefit to the State. It compelled the owners of large areas, practically unimproved, to invest large sums for the construction of water-works in order to make their lands valuable and to aid in the production of crops, by means of which an income could be procured to pay the taxation imposed. In other words, land owners have found it necessary to improve their lands, when they had to pay no more taxation for such improvement than if their land remained in a wild state. Many millions of dollars have since 1880 been most beneficially invested in the construction of irrigation works, especially in southern California, with the result as stated elsewhere in this report.

The first step was produced by the taxation clause of the State constitution of 1880. The second is found in the necessary investment of capital for irrigation works. The third and larger step towards the prosperity now being developed in the use of irrigation for the cultivation of the soil within the borders of California has grown out of the passage and administration of the Wright system of irrigation districts, which provides compensation for all legal claims and ownerships, enables the citizens of any proper hydrographic and drainage district having land to irrigate to quiet the prior appropriator of riparian title and disputes, to absorb all canal systems, obtaining the public ownership of water and the works required for their beneficial use, while maintaining the same at public expense and by public taxation. The quieting of such rights and title with the construction of works must necessarily be a costly affair. As, however, the element of private profit is removed, its distribution through the issuing of bonds insure that the distribution of the burden will be equitable and not difficult to bear, even by the poorer land owners and water users. In every case so far, where irrigation districts have been formed in California, the chief supporters of the policy and the most active voters therefor have been the small farmers within the area embraced, and, as a rule, the large owners have been persistent opponents of the legislation and steps which provide for irrigation districts.

The removal of all reasons for litigation as to water titles is a benefit that more than compensates for any annual cost imposed upon the poorer farms at the beginning. As a matter of fact, however, the irrigation district system, so far as reported, will provide for less rental charges than the old system of incorporated canal or colony companies has ever done. With the progress of the years for which the irrigation bonds are permitted to run the charge per acre necessarily becomes considerable. The period of payment covers 21 years, payment beginning by series, however, at the close of 11 years. The annual interest charges are thus lessened after 11 years, and that burden will of course cease entirely with the payment of the construction bonds. The costs thereafter and for a considerable period before the bonds are finally paid, will mainly be that which is required for repairs and maintenance, with a small annual charge for a permanent fund to meet any deficiency.

JUDICIAL DECISIONS AFFIRMING CONSTITUTIONALITY.

Mr. L. M. Holt, editor of the Orange Belt, Redlands, Cal., who is considered one of the best authorities in that State on all irrigation matters, states that the district laws have at no time been subject to unfavorable criticisms, but that its practical operation has depended upon judicial judgments. Two of great importance have been rendered. In one, relating to the Furlock district, embracing lands in two counties, the case submitted put in issue all matters relating to the constitutionality of the Wright laws. The court rendered its opinion in the case sustaining the law at all points. In the course of its opinion the court said:

The act under discussion *in all respects* complies with the various provisions of the State constitution.

And again:

The general welfare of the whole people inseparably bound up with the interests of those living in sections which are dry and unproductive without irrigation, is plain to be seen pervading the whole act in question. This is not a law passed to accomplish exclusive and selfish private gain; it is an extensive and far-reaching plan, by which the general public may be vastly benefited, and the legislature acted with good judgment in evolving it.

In another case the Supreme Court laid down the doctrine that the strict rule of construction would not be adopted by the court in construing those provisions of the law relating to the organization of a district, or to the issuance of its bonds. In effect it was declared that any omission, not affecting a substantial right, would not be regarded by the court.

Steps have been taken to form a representative State organization of irrigation districts, legal recognition of which is asked from the State legislature. A State convention was held at Tulare in October, 1890, which adjourned to meet at the State capitol, Sacramento, on the 8th of January, 1891. The policy of California tends to such recognition by State commissions, or other methods. There are already in existence a State board of agriculture, and State commissions of horticulture and viticulture.

PROPOSED ACT FOR STATE IRRIGATION ASSOCIATION.

The following is the bill referred to and the full text is given as its object is rather a novel one to the people of the arid region:

The people of the State of California, represented in senate and assembly, do enact as follows:

SECTION 1. It shall be lawful for five or more irrigation districts organized under and by virtue of an act entitled "An act to provide for the organization and government of irrigation districts," approved March 7, 1887, to unite in forming a State association of irrigation districts to which all irrigation districts organized or to be organized under and by virtue of said act shall be entitled to membership upon terms of equality. Such association when formed shall be a State institution.

SEC. 2. The State Association of Irrigation Districts shall have power and it shall be its duty to inquire into the acts and inspect the works of all irrigation districts organized or to be organized under the laws of this State, and its authorized agents shall not be denied access to the books and archives of any of said districts. Said association shall have power to make, ordain and establish and put into execution such by-laws, ordinances, rules, and regulations as shall be necessary for the good government of said association; provided that said by-laws, ordinances, rules and regulations as shall not be inconsistent with the laws or Constitution of this State or of the United States. Said association shall have power to contract and be contracted with, to sue and be sued, and its purpose shall be to promote the development of the district system of irrigation in California by securing the coöperation of the irrigation districts of the State in a united effort to that end. Said association shall have power to act as special agent for any irrigation district affiliated therewith, and when duly authorized so to act by such district may do any of the acts which such district itself may do, but said association shall have no power to bind any district without such special authority except as herein provided.

SEC. 3. The State association of irrigation districts shall meet in open session in October of each year upon such day and at such place as shall have been determined at the preceding annual meeting, and each district belonging to such association shall be entitled to one vote in the meetings of such association and shall designate some member of its board of directors to represent such district at such meetings. Provision shall be made at such meetings for consideration and discussion of matters important to the development of irrigation in California, and industries dependent thereon; and it shall be the duty of such association to use all suitable means to collect and diffuse such information as is calculated to aid in the development of irrigation and the district system thereof in this State, and shall make such recommendations and suggestions as experience and good policy shall dictate.

SEC. 4. The officers of said association shall consist of a board of five trustees, to be selected from among its accredited representatives, in whom shall vest the general, prudential, and financial affairs of said association, and whose duty it shall be to execute its by-laws, ordinances, rules, regulations, and recommendations. There shall also be a president and vice-president of said association, who shall be members of the board of trustees and *ex officio* president and vice-president thereof; and a secretary and treasurer who shall not be members of said board. The president and two trustees shall, at the first meeting of this association held subsequent to the approval of this act, be elected to hold office until the second annual meeting of said association, and the vice-president and one trustee shall be elected to hold office until the first annual meeting held subsequent to the approval of this act; and thereafter the terms of office of all trustees shall be two years, but all shall hold office until their successors have been elected and have qualified. If from any cause a vacancy shall occur in said board, it shall be filled by the remaining members until the next annual meeting of the association. The secretary and treasurer shall be appointed by the board of trustees and shall hold office for two years unless removed for good cause shown.

SEC. 5. For its maintenance said association shall have power at its annual meetings to levy an assessment upon the taxable property of all irrigation districts belonging thereto not to exceed one cent upon each $100 of assessed valuation of property in such districts, and it shall be the duty of the boards of directors of such districts to include the same in their next regular tax levy, to collect the same with its other taxes and pay it over to the treasurer of the association on or before the first day of March of each year. The by-laws of said association may also provide for the payment by each district of an admission fee of $50 before being entitled to membership therein. The association shall have the power to negotiate the sale of bonds of any district belonging thereto, when specially authorized so to do, and at a price not lower than a minimum price to be prescribed by the board of directors of said district; but before undertaking to negotiate the sale of such bonds, the legality of such bonds must be affirmed by an attorney to be selected by the board of trustees of said association, and the proposed work must be approved by a civil engineer to be selected by said trustees. The expense of such affirmation and approval shall be borne by the district offering bonds for sale, and for its services in selling said bonds the association shall be entitled to receive a commission not exceeding one per centum upon the face value of said bonds so sold, but from which said commission there shall be deducted the expense of affirmation and approval above referred to, whereupon the residue shall be paid to the treasurer of said association and become a part of the general fund thereof.

SEC. 6. It shall be the duty of the secretary of said association to attend all meetings of the association and of the board of trustees, and to make and preserve a record of such meetings; to conduct the correspondence of the association and of the board of trustees and preserve a record of the same; to collect statistics and other information showing the actual condition and progress of irrigation in this State and elswhere; to keep all accounts of the association and of the board of trustees; to visit each irrigation district in the State and prepare and cause to be published a report touching the area, character of soil, and production of said district, together with the nature and cost of irrigation works, quantity of water utilized, source of supply, system of distribution, and such other matters as the board of trustees or association shall require, or shall seem to be of public concern. He shall correspond with investors and financial agencies, and use all proper means to develop and maintain a ready market for irrigation district bonds. He shall collect books, papers and pamphlets relating to irrigation and forms of production dependent thereon, and preserve the same. Under direction of the association and the board of trustees, he shall prepare for publication such reports as are required by law or the association or trustees; and by means of the issuance of periodical bulletins, he shall keep the irrigation districts belonging to the association constantly advised concerning all occurrences touching their interests. He shall appoint, subject to the approval of the board of trustees, a competent person as clerk and shall be responsible for the acts of said clerk. He shall maintain an office in the city of San Francisco at an expense for rent, stationery, and incidentals, not exceeding $500 per annum, and said office shall be open daily, except Sundays and legal holidays, from 9 o'clock a. m. to 4 o'clock p. m. He shall be paid for his services as secretary the sum of $200 per month, and his actual traveling expenses not to exceed $500 during any one year. His clerk shall be paid a salary (as such clerk) of $50 per month, each to be paid as other State officers are paid. Said expenditures herein provided for are to date from the day upon which a copy of the by-laws of said association, together with a certificate of organization, signed by the president and secretary thereof, is filed in the office of Secretary of State, and are to be paid out of the general fund in the State treasury.

SEC. 7 All printing required to be done by this act shall be done by the State printer.

PROPOSED COLORADO CODE—MAJORITY AND MINORITY REPORT.

Returning to Colorado, it should be borne in mind that its laws relating to water have been considered the most complete in all legalities essential to irrigation requirement. During the past year, however, the proofs of many contradictory features therein, as well as a deeper cause of discontent, brought about the appointment, under legislative enactment, of a commission to codify these laws. Two reports from this commission have been made. As they touch pro and con the fundamental sources of water litigation it has been deemed desirable to incorporate herein the main features of difference and the argumentative statements thereof. The farmers are united, it seems, in favor of the minority report.

Two important issues are involved: First, as to what constitutes an "appropriation" of water, and second, as to the extent of right under the term "domestic water." The two sections of importance in the State constitution are the following:

SEC. 5. [*Water public property.*]—The water of every natural stream not heretofore appropriated, within the State of Colorado, is hereby declared to be the property of the public, and is dedicated to the use of the people of the State, subject to appropriation as hereinafter provided.

SEC. 6. [*Diverting unappropriated water—Priority.*]—The right to divert unappropriated waters of every natural stream for beneficial uses shall never be denied. Priority of appropriation shall give the better right, as between those using the water for the same purpose; but when the waters of any natural stream are not sufficient for the service of all those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming for any other purpose, and those using the water for agricultural purposes shall have the preference over those using the same for manufacturing purposes.

The minority report, voicing the desires and demands of the farmers, declares that the *application to the land* constitutes the appropriation and not the conveyance thereto. That is to say, it is the land and not the ditch which makes the beneficial use that completes the appropriation. The ditch or other method of conveying is but part of method or machinery required to make "use" a practicable fact. Mr. Greene's definition of "conveying" or "carrying" are thus made clear.

In the matter of "domestic use," the minority report disallows use in lawn, garden, flower beds, or other house appurtenances as "domestic," and forbids the same. An abuse of the constitutional proviso quoted, as certainly grown up by judicial interpretation, which has required the conveyance of "domestic" water in open ditches, often for long distances, thus rendering possible great loss through evaporation and seepage. This has sometimes consumed 99 per cent. of the supply, and that for the benefit only of one domestic user living at the end of such ditch.

The commissioners are Messrs. E. T. Wells (formerly a State judge), T. C. Henry (a prominent irrigator, ditch owner, and constructor), and J. S. Greene (ex-State engineer). The latter makes a minority report. The majority state, preliminary to the presentation of their measure, that—

> Upon mature consideration of the subject it has seemed to the commission that the ideas fundamental to the system heretofore in force in this State, to wit, that a right to the use of water may be acquired by the diversion and application thereof to beneficial uses that priority of appropriation ought to control; that unappropriated waters are public property subject to appropriation by all, that all persons and corporations diverting the waters of the natural streams for use wholly or in part by others, are public servants and subject to regulation, and that the rights of all persons entitled to divert water from the natural streams in each principal drainage basin may properly be ascertained and determined in one proceeding, and regulated by one controlling authority, were founded in a wise consideration of the nature of the subject-matter, and deserve perpetuation.

References are then made to the constitutional division and preferences in relation to water for "domestic" and for "manufacturing" uses. That in relation to "domestic" over "agricultural" uses is considered unwise and the commission offers a separate proposition for an amendment to the constitution abolishing the same. The act submitted proposes—

> That the area about the house within which water may be supplied to the sustaining of the trees, flowers, and shrubbery shall not exceed one-half acre. If the application of water to this purpose is to be deemed a domestic use, this limitation of area seems to be a reasonable one, and to some of the commission it appears equally reasonable that such application of water ought to be classified as a domestic use.

It also offers provisions for preventing waste and abuse of privileges. Mr. Greene considers it a "perversion of language to classify as a domestic use the irrigation of lands to any extent, or in any place whatsoever."

Article 2 treats of the acquisition of the right to the use of water. It contains nine sections and embodies the doctrine of "prior appropriation." Owners of lakes with no outlets are to have the right to draw off and appropriate such waters.

Appropriation is defined as the application of the water to any beneficial use whatever, and waste is prohibited. Change in the place of diversion may be made with the provisos that such change involve no injury to any other appropriator, and that it shall not be necessary to retain the waters in the same course to give opportunity to others to enjoy the seepage from such works.

"Abandonment" is defined as failure to apply the water to beneficial uses for three irrigation seasons consecutively; water so abandoned shall be subject to reappropriation. Certain indulgences are granted, however, such as excessive rainfall rendering further irrigation unnecessary, sickness and disability, imprisonment or other process of law whereby the appropriator is withheld from the use of his land.

Provision is made for the storage of unappropriated water for future use.

Articles 3 to 8 provide for the acquiring and conveyance of lands for water uses, the conduct of water in natural channels, the overflow, etc., of streams, the construction, maintenance, and supervision for use and safety of all works, the administration of the waters of the State, duties of State engineers and deputies, of superintendents of irrigation and water commissioners, of irrigation divisions and water districts, of regulations, judgments, appeals, and their conduct, and for defining a unit of measurement, which is as follows:

In all calculations, measurements, records, and reports the State engineer and assistant shall use the cubic foot per second of time as the unit of measurement of flowing water and either the cubic foot or the acre foot as the unit of measurement of volume. The acre foot is the quantity of standing water which will cover 1 acre of land to the depth of 1 foot, and is equivalent to 43,560 cubic feet.

Article 6 provides the more complete recording of water rights and of the quantities appropriated. The special feature of this article, apart from its careful provisions for records, is the declaration that—

"The right to the enjoyment of water * * * shall be deemed *real estate*." It is also declared that no conveyance of such right can be made unless by operation of law or conveyance in writing, etc., and that every agreement for sale, transference, etc., shall be void unless note be made expressing the consideration.

The next article provides for the "adjudication of rights and priorities of right to divert, carry, or store water." It provides also for the method in which dams may be entered and decrees obtained for appropriation of water.

Article 12 defines "Subterranean waters and artesian wells." Defined water channels and courses with flow in them found below the surface are subject to appropriation as are superficial bodies. Record is to be made with the county clerk, etc., of the sinking and character of all artesian wells, of the stratum passed, each volume of water found, and in fact of all details of importance arising during such operations. This is to be done within 90 days after the well is bored or sunk in order to complete the appropriation therefor. Every person sinking or boring an artesian well shall cause to be placed a proper casing of strength sufficient to prevent the caving in of strata of clay, sand, or other matter carrying water; not appropriated or claimed by such well proprietor, the well shall be so cased as to prevent the escape of its waters into such strata. Proper appliances shall be at or near to the surface as will readily and effectively arrest and prevent the flow of water from such well. Every person complying with these provisions and using the waters for beneficial uses, shall be deemed to have appropriated them to the extent to which the same shall be so applied within a reasonable time after the commencement of the works; such appropriation shall have effect as of the day of commencement of such work, provided the same is prosecuted with reasonable diligence—otherwise from the time of the application of the waters thereof to beneficial uses. No person controlling an artesian well shall suffer or permit the waters thereof to flow to waste except reasonably to prevent obstruction.

Mr. Greene, in this minority report, presents the following two sections in place of others in the majority report:

SECTION 1. Any person owning or controlling any tract or parcel of land shall be entitled to, at any time, apply to beneficial uses upon such land the waters of any natural lake or pond having no natural outlet, situate upon such land, the rain and snow waters falling upon such land, and any of the water theretofore lawfully used in the irrigation of any part of such land, which may have seeped, drained, or discharged into any ravine or surface channel upon such land, and any of the water percolating in or through such land and not part of the water of any natural stream or well defined subterranean channel.

SEC. 2. Whenever the State engineer shall have presented to him reasonable evidence that any person, such as mentioned in the preceding section, shall, under a claim of using the waters therein mentioned, be diverting, conveying, or storing the water of any natural stream or well-defined subterranean channel to the carriage or employment of which any other person is entitled, the State engineer shall, from the best information accessible to him, ascertain and determine what waters any such person is entitled to use and what not, and shall in writing direct the superintendent of irrigation of the proper division, and the water commissioner of the proper district accordingly, reserving, however, to every person aggrieved the right to apply for relief to the district court whereunto by this act is committed jurisdiction for settling and adjudicating the rights and priorities of the carriers and consumers of water in such water division.

The definition of the water carriage is the supreme question among several important ones involved in the preparation of and discussion of a new code. Under the majority report canal operators shall not be required to deliver up to others any of the water they devote to beneficial uses. The majority report says, in considering the provisions that it offers, that—

As the law stands at this time the duty and authority to fix the maximum rate to be charged by the carrier is devolved solely upon the county commissioners in the county in which the water is used. In many cases it is believed the commissioners have been directly interested in the question, sometimes as proprietors of the works, sometimes as consumers therefrom. Until this time also their determinations have been absolute, no appeal or other method of review of their errors being provided.

It has seemed to the commission that an attempt, whether by fundamental or ordinary legislation, to confer upon the proprietor of the works on the one hand the absolute power of determining what he shall receive, or upon the consumer on the other the absolute right to say what he shall pay for the service, is so manifestly unjust as to come within the denunciation of the fifth article of the amendments of the constitution of the United States prohibiting the deprivation of life, liberty, or property without due process of law. We have therefore suggested provisions allowing a change of the venue where any member of the board of county commissioners is in any case interested in the question of the rate to be fixed by the carrier, and for allowing an appeal to the supreme court.

* * * * * * *

One member of the commission is of the opinion that regulations which to the others seem a departure from the lines heretofore laid out, and which treat the application of water to beneficial uses as an appropriation of water, and the diversion, conveyance, or storage of water as a carriage of water, and provide that no right of appropriation or carriage of water confers upon the carrier or appropriator thereof any right of sale or lease of such water, or right to make any charge therefor, save that for the carriage of such water, may be wisely enacted, and a separate report will be presented embracing these views.

The minority report, filed by ex-State Engineer J. L. Greene, goes direct to the chief controversial points involved in the preparation of an irrigation code, not alone in Colorado but elsewhere, that aridity compels the industrial use of water by means of artificial storage, of carriage to and distribution of the same to the land to be cultivated. Mr. Greene's report is brief and is as follows, addressed to the secretary of state. He says:

Being convinced—

First. That right and justice and the spirit of the constitution imperatively demand that the sale or lease of the waters of the streams, or any traffic therein, or any charge therefor whatsoever, save the lawful charge for the carriage thereof, should be prohibited by law.

Second. That in order to an effectual judicial determination of the rights of the several persons entitled to divert, convey, store, or use the waters of the streams, and in order to a satisfactory administration of such waters by the officers of the State, the law should clearly distinguish between a right of appropriation, a right of carriage, and a right to the use of water.

Third. That water for "domestic purposes," as the phrase is used in the constitution, should not be interpreted or defined so as to include water for irrigation to any extent whatever.

Fourth. That water applied to the irrigation of land or to the operation of any mine or of any mill, smelter, manufactory, or other works, shall be made an appurtenance of the land, mine, mill, smelter, manufactory, or works to the irrigation or operation of which such water is applied.

And having presented these views without their having received favor in the eyes of a majority of the commission, it devolves upon me to present to you, for submission to the next general assembly, a report relative to the above matters, and other matters of minor importance wherein I differ with a majority of the commission. This I do in the form of a bill, in which such matters of difference are set forth in full, and those matters upon which there is no difference of opinion are set forth by reference.

The first four sections of Mr. Greene's proposed amendments have the merit of clearness and are therefore given in elucidation of this discussion:

SECTION 1. The lawful diversion, conveyance, retention, or storage of the water of natural streams or the water flowing in well-defined subterranean channels, for application to beneficial uses within the State, shall be deemed and taken to be a *carriage* of water. Any person, association, or corporation effecting such a carriage of water shall be deemed a *carrier* of water and the right to divert, convey, retain, or store such water, for application to a beneficial use within the State, shall be taken and deemed to be a *right of carriage* of water.

SEC. 2. Any person, association, or corporation effecting such a carriage of water by means of any ditch, conduit, reservoir, or other works shall, when such water is conveyed or stored in whole or in part for hire, or to be applied to a beneficial use in whole or in part by others, be deemed in relation to such water and works to be a *public carrier* of water.

SEC. 3. The lawful application to a beneficial use of any of the water diverted, conveyed, retained, or stored under any right of carriage of water shall be deemed and be taken to be an *employment* of water. Any person, association or corporation effecting such an employment of water shall be deemed a *consumer*, *employer*, or *user* of water as the words "user," "consumer," and "employer" are used in this act.

SEC. 4. The definitions given in this act of the words "carriage" and "employment" shall not be so taken or construed as to limit or affect the judicial definition of a constitutional "appropriation of water," which includes both the carriage and employment of water.

WYOMING LEGISLATION.

State Engineer Meade, of Wyoming, in his report for 1890, dated October 30, discusses the character of the laws governing the disposal of the public lands, which he declares have made the year a very unfavorable one for ditch building or the extension of the irrigated area. The law withdrawing all public lands from entry or sale was in effect until midsummer, and until repealed there was an absolute cessation in the construction of canals and the immigration of farmers. Even since its repeal the uncertainty as to the possible future action has tended to delay investment in works of considerable magnitude. The transition from Territorial to State organization has somewhat delayed the adjudication of ditch priorities. In a very important case involving the rights of 220 claimants, the United States district court suspended action until the State board of control should be duly organized. Considerable distrust has arisen over the complicated modes of adjudication required under the Territorial laws. There were in October, 1890, 5,000 unadjudicated water-right priorities. The State provisions, though novel, are, Mr. Meade says:

Regarded with favor by investors, and the resources of the State are becoming more widely known. As an evidence of increased interest I would state that more letters of inquiry about irrigation are now answered from this office in one month than were in half a year when first established.

Mr. Meade presents with vigor as a remedy for much that now hinders irrigation, the transfer to the State by the general Government of the public lands within the boundaries of Wyoming, upon the proviso that the State authorities secure their reclamation "by such methods as were best suited to the local conditions."

Engineer Meade claims that such transfer would result—

(1) In enabling the State to frame land laws adapted to its circumstances.

(2) It would insure the making of proper surveys and plans for the reclamation of the best lands.

(3) It would give over the State's land area an efficient management. The enhanced value of such lands would repay the outlay required.

(4) It would make it possible to connect water rights with land title.

The engineer says:

Under the provisions of the State constitution, approved by Congress, all the waters of our streams are declared to be the property of the State. Nothing will be of greater service in securing their economical utilization or in promoting the extension of our agricultural area than the donation to the State of the lands along the borders of these streams.

The management of the public water supply of Wyoming is placed under control of a State board* "to be composed of the State engineer and superintendents of the water divisions, which shall, under such regulations as may be prescribed by law, have the supervision of the waters of the State and of their appropriation, distribution, and diversion, and of the various officers connected therewith."

It is urged as absolutely necessary that more care be taken "in permitting appropriations and affording greater protection to those to whom made." On this point Mr. Meade states that—

If possible, titles to water should be made as definite and as completely a matter of record as deeds to land. Doing this will make the construction of irrigating works one of the safest forms of investment. To secure this it is indispensable that the past practice of permitting the unrestricted diversions of streams should cease. We have been giving away the State's most valuable property to parties who have no land on which to apply it and who have no use for it except as a speculative commodity. We have permitted diversions that are wasteful of water, expensive of supervision, and against every consideration of public welfare. We have granted appropriations for which there is no water in the streams, and the only effect of which is the robbery or annoyance of the party justly entitled to the water. All these have been errors of omission, but they throw a vexatious uncertainty around water titles and are prolific sources of discord in irrigation communities. Where the State fails to protect the property on which all propriety is based, every man becomes the enemy of his neighbor, and the result is a state of affairs more demoralizing than pestilence or famine.

The troubles so far have not been numerous, because as yet irrigation is still in its infancy as far as Wyoming is concerned.

SUMMARY OF PENDING ACT.

A water bill is now pending before the State legislature of Wyoming. As it will probably be adopted without material changes, the following synopsis is given for information:

The State of Wyoming is divided into four water divisions.

No. 1 t consist of all lands in State drained by the North Platte River and its tribut ri s, the South Platte River, Snake River (a tributary of Green River) and its tribut r es.

Water division No. 2 to consist of all lands drained by the tributaries of the Yellowstone and Missouri Rivers, north of the watershed of the North Platte River, and east of the summit of the Big Horn Mountains.

*Article VIII, Irrigation and Water Rights, Sec. 2.

Water division No. 3 to consist of all lands within this State drained by the Big Horn River and its tributaries.

Water division No. 4 shall consist of all lands drained by the Green, Bear, and Snake Rivers and the tributaries thereof, except Snake River (a tributary of Green River) and its tributaries.

The State engineer to receive a yearly salary of $2,500. * * * No person shall be appointed as such State engineer who is not known to have such theoretical knowledge and practical skill and experience as shall fit him for the position. * * * He is to perform such duties as are prescribed in the law defining the duties of the board of control, and, in addition, shall make or cause to be made measurements and calculations of the discharge of streams, from which water shall be taken for beneficial purposes, commencing such work upon those streams as are most used for irrigation or other beneficial purposes. He shall collect facts and make surveys to determine the most suitable location for constructing works for utilizing the water of the State, and to ascertain the location of the lands best suited for irrigation; examine reservoir sites, and in reports embody all the facts ascertained, including, wherever practicable, estimates of the cost of proposed irrigation works and of the improvement of reservoir sites; also become conversant with the State waterways, and its needs as to irrigation matters, and in his reports to the governor he shall make such suggestions as to the amendment of existing laws, or the enactment of new laws, as his information and experience shall suggest, and he shall keep in his office full and proper records of his work, observations, and calculations; all of which shall be the property of the State. He is authorized to employ certain assistants, and make an annual report.

Division superintendents are provided for each of the water divisions created, to be appointed by the governor, with the consent of the senate, and hold office for 4 years and to reside in the water district for which appointed. The superintendent of each water division shall have immediate direction and control of the acts of the water commissioners and of the distribution of water in his water division, and shall perform such duties as shall devolve upon him as a member of the board of control. He shall have general control over the water commissioners of the several districts within his divisions and, under the general supervision of the State engineer, execute the laws relative to the distribution of water in accordance with the rights of priority of appropriation, and perform such other functions as may be assigned to him by the State engineer. He is to be governed by the proposed act in the distribution of water.

Any person, ditch company, or ditch owner who may deem himself injured or discriminated against by any such order or regulations of such division superintendent shall have the right to appeal from the same to the State engineer by filing a copy of the order or regulation complained of and a statement of the manner in which the same injuriously affects the petitioner's interest. The State engineer shall, after due notice, hear whatever testimony may be brought forward by the petitioner, either orally or by affidavits, and, through the division superintendent, shall have power to suspend, amend, or confirm the order complained of.

All water commissioners shall make reports to the division superintendent of their divisions as often as may be deemed necessary by said superintendent. Said reports shall contain the following information: The amount of water necessary to supply all the ditches, canals, and reservoirs of that district; the amount of water actually coming into the district to supply such ditches, canals, and reservoirs; whether such supply is on the increase or decrease; what ditches, canals, and reservoirs are at that time without their proper supply; and the probability as to what the supply will be during the period before the next report will be required; and such other further information as the division superintendent of that division may suggest. Said division superintendent shall carefully file and preserve such reports, and shall from them ascertain what ditches, canals and reservoirs are and what are not receiving their proper supply of water, and if it shall appear that in any division of that district any ditch, canal, or reservoir is receiving water whose priority postdates that of the ditch, canal, or reservoir in another district, as ascertained from his register, he shall at once order such post-dated ditch, canal, or reservoir shut down and the water given to the elder ditch, canal, or reservoir, his orders being directed at all times to the enforcement of priority of appropriation, according to his tabulated statement of priorities, to the whole division, and without regard to the district within which they ditches, canals, or reservoirs may be located; the reports to be kept on file by the State Engineer; the pay to be $10 per diem when actually employed.

A board of control is constituted, to be composed of the State engineer and the four water division superintendents, to have an office with the State engineer, and hold two meetings each year for the transaction of such business as may come before it. The State engineer, as ex-officio president of said board, shall have the right to vote on all questions coming before it, and a majority of all the members of said board shall constitute a quorum to transact business.

It shall at its first meeting make proper arrangements for beginning the determination of the priorities of right to the use of the public waters of the State, which determination shall begin on the streams most used for irrigation, and be continued as rapidly as practicable until all the claims for appropriation now on record shall have been adjudicated. The method of determining the priority and amounts of appropriations to be as follows: The board of control shall decide at their first meeting the streams to be first adjudicated, and shall fix a time for beginning the taking of testimony, and the making of such an examination as will enable them to determine the rights of the various claimants.

Said board shall prepare a notice, setting forth the date when the engineer will begin a measurement of the stream, and the ditches diverting water therefrom, and a place, and a day certain when the superintendent of the water division in which the stream to be adjudicated is situated shall begin the taking of testimony as to the rights of the parties claiming water therefrom. Said notice shall be published in two issues of a newspaper having general circulation in the county in which such stream is situated, the publication of said notice to be at least 30 days prior to the beginning of taking testimony by said division superintendent, or for the measurement of the stream by the State engineer or his assistant, and the superintendent taking such testimony shall have the power to adjourn the taking of evidence from time to time, and from place to place; provided, all places appointed and adjourned to by the superintendent shall be so situated, as related to the stream, as shall best suit the proper convenience of the persons interested in the determination of such priorities and appropriations. It shall also be the duty of said division superintendent to mail to each party having a recorded claim to the waters of said stream, by registered mail, a similar notice, setting forth the date when the State engineer, or his assistant, will begin the examination of the stream, and ditches diverting water therefrom, and also the date when the superintendent will begin the taking of testimony and the date when the taking of such testimony by said division superintendent shall close, and he shall in addition inclose with said notice a blank form on which said claimant shall present, in writing, all the particulars, showing the amounts and dates of appropriations to the use of water of said stream to which he lays claim; the said statement to include the following:

The name and post-office address of the claimant.

The nature of the use on which the claim for an appropriation is based.

The time of the commencement of such use, and if distributing works are required.

The date of beginning of the survey.

The date of beginning of construction.

The date when completed.

The date of the beginning and completion of enlargements.

The dimensions of the ditch as originally constructed, and as enlarged.

The date when water was first used for irrigation or other beneficial purposes, and if used for irrigation, the amount of land reclaimed the first year, the amount in subsequent years, with the dates of reclamation, and the amount of land such ditch is capable of irrigating.

The character of soil and the kind of crops cultivated, and such other facts as will show a compliance with the law in acquiring the appropriation, and the rank of priority claimed.

Each claimant is to certify his statements under oath.

Upon the date named in the preceding notice the division superintendent is to begin taking testimony, and continue until it shall be completed. If the division superintendent of any water district is directly or indirectly interested, the taking of evidence, in so far as relates to said stream, shall be under the direction of the division superintendent of the next nearest water division, or under the direct personal supervision of the State engineer, as may be deemed most expedient.

Upon the completion of the taking of evidence by the division superintendent, it shall be his duty to at once give notice in one issue of some newspaper of general circulation in the county where such determination is, and by registered mail, to the various claimants, that upon a certain day and a place named in the notice, all of said evidence shall be open to the inspection of the various claimants, and said superintendent shall keep said evidence open to inspection at said place not less than 1 day and not more than 5 days.

Should any person, corporation, or association of persons owning any irrigation works, or claiming any interest in the stream or streams involved in the adjudication, desire to contest any of the rights of the persons, corporations, or associations who have submitted their evidence to the superintendent, such persons, corporations, or associations shall, in writing, notify such party, corporation, or association to appear before the water superintendent at the place where the said superintendent has been taking evidence in said adjudication, fixing the time both as to the day and the hour, which said date shall not be less than 10 nor more than 15 days from the date the notice is served on the party, association, or corporation. The party giving the notice shall, at the same time, notify the water superintendent of the time fixed for such contest. Before the superintendent shall proceed to take the evidence in the disputed rights, an affidavit shall be filed showing that service herein required has been made upon the party or parties whose rights are to be disputed.

The evidence of such proceedings shall be confined to the subjects enumerated in this act for the establishment of rights to water.

A deposit of $10 per day to be required from a party to contest, while evidence is being taken. This amount to the board of control fund.

It shall be the duty of the State engineer, or some qualified assistant, to then proceed to make an examination of stream and the works diverting water therefrom, including the measurement of discharge and of the carrying capacity of ditches and canals diverting water therefrom; an examination of irrigated lands, and an approximate measurement of the lands irrigated or susceptible of irrigation from the various ditches and canals. These are to be made a matter of record. Then a map or plat on a scale of not less than 1 inch to the mile, showing with substantial accuracy all the facts, is to made, etc.

At the first regular meeting of the board of control, after the completion of such measurements, it shall be the duty of the board to make and enter of record an order determining and establishing the several priorities of right to the use of waters of said stream, and the amounts of appropriations of the several persons claiming water from such stream, and the character and kind of use for which said appropriation shall be found to have been made.

Each appropriation shall be determined, in priority and amount, by the time by which it shall have been made, and the amount of water which shall have been applied for beneficial purposes; provided that such appropriator shall at no time be entitled to the use of more water than he can make a beneficial application of to the lands for the benefit of which the appropriation may have been secured, and the amount of any appropriation made by reason of an enlargement of distributing works shall be determined in like manner; provided that no allotment shall exceed one cubic foot per second for each seventy acres of land for which said appropriation shall be made.

Within ten days thereafter after the determination the State engineer shall issue to each person, association, or corporation represented, a certificate, to be signed by said State engineer and attested under seal by the secretary of board, setting forth name and post-office address of the appropriator, the priority number of such appropriation the amount of water appropriated, and the amount of prior appropriations; and if such appropriation be for irrigation, a description of the legal subdivisions of the land to which said water is to be applied.

Said certificate shall be transmitted by the said State engineer, or by a member of the board of control, by registered mail, to the county clerk of the county in which said appropriation shall have been made, and it shall be the duty of said county clerk, within 10 days after the receipt of said certificate, to record the same in a book specially prepared and kept for that purpose, and to notify the party or parties in whose favor the said certificate is issued of such record, and to transmit the said certificate to said party or parties on payment of the fee for recording, which said fee shall not exceed 75 cents for each certificate so recorded.

Any party or number of parties acting jointly, who may feel themselves aggrieved, may appeal from the board of control to the district court of the judicial district within which the appropriation or appropriations of the party or parties so aggrieved may be situated.

They shall within 60 days file, in the district court to which the appeal is taken, a notice in writing stating that such party or parties appeal to such district court from the determination and order of the board of control, and upon the filing of such notice the appeal shall be deemed to have been taken; provided, however, that they are required to enter into an approved undertaking to meet all costs and damages.

Every person, association, or corporation hereafter intending to appropriate any of the public waters shall, before commencing the construction, enlargement, or extension of any distributing works, or performing any work in connection with said appropriation, make an application to the president of the board of control for a permit to make such appropriation. The application shall set forth the name and post-office address of applicant, the source from which said appropriation shall be made, the amount thereof as near as may be, the location and character of any proposed works in connection therewith, and the time required for their completion, said time to embrace the period required for construction of ditches thereon and the time at which the application of water for beneficial purposes shall be made, which said time shall be limited to that required for the completion of work when prosecuted with due diligence, the purpose to which water is supplied, and, if for irrigation, a description of the lands to be irrigated thereby, and any additional facts which may be required by the board of control. On receipt of this application, which shall be of a form precribed by the board of control, and to be furnished without cost to the applicant, it shall be the duty of the State engineer to make a record, cause the same to be recorded in his office, and to make a careful examination in order to ascertain whether it sets forth all the facts necessary to enable the board to determine the nature and the amount of the proposed appropriation. If found in any way defective it shall be returned to the applicant for correction. If there is unappropriated water in the source of supply named, and if such appropriation is not otherwise detrimental to the public welfare, the State engineer shall approve the same by indorsement thereon, which shall be of record in his office, and return the same so indorsed. On receipt thereof the applicant shall be authorized to proceed with such work and to take such measures as may be necessary to perfect such appropriation. If there is no unappropriated water in the source of supply, or such appropriation is detrimental to public interests, the State engineer shall refuse such appropriation, and the party making such application shall not prosecute such work so long as such refusal shall continue in force. He may indorse it approved for a less amount of water than the amount stated in the application and for a less period of time than that named for perfecting the proposed appropriation. An applicant, feeling himself aggrieved by any indorsement, may in writing, in an informal manner, and without pleadings of any character, appeal to the board of control, and if he shall deem himself aggrieved by the order made by the board of control with reference to his application he may take an appeal therefrom to the district court of the county in which he shall be situated, the point upon the proposed source of supply at which the diversion of the proposed appropriation is to be made. Such appeal shall be heard and determined upon such competent proofs as shall be adduced by the applicant, and such like proofs as shall be adduced by the board of control or some person duly authorized in its behalf.

Upon the approval and allowance of an application the applicant shall send to the engineer's office, within 6 months thereafter, a map or plat, upon a scale of not less than 2 inches to the mile, showing the location and amount of the distributing works, the source from which the appropriation is taken, and the legal subdivisions of the land upon which the water to be appropriated is to be applied, which said map or plat shall be filed and preserved in said office.

Upon it being made to appear to the satisfaction of the board of control that any appropriation has been perfected in accordance with law it shall be the duty of the board of control, by the hand of its president, attested under the seal of the secretary, to send to the county clerk a certificate to that effect, which shall be recorded in the county clerk's office.

The priority of such appropriations shall date from the filing of the application in the engineer's office.

A cubic foot of water per second of time shall be the legal standard for the measurement of water in this State both for the purpose of determining the flow of water in the natural streams and for the purpose of distributing water therefrom.

The board of control shall divide the State into water districts, said water districts to be so constituted as to secure the best protection to the claimants for water and the most economical supervision on the part of the State; said water districts shall not be created until a necessity therefor shall arise, but shall be created from time to time as the appropriations and priorities thereof, from the streams of the State, shall be adjudicated.

For each water district created under this act there shall be appointed one commissioner, to be a resident of the district in which he is to serve, and appointed by the governor from persons recommended by the water division superintendent, each commissioner to hold office 2 years and until a successor is appointed and qualified. The governor shall by like selection and appointment fill all the vacancies which may occur in the office, and may at any time remove any commissioner for failure to perform his duties upon complaint to him in that respect being made to him in writing.

It shall be the duty of said commissioner to divide the water in the natural stream or streams of his district among the several ditches taking water therefrom according to the prior rights of each respectively in whole or in part, and to shut and fasten, or cause to be shut or fastened, under the direction of the superintendent of his water division, the head gates of ditches heading in any of the natural streams of the district when, in times of scarcity of water, it is necessary so to do, by reason of the priority of rights of others taking water from the same stream or its tributaries. Every person who shall willfully open, close, change, or interfere with any head gate or water box without authority shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be fined a sum not exceeding $100, or to be imprisoned in the county jail for a term not to exceed 6 months, or by both such fine and imprisonment. The water commissioners, or their assistants, shall have power to arrest any person or persons offending and turn them over to the proper county sheriff, and upon delivering any such person so arrested it shall be his duty to immediately, in writing and upon oath, make complaint before the proper justice of the peace against the person so arrested.

Water commissioners herein provided for shall each be entitled to pay at the rate of $5 per day, for each day he shall be actively employ ed in the duties of his office to be paid by the county in which the work is performed.

Said water commissioner shall have power in case of emergency, to employ suitable assistants. They shall each be entitled to $4 per day for every day employed, not to exceed thirty-five days in one year, to be paid upon certificates of the division superintendent in the same manner as provided for the payment of the water commissioners.

The commissioners shall not begin work until they have been called upon by two or more owners or managers of ditches, or persons controlling ditches in the several districts, by application in writing stating that there is a necessity for the use of water, and they shall not continue performing services after the necessity therefor shall cease.

The appropriator of any of the public waters of the State shall maintain, to the satisfaction of the division superintendent of the district in which such appropriation is made, a substantial head gate at the point where the water is diverted, which shall be of such construction that it can be locked and kept closed by the water commissioner; and such appropriator shall construct and maintain, when required by the division superintendent, a flume or measuring device, as near the head of such ditch as is practicable, for the purposes of assisting the water commissioner in determining the amount of water that may be diverted into said ditch from the stream. If any owner or appropriator of the public waters that have been adjudicated upon should neglect or refuse to put in such head gate, or measuring device, after thirty days' notice the division superintendent may notify the county commissioners of the ounty where such head gate, flume or measuring device is situated, and it shall be the duty of the county commissioners to put in such head gate, flume or measuring device, at the expense of the county, and present a bill of costs to the owner or owners of the ditch, and if such owner or owners shall refuse or neglect, after three days after the presentation of such bill of costs, to pay the same, the said costs shall be made a charge upon said ditch and shall be collected as delinquent taxes and be subject to the same conditions and penalties, and until the full and complete payment of such bill of costs it shall be the duty of the water commissioner in which such ditch is situated to close and keep closed the head gate of such ditch, and to take such needful steps as will prevent any water from being diverted therein from the source of supply.

The State courts are required to proceed with all pending cases.

Any person, corporation, or association, intending to construct any dam for reservoir purposes, or across the channel of any running stream above 5 feet in height shall, before beginning the construction, submit plans to the State Engineer for examination and approval, and no dam above 5 feet in height shall be constructed until the same shall have been so approved.

Upon any appeal being taken from the board of control to the State district court the court shall advance such appeal to the head of its trial docket and give it precedence over all pending civil causes. If an appeal be taken from the district court, the supreme court shall also advance such appeal to the head of its docket for the trial of civil causes and give it in like manner precedence to trial.

IRRIGATION DISTRICTS IN CALIFORNIA.

Among the more important developments of irrigation organization is that now under rapid headway in California. Growing out of the conflict between the legal principles of "riparian rights" and "prior appropriation," the system known as the "Wright laws," from the name of their author, Mr. C. C. Wright, of Modesto, Stanislaus County, offers as the basis of final settlement the creation of a municipal organization by the votes of all citizens within its lines, which shall thereafter become the owner of water and works, and the conservor, director, and distributor of water needed for and used in the cultivation of the soil by means of irrigation. The district under this system has the power to issue bonds for the construction of new works and the purchase of old ones within its lines, to contract for the purchase of water, as is the case with the Alessandro district in San Bernardino County, which will buy its water from the Bear Valley Reser voir Company. The power to lay taxes for water rights and works as well as to regulate rates, etc., is also included.

The first of these laws was passed by the State legislature at the session of 1886-'87, and in July, 1887, the Turlock district was organized. Within the central portion of the San Joaquin Valley, there are four irrigation districts embracing 720,000 acres, with an average bonded debt of $5 per acre, or in all $3,600,000. Taking out the proportions borne by towns and villages embraced for their water supply, and the farm indebtedness will not exceed $4.20 per farm acre, without the annual interest; a sum so moderate as not to impede the borrowing ability of individual farmers within the bonded area. This is the judgment at least of those who speak for the mortgage and money-loaning interests of California. The legal questions, as elsewhere shown, are all favorable for the districts. It is beyond question that this system has put an end to the litigious aspects of irrigation in California. This alone warrants all the process may cost.

The district system provides plainly, then, for these things:

(1) The transfer from individuals or companies of all water rights, whether pueblo or communal, servitudes, prior appropriation, or riparian in character, to the municipal body politic that has been created.

(2) The public construction or purchase, and consequent ownership, of all works necessary for the economic conservation, distribution, and use of water in agriculture and horticulture.

(3) The district or public control of works, their maintenance, and of the rates to be levied for the service of water.

(4) For a growing unity of supply, a more economic use of water, and a diminishing rate of cost therefor.

There will be some waste and loss in the beginning of such a system. That is almost unavoidable. It will cost more to inaugurate now than it will a few years later. Other States will profit largely from the experiences of California. The chief resistance has been so far due to the large land and water owners, who naturally want to hang on to their possibilities of profit as long as may be. But these are all being overcome. The cost of this system may be realized by the following hypothetical case: The laws provide 6 per cent. on the bonds and 20 years for their repayment, with a call on the issues after 10 years. Suppose, then, 100,000 acres are bonded at $10 per acre, or $1,000,000 in all. At the end of 10 years $600,000 will have been paid as interest. If the bonds are then called in at the rate of $100,000 per year the entire debt will have been wiped out at a cost of interest of $930,000, or with the total of obligation and repayment—a full payment—of $1,930,000. This will be a tax or cost per acre of $19.30. The average annual water rental paid to private companies will not be less than $2 per acre, or $40 on a capitalization of 20 years. In addition, every land owner buying since water was brought to their land has paid an average royalty or bonus for the privilege of obtaining water of at least $10 per acre. Under the district system no such bonus will be required. The debt obligation in some senses may be considered as taking its place; but all that is compensated for by the fact that the water belongs absolutely and in perpetuity to the land, and the price paid includes all the works also. The average cost of maintenance and service will at once, under the district system, be largely reduced. In most cases it will at once be placed at one-half, as there are no dividends to make, and in a few years the average annual cost will hardly be more than one-fourth of present rates, or, say 50 cents per acre, where now $2 is paid.

But the advantage is to be most clearly seen in the rapid growth of reclamation and increase in land values. For example, in any 100,000 acres embraced by an irrigation district in California probably less than one-fifth will be under cultivation by irrigation. The selling price of this area, if used for family crops only, will be about $40 per acre. If used for deciduous fruit and vegetables, it will reach an average of $100 per ac e. If for special crops, like wine grapes, prunes, etc., the value will be at least $100 per acre. If for raising grapes and citrus fruits, it will certainly reach $250, and probably more, per acre. Each acre of the 80,000 that is reclaimed will add largely to the selling value of every acre embraced in the 20,000 first cultivated, and a rapid doubling of values will be sure to follow, and that, too, within a comparatively short period.

The following table presents all the facts that this office has been able to obtain and reasonably verify:

County	Name of district.	No. of acres.	Bonds voted.	Bonds sold.	Bonds per acre.
Colusa	Orland Southside	2,500	$100,000	...	$4.0
	Central	156,550	750,000	$286,000	4.78
	Kraft	13,500	80,000	...	5.93
	Colusa	100,000	600,000	...	6.00
Fresno	Madara	305,000	850,000	...	2.78
Fresno and Tulare	Alta	129,927	675,000	410,000	5.19
	Selma	217,000	...	...	...
Kern	Poso	40,000	500,000	250,000	12.[illegible]
Kern and Tulare	Kern and Tulare	66,240	700,000	...	10.56
Los Angeles	Palmdale	50,000	175,000	...	3.50
	Orange Belt	4,500	200,000	...	44.44
	Big Rock Creek	30,400	400,000	50,000	13.10
	Vineland	4,500	50,000	50,000	11.11
Orange	Anaheim	32,500	600,000	...	18.46
San Bernardino	Grapeland	10,787	200,000	...	18.54
	Rialto	7,200	500,000	500,000	69.44
	Citrus Belt	12,160	800,000	800,000	65.78
	Alessandro	25,340	760,000	760,000	30.00
	East Riverside	3,000	250,000	...	83.33
San Diego	Perris	17,680	442,000	252,000	25.00
	Escondido	12,814	450,000	...	35.12
	Elsinore	11,300	...	...	...
	Murietta	15,600	...	...	...
	Spring Valley	22,000	...	...	...
Stanislaus	Modesto	81,500	800,000	117,000	9.81
Stanislaus and Merced	Turlock	176,346	600,000	320,000	3.40
Tulare	Tulare	34,149	500,000	100,000	14.64
Yuba	Brown's Valley	43,000	110,000	80,000	2.56
	Total	1,623,493	11,092,000	3,975,000	...

The average amount of bonds in the State amount to $8.02 per acre within the areas embraced. In the Sacramento Valley it is $4.85 per acre. In the San Joaquin Valley the average is $5.55. In the four southern California counties, outside the antelope district, (one of new settlement and cheap lands), the average per acre is $32.58. The average of the antelope valley district is $7.02 per acre. A careful estimate of the irrigation districts, made by Mr. L. M. Holt, of Redlands, San Bernardino County, California, gives the following as their assessed valuation made on the basis of values before irrigation works are constructed:

Three Sacramento Valley districts	$10,141,500
Eight San Joaquin Valley districts	21,003,240
Fifteen Southern California districts	14,935,575
Total	46,080,315

In addition to those that are named, reports without details have been received of the "West-side," located in Tulare County; the "Mokelumne," in Butte County, to embrace the fruit colonies of Thermalita and Palermo, etc., and the San Jacinto, San Diego County, with

25,000 acres, are in process of organization. The Selma, in Fresno County, has been organized, except as to authorizing the issue of bonds, the vote on which was in the negative. The area embraced is reported at 300,000 acres. This set-back is a case of small land owners refusing to burthen themselves with improvements, the largest benefits from which must accrue to a few extensive land owners, who have failed to enter into the small land-holding policy that has been so successful in that section. There was another district proposed, to embrace 600,000 acres, and include the city of Fresno and its contiguous colony farm lands. These people deemed it an unwise venture, and the district was not organized. It is now proposed to form several smaller districts. Some day the major portion of Fresno County will be under one district management. The districts in which the heaviest cost will have to be borne will be seen at a glance to be those in which the citrus culture has so greatly increased the value of land. But the value of the crop is only the incentive to outlay, because the cost is found in the special character of the water supply, or rather of the localities in which it is found. Take San Bernardino County, for example, and a great portion of its waters are obtained from bowlder beds, by tunnels into the foothills, by damming up its numerous cañons, by a costly well system, and by the plan of piping which delivers the life-giving fluid to the roots of tree and plant. The relations of soil and sunshine, so favorable to luxuriant crops, compelled the obtainance of water at any cost. In other portions of the citrus-growing areas—as, for example, in San Diego and on the warm foothills of Kern, Tulare, and Fresno at least—the problems of irrigation will be solved at very much less cost than has been the case in San Bernardino and Los Angeles Counties.

In the early work of organization, the Turlock, Alta, Modesto, and Madera districts had the advantage of considerable preceding work. They all had somewhat extensive systems of canals, owned largely by farmer companies, and available for improvement, on scale of unification with source supply and duty which necessarily becomes the primary conditions of such public enterprises. The four districts named had, when organized, a main ditch of about 125 miles in length. This has already been largely increased, and it will, when completed, be nearer 400 miles in length. Elsinore, San Diego County, is constructing 40 miles of canals. The Mokelumne work will have a length of about 60 miles. Those it bought in have cost $250,000. The Colusa County districts are laid out on a large scale. The lands thereof are largely devoted to wheat raising, a product which the statistician of the department* clearly shows to be a rather unprofitable product, even in California.

LAND VALUES CREATED BY IRRIGATION.

One of the most interesting questions is that of land values as produced by irrigation. The nature of the products raised under this system of farming and the intensive culture which it generally demands have much to do, of course, with the large increase in the commercial value of land cultivated by this system as compared with contiguous areas and acres not "under ditch." The value of irrigation can well be tested by the evidences of profit. An examination of the evidence given by the witnesses before the United States Senate Special Committee on Irrigation and Reclamation of Arid Lands † will show that in

*Monthly report for December, 1890.
† Senate Report No. 928, Fifty-first Congress, first session.

no case were the estimates of increased land values, as arising from the artificial application of water to the soil, less than $2 to $5 per acre over similar and adjacent land not "under ditch." Indeed the estimates generally run from $15 increase up to $250 per acre, and even more, for land not actually cultivated, but in a position to be made at once available by reason of its convenient access to water. These larger prices are, of course, the scale only of the semitropical or other exceptional areas, wherein fruits and special products of high marketable value are most readily produced.

But it will be found during the development of irrigation and the cultivation of the soil thereby that the area of special products, in its relation to the whole arid region, will enlarge almost continuously until the two become synonymous in character.

ARIZONA AND CALIFORNIA.

In Arizona land as a general rule has no value for farming unless irrigated. In Maricopa County, where irrigation is largely practiced, farm areas are worth from $10 to $50 per acre; fruit lands from $75 to $150 per acre. Pima County lands have about the same average value for farm purposes, but owing to its more limited irrigation system, fruit lands are only worth from $50 to $100. Pinal County is about the same average value as Pima, and for the same reason. Throughout the remaining counties of Apache, Cochise, Graham, Mohave, Yavapai, and Yuma the values range for farms from about $3 to $15 per acre and for fruit lands $35 to $75.

In California the small farm, fruit culture, and their necessary intensiveness of culture have added greatly to the value of all arable land. Throughout the State unirrigated land commands from $5 to $50 per acre; and there have been many sales in excess of the larger figure. In Los Angeles County, at the mouth of the Cahuenga Pass, unimproved land with a water-right has sold at $450 per acre; ordinary vine land, unirrigated, is worth $40, and farm land $10 to $30 per acre. Irrigation increases the values to $150 and $800 per acre.

In San Bernardino and Los Angeles Counties the factors of values are far above the average and the prices generally equal thereto. In San Bernardino 8,300 acres with water right (uncultivated) were recently sold for $556,000, or a small fraction over $67 per acre; at Redlands 5 acres (cultivated) sold for $7,500, or an average of $1,500 per acre. In San Diego County farm lands are worth $20 to $100 per acre, while land for orchard and vineyard sells at $250 to $500 per acre. In Fresno grain land sells at from $20 to $50 per acre, and $100 to $800 per acre is paid for fruit land. In Butte County, northern California, $650 per acre is the highest price yet paid for orchard land. The average will be about $400 per acre. Kern County lands run from $5 to $20 per acre for nonirrigated land. For farming purposes water increases this value to $25 and $40, and for horticulture to $60 and $100. Merced holds about the same average for non-irrigated and as high as $75 for irrigated farms, and $150 for fruit culture. Modoc lands are worth, with irrigation, about $40 for farming.

COLORADO AND KANSAS.

In the counties of Arapahoe and Weld (Colorado) near Denver, Greeley, and Grenada, non-irrigated land ranges from $2 to $30. Irrigation adds value thereto up to about $100, and irrigated land under fruit is worth from $200 to $500 per acre. There is a permanent increase in value for small farms and irrigation of from $50 to $400 per acre over all rain-belt localities, so called. In western Kansas careful inquiries made by Special Agent J. W. Gregory show that the increase in value of farm lands, by the creation of a water supply, average from 50 to 250 per cent. Non-irrigated land, within the semi-arid section of the State and in 28 different counties, is quoted as selling at from $1.25 to $37 per acre. With water, so as to increase security for farming operations, the same quality of land is quoted at from $8 to $275 per acre, the average range being from $20 to $50 per acre.

MONTANA AND TEXAS.

In Montana the ruling rate will be for non-irrigated land, $1.25 to $10; for irrigated, from $25 to $75 per acre. In the Gallatin Valley and some other areas favorably located, the average price will range from $100 to $200 per acre. In Idaho the ruling rate will be about the same as in Montana, and in the neighborhood of Boisé City and some other favored points the values will range about as in the Gallatin Valley. In eastern Oregon the small area of irrigated land increases in value at the rate of 300 to 500 per cent. In Washington the average price of land, with water, wfll range from $50 to $150 per acre. Non-irrigated land, according to its accessibility to sub-irrigation or irrigation from the phreatic flow, will range from $3 to $50 per acre.

In Texas, 52 counties included within the area west of the 97th degree show a range of selling prices for land as follows: Non-irrigated, from $1.50 to $50; with water, $20 to $500 per acre. In Bosqui County, in the central part of Texas, non-irrigated land sells from $3 to $20 per acre, while the application of water increases the value to from $40 upward. In De Witt County, in the southern part of the State, near Yorktown, $10 to $25 is the ruling price for non-irrigated land, which is doubled by the application of water. The average value of unirrigated land fit for farming throughout the western part of the State, without water, is about $8; under irrigation the selling price is about $75. The $500 price per acre is purely speculative; the average range where irrigation is practiced being from $25 to $75, or about $50 per acre. This will stand alike for the Rio Grande and the Rio Pecos Valleys.

WHAT FRESNO COUNTY SHOWS.

In further illustration of this matter of land values and of the tendency which irrigation is rapidly producing, a couple of small tables showing the total areas and subdivisions, with the yields thereof, in the raisin-growing districts of Fresno County, California, will be of value. The first one gives the number of holdings of from 2 to 100 acres, and also states the number held in areas above the last group. The second table gives the returns per acre from a number of holdings. It will be observed the best returns are from the smaller holdings.

Number of holdings.	Aggregate acreage.	Average acreage per holding.	Remarks.
473	4,087	8.64	From 2 to 10 acres.
570	9,068	15.90	More than 10 and not more than 20 acres.
207	5,552	26.82	More than 20 and not more than 30 acres.
156	5,755	36.90	More than 30 and not more than 40 acres.
43	2,072	48.18	More than 40 and not more than 50 acres.
44	2,571	58.43	More than 50 and not more than 60 acres.
22	1,429	64.95	More than 60 and not more than 70 acres.
55	4,279	77.8	More than 70 and not more than 80 acres.
6	510	85	More than 80 and not more than 90 acres.
10	985	98.5	More than 90 and not more than 100 acres.

In addition to the 1,586 holdings given above there are 77 embracing from 107 acres up to 800 acres, making a total in these larger holdings of 15,407 acres, or an average of over 200 acres each. The total area in the smaller holdings reaches 49,325 acres, and gives an average holding of a little over 31 acres each. The following brief table illustrates the yield of some of these holdings:

Total acreage.	In vines.	In fruit.	Yield of raisins.	Per acre in grapes.	Per acre in fruit.	Total value of yield.	Number of acres.	Yield per acre.
	Acres.	*Acres.*	*Tons.*	*Tons.*				
8	8	....	....	137	....	$1,100	8	$137.50
14	9	3	....	244	$133.33⅓	2,609	14	185.90
20	12	2½	16	133	228	2,167	14½	155.00
20	20	....	20	....	150	3,000	20	150:00
20	7	2	18	259	50	1,963	9	218.00
20	15	3	....	247	60	3,705	18	205.89
30	....	30	....	....	83.33⅓	2,500	30	83.33
40	11	20	14	127	93.75	3,197	31	103.12
40	30	....	45	145	....	5,400	30	184.00
40	15	11	33	151	100	4,430	21	163.33
80	70	....	70	....	100	7,000	70	100.00
80	20	1	12	60	150	1,350	21	65.00
118	118	....	113	118	....	13,962	118	118.37

The difference in yield is of course due wholly to the various stages of growth in vine and tree.

RESULTS IN FRUIT GROWING, SOUTHERN CALIFORNIA.

Statements could easily be presented showing much larger values and returns also than the foregoing statements indicate, but they are sufficiently moderate to be taken as a reliable basis for calculating the returns from nearly all fruit land in California except that devoted to citrus culture. The average net returns per acre of wine and raisin grapes, prunes, and deciduous fruits generally when they are in a matured state will range from $80 to $200 per acre. The average net returns for matured orange and lemon orchards will not be less than $350 when all conditions are fair. This is illustrated by the statements made in San Bernardino County, California, as to the value of orange orchard land. The testimony of fifteen residents there, for example, sets the ordinary value of such land at $300 to $1,500 per acre. These witnesses embrace viticulturists, merchants, real estate operators, a banker, and an editor. The majority of them placed the selling value of such orchards at from $800 to $1,000 per acre.

These estimates refer of course to the more improved areas of that section, but it is safe to estimate citrus lands with water and a growing orchard fairly located as selling at about $400 per acre. Land which is not yet under water has recently sold at from $60 to $90 per acre, because it is adapted to fruit culture and will be served at no distant day with an abundant water supply. This rise in value is not confined to southern California alone, though its effect is seen there in the most marked manner. It extends throughout the State. It prevails also in eastern Washington at Walla Walla and the region round about, at Boisé City, Idaho, and in the Bitter Root Valley, Montana, where railroad facilities have already, to a limited extent at least, opened for these valuable fruit-growing centers an opportunity to reach a market. Colorado horticulturists also, with those of New Mexico, are alive to the importance and commercial value of their products and of the increased value that is given through irrigation and intensive culture to their land. The difference everywhere is at least as $10 to $1 in favor of the special product, the secure culture, and the small farm which irrigation brings over that of ordinary farming even with the aid of water and within the arid region.

The rapid increase under such incentives of irrigation enterprise is easily illustrated. Of course the most favorable examples must be taken from southern California. On the authority of L. M. Holt, of Redlands, the following table of water systems, under date of December, 1890, is given for that county of California:

Acres under ditch.

Water systems.	1880.	1890.
Riverside	5,000	10,000
Gage Canal	....	15,000
South Riverside	....	6,000
Pomona	1,000	12,000
Ontario	....	5,000
Etiwanda	....	3,200
Cucamonga	2,000	10,000
Lytle Creek	500	15,000
North Fork Ditch	1,000	4,000
South Fork Ditch	1,000	4,000
Mill Creek	3,000	5,000
North Riverside Canal	....	10,000
Vivienda Pipe Line	....	5,000
Rincon Ditch	3,000	4,000
Chino Pipe Line	....	2,500
City Creek	....	500
Twin Creeks	500	3,000
Banning	....	4,800
Colton Terrace	....	1,500
Bear Valley Reservoir	....	18,000
Glen Ellen	500	2,000
Meeks and Daly Ditch	500	4,250
Total	18,000	144,750

Works now under construction will easily and early double the area. The enormous growth of values as fostered by irrigation is further illustrated by the following figures, those for 1880 being taken from the published report of the State board of equalization for 1880 and those for 1890 being furnished in advance to this office by the courtesy of Mr. E. W. Maslin, secretary of the State board. They are to be considered as only one-half of the commercial value.

Valuations of fruit raising counties in southern California.

Counties.	Real estate.		Improvements.	
	1880.	1890.	1880.	1890.
Los Angeles*	$10,477,432	$45,454,995	$3,033,059	$14,453,300
Orange	....	5,495,015	....	1,468,337
San Bernardino	1,669,007	12,990,005	586,577	4,198,550
San Diego	1,307,302	20,000,085	341,948	4,450,286
Total	13,453,841	83,940,100	3,961,584	24,560,473

*Los Angeles in 1880 included Orange County.

A cloud of witnesses as to the causes of this great prosperity may be cited, but one will do. Charles Nordhoff, journalist and author, says:

With water applied to the soil, what wonders, what miracles, have been wrought in southern California in a few years! I saw Riverside in the spring of 1872, when it was so dreary and desolate a spot that to my eyes, and to those of many others, it seemed a hopeless desert waste. We all know what Riverside is now. * * * Water judiciously applied produced that magnificent result, and in 10 years made a lovely and rich garden spot out of what was originally a barren and most unpromising waste.

I drove the length and breadth of the Fresno country in 1872, when even the cattlemen thought it too arid and desert for their cows; now it is one of the justly famous garden spots, rich with every product, from grain to raisin and other valuable fruits. The settlement * * * was largely by colonies.

The colony plan, as it was called, was laughed at for a while in California. I have watched the development of several of the most noted experiments with careful interest, and I do not know of one in which the members held together for even 8 or 10 years without every man becoming comfortably independent.*

IRRIGATION WORKS—CONSTRUCTING AND PROJECTED.

The statistics of irrigation works are necessarily imperfect. As to mere ditch-making it would be impossible to obtain data without the active coöperation of local authority. In Colorado alone it is estimated that several thousand miles of farm ditches are never reported to the county clerk and State engineer's office. In California, except as to the assessors' return, no effort has ever been made to ascertain the extent of small, private irrigation works. The larger operations, being generally conducted by corporations, are better known. Considerable activity has been displayed for the past year and a half. Many extensions are in progress. New canals and other works are under way. Some of the larger ones will be indicated. The chief work, measured by area, to be reclaimed, is that of the Bear Valley Reservoir, in San Bernardino County, California. Its dams, pipe lines, and tunnels are pieces of bold engineering. A brief sketch will be in order.

THE BEAR VALLEY RESERVOIR.

In 1880 it was believed that the interior valleys of southern California would forever remain sterile, as there was not sufficient water to irrigate properly even a limited arable area. Among the many schemes of reclamation put under way the Bear Valley Reservoir is the most important. This plan was first projected in 1883, and after examining the valley, which had for outlet a narrow rock-bound gorge, it was determined that the building of a dam for reservoir purposes was entirely practicable. At the time of examination there was no water running in the cañon or its stream bed. Taking the high-water mark of the valley, however, as a guide, it was believed that the reservoir would fill, and construction work was decided upon, notwithstanding the hostile general opinion to the contrary. A company was then organized and 3,300 acres of land were purchased for the site. Gates were built and observations taken during winter of 1883–'84 of the precipitation, which was shown to be 93 inches over the watershed or drainage basin from which the reservoir was to fill. The fall in valleys below is barely one-seventh of this fall.

The fact was thus demonstrated that were a dam built of proper height, 360,000 acre-feet of water could be stored, a supply sufficient to irrigate 360,000 acres of land, on a basis of 1 inch to 8 acres, or enough to irrigate for 10 years every acre then cultivated in San Bernardino. Surveys further demonstrated that it was practicable to build a large canal from the Santa Ana River along the north side of the main stream, and cut through the mountains by means of a short tunnel, emptying the Santa Anta into the reservoir and thereby greatly increasing its tributary area. Another source of supply is from the Whitewater

* Peninsular California, 1888, pp. 66–68. N. Y., 1888.

River, which comes down from the southern and eastern slope of Grayback and San Bernardino Mountains, by a canal around the eastern base of Mount Grayback, picking up all the mountain streams on that side of the range.

In 1884 the first dam was completed in the face of great difficulty and the reservoir permitted to fill gradually, until in the month of April, 1886, the water began to run through the waste weir. Since that time the reservoir has been constantly full. Its summer use is fully replenished in winter. The holding capacity is remarkable. The loss between maximum and minimum by evaporation and seepage is only between 2 and 3 feet, or less than if the whole area had been paved and cemented, proving that there is a large phreatic, that is, underflow or springs, supply, besides the natural surface drainage. The capacity of the first reservoir was about 36,000 acre-feet of water.

The next year and a half was spent in the amicable settlement of certain disputes about water rights, some important results of which were that a canal 9 miles long was built due east from the mouth of the Santa Ana Cañon along the foothills to Highlands and vicinity. On the south side another canal was built in coöperation with another company. The dam now being considered is 20 feet at foundation base, 12 feet at top of foundation, 8 feet 6 inches at base of dam, 3 feet 2 inches at top, and 60 feet high. It is of the arch type. Another branch of the system is a small reservoir on the Santa Ana River, where a dam of 150 feet high is being erected, completely stopping the flow of the Santa Ana and conserving every year, no matter how dry the winter, 12,000 acre-feet of water.

It is intended to build a new dam about 150 feet below the present one, where the sides of the gorge are more precipitous, to a height of 120 feet above the old datum plane, or 133 from base to top of the actual structure. This dam will also be of the crown arch type; about 600 feet in the arc, 1[illegible]0 feet high, and stepped-off in regular courses from base 73.70 feet thick to the parapet of about 14.55 feet. This formation, it is claimed, properly distributes the strains. At the center of the arc of the dam there is to be erected an outlet well, fitted with three outlet 36-inch pipes, capable of discharging 75,000 miner's inches of water. The lake to be formed by this dam will be 12 miles long, and is situated in townships 2 east and west, and ranges 1 east and west, and is 12 miles long by about a mile and a half wide. The amount of water stored will be 105,419,000,000 gallons, or larger than the ten greatest reservoirs of the United States. The waste-weir is situated at the end of the lake farthest from the dam.

The watershed of the combined Bear Valley and Santa Ana reservoirs is 271 square miles, with an average annual precipitation of at least 56 inches. The whole area is densely covered with pine, cedar, live oak, and a heavy undergrowth, adding greatly to the possibilities of water storage by retarding the melting of the snow until late in the season, thus serving as natural reservoirs. The Bear Valley system is expected to irrigate about 500,000 acres of land and furnish power for an immense amount of machinery. It can easily be imagined that this body of water, having a fall of 300 inches in 3 miles, if sent over turbine wheels at proper intervals, is capable of furnishing all the power the region served will ever demand. At the present time distributing works are being pushed with rapidity. A tunnel, 2,300 feet in length, is under contract to be completed in February. A large pipe-line trench is in progress and a canal, with 30 feet grade to the mile, is also under way. About 70,000 acres has been sold of the Alessandro tract, and work in planting and laying is being actively pushed.

WORKS IN SAN DIEGO COUNTY

Another construction which will have an important relation to the Bear Valley enterprise is that of the San Jacinto Flume and Irrigation Company, in San Diego County. It is intended to utilize a large *cienaga* or marshy area, and supply several thousand acres with needed water. Its cost will be $75,000, and the work will be finished before the early summer of 1891. In connection with the Heinel Valley Reservoir and distributory works, the whole area in San Diego, contiguous to the proposed Bear Valley service, there will be reclaimed in San Diego County about 65,000 acres.

Another great work in southern California recently completed is the San Diego Flume Company, which was organized May 27, 1886, to bring water from the high mountains east of San Diego to supply the urgent need of the city for pure water in abundant quantities under pressure, and also to irrigate the rich valley and table lands around it.

This company constructed a reservoir in the Cuyamaca mountains nearly 5,000 feet above the sea, having a dam 35 feet high and 700 feet long, with a capacity of 3,739,119,324 gallons—from whence the water as needed is taken down a rocky cañon, through which, as shown by actual trial, it suffers no appreciable loss, to the San Diego River. Just below this point of junction is built a diverting dam of solid masonry, through gates in which the water passes into the flume.

The flume is 6 feet wide and 4 feet high, built of clear dressed redwood plank 2 inches thick resting on heavy mud sills, stringers, and cross ties, the whole on a foundation of rock or earth in its natural position. It is believed to be the most solidly and thoroughly built structure of its kind in the United States and it is expected that it will continue to be, as it now is, practically free from leakage.

Its full capacity is 5,000 inches daily, equal to 65,000,000 gallons, a supply sufficient to irrigate 100,000 acres. Its length is nearly 36 miles, following the course of the San Diego River to the Cajon Valley at a height sufficient to irrigate the best lands in that valley, and thence to the edge of the mesa or table land adjoining the city, terminating at a point 630 feet above the sea and 8 miles distant from the city limits, to which a pipe line or a flume and pipe line will connect it with the main of the San Diego and Coronado Water Company, already extended to the city.

THE ONTARIO COLONY PIPE SYSTEM.

The Ontario colony in San Bernardino County affords so instructive an example of utilizing waste land and water to the maximum of benefit that it will be well to present the chief facts. Messrs. Chaffey Bros., its organizers, decided to carry out their irrigation and land development scheme on a theoretically correct system, arguing that after land is sold in small tracts to many persons, they can never be united to carry out works that will be for the general good. They therefore determined on carrying out a complete irrigation system to the extent of the water supply available; also to give all the conveniences and appliances necessary for a community in accordance with modern ideas, and then make the purchasers of the land pay such prices as would cover the cost of producing these advantages. The site for their colony was selected on the sloping land from the foothills of the Sierra Madre

Mountains, where the San Bernardino and Los Angeles join the San Antonio cañon or valley, giving a perpetual supply of water from the mountain snows in the summer, and rain water from the lower slopes and hills in the cold months. The Southern Pacific Railroad bounds the land of the colony to the south, 7 miles from the foothills, and has its station of Ontario in the middle of this boundary, 36 miles from Los Angeles, the principal market for the colony's produce.

The site selected has the elements for success as a colony—productive land in a suitable climate, and a good commercial position, with abundance of water. Water rights were secured, the land purchased, and, after a careful examination of other enterprises, it was decided to distribute the water by means of cement pipes over the whole tract divided into 10-acre lots, so that each lot should be supplied at the highest point. The main roads were also constructed. In accomplishing this the Chaffees spent about $170,000 for these purposes:

Dam across channel	$2,500
Masonry-lined channel and tunnel	35,000
Laying 27 miles of cement pipes	45,000
Iron pipes for supply of township	10,500
Improving streets and tree planting	18,000
Station, college, and hotel improvements, etc	59,000
Total	170,000

A dam diverts the water from the channel, but a large quantity passes below the bed, to intercept which a tunnel 3,000 feet long was driven to cut across this drainage, and thus lead it into a masonry-lined channel, 6,000 feet long. The water is taken from this channel by the cement pipes, but it is intended to construct a reservoir in which to store the surplus water not required during the non-irrigating season, with which the pipes will then be connected. Several miles have been laid of 4-inch lap-welded pipe for distribution purposes. Laminated wrought-iron pipe is now used. The water is delivered and measured from cement pipes by means of a vertical connection, at which point a valve is fixed. This consists of a cast-iron plate, with an aperture the size of the pipe in it and a groove for the valve to slide in. The valve is simply a plate of cast-iron, with a wrought-iron lifting rod.

The tunnel construction was decided upon after sinking experimental shafts across the valley, and thereby ascertaining the existence of a subterranean flow of such force that a chip of wood or other substance could be carried across the bottom of the shaft.

The quantity of water used for irrigating by the pipe system is 500 acres per cubic foot of water per second. The value at Ontario of 1 cubic foot of water per second is estimated at $40,000. The unit of measure is one-fiftieth of a cubic foot, or a miner's inch of water. The discharge of a stream for irrigating purposes is estimated for the midsummer period—that is, from the 15th of July to the 1st of August, when it is at its lowest.

WORKS IN PROGRESS.

Among other large California works in construction at this time are the Woodbridge Canal in San Joaquin; the improvements of the Gage Canal, wells, and other works at Riverside; the Panoche Canal in Fresno County; extensive operations in progress on the Kern and Tulare Irrigation District Works, the Turlock District Canals and Works, the Brown Valley Works, Yuba County, consisting of canals and floating dams in the river to catch the "slickens" or hydraulic mine débris.

Also another extensive canal, in opposition to the District, the Fleming Canal in Butte County, the Folsom Water-power Works at or near Folsom on the American River and within Sacremento County; large works are under way in Colusa, Butte, Ingo (where English capital has recently been invested in an extensive canal enterprise of from 30 to 40 miles in length), Lassen (where about 30 mountain lakes and ponds have been utilized for storage), Shasta, Fresno (the Panoche), San Joaquin, Tulare (west side), San Luis Obispo (east side), and in Kern and Tulare Counties. All through the foothills and central counties, as well as in southern California, there are very many private and individual enterprises in progress; these will rise into the hundreds. As accurate details are unobtainable, no attempt is made to present the imperfect data at command, for to do so would probably only arouse local or personal jealousies.

PROSPECTS AND CONSTRUCTIONS IN THE NORTHWEST.

In eastern Oregon and Washington considerable progress is being made. Several large works are under way in the neighborhood of Baker City, Oregon, and by the use of powerful pumping machinery on the Snake River a considerable addition has been made to the irrigated area in southeastern Oregon. In eastern Washington the chief irrigation interest centers in the proposed conservation of a water supply for the Great Bend section of the Columbia Valley. The Northern Pacific Railroad is still in possession of a great portion of its land-grant areas within that section, and under its direction the well-known hydraulic and irrigation engineer William Hall, of San Francisco, has been making preliminary surveys, and is now preparing plans for the supply of several million acres of valley and tablelands.

The Yakima Irrigation and Improvement Company, operating in the county of that name, will serve as an illustration of several other enterprises in progress in the eastern portion of Washington. It was incorporated in October, 1888, is designed to serve about 20,000 acres of land, which, when taken up, was classed as "desert," and is now saleable at from $30 to $50 per acre, with water. The source of supply is the Yakima River. The main canal at Kiowa, the headquarters of operations, is completed. Extensions covering about 20 miles in all are now constructing. They include ditches, head gates, and a wing dam, in the Yakima River.

LARGE CANALS UNDER WAY IN IDAHO.

Several of the larger enterprises of southern Idaho, in both its eastern and western sections, have been extended and improved. Canals of large size at and near Nampa and Boisé City have been in process of construction. The work has, so far as the evidence and reports show, been done in a permanent and complete fashion. The New York and Idaho Canal is larger for a considerable number of miles than the Erie, being 75 feet in width. Other projects are under way, directed from Salt Lake City. In Bingham County the works for the taking out, conservation, and utilization of the Snake River are still in progress and made considerable headway during the years 1889 and 1890.

The accompanying map will give conception of their extent and importance, as well as illustrate the numerous small neighborhood and farm ditches which have been constructed and operated by the Mormon farmers of that section. It is asserted that they are likely to be vitally and perhaps injuriously affected in the southeast portion of the county at least by the construction and operating results of the Bear Lake project now under way in northern Utah. Be that as it may, that is the only large construction now in progress in Utah.

In Montana the chief irrigation construction has occurred in the northern part of the State, in the counties of Choteau and Cascade, and in the vicinity of Great Falls. Progress has been made in the Gallatin Valley, along the Yellowstone and in the central section, in continuing or completing projects previously started.

COLORADO AND WYOMING WORKS.

In Wyoming very little construction was begun or continued in 1890. Projects of some considerable importance have been inaugurated in connection with Colorado enterprise in Routt County. The drainage basins are interlocked and belong to both States. These projects will prove of considerable interest for that reason and because they will develop for Colorado and Wyoming a new and extensive area.

In Colorado considerable activity has prevailed in all directions, but the most important has been that of increasing storage facilities, as well as utilizing a large phreatic supply. The construction of the Denver Water Storage Company, is of importance as to the first. Under its operations a reservoir site was selected 27 miles south and 13 miles east of Denver. The creek enters a narrow rocky cañon from a large basin. A dam 70 feet high from the bed of the creek covers this to an average depth of about 35 feet, with a superficial area of about 200 acres. Its capacity is about 250,000,000 cubic feet of water. The watershed above the reservoir is about 225 square miles, over which the average rainfall is moderately estimated at 25 inches annually. The watershed varies in altitude from 6,500 to 8,000 feet and the annual precipitation varies from 15 to 45 inches. The dam is on top about 635 feet. Its extreme height above the creek bed, 70 feet. The face wall recedes 1 foot in 10; it is 13 feet thick at base, resting on concrete foundations, and 4 feet thick at top, with random rubble masonry of hewn stone laid in strong Portland cement. The outer wall is blocked with the same, stepped in 2-feet props, laid of stones not less than 4 feet in length, 2 feet thick, and from 18 inches to 4 feet wide. The slope of the outer wall is 1 to 1, or an angle of 45 degrees. Against this face wall there is an earth apron to within 25 feet of the crest of the dam, with a slope of 3 to 1. The water shaft (with discharge values) is of solid masonry. There are 8 discharge pipes from the reservoir into this chamber, each 12 inches in diameter, laid in pairs at four levels, from 10 to 30 feet above the base of the dam. The outflow from the chamber is from a 36-inch conduit, with a gradient of 3 feet in 60.

The precautions against damage from overflow, besides 8 discharge pipes, are a by-pass, 30 feet base, 3 feet deep below the crest of the dam with side slopes 1½ to 1. Midway over the creek there is a drop in the dam crest of 4 feet for a width of 100 feet.

The weight of the rock used in the construction of this dam (150 pounds to the cubic foot) is estimated at 80,000 tons. For a water way the rocky bed of the creek is utilized for about a mile and a half, the diverting dam of solid masonry, on concrete footings, being placed just below the outlet of the cañon. The head gates are steel trussed, each 4 feet wide, raised by milled screws in brass nuts, sliding in angle iron grooves, carefully fitted. These are built into the masonry. The main canals and flumes are substantial, covering about 50 miles in length.

With the laterals constructing the service will cover 70 square miles, or 44,800 acres. The system may be extended to cover 160 square miles. One advantage in it is the service that can be given to Denver itself. Two other storage reservoirs are in process of construction. They are in natural depressions, probably old lake beds, below the canal line, one having a capacity of 30,344,400 cubic feet, with a superficial area of 59 acres and an extreme depth of 16 feet, and the second a capacity of 15,000,000 cubic feet. These reservoirs will receive their supply from the discharge and overflow of the main one. They will also intercept water along the line of the canal and store the same. This local supply from tributary creeks, etc., is estimated by engineers as equal to the original drainage basin. The three reservoirs are estimated to have a united capacity of 300,000,000 cubic feet. It is believed they will fill at least three times per year.

Bear Creek Valley, near Denver, has also been the scene of considerable storage enterprise. Some thirty local reservoirs have been made during the past year, the contents of which will serve from 2 to 250 acres each. The largest work of this class is in the Upper Cherry Creek Valley.

The enterprise of the Pueblo Gravity Water Company is of considerable significance, especially in its bearings upon the drainage supply to be derived from the natural gravel-bed reservoirs, which are believed to be periodically filled from the precipitation on and drainage of the frontal range of the Rocky Mountains. The engineer of this important enterprise is Mr. James D. Schuyler, of California. The Pueblo supply is designed for town purposes, but the conditions and designs make it, or similar ones, readily available for irrigation also. The source of the water supply is the underflow of the Fontaine qui Bouille, which it is proposed to draw out by means of drain pipes of large size, to be laid across the subterranean channel on the bed rock or clay subfloor of the valley.

Overlying this floor are beds of coarse, saturated gravel, which extend up the stream some 30 miles to and above Colorado Springs, as well as for some distance up all the tributaries. The site selected for development work is 19 miles above the stream mouth at Pueblo, where sufficient land has been secured to give control of the major part of the valley gravel beds from side to side. The elevation of the surface here is about 5,200 feet above sea level or 525 feet above the level of ordinary low water in the Arkansas. The main conduit will be 75,380 feet long and have a fall of 216 feet, or an average of 15.1 feet per mile. The reservoir depth is 20 feet, with a height on the bottom, above the city's main streets, of 258 feet. The area of saturated gravel immediately over the 2,400 feet of drain pipe will be 32,000 square feet. Experiments made at Wigwam, which were confirmed by the flow observations at development works on Monument Creek, led to the conclusion that on that slope water found its way through the gravel at the rate of about 7 feet per hour. On this basis the area of the voids in the saturated gravel cross-section at Wigwam would carry about 24,000,000 gallons daily.

The plan proposed for development of the new water supply is as follows:

Starting at a point down the stream, where the required grade from the bottom of the collecting well approaches the surface, it is proposed to make an open cut about 5,600 feet in length, wide enough to carry two lines of 30-inch wooden pipe, both of which are being laid at once to the collecting wells, although only one of them will be used immediately. These pipes will be covered as laid. and will serve to drain oft the water from the cross-cut above. The drainage pipes will be of cement, 30 and 36 inches in diameter, laid with open joints to admit of the free passage of water. Two lines of drain pipe, each 400 feet long, will be projected up the valley, one on the west side, the other near the lowest depression of the clay. There are in all eighty-one collecting wells in use.

The system calls for the use of 5,630 feet of 30-inch, and the remainder, 70,140 feet, of 24-inch pipe, to be made of California redwood staves, built continuously in the trench and banded with round steel bands. The importance of this material and its use is shown by Mr. Schuyler in the following statements:

First. After thoroughly investigating the history of wooden pipe as laid for 7 years past in Colorado, and after examining a number of lines in use, I have come to the conclusion that if the bands are properly coated and the pipe kept full of water it is practically indestructible, and certainly has a longer life than sheet-iron or steel riveted pipe.

Second. The interest on the difference in cost between wood and cast-iron pipe of the same capacity will replace the wood pipe every 10 years, which I think is but a fraction of the life of wood pipe, and therefore it would be a prodigal waste of money to put the amount of capital necessary to lay cast-iron mains into the enterprise.

Third. The wood pipe is cleaner, does not become foul, does not rust, does not fill with tubercles that diminish the capacity year by year, has no yarn to rot and contaminate the water, will not break by settlement, will not burst so readily under water hammer, and so long as it lasts is in every respect cleaner and more desirable.

It has been made to stand 180 feet head, without leaking, or double the maximum pressure on your pipe. California redwood is so much better adapted to that purpose than any other wood available that I recommend that material.

Among the principal canal enterprises of the past year, in construction or projected, are the following:

County.	Name of company.	Source.	Mileage.	Acres to be served.	Remarks.
Kiowa and Otero	Pueblo	Bob Creek	60	50,000	State lands and convict labor.
Mesa		Grand River	100	200,000	Masonry dam 15 feet high.
Rio Grande, Saguache, and Costillo.	Mosa	Rio Grande River.	85	175,000	
Routt		Elk River	20	40,000	Near Hayden.
Larimer and Weld	Mesa				To fill an old ditch and widen a canal, bringing sufficient water to insure potato crop.
Grand, etc	Berthoud Pass				To collect Pacific slope waters and bring them east of range to Golden City by flume to Berthond Pass, tunnel under it, and beds of Clear and Middle Creeks.

In the Arkansas River Valley there are 500 miles of ditches projected and in process, generally neighborhood and local farm affairs. There will be reservoirs covering 5,000 acres constructed during 1891, which service will exceed 50,000 acres. During the past 5 years there has been great activity in this section. Besides 500 miles of corporate ditches 350 have been made as individual enterprise.

ON THE GREAT PLAINS.

In western Kansas and Nebraska considerable activity has been displayed. The interest aroused by the investigation ordered by Congress has had the effect of renewing courage among the disheartened settlers.

By the following table, compiled from replies to circulars sent from this office, some conception can be had of the work in hand.

County	Location.	Source.	Irrigated under ditch or to be served by works constructing.	Number of ditches.	Ditches existing or constructing.	Systems.	Cost.	Remarks.
			Acres.		*Miles.*			
Cheyenne	St. Francis	Republican River.	1,200	3	6	....	....	3 headgates; many drive wells.
Clark	Englewood	Arkansas River.	600	2	*18	1	....	1 dam, 1 reservoir, 1 headgate, 3 weirs. Reservoir constructing; when completed will serve 2,000 acres. Bored wells give abundant supply.
Decatur	Oberlin	Republican River.	....	....	....	....	....	9 dams used to make subirrigation possible; 1 artesian well.
Finney	Garden City	Arkansas River.	150,000	5	*200	3	$200,000	3 dams, headgates, and wing dams.
Do	do	do	200,000	....	120	....	....	4 dams and headgates. A few driven wells used for irrigating small orchards.
Ford	Dodge City	do	500,000	2	240	....	1,000,000	This is the headquarters of sub-canalling work, or irrigation by river underflow; 1 artesian well in county.
Graham	Penokee	Solomon River.	75	*23	....	....	1,600	3,000 dug and driven wells.
Gray	Cimarron	Cimarron River.	5,000	*20	†90	....	30,000	1 dam, 1 headgate.
Kearney	Lakin	Arkansas River.	2,500	3	†250	....	50,000	3 dams, 3 headgates, 3 wing-dams. Underflow or sub-canal now constructing; many bored wells.
	Hartland	do						
Ness	Ness City	Saline, So. Fork of Arkansas River.	40	1	½	....	....	Many wells; water lifted by windmills; serve gardens of 1 or 2 acres each.
Rawlins	Atwood	Republican River.	500	3	4	....	....	3 small reservoirs and 60 dams.
Scott	Scott City	Arkansas River.	....	....	....	....	....	25,000 under Amazon ditch from Kearney county; 45 miles main and laterals.
Seward	Arkalon	Cimarron River.	10	1	½			
	Hoxie	....	35	3	1½	....	500	2 small reservoirs or tanks, 2 dams; many bored and driven wells.
Total	....	....	‡860,010	66	880½			

* In addition there are 10 miles of laterals. * 120 miles of laterals. * 140 miles of laterals
* 8 miles of laterals. * 3 miles of laterals.
†The ditch mileage here referred to is part of the Amazon Company's works, which begin in Kearney County.
‡This total is to be taken with many grains of salt, or at least is to be considered in connection with the area of possible not actual irrigation.

To show what may be done in this section of the Great Plains, the experience of a farmer living in Decatur County, northwestern Kansas, may be cited. He made a farm reservoir by damming up Prairie Dog

Creek, a branch of some importance of the Republican River. From the reservoir thus created he constructed 1,500 feet of ditches, conveyed the water to and irrigated 60 acres, from which, besides a large crop of corn, averaging 40 bushels to the acre, he obtained 2,500 bushels of fine potatoes, giving about 118 bushels to the acre. From 2½ acres of onions he obtained 500 bushels. This result illustrates the reclaiming possibilities on the Great Plains.

If the homesteaders and other farmers will determine to obtain water by conserving in draws, ravines, and other appropriate places, or from bored and driven wells, which can everywhere be made a moderate success, and with its aid cultivate a sufficient area of land to feed their family well, to care for their stock, etc., and obtain as this Decatur farmer has done, a reasonable surplus, without seeking, as in a majority of cases, to extend by preëmption and timber claims, or by purchase, the area of their land holding, they would soon begin to feel not simply independent, but prosperous. With the rainfall and the farm reservoir or wells, the plains farm of 160 acres could always have from 30 to 50 acres under close and thorough cultivation, and be able to seed the balance down to good grass, supporting from it fine cattle and other stock. Such practice would tend rapidly to change the local precipitation from furious showers of little value into rain more equalized in fall, and, as a consequence, more valuable in its effect. The area of cultivation would thus be easily and widely extended, as well as made secure.

The progress of water conservancy is again illustrated by the development of the artesian (Tertiary grit) basin in southwest Kansas. In Meade County, for example, sixty-five wells were reported at one point (Meade Center) by division agent J. W. Gregory, in the first or summer investigation of 1890. Chief Engineer Nettleton notes on profiles accompanying his Progress Report for November and December, 1890, (to be hereafter published) that there are now ninety-five wells at that point. Similar development has occurred throughout the whole region. The engineers have lines across the North Platte and Arkansas River basins, taking wells on either side of sufficient altitude by which to construct or define the water plane, and by this process are endeavoring to ascertain the depth of the phreatic supply and to learn definitely as to whether or no, there is sufficient proof on which to predicate belief in the existence of an under sheet or connected supply of earth or drainage waters that can be restored to the surface.

Of the existence of a large supply of underground waters there is no longer any doubt, but as yet there is some question as to whether the same may be found over the whole area with anything like connectivity, or whether it is somewhat irregular. So much is certain from the evidence afforded by the engineers' lines that the supply is related to a very large area; that it is of great value and extent; that it is probably periodic in character, having its seat of supply in the mountain drainage, reinforced by local precipitation, disappearing by surface percolation and the imbibation of the strata beneath. If breaks in continuity occur they will be the result of geologic condition, and not of those directly relating to hydrology. As already stated the subcanal system is already under way. At Dodge City and Garden City, on the Arkansas River, in Ford and Finney Counties. Works are in progress also in the North Platte Valley, Nebraska. In the Arkansas Valley the existence of an underground supply greater in volume than that of the river channel itself, has been clearly demonstrated. Water bearing or saturated strata has been found at the depth of from 4 to 200 feet from the surface.

THE NEW SUB-CANAL SYSTEM.

A favorite test as to the possibility of the flow or pressure of water horizontally is to put chips into a well and observe that they move from the west to the east side now. The Department is now preparing to inaugurate a series of continuous observations in connection with a large number of wells connected with the railroad service across a considerable portion of the great plains. Fixed gauge rods will be placed in these wells and observations taken and recorded at certain periods of the day as to the quantity of water in each of the wells. Allowing for the pumping for the tanks for locomotive service, these observations taken over a series of months will undoubtedly tend to solve the question of periodic or other rise and fall of water within the well. The temperature will also be recorded by a self-registering thermometer, and floats are to be arranged by which a self-registering record can be had of any horizontal movement or pressure within the water plane. The construction of subcanal enterprises in the valley of the Arkansas for the purpose of utilizing the supplies found within the saturated sand stratum have been thus described.

A ditch has been opened alongside the Arkansas River, about 100 miles east of the Colorado line. It is 14 feet wide and drifted up the valley westward. The river's fall is 7 feet to the mile; but the ditch, commenced 3 feet below the surface, was extended westerly at a grade of 3 feet to the mile, and that grade was extended 3 miles, or until the excavation was found to be 12 feet deep and 6 feet below the bed of the river. The sand of the river bottom is distant at this point more than half a mile, owing to a bend in the stream, but the fact did not affect the underflow ditch or subcanal in the least. So great was the amount of water percolating through the sides of the ditch in the hot August weather that at the point of beginning, where a dam was constructed, the amount of water flowing over it was found to be 30 cubic feet per second. It has demonstrated a most remarkable theory, the author of which, Mr. J. W. Gregory, of Garden City, has since April, 1890, been one of the staff of the artesian and underflow waters investition.

A ditch was opened easterly from the dam along higher land and allowing a fall of only 1.7 feet fall per mile. By extending it for some distance a point is reached a few miles away where a perpendicular fall of 20 feet is secured, and the traveler over the apparently level plain sees a pretty waterfall falling, fed from what is doubtless an inexhaustible subterranean supply.

This ditch, with its assurance of a permanent supply the year round, as no diminution could be detected after 6 months of trial, irrigates 25,000 acres of lands and cost $60,000. It is believed that it could be duplicated for about $10,000 less, owing to new methods and experience gained. The velocity of the flow is about 3 miles an hour. Certain minor matters, such as the inflowing of sand was at first necessary to overcome, but that was accomplished by the placing in the ditch a long plank box, four feet square, with holes bored in the sides and covered with fine screening. This allowed the water to enter but did not permit the sand to pass through. Various shaped ditches were also tried and a form finally settled upon which proved to be the least productive of caving banks and incoming sand.

SALT RIVER VALLEY WORKS.

The most important work yet completed in Arizona is that of the Salt River canal system, by means of which that fertile river valley is mainly watered. Maj. C. W. Greene, a well-known engineer and business man, largely interested in irrigation enterprises, sends to this office an account of a recent visit, from which the following relative to the Arizona Canal and other large ditches is condensed:

A crosscut canal, to connect the Arizona with four smaller and older canals which have been consolidated into one system, receiving their supply from the main Arizona Canal, carries a large body of water, dropping it in a comparatively short distance 107 feet. The main fall in the canal and the several drops in the crosscut canal together are capable of exerting an immense water-power, which up to the present time has not been utilized. By merging into the Arizona Improvement Company, formed for the purpose of consolidating the Arizona Canal and four of the older canals in the valley, which are located at a lower level, the smaller canals are all supplied with water economically, and much interference and consequent litigation are thereby avoided.

This system covers about 150,000 acres of choicest valley land, all of it having an almost absolutely plane surface, with a gentle inclination toward the river of perhaps 10 to 15 feet per mile, so that it can be cheaply and quickly irrigated from laterals and ditches parallel with the sectional lines. While all of these canals have been exceptionally profitable to the several companies building them, the method of financeering has been such that the profits have not been paid in the form of dividends, but are realized in the enhanced value of the property or by the rapid growth of a sinking fund already amounting to about one-half the total amount of bonded indebtedness ($398,000), which bonds are not due until 1900, and only $50,000 of them are subject to call until maturity.

The Highland Canal is another important Arizona improvement, the lands under which are located some 20 miles from Phœnix, in the same valley. About 10,000 acres are now cultivated and as much more is under the ditch. Major Greene says, that—

The water supply is more than ample for all the canals now built. No reservoiring has been done, but the capacity of the river, if all the annual flow could be stored and utilized, would be sufficient for three times the amount of land now covered. The opportunities for such storage are now at hand, and there is no doubt that within a few years it will be found necessary to adopt this plan.

THE PECOS VALLEY WORK IN NEW MEXICO AND TEXAS.

Mr. F. E. Roesler, civil engineer, who efficiently served the first artesian wells investigation for western Texas, sends this office an account of the extensive works of New Mexico and Texas lying in the Pecos Valley. From his interesting paper the following data is taken:

The Pecos Irrigation and Investment Company are engaged in the southeastern counties of New Mexico. During the past year a considerable amount of construction work has been done. Mr. Roesler says:

Their northern or upper canal is taken out of the Hondo River, a tributary of the Pecos, distant about 4 miles east of Roswell, New Mexico. The entire length of the canal is to be about 43 miles. At the present time 20 miles are completed, and about 60,000 acres can now be irrigated from it. The dimensions of the canal are: width at bottom 25 feet, depth 7 feet, fall 18 inches to the mile; cost about $100,000. The work of extending this canal is now going on. When entirely finished its irrigation capacity is estimated at 120,000 to 125,000 acres. There is as yet no land in cultivation under this canal, but about 30,000 acres have been taken up by settlers.

The head of their southern canal is located at a point about 7 miles north of the town of Eddy. Here a dam has been thrown across the Pecos River. It is built on the bed rock of the river and is 1,120 feet long. It is faced with rock and riprap, has a thickness of 250 feet at the bottom and 20 feet on top. The height from rock bottom to crown is 45 feet and the dam will hold in front of it 40 feet of water. The overplus is permitted to escape over two spillways cut into the rock, having each a depth of 5 feet and a width of 300 feet. When there is an overflow from the spillways, the mouth or head of the canal, also cut through solid rock, will be filled to a depth of 15 feet. The cost of this dam is given at $65,000.

Extending south from the dam on the east side of the Pecos River for a distance of 4 miles is the southern canal, having a width at Battern of 45 feet and a depth of 7 feet. Here the canal branches. The southern branch is now 27 miles long, 25 feet wide at bottom, and 7 feet deep. During the year 1891 this branch will be extended into Texas. The eastern branch is 20 feet wide, 14 miles long, and 7 feet deep, and the work of extension is still going on. The present capacity of the two branches is given at 100,000 acres, and when the work mapped out is completed the capacity of the canals will be 200,000 acres. The cost is given at $200,000. At present there are about 1,000 acres under cultivation, but applications for water-rights for 40,000 acres are reported. It is probable that this acreage will be in cultivation before the close of the year 1891.

The Lake View Canal has its head gate on the east side of Pecos River, 15 miles below Eddy, New Mexico. The water is run from the river to a lake 1 mile wide and 6 miles long, and from this lake extends a canal 10 miles long, 10 feet wide at bottom and 4 feet deep. Cost about $50,000.

The Pioneer Canal, in Reeves County, Texas, is taken out of the Pecos River about 12 miles north of Pecos City. The canal is 23 feet wide at bottom and 44 feet wide at top, 7 feet deep, and is estimated to carry 1,020 cubic feet of water per second; allowing 153 acres as the duty of a cubic foot, the irrigable acreage, when the canal is completed, will be 156,000 acres. At the present time about 17½ miles of main canal and laterals have been completed and 12,780 acres are now supplied with water. All the work done to date is on the west side of the river. The canal will soon be flumed over to the east side and rapidly extended southeastwardly 50 miles. About 745 acres are now in cultivation under this ditch, and about 12,000 acres have been acquired by private parties and will be under cultivation before the close of the year.

THE SERVICE OF WATER.

Estimating the service of water per acre, the measurement is usually made at the head of the diverting and carrying surface channels, a process of excellent profit for the water-carriers where that service is separate from the land ownership, and one of waste in any event, owing to loss by evaporation and percolation. The Mormon and Mexican farmers, the former especially, have a more equitable process in existence. The measurement of the water they use is made at the farm intake or head gate to the laterals, by which the supply is delivered from the main ditch wherein the water is conveyed from the place of appropriation. Pipe line conveyance is of the same order, and the "duty of water" per acre can be almost absolutely determined under such process. The economy of the practice is exhibited at Ontario and some other fruit colonies in southern California, which are served by pipe lines. At Ontario it is claimed that one miner's inch serves 10 acres; others claim that the service can not exceed 7 acres.

In the service proposed by the projected pipe service from the Bear Valley reservoir, 4 acres is the limit given. Elsewhere in the fruit region such service is estimated at from 5 to 6 acres. These varying figures make 7 acres to the miner's inch—the most reasonable estimate; and there is no loss by evaporation. So, as the records show, this is the highest service in the world rendered by water to agriculture. In tropical countries and in Australia, the irrigationists, both ancient and modern, have always sought, and now seek, to prevent loss by evaporation as much as possible. The modern works of India are sedulously shaded by trees whenever possible. In the same region and in Ceylon, the great reservoir works of antiquity were generally placed at high altitudes and under forest shades. In Central Asia, the use of underground conduits was, and still is, a notable feature in irrigation. In Australia the large tanks used for watering stock are commonly dug so that part of their surface, at least, is under cover. Phreatic waters then will have the advantage of economy. It is a question, of course, whether they may or not lose somewhat in fertilizing qualities from want of aëration and the presence of microscropic life and vegetable germs. These are issues belonging to the region of unsolved problems in irrigation, and are not to be answered here and in this progress report.

THE MEASUREMENT OF WATER—MODES AND MEANS.

As the area of cultivation thereby increases the necessity of the closest economy will daily become more important. Under the primary ditch system, made by the individual farmer or by a "combine" of neighbors and managed by local regulation, great wastefulness naturally occurs. Not only is wastefullness a result, but malaria is created by the formation of wet places making marshy ground and finally necessitating more or less costly drainage. The economy of water has been enormously practiced in Oriental countries, and the same closeness in use prevails among our Pueblo Indians, by whom the water is often carried from plant to plant and applied in that way directly to their roots. The best managed primary system in America is that of the Mormons. In their operations the water is conveyed at night to the fields and measured at the main ditches as the point of delivery. As the land owners are also the water owners there is no division of profit. The common interest is to bring the water without loss to the point where it is to be utilized. The increase of irrigation, with the fact that only a definite supply is in sight, renders the question of measurement one of the gravest character. The unit of measurement in the United States is known as a "miner's inch," that is, a stream of water flowing through an aperture one inch square with a pressure behind it of 4 or 6 inches, in California, the former; in Colorado it has been the latter. The miner's inch is still largely the unit of measurement. In Colorado, by law, the official or State unit is now 1 cubic foot per second. The adoption of this unit is progressing largely throughout the arid regions. There are various methods of making the measurements. What is known from Italian practice as a "module" is the most common. In the later and larger canals in Italy after 600 years of practice, the system of measurement adopted all depends on the use of the weir. In the concessions made by the Government for the construction of the latest large canal, a proposition for the adoption of a new and practical module was made a prerequisite.

In the measurement of water two distinct measuring boxes are now used, each different in their object. One might be termed the neighborhood system. It consists of a dividing box, the purpose of which is to give to each consumer a definite proportion of the water flowing in the ditch. The Mormons accomplish this by a small head gate at the top of the laterals, which is marked off in units, and by the raising of which the water-master is enabled to fill the farm laterals to the extent to which they are entitled. The ordinary dividing-box then will divert the stream or flow by means of a board, measuring with more or less accuracy the quantity for each consumer. The measuring box belongs to the larger systems, and has for its object to give the consumer a definite quantity of water, such as 1 cubic foot per second. These also need to be fitted with lifting gates so that the quantity may be reduced in times of scarcity proportionately to each consumer. It is these contrivances which the Italians and the French have named "modules," a term which has been adopted by English engineers also. Following the rule adopted by Prof. L. G. Carpenter, in a recent monograph, the first contrivance may be known a divisor box and the second as the module. In Colorado the divisor method of distribution is termed pro rating the water. In the matter of exactness it is seldom correct, so much depending upon whether or no the mining ditches are identical in relation to the main ditch; that is, whether they run with it in a straight or uniform channel or not. Where the body of land to be irrigated is small, compact and co-related in character, receiving its supply from a common source, the divisor system may prove the most useful and available. Under such conditions the irrigation works may be built by the neighborhood farmers, and the ditches, main and lateral, can be so arranged as to fulfill the engineering requirements of identical relations.

In its most common form the divisor consists of a partition into two portions, in proportions to the respective planes. This in effect assumes that the velocity is uniform across the whole cross section, which is not the case, even in a uniform channel, and much less so in one irregular or in poor repair. * * * The nearer the velocity is uniform across the whole channel the better is the division evidently. Accordingly means are frequently taken, by weir boards or otherwise, with this object in view. One form often used and seen in various places has a movable partition board.*

By moving this board out to any accepted distance the consumer can approximately receive the amount of water that he is entitled to. In one ditch in the San Luis Valley, which is broad and shallow, there is used a simple truss across the ditch at the height of the division board. A depending cleat from this prevents more than a certain movement. In some cases a board is put vertically with the edge raised two inches above the bottom of the channel, by this means the channel is kept as the point of division of uniform depth. This is an advantage which is better retained by a weir board of some height with a sharp crest on the up-stream side, the partition extends lengthwise and has its upper end sharpened. As the water falls over the weir it flows away in the respective ditches, by bringing the water to a state of rest, or very nearly so, and allowing it to flow over the weir without lateral contraction, this method will give satisfactory results. Divisors of this character have been used in Spain for several centuries; the system was brought there by the Moors. Irrigation appliances and methods, as found in Oriental countries, though based on empirical ideas, will be found to have been reduced by practice to a degree of accuracy that modern science can hardly parallel. One of these divisors used at Elche, in Spain, has two drops instead of one and more pains than usual is taken with the canal of approach or delivery. For 200 feet above the divisor the fall is very slight, so that the water may have but little velocity; for 10 feet above the divisor the canal is paved; the two drops are about 3 feet apart, the upper one of 10 inches and the lower one a little more; the water is divided at the upper drop by a movable beak of wood, by which the width of the opening may be changed or closed; the second drop produces a constant current away from the point of division.

The modules can not be of the same form in every instance; modifications must occur according to the fall. Buffon, in his "Des Canaux d'Irrigation de l'Italie Septentrionale," assumes the following conditions as necessary for the satisfactory module:

(1) The quantity of water discharged should be readily convertible into absolute measure—cubic inch or foot.

(2) When designed for equal discharges they should so operate in a given time wherever placed.

(3) The ratio indicated should be the actual one when connected with the discharge from two outlets.

(4) Variations in the level of the supplying canal must not sensibly affect the flow.

(5) The module should be reliable, either with large or small quantities of water.

(6) Attempts to alter discharge should be easily recognized.

(7) It must be simple in construction, so as to be managed by ordinary intelligence.

(8) It must practically be automatic, so as to require no calculations as to discharge.

(9 and 10) It must occupy but a small space and require but little fall or expense.

*Bulletin No. 13, State Agricultural College, Fort Collins, Colo. "The Measurement and Division of Water," by L. G. Carpenter, meterologist and professor of irrigation engineering.

These conditions are not all of equal weight, the most important being those which relate to accuracy; a condition which must increase with a growing scarcity of water. Careful readjustment of the module is necessary to insure equality, for unless regulated with every variation in the supply canal the module does not secure a constant flow. Efforts have been made by the Italian engineers to accomplish this by varying the regulating chambers in length and breadth, but without much result. This method is that of the famous Milanese or Soldate module, and it has been extensively adopted in Colorado under the name of the Max Clarke box. Other forms are in use in Europe, but as yet untried in this country, to which they do not seem quite applicable.

Mr. A. D. Foote, C. E., of Boisé City, Idaho, has constructed what is known as the excess weir or "spill box." The main ditch is fitted with a side gate forcing a portion of water through a box. This has a board on the side towards the main ditch with its upper edge at such a height as to give the required pressure at the orifice. Then if water be forced through the box, the amount in excess of the pressure will spill back into the ditch. If the box is made long enough and the spill or weir board be sharp edged (this is placed on the side where the laterals connect) the excess will nearly all spill back into the ditch, leaving a constant head at the orifice. This arrangement has been put in use on the large canals of the San Luis Valley. Mr. Graves, the engineer of these canals, constructs a weir and places the box on one side, using two if possible, one at each side, to save fall and expense. The spill box, as he terms it, is generally 16 feet long, 14 inches wide, and set perfectly level. The crest next the canal is sharp edged, as are the pieces on that side of the box. The gate opening into the orifice is of galvanized iron, worked so that it may be adjusted to any opening and locked. Mr. Foote holds that the main ditch need not use more than 2 inches of fall; Mr. Graves prefers a foot. The success attained by this device for maintaining the head constant is nearly perfect. It is found in use that there is a slight difference of flow in favor of the larger user, a difference which may be corrected by proportioning the size of the box to the amount that it is expected to discharge.

Professor Carpenter, with other engineers, agrees however that the weir is the most satisfactory. Civil Engineer J. B. Francis, Lowell, Massachusetts, is regarded as the best authority as to the flow of water over weirs. The rectangular form is regarded by him as the best and if the following conditions are met the weir may with confidence be used so that the result may be correct within 1 per cent. of the total discharge.

(1) Water must not exceed 24 nor be less than 3 inches in depth.

(2) The depth of water on the crest shall not be more than one-third the length of the weir.

(3) The crest of the weir itself must be horizontal, the sides vertical; both crests and sides must be brought to a sharp edge on the upstream face; the discharge is increased by the least rounding. The face upstream should be vertical. It is also necessary to secure the complete contraction of stream, a free discharge and approach to the weir without perceptible velocity, eddies, or cross-currents.

(4) To secure contraction the distance from the side walls to the crest must be equal to the depth on the weir.

(5) The crest should be at least twice the depth of the water flowing over it above the bottom of the channel.

(6) There must be free access of air under the falling sheet.

(7) The channel of approach must be larger than the weir opening to bring the velocity within low limits.

A module based on the principles and experiments made by Francis, but differing in shape, has been adopted on the latest Italian canal, known as the "Villoresi." In the act of concession, the Government imposed as a condition the proposing of a module based on the theory of the weir with free fall for the measurement and sale of water. The experiments and practice have proved almost perfectly satisfactory. The improvement consists principally in automatically overcoming by the shape of the opening the matter of contraction, so that no single cause would produce more than one-half of 1 per cent. difference between the actual discharge and that given by the Francis formula. The effective length of the weir remains the same and the discharge from two weirs for the same depth will be in the ratio of their length—one twice as long discharging twice as much. The weir adopted is of trapezoidal shape, the sides being inclined at one-fourth horizontal to one vertical. This enables the actual length of the weir to be used. It also prevents contraction and simplifies calculation.

PREPARATION OF LAND AND DISTRIBUTION OF WATER.

Where large areas have to be irrigated, or the supply of water is limited and labor scarce, time as well as the economy of water must be considered in preparing the land. The least labor required is in flooding; sluice gates only have to be opened and kept so until the required quantity of water has been supplied from the main ditch to the prepared area or "check." The quantity of water used in excess of what is sufficient for the crop will be in proportion to the size of the area irrigated and the volume of water thrown thereon. It would be better this should be smaller or the supply increased. The latter would cause it to be covered in a shorter time, and lessen the loss of water in excess of what is essential. Where the soil is compact the area of the check would be made larger than if it be absorbent, so that all these conditions have to be considered in laying out distributory channels. In the larger California works the distributory channels are usually placed one-fourth of a mile apart, and their banks form two of the bounding ridges or levees of the checks, the fourth boundary being a contour or level levee connecting the channel levees. The top of the contour levee must be 3 or 4 inches above the level of the opposite side, so that it can be covered with water to that depth. The levee should have a base of 20 to 1 vertical, forming a gentle swell in the land upon which the crop grows. The less the height of this contour levee the better, because the quantity of water spread over the land will be of a more uniform depth, and will interfere less with plowing and harvesting operations. Six inches has been found to be the best height, with a base of 10 feet, but 12 inches has been used.

Small checks are preferable, as the crops produced by a short submergence are as good as those longer submerged, in which the waste must be greater. On more level land the check need not, of course, be so high to divide off the same area, and where level only as high as the depth of water applied at each irrigation. The low levees are less liable to be breached and more easily closed when such may occur. The crop growing over it protects it from being eroded and does not require to have the excess water against it passed on to the next by levee gates or by making an opening, as the small depth of water would be absorbed before the crop would be injured.

The supply canal must be placed along the highest part of the land to be irrigated. Stop-gates are placed at intervals along the distributories, by means of which the level of the water is raised, to cause it to be discharged on to the checks. These stops also act as drops where the fall of the channel is greater than the soil will stand. Of check or side gates there should be two to each 20-acre check.

As soon as the check is covered, the side gates are closed and the contour-levee gate opened that passes the surplus water collected at the low part of the land into the next check, so that the excess depth of water in the first is not lost nor allowed to stand and injure the crop. This extra supply expedites the covering of the second check, of which the side gates are now opened, and the process repeated. Two or three such checks are generally irrigated at the same time by one man. The checks that are below the drops in the distributories, and can not receive a supply from them, are irrigated from the check above, one or more extra levee gates being inserted; the flooding of these checks, therefore, takes a longer time, on account of the loss by absorption in passing through the upper check; consequently the checks below the drop should be of a less area than those receiving their supply direct from the distributory. The contour-levee gates should be put in on the higher points of the lower checks, if possible, so that the water will flood this by flow instead of inundation, which would require an increased depth of water over the whole check. The contour-levee gates have 4 feet water way by 2 feet deep. These side gates have frequently been washed out, although their floors are placed 12 inches below the surface, and have had to be protected downstream by extending the floor and packing with brush; sand boxes placed on the downstream side would be the best protection; or they should be widened and lengthened.

Four of the distributaries are worked by four men, and they irrigate 500 acres in 6 days. Where the soil is stiffer and less absorbent, they could irrigate a proportionately larger area. Irrigating the same land by branch drains and distributing by hand, experts say, would require six times the labor and consume twice as much water, and be no advantage to the crop. This type of irrigation by checks is employed largely on the Poso and Calloway Canal system in Kern County, California.

Furrow irrigation is effected by a channel carried along a ridge and the plough furrows on either side of the crops are carried up to and across the drain. Where the land is too steep they are carried diagonally across the sloping land. The crop is generally planted in rows, about 6 feet apart; a man directs the water into a number of furrows, by placing a portable dam, called in California, "a tapon," across the channel below the furrows to receive the water; before the end of the furrows is reached by the water, the dam is removed, and the supply stopped, leaving the lower portion of the furrows to receive what remains, which can be easily regulated to suffice. The tapon consists of a sheet of iron, rounded on the lower edge, with a wooden batten riveted to its upper one, to stiffen it and facilitate its being driven into the mud and withdrawal by hand.

Depressions that have evidently been the courses of rivers at some remote period, but are now covered with soil in continuation of a more level country, are generally irrigated by means of embankments thrown across them. These embankments are very irregular in course, following the higher ground, and terminating, in some cases, in contours along the slopes of the depressions.

This California plan has suggested the possibility of utilizing the valleys of water-courses as storages for flood water between the freshets, the collected water being led off to irrigate prepared land before the next freshet occurs. Banks can be extended to great distances in some localities, raising the water 2 to 3 feet above the level of the land on either side. The land so flooded would be soaked, and the surplus water being led off to irrigate lower-lying land, the storage would be ready to receive the next freshet. In some cases, and especially in very dry localities, surplus water not immediately required might be stored in tanks, to be utilized at a future time by pumping, for the irrigation of specially valuable crops. This would necessitate broad shallow channels and large gates or movable wiers, because the flood water must be taken off in large volume, as it may last only a few hours. The water stored by these embankments over the land must not be allowed to stop long enough to kill the vegetation it covers, and the storages must be ready to receive the next freshet water which may come down. Of course, if extensive storages could be economically constructed, in which water might be impounded until wanted, they would be preferable. There are doubtless depressions, around which or across whose lower sides low embankments might be thrown up, that would impound a large portion of the freshets. The cost of constructing all such possible storages should be ascertained, and also the area of land that could be watered by them to a certain depth, the owners of the land deciding whether carrying out the work at the estimated cost would be justified by the return to be calculated on, which must vary with the produce to be cultivated.

CALIFORNIA ORCHARDS AND HOW IRRIGATED.

In connection with these descriptions and statements the experience of California is necessarily largely drawn upon. In fruit raising, for example, its methods and modes of distribution will be sufficiently general as to afford illustrations for most localities in which irrigation and horticulture will go side by side. Prof. E. J. Wickson's report on "California's Fruits and How to Grow Them" is the best authority in vogue as to the methods pursued in that State.* Mr. Wickson says:

Permanent runways or ditches for water are far less common than in earlier days Intensive cultivation is more in vogue. On hill lands, difficult to plow and cultivate and prone to wash, ditches are laid down on grades suitable for securing the slow movement of water. By this method it is expected that seepage and percolation supplys the moisture to the trees needing it. Irrigation by fresh furrows is a popular method for orchards. To be effective the soil must be such as to enable the water to distribute itself laterally. In many instances the tendency is to pour downward. The Riverside furrow system will illustrate the method. The laterals or distributing ditches are commonly paved with rock or faced with lumber, running along the highest ground in the orchard. As the ditch passes each row of trees, a board is inserted in the side and enough auger holes are bored to let water sufficient out to flow to the end of the row within 10 or 12 hours. The time of irrigation depends upon conditions other than those of the method. In Placer County, now being largely devoted to fruit raising, the horticulturists irrigate by plowing once in 2 weeks a furrow on each side of the tree in young orchards and filling these furrows with water. Where the grade is steep dirt is thrown in with a shovel to make the water stand in the furrows. When the latter are full the water is shut off. With large trees furrows are made 4 to 6 feet apart. Cultivation is done crosswise of the same. At subsequent irrigations they run the furrows in a different place, so that the soil may be thoroughly saturated. The difference between the two methods is this: At Riverside the water runs slowly for a specified time without overflowing, so that the supply reaches the end furthest from the distributing ditch. In Placer the water is taken from the furrow as soon as it is once filled by a large flow. Flooding and checks are designed for bringing water to a broad expansive surface and are adapted best for deep leachy soils, in which from the downward course of the water distribution by furrows would be very imperfect. Flooding can be used only where water is plenty and where the soil imperatively requires this treatment.

In the orchard the use of checks is to retain the water upon a broad area of soil around the trees. A shallow excavation is made with a hoe and the water is run into this as long as necessary. When the plow is used the term "check" is applied to

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* Dewey & Co., San Francisco, Cal., 1889.

the back furrows. When the excavation is made circular, as is usually the case, the inclosed space is termed a "basin." Checks are usually connected by a furrow down which is run the water to fill them. Beginning with the lowest, when filled, the furrow is closed. The check next above is then filled and so on through the row. This is an economical though laborious method. It saves the water and all the fertilizing qualities it may contain. The basin method is largely employed in the San Gabriel Valley and other points in California. The basins are made but once a year and summer cultivation is thereby prevented. Sometimes it is well to work them with a spading fork so as to prevent evaporation. Others fill them with mulch straw, but this, it is claimed, harbors the gophers. When the trees are large their branches shade sufficiently to prevent loss by evaporation. In running lines for small irrigation ditches many questions have to be considered. In large constructions of a permanent character, the engineer would necessarily go as high up the stream to its source as possible. In storage works necessarily the higher elevations would be selected. But many other conditions enter into the problems of the individual irrigator. One point to be considered is the amount of fall necessary, and that is of course regulated by the quantity to be discharged. The width and depth to which the water must flow has also to be considered. The nature of the soil and the character of the water to be conveyed also enter into the problem. Mischievous erosions will arise from a strong current in soft soil. Water carrying much sediment must be induced to move rapidly. Having decided these conditions, the nearest place at which water can be taken out of a creek for any certain piece of land is to be found by commencing where the water is to be delivered. That must generally be the highest point of the land to be irrigated. A line will then be run up stream so as to afford the inclination intended for the ditch. A simple level can easily be made for this purpose in the form of a triangle. Every intelligent farmer understands the use thereof. The same level is useful in the locating of "check" contour lines for the distributing ditch.

Southern California has especially made progress in the storing of water from small and often hidden sources. Hillside springs are cleared out and stored. Small tunnels are bored into the foothills and the drainage supply carried off by rude pipes to the point where needed. A spring yielding but 2 quarts per second is found to be equivalent to a stream of 3 miner's inches, yielding about 150 gallons per second. This would be sufficient to irrigate 15 acres of fruit trees and a larger area by means of subirrigation methods. A small tank for storing is necessary. The use of a spring by driblets is pure waste. The California practice in constructing such a reservoir is to excavate it entirely in the ground where the slope will admit of the same. The bottom and sides are lined with clay well puddled. In western Texas small reservoirs with open surfaces are often made, the bottoms are made tight with coal tar and gravel. The loss by evaporation in these is very great. Adobe is sometimes used in San Bernardino County. Concrete of lime, sand, and broken stone, however, forms the best material. A number of small springs can be gathered by underdrains into one such tank or reservoir. These can be chiefly made with broken stone. A grade of 6 inches to 100 feet will not wash in ordinary soil. It will also keep the drain free from sediment. If a greater fall is required the drain should be paved with stone A better way still would be to use concrete sand pipes or light wooden piping. The value of water and its loss by evaporation and seepage is rapidly increasing for horticultural purposes the use of piping in subirrigation.

Professor Wickson makes these further suggestions, though not as explicit directions:

Water usually should be prevented from actual contact with the tree trunk. Citrus trees are especially sensitive to such contact. Care must, therefore, be taken not to set trees which are to be irrigated too low. It is better to raise them up a little and draw the earth around them. The ditch, when possible, should be upon the shady side of the tree, because sunshine reflected from the water surface may burn the bark.

In examining soil to ascertain dryness, one must dig deeply. Lower layers where the feeding rootlets are will often be arid. In irrigating, thorough, deep soaking is necessary. Examination must be made to see if an artificial hardpan which prevents the descent of the water has been formed. Hillside ditches must follow serpentine courses, to give the water a slow flow which is conducive to seepage. Such ditches will prevent water in winter from conducting the storm waters to the bottom of the hill.

Irrigation must not be continued late in the season. Deciduous trees need a certain amount of dormancy. Citrus trees if overirrigated in the fall will grow tender shoots until they are injured by severe frosts. One service of water is sometimes necessary after gathering the fruit from deciduous trees so as to prevent the soil becoming dry, otherwise the trees may shed their leaves too soon. Cold water is always undesirable, especially in fruit culture. Hence the value of water drawn from phreatic sources is greater than that supplied from surface channels, the temperature of the same usually being above that of the surface supply. In districts which have been either long irrigated or oversupplied with water, the land as a rule will fill up and the water plain necessarily moves nearer the surface. Drainage will almost inevitably become a necessary corrolary of effective irrigation long continued, unless, indeed the same is carried on solely by subirrigation, tiling, or pipes. Where ditches are used, in any event drainage outlets should also be constructed. On soils impregnated by alkali, the artificial application of water will draw the same to the surface. Without drainage such areas will soon become worse than worthless.

UTILIZATION, IN IRRIGATION, OF ARTESIAN WELLS.

Artesian waters are, as a rule, too costly in securing to warrant any expectation that they may become largely operative in the reclamation of single areas of any considerable extent. They are not likely to be used, for example, in raising grain or other ordinary farm crops, unless it shall be under exceptional conditions of flow, volume, numbers, and contiguity of wells, etc., but the developments now in progress give assurance to the expectation that artesian wells and their supplies will become a widespread and most important factor in irrigation by their use in the cultivation of small fruits, orchards, vineyards, vegetables, and similar products and crops under conditions which will bring large returns for outlay and insure success thereby.

Artesian water is used in Utah, for instance, but to a limited extent, in the irrigation of grass and alfalfa, but all such modes of service as "flooding" and "checks" afford are necessarily lavish and justifiable only under conditions of large supply into which artesian or phreatic sources of water supply ought seldom to enter.

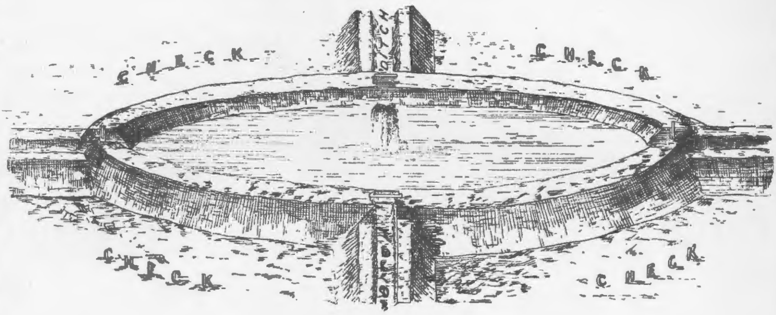
The utilization of artesian waters and wells must, as a general rule, be directed toward special crops and intensive culture on defined and limited areas, under conditions involving more outlay than is usually required in ordinary irrigation from surface sources. Without question, by careful storage of the supply derived from such large wells as are already found in South Dakota, the San Luis Valley, Colorado, and the northeast section of Kern County, California, and the systematic construction of appropriate means of distribution, artesian water will be found in such sections of great importance for ordinary irrigation purposes. But it will be well to emphasize again that the chief value of water supply derived from artesian sources must be for limited area, intensive culture, and special products of high or ready commercial value. The following brief description then of the method employed (where such application is made) of impounding the waters of a flowing well in order to utilize them in irrigation will be found of interest and value.

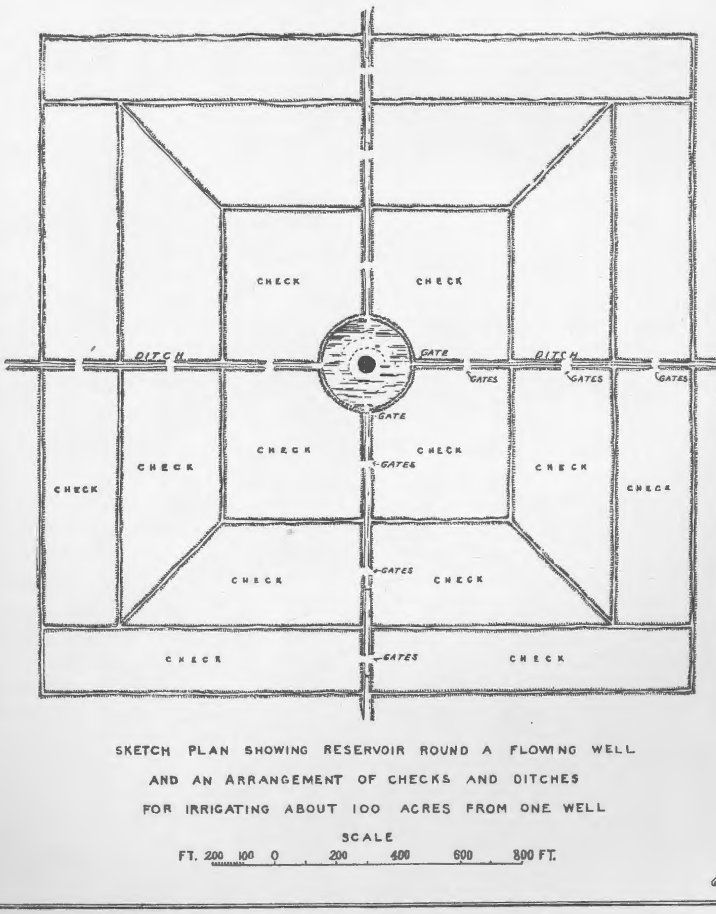
A circular reservoir is built around the well, where the elevation in connection with the land to be irrigated will justify the same, or near to it if mechanical lifting shall be required. The size of this reservoir will be regulated by the volume of flowing water. The embankment is made with sloping sides, the interior slope being slightly steeper than the exterior ones. Ditches are then run as shown in the diagram, gates being constructed at their heads.

To irrigate 100 acres, for example, from one well would require the construction of a circular reservoir 300 feet in diameter. According to conditions this would be built around the well or near to it.

The plan suggested is based on the first requirement. Four main ditches would be required, built at right angles to each other, which should be from 4 to 5 feet wide at the top with a gentle slope inward, the depth to be from 2½ to 3 feet. The fall of the ditch must be as gentle as the ground will permit in order to prevent washing and erosion, yet sufficient to carry the water well to the lower end of the distributory. As well water is without sediment, the fall can be lessened

SKETCH SHOWING THE APPEARANCE OF A FLOWING WELL
WITH THE SURROUNDING RESERVOIR FOR IMPOUNDING THE WATER





SKETCH PLAN SHOWING RESERVOIR ROUND A FLOWING WELL
AND AN ARRANGEMENT OF CHECKS AND DITCHES
FOR IRRIGATING ABOUT 100 ACRES FROM ONE WELL

SCALE
FT. 200 100 0 200 400 600 800 FT.

somewhat. The æration of the water in the well reservoir is most desirable, and after that conveyance by pipes would be more economical than by open ditches. The length of the four main ones proposed in the diagram would be about 1,700 feet each. Small laterals could easily be made to connect as desirable with the distributories, some of the means for regulating their flow, that have already been described, being used. Furrow or pipes could readily be run in any direction necessary. Their use would connect the farm system, the laterals and furrows serving as checks when that method is required.

A most remarkable group of flowing wells is found to-day in Kern County, California. The tract of country which embraces these wells is only about 18 miles long by 14 wide. To the east of it towers the enormous bulk of Mount Whitney, 15,000 feet above sea level and forming the culminating center of the Sierra Nevada. The district ends at about the 300-foot elevation above the sea. The flow of 54 wells is given.

	Name.	Depth in feet.	Daily flow in gallons.		Name.	Depth in feet.	Daily flow in gallons.
1	Smyrna Colony	524	1,500,000	29	Blaisdell	253	580,000
2	....do	600	3,500,000	30	Easton	600	500,000
3	Spring	355	2,000,000	31	do	550	700,000
4	Raymond	340	1,500,000	32	Loutitt	443	500,000
5	Smith	585	3,000,000	33	Holden	625	250,000
6	Robinson	600	2,500,000	34	Hoskins	374	500,000
7	Bruise	480	2,000,000	35	Haggin	470	1,400,000
8	Haley	640	2,000,000	36	Fanning	420	1,500,000
9	Columbia Colony	607	1,500,000	37	Gilmer	504	1,500,000
10	Hooker	636	300,000	38	Cox & Clark	604	900,000
11	Little	330	350,000	39	Gilogly	666	200,000
12	Chauvin	704	220,000	40	Haggin	512	1,400,000
13	Mays	425	1,600,000	41	....do	480	1,500,000
14	Robinson	452	1,500,000	42	....do	703	200,000
15	Moore	360	2,200,000	43	...do	400	900,000
16	Mœbus	402	750,000	44	Butcher	370	500,000
17	Miramonte Colony	630	2,700,000	45	Preuz	345	1,500,000
18	....do	568	2,700,000	46	Anderson	800	1,200,000
19	Sewall	310	250,000	47	Kolb	305	1,300,000
20	Hutchins	512	2,200,000	48	Cox	......	......
21	Hogan	369	2,000,000	49	Phillips	526	700,000
22	Henry	320	1,000,000	50	Leake	750	4,000,000
23	Morgan	457	1,100,000	51	Duncan	360	900,000
24	Watrous	440	700,000	52	Haley	600	1,400,000
25	Phillips	420	500,000	53	Hebert	290	200,000
26	Arnold	358	1,600,000	54	Sinclair	270	150,000
27	Davis	234	600,000				
28	Martin	525	800,000		Total	......	61,970,000

In California there are 25 artesian basins of varying character and pressure, but that of Kern County is the most remarkable. The State Engineer's office, in its volume of "Physical Data and Statistics" for 1889, gives the following for the—

Central Valley.

Counties.	No. of artesian wells.	Above sea level, depth of wells.	Diameter of casing.	Average flow of wells in gallons per 24 hours.	Total flow in gallons per 24 hours.
			Inches.		
San Joaquin	12	920 to 1,250	7	315,000	2,538,000
Stanislaus	19	270 to 1,000	7	101,300	1,178,800
Merced	86	127 to 675	7	70,800	2,769,000
Tulare	101	214 to 928	7 to 10	442,450	28,810,900
Fresno	24	150 to 910	6 to 7	150,400	3,105,900
Kern	36	180 to 630	7 to 9	790,150	6,562,600
Sacramento	19	60 to 2,160	2 to 10½	......	......

The 18 additional wells given in the Kern County list have been sunk since the date of the above data.

MACHINERY, MEANS AND APPLIANCES OF IRRIGATION.

The tools, appliances and machinery in use for hydraulic construction and well boring, with the materials, means and forms used therein, present an important part of the irrigation problem. Inquiries are being daily made to this office in relation to them. It has, therefore, been deemed appropriate to insert here a summarization of such matters. This work has been carefully done by Mr. Frank Blaisdell, civil engineer, who is engaged as office engineer expert and draftsman. Those interested in irrigation will find this paper of value.

PUMPS.

There are so many styles of pumps used, some of which would only be suitable for special localities and conditions, that to recommend any particular pump would be unfair, not only to makers, but those contemplating using the same. Sixty-nine per cent. of the water-works of the United States pump either a whole or a part of their supply.

For raising water for irrigation from wells, streams, lakes, or reservoirs, chain or link elevators are now being used and give satisfaction. They handle large quantities of water with small expenditure of power; can be operated by horse, steam, or water-pump, and will pump from 300 to 2,200 gallons per minute.

An improved patent water elevator is here briefly described. It differs materially from other elevators as to its construction, working as it does on an inclined railway, and carrying cups in very close proximity to each other, propelled by an endless chain, and are emptied at such an angle as to give a continuous stream of water.

The capacity of this elevator is without limit, as the cups, tanks, or cars, as they may be called, form a complete endless train that can be delivered of their load at any given height and return empty, and are again filled automatically without any strain on the elevator or slacking of its speed.

A farmer having only a quarter section of land can own an elevator and irrigate his farm by the use of one horse with the ordinary spur-wheel horse-power, and the large farmer or ranchman by the purchase of a large elevator and a small increase of power, can have water on any part of his property.

Pulsometer steam pumps having a capacity of 600 to 120,000 gallons per hour are used in raising water where the source of supply is from wells and beds of rivers, or from other positions awkward for irrigation purposes. The pulsometer pump is specially suited for use by unskilled labor on account of its simplicity and freedom from derangement. Water, if containing 60 per cent. of mud or sand, can be readily pumped from wells or streams by the pulsometer pump.

The expense of running these pumps is inconsiderable. A number 8 size, discharging 45,000 gallons of water per hour, which was used by ranches and fruit-growers on Snake River in Washington and Idaho, was run at an expense of about $1.50 per day.

Centrifugal pumps are very effective for raising water and of any size and capacity; such a one was used at the Centennial in Philadelphia and was able to throw 100,000 gallons per minute. That would be sufficient to supply about 7,000 acres of land with water for continuous irrigation. The principle upon which this pump works is that of the common propeller of the steamship. An ordinary propeller shaft is inclosed in an iron pipe and is rotated by means of a pulley and a belt from an engine.

Water can be lifted any desired height with this pump by proper adjustment. For extensive irrigation it is well adapted. At the present time smaller pumps will be most available for watering crops when rain is inadequately supplied.

For such purposes small pumps are manufactured at a comparatively trifling cost. One of these, which is operated by steam, is an engine and pump combined, manufactured at Little Falls, New York, at a cost of $75. This pump will raise 30 gallons a minute, which will be sufficient to daily cover 2 acres of land an inch deep.

The engine is of 2-horse power and requires a boiler of equal capacity. The whole complete will cost but little over $200. It can be put to profitable employment by almost every market gardener or fruit-grower who cultivates 10 to 12 acres.

Portable centrifugal pumps for irrigation purposes are manufactured. They are fitted on wrought-iron carriages with four iron wheels, with front ones to swivel. They can also be fitted on two-wheel carriages with suitable wooden draw-poles, shackles, etc. Junction and discharge pipes may be fitted either with plain or swiveling heads.

In the choice of pumps, where the height to which water is to be lifted is to be taken into consideration, the centrifugal will be found economical and effective. These pumps are capable of lifting enormous quantities of water at a comparatively small expenditure of power. Where the lift is above 9 feet, centrifugal pumps are almost always preferable.

There are in use several kinds of vacuum pumps, and centrifugal and electrical pumps for raising water for irrigation purposes from deep and shallow wells. The extent to which pumps of different makes are used is largely dependent upon local conditions. In some localities one make of pump alone is used. A different style of pump was found on being tested not to give satisfaction. For irrigation purposes, small steam vacuum pumps manufactured at Greeley, Colorado, have given great satisfaction.

An elevator is used, with steam power or any power that will give a steady, rapid motion; as the wooden buckets fit into a wooden shoe loosely, by a swift motion they carry the water out very rapidly. This is, however, not suitable for wind power nor any power where the motion may occasionally be slow.

Wind-mill pumps are used in raising water from wells and streams. Some are warranted to stay up in any storm, no matter how severe. A 16-foot mill with an ordinary trade wind will pump 2,400 gallons per hour, the pump being a 5 inch suction and a 7-inch stroke.

A windmill known as the Gibson Cyclone Mill, for irrigation purposes, has been invented but not yet placed on the market, by Mr. S. G. Gibson, of Mineola, Holt County, Nebraska. This wheel is said to run with all the force of the wind against it without moving a particle the end of a shaft. It can be built up to 100 horse-power with a trifle more cost than a 30 horse-power mill. The sails are made of strong duck, put in a frame of 1½-inch by 1½-inch lumber, and are so fastened in the wheel that they can be dropped on the ground and stored away, leaving nothing but the bare arms for the wind to blow through. Sails can be put in again in 10 minutes. As the tower for a 35-foot wheel is only 18 feet high, the wheel comes close to the ground. On Mr. Gibson's windmills, Nos. 12 and 4, the sails are not dropped out but rolled up on forty rollers. This style of wheel costs $150 more and is a great deal heavier in construction.

A cheap and simple windmill that is recommended is known as No. 3; the wheel is 35 feet in diameter, has a 15-inch cylinder and a 12-

inch stroke. The cost will be about as follows: The tower and lumber in the well, from $225 to $250; labor, $80 to $95; a 5-acre reservoir 4 or 5 feet deep, $80; total cost about $400, or $2.50 per acre, calculated for a 160-acre farm. This mill will, in a fair day's blow, cover 10 acres 2 inches deep. Such a mill as this is of 30 horse-power.

Irrigation windmills have proven to be a cheap and ready method of furnishing water for irrigation purposes.

Two mills, one 20 and the other 24 feet, are used at French Camp, California, to fill a reservoir having a capacity of 2,000,000 gallons. These mills will fill the reservoir in 5 days. When the reservoir is full, the gate is opened and 20 acres of alfalfa, several acres of fruit trees, and a young vineyard are irrigated. A 16-foot mill with 5-inch suction lift pump, with 7-inch stroke, will fill a tank of 12,000 gallons capacity in 5 hours.

Electric pumps are now being placed on the market, and are said to be cheap in construction, inexpensive to run, noiseless, and perfectly safe. Experiments by Mr. Edison, now in progress, indicate that in a short time an independent electric motor may be put upon the market powerful enough to run this pump. This will widely extend its field of usefulness.

LIFTING BY STEAM.

Special Agent Nimmo reports that Mr. M. W. Hazelton, a mechanical engineer of Chicago, Illinois, claims to have perfected a device by which 1,000 tons of water can be raised 25 feet at a cost of $1 upon the basis of $2 per ton for coal. He proposes to do this by filling a large steam chest or reservoir, then by cutting off the steam and opening a valve in a pipe descending to the water to raise the contents of any such reservoir by the condensation of the steam. Mr. Hazleton's chief reliance would seem to be in the economical manner of generating steam which he proposes to use in a boiler also of his own invention.

METHODS OF BORING WELLS.

In the construction of artesian wells great care must be taken to make the casing water tight. The casing in common use for artesian wells, in which water is to stand under the pressure of frequently one or more atmospheres, is often deficient in this regard. Through every opening in the casing, when the same serves, as it often does, as pipe to conduct the water to the surface of the ground, there is a flow of water due to the particular size and form of opening and the excess of pressure within the casing over that upon its outside. The greatest loss will occur in water-transmitting strata, where, no matter how great the leakage from the well, the outside pressure is not increased. The loss will be comparatively slight in clay and other nearly impervious strata which are soon saturated with water, under quite or very nearly the same pressure as the water in the well.

* Ordinary artesian well-casing is double. It consists of inner and outer joints, which overlap each other one-half of their length. The casing is forced into the ground as the boring progresses by means of powerful levers. It is presumed that the ends of the joints fit snugly against each other. The seam is nothing more than one of simple contact, and can not be expected to be water-tight even when well-fitting. The longitudinal seam of each joint is riveted. The rivets are about 3 inches apart in a single line. This seam is practically water-tight.

The rivet heads of inside and outside casings prevent their perfect contact. Water escaping from the inside casing finds easy passage to the nearest horizontal joint of

* From notes made by C. F. Grunsky, C. E., in State Engineer Office, California, 1885-'86.

the outside casing, and there escapes into the pervious strata adjoining, or is held back by the water already under an equivalent pressure in the impervious one, as the case may be. * * * Water outside, from top to bottom of the strata, has a uniform excess of pressure over that within the casing; consequently, each opening in the casing, if we suppose them to be of uniform size, admits the same quantity of water. If there be 20 openings from top to bottom of the strata, and no water enters the casing from below, then it is evident that the upward mean velocity in the casing will be 20 times as great above the uppermost opening as it is just above the lowest. Unless the artesian water flow with unusual force, the result is that particles of sand enter the casing through the lowest slits, and sinking to the bottom they gradually fill the well with sand, choking off the flow of opening after opening, no doubt frequently impairing or destroying the flow of the well.

Water should always be admitted through sufficiently large openings near the top of the water-bearing stratum. Only when the stratum next above is soft clay, which is likely to sink into the water-filled cavity caused by the outflow of sand, ought this rule to be ignored.

Sometimes a number of strata of sand or gravel, bearing artesian water, are bored through before the boring is stopped. The question then arises, shall they all be tapped, or is it policy to exclude some of the weakest flows? The pressure within the casing, at any point, is that due to the height of the outflow of the well above that point. No strata send up water to the outflow unless the water pressure in them is greater than the pressure in the casing. But when the flow is a small one from any stratum, and its permanency has not been established, it is always wise to exclude it, provided that in the same boring other and larger supplies of water have been found. Even a slight decrease in the pressure existing in the stratum which yields little water may reduce it to less than the hydrostatic pressure in the casing, and immediately an outflow of some of the water from other sources into this stratum is the result.

When the lowest of the artesian water-bearing strata of any well supplies only a small proportion of its water, then sands, etc., brought into the well through openings in the other strata, sink to the bottom. The well is gradually filled up to the elevation at which water enters with force enough to move sand grains upward. The lowest flow is partially or entirely sacrificed until the well is cleaned out. The cleaning-out in such a case will be necessary, more or less frequently, according to the amount of sand moving with the water in the upper strata.

Water should rise in casings or pipes adapted to the flow, having such diameter as to make the upward velocity of the water not less than 3 feet per second. No water is lost thereby; the well will never need cleaning.

WELL-BORING MACHINERY.

There are a great many companies in the United States manufacturing machinery for gang, driven, and bored wells. Wells may be sunk of any size, from 2 to 44 inches in diameter.

Well machines are made for sinking bores through all formations and for any depth. When rock is encountered diamond-pointed rock drills are used for boring. These drills take out a cylindrical core for the entire distance through the rock stratum. Well augers are also used for cutting holes through rock.

"Club-churn" drills have been found to be a cheap and quick method of sinking artesian wells. They have been known to sink 45 feet in 12 hours as against 15 feet with the diamond drill, or 90 feet in 24 hours against 35 feet.

The hydraulic and jetting process for sinking wells is done by raising and dropping the drill, forcing a stream of water down through the drill rods and washing the dirt out as the work progresses. They are suitable for sinking wells in the alluvial deposits where there are gravel and stones in the soil. They are better adapted for small than for large wells. Those from 2 to 6 inches in diameter may be sunk to a depth of 1,000 feet.

The revolving and hydraulic process for sinking wells consists of revolving well or the drill pipe inside of the casing. The advantage of the revolving process over others is, that the pressure of the water on the outside of the turbine carries out the débris and holds the bank from caving and binding the tubing, allowing it to descend more easily and rapidly than is permitted by any other process.

A drive well is formed by driving a tube into the earth for water, without bringing the dirt out. An auger well is one which is sunk into the alluvial or soft formation by boring with an auger, and it is curbed with wood, cement, or sheet iron pipe.

PIPES.

Wrought-iron bids fair to supersede cast-iron for large mains, on account of its lightness and great tensile strength. Wrought-iron pipes of 24-inch diameter and under, for the purpose of irrigation works under light pressure, may be safely made of wrought-iron plate with tight riveted seams.

Wrought-iron pipes when in the ground are in more danger of corroding than those made of cast-iron. They are subjected to a treatment of the application of a coating of asphaltum and coal tar properly prepared. Wrought-iron pipes are specially suitable for an uneven country. The reduction in the weight of the iron has reduced the cost of the completed pipe in the trench.

On account of the ready corrosion of wrought-iron when exposed to a flow of water and to the dampness and the acids in the soil, wrought-iron cement-lined pipes have been used with success.

The method of manufacture is simple. The sheet-iron is formed and closely riveted into cylinders of 7 or 8 feet in length, and of a diameter of from 1 to 1½ times greater than the clear bore of the lining. The pipe is then set upright, and a short cylinder of a diameter equal to the desired bore of the pipe is lowered to the bottom of the pipe. Some freshly mixed hydraulic cement mortar is then thrown into the pipe and cylinder, which has a cone shaped front, and guiding spurs, to maintain its central position in the shell, are draw up through the mortar. A uniform lining of the mortar is thus compressed within the wrought-iron shell. The ends are then dressed up with mortar by the aid of a small trowel or spatula, and the pipes carefully laid upon skids until the cement is set. Interiors of pipe lining are treated to a wash of liquid cement while still fresh, so as to fill their pores. In another process of lining smoothly turned cylindrical mandrils of iron, equal in length to the full length of the pipe and in diameter to the diameter of the finish bore, are used to form the bore and to compress the lining within the shell. A fortnight or three weeks is required for the cement to set, so as safely to bear transportation or haulage to the trenches.

In the mean time the iron is or should be protected from storms and moisture, and also from the direct rays of the sun, which unduly expands the iron and separates from a portion of the cement lining.

When these pipes are laid in the trench, a bed of cement mortar is prepared to receive them and they are entirely coated with 1 inch thickness of mortar. The smaller sizes of this kind of pipe have proved uniformly successful. The iron is relied upon wholly to sustain the pressure of the water; the cement is depended upon to preserve the iron. Both objects are accomplished.

Wrought-iron pipes, coated with asphaltum, have been used almost exclusively in California, Nevada, and Oregon, some of those of the San Francisco water supply being 30 inches in diameter.

Some of these wrought-iron pipes in siphons are subjected to great pressure, as, for instance, in the Virginia City, Nev., supply main portion of the pipe is subjected to a steady static strain of 750 pounds per square inch. The thickness of this pipe shell varies, according to the pressure upon it, as follows:

Head.	No. of iron, Birmingham gauge.	Thickness.
		Inch.
200 feet or less	16	.065
200 to 330 feet	15	.072
330 to 430 feet	14	.083
430 to 570 feet	12	.109
570 to 700 feet	11	.12
700 to 950 feet	9	.148
950 to 1,050 feet	7	.18
1,050 to 1,250 feet	5	.22
1,250 to 1,400 feet	3	.259
1,400 and over	0	.34

The joints are covered with a sleeve and the joint packing is of lead.

The shells of wrought-iron conduits and pipes should be of the best rolled plates, of tough and ductile quality, of ultimate strength not less than 55,000 pounds per square inch and capable of elongating 15 per cent. and being reduced in sectional area 25 per cent., before fracture.

RIVETED IRON OR STEEL PIPE.

Riveted iron and steel pipe offers great advantages in irrigating purposes. The main advantage of this class of pipe is its cheapness compared with the price of heavy cast-iron pipe, its light weight per foot, consequent ease of handling and low cost of transportation, and its great tensile strength, enabling it to convey water under very heavy pressures. In all irrigation systems where it is desirable to convey water under pressure, this pipe is extensively used.

Great care must be taken in manufacturing it; the exactness of fitting, the method of riveting, the selection of material, all have to be honestly and intelligently attended to, otherwise the pipe is a failure. To prevent it from rusting the pipe is coated thoroughly inside and out with a mixture of crude petroleum and asphaltum and in a bath of great heat.

The pipe is manufactured from a high grade of sheet-iron or sheet-steel, varying in thickness from No. 8 to No. 12, Birmingham wire-gauge, at a temperature of 300° to 350°.

DRAIN PIPES.

Drain pipes made of porous clay are perforated and are used to a considerable extent for subsoil irrigation, though the common drain tile will answer every purpose. This kind of pipe has the advantage of cheapness of material.

CONCRETE OR CEMENT-LINED OPEN CHANNELS.

Concrete or cement-lined open channels may be used where local gravitation is sufficiently favorable, thus preventing loss by percolation. These open channels, however, are subject to evaporation. In cases where there would be very low pressure, cement pipes are recommended, as they have the advantage of cheapness compared with iron pipes.

WOOD WATER PIPES.

The patent wood pipe, manufactured at Bay City, Michigan, has been used in many western towns and has developed unusual strength.

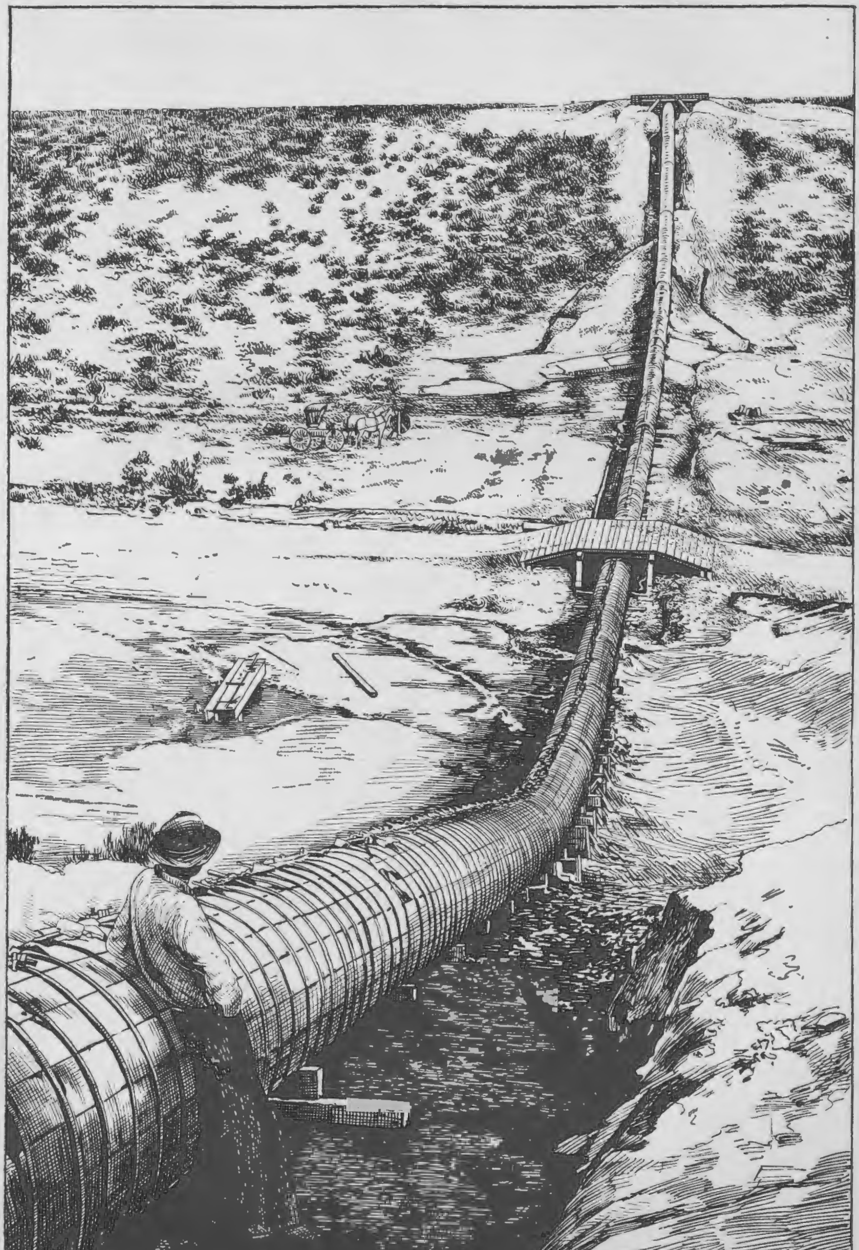
Its chief peculiarities are a spiral band of hoop-iron to increase its resistance to pressure and water-ram, a coating of asphaltum to preserve the interior of the shell, and a special form of thimble joint. These pipes are made from white pine logs in sections usually 8 feet in length. These wood pipes no doubt can be manufactured so as to stand pressure of water for general irrigation purposes, although they have not been used to any great extent for that purpose.

California has done much to perfect a subirrigation system. Besides the asbestine or concrete form of water pipes, the following impervious conduits are in use there:

The Zanja Madre channel at Los Angeles is lined with concrete, and has a cross-section of a segment of an ellipse with a diameter of 5 feet and depth of 3½ feet. The thickness is 6 inches. The ingredients used are: Hydraulic lime, 2 parts; clean sharp sand, 3 parts; pebbles (1-inch diameter), 4 parts; small stone (2-inch to 3-inch diameter), 4 parts; large stones (not exceeding 5-inch diameter), 4 parts. This cost about $1.80 cents per lineal foot. Another concrete-lined channel has been constructed at the Lake Vineyard. It is 17,000 feet long, with a cross-section of 4 feet across and 3 feet deep; cost, $1.46 per lineal foot. A tunnel conveying water to Los Angeles, lined on the bottom with concrete 4 inches thick, forming a semi-circle of 4 feet diameter, cost about 75 cents per lineal foot. The concrete consisted of 28 cubic feet of gravel, 8 feet of sand, to 1 one barrel of Portland cement. The sand and cement were mixed separately with water, with white lime to retard the setting of the concrete while being consolidated. The laggings were inserted as the concrete was brought up. The roof of the tunnel is formed of brick, set in cement.

To prevent erosion and percolation, channels are sometimes pitched with cobblestones. It has been proposed to prevent the percolation from ditches by silting gypsum through the water in the ditches.

Metal pipes, iron and steel, are now used in Southern California, for conveying water for irrigation. Wrought-iron riveted and asphalted pipes are jointed stove-pipe fashion, set with red or white lead, when not subjected to greater pressure than 125 feet. Three men would lay 2,000 lineal feet per day up to 8-inch piping, and from 8-inch to 12-inch 1,000 feet per day. The laminated pipe is made of two shells of sheet-iron. These shells are wrought from one sheet of iron 8 feet long, rolled and lapped 1 inch, and united by a composition solder. They are half the thickness of iron that would be necessary for the ordinary sheet-iron pipe. The inner shell is telescoped into the outer shell while immersed in hot asphalt, specially prepared, giving a thickness between the shells of one-sixteenth inch or more if desired, thus making an impassable barrier to corrosion from outside or inside. Inside and outside coatings are also substantial. This produces a solid shell 8 feet long, with an inner surface free from all excrescences. The pipe is also made double of one sheet, by rolling a sheet that is twice the width of the shingle until the edges will lap, with a thickness of iron between them; the lap is riveted These are in asphalt, but it can not have the intermediate lamina of asphalt, which is the main advantage of the laminated over the single sheet iron pipe. Both these descriptions of pipe are joined end to end, an inner sleeve being fixed in the shop; in laying, this end is dipped in hot asphalt, and an outer sleeve also dipped and pressed on by a clamp



PIPE LINE ON PHYLLIS CANAL.

IDAHO MINING AND IRRIGATION CO.

Pipe made of wood (pine) with 1 inch iron (round) bands.
Diameter 48 inches. Length 500 feet. Pressure 54 lbs.
Inlet 4 feet below outlet. Capacity 150 cubic feet per section.

over the joint, until the asphalt is set. Bends and branches are of cast-iron, as in the ordinary sheet-iron pipe, and the joints made of cement. The 4-inch laminated pipe has been tested up to 500 pounds per square inch. The soldering of the joint is a source of danger; this, of course, could be guarded against.

Concrete pipes, where good sand is obtainable and no pressure is required, have been extensively used. Ontario Colony, San Bernardino County, is mainly dependent on concrete pipes for conveying the water from the cañon. Thirty miles of 12-inch concrete pipe have been laid here at a cost of 42 cents per lineal foot for making. The ingredients are cement, sand, and gravel, in the proportion of 1 of cement to 4 of clean, sharp sand and gravel. The gravel may be as large as half the thickness of the shell of the pipe. The pipe is formed in moulds of sheet-iron. These consist of two sheet-iron cylinders, an inner and an outer, both of which can be expanded and contracted by means of a bar fixed parallel to the joint, from which four arms project that are connected with the outer edge of the joint so as to close or open it. Between these cylinders is a cast-iron ring forming the base. This cast-iron ring is shaped to mould the end of the pipe to form a socket. The inner cylinder or core is kept central at its base by being inside the cast-iron base. It is centered above by hand, until sufficient of the concrete mixture has been consolidated around it to keep it so. The filling is then completed, being put in in small quantities at a time, and consolidated with an iron rammer. The upper end of the pipe is shaped to form a spigot, by means of a cast-iron ring that is worked round by hand. A 6-inch diameter 2-feet-long pipe is made, at the rate of 1 per minute by 3 men. Only as much of the mixture must be made at one time as can be used within 10 minutes after mixing, or its settling qualities will be injured. The newly-made pipe is removed from the mould, or rather the mould is removed from it, on the drying area, the base being left for it to stand on until sufficiently set to handle. For handling the larger sized sections a clip with handles is used and another for laying. The joint is made with cement. The pipes made with the mixture of 1 to 4 are not guarantied to stand pressure, but with a slight increase and well consolidated, they will stand a considerable head. These concrete pipes are cheaper than any other when suitable sand and gravel are obtainable near the site where they are to be used.

The continuous pipe-making machine consists of a cylinder of the size of pipe required, in which an India-rubber core is moved backwards and forwards by a lever, the concrete material being thrown into a funnel fixed at right angles to the pipe-making cylinder. By this means three men can make over 1,000 feet of 2-inch piping in 10 hours.

Asphalt concrete pipes are made in the same moulds as described for concrete pipes, and are superior to them, being perfectly impervious and capable of withstanding much greater pressure. The proportion of sand to asphalt and other ingredients—sulphur, cement, and oxide of iron—could not be ascertained, but it is not necessary to limit the quantity as in cement concrete, for the larger the quantity of sand that is used the harder and better are the pipes. This material has been extensively used for sewer pipes as well as for floors and pavements. Of course the material is melted for mixing with the sand and other ingredients and is poured into the moulds. The pipes are united, when laid, by heating them, so that it becomes a continuous pipe, as strong at the joints as at any other part. Where the ground is yielding, they they are laid on piles driven 6 feet into the ground, and a plank is laid on top of the pile; on this plank the pipe rests.

The asbestine system consists in conducting the water in concrete pipes, below the reach of the plow, along each row of trees. At each tree a plug is set in the upper side of the pipe. Each plug has a small hole through it, through which, and nowhere else, the water escapes, falling on the outside of the pipe, and being taken into the soil by capillary attraction. It saves from three-fourths to nine-tenths the water used in surface irrigation. It is under perfect control and can be applied wherever irrigation is needed. No grading is necessary, as the plant works as well on the hillsides and undulating land as on ground uniformly sloping. The practice of it does not seem to be extending so fast as it did when first introduced. The water will spread over a circular area of 16 feet diameter in 4 or 5 hours in ordinary soil.

Where water is scarce and has to be conveyed long distances in channels excavated in the soil, exposing it to too great a loss, impervious channels and pipes of various kinds have been resorted to, to convey water to land that was valueless without it. This has caused the adoption of a variety of materials to render conduits impervious, and various modes of application of water by their means.

A new irrigating hydrant affords a quick and efficient means of shutting off the flow of water from pressure pipes. The valve is so arranged that when opened it allows the escape of the whole volume of water flowing through the pipes, and the flow is also easily regulated. It is made with a concave top which completely arrests the force of the flow and causes the water to descend in easy flow to the ground. An irrigating hydrant with spout is mostly used where it is designed to conduct the water on the surface of the ground troughs. The area of the spout is equal to that of the upright pipe, and permits the full flow to be discharged. The valve is so constructed that it can be raised to the top of the head of the hydrant, or it can be opened only sufficiently to allow the escape of any quantity of water desired. These hydrants are also made with an attachment for locking them either when opened or closed, or when the valve is in any position.

FLUMES.

The use of flumes as the means of conducting water by gravitation is recommended. The materials from which flumes may be economically and safely made are limited to wood and galvanized iron. Properly constructed, there is no difficulty in keeping wooden flumes water-tight.

For flumes up to 2 square feet of sectional area, galvanized iron, soldered at joints, is inexpensive and efficient, combining lightness with durability and security. A proper system of erection and support should be adopted. The flume should be laid along a longitudinal beam or girder, supported sufficiently to prevent warping or bending with the weight of water. Iron U-straps should be fixed to the girder at intervals, holding the flume in position.

In distributing water by means of wooden flumes it is found difficult to intercept it en route without encountering loss by leakage. The water is intercepted by a sluice door and backed up until it overflows into the funnel. The amount of water intercepted can be regulated by the height at which the door is fixed. The flume would require to be of larger dimensions at the "offshoot," and should be run back level until it meets the sloping side. The funnel should be made of galvanized iron.

The sluice door should be made of $\frac{1}{8}$-inch plate iron, traveling in saw cuts ¼-inch deep. Indentations should be provided on the surface of the plates with which the adjusting peg should be engaged.

It is entirely practicable to make flumes water-tight, as for instance the San Diego flume in California, which is nearly 36 miles in length. The flume is 6 feet wide, 4 feet high, built of clear, dressed redwood plank 2 inches thick, resting on heavy mudsills, the whole on a foundation of rock or earth in its natural position, and is said to be one of the most solidly built structures of the kind in United States. It is practically free from leakage.

IMPLEMENTS.

The leveling of the ground is the first work to be done after plowing. To do this effectively and cheaply, a scraper operated by horse power is necessary. Such a one, much in vogue in California, consists of a frame 4 feet wide and 6 long, mounted upon low wheels and constructed of planks upon which the driver rides. A tongue is attached to the front of the frame, in a perpendicular or sloping direction as may be desired. Handles or guides are fixed to the scraper. The scraper itself is a plank 12 feet long, 1½ feet wide, and shod at the bottom edge with a steel shoe. A half-circular flat iron bar is bolted to the front of the scraper and passes through an iron strap fastened under the tongue. The bar is pierced with a number of holes, through one of which, in the middle of the tongue, a bolt may be passed, so as to hold both tongue and bar. By means of this contrivance, the plank may be moved from a straight to a diagonal direction across the path traveled, and the earth drawn forward or thrown to one side, or both.

A very effective implement, extensively used among the French and Italian irrigators, consists of a frame of timber bolted or mortised together and braced with two diagonal braces at the front. It is generally square in shape, and may be made of any suitable size. Two crosspieces are made of metal shoes, similar in shape to plate irons, which project beneath the surface. As the machine is passed across the field, it will in time make a perfectly smooth surface, by removing all protuberances and depositing the loose soil in the hollows.

After the ground has been brought to a smooth level surface, the seed sown and field harrowed, the soil may be furrowed by passing over it with the scraper in the direction in which the water is to flow.

The buck scraper is used for excavating channels with slopes of not more than 1 to 4 feet, and is especially suited for sandy and loamy soils, where it is found to be superior to the scoop.

DITCHING MACHINES.

Ditching machines are used with great success in the construction of water ways for the purpose of irrigation. By using the grading machines in constructing irrigating canals it is found that they are labor-saving; they are also adaptable in building all ditches, great and small.

A modern grading and ditching machine will elevate and place in embankment 1,000 cubic yards of earth in 10 hours, at a cost not exceeding 2 cents per cubic yard. The multiplication of irrigating canals and ditches has made earth handling by steam a necessity.

DAMS.

Stream water for irrigation will generally be taken from the level by means of a main supply canal; but where it is desirable to secure the greatest possible head of water, the stream level must be raised by a dam, and the supply canal laid on a higher line than the normal water level. A wing-dam is probably the best where only a small raise is needed, and its construction will vary according to the materials to be used and the nature of the stream and its bed. To obtain a small head a simple structure of brush, stone, and earth will suffice, and work should be commenced at the head of the canal, which is first excavated to proper depth up to the river-bank when the head-gate is properly constructed. The wing-dam is then carried up the stream, and a double row of piles, 3 feet apart, driven in the river-bed carried as far as necessary up stream would be advisable, as this point is exposed to the greatest pressure, and generally the weakest because of the junction of the new dam formation with the old earth bank. Brush, if convenient, may be interwoven between the piles of each row, and rammed compactly, and cross-ties bolted or pinned to them to prevent spreading. The space between the rows should be filled with alternate layers of brush and earth well rammed, the brush laid with butts down stream. Coarse gravel may be used to fill on the outside. Beyond the piles brush covered with earth will divert the current where the difference of levels is slight. In a swift current crib-work would be required, or else the piling continued to the end of the wing.

The water pressure on a dam is always exerted to overthrow or push it from the foundation, and therefore the form has much to do with its stability and resistance to the abrading force of water. The danger of overthrow may be considered thus. The pressure of water upon any surface immersed therein is equal to the area of the immersed surface multiplied by the depth of its center of gravity below the water level and by the weight of the unit of water. The usual unit is a foot, and a cubic foot of water weighs 62½ pounds. The conditions of a stable foundation include a weight of bank, which, with the vertical pressure of water to hold it down, equals the horizontal pressure of the water against the dam. It leaves a surplus to meet unexpected contingencies. The material must also be such as will thoroughly band and cohere to prevent percolation. Good examples of the inside slope of a dam are 3 feet horizontal to 1 foot perpendicular or 2½ feet horizontal to 1 foot perpendicular, with the outside slope from 1½ to 3 to 1, dependent upon the character of the material and means used to prevent wash. In case no overflow is permitted, a sodded face will prevent washing, though masonry or planking is preferable. The modern method of constructing a dam is to introduce a puddle wall in the middle, placing selected material on either side, and forming the slopes of gravel, rubble stone, waste, broken rock, or other like and convenient material. In forming the puddle wall the earth or clay, well selected, should be disposed in thin, regular layers, and well rammed; on either side the earth should be disposed in even layers from 2 to 3 feet thick over the whole, and depressed in the center of the work so as to form a basin. The facing on either side may be continued with any material that will serve—the inner of soft material, but the outer of solidity and permanency of position, such as shaley soil, broken stone, or rock. Puddling should never be omitted, unless the circumstances are exceedingly favorable.*

* For this list of some dams and reservoirs recently constructed or now being built we are indebted to the State Surveyor-General of Nevada. It has value in connection with this summary.

Name and location.	Height.	Length.	Width.		Area.	Irrigated.	Cost of construction.	Of what material constructed.
			Base.	Top.				
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Acres.*	*Acres.*		
Donner Lake, Cal	20	(1)	(1)	(1)	1 228	24,020	(1)	(1)
Sardine Valley, Cal	40	963	(1)	(1)	1,025	21,935	(1)	(1)
Henness Pass, Cal	50	550	(1)	(1)	590	23,600	(1)	(1)
Honey Lake Water Co., Cal.	68	411	188	30	289	32,000	$28,726	Clay and stone.
Salt River Dam, Ariz	40	450	50	(2)	(3)	(1)	500,000	Red sandstone.
New River, Ariz	75	2,640	320	90	20,480	75,000	300,000	Rock, in hydraulic cement.
Agua Fria, Ariz	175	[4]1,000	(5)	(1)	(6)	75,000	(6)	Rock and lime.
Rocky Prairie, Modoc Co., Cal.	9½	500	22	8	500	(7)	600	Clay and rock.
Stone's Canyon, Modoc Co., Cal.	9	400	32	8	(1)	(7)	500	Do
Dry Creek, Modoc Co., Cal	8	400	32	8	40	(7)	500	Do.
Lassen Co., Cal	23	160	70	20	(1)	1,280	700	Do.
Do	20	160	60	20	200	1,280	600	Do.
Gallatin's Ranch, Lassen Co., Cal.	16	812	85	14	96	800	1,250	Clay.
Brannon's Flat, Lassen Co., Cal.	20	228	111	(1)	170	700	5,500	Do.
Northern Development Co., Lassen Co., Cal.:								
Dam No. 1	20	600	70	15				
Dam No. 2	13	1,700	64	15	940	20,000	15,000	Clay and rock.
Dam No. 3	22	600	80	15				
Cuyamaca, San Diego Co., Cal.	40	(1)	(1)	(1)	12,000	(1)	47,000	Earth.

[1] Unknown. [2] Depth, 6 feet. [3] 5,000 minimum inch. [4] On top. [5] Ample width. [6] Not given. [7] Water for stock.

The most important points in a dam are the waste gate, the outer slope over which the water flows away, and the foundation. The waste gate should be built in the bank, thoroughly framed and cased with planking and protected with puddled clay. The outer face or slope should be protected with a plank or timber apron upon which the underflow is received or carried off. The foundation has already been described. In addition to the waste gates other appliances or of a storage reservoir are the distributing pipes and valves. The valve is a circular plate which slides between two flanges within the pipe. The surfaces which come in contact are ground to fit accurately together.

Subsoil dams are frequently constructed with the object of cutting off the subterranean flow of water in channels whose beds soon become dry on the surface, or those in which the surface flow sinks rapidly. It is first ascertained by sinking shafts across the channel when water is thus passing subterraneously. This will be observable in some cases by floating substances traversing the shaft; but if the flow is very slow, it may not be detected by this means. Coloring the water with a dye will show it through the replacement of the colored by pure water. This bringing to the surface of subterraneous waterflow is frequently done naturally by impervious strata traversing the water course; such localities are the best sites for weirs. Such natural bars are often to be found in the plains, far removed from the source of supply, and to produce them artificially, in such situations, would generally necessitate very deep and probably also extended walls. The inference is, that we should make our trial shafts where the valley is well defined in character. Of course, these submerged dams can only bring water to the surface of the channel where it is of sand or gravel, but if of impervious material, openings would have to be left in it, to be filled with sand or gravel, through which the water would rise, forming an artesian supply. In such cases the elevated water should be allowed to continue its course along its natural channel without fear of its being again lost in the impervious bed. Where the surface of the bed is of sand in which the water could be again lost, the elevated water must, of course, be diverted to an impervious channel provided for it. Where such subterranean water can be intercepted, a considerable supply can be expected after the water has ceased to flow previous to this interception, for in many cases, according to the geological formation and its porosity, a large proportion of the rainfall is absorbed and given off gradually to subterranean strata. This subterranean flow has also, in several instances, been intercepted by means of tunnels run in from the surface 2,000 and 3,000 feet, the floor being planked to form a flume, and the water thus conducted to open channels.

A COMBINED SYSTEM OF DRAINAGE AND IRRIGATION.

A system of agriculture originated by A. N. Cole, of Wellsville, New York, which is now being carried on and extended by A. P. Cole, has given evidence of success. The system is alike applicable to flat or hilly lands, on those which are found stone or on those which are free from it; in arid districts, or in sections where the rains and snows of fall, winter, and spring are ample. The minor points to be considered, however, are the materials used in construction and depth of drainage and of soil over the stored waters.

A general description of this system as applied on a hillside where stone was abundant is as follows: A trench 3 feet wide and 4 feet deep was opened along the hillside, crossing the field at a distance of about 12 rods. Two rods below this and parallel with it, another of the same dimensions was constructed, and so on down the slope. At the bottom of these were loosely placed cobble and blocky stones until the trench was nearly half filled, then smaller stones laid over these, finer ones then added until a comparatively even surface was had. Two layers of shingling from end to end with flat stone, breaking joints, were required. In order to prevent the crevices between the stones from filling, sods, weeds, or the best materials to be had were placed. The excavated soil was then placed over all, the clay being first returned to the trenches. The remaining surface and subsoil was pulverized and admixed, all fine stone being raked out, when the trench was filled to a point slightly above the original surface. This is done so when settled all should be even.

As these trenches were dug they were connected by overflow or drainage trenches, three in number, one at each end and one in the middle. These were sunk in the soil about 18 inches, and being filled with fine stone raked from the soil, to a depth of about 6 inches, shingled and sodded same as the reservoir, until the entire hillside presented a uniform surface throughout. This results in the formation of two water tables beneath, one of percolation from the bottom of the reservoir trenches, the other of overflow and filtration in time of surfeit. These trenches formed elongated reservoirs, which filled by the water courses that are cut off or by melting snows and early rains, thus holding in storage thousands of barrels of water.

Level lands are laid out, trenched and connected in the same way, the only thing necessary being some point from which the surplus water can be drawn off at the desired depth beneath the surface soil. This outlet can be made from any one of the trenches in the system.

The waters in the trenches can not rise above the overflow or drain trenches, and when below them distribute themselves evenly below the subsoil. If there is no point where drainage can be easily secured, a dry well can be sunk where the water will pass off.

Round tile is used where the soil is level and stone not to be had; also in lands not underlaid by retentive subsoils. In adopting this method the large reservoir pipe must be laid above and across the reservoir tile. Large reservoir pipes should be laid on a level and closed at each end, water passing out slowly through the joints of the pipe.

The clay near the joints will soon become puddled, so that the water will percolate through it slowly when laid in clay. In order to prevent the rapid escape of the waters if laid in sandy, light, or porous soil, the joints should be puddled. A small escape at the joints, in addition to that which will pass through the porous tile, will be ample and effective. At the point where they cross, it was intended that connections be made by openings in both the reservoir and overflow or drainage line of tile. The latter may be constructed of 3-inch tile, and laid at such distance apart as the character of the soil may require.

When small plots are to be irrigated, or the nature of the soil is such that there is danger of the trenches filling with silt, a square tile can be used for the storage trenches. The trench can be opened, the top plate taken off, and the silt thrown out with comparative ease. Where lumber can be had cheap, any planking may be used which will last well beneath the soil. Round 3 inch tile will also answer for overflows.

On lands where the sand is deep and leaches rapidly, trenches are opened and the bottoms and sides made nearly water-tight by spreading a thin layer of mortar on the bottom and as high up on the sides as is desired. The mortar is made by using 1 part Portland cement and 7 parts sand.

As different soils have different capillary powers, the depth of soil to be left over and above trenches and overflow drains should be considered. For general purposes the following depths at which to put the overflow and drains are recommended:

	Inches.
In muck lands	18
In garden soils	20
In sand soils	12 to 15
In clay soils	18 to 20

For all shallow rooting vegetation the soil should have less depth than for deep-rooting.

For shallow growths the soil should be:

	Inches.
In muck, not less than 15 inches or over	24
In garden soil, not less than 20 inches or over	30
In sand soil, not less than 10 inches or over	16
In clay soil, not less than 18 inches or over	26

The following table is a good guide for use in laying out lands:

Will lift water in about 30 days—	Inches.
Muck	18
Garden soil	28
Sand	10
Clay	28

The following is a proposed plan by Col. W. Tweeddale, civil engineer, of Topeka, for the irrigation of western Kansas where water for irrigation can be procured from the underflow of ground water by pumping from wells and distributing by pipes:

ELECTRIC SYSTEM OF DISTRIBUTION OF WATER FOR IRRIGATION.

The use of wells as a means of water supply will prove more economical and effective in the practice of this system. Steam pumps should be used, obtaining their supply from a system of tube wells connected to a horizontal main which constitutes the suction pipe of the pump.

From one hundred well points, ranging in depth from 50 to 75 feet, 7,000,000 gallons were pumped daily. With the increase of area to be irrigated the cost of adoption of this system is proportionately decreased per acre.

With two sections of land as the area to be irrigated, divided into units of 20 acres each, place the engine and dynamos at the center of the area; locate each battery of wells at the adjoining ends of two 40-acre tracts, the motors and pumps to be portable, and the power to be transmitted by means of copper wires from the dynamos to the motors; the capacity of engine, dynamo, wires, wells, motors, and pumps to be such as to provide for the covering of the whole area of two sections of land with 1 inch of water per week.

For the installation for an area of 1,280 acres, consisting of a 60-horse power engine, dynamo, poles, wires, insulators, sixteen batteries of wells of fifteen points each, six motors and six pumps, two extra motors and pumps being provided for the purpose of allowing for moving to new stations, thus keeping the pumps running continuously, on the basis of one watering per week of 1 inch depth of water, each under a head of 30 feet, the cost will be $25 per acre. The cost of pumping, consisting of fuel, oil, attendance, and depreciation of plant, will be 12 cents per acre per watering.

The water may be distributed either by means of ditches or by pipes, hose, and monitors. In the irrigation of fruit lands it is sometimes necessary to run small perforated pipes between the rows of trees.

Estimated cost of irrigating by this system is as follows:

Installation of plant proper for one acre	$25
Installation of pipe system	20

WATER INDICATOR.

An apparatus has been invented by which it is claimed that the existence, direction, and volume of subterranean water to any depth can be very closely approximated.

The makers of this electrical device are Heerdegen & Schnee, of New York. They furnish estimates for sinking wells with guaranty of water, where supply from artesian wells is desired.

BRASS TUBE WELL STRAINER.

In obtaining water from an undeground stratum of sand or gravel, a strainer made of one piece of seamless brass tubing with fine slots cut in same, the slot cut opening being cut from the inside and being larger on the inside will not choke up. These strainers can be nickel-plated at a slight additional cost, rendering the surface harder.

WELL TUBING.

Within the past few years stoneware pipes have come into very general use for tubing bored wells. Where there are no stones to obstruct the boring wells can be easily and cheaply made with augers similar to post augers, constructed for the purpose, and such wells, when lined with stoneware tubing, are found to possess qualities of cleanliness and durability.

For this use the sections are sometimes made without sockets, so as to fit the hole more closely, but the regular socket joint is by far the best, as this makes a more solid joint, each piece fitting accurately into the end of the next, thus forming a continuous tube, leaving no crevice for the dirt to fall in, doing away with the necessity of cleaning the well. Vermin can not crawl through the joints and fall in. Dug wells are curbed with the larger sizes.

EXTENT OF THE ARID REGION.

The areas involved in the semi-arid and arid regions, the conditions and progress of which have been presented in this report, are given as follows by the United States census:*

* Bulletin, January 21, 1891, areas of States and Territories, Henry Garnett, geographer.

States and Territories.	Gross area.	Water surface.	Land surface.	States and Territories.	Gross area.	Water surface.	Land surface.
	Sq. miles.	*Sq. miles*	*Sq. miles.*		*Sq. miles.*	*Sq. miles*	*Sq. miles.*
Arizona	113, 020	100	112, 920	Oklahoma	39, 030	200	38, 830
California	158, 360	2, 380	155, 980	Oregon	64, 343	735	63, 608
Colorado	103, 925	280	103, 645	South Dakota	77, 650	800	76, 850
Idaho	84. 800	510	84, 290	Texas	193, 920	233	193, 687
Kansas	54, 898	95	54, 807	Utah	84, 970	2, 780	82, 190
Montana	146, 080	770	145, 310	Washington	42, 028	1, 150	40, 878
Nebraska	67, 228	168	67, 050	Wyoming	97, 890	315	97, 575
Nevada	110, 700	960	109, 740				
New Mexico	122, 580	120	122, 460	Total	1, 632, 217	13, 092	1, 621, 013
North Dakota	70, 795	600	70, 195				

This makes a total area of 1,037,448,320 acres, according to the figures of the General Land Office, which does not include Texas, up to the 1st of July 1890.

Total surveyed and unsurveyed land open to settlement.

State or Territory.	Surveyed land.	Unsurveyed land (open to settlement).	Total.
	Acres.	*Acres.*	*Acres.*
Arizona	11, 983, 625	37, 715, 426	49, 699, 052
California	38, 750, 564	15, 172, 154	53, 922, 718
Colorado	34, 354, 550	5, 639, 893	39, 994, 446
Idaho	3, 938, 277	43, 019, 013	46, 957, 290
Kansas (west of ninety-seventh meridian)	604, 632. 80		604, 632. 80
Montana	6, 789, 052	44, 157, 049. 6	51, 846, 101. 60
Nebraska	11, 226, 584		11, 226, 584
Nevada	27, 316, 167	23, 488, 373	50, 804, 540
New Mexico	39, 660, 806	16, 699, 520	56, 360, 326
North Dakota	14, 318, 400	16, 179, 000	30, 497, 400
Oklahoma	22, 053	3, 694, 693	3, 694, 693
Oregon (east of Cascades)	15, 586, 643. 66	9, 929, 494	25, 515, 485. 66
South Dakota	2, 043, 374	8, 198, 124	10, 241, 498
Utah	7, 029, 100	29, 176, 000	36, 205, 100
Washington (east of Cascades)	2, 770, 114	10, 327, 430	13, 097, 544
Wyoming	37, 578, 200	11, 431, 860	49, 010, 060
Total	253, 972, 142. 46	274, 828, 029. 6	529, 677, 470. 06

AREAS OF SETTLEMENTS.

There are two outside areas not given; these are portions of Texas and the Indian Territory, lying west of the ninety-seventh meridian. A moderate estimate of their extent will make the total at least 750,000,000 acres. Within the limits defined as arid, semi-arid, and sub-humid—all requiring the artificial use and distribution of water in order to insure successful cultivation of the soil—it may be safely estimated that there are of—

	Acres.
Fruit, farm, or ranch lands privately owned, inclosed, or cultivated	100,000,000
Owned by railroads as Mexican land grants, school lands, etc.	125,000,000
Indian and military reservations	50,000,000
Total	275,000,000

GRAND TOTAL OF AREAS RECLAIMABLE OR OTHERWISE.

A conservative estimate of the reclaimable areas west of the 105th meridian will be 100,000,000 acres. For the Great Plains region eastward to the 97th meridian as moderate an estimate will give 120,000,000 reclaimable acres. The total mountain area is estimated at 115,000,000 acres; the water surface, exclusive of coast lines, at 9,278,880 acres; the desert area will not exceed 25,000,000 acres, making a total of 149,278,880 acres not now to be considered as in any part reclaimable. The pastoral land, bench or table, plains and high plateau, may fairly be estimated at 325,000,000 acres. The timber area is conservatively stated at 175,000,000 acres. This will give a total of 650,000,000 acres as without the present area of reclaimability by irrigation. As our knowledge of the problems of water storage and distribution enlarges, it is more than probable that a considerable addition will be made from the great total of pastoral, desert, and mountain land to that portion of the area of the region which will be brought under cultivation. It is difficult to estimate the total of detached sections in which the water will be supplied for cultivation purposes by natural sub-irrigation, but it certainly can not be less than 25,000,000 acres, most of it lying west of the 105th meridian. These figures make a total estimate of reclaimable area of not less than 245,000,000 acres, provided that water can be obtained for that purpose; but, admitting that only three-fifths of this total can with scientific administration and the closest economy of water be reclaimed by the supply in sight or known to be available, we shall still have an area embracing 147,000,000 acres. It will be a large valuation which would place the present selling price of these lands at $3 per acre or a total of $441,000,000. At an average cost of about $7 per acre the expenditures needed for reclamation for such an area will probably be covered. The total will not in all probability exceed $1,000,000,000. The evidence gathered by the irrigation inquiry office warrants the statement that every acre so reclaimed will without cultivation be at once worth three times as much as the estimated selling price and the cost of reclamation, or $30 per acre. A bare statement of such an estimate as this is sufficient to show the enormous possibilities involved in the progress of irrigation, more especially when it is remembered that this progress must be comparatively slow and that each acre of land unreclaimed during it will be increased more or less rapidly in value by the areas reclaimed.

RECLAIMABILITY BY STATES.

I quote from a paper prepared by myself for publication elsewhere, a statement estimating the areas available in each of the several political divisions into which the arid region is divided. It is sufficiently carefully drawn to warrant insertion here after making a few changes:

Political divisions.	Reclaimable by irrigation.	Political divisions.	Reclaimable by irrigation.
	Acres.		*Acres.*
California	25,000,000	Wyoming	12,000,000
Colorado	20,000,000	Public land strip	2,000,000
Dakotas, North and South	33,000,000	Texas, west of 97°	20,000,000
Nevada	7,000,000	Oregon and Washington, east of Cascade Range	20,000,000
Arizona	12,000,000		
Montana	30,000,000	Kansas, Nebraska, Oklahoma, and Indian Territory, west of 97°	30,000,000
Idaho	10,000,000		
New Mexico	14,000,000		
Utah	10,000,000	Total	245,000,000

In illustration of the growth of the region investigated by this office the following tabular statement condensed from a bulletin of the United States Census Office is given:

Population and the ratios of increase in the decades of 1860 *to* 1870, *to* 1880, *to* 1890, *together with estimated arid and semiarid areas.*

States and Territories.	Population.		
	1890.	1880.	1870.
Arizona	59, 691	40, 440	9, 658
California	1, 204, 002	864, 694	560, 247
Colorado	410, 975	194, 327	39, 864
Idaho	84, 229	32, 610	14, 999
Kansas*	† 1, 423, 485	996, 096	364, 399
Montana	131, 769	39, 159	20, 595
Nebraska*	1, 056, 793	452, 402	122, 993
Nevada	44, 327	62, 266	42, 491
New Mexico	144, 862	119, 565	91, 874
North Dakota	182, 425	36, 909	} 14, 181
South Dakota	327, 848	98, 268	
Oklahoma	61, 701	....	....
Oregon*	312, 490	174, 768	90, 923
Texas*	2, 232, 220	1, 591, 749	818, 579
Utah	206, 498	143, 963	86, 786
Washington*	349, 516	75, 116	23, 955
Wyoming	60, 589	20, 789	9, 118
Total	8, 293, 420	4, 945, 120	2, 310, 662

States and Territories.	Increase from—						Proportions in each State or Territory.
	1880 to 1890.		1870 to 1880.		1860 to 1870.		
	Number.	*Per cent*	*Number.*	*Per cent*	*Number*	*Per cent*	
Arizona	19, 251	47. 60	30, 782	318. 72	9, 658	....	Arid.
California	339, 308	39. 24	314, 447	54. 34	180, 253	47. 44	Two-thirds arid and one-third semi-arid.
Colorado	216, 648	111. 49	154, 463	387. 47	5, 587	16. 30	Do.
Idaho	51, 619	158. 29	17, 611	117. 41	14, 999	....	Three-fourths arid and one-fourth semi-arid.
Kansas*	427, 389	42. 91	631, 697	173. 35	257, 193	239. 91	One-third semi-arid.
Montana	92, 610	263. 50	18, 564	90. 14	20, 595	....	Arid.
Nebraska*	604, 391	133. 60	329, 409	267. 83	94, 152	326. 45	One-third semi-arid, one-third sub-humid.
Nevada	† 17, 937	† 28. 81	19, 775	46. 54	35, 643	519. 67	Arid.
New Mexico	25, 297	21. 16	27, 691	30. 14	1, 642	1. 76	Do.
North Dakota	145, 516	394. 26	} 120, 996	853. 23	9, 344	193. 18 }	One-half semi-arid, one-half arid.
South Dakota	229, 580	233. 63					Three-fifths sub-humid and two-fifths arid.
Oklahoma	61, 701	....	....	....	....	....	Sub-humid or semi-arid.
Oregon*	137, 722	78. 80	83, 845	92. 22	38, 458	73. 30	One-third arid and one-third semi-arid.
Texas*	640, 471	40. 24	773, 170	94. 45	214, 364	35. 48	One-fourth arid and one-fourth semi arid and sub-humid.
Utah	62, 535	43. 44	57, 177	65. 88	46, 513	115. 49	Arid.
Washington*	274, 400	365. 30	51, 161	213. 57	12, 361	106. 52	One-third arid, one-third semi-arid or sub-humid.
Wyoming	39, 800	191. 45	11, 671	128. 00	9, 118	....	Arid.
Total	3, 348, 320	....	2, 632, 359	....	951, 882	....	

* Exact figures of the population of the States known as partially arid can not be given, because the Eleventh Census has not yet been completed or published. The county divisions are therefore inaccessible. Estimates have been made from the best data obtainable of persons within the *semi-arid* portions as follows:

Kansas	400, 000
Nebraska	500, 000
Oregon	100, 000
Texas	1, 000, 000
Washington	140, 000
Total	2, 140, 000

Making the necessary deduction, therefore, from the total estimated population of these States as given in the above table will give a total number of persons within the arid and semi-arid areas of 5,048,734. The figures for the States not here noted are those of the Eleventh Census.

† Decrease.

SOME MARKED CLIMATOLOGICAL DIFFERENCES.

A report prepared by the United States Weather Service on the Climatology of the Arid Region, being now in the Public Printer's hands, under a resolution of the House of Representatives, it is not necessary to discuss that subject here. But the following tables, carefully collated from the records of the Weather Service, and covering the mean of all observations taken at the stations given, are presented with the view of calling special attention to some of the conditions attending the summer precipitation.

The figures of the weather service observations have been recast, as to rainfall, into three periods of four months each, thereby bringing into prominence the amount of such precipitation at the points named during the four principal growing and ripening months. The lines of stations given are such as to present in general a uniform set of parellels across the western portion of the continent, with the exception of the last or No. 7, which covers stations as wide apart as Ellensburgh, Washington and San Diego, California or a range of 4½ degrees of longitude. In actual relations to climatic influences such a variability does not exist, as the coast trend makes the line of stations almost as uniform, north and south, as is the fact with stations in the tables preceding.

The value of these tables is found in their showing the wide variation between the summer supplies of precipitation and moisture in the eastern and western halves of the semiarid and arid region. From 97 degrees to 107 degrees the heaviest amount of precipitation recorded is found in the four summer months of May, June, July, and August.

On the first line of five stations upon or near the ninety-seventh meridian from Pembina to San Antonio, a stretch of about 1,000 miles, the average mean of moisture for those months has been during the period of observations, 14.34 inches per term. The winter and fall periods do not show over one-half that average.

On the second line of six stations upon or near the one hundred and second meridian, ranging from Bismarck to Fort Stockton, a length of about 700 miles, the average mean of summer precipitation is seen to be 9.90 inches. The winter and spring terms preserve the ratio of about one half that average.

On the the third line, or the one hundred and fifth meridian, four stations, running north and south from Poplar River to Fort Davis, about 750 miles in length, show a summer mean of 8.50 inches.

Coming to the one hundred and seventh meridian, with five stations, north and south, from Assiniboine to El Paso, about the same in mileage as the preceding lines, and we have a mean for the four summer months over this degree of but 6.25 inches. On these lines the same ratio to the summer fall of about one-half is preserved. The average annual mean of these five lines will be as follows:

Table No.—	West longitude.	Average annual mean north to south.
		Inches.
I	97°	26.67
II	102°	19.12
II	105°	13.83
IV	107°	12.83

The marked climatological differences which these little tables show becomes very apparent on examination of the remaining three. In that of the one hundred and twelfth meridian, with four stations ranging north and south from Helena to Phœnix, a distance of about 650 miles, we find a mean precipitation for the summer period of 4.24 inches Eagle Rock, which is embraced in the table, is omitted in calculating the average, as its proximity to the Rocky Mountains gives it an exceptional precipitaton.

On the line of the one hundred and seventeenth meridian, passing east of the Cascade range, we have for four stations and a distance of about 750 miles a mean seasonal precipitation of but 2.54 inches.

The third and last line of this division gives us thirteen stations over a range north and south of about 900 miles, and an average mean of 2.84 inches. Commencing with table No. V and the period of greatest precipitation for the year will be found within the months of January, February, March, and April. This mean and that for the year will be as follows:

Table No.—	West longitude.	Average mean rainfall of first 4 months.	Average annual mean.
		Inches.	
V	112°	*3.20	*12.22
VI	117°	5.72	14.00
VII	121° to 125°	10.82	18.00

* Eagle Rock is omitted.

These two remarkable climatic divergences, thus broadly indicated, offer a key to many of the problems still unsolved in irrigation economics. They point strongly to at least these phenomena or their results, viz:

That the early melting of snow upon the California Sierra, the Cascade Range, and upon the northern sections of the Continental Divide in Montana and Idaho is due to the influence of the Pacific Ocean, its currents, and trade winds.

That the general or globe movements of the aerial currents which bear moisture across our continental interior, and deposit the same as rain or snow, is from the northern Arctic circle, moving generally for us from northwest to southeast. They are enabled to carry a large degree of the moisture they contain to the eastern summits of the Rockies in consequence of the comparatively low altitude of the northwestern sections of those mountains and of the formations further west and nearer to the Pacific coast. The movement east by south of these world or passage winds is also facilitated by the great inlet known as Puget Sound, and by other coast formations to the northwest.

That the regional sources of moisture supply which are found disturbing the regular movement suggested are to be traced (*a*) to the influence of the Gulf of California to the southwest, drawing like a huge funnel the ocean moisture and distributing it, as topographically affected, over the adjacent portions of the arid region. (*b*) To the east and south regional precipitation influences are drawn from and affected by the Gulf of Mexico. To the northeast and the north (*c*) there are vastly modifying forces drawn from the Great Lakes, and influenced also by the wide expanses of the new dominion's vast northwest, with its interior sounds, great lakes, and wide plains.

At any rate these suggestions are significant enough for consideration. The practical fact to the irrigator shown by the tables that follow is the summer difference in rainfall east and west of the one hundred and seventh meridian of west longitude.

Mean seasonal rainfall, mean normal (seasonal) temperature, and elevations of stations named, lying within the semiarid and arid region, west of the ninety-seventh meridian of longitude west of Greenwich and east of the Cascade and Coast Ranges, on the Pacific coast.

State.	Station.	Mean rainfall.			Annual average rainfall.	Mean normal temperature.		Elevation above sea level.
		Jan. Feb. Mar. Apr.	May. June. July. Aug.	Sept. Oct. Nov. Dec.		Nov. Dec. Jan. Feb. Mar.	Apr. May. June. July. Aug. Sept. Oct.	
		Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Feet.*
	I.—*On or near the ninety-seventh meridian.*							
North Dakota	Pembina	2.88	13.92	4.40	21.06	....	....	791
Do	Morehead	4.72	14.24	6.28	25.61	....	....	903
South Dakota	Yankton	5.76	15.80	5.80	27.84	23.3	62.4	1,234
Kansas	Concordia	5.32	13.60	5.88	25.58	....	....	1,384
Indian Territory	Fort Sill	6.20	15.88	9.44	32.28	43.3	72.6	1,200
Texas	San Antonio	8.56	12.80	9.92	31.63	55.9	77.2	781
	II.—*On or near the one hundred and second meridian.*							
North Dakota	Bismarck	4.80	11.12	3.76	19.57	14.6	57.1	1,681
South Dakota	Fort Sully	3.20	10.04	2.14	15.81	....	....	1,600
Nebraska	North Platte	3.44	11.84	3.80	19.11	30.7	62.6	2,841
Colorado	Las Animas	2.56	8.48	2.24	13.46	....	....	3,899
Texas	Abilene	6.00	9.72	8.24	24.78	....	....	1,748
Do	Fort Stockton	2.76	7.96	8.20	20.09	....	....	3,010
	III.—*On or near the one hundred and fifth meridian.*							
Montana	Poplar River	2.08	7.76	2.24	10.79	....	....	2,002
Wyoming	Cheyenne	6.32	6.56	7.84	9.96	29.4	56.0	6,105
Colorado	Denver	4.27	7.04	3.15	14.58	34.2	61.0	5,281
Texas	Fort Davis	1.95	10.45	6.87	17.71	48.2	69.3	4,928
	IV.—*On or near the one hundred and seventh meridian.*							
Montana	Fort Assinniboine	3.41	9.02	3.12	16.32	19.8	55.9	2,690
Do	Fort Custer	3.24	7.54	2.95	13.64	28.7	59.1	3,040
Colorado	Montrose	2.88	3.48	3.32	9.34	....	....	5,780
New Mexico	Santa Fé	2.49	7.70	4.24	13.94	33.6	59.2	7,026
Texas	El Paso	1.77	5.49	3.61	11.08	49.3	74.4	3,796
	V.—*On or near the one hundred and twelfth meridian.*							
Montana	Helena	.52	5.68	3.92	13.89	25.1	55.3	4,069
Idaho	Eagle Rock	20.20	17.40	15.40	53.47	....	....	....
Utah	Salt Lake	7.24	3.00	5.48	16.68	34.6	63.6	4,348
Arizona	Prescott	5.88	6.64	4.48	17.06	....	....	5,389
Do	Phœnix	2.40	1.44	3.00	7.38	55.9	78.0	1,120
	VI.—*On or near the one hundred and seventeenth meridian.*							
Washington	Spokane Falls	7.52	4.44	7.56	19.08	32.1	58.5	1,909
Idaho	Boisé City	6.24	2.56	4.60	13.47	35.5	61.5	2,750
Nevada	Winnemucca	3.80	1.76	2.92	8.92	....	....	4,340
California	Tehachapi	7.64	.64	2.72	11.04	....	....	3,964
	VII.—*Stations near the one hundred and twenty-first to the one hundred and twenty-fifth meridians.*							
Washington	Fort Simcoe	6.72	1.12	2.72	10.61	....	....	....
Do	Ellensburgh	3.72	1.76	3.44	8.97	....	....	....
Oregon	Fort Dallas	9.72	2.08	10.12	21.96	....	....	350
Do	Linkville	8.56	3.48	4.92	14.41	36.0	55.2	....
California	Berryvale	5.48	1.20	13.00	28.84	....	....	....
Do	Red Bluff	17.92	1.60	10.04	2[illegible].99	49.9	71.2	342
Do	Sacramento	8.44	1.56	5.80	19.69	50.1	67.4	65
Do	Stockton	8.92	.68	4.28	13.91	....	....	....
Do	Merced	7.28	.72	3.72	11.75	....	....	17
Do	Fresno	5.36	.40	3.00	8.79	....	....	295
Do	Visalia	6.72	.60	4.00	9.25	....	....	348
Do	Los Angeles	10.92	.68	4.56	16.3	55.7	67.0	371
Do	San Diego	6.68	.64	3.36	10.26	55.5	64.7	66

Chief Engineer Edwin S. Nettleton has sent in a progress report for November and December, 1890, with maps, profiles, and observations taken by himself and the assistant engineer, Mr. W. W. Follet. These latter have not been redrawn to scale and with the engineer's report will be transmitted at a later day.

Accompanying this report are attached, however, progress reports from the chief geologist, Prof. Robert Hay, special agents J. W. Gregory, of the central division, (western Kansas, Nebraska, etc.) and Joseph Nimno, jr., of the northwest division. Mr. Nimno's report covers Montana; the balance will be sent in with the final report called for under the law. In addition to these the office has been favored with a valuable report from Prof. L. G. Carpenter, of the State Agricultural College, giving a full statement of irrigation, acres cultivated and under ditch, works finished, constructed, and projected. Also papers of value from Nevada, prepared by the former United States Surveyor-General, Mr. Irish, C. E., of Reno, Washoe County, and Mr. Nichols, of the State Board of Trade, of Belmont, Nye County. Professor Hill, assistant geologist of the Artesian and Underflow Investigation, has furnished an interesting monograph on "The Imbibition of Rocks." Besides these there are attached papers on raisin and currant culture by irrigation, "Irrigation in Australia," a summary of conference proceedings had at Melbourne, Victoria, in March, 1890; also a summary of physical data relating to irrigation facts within the States and Territories west of the ninety-seventh meridian of longitude, with copies of the important circulars sent by the Irrigation Inquiry, valuable answers to which to the extent of 30 per cent. have been received. These were all prepared in this office. I am indebted to Mr. Blaisdell, my engineer expert, especially for valuable aid, and to all connected for earnest and faithful service.

Following this I attach a series of important tables and formulas, carefully proved and revised by Mr. Blaisdell, my engineer expert.

USEFUL MEMORANDA, TABLES AND ITEMS RELATING TO WATER.

The chemical composition of pure water is:

By volume—		By weight—	
Hydrogen	2	Hydrogen	1
Oxygen	1	Oxygen	8

One cubic foot of water at 62° F. = 62.321 pounds; cubic feet in 1 ton, 2,000 pounds = 32.09.

One cubic foot at 62 is 427 grains lighter than water at maximum density 39.38°, or .976 ounces, or nearly 1 ounce.

Gallons in a cubic foot = 7.4805; gallons in a cubic yard = 201.9735.

Weight of 1 gallon at 39.38° = 8.3393 pounds; weight of 1 gallon 620 = 8.3311 pounds.

At 39.38° a column of water of 1 square inch base and 12 inches high gives .433 pounds pressure. At 62° the same column gives .4328 pounds pressure.

At 39.38° a column of water of 1 square inch base and 2.3084 feet (27.711 inches) high gives 1 pound pressure.

At 62° 2.3105 feet (27.726 inches) height is required to give 1 pound pressure.

One cubic inch of water at 39.38° = .0361 pounds; 1 cubic inch of water at 62° = .03606 pounds.

One inch of rainfall on 1 acre = 3,630 cubic feet, or 27,154.4 gallons = 113.12 tons.

One foot, 12 inches, of rainfall on an acre = 43,560 cubic feet, or 325,852.8 gallons, or 1,357.44 tons.

One inch of rainfall on 1 square mile, 640 acres, = 2,323,200 cubic feet, or 17,378,816 gallons.

One foot rainfall on 1 square mile = 27,878,400 cubic feet = 208,-545,792 gallons.

A MINER'S INCH OF WATER.

This is usually estimated in the amount that will flow through an opening 1 inch square, under a head of 6 inches above the upper side of opening, this giving a discharge of about 12 United States gallons per minute. In some parts of California the head is taken at 4 inches above upper side of opening which gives a discharge of about 9 gallons per minute.

Fifty miner's inches equal 1 cubic foot per second.

To ascertain gross power for raising water, multiply the number of gallons per minute by the height in feet and divide by 2,000.

One ton of good coal or its equivalent in other fuel, will raise 5,000,000 gallons of water 20 feet high.

5,000,000 gallons will cover 100 acres 2½ inches deep, or is equal to 1 inch of water on 250 acres.

The speed of a centrifugal pump is found by multiplying the square root of the head in feet by 500 and adding 550. This gives the speed of the runner in feet per minute at the periphery.

One acre-foot of water is 43,560 cubic feet, or 1 foot of water 12 inches deep over 1 square acre.

SNOW AND ICE.

Water expands in freezing about one-twelfth of its bulk, or from 1000 to 1083.

Specific gravity of ice	0.916 Ure.
" " "	0.918 Miller.
" " "	0.9184 Abel & Bloxam.

1,595 cubic inches of water will expand in freezing to 1 cubic foot of ice.

	Pounds.
One cubic foot of ice weighs	57.135 Ure.
" " " "	57.260 Miller.
" " " "	58.632 Abel & Bloxam.

Sound ice, 2 inches thick, will bear the weight of the average man; 4 inches, a man on horseback; 6 inches, cattle and teams with light loads; 8 inches, teams with heavy loads; 10 inches, will sustain a pressure of 1,000 pounds per square foot. The ice must be sound, free from shakes, cracks, and frozen snow.

Snow is ten to twelve times lighter than an equal volume of water; that is, 1 inch of rainfall will make from 10 to 12 inches of good clear crystalline snow.

Molesworth gives the following relating to snow:

Specific gravity is 0.0833; 1 cubic inch of snow = 0.003 pound; 1 cubic foot of snow = 5.2 pounds; 1 pound of snow = 332.6 cubic inches; 1 pound of snow = 0.1923 cubic foot; 1 inch snow fall = 0.433 pounds per square foot.

The pressure of the atmosphere is 14.73 pounds per square inch at the mean level of the sea, the mercurial column standing at 30 inches.

The atmosphere will balance a column of water 34 feet high.

Common pumps will lift water by suction about 25 feet. Steam pumps will not work well with over 18 feet suction.

Each nominal horse-power of boilers requires 1 cubic foot of water per hour.

In calculating horse-power of steam-boilers consider, for tubular boilers, 15 square feet of heating surface equivalent to 1 horse-power; flue boilers, 12 square feet of heating surface equivalent to 1 horse-power; cylinder boilers, 10 square feet of heating surface equivalent to 1 horse-power.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

FORMULÆ FOR ESTIMATING THE QUANTITY OF WATER RAISED BY PUMPING ENGINES AND THE AMOUNT OF POWER REQUIRED.

Q = Quantity of water raised per minute in cubic feet.
H = Height or lift of pump in feet.
G = Gallons raised per minute.
P = Pressure in pounds per square inch due to the head or lift H, as indicated by the water-pressure gauge.
HP = Nominal horse-power or the power required to lift 33,000 pounds 1 foot high in 1 minute.
D = Diameter of pumping cylinder in inches.
S = Length of stroke of the piston in inches.

Formulæ for finding the quantity of water thrown at each stroke of the piston of a pump.

$$0.7854 \times D^2S = \text{Total cubic inches displaced.}$$
$$0.0034 \times D^2S = \text{United States gallons.}$$
$$0.0004545 \times D^2S = \text{Cubic feet.}$$
$$0.02832 \times D^2S = \text{Pounds of water } 62^\circ \text{ F.}$$

To find the nominal horse-power required to raise certain quantities of water:

$$HP = \frac{Q\,H}{529}$$
$$HP = 0.00189\,Q\,H$$
$$HP = 0.00436\,Q\,P$$

The actual horse-power required to raise water is placed by some authors from 60 to 80 per cent. over the nominal.

If the dimensions are taken in *feet* and the coefficients modified accordingly, these formulæ are applicable to the estimation of the capacity of standpipes, cisterns, boilers, and all straight cylinders with circular sections.

In these formulæ let H = the height of the standpipe, depth of the cistern, length of the boiler or water pipe in feet. All other dimensions to be in feet.

$$0.7854 \times D^2H = \text{Cubic feet.}$$
$$5.8748 \times D^2H = \text{Gallons.}$$
$$48.947 \times D^2H = \text{Pounds of water.}$$
$$0.02447 \times D^2H = \text{Tons of 2,000 pounds each.}$$

That is, square the diameter of the given cylinder, multiply it by the length, and this product by the given coefficient, and the result in each case will be in terms as stated in the formula.

Table giving the United States gallons in the number of cubic feet shown in the left-hand columns.

Cubic feet.	Gallons.	Cubic feet.	Gallons.	Cubic feet.	Gallons.
0.1	0.75	50	374.0	8,000	59,844.1
0.2	1.50	60	448.8	9,000	67,324.6
0.3	2.24	70	523.6	10,000	74,805.2
0.4	2.99	80	598.4	20,000	149,610.4
0.5	3.74	90	673.2	30,000	224,415.6
0.6	4.49	100	748.0	40,000	299,220.7
0.7	5.24	200	1,496.1	50,000	374,025.9
0.8	5.98	300	2,244.1	60,000	448,831.1
0.9	6.73	400	2,992.2	70,000	523,636.3
1	7.48	500	3,740.2	80,000	598,441.5
2	14.9	600	4,488.3	90,000	673,246.7
3	22.4	700	5,236.3	100,000	748,051.9
4	29.9	800	5,984.4	200,000	1,496,103.8
5	37.4	900	6,732.4	600,000	2,244,155.7
6	44.9	1,000	7,480.0	400,000	2,992,207.6
7	52.4	2,000	14,961.0	500,000	3,740,259.5
8	59.8	3,000	22,441.5	600,000	4,488,311.4
9	67.3	4,000	29,922.0	700,000	5,236,363.3
10	74.8	5,000	37,402.6	800,000	5,984,415.2
20	149.6	6,000	44,883.1	900,000	6,732,467.1
30	224.4	7,000	52,363.6	1,000,000	7,480,519.0
40	299.2				

From the foregoing table the number of gallons in a given number of cubic feet may be computed by simple addition.

Example.

How many gallons in 37,629 cubic feet?

30,000	224,415.6
7,000	52,363.6
600	4,488.3
20	149.6
9	67.3
Gallons	281,484.4

CUBIC MEASURE.

Inches.	Feet.	Yard.	Cubic metres.
1. equals	.0005788	.000002144	.000016386
1728. "	1.	.03704	.028315
46656. "	27.	1.	.764513

One cubic foot equals 7.48 United States liquid gallons of 231 cubic inches.

One cubic foot equals .23748 United States liquid barrel of 31½ gallons.

One cubic foot equals .803564 United States bushel of 2150.42 cubic feet.

Capacity of cisterns in barrels of United States standard, 31½ gallons.

Depth.	Diameter, in feet.										
	5	6	7	8	9	10	11	12	13	14	15
Feet.											
5.....	23.3	33.6	45.7	59.7	75.5	93.2	112.8	134.3	157.6	182.8	209.8
6.....	28.0	40.3	54.8	71.7	90.6	111.9	135.4	161.1	189.1	219.3	251.8
7.....	32.7	47.0	64.0	83.6	105.7	130.6	158.0	188.0	220.6	255.9	293.7
8.....	37.3	53.7	73.1	95.5	120.9	149.2	180.5	214.8	252.1	292.4	335.7
9.....	42.0	60.4	82.2	107.4	136.0	167.9	203.1	241.7	283.7	329.0	377.7
10.....	46.7	67.1	91.4	119.4	151.1	186.5	225.7	268.6	315.2	365.5	419.6
11.....	51.3	73.9	100.5	131.3	166.2	205.1	248.2	295.4	346.7	402.1	461.6
12.....	56.0	80.6	109.7	143.2	181.3	223.8	270.8	322.3	378.2	438.6	503.5
13.....	60.7	87.3	118.8	155.2	196.4	242.4	293.4	349.1	409.7	475.2	545.5
14.....	65.3	94.0	127.9	167.1	211.5	261.1	315.9	376.0	441.3	511.8	587.5
15.....	70.0	100.7	137.1	179.0	226.6	279.8	338.5	402.8	472.8	548.3	629.4
16.....	74.7	107.4	146.2	191.0	241.7	298.4	361.1	429.7	504.3	584.9	671.4
17.....	79.3	114.1	155.4	202.9	256.8	317.0	383.6	456.6	535.8	621.4	713.4
18.....	84.0	120.9	164.5	214.8	272.0	335.7	406.2	483.4	567.3	658.0	755.3
19.....	88.7	127.6	173.6	226.8	287.0	354.3	428.8	510.3	598.9	694.5	797.3
20.....	93.3	134.3	182.8	238.7	302.1	373.0	451.3	537.1	630.4	731.1	839.3

Diameter of a circle multiplied by 3.1416 equals circumference.
Circumference multiplied by .31831 equals diameter.
Square of diameter multiplied by .7854 equals area.
Cube of diameter of sphere multiplied by .5236 equals solidity.
Doubling the diameter of a pipe increases its capacity four times.
Friction of liquids in pipes increases as the square of the velocity.

RAINFALL MEASURES.

The following table shows the quantity in cubic feet and gallons, per acre, from one-tenth to 1 inch rainfall:

Depth of rain.	Per acre.	Per acre.	Depth of rain.	Per acre.	Per acre.
Inch.	*Cubic feet.*	*Gallons.*	*Inches.*	*Cubic feet.*	*Gallons.*
0.1......	363	2,262	0.6......	2,178	13,573
.2......	726	4,524	.7......	2,541	15,830
.3......	1,089	6,787	.8......	2,904	18,098
.4......	1,452	9,046	.9......	3,267	20,360
.5......	1,815	11,311	1	3,630	22,622

LONG MEASURE.

Inches.	Feet.	Yards.	Fathoms.	Rods.	Furlongs.	Mile.	French meter.
1 equals	0.083	0.02778	0.0139	0.005	0.000126	0.0000158	0.0254
12 "	1	.333	.1667	.0606	.00151	.0001894	.3048
36 "	3	1	.5	.182	.00454	.000568	.9144
72 "	6	2	1	.364	.0091	.001136	1.8287
198 "	16½	5½	2¾	1	.025	.003125	5.0291
7920 "	660	220	110	40	1	.125	201.16
63360 "	5280	1760	880	320	8	1	1609.315

A palm equals 3 inches.
A span equals 9 inches.
A hand equals 4 inches.
A cable's length equals 120 fathoms.

SURVEYING MEASURE (LINEAL).

Inches.	Links.	Feet.	Yards.	Chains.	Mile.	French meter.
1 equals	0.126	0.0833	0.0278	0.00126	0.0000158	0.0254
7.92 "	1.	.66	.22	.01	.000125	.2012
12 "	1.515	1	.333	.01515	.000189	.3048
36 "	4.545	3	1	.04545	.000568	.9144
792 "	100	66	22	1	.0125	20.116
63,360 "	8,000	5,280	1,760	80	1	1,609.315

One knot or geographical mile equals 6,086.07 feet or 1,855.11 meters or 1.1526 statute miles.

AVOIRDUPOIS WEIGHT.

The standard avoirdupois pound is the weight of 27.5015 cubic inches of distilled water, weighed in the air, at 30.83° Fahr., barometer at 30 inches; 27.343 grains equals 1 drachm.

Drachms.	Ounces.	Pounds.	Quarters.	Cwts.	Ton.	French grams.
1 equals.......	0.0625	0.0039	0.000139	0.000035	0.00000174	1.771846
16 "	1	.0625	.00223	.000558	.000028	28.34954
256 "	16	1	.0357	.00893	.000447	454.59
7,168 "	448	28	1	.25	.0125	12,700
28,672 "	1,792	112	4	1	.05	50,802
573,440 "	35,840	2,240	80	20	1	1,016,048

A stone equals 14 pounds.
A quintal equals 100 pounds.
7,000 grains equals 1 avoirdupois pound or 1.21528 troy pounds.
5,760 grains equals 1 troy pound or 0.82285 avoirdupois pound.

SQUARE MEASURE.

Inches.	Feet.	Yards.	Perches.	Roods.	Acre.
1 equals.....	0.00694	0.000772	0.0000255	0.00000064	0.000000159
144 "	1	.111	.00367	.0000918	.000023
1,296 "	9	1	.0331	.000826	.0002066
39,204 "	272¼	30¼	1	.025	.00625
1,568,160 "	10,890	1,210	40	1	.25
6,272,640 "	43,560	4,840	160	4	1

100 square feet equals 1 square.
1 square mile equals 27,878,400 square feet, or 3,097,600 square yards, or 640 acres.
A section of land is 1 mile square and contains 640 acres.
A square acre is 208.71 feet at each side, or 220×198. A circular acre is 235.504 feet in diameter.

PROGRESS REPORT

OF

ARTESIAN AND UNDERFLOW INVESTIGATION.

BY

ROBERT HAY,
CHIEF GEOLOGIST.

PROGRESS REPORT OF ARTESIAN AND UNDERFLOW INVESTIGATION.

By Robert Hay, *Chief Geologist*.*

INTRODUCTORY.

Summoned to Washington on the 11th of October I reached there on the 15th, was commissioned and instructed, and on my way to Nebraska on the 20th of the same month. At Lincoln I conferred with Prof. L. E. Hicks, the State geologist, who had assisted in our brief investigation last spring. Thence I proceeded to Culbertson, and Benkleman on the Republican River, making those places headquarters while examining the water supply of the main valley and those of important affluents on both sides of the Republican. Thence I examined the country across the watershed to the South and North Platte Rivers and returned to the Republican Valley through the northeastern counties of Colorado. Thence I went to McCook and then south into Kansas. At all points I had conferences with citizens interested in the work of irrigation and water supply and was enabled to give and to obtain valuable information. For 300 miles of the overland trip I had the company of Judge J. W. Gregory, and the companionship was, I believe, mutually beneficial and to the advantage of the investigation. At Julesburg, Colorado, we were delayed two days by a fall of snow; so when a second snowstorm caught me on November 16, at Norton, Kansas, I judged that it would be best to go into office quarters and make the studies of notes necessary for this report before proceeding southwest, where the weather on the plains is usually good enough to allow considerable field work to be done during the winter.

THE WORK OF ASSISTANT GEOLOGIST ROBERT HILL.

The field investigation has been fortunate in obtaining the services for work in the Southwest of Prof. Robert Hill, of Texas, who has made the water-bearing strata an important part of his geologic studies. Quite recently he has made an exhaustive report on the artesian possibilities about El Paso, at the instance of the municipal council of that city, and this gives important data as to conditions not only in Texas but far into New Mexico. Commencing work in the third week of October, Professor Hill has made observations on the artesian areas of Fort Worth, Waco, and Dallas, which, combined with his former knowledge, practically completes the field work in those localities and enables important deductions as to the position of water-bearing strata to be

*The progress report of the chief engineer, Edwin S. Nettleton, was received too late to prepare the maps and profiles accompanying it in time for this report. It will be sent in later.

made elsewhere. In Oklahoma and neighboring parts of the Indian Territory, Professor Hill has connected with my own observations, formerly made from southern Kansas near the eastern limit of the district to be investigated. He has also provisionally divided the area to be examined into convenient hydrographic and geologic districts, so that future work will be done efficiently and economically. From a detailed report of his work received November 30, I extract the following:

* * * The new well at Fort Worth is situated on the high hill in the southern part of the city, and has been bored over 1,000 feet, or some 400 feet deeper than any of the Fort Worth wells, which have averaged from 300 to 600 feet deep, and yielded only a moderate amount of water. At 980 feet the new well struck a new and better flow, aggregating 300,000 gallons per day, and of a much better quality.

The source of this water is the lowest bed of the Trinity sands, which had not before been penetrated at Fort Worth, and, with the evidence from the Waco and Austin wells, demonstrates the existence of several water-bearing strata at the base of the lower cretaceous series underlying the Grand Prairie region of Texas, and proves that each set of strata yields a different volume and quality of water. These basal strata are separated by limestone layers, and aggregate from 250 to 500 feet in thickness, as seen in the geologic section exposed between Millsop and Weatherford.

Of a district west of Fort Worth, in the Brazos, Palury, and Squaw Valleys, Mr. Hill says:

* * * The region is subject to serious droughts, and the average yield is small—from one-quarter to one-half bale of cotton per acre. Yet most of this superb flow of water is not utilized for irrigation, because the methods and benefits of irrigation are not understood.

A few farmers, however, have obtained good results from irrigation. Mr. William Lanham, who lives 6 miles west of Glenrose, has an 8-inch well which flows about 400,000 gallons per day. With this he irrigates abundantly 30 acres of land, utilizing the water only a few days in the year. Although he came to Texas from more humid regions, and had never before seen irrigation, his success has been great. He has confined his efforts to the least profitable irrigable crops (corn, cotton, and Louisiana sugar cane), and has never manured his land. The following table shows his success in a striking manner:

	Average yield without irrigation.	Yield of same land irrigated.		
		1888.	1889.	1890.
Corn .... bushels..	25	75	66	40
Seed cotton .... pounds..	250 to 500	2,200	3,000	4,000
Molasses, Louisiana or ribbon cane .... gallons..	....	....	350	350

Several other experiments in irrigation in the same neighborhood have met with equally successful results. No one has irrigated alfalfa, clover, small grains, or small fruits, which are most susceptible to profitable irrigation.

At Palney village, 10 miles west, were two irrigated farms upon which cotton was growing 2 bales to an acre.

In general, however, the waste of this water is most unfortunate, for if properly used it would be of priceless value to the agricultural interests of Texas.

The facts stated in the last paragraph by Professor Hill are repeated in Kansas, Nebraska, and elsewhere in the plains region, and show at once the necessity of a thorough investigation and the great utility that may be expected from a publication of results. How definite results may be obtained by an investigator of experience is illustrated in further extracts from Professor Hill:

Concerning the artesian conditions of the Grand and Black Prairie regions of Texas the following rules can now be formulated with a remarkable degree of certainty:

(1) Artesian wells are obtainable in any locality where altitude is less than 750 (700?) feet above mean sea level.

(2) Wells can be obtained on all the uplands east of the junction of the Black and Grand Prairies and throughout the Lower Cross Timbers.

(3) Wells can be obtained in the valleys only west of the above line.

(4) The depth of wells decreases at about 50 feet per mile to the westward and increases at the same rate to the eastward.

(5) There are at least two principal water-bearing strata, some 250 feet apart, and often others, all differing in volume and quality. The lower one is usually the best and greatest.

THE COST OF IRRIGATION METHODS.

In this investigation the question of the cost of putting water on the land, whether by ditches from the surface or underflow, or from artesian wells or by pumps or water lifts, is one of the greatest importance to the beginners in irrigation. I understand that it will receive full attention from the engineers of the Department. It is mentioned here to say that there are scattered over the plains examples of individuals trying to work out their own salvation from drought by irrigating by methods within their reach. Some of these cases have come under the notice of the writer, and are as strikingly successful as those given above from Texas:

1. In 1873 Mr. George Allaman settled on lands of the Smoky Hill River bottom, a little above Fort Wallace, Kans. He duly proved up his homestead, and in his statement of improvements on the land described a ditch into which he took the first surface water of the river. He has sold vegetables to the fort and the town ever since, and has raised alfalfa and other forage in the driest of years, and has been always successful.

2. Two miles below Culbertson, on the Republican River, in Nebraska, a Mr. Gessleman, 3 years ago, put in a water elevator to irrigate 3 acres of land. The machine is simply a series of boxes, forming a chain like a grain elevator, and there are ten of these chains moving about a common axis, and the power is supplied from a common horse gin. The source of the water is a spring-fed bayou, in the side of which a box is placed, into which the series of elevators dip. A sufficiency of water for the 3 acres was raised by two horses this last season without storage, and besides onions, cabbage, and other vegetables the owner marketed 2,000 quarts of strawberries at 20 cents a quart. Thus in dry seasons, for the rest of the farm, a few acres saved it from making the owner poor. In this case water was raised 12 feet. It could be as easily raised a few feet higher on neighboring land and a much larger area irrigated. The cost with horses is perhaps relatively high, but farmers usually have horses that are often idle.

3. Above Benkleman, in Nebraska, a spring-fed creek (Horse Creek), just where it enters the Republican valley, is very slightly dammed, and its water taken in a pipe under the railway to irrigate about 12 acres of a farm occupied by Mr. Nisbet. Four acres of cabbages, each from 15 to 25 pounds weight, 3 acres of fine potatoes, 8 bushels to the acre, and sundry fruit trees and vegetables in proportion show the power of the soil of that valley under proper conditions.

4. In the Prairie Dog Valley of Decatur County, Kans., 10 years ago, a dam was built and a mill race constructed. This raised the water about 8 feet, and ever since then land contiguous to the mill pond and race has by the seepage of both been made productive in the driest years. A farmer seeing this has built a dam a quarter of a mile below and similarly influenced 32 acres of land, and this fall has built another dam to bring under similar conditions 40 acres more. In the neighborhood this is called sub-irrigation, though it is not what is usually so designated. A small tract has been similarly treated in the valley of

the Sappa, in the same county, near Oberlin. It is not improbable that numerous small areas, aggregating altogether a large amount of surface, may thus be made fertile in the sandy alluvia of many Western valleys.

The character of the alluvia should be first examined or this simple method of using water may be a failure.

There are cases where small areas have been irrigated by water pumped from deep wells on high prairie land, as at Imperial, Chase County, Nebr., and it seems probable that areas of from 5 to 15 or 20 acres on a large number of farms could in this way be irrigated by means of wind pumps or horse-power. One well 240 feet deep with a small pump gave water, which we measured at the rate of 90 gallons per hour with a moderate breeze. By a storage tank this well with a somewhat larger pump could irrigate 10 acres.

At Dodge City and Hartland on the Arkansas, in Kansas, and also above Ogalalla on the Platte, in Nebraska, the subflow of those river valleys has been tapped and is being led out into lengthy ditches for irrigation. The underflow of the Big Sandy is to be utilized at an early date in the same way in eastern Colorado. There are large schemes for hundreds of miles of ditches for the utilization both of surface waters and underflow which will in time make fruitful large areas of the subarid plains. But the writer believes that the small attempts at irrigation from artesian wells, as in the Dakotas and Meade County, Kans., and as before mentioned in Texas, from small streams and springs as described above, and by pumping from wells, as previously indicated, will be the first means to bring irrigation largely into use on the plains away from the great rivers. These things can be made or used at small cost on acres sufficiently large on each farm to save the farm from ruin in the driest seasons. The examples now in existence can be brought to the notice of others, and their methods numerously imitated before the larger schemes can be in operation. In this way the hundreds of farmers may get over the first difficulty of irrigation and multitudes of small cases become demonstrators of the fertility of the plains.

RIVERS OF THE PLAINS AND MOUNTAINS IN CONNECTION WITH IRRIGATION.

The question as to the sources and quantity of water available for irrigation in the plains region is the one which the geologists of this investigation are mainly concerned to answer. The artesian supplies in the Dakotas and elsewhere has had some notice in the preliminary report of last summer's work. It will have more exhaustive treatment at a later date. The examination of more apparent supplies of water can be referred to here so far as to show the methods of investigation.

If the area between the Niobrara of Nebraska to the Red River of Texas be called the mid-plains region, an examination of the map will show that a very important fact groups the rivers of the mid-plains in two classes:

(1) Rivers whose origin is in the mountains.

(2) Rivers whose origin as well as course are in the plains.

The first rivers have their headwaters as mountain torrents made cold and plentiful by the melting of the snows and the abundant rains of the high Rockies. The rivers of the second class have their first channels merely as shallow sandy or gravelly depressions in a rolling prairie with rarely any water to show. Reaching a certain depth or

A River of the Plains.

rather cutting through a certain deposit these stream beds have water thenceforward. The Republican has no permanently running water west of the one hundred and third meridian. Smoky Hill only shows water east of the one hundred and second. Long affluents like the Prairie Dog and Saline only cut to their water base about the one hundred and first degree.

The source of the waters of the rivers of the plains is the rainfall of the region. The soil and especially the alluvial débris of the dry arroyos is very absorptive, so the waters find their way down into the sands and gravels of the water courses, and, slowly percolating, issue as isolated springs, or those numerously supplying waters for the lower stream courses.

If the streams and underflow of the rivers of the first class, as the Platte and the Arkansas, are sufficient for the irrigation of the land on each side of their valleys a glance at the map will show that large areas of the plains region if irrigated must be furnished by supplies obtained on the plains themselves, from the plains rivers, and the sheet water or underflow of the interfluvial high prairie.

THE UNDERFLOW.

It is believed that this irrigation will show whether the term *underflow* is justly applicable to waters generally on the plains or must be restricted to the larger river valleys. One fact is already well determined, viz: That the water in the wells of the "divides" or plateaus between the longer affluents of the rivers of the plains is obtained at a nearly uniform depth for each divide, but very various for the different divides. The plateau north of the Frenchman, in Chase County, Nebr., has wells over 100 feet deep near the Colorado line and increasing gradually to 300 eastward. The divide south of the Frenchman has the wells from 240 feet down decreasing southward. The high prairie of Meade County, Kans., has wells from 150 to 180 feet for long distances. Further west the wells increase to 80 feet. Careful observations with engineering instruments will show what relation these depths have to the neighboring water courses and whether the water under the plateaus is in a succession of reservoirs whose overflows are the springs and rivers of the region, or whether it may be called an underflow or a series of underflows. The facts already collected warrant the expression of the opinion that the water is found in the same formation from the Niobrara to the Cimarron and that no water from the mid-plains comes from the Rocky Mountains except that in the beds and valleys of the rivers of the first class.

If the time of the investigation allows it is proposed to treat the rivers of the plains (second class) in an exhaustive manner as to the source and quantity of their waters and their relation to the waters beneath the interfluvial plains. The treatment would be in groups about thus:

1. The Loup Rivers' group, in Nebraska.
2. The Republican group.
3. The Smoky Hill group.
4. The Cimarron group.
5. The Red River and Pecos group.

Conditions similar to those in some of these groups are believed to exist in regions far to the southwest and this to be verified or other conditions noted. To fully work out the investigations suggested and more completely to define the artesian basins of the Dakotas, Montana, and Wyoming are the tasks before the geologists engaged on the work. As one method towards its accomplishment it is intended to survey certain selected meridional lines showing the relative elevations of high prairies, river valleys, and underlying waters; to give the topographic profile and the geologic section indicating the water bearing compound rocks with their outcrop and other relations. Conference with my colleague, Colonel Nettleton, the chief engineer, has been had on this point, and we believe that by our joint work such a presentation of the sources of the water supply of the plains as will secure large benefit to agriculturists as well as to the capitalists and engineers, who, with this information, will be able to reduce large areas of the now lonely wilderness to the conditions necessary for the best development of man.

PROGRESS REPORT

OF

CENTRAL DIVISION OF THE GREAT PLAINS.

BY

J. W. GREGORY,

SPECIAL AGENT ARTESIAN AND UNDERFLOW.

PROGRESS REPORT OF CENTRAL DIVISION OF THE GREAT PLAINS.

BY J. W. GREGORY,
Special Agent, Artesian and Underflow Investigation.

Among the instructions received I note the following:

By or before the 1st day of January, 1891, you will forward to this Department your written progress report on the general subject, as seen and understood by you, of said underflow and artesian waters.

In accordance with such instruction I would respectfully report as follows:

At times alone, and at others in company with Col. E. S. Nettleton, Chief Engineer of the United States Irrigation Investigation, and with Prof. Robert Hay, Chief Geologist, I have made personal examination of various portions of western Nebraska, western Kansas, and eastern Colorado, supplementing, as far as practicable, the information gained in the artesian wells investigation from April to July last.

PHYSICAL CONDITIONS OF THE DIVISION.

The field assigned me, embracing the middle portion of the Great Plains, is a region not only wide in extent, but, as investigations show, also rich in possibilities. As to surface, it consists of a number of more or less distinct drainage areas, varying in size and irregular in outline; but, for the most speedy, thorough, and economical employment of irrigation neither the whole nor any part is an excided or independent area, but each and all constitute simply a part of a complex, interlocking and interdependent system, whose western bound is the crest of the Rocky Mountains, its southern the Rio Grande and the Gulf, its eastern the Missouri, and its northern, in part at least, extraterritorial.

METHODS OF INVESTIGATION.

The method employed in the investigation is to study the extent and peculiarities of the various drainage areas, noting the superficial characteristics which not only often indicate quite clearly the quantity of the subwater supply, but so largely affect the methods and economy of procurement and utilization of the same for irrigating purposes. With these are noted and synthetized the facts drawn from a careful study of springs and spring-fed streams, of erosion and outcrop of geological formations, and of the depths, capacities, and stratifications developed by the wells in the territory defined.

At two places in the valley of the Arkansas River and at a like number in the Platte Valley in southern Nebraska, "fountains"* constructed to tap the underflowing waters of those valleys are producing very satisfactory results by bringing large quantities of water to the surface. These have been producing water to such an extent, and for such a length of time, accompanied by such indications of permanency of supply that there is reason to hope for most extensive benefits from this method of obtaining water for irrigation in favored localities.

Excepting the foregoing specific developments, and, further, the artesian wells, used for irrigation in Meade County, Kansas, described in my report in the artesian wells investigation (which wells have been somewhat increased in number, with indications of a slight decrease in flow), but little more than outlines and generalizations can be given at the present stage of investigation. A careful study, however, of the surface characteristics of the Plains country, its valleys and "divides," its "draws" and their outcrops, its springs, sand beds, streams, and pools, together with an intelligent consideration of the facts to be drawn from a knowledge of the wells and borings made by private enterprise throughout the region, show forth its subterranean aqueous resources as clearly and with as much certainty as a man's character may be judged from his face and an intimate acquaintance with his daily conduct, and I have learned to detect with readiness many important facts concerning the invisible irrigation resources of any portion of the plains; yet there are as many modifiers of such surface indications as there may be of the opinion of an individual, which one may form at first sight. So every new experience, in such an investigation as the present one, is, to a greater or less extent, a modifier of opinion and a teacher of caution. But, to the present time, all the facts I have been able to gather, in this inquiry, have but confirmed the opinion expressed in my previous report, already referred to, that the subterranean waters of this portion of the Great Plains constitute a sufficient factor to solve the problem of the entire reclamation of this region to agricultural occupancy.

Frankly acknowledging the possession of an earnest hope that such may be the case, and that the fact may soon be made clear that the irrigation resources of the plains may be sufficient to completely protect them from the uncertainties and losses incident even to partial aridity, and being aware of the bias such desire may be expected to cause in the formation of opinion, I have taken great pains to regard only established and mathematically demonstrated facts in arriving at the conclusions expressed, and believe that I neither have made nor shall make any statement concerning the same which the near future will not fully justify and confirm. Upon filing my final report I expect to incorporate therein valuable proofs of the correctness of the conclusions herein and heretofore stated. There is great embarrassment, however, in the fact that, while so wide a field ought to be studied to show such results as will be conclusive even as to any single part, the time and facilities allotted to the work are so scant that there is little room for expectation that the investigator will do credit either to himself or to the work under his hand.

*The Chief Engineer, after consultation, and with the approval of Department and this office (Irrigation Inquiry), has decided to use the term "sub-canal" to express the character of the excavations made in the valley sand stratum. They are open cuts run westward with plane of the river seepage, and supplied with water by that natural process.

PROGRESS OF IRRIGATION IN THE NORTHWEST.

MONTANA, IDAHO, EASTERN WASHINGTON, AND OREGON, IN 1890.

BY JOSEPH W. NIMMO, JR.,

SPECIAL AGENT FOR MONTANA, IDAHO, EASTERN WASHINGTON, AND OREGON.

PROGRESS OF IRRIGATION IN THE NORTHWEST.

MONTANA, IDAHO, EASTERN WASHINGTON, AND OREGON, IN 1890.

By Joseph W. Nimmo, Jr.,

Special agent for Montana, Idaho, Eastern Washington, and Oregon.

After Mr. Nimmo's appointment as special agent in connection with the Irrigation Inquiry Office, he was assigned to an investigation of western Montana, Idaho, and of Oregon and Washington east of the Cascade range. The following report, dated Spokane Falls, Wash., December 30, 1890, has been received:

MILES CITY, MONT.

The chief irrigating work in the vicinity of Miles City is the Tongue River Canal, constructed and operated by the Miles City Irrigating Company, of which Mr. George Scheetz is engineer. This ditch is now 22 miles long, having been extended 9 miles since the Senate committee visited this place in 1889. The entire work has also been improved. It has yet to be extended 6 miles, which will make the total length 28 miles. The prism of this ditch is 28 feet wide on top, 20 feet on the bottom, and 4 feet deep. It carries 3 feet of water; the grade of the ditch in its upper portion is 4 feet to the mile, giving a flow of about 2 miles an hour. The grade of the lower part of the canal is 2 feet to the mile, giving a flow of about 1 mile an hour. This canal is not puddled, and the soil is of such a nature that it holds water very well. About 10 miles from the town there is a distributing reservoir containing about 5 acres, with a depth of 6 feet. Five feet of water can be drawn from the reservoir. The Tongue River rises in the Big Horn Mountains, and the flow of water is sufficient during the summer months to supply all the water "covered" by the canal. In this connection I would remark that the expression "land covered by a ditch or canal" is generally understood to mean the land which could be served with water by such a ditch or canal provided the ditch or canal carried sufficient water to irrigate the whole. Such lands are said to be "under ditch." It appears advisable to follow the terminology of the country. The ditch of the Miles City Irrigating Company covers 30,000 acres of land, of which about 15,000 acres are now irrigated. The crops raised on these lands are wheat, oats, a small variety of corn, known as squaw corn, barley, and the various cultivated grasses.

Beside the large Tongue River ditch first described, there are three other ditches on that river ranging from 2½ to 4 miles in length.

On Ottar Creek there are two ditches, one 3½ and the other 4⅞ miles in length.

On the Rosebud River there are now 15 ditches, irrigating from 200 to 800 acres each. About one-third of these works have been constructed since the visit of the Senate committee in the year 1889.

At Rosebud Station there is a ditch 5 feet wide on the bottom and 1½ feet deep, which is supplied with water from the Yellowstone River by means of a steam vacuum or Hufner pump, having a capacity of 2,000 gallons of water per minute. The smaller ditches of this section generally have a grade of 1 foot to 1,000 feet or 5.28 feet to the mile. It is found that the shallower ditches are less liable to scour than the deeper ditches.

The market for all the farm produce of the Yellowstone country is local, and besides, large supplies are shipped in from the Eastern States. This is essentially a cattle-raising country, but the range cattle business is becoming more and more allied to farming. Stockmen now come into Miles City even from a distance of 150 miles for horse feed. Sheep raising is increasing faster in this valley than that of cattle.

In Colorado the irrigating season is reported to be from April 20 to October 1, whereas here it is only from May 1 to October 1.

By an inch of water is here meant the quantity of water which will flow through an inch square orifice under a 6-inch pressure. The people along this portion of the Yellowstone Valley are very anxious for the extension of irrigating works, as the development of the country is entirely dependent upon irrigation. Nothing of importance has been done in Dawson County in the construction of ditches since the visit of the Senate Committee in 1889.

ARTESIAN WELLS AT MILES CITY.

Mr. T. J. Porter, of Miles City, has described for me the artesian wells of Miles City, as follows:

> I can now from my own knowledge count twenty flowing wells. Some of them furnish water to irrigate 2 or 3 acres of truck-farming land; others furnish sufficient only for domestic use for two or three families. Most of these wells cost from $1.50 to $2 per foot, including tubing for the entire depth; however, through the improvement of machinery for drilling and the reduction of the cost of labor, such wells can now be put down, with tube and everything complete, for from $1 to $1.25 per foot. If the well is cased with good iron tubing, having in it a rubber joint just above the stratum in which the water is found in order to keep the water from coming up on the outside of the casing, there is but slight diminution in the flow of the wells at any time. The oldest of these wells were put down in 1884 and 1885.

Mr. T. J. Porter also informs me that the flowing artesian wells of Miles City have a depth of from 450 to 500 feet. The water in them would rise to 12 to 18 feet above the surface of the valley. These wells are all on the south side of the river. Mr. Porter mentions the remarkable fact that on the north side of the Yellowstone River, opposite Miles City, there is an artesian well having a depth of only 160 feet which raises water about 30 feet above the surface and yields about four or five times as much water as any well on the south side.

ARABLE LANDS SITUATED BETWEEN THE MAIN DIVIDE OF THE ROCKIES ON THE WEST AND THE BIG BELT AND SNOW MOUNTAINS ON THE EAST.

The area here referred to comprises three large and fertile valleys, viz, the Gallatin, the Madison, and the Lewis and Clark or Prickly Pear. The largest of these is the Gallatin Valley. Bozeman is the commercial center of Gallatin County. Here irrigation is apparently more advanced than in any other county of the State, although this county is more elevated than any other irrigated portion of Montana. The total area of the Gallatin and Madison Valleys is given at 345,600 acres, the dimensions thereof being an average length of 30 miles and a width of 18 miles. It was stated that there are about 75,000 acres of land "under ditch" in Gallatin County, of which about one-half is actually irrigated. Since the visit of the Senate committee in 1889 there have been two large ditches taken out in this valley. One of these is 20 feet wide at the bottom, 18 inches deep, and nearly 13 miles in length. The other is the West Gallatin Ditch, about 30 miles in length and diminishing in width from 24 feet at its head to 15 feet at its lower end. It is expected to serve 50,000 acres of land, almost all of which is now owned by the Govenment or the Northern Pacific Railroad Company. This latter work is attracting much attention. The president of the company, Mr. Henry Altenbrand, of Brooklyn, has engaged in this work as a source of barley supply on account of the recent increase in the duty on imported barley from 10 to 30 cents a bushel. He declares that there is no barley in the world superior to that of Montana, and particularly that of the Gallatin Valley. In this connection Mr. Lamborn, land commissioner of the Northern Pacific Railroad, states that that the protection afforded to barley by the recent tariff act will greatly inure to the benefit of raisers of barley in Minnesota, the Dakotas, and Montana.

Since the visit of the Senate Committee on Irrigation in 1889, the Kleinschmidt Ditch has been extended and it is now 15 miles in length. There are now between two and three hundred small irrigating ditches in Gallatin County. There is no artesian well in this part of the county. A boring was made to a depth of 400 feet without reaching water. Canada corn is grown to a limited extent in the lower part of the county, but not near Bozeman. Irrigation in the Gallatin Valley is generally by "flooding." It is found in the irrigated portions of Gallatin County that land is becoming so full of water that drainage is necessary. Drain-pipes are now being laid. Twenty-four years ago water was not found even at a depth of 60 feet. Now, in the same localities, wells reach water at a depth of only 14 feet, and when all the irrigating ditches are in operation water rises to within 6 or 8 feet of the surface. This indicates not only a porous soil, but it points also to the general fact that as the years pass, such soils need much less water than in the beginning. In most cases drainage must eventually accompany irrigation. It has also been found that the beds of streams, where cattle and sheep walk during low water, have thereby become puddled, and that this has considerably increased the supply of water in such streams available for irrigation, the waste of seepage being practically prevented thereby.

By virtue of the fact that the supply of Montana is very much less than the consumption, the price of agricultural products is generally the price in St. Paul or Minneapolis plus the freight to local points of consumption in Montana. The following are some of the quotations in Bozeman November 18, 1890:

Wheat, best	per bushel..	$0.90
Oats	per 100 pounds..	1.35
Barley	do....	1.12½
Potatoes	per pound..	.01½
Hay	per ton..	3.00

PHENOMENAL RESULTS IN THE GALLATIN VALLEY.

The following data as to exceptionally large or phenomenal crops as the result of irrigation, in Gallatin County, were furnished to me:

First. A farm on Cottonwood Creek, belonging to a Mrs. Godson, yielded on a certain 40-acre tract, 5,000 bushels of oats or 125 bushels to the acre.

Second. Mr. Hoffman, president of the National Bank of Bozeman, has produced on a small farm 110 bushels of oats to the acre.

Third. The highest wheat yield recorded in Gallatin County is 69 bushels to the acre.

Fourth. A hay field belonging to the county treasurer cut 3 tons to the acre; the hay was sold for $15 a ton and netted a profit of $30 an acre.

Fifth. Mr. Patterson, county treasurer, planted potatoes this year on 8 acres of land within 1 mile of Bozeman. He had them dug and sold the crop lying on the ground for $1,200. The net profit of the crop was stated to me at $800, or $100 an acre.

Just here it appears proper to observe that lack of water is the great obstacle to agricultural progress not only in Montana, but throughout the arid region. No attempt has yet been made to store the waters of Montana. All the irrigating ditches, large and small, are simply taken out of streams and dependent alone for supply when the water is running in such streams. The result is, already, that in midsummer, when these streams run low, there is not water enough to supply all the ditches or canals taken out on any one stream. A proper storage of water during the spring months would obviate all this in the Gallatin, Madison, and Prickly Pear Valleys. This water supply could be greatly increased by the construction of storage dams at favorable locations. In certain cases such dams would cost but little, and yet the work is so much of a public nature that private enterprise hesitates about engaging in it. In this connection it may be stated that the laws of Montana fail to make clear and to adequately protect the water rights of individuals in case of a lack of water. An adequate supply of water through a judicious system of storage would obviate such difficulties, because generally the water supply could be made to exceed the demand for the irrigable lands of the State.

A considerable portion of the land of Gallatin County is allowed to lie fallow every alternate year, but much land is cultivated every year. No fertilizers are used, reliance for fertilization being had upon the silt brought down by the waters of irrigation.

The period of growth for barley in Gallatin County is 90 days from planting to reaping.

AT HELENA.

The irrigable or arable lands of Lewis and Clarke County are chiefly embraced in the watersheds of the Big Prickly Pear Creek, the Little Prickly Pear Creek, the Dearborn River, and their tributaries. The three streams just mentioned empty into the Missouri River. During the past year (1890) several ditches in course of construction have been extended and some of them completed. There are now about 200,000 acres of land under cultivation in Lewis and Clarke County. Mr. W. C. Child, of Helena, who is engaged in farming, dictated to me a statement which is so clear and closely connected that I present it substantially as he gave it to me.

Mr. Child expresses the opinion that water enough flows from the mountains, which, if stored in reservoirs, would be amply sufficient to irrigate all the agricultural lands of the State.

The topographical features of the Prickly Pear watershed are such that at a point best suited to serve the entire valley a dam can be constructed at a cost not to exceed $50,000, thereby creating a reservoir with a capacity of 600,000,000 gallons of water. He also believes the natural conditions are such as to admit of the construction of a series of such dams. He believes that the flow during the first week of the spring rise would be sufficient alone to fill all of these reservoirs. The spring flow usually occurs during the months of May and June and usually continues from 4 to 5 weeks. By means of such reservoirs the most valuable lands and particularly those producing hay could be reached. What is true of Prickly Pear Creek Mr. Child believes is substantially true of the State, viz, that at comparatively small expense, extensive irrigable lands can be reclaimed. Mr. Child suggests the desirability of such legislation as will make it possible for individuals or corporations to acquire the title to such portions of the public domain as may be necessary in order to enable them to construct storage reservoirs.

Mr. Child has an artesian well at the foot-hills of the mountains 6 miles east of Helena, and three-quarters of a mile west of Prickly Pear Creek. It has a water supply at the depth of 20 feet, 40 feet, and 80 feet. It passes through a sort of sandstone formation. This well yields water for domestic uses and the supply of cattle. Nowhere in Montana, except at Miles City, have I found any instance of an artesian well yielding water for agricultural purposes, or a belief in the minds of the people that any such supply is available.

Mr. Child has, during the past year, been engaged in the development of the underflow on McClelland Creek, a branch of the Prickly Pear. This has been done by what he terms "running a bed-rock drain." This expression has the significance given to it by the miners.

They call everything "bed rock" which holds placer gold, even if it be clay. Mr. Child means by "bed rock" any strata which holds water. He believes it to be true that nearly all the streams of the State have an underflow through gravel beds, varying from 5 to 80 feet in thickness; that a large proportion of such waters are retarded or held back during the entire season of irrigation, and could be tapped and rendered available for irrigation by means of tunnels and other underground drains.*

Mr. Child states that the usual time of harvesting the hay crop in the vicinity of Helena is from the 6th to the latter part of July. At this time the fields are irrigated and a second crop matures in about 2 months. Then water is applied again, and it puts the land in the best possible condition for an early crop the next spring or for early plow-

* Since Mr. Nimmo's return Mr. Child's experiment has been demonstrated to success, and a flow of over 100 miners inches has been obtained by a bed-rock drain he has driven. A larger supply is expected from an extension now in progress.

ing. The seasons of 1889 and 1890 were the driest ever known in the history of Montana, and particularly in the Prickly Pear Valley. But notwithstanding this fact, Mr. Child states that on irrigated bench or foot-hills lands he cut two crops of timothy and clover mixed, which yielded 2 tons per acre at each cutting.

Mr. Child, in closing his statement, said that in the vicinity of Helena there was harvested, in 1876, oats, wheat, and barley which took the first prize at the Centennial Exposition at Philadelphia, and at the World's Fair held at London. This year small areas of land have yielded 800 bushels of potatoes per acre, unsurpassed for quality in the United States. The experiment of raising wheat from seed brought from the extreme northern part of Russia, and supplied by the Department of Agriculture, has proved a splendid success both as to yield and quality. The experiment of growing the sugar beet, from seed supplied by the Claus Spreckels Sugar Refinery Company, has succeeded equally well. There was harvested on a small tract of land near Helena, in the year 1876, wheat which yielded 113 bushels to the acre. This is attested by the Board of Trade of Helena, in a document which I have already sent to the Department. I have heard of no other yield of wheat which equaled this.

Wheat has been produced in this vicinity weighing 65 pounds to the bushel, barley 55 pounds, and oats 51 pounds. The heaviest cabbage on record weighed 48 pounds. Onions from the seed yield, in quality, equal to the best Bermuda.

Mr. John B. Wilson is president of the Crown Butte Canal and in charge of Wilson & Thompson's system of irrigation and reservoir systems, both in Cascade County, about 90 miles from Helena. He thinks the present mode of irrigation, including all the large corporate enterprises, will not cover more than from 10 to 12 per cent. of the land and that a system of reservoirs is greatly needed.

The Dearborn River irrigating works embrace a larger provision for the storage of water than any other enterprise of the soil to which my attention has been directed in Montana. This work has a reservoir in the mountains, formed by a dam 108 feet high, 250 feet thick at the base, and firmly connected to the rock at both sides. By means of a cut 80 feet deep and a tunnel the water is carried from the Dearborn River into Plat Creek. This enterprise is being carried on by a corporation of which Mr. Donald Bradford, mayor of Helena, is president. The enterprise as yet is in its infancy. There are now 28 miles of the main canal completed, which is 38 feet wide at the top and 28 feet wide at the bottom. Its grade is 3.1 feet to the mile. The canal flows through a sandy loam which puddles itself. There are 1,500 feet of fluming on the line, the flume being 14 feet high and 6 feet deep, with a grade of 4½ feet to the mile. The entire works, including reservoir and flume, have cost an average of $15,000 a mile. It is found that where riprapped the bottom and sides do not scour or become injured with a fall of 3.1 feet grade to the mile. It is expected that the Dearborn River Canal will eventually irrigate 75,000 acres of land. The company is not the owner of any of the lands to be irrigated, but will sell water to land owners. In this respect the enterprise differs from all other irrigating enterprises to which my attention has been directed, the general assumption being that the chief profit of irrigating enterprises must be expected to be realized from the enhanced value of lands purchased at low rates by the constructors of the irrigating works. The Dearborn Canal Company is now selling water at $1 per acre for the season of irrigation. Mr. Bradford estimates that the total cost of the works will be about $150,000, or $2 an acre for the land covered by water. It will be observed that this is the largest irrigating enterprise between the main divide of the Rockies and the Belt Mountains, as it covers 75,000 acres while the Belt-Gallatin Canal covers only 56,000 acres.

PROGRESS MADE IN THE CONSTRUCTION OF IRRIGATING WORKS BETWEEN THE MAIN DIVIDE OF THE ROCKIES AND THE BELT MOUNTAINS SINCE THE VISIT OF THE SENATE COMMITTEE ON IRRIGATION IN 1889.

The following statements in regard to papers were made to me by Mr. John B. Wilson, of Helena. Quite a number of small ditches have been taken since the visit of the Senate committee in 1889, no record of which is preserved; also the following large ditches:

(1) The Crown Butte Canal, in Cascade County, near Fort Starr, 10 feet wide at the bottom, 18 feet wide at the top, and carrying water 3 to 4 feet deep. The main canal is 22 miles in length. The total length of the canal, including laterals, being 40 miles, begun this year and finished this year. The main canal has a grade of 2 feet to the mile, believed to be about right for a canal of its size. It is riprapped on the exterior side of curves. Puddling is not resorted to. Several ditches puddle themselves.

(2) The Choteau Canal, of Choteau County, beyond Great Falls. The size of this canal is not known by Mr. Wilson. It was begun this year and will cover about 100,000 acres of land.

(3) The Dearborn Canal, already described.

(4) The West Gallatin Canal, already described.

The Crown Butte Canal, which is taken out of the Sun River, will feed the reservoir of the Muddy Creek Canal, a part of the Wilson & Thompson Canal and Reservoir System. The Muddy Creek Canal will also draw supplies from Lepley Creek, Eagle Rock Creek, and Muddy Creek.

Mr. Wilson believes that there is ample water, if stored in these lateral valleys opening into the Missouri River Valley, to supply all the irrigable lands in this section of the country.

At "The Gates of the Mountains" the Missouri River debouches into a vast prairie and plateau country stretching far to the east and to the north beyond the Canadian border line. The question as to the reclamation of this vast area is a very large one and involves considerations which there was not sufficient time to investigate or to consider with sufficient care to enable the offering the Department any well-matured views.

Very little has been done since 1889 in the Missoula and Bitter Root Valleys. The side streams are not sufficient, by their natural flow, to supply the land. Storage reservoirs are greatly needed and can alone supply the necessary water of irrigation. The bench lands above the valleys are the best lands. These are not now reached to any considerable extent. The Flathead Valley and the Horse Plain Valley are arable without artificial irrigation, for the reason that they have a rich soil on the clay subsoil; but the Bitter Root, Missoula, and Frenchtown Valleys have a gravelly subsoil, and therefore need irrigation. There is no artesian well in this vicinity. The Missoula Valley appears to be just at the eastern end of the Pacific slope fruit country, which will hereafter be more fully described.

Incidental to the collection of other data at Helena, the following facts were obtained in regard to the cost of constructing irrigating works. Mr. John B. Wilson states that on Crown Butte Canal there has been paid 9 cents per cubic yard for earth work, 25 to 30 cents for loose rock and cemented gravel, and 50 to 60 cents per cubic yard for solid rock. Laborers are paid from $2.25 to $2.50 per day. No Chinese labor is employed. It is found that the Chinese although agile lack the physical stamina for severe physical labor.

It was stated in the office of the board of trade, the mayor of the city being present, that about three-fourths of the agricultural products consumed in Montana excepting hay, are shipped into the State from abroad, and that some hay comes in from Minnesota. Cheapness of product depends mainly upon the price at which the water of irrigation is procured and distributed. In a word, a large proportion of the wheat, oats, corn, and vegetable food generally comes in from abroad. The demand for such products in Montana is growing faster than the supply within the border of the State.

Irrigable seasons and frosts.—The irrigable season of the Prickly Pear and other valleys bounded on the west by the main divide of the Rocky Mountains is from April to August for cereals and all crops except hay. Early frosts in August which elsewhere blast wheat "in the milk" are unknown here. Sometimes plowing is done during the entire month of March. Occasionally early plowing begins about the 15th of February. Wheat, oats, barley, and hay are never injured during the season of harvesting. Hay is always preserved, a fact indicated by color when thoroughly cured. Frosts which kill vegetation usually occur about September 15.

Fruit.—Montana east of the main divide of the Rocky Mountains is not much of a fruit country. The small fruits, currants, gooseberries, and berries, however, flourish luxuriantly.

Sub-irrigation and sub-drainage.—From all the statements of fact and opinion which have engaged my attention, it appears that the question of sub-irrigation and sub-drainage depends entirely upon the physical characteristics of the soil and subsoil. Mr. Albert Kleinschmidt, of Helena, who has studied this subject closely in California, Washington, and Montana, states that a gravel subsoil effectually obviates the necessity for sub-drainage, whereas a sandy subsoil in time packs and becomes impervious from the silt carried by the water of irrigation. In California the subsoil is generally decomposed granite which packs tightly and needs sub-drainage. In Montana, on the other hand, the valleys have usually an underlying layer of gravel and bowlders which afford ample subdrainage. Mr. Kleinschmidt thinks that there will be no need of sub-drainage nor occasion for sub-irrigation in the State of Washington, for the reason that the central and eastern portions of the State are underlaid by a porous decomposed lava or basaltic rock. In his view sub-irrigation is an expedient of the future, being altogether too expensive now.

The duty of water.—It seems very difficult, if not impossible, at the present time to arrive at any clear statement as to the duty of water, owing, first, to the fact that there are at least eight or ten definitions given as to the term "an inch of water" or a miner's inch;" second, that the modes of measuring water vary; third, the service of water in irrigation varies in different parts of the country, owing to difference in evaporation, leakage, and the different quantities required for different crops.

ARTESIAN WELLS IN THE VALLEYS BOUNDED ON THE WEST BY THE MAIN DIVIDE OF THE ROCKY MOUNTAINS AND ON THE EAST BY THE BELT MOUNTAINS.

An unsuccessful attempt to secure artesian water in the Gallatin Valley has been mentioned; also the well at East Helena, a flowing well put down by Mr. W. C. Childs, which is useful only for watering cattle. An artesian well was sunk by Dr. D. C. Brook, of Helena, within the city limits. This well is located at a point about 200 feet above the Prickly Pear Valley. It is down 900 feet and water rises in it to within 100 feet of the surface. Mr. Albert Kleinschmidt, of Helena, is well informed in regard to artesian wells. He says that a well flowing 50 miner's inches is an exceedingly large well. He has ascertained in San Bernardino County, California, that one artesian well detracts from the flow of others in the same locality. The San Bernardino wells are periodic in flow and fed by seasonal drainage waters. Being now under public regulation there is no danger of cessation felt as one set of wells are shut off while others are in use. These wells are also closed under municipal rules during the nonirrigating season. The stratum from which their supply is derived has been ascertained to be one of glacial drift and erosion made up of gravel, small stones, sand, and bowlders. It is filled as the snows melt from the abundant mountain drainage and forms in fact a natural subterranean reservoir whose contents are under hydrostatic pressure.

He believes, however, that artesian wells are persistent, *i. e.*, that their flow does not diminish from year to year, unless by sinking other wells in the same locality. He has no faith in artesian wells as a source of irrigation and is of the opinion that at the present time it is impracticable to supply water for irrigation purposes to any extent by gravitation.

Mr. John B. Wilson, of Helena, informs me that there are only about half a dozen pumps in the Prickly Pear Valley employed for raising water from the bed rock to the land. The pump known as the "Pulsometer" is the one now preferred.

LANDS OF THE ARID REGIONS WHICH ARE SUFFICIENTLY IRRIGATED BY NATURE FOR SUCCESSFUL AGRICULTURE.

There are two classes of lands in this portion of the arid region which are sufficiently irrigated by nature for successful agriculture, both of which are exceptional in character and occupy a comparatively very limited area. The first of these are valley lands, having a gravelly subsoil, through which water freely percolates from the rivers and streams. The surface soil is sufficiently porous to draw moisture from below like capillary attraction and the process of evaporation. The other naturally irrigated lands are on mountain slopes lying just below the snow line in the spring. Such lands having a southern exposure and having also a favorable soil and subsoil, draw a sufficient supply of moisture during the season of vegetable growth from the melting snows above. These, in certain instances, constitute the finest lands for cereal productions. Lands of this character are in full view from the city of Bozeman. Such naturally irrigated lands are exceptional. Extensive regions in the arid regions have been represented as being arable without irrigation and probably in good faith; but two such seasons of drought as those of the years 1889, and 1890, proves that they are not lands which can be regarded as agricultural lands without artificial surface irrigation. The lands of the Missouri River bottom in the vicinity of Great Falls, and below that point, which are not more than 10 feet above the level of the river at its ordinary stages, generally produce good crops without any artificial supply of water, but the bench lands, only 20 feet above, and the higher table-lands back to the bluffs, supposed from a succession of "wet years" to be arable without irrigation, are found to be arid in "dry years," which years are during a long period of time much greater in number than the "wet years." The valley lands, not more than 10 feet above the streams which are irrigated by nature must be exceedingly limited in extent.

THE NORTHWESTERN BOUNDARIES OF THE ARID REGION, OR REGION WITHIN WHICH AGRICULTURE CAN BE CARRIED ON ONLY BY MEANS OF IRRIGATION.

No question as to the boundary lines of the arid region confronted me in Montana, because it may be safely said that all arable lands of that State are productive only by means of irrigation, other than the naturally irrigated bottom lands and mountain slopes already referred to, which are comparatively of small extent. But when I passed from Missoula to Spokane Falls, in eastern Washington, the question as to the northwestern boundaries of the irrigable regions at once confronted me, for I found myself on the border of perhaps the most productive wheat-producing area on earth without irrigation, beyond which area there again occurs a region which is arable only by means of irrigation.

There are four conditions which discriminate the arable lands lying west of the Bitter Range and east of the Cascade Range from those which are productive without irrigation, and those which are productive only by means of irrigation. These conditions are:

First, the amount of rainfall; second, elevation; third, the nature of the soil and of the subsoil; and fourth, the situation with respect to the Cascade Range.

The precipitation of this section of the country all comes from the Pacific Ocean. The moisture-laden winds sweep across the Cascade Range and pass over the lands immediately east of that range with little precipitation, but they yield an adequate supply to the more elevated lands east of the Columbia River. The Bitter Root Range is much higher than the Cascade Range, and therefore its summit catches and discharges upon its western slopes and bench lands the moisture that gives life to them. These lands are from 1,200 to 3,000 feet above the level of the sea. The Big Bend and the Palouse country represent the elevated arable lands east of the Columbia River. With this general statement of physical characteristics I proceed to describe the arable areas which do and do not need irrigation

The 5 northern counties of Idaho, viz: Kootenai, Latah, Shoshone, Nez Perces, and Idaho, form what is known as the "Panhandle" of that State. Much the larger part of this area is mountainous, and for that reason is nonarable. The arable lands are those which have been surveyed and are so designated on the land-office map. The Spokane Valley, extending up almost to Pend d'Oreille Lake, is productive without irrigation during seasons of large rainfall, but on account of a gravelly subsoil needs irrigation during the "dry years." There is no apparent means of irrigating this region by gravity, as the Spokane River is below these lands. Whether adequate water can be secured by storage in the side valleys is yet to be determined. The arable lands of the Coeur d'Alene reservation are all fine, productive lands without irrigation. These amount to about 8 sections in all. Latah County, Idaho, is a fine body of land highly productive without irrigation, having an excellent soil. It is an integral part of the famous Palouse country. The arable lands of Nez Perces County, the surveyed lands in the southwestern corner of Shoshone County, and the surveyed lands in the northwest corner of Idaho County, are good agricultural lands and need no irrigation, not alone on account of their rainfall but also on account of the nature of their soil. The lands about Lewiston and above that point in the valley of the Snake River being about 2,000 feet below the contiguous Palouse country lands, need irrigation for lack of rainfall.

The Palouse country and the Walla Walla country are highly productive of wheat and other cereals, far exceeding in their average yield per acre any of the States east of the Rocky Mountains. Their western contour line therefore approximately defines the boundary between irrigable and nonirrigable lands.

EASTERN WASHINGTON.

The Cascade Range separates an area of irrigable lands on the west, with an abundant rainfall, from an area situated between the base of that range and the Columbia River which has a rainfall insufficient for the growth of any agricultural crop without irrigation. I pass, therefore, to the consideration of the arid area lying just east of the Cascade Range in the State of Washington.

AT ELLENSBURGH.

The construction of the Ellensburgh Water Company's canal was mainly done in the year 1889. It has since been extended about 4 miles. It covers about 16 sections, or 16,640 acres of land. Water is taken out of the Yakima River, about 6½ miles above North Yakima. There is no reservoir for this canal, the supply being abundant. This canal is 12 feet wide at bottom, carries 3 feet of water, and has a grade of 30 inches to the mile. The cost of this work has been about $40,000. Plans are now being made to enlarge this canal so that it shall carry double the quantity of water and reach more land.

There is also a canal on the west side of the Yakima River, taken out at a point about 11 miles above Ellensburgh. The dimensions of this canal are 16 feet at the bottom, slopes 1 to 1 in excavation and 2 to 1 in embankment; depth of water, 3 feet; grade, 1½ to 2 feet to the mile. This work covers about 45 sections of land. It was begun about eighteen months ago, is nearly completed, and has been constructed mainly since the Stewart committee visited this section. The cost of this canal has been about $28,000.

Session Laws of Washington, page 321, provides for the creation of irrigation districts, and was copied from the so-called "Wright law" of California. Under this statute the Kittetas irrigation district was formed. This provides for a large canal which will cover 100,000 acres, or 80,000 not now reached by any canal. The proposed canal is to be 30 feet wide at bottom, 4 feet deep, slopes 1 to 1, and grade of 2½ feet to the mile. The work embraces the use of Lake Kahchass, Lake Keechelus, and Lake Tlecalum as reservoirs, about 50 to 60 miles distant, and not now embraced within the limits of the Kittetas irrigation district. The estimated cost of the whole work is between $700,000 and $800,000. It is proposed under the provisions of the statute to bond the irrigation district.

UNDERFLOW OR UNDERLYING WATERS.

It is believed that there is a very considerable underflow in the Yakima River, and also in several of the side streams. The main evidence of this on the Yakima, as elsewhere in the arid region, is the disappearance of water in the bed of the stream where it flows through valley lands, and its reappearance in the cañons. No attempt has been made in Kittetas County to utilize the underflow. Both spring and fall plowing is practiced in the Kittetas Valley. The planting season embraces March and April. Wheat is here harvested from July 20 to August 15.

AGRICULTURAL PRODUCTS.

The agricultural products of the Kittetas Valley are chiefly wheat, oats, barley, hay, apples, pears, prunes, plums, small fruits, berries, and the hardier vegetables generally. Land is here worth about $50 when improved and irrigated. I was informed of a barley crop of 117 bushels to the acre, and of a wheat crop of 70 bushels to the acre, under irrigation.

All fruit trees are irrigated. Land in the Kittetas Valley requires about half a miner's inch for the season, the inch being the quantity of water which will flow through an aperture 1 inch square, under a head of 6 inches. It is said to be the equivalent of .025 cubic feet a second.

THE YAKIMA VALLEY.

The largest wheat crop of which I heard in the Yakima Valley was 100 bushels to the acre, and the largest crop of oats 110 bushels to the acre. The average wheat crop is 40 to 60 bushels to the acre. Alfalfa probably brings more money to the farmer than any other crop. It is cut two and three times during each season, and the total product for the season averages from 6 to 9 tons to the acre.

The opinion appears to be entertained by the best-informed men that it will not be profitable to raise wheat in the Yakima Valley, although it is produced at the average rate of 40 to 60 bushels to the acre, and for the reason that fruit and hay—alfalfa and timothy—hops and tobacco will pay so much better. The Yakima Valley is a most prolific fruit country under irrigation, its products embracing apples, pears, plums, prunes, peaches, grapes of many varieties, small fruits, and berries.

PROGRESS MADE IN IRRIGATION IN THE YAKIMA VALLEY.

No marked progress has been made in the actual construction of irrigation work in the Yakima Valley, since the visit of the Senate committee in 1889; but there is in contemplation and in the preliminary stages of survey and location, a work of great magnitude. This work is being prosecuted by the "Northern Pacific, Yakima and Kittetas Irrigation Company." Already about $50,000 has been expended on surveys, and the total cost of the work is expected to be from $2,000,000 to $3,000,000. Water will be taken from the Yakima River and its branches, but the most important source of water supply seems to be in a system of reservoirs, embracing Lakes Keechelus, Kahchass, Tlecalum and Tannum. It also proposed to build reservoirs in the several valleys tributary to the Tetan, which will draw supplies from glaciers of the Cascade Range.

The lands to be covered by these works lie in the Yakima Valley, in the Yakima Indian Reservation, and in a body of lands east of that reservation, known as the "Sunny Side Valley." It is also believed that one of the canals of the system can be made to wind around the hills so as to reach a large body of lands on the Columbia River bottom, or mesa lands. The full development of the scheme awaits the completion of a topographical map, showing the waters to be used and the lands to be irrigated.

The climate of the North Yakima and Sunny Side Valleys is claimed as similar to that of San Francisco, Cal. The Sunny Side Valley is from 400 to 500 feet lower than the North Yakima Valley, and is more favorable for the culture of peaches, plums, prunes, and grapes. Large canneries are reported to be coming as soon as these lands are reclaimed. The period of vegetation is said to begin from 2 to 3 weeks earlier in the Sunny Side Valley than in the North Yakima Valley, and to continue about as much longer in the autumn.

The Northern Pacific Railroad Company is aiding the grand development promised by the Northern Pacific, North Yakima and Kittetas Irrigating Company. This is done by contributing all its lands, constituting nearly half the area to be reclaimed, at an agreed price, which as I understand is very low.

The Konnewoc Ditch.—Mr. Edgar T. Stone, of North Yakima, is president of this ditch company. It starts from a point about 6 miles below North Yakima and extends about 18 miles. It is 7 feet wide at bottom and about 2 feet deep. Its grade at the upper end is 5.1 inches per mile and less below. It covers about 3,000 acres of land and cost about $15,000.

The Wenass Valley.—Mr. Daniel Sinclair, county commissioner, informed me that the Wenass Valley, which joins the Yakima Valley, about 6 miles above North Yakima, is imperfectly irrigated, but believes that the perfect storage of water will afford sufficient water for the reclamation of all its irrigable lands. There are now about forty to fifty private ditches in the valley. Mr. Sinclair believes that the work of building reservoirs can only be undertaken by a company possessed of sufficient capital to construct such expensive works.

The Oneida Colony, near Pasco.—A colony of people from Oneida, N. Y., have taken up about 20,000 acres of land west of the Columbia River, and not far from Pasco. They take water from the Yakima River. I did not visit the place, but am told that these people have succeeded admirably in their operations. The people of Kennewick voted about December 10, 1890, for the issue of bonds in favor of an irrigation district, to construct a ditch covering 12,000 to 14,000 acres of land, located in the Columbia Valley, on the west side of the river, below the mouth of the Yakima. The water is to be taken from the mouth of the Yakima River, just opposite "Rattlesnake Mountains."

PASCO, WASHINGTON, AND VICINITY.

The town of Pasco is situated on the east side of the Columbia River, at a point where the Northern Pacific Railroad crosses that river, and a short distance above the junction of the Snake River. The elevation of Pasco is only 312 feet above the sea level. It is the natural commercial center of Franklin County, which lies between the Columbia and Snake Rivers. This county has a rich soil, but it is part of an area west of the fruitful "Palouse country" and south of the "Big Bend country," which is absolutely arid and barren without irrigation. Abundant waters are flowing by on either side, in the Snake and Columbia Rivers, and the problem of the hour is how to get these waters upon the vast arid waste. Various plans have been suggested. "Priest Rapids," on the Columbia River, have a total fall of 59.4 feet, and a canal taken out at the head of these rapids would cover a large proportion of the irrigable lands of Franklin County. A competent engineer has, however, estimated that it will cost about $1,000,000 to construct the ditch. Such expenditure seems impracticable at the present time.

It has been proposed to use Moses Lake, in Douglas County, as a reservoir for the irrigation of lands below in Douglas and Franklin Counties. The people of Franklin County have, however, hit upon a plan from which they expect highly beneficial results. They have organized their county as an irrigation district, covering 19,000 acres of land, under the laws of the State of Washington, and have authorized the issue of bonds to the amount of $200,000 for the construction of a canal and hydraulic works, whereby water may be lifted from the Snake River, the level of which is 110 feet below Pasco, and carried upon the lands proposed to be irrigated and bonded. It is thought the works will not cost over $110,000. The preferred plan appeared to be that of a steam pump. Another plan being considered, the suggestion of a California party, was to go 9 miles up the Snake River, where a canal or flume could be conducted along the valley of the Snake, so as to secure a fall of 25 feet at Pasco, thus furnishing abundant power for pumping water from the river upon the lands above. The size of the proposed Franklin County ditch is 17 feet wide at top, 9 feet wide at bottom, and 4 feet depth of water.

The elevation of lands near the mouth of Snake River is only 312 feet, the elevation of Walla Walla being 965 feet. This difference in elevation causes crops generally to be about 3 weeks earlier at Pasco.

Artesian wells.—Under an appropriation of $60,000, made by the State of Washington, an attempt was made to sink an artesian well at Pasco, but without success. The boring was put down 400 feet, but did not reach water nor pass through the basalt rock.

AT WALLA WALLA.

The famous "Walla Walla country" is highly productive of wheat, barley, and oats, without irrigation; but all vegetables and fruits need irrigation, for which purpose water is taken from the Walla Walla River, which takes its rise in the Blue Mountains. There were in December, 1890, about 12,000 bushels of wheat in the vicinity of the valley of Walla Walla awaiting transportation. The entire soil of this region and the underlying rock is basaltic. Native rock is not found, except far up on the sides of the mountains. Water for city uses generally is obtained from the Walla Walla River. There is no rainfall at Walla Walla from June 1 until September 15 to 20. I would here remark that wheat, barley, and oats appear to be about the only crop which can be raised in the wonderful "Palouse country" without irrigation. Fruit and berries raised in the vicinity of Walla Walla by means of irrigation are shipped daily by carloads. The markets are chiefly Spokane Falls, Butte, and Helena, Mont., and even occasionally to St. Paul. It is thought that fruit can be shipped from the irrigated lands of Pasco 2 to 3 weeks earlier than from Walla Walla.

Stable manure is used at Walla Walla for vegetable gardens, and is worth 50 cents a load. Irrigation at Walla Walla is done "in the row," and not by flooding. No fertilizers of any sort are used on wheat lands

Phenomenal crops.—Dr. Blalock, mayor of Walla Walla, in speaking of the enormous crops produced at that place by means of irrigation, stated that he had seen 75 tons of carrots produced in one season from a single acre, and added that 1,000 bushels of onions from an acre was not an uncommon crop.

EASTERN OREGON.

The eastern or arid section of the State comprises about two-thirds of its entire area. The aridity of the arable lands of eastern Oregon is not due alone to meteorological influences exerted by the Cascade Range. As the moisture-laden winds from the Pacific Ocean pass over this range a certain amount of precipitation takes place, but these aërial currents retain a large proportion of their original humidity. As they move eastwardly their reduced burden of moisture is held aloft by and is precipitated upon the summits of mountain ranges and groups scattered throughout eastern Oregon and Idaho. A considerable proportion of humidity also passes still farther eastward, and is precipitated upon the Bitter Root Range and the Main Divide of the Rocky Mountains. This distribution of precipitation east of the Cascade Range is clearly manifested in the abundant and luxuriant forests which flourish perpetually upon the more elevated portions of all these ranges and groups of mountains east of the Cascade Range in Oregon, Idaho, Montana, and Wyoming. Some of the loftiest peaks in this vast area have a high "timber line" as well as a low "timber line," the upper line being determined by frost, and the lower line by lack of precipitation.

The orological features of the country just mentioned are the potential cause of the aridity of the arable and pastoral lands of eastern Oregon. These lands, although embraced under the general designation of "arid lands," have a sufficient rainfall for the growth of the peculiar nutritious grasses of the arid region. Such grasses furnish abundant pasturage for hundreds of thousands of horses, cattle, and sheep "on the range." There is a much larger possibility of agricultural development in eastern Oregon by means of irrigation than has heretofore been supposed. The mountain streams yield large supplies of water which, when utilized for the irrigation of lands, yield results phenomenal in agriculture.

The influence of the topographical and orological features of eastern Oregon upon the rainfall, and upon general climatic conditions governing agricultural production, is nowhere more strikingly manifested than in the northeastern corner of the State. Umatilla, on the Columbia River, has an elevation of only 300 feet, and it is extremely arid. Walla Walla, about 50 miles east, has an elevation of 926 feet, and West Oregon, only 28 miles south of Walla Wall, an elevation of 1,800 feet. Yet both these points have a rainfall sufficient for an abundant cereal production. Again, Pendleton, 32 miles southeast of Umatilla, has an elevation of 1,070 feet; but there has not been rainfall enough at that place during the last three years for the successful production of any agricultural crop.

All this appears to be the result of the fact that the moisture held by the aërial current which sweeps up the Columbia River is repelled by the low warm lands about Umatilla, but it is to a certain extent precipitated upon the higher and cooler lands of the "Walla Walla country;" while the high lands about Pendleton fail to receive a share of such precipitation because out of the course of these moisture-laden winds.

The counties of Klamath, Lake, Harney, Crook, and Grant are now devoted almost entirely to pastoral pursuits, while the counties on the Columbia and in the eastern part of the State are in the course of agricultural development in connection with important lumbering and mining operations.

THE DEVELOPMENT OF AGRICULTURE IN EASTERN OREGON.

Historically, agriculture in eastern Oregon, as in almost every other part of the arid region, has been an incident of mining and of pastoral pursuits. In fact, the irrigation of arid lands is to a great extent an outgrowth of gradually developed art of carrying water for great distances in ditches and in flumes for mining purposes. Thus the mining engineer has become the most practical and skillful irrigating engineer, and the increasing demand for food in the mining camps has led the miner to become a farmer in a country where the favorite word "rustle" means to adopt oneself readily and courageously to the varying demands of a rapidly developing country.

AT PENDLETON.

The city, which has a population of about 2,500, had for several years a steady and somewhat rapid growth. It is the center of an agricultural region which a few years ago was believed to be reliably productive without irrigation. But in the course of time that has proven to be a mistake. A series of years with a sufficient rainfall for the production of wheat and the other cereals, has been followed by a series of years in which the rainfall has been insufficient for crops of any sort without irrigation. As yet irrigation has not been practiced in this vicinity. During the year 1890 the rainfall at Pendleton was only 11.45 inches. The distress which these "dry years" has induced is already very great, and it threatens the depopulation of a considerable proportion of the surrounding country unless relief can be afforded by means of irrigation. In certain instances, farms have been abandoned; wire fences have been taken down and sold to obtain the necessaries of life. Wells which formerly yielded sufficient supplies of water have failed, and a large proportion of the farming community have for months been hauling water from 2 to 10 miles for domestic purposes. A few years ago lands which produced 30 to 50 bushels of wheat to the acre, this year produced only from 4 to 10 bushels to the acre. During the season of 1890 many farmers made no attempt to harvest their crops. The distress has gradually been increasing for the last 5 years.

In this time of trouble all minds turn to the relief which may be afforded by means of irrigation. It is confidently believed that adequate relief can be secured by utilizing the waters of the Umatilla river. It is proposed to accomplish this by taking the water out of the river at a point about 20 miles above Pendleton, and carrying it out upon the high plateau lands by means of a high-line canal. This will be necessary for the accomplishment of any great good for the reason that there is but a small amount of agricultural lands in the immediate valley or bottom of the Umatilla. It is believed that there is not more than 3,000 acres of bottom land between Pendleton and the Columbia river.

A corporation known as the "Umatilla Irrigation Company" has already been formed. This company proposes to take the water out of the Umatilla River at a point about 20 miles above Pendleton and to follow the river bank about 8 miles. It will then catch the high lands, where the agricultural population chiefly reside, and by this means irrigate from 75,000 to 100,000 acres of land. The quantity of land to be irrigated will be determined by the available quantity of water in the river and not by the area of land "under the ditch," which aggregates about 220,000 acres. It is not proposed to construct a reservoir at first, but it is believed that eventually, by the storage of water, a much larger water supply can be rendered available.

The farmers throughout the area to be irrigated earnestly indorse the scheme, and will become share holders in the irrigation enterprise, upon the success of which their interests appear to be at stake. The business men and citizens of Pendleton generally are also strongly in favor of and are interested in this irrigation enterprise.

THE UMATILLA INDIAN RESERVATION.

The Umatilla Indian reservation is contiguous to the city of Pendleton, and the point where the water is to be taken out of the Umatilla River is upon that reservation. The United States agent of the tribe states that the "head men" are in favor of the irrigation enterprise, and that he had already recommended to the Indian office at Washington the granting of the right of way for the ditch through the reservation. This enterprise would also serve the purpose of irrigating about 15,000 acres of land within the reservation.

AN OBSTACLE INTERPOSED BY THE LAWS OF OREGON.

The constitution of the State of Oregon and the laws originally passed with reference to the subject of running water were framed before the subject of irrigation had attracted attention in that State or elsewhere in this country, and are in conformity with the doctrine of law known as "the law of riparian rights." This principle of law is entirely consistent with the conditions governing agriculture by means of the natural rainfall which prevail in the Willamette and other valleys on the western side of the Cascade Range, but as the experiences of all the States of the arid region, and of every country where irrigation is practiced, clearly prove this rule of law is entirely impracticable in an arid area. There the law of the appropriation of water for beneficial uses, involving the permanent deflection of water from its natural channels into canals or ditches, is a public necessity, and, as such, the right of eminent domain inherent in the State governments must be exercised when necessary to secure the passage of irrigating ditches through lands belonging to private owners.

All experience proves that in every community either the law of riparian rights, or the law of appropriation for benefical uses must absolutely prevail. Their coexistence invariably gives rise to "an irrepressible conflict between opposing and enduring forces." In so far as I was able to learn in eastern Oregon, there is a general desire that the law of the State in regard to the water in streams available for irrigation shall be changed, with respect to all that part of the State lying east of the Cascade Range, and a belief was expressed to me that the State legislature will make such change during its present session.

Evidences of underflow.—The engineers who have been employed upon the surveys for the proposed Pendleton canal assert that there is much more water in the river 20 miles above than at Pendleton. The bottom lands are underlaid with gravel through which the waters from the river freely percolate, and are reached by wells at the depth of only 6 feet. It has been proposed to irrigate the lands lying south of the Umatilla river, but nothing has yet been done toward the construction of the necessary works.

Artesian wells in Oregon.—No attempt has been made to secure water at Pendleton by means of artesian wells, apparently for the reason just stated that the Umatilla River underflows its valley lands, and that water of good quality may be secured from this source at the depth of only 6 feet. An appropriation of $5,000 was made by Congress about a year ago for the ascertainment of sources of artesian water in Oregon, to be available whenever a like amount was appropriated for the same purpose by the legislature of that State. The result of that offer has not been learned.

AT BAKER CITY.

The population is about 3,500. It is situated in the valley of Powder River and is the county seat of Baker County. This valley has an average length of about 30 miles from north to south, by about 20 miles from east to west. The soil here is a lava ash, intermingled with sand and loam. It is strong and exceedingly fertile, producing in abundance the cereals, hay, fruit, and vegetables.

At the present time irrigation is practiced in the Baker City Valley only in a small way, but with results which demonstrate the importance of a large and general system of irrigation. The fact that this valley, like the Grande Ronde Valley, is largely sub irrigated is undoubtedly the cause of delay in securing an adequate system of irrigation. Lands which without irrigation produce about 20 bushels of wheat to the acre, are found, however, to produce 40 to 70 bushels per acre with irrigation. The knowledge of these facts has led to the formation of the Baker Valley Irrigation Company, which proposes by means of reservoirs and ditches to reclaim and greatly improve about 75,000 acres of land. William Hammond Hall, C. E., of California, is the consul ing engineer of this company. The works of the company are to be used both for the purpose of irrigation and of hydraulic placer mining. The main reservoir is located in Sumpter Valley, about 20 miles from the town. It will cover 1,500 acres. By means of a dam 130 feet high, the reservoir will have an average depth of 39 feet, and its capacity will be about 2,501,000,000 cubic feet.

The following description of the Baker Valley Irrigation Company's canals was prepared by Mr. William Doterlee, manager of that company:

Low-level canals.—(*a*) West side of Powder River Valley. Capacity, 8,000 miner's inches; 20 feet wide; 12 miles long.

(*b*) East side of Powder River Valley. Capacity, 10,000 miner's inches; 24 feet wide; 25 miles long.

High-level canals:—(*a*) From dam to Baker City. Capacity, 8,500 miner's inches; 20 feet wide; 26 miles long.

(*b*) From Baker City to Virtue Placer mines. Capacity, 3,500 miner's inches; 12 feet wide; 24 miles long.

(*c*) From Baker City to Pocahontas. Capacity, 1,500 miner's inches; 10 feet wide; 10 miles long.

The last two mentioned are branches from the main canal, dam to Baker City.

It is also proposed to take water from Rock Creek and North Powder River, but surveys have not been made for those canals nor for the numerous laterals to distribute the water. The capacity of the storage reservoir will be about 19,000,000,000 gallons.

Artesian wells.—Baker City is now abundantly supplied with water by means of two driven wells, one 2 inches in diameter and the other 5 inches in diameter. Other wells have been put down by private parties. These wells vary in depth from 155 to 400 feet. Water in the city wells rises to within 5 feet of the surface, and flows from certain of the other wells. None of these wells penetrate the solid rock. The supply from these wells by means of pumping is sufficient for domestic and other city purposes and for the irrigation of gardens and city lots. The opinion appears to prevail in Baker City that this supply of water is some sort of an underflow proceeding directly from the mountains, and not from the streams which flow through the valley. The subject is worthy of a more careful investigation than the time at my disposal enabled me to give it.

Evidences of underflow.—That the lands of the Baker Valley are naturally sub-irrigated appears to be evident from the fact that with an annual average rainfall of only 15 inches they generally produce fair crops without artificial irrigation. Other evidences of an underflow in the Baker Valley were as follows:

(*a*) Dr. J. M. Boyd states that for 28 years the valley lands of Pine Creek, a branch of Salmon Creek, yielded abundant crops by the underflow which afforded sufficient irrigation. Two years ago, *i. e.*, in 1889, the water of Pine Creek was diverted from its bed for the use of certain mining operations. The result was an entire failure of crops, for the obvious reason that the water of sub-irrigation had been cut off.

(*b*) Mr. W. H. Parkwood mentions a case where sub-irrigation had been induced. This was on the lands of Mr. E. D. Cranston on Clover Creek, a branch of Pine Creek. The water in this stream was several feet below the surface of the adjoining land. Mr. Cranston has put in a set of dams, so as to bring the water in the stream almost even with the surface, and found that by this means the water underlying the lands adjoining the stream was so raised as to afford a sufficient sub-irrigation for his crops.

PASTORAL INTERESTS.

Baker City is the center of a large range-cattle interest. It is estimated that there are from 75,000 to 100,000 cattle "on the range" within 50 miles of this place. Sheep husbandry is also an important interest. As elsewhere in the arid region, it has been found that the range cattle business, in order to be secure against large winter losses, requires the cutting of large quantities of hay for feed during the winter months.

Hay is not only an important crop for the use of horses, cattle, and sheep "on the range," but also for horses and cattle on farms. Timothy and alfalfa are the most valuable hay crops. The timothy crop on good lands is from 2½ to 3 tons to the acre. Alfalfa is cut twice and yields as high as 2½ tons at each cutting. It is found that both timothy and alfalfa, like the natural nutritious grasses, will cure perfectly in the open air. There is no crop more dependent upon irrigation than the hay crop.

Fruits and vegetables.—The Baker Valley produces abundantly apples, pears, plums, cherries, peaches, apricots, and the smaller fruits and berries. Fruit generally is free from insect pests and injurious parasites. Vegetables of all sorts grow luxuriantly. The soil and climate are said to be highly favorable to the culture of the sugar beet.

The use of fertilizers.—The more thrifty and industrious farmers spread their stable manure upon their lands, but many farmers waste it. The general belief is that the water in the streams bear a fertilizing silt from the mountains.

Summer fallowing.—The practice of summer fallowing prevails to a considerable extent in the Baker Valley, as in other parts of the arid region. The largest crops are generally the product of lands so treated.

Phenomenal crops.—It has been stated that 200 bushels of potatoes to an acre have been raised as the product of a single crop. Cabbages are raised which weigh from 40 to 60 pounds. As high as 70 bushels of wheat have been harvested from a single acre.

Markets.—The local demand for hay, grain, fruit, and vegetables, created by the mining, lumbering, and stock-raising industries not only absorbs the entire products of agriculture in this section of eastern Oregon, but renders necessary the importation of agricultural products from the Pacific coast, and from points east of the eastern border of the arid region. It is believed that the home market will increase quite as fast as the development of agriculture by any means of securing irrigation which may be devised. As a rule, the prices of agricultural products in eastern Oregon and in Idaho are equal to prices in Porland, Oregon, or Kansas City, Mo., plus the freight charges on such products.

The miner's inch.—The somewhat variable unit of measurement, "a miner's inch," is defined by Mr. W. Dieterle, civil engineer and manager of the Baker Valley Irrigation Company, as follows:

> One miner's inch is equivalent to 1,728 cubic feet of water in 24 hours. It is sufficient to cover an acre of ground to the depth of 1.19 feet once in 30 days. Hence the theory prevails that a miner's inch having a continual flow during the season (120 days) is sufficient for the irrigation of 3 acres of ground.

MALHEUR COUNTY.

The southern portion of this county, covering two-thirds of its entire area, is mountainous, but embraces extensive and valuable ranges and many valleys, in which there will undoubtedly be considerable agricultural development in the course of a few years. The valley of Willow Creek is said to be a fine farming country. The valley of the Snake River, in Oregon, also embraces extensive areas of the finest agricultural land. These lands may be irrigated extensively from the mountain streams and also presumably from the Snake River. Large areas of bottom lands are being irrigated from the Snake River, in Cassia County, Idaho, by means of current wheels anchored in the river or built along the shore, and it is assumed that similar irrigation can be practiced on the bottom lands of Snake River, in Malheur County, Oregon.

THE STATE OF IDAHO.

The orological features of the Pacific slope which determine the precipitation of moisture in Idaho have been described in that portion of my report which relates to the State of Oregon. The topography of Idaho is in a general way fairly illustrated by the United States Land Office maps. It is a mountainous State, interspersed with numerous valleys and with expensive pastoral lands. Its various drainage basins are tributaries to the Columbia River, with the exception of the Bear River watershed, the waters of which flow into Great Salt Lake, in the Territory of Utah. The Great Snake River Desert constitutes the most remarkable topographical feature of the State. This is a vast lava bed into which or beneath which all the streams flowing south from the vast mountain ranges and groups at the north are lost. There is apparently no stream emptying into the Snake River on its northern side from Shot Gun River, in Bingham County, to Wood River, in Alturas County, a distance of over 400 miles.

The law of water rights.—Under the constitution of Idaho "the use of all waters now appropriated, or which may hereafter be appropriated, for sale, rental, or distribution," is declared to be a public use, and subject to the regulation and control of the State, in the manner prescribed by law. The general drift of the testimony which I received was to the effect that the Territorial laws were inadequate to the proper protection of water rights, and that such rights could only be determined "at the end of a lawsuit." A bill defining water rights and providing for the administration of the law has been before the State legislature.

WASHINGTON COUNTY.

The Weiser River has a broad and fertile valley with many tributaries on either side, all of which are bordered by fertile lands. Abundant evidences exist of a large underflow. There is more water in the river in the upper part of the valley than in the lower part. A few feet beneath the surface an underlying gravel is found, and water can be obtained only 15 feet beneath the surface. There are twenty-six ditches in Washington County, and over 200 water rights have been recorded.

Mr. Thomas C. Galloway, of Weiser, states that there are twenty streams emptying into the Weiser, each one of which affords the natural facilities for abundant storage of water at comparatively small expense. He believes that by means of proper storage and irrigating ditches Man's Creek could be made to irrigate 10,000 acres of land. The Weiser and other valleys of Washington County where irrigated produce abundantly hay, grain, and vegetables; also fruit of the best quality, including apples, pears, peaches, plums, and prunes. Already the county is shipping hay to Portland, Oregon; also hay and fruit and vegetables to Butte, Montana, and to points in Idaho also.

The average cereal yield of the grain crops of Washington County are: Wheat, 40 bushels per acre; corn, 50 bushels per acre; oats, 60 bushels per acre; barley, 50 bushels per acre. The water from the mountains bears an abundant fertilizing silt, and barnyard manure is generally wasted. There is a large range-cattle interest in Washington County, and the practice of providing hay for such animals during the severe weather of the winter months is increasing.

There are no artesian wells in Washington County. Mr. Sol. Hasbrouck, clerk of the supreme court of Idaho, strongly recommends the construction of a series of reservoirs in the small valleys of the tributaries of the Weiser River.

ADA COUNTY.

There are from 30,000 to 40,000 acres of land irrigated in the vicinity of Boisé City by means of ditches taken out of the Boisé River at points above and below that city; while the works of the Idaho Mining and Irrigating Company, now in progress, provide for the reclamation of 350,000 acres of additional land.

The dimension, grade, and other data concerning this work are indicated as follows:

IDAHO MINING AND IRRIGATING COMPANY'S MAIN CANAL.

First section, head to Five-Mile Creek (grade 2 feet to mile): Bed width, 40 feet; top width, 70 feet; banks, 12½ feet high; depth, 10 feet; area, 550 square feet. Velocity, 4.7 feet per second; flow, 2,585 cubic feet per second.

Second section, Five Mile Creek to Ten Mile Creek (grade 2 feet to mile): Bed width, 40 feet; top width, 67 feet; depth, 9 feet; area, 481.5 square feet. Velocity, 4.52 feet per second; flow, 2,176 cubic feet per second.

Third section, Ten Mile Creek to Indian Creek (grade 2 feet per mile): Bed width, 40 feet; top width, 65.5 feet; depth, 8.5 feet; area, 448.4 square feet. Velocity, 4.41 feet per second; flow, 1,977 cubic feet per second.

Fourth section, Indian Creek to head of main branch (grade 2 feet per mile): Bed width, 35 feet; top width, 59 feet; depth, 8 feet; area, 376 square feet. Velocity, 4.2 feet per second; flow, 1,579 cubic feet per second.

Main branch, first section (grade 4 feet to mile): Bed width, 35 feet; top width, 51.5 feet; depth, 5.5 feet; area, 237.88 square feet. Velocity, 4.73 feet per second; flow, 1,125 cubic feet per second.

Main branch, second section (grade 4 feet per mile): Bed width, 30 feet; top width, 45 feet; depth, 5 feet; area, 187.5 square feet. Velocity, 4.5 feet per second; flow, 844 cubic feet per second.

The main canal of the Idaho Mining and Irrigation Company takes water from the Boisé River at a point 10 miles above Boisé City. The reservoirs of this system, five in number, are located on Smith Creek, Fall Creek, and Blind Creek. Their total capacity is 9,618,048,000 cubic feet. It is estimated that the dams necessary for the formation of these reservoirs can be constructed at a cost of only $142,217, and that the additional quantity of water thus impounded will be sufficient to supply the needs of the area to be reclaimed during the season when the supply direct from the mountains would be insufficient. It is expected that the works of the Idaho Mining and Irrigation Company will be completed about the spring of 1892.

ARTESIAN WELLS.

A series of remarkable artesian wells are located about two miles from Boisé City, and at an elevation of 163 feet above the Boisé River, or about 152 feet above the main business street of the city. This source of water supply was discovered in the month of May, 1890. The circumstances of the discovery were as follows: There was a slight surface indication of a spring in the gulch in which the wells are located. By boring to a depth of about 65 feet, the supply was struck. There are two companies now engaged in conveying water to Boisé City from this source of supply, which, in so far as yet developed, is embraced within a space of 500 feet by 700 feet. The reservoir of the company whose works were shown to me is 200 feet long by 50 feet wide and has a depth of 8 feet. It has a capacity of 550,000 gallons, and can be filled by the five wells which flow into it in about 12 hours.

The water was struck in a very soft sandstone rock, which extends from about 6 feet below the surface of the ground in the gulch to a depth not yet ascertained. Boisé City, which has a population of about 5,000, and is now supplied with water from this source for domestic, fire, and to some extent mechanical purposes. Water can be thrown to a height of 85 feet, through hose with an inch nozzle, by the pressure from the reservoir.

BOISÉ COUNTY.*

This county is rough and rugged and is strictly a mining country. The valleys are generally too elevated for successful agriculture. Some grain is raised in the valleys. There are but few fruit trees; but the mines are rich, abounding in gold, silver, and lead, and timber is abundant. The industries to which these resources give rise afford markets for the agricultural products of other counties. There are, however, excellent locations for reservoirs, the waters from which could be utilized in the irrigation of the arable lands of Ada County, and a small portion of Washington County. The western portion of Boisé County has extensive stock ranges.

There are many mining ditches, but few irrigating ditches. To some extent farms are supplied with water from mining ditches. But farming cuts but a small figure in a county of 7,000 to 8,000, where 80 per cent. of the laboring classes are employed in the mines.

ELMORE COUNTY.

Its arable lands are situated between the base of the mountains and the Snake River. A ditch has been run from Little Camas Creek by which about five sections of land are irrigated. The elevation of these lands above sea level is about 4,500 feet. All the lands south of the mountains, through which a large number of creeks run, as shown on the map, are Snake River Valley lands, and are believed to be irrigable. It has been proposed to carry the water of the South Boisé across the low divide which separates the valley of that river from the Snake River Valley lands just mentioned, and Mr. White expressed to me the belief that this can be done without interfering with the irrigation of lands in Ada County. There is a scheme on foot for irrigating the valley of Cañon Creek. It is believed that about 1,400 acres of land can thus be reclaimed.

ALTURAS COUNTY.

Strictly speaking, this county is a mining county. The irrigable lands are comprised mainly in the valleys of Big Wood River, Little Wood River, Lost River, and the valleys of the tributaries of these streams, all of which head in the Saw-Tooth Range, where the snowfall is very heavy. In the spring of the year these streams carry an immense body of water, which it is believed can be stored and utilized in irrigating the Snake River Valley below Wood River. There is a large body of good arable land on Big Lost River, between the point where it comes out of the mountains to Barnett's, and thence all along its northern border to where it disappears beneath the vast lava plain. There are also on Big Lost River and its tributaries abundant facilities for reservoirs.

* For the county statements herein made Mr. Nimmo expresses his indebtedness to the members of the State legislature.

LOGAN COUNTY.

There is a large amount of arable land in this county, but at the present time a lack of water supply. Camas Prairie is in the northern part of the county. It is a mountain park, about forty miles long by ten miles wide, having an elevation above sea level of 5,300 feet and lying on both sides of Malad Creek. Both Senators Smith and Gunn express the belief that an adequate supply of water can be secured by storage at the head of the valley and on the tributary streams from the north. In the absence of such storage, the water supply usually fails about July 1. In favorable years, excellent crops of grain, hay, and vegetables are secured, but irrigation is needed for the full development of agriculture. North of Camas Prairie there is a high mountain horse and cattle "range country." There is a considerable amount of good irrigable land on Little Wood River.

CUSTER COUNTY.

The valley of Lost River is about 60 miles long, and varies in width from 2 to 8 miles. It has about 10,000 acres of good irrigable land. Not more than 10 per cent. of all these lands are now irrigated, but it is the belief of Senator Shoup that the entire area could be reclaimed by means of a system of storage reservoirs, and that the people will in time be able to do all this for themselves without the aid of outside capital. It is his opinion also that it is not for the interest of the people of Custer County that either the State or national governments should in any manner interfere with such development. The whole irrigation development of the county appears to be entirely within the power of the people to accomplish, as no large nor very expensive works will be involved in such development.

The lands in the lower valley of Lost River produce the cereals, vegetables, hay, and the hardier varieties of apples. The mining camps furnish an abundant market for these products; besides, large quantities of food are imported into the county across the mountains. Senator Shoup believes the desert land law is still beneficial to his county. Round Valley, about 10 miles in diameter, in which Challis is situated, has an excellent soil. There is but a small quantity of arable land on Salmon River. The Pahsamarie River has a narrow valley, in which are some good lands. Here about 40,000 bushels of wheat and oats are raised. The altitude of Pahsamarie Valley is about 4,500 feet at its lower end. Senator Shoup thinks there is now 100,000 acres of land in Custer County which can be irrigated without reservoirs, and that this can be largely increased by the use of reservoirs.

LEMHI COUNTY.

Lemhi River Valley is about 65 miles long and has an average width of about 3 miles. The farmers take water from the side streams, and only cultivate the bottom lands. It is believed that by means of a system of reservoirs a large amount of bench land might be reclaimed. At the head of Lemhi River there is a broad valley about 10 miles wide. It is believed that large bodies of land could be reclaimed by means of reservoirs. The principal agricultural products of Lemhi County are grain and vegetables, which find a good market in the mining camps.

CASSIA COUNTY.

There are a large number of small irrigating ditches in various parts of the county. Very much may be accomplished by means of reservoirs on all the streams which head in the mountains at the south and empty into Snake River; also on many of the tributary streams. An adequate reservoir can be constructed on Goose Creek for $10,000, and also one on Raft River for about the same amount. At the present time there are no reservoirs in the county, as there is not capital enough for such works.

The soil of Cassia County is excellent, producing in abundance, under irrigation, the cereals, vegetables, and fruits. The average wheat crop is about 40 bushels to the acre. The principal market for the agricultural products of Cassia County is in the mining camps of the Saw-Tooth Mountain country.

Mr. Frank Riblett, civil engineer, under date of December 17, 1890, writes a valuable statement, which is attached. He suggests the use of current wheels in Snake River for the purpose of throwing water upon the adjacent bottom lands. This is an ancient and where practicable an economical method of irrigation. He also speaks of various projects of great magnitude, one of which is that of taking water out of the Snake River near Eagle Rock (now Idaho Falls) and carrying it in a canal around the head of the various valleys of Oneida, Cassia, and Owyhee Counties, so as to reclaim a large body of land in these counties. This would be an heroic work, comparable to a Ganges Canal of India. Mr. Riblett also calls attention to the enterprise already organized for utilizing the power of Shoshone Falls, said to be 200,000 horse-power at low water, for the purposes of hydraulic mining along the river, and also for the irrigation of 100,000 acres of land.

Artesian wells and underflow.—Mr. Riblett states that no artesian wells have been bored in Cassia County, but believes there are immense stores of subterranean water, and that attempts to reach them would meet with success. He also believes that all the streams of the county, especially the smaller ones, are subject to underflow.

BEAR LAKE COUNTY AND WATERSHED.

The Bear River watershed embraces a part of the Territory of Wyoming, Idaho, and Utah, and is a part of the Salt Lake basin. The irrigable lands of Bear Lake County are entirely comprised in the Bear Lake Valley. The sources of water are the Bear River and a large number of mountain streams. Water is taken out of the Bear River throughout its extent in Bear Lake and Cassia Counties, by means of low dams and ditches, which cover more or less of the strictly bottom lands. A very large amount of excellent bench lands may be reclaimed by means of reservoirs on the small streams from the mountains, which now discharge their waters before the season of irrigation is ended. Reservoirs can be constructed on all these streams.

Thomas Fork, a valley about 20 miles long and from 3 to 4 miles wide, lies in the eastern part of Bear Lake County. This is a beautiful and productive valley, the chief products of which are hay, grain, and vegetables. Here much could be effected by means of reservoirs.

THE OWYHEE RIVER BASIN, OWYHEE COUNTY.

Mr. J. C. Pence, a cattle-raiser who has resided for 21 years at Mountain City, Nevada, on the middle fork of the Owyhee River, gave the agent an interesting account of this important section of Idaho, Oregon, and Nevada. The arable lands of this basin in Nevada are high, about 5,000 to 6,000 feet elevation, and are subject to early frost. They are rather too cold for wheat, but produce oats and barley, also potatoes and other vegetables. The difficulty is that cattlemen have taken all the available lands along the north fork of the Humboldt River, and along the middle and south forks of the Owyhee River, and thus keep settlers out.

The Bruneau River of Owyhee County, Idaho, runs through a cañon from 2,000 to 3,000 feet deep, with no opportunities for agriculture except for 20 miles above its mouth. There is considerable irrigation by ranchmen on the different branches of the Owyhee River in Nevada, but none in Idaho, as both the Owyhee and south fork of the Owyhee in Idaho run through cañons. The lower Bruneau Valley, about 20 miles long and 1¼ miles wide, is irrigated and in the possession of ranchmen. There was a dam built across the Bruneau River about half a mile from its mouth, 28 feet high, from which a ditch supplied a large body of land on the Snake River bottom. This dam was carried away in the spring of 1890, but is to be reconstructed at a cost of $75,000. The principal crop here raised is hay for stock "on the range;" fruit, vegetables, and grain are also raised to some extent.

There is also considerable irrigation on Jordan Creek and its branches. This creek empties into the Owyhee River in Malheur County, Oregon. These valleys are quite elevated. They produce hay, grain, and vegetables, but no fruit except small fruits and berries. The Salmon River runs through a cañon in Cassia County to the Snake River and admits of no irrigation.

BINGHAM COUNTY.

From Mr. G. G. Wright, of Idaho Falls, the following information concerning irrigation enterprises in the vicinity of Idaho Falls has been received:

1. The Idaho Canal Company takes water from the Snake River at a point 12 miles above Idaho Falls. It has a canal built down to Blackfoot River, and proposes to cross that river into the Fort Hall Indian Reservation if satisfactory arrangements can be made with the authorities at Washington. It covers 100,000 acres of land already filed upon, and carries 100,000 inches of water.

2. The canal of Idaho Falls Company is now completed to a point just east of Idaho Falls.

3. The Farmers' Friend Canal Company, owned by farmers, is 12 miles long. It takes water out of the south fork of the Snake River, at a point northeast from Idaho Falls, and carries 18,000 inches of water.

4. The Park and Louisville Irrigation Company has a small canal.

5 The Burgess Cereal Canal is another enterprise just under way.

The Miner's inch in Idaho.—The following definition of the miner's inch in Idaho, as a unit of measurement, is given.

Mr. Willis S. Duniway, lawyer and rancher, of Houston, Custer County, states that:

> An inch of water is the quantity of water which will flow continuously from a square inch opening under a pressure of 4 inches above the center line of the aperture. The equivalent of 90 miner's inches is a stream flowing in a flume, with a quarter of an inch fall to the rod, the stream in the flume being 9 inches deep. If this flume is 10 inches wide, it is found to flow about 90 inches of water, or what would be 90 inches of water under a 4-inch pressure.

Mr. C. H. Tompkins, jr., chief engineer of the Idaho Mining and Irrigation Company, gives the following definition:

The miner's inch of Idaho is the quantity of water which will flow in one second from an inch orifice, under a pressure of 4 inches on the middle line of the orifice. It is the one forty-eighth part of a cubic foot of water per second. In agreements for the sale of water the Idaho Mining and Irrigation Company agree to furnish such flow for 24 hours as the unit of measurement upon which payments are to be made. It is found that one miner's inch of water flowing for 24 hours as just described will almost exactly cover 1 acre to a depth of one-half an inch, *i. e.*, amount to about half an acre inch.

ECONOMY IN THE USE OF WATER IN IRRIGATION.

Mr. Willis S. Duniway, of Houston, Custer County, as the result of careful experiment and very close observation, expresses the conviction that grain which is sown in the fall upon ground well plowed and well harrowed in, and which has the benefit of the winter snows, will not require in order to mature the crop, *i. e.*, wheat, barley, or oats, more than from one-third to one-half the quantity of water of irrigation which is required for spring-sown grain. He states that grain sown in the fall, which has the benefit of a long continued snow covering during the winter, will need only one irrigation in order to mature it, and that in case of an open winter, or small snow fall, it will require two irrigations; whereas grain which is sown in the spring always needs three irrigations, and in the case of an open winter or small winter precipitation, will require four irrigations. This fact he declares that he has fully demonstrated in Custer County.

Fall sowing, therefore, subserves two important economies: First, the saving of the water of irrigation, and second, the labor involved in irrigation. As the quantity of land which can be reclaimed depends entirely upon the amount of water which can be secured for irrigation, this view as to the economic use of water has an important bearing upon the general subject of the reclamation of arid lands.

Water-rights in the States of Montana and Idaho.—In Montana and Idaho it is almost impossible for a man to acquire title to a water-right except at the end of a lawsuit. In other words, the administrative features of the laws pertaining to water-rights are so illy defined that it is necessary in almost all cases when the contesting parties can not agree to have recourse to a judicial decision, with all the vexations and damaging delays incident to such mode of procedure. The people of both these States are earnestly seeking a solution of this difficulty under the general provisions of the law of appropriation for beneficial uses.

Civil Engineer Riblett's paper.

ALBION, CASSIA COUNTY, IDAHO, *December* 17, 1890.

JOSEPH NIMMO, Jr.,
Special Agent Department of Agriculture,
Boisé City Idaho:

DEAR SIR: Your circulars and inquiries received sometime since. In general answer to inquiries, will say that no very great progress has been made in irrigation matters in this section of Idaho since the visit of the Senatorial committee last year. There are some matters, however, that are worthy of mention. The use of current wheels running in Snake River for the purpose of raising water is becoming extensive, notably at Story's Ferry, at Starrh's Ferry, and at Anderson's, just below Starrh's Ferry.

Mr. A. A. Hard is superintendent of the works at Story's Ferry and at Anderson's. His post-office address is Tremont, via Albion, Cassia County, Idaho.

Mr. T. A. Starrh has a wheel at Jessie, Cassia County, Idaho; also Mr. Samuel Holt.

This last season the Alturas Land and Irrigation Company was incorporated under the laws of Utah Territory, for the purpose of diverting the waters of Snake River, at a point near Story's Ferry, for the irrigatión of large bodies of land in Logan and Cassia Counties, in the State of Idaho; also to furnishing water for the development of placer mines, and for water-power and other purposes. The intention is to span Snake River with a dam 53 feet in height. The situation for a dam is very favorable. The start of this enterprise was mentioned in the report to the Senate committee. The original locators have transferred their interests to the incorporated company mentioned above, retaining a portion of the stock.

The officers of the Alturas Land and Irrigation Company are N. Treweek, president; William Babcock, jr., vice president; C. T. Stevenson, secretary and treasurer, room 49, Scott-Auerbach Building, Salt Lake City, Utah.

Locations of water rights were lately made at the Shoshone Falls and at the Twin Falls (3 miles above the Shoshone Falls) by G. V. Bryan, Maj. Edmund Wilkes, F. M. Washburn, George M. Parsons, Texas Angel, and Samuel Friend, for the purpose of diverting the waters of Snake River for domestic, mining, manufacturing, agricultural, power, and other purposes. The notice of location reads that they intend carrying the waters (after diverting them) down the river about a mile, then they can be carried down the river by means of flumes and other conduits to great distances, for the purpose of furnishing water and hydraulic power for the great number of rich bars that are found along the river. The surplus power can be used for the purpose of throwing the surplus water to the top of the bluff for all purposes mentioned in the location notice.

A great manufacturing city could be located on top of the bluff in Cassia County, and great bodies of fine agricultural land stretch off in the distance to the south and west. The falls furnish at least 200,000 horse-power (available) during low-water time, and enough water can probably be thrown to the top of the bluff after other uses are supplied to irrigate 100,000 acres of land.

Texas Angel, of Hailey, Alturas County, is the president, I believe; G. V. Bryan, a prominent mining man, is also of Hailey. Major Wilkes, who is also concerned in the Utah and Idaho Railroad scheme, resides, I believe, in Salt Lake. He is a greal civil engineer and railroad promoter. George M. Parsons is a prominent attorney of Hailey. I am informed that F. M. Washburn is a member of a Minneapolis investment company. I am not acquainted with Mr. Friend, but am informed that he is a man of prominence in the Wood River region.

The project is a magnificent conception, is entirely feasible, and will be a grand achievement. The Twin Falls has (we understand) been selected for the crossing of Snake River by the Utah and Idaho Railroad. No artesian wells have been bored, or no such work is now in progress in Cassia County, although the indications of immense stores of subterranean and artesian waters are favorable in many places. We think such wells would be a success in Cassia County.

The waters of all our streams, especially the smaller ones, are subject to underflow. The waters generally reappearing below in the bed of the same stream, although this is not always the case. Some of these waters probably do not show again until they reach Snake River.

Canals in places are subject to great seepage until the bottom becomes puddled by the sediment. No irrigation is done by means of pipes or other subterranean conduits, although I think it could be extensively used to advantage. No steam pumps are used; fuel is too expensive. A poor quality of surface coal has been discovered on Goose Creek. Campers have used it to cook their meals. Further and deeper investigation may disclose good coal.

One of our great present and pressing needs is Government surveys. Many settlers are located upon unsurveyed land. In Logan County the great body of lands to be covered by the proposed system of canals heading near Story's Ferry is unsurveyed. If the canals are taken out, or work is even started, these lands will be immediately taken up and almost endless confusion will result.

The only way Snake River can be tapped high enough to cover the greatest part of the Cassia County lands is to go about or above Eagle Rock, swing around through Bingham and Oneida Counties, and around the upper part of Raft River, Goose Creek, and Salmon Creek Valleys. By running on toward the Bruneau large quantities of Owyhee County lands may be covered. A similar system of canals can do much on the north side of Snake River; but this will require the construction of large reservoirs, for which the country around the head of Snake River affords peculiar facilities. State or Government aid may be necessary.

Very truly, yours,

FRANK RIBLETT,
Civil Engineer.

Statement by Mr. Thomas C. Galloway, of Weiser.

Land in Washington County without water, except on the narrow strips along water courses, is valueless for farming or grazing purposes. With water it is worth $20 to $25 per acre.

Water contains all the fertilizers necessary to produce abundant crops thus far. Corn, oats, and barley mature in four months, wheat in five months. We have a home market for all we raise usually. This year we are shipping hay and potatoes to Montana, hay to Portland, Oregon, and potatoes to the Missouri River.

Our fruits and garden produce being of superior quality and texture command the highest price where samples have been forwarded.

We have no unit of measurement. What is called a " miner's inch " is a very indefinite quantity.

As most of the land is of a granite sand formation, and the surface inclines to the water courses, no drainage is necessary. The soil is from 10 to 30 feet deep.

As nearly all ditches in southern Idaho pass through chalky bluffs, seepage is very great. With use and puddling with sand, the bottoms and banks in time become firm and water-tight. The sediment in times of a freshet is the best puddling agent.

Washington County has a watershed of its own, in the shape of a horseshoe. The Weiser River and its twenty-five tributaries furnish the water.

There arethree large ditches and many small ones. The largest is 17 miles long, 14 feet wide at the bottom, and has three-eighths of an inch grade to 100 feet.

There are 10,000 acres of land under the ditch, above and below Weiser City. The cost of construction was $40,000, and it will require $10,000 to complete the same. The property is owned by an incorporated company, with office at Weiser City.

Water is sold at $1 per inch, measured under 4 inches pressure; cost per acre about $1 per year.

Washington County furnishes the best possible field for local experiment. Dams or reservoirs could be cheaply and substantially constructed to hold back the abundant supply of spring for summer use. Not more than one-tenth of the half million acres of land in this county can be safely improved with the present supply in July and August; for we occasionally have dry seasons following a light fall of snow in the mountains, which would make farming unproductive and uncertain.

IRRIGATION STATISTICS AND PROGRESS IN COLORADO

FOR

1890.

Prepared for the Office of Irrigation Inquiry, Department of Agriculture, by

L. G. CARPENTER,

Professor of Irrigation Engineering, State Agricultural College.

IRRIGATION STATISTICS AND PROGRESS IN COLORADO FOR 1890.

By L. G. CARPENTER,

Professor of Irrigation Engineering, State Agricultural College.

WATER SUPPLY OF THE YEAR.

It is too well known to repeat that the source of the water supply of Colorado is the mountain snows, which, falling in winter, last until late in the summer. Consequently the farming community watches the gathering snow upon the mountains through the winter with much interest, for the prosperity of the community will largely depend upon its amount. The streams, fed by the melting snows, partake of the character of such streams, small in winter, with the returning warmth of spring they increase and rise steadily as long as the fields of snow remain practically undiminished in size. Then there comes a limit and though the heat is greater, there is less snow to melt and it is largely on the northern slopes and in the gulches. The maximum usually occurs in May or June. So closely is the connection between the melting snows and the streams that the daily heights of the rivers show markedly the variation due to the heat of the day and the freezing of the night. A cold spell of weather is followed immediately by a fall in the streams.

During the winter of 1889–'90 the farming communities felt satisfied that there was a large supply of snow in the mountains, and consequently rested content in the spring when the flow of the first rise was going past, for they believed there would be an ample supply at the time when the ordinary irrigating season began. But as it proved they were greatly mistaken. Just as water was needed most a cold spell greatly reduced the insufficient supply, and there has been much suffering of crops for water. The necessities of the year have caused a great deal of discussion as to means of increasing the water supply.

The following have been the maximum discharges of the streams named during the year, in cubic feet per second:

Stream.	Discharge per second.	Date.
	Cubic feet.	
Cache a la Poudre	1,804	June 2
Big Thompson	675	July 21
St. Vrain	544	June 2
Boulder Creek	1,200	Aug. 11
South Boulder	544	May 28
Bear Creek	75	July 22
South Platte (in the cañon)	....	....
Arkansas River	3,270	May 28

The following have been the corresponding flood flows for some other years:

Stream.	Maximum flow.	Date.
	Cubic feet.	
Cache a la Poudre	5,600	June 28, 1884.
Do	3,850	June 5, 1885.
Do	2,730	May 30, 1886.
Do	1,550	June 19, 1888.
Big Thompson	830	June 16, 1888.
St. Vrain	490	June 19, 1888.
Boulder Creek	325	Do.
South Boulder	230	Do.
Bear Creek	130	June 1, 2, 3, 1888.
Clear Creek	490	June 13, 14, 1888.
South Platte	780	June 21, 22, 1888.
Arkansas River	2,750	June 19, 1888.

The last river had a maximum flow of 7,700 cubic feet per second May 29, 1886; of 6,500 cubic feet per second July 18, 1887. These are all part of the drainage system of eastern Colorado.

WATER DIVISIONS.

In Colorado the waters of the State, flowing in their natural channels, are declared to be the property of the State, and the State in some measure exercises a control over them. For the purpose of administration the State is divided into numerous water districts, each having a water commissioner, if the people of that district think it is necessary, and these districts are combined into a few divisions. The divisions consist of all the tributaries of some principal line of drainage, and, except in a few cases, no more, it is convenient to refer to the various divisions by number and they are therefore given here. They are as follows.

DIV. I.—The South Platte and its tributaries. In addition it includes the area in North Park, drained by the North Platte, and a small area in eastern Colorado drained by Frenchman's Creek and the North and Middle Forks of the Republican, not important enough districts to constitute separate divisions.

DIV. II.—The Arkansas River and its tributaries. This division likewise includes small areas drained by the South Fork of the Republican and the Cimarron, which do not flow into the Arkansas within the limits of Colorado. The largest amount of irrigation development in 1890 in the way of canal construction has been done in this division.

DIV. III.—The Rio Grande River and its tributaries in Colorado. This consists principally of the San Luis Valley and the area watered by its immense canals.

DIV. IV.—The tributaries of the San Juan. This is in southwestern Colorado and is the smallest of the divisions.

DIV. V.—The Grand River and its tributaries. This is in western Colorado and, like Divisions IV and VI, is entirely west of the continental divide.

DIV. VI.—The tributaries of the Green River. The rivers which drain it immediately are the Yampah or Bear River and the White.

Of these divisions No. I is that which has been settled the longest, has the greatest development of agriculture and irrigating interests, and is crowding its present water supply the most.

The following are the amounts of water decreed by judicial investigation as far as decrees have been rendered:

Of the 67 water districts into which the State is divided, many have not yet rendered their decrees. Many of the districts have been slow in securing decrees, for as long as there has been plenty of water in the special district there would be no immediate advantage of incurring the expense of investigating the claims of the various users. Until this is done there is no official determination of the amounts of water to which each canal is entitled. Still, it should be said, that the decreed amounts often bear but little relation to the capacity of the canal. This is due largely to the lack of knowledge of the meaning of the unit used—a cubic foot per second—and to lack of sufficient knowledge of the flow of water on the part of many intrusted with this important determination, as well as from the fact that the public had no one to officially represent them. In consequence the decreed amounts are frequently largely in excess of the carrying capacity of the ditch. The older districts of the State are those most subject to these decrees. If comparison be made between the decreed amounts and the maximum flow of the streams, it will be noticed that the decreed amounts largely exceed the flow of the stream, even at its maximum. The decrees of district 23 have been given this year. That of district 20 has been in court for a year or more past, and it is soon expected to be rendered for that district, which, if gauged by the number and importance of its large ditches, is the most important district in the State.

Number of districts and amounts of water decreed in each per second.

	Cubic feet.
1	3,026.00
2	3,480.82
3	4,636.62
4	2,527.73
5	2,856.19
6	4,840.99
7	1,180.00
8	2,428.68
9	437.55
10	*770.82
11	673.00
16	402.00
23	4,635.00
37	192.00
38	545.00
39	368.00
40	797.00
41	1,289.00

* State Engineer Report, 1888, gives the appropriation at $779.99.

AREA "UNDER DITCH."

The following is an estimate of the area "under ditch" in Colorado at the present time. By this area we mean that which lies under the line of some existing canal and could receive water from it by gravity. The possibility that there may not be sufficient water to supply these areas is not taken into account.

The estimate of areas as published in the annual report of the Colorado Agricultural Experiment Station for 1889 was based largely upon unpublished data, including maps of the routes of canals. The present one is based upon additional information of the same kind, supplemented by information collected by personal visits to various parts of the State, and includes the canals constructed during 1890, but includes the areas only to the points where constructed. The record must be looked upon as incomplete, especially for the divisions west of the continental divide. These divisions consist almost entirely of narrow mountain valleys, where the ditches are short and small, and where it is difficult to secure information. In these divisions the aggregate may quite likely exceed that given here by a considerable amount. The estimate of 1889 made the area under ditch as 4,500 square miles in round numbers, or 3,000,000 acres. The present estimate makes it to be more than a third greater. This increase is not entirely due to new construction. The area assigned to Divisions IV, V, and VI was shown by more complete information to be too small. But the area brought under ditch for the first time this year exceeds three quarters of a million acres.

Square miles and acres covered by ditch in Colorado.

	Square Miles.
Division I:	
Platte below Poudre	283.21
Platte above Poudre, with Bear and Clear Creeks	551.04
St. Vrain and Bowlder	294.59
Big Thompson	134.21
Poudre	393.54
North Park	250.00
South Park	100.00
District 65 added since last year	40.00
	2,046.59
Or 1,309,818 acres.	
Division II:	
Arkansas River east of Pueblo, north side	1,080.50
Arkansas River east of Pueblo, south side	139.20
Huerfano, Cuchara, La Veta, Apishapa, and others	173.60
Upper Arkansas and Cañon City and Fountain	250.00
	1,648.30
Or 1,054,918 acres.	
Division III:	
San Luis	1,575.00
Or 1,008,000 acres.	
Division IV:	
Dolores	120.00
Mancos	60.00
Pine	20.00
Florida	10.00
La Plata	7.00
Animas	50.00
	267.00
Or 170,880 acres.	
Division V:	
Grand River above Junction	50.00
Grand Junction	120.00
Montrose	250.00
Additional	100.00
	520.00
Or 332,800 acres.	
Division VI:	
Bear and White Rivers	200.00
Or 128,000 acres.	

Making a total of 6,256.89 square miles in the State, and 4,004,409 acres.

AREA IRRIGATED.

The following is an estimate of the area irrigated in some portions of the State during 1889 and 1890. The areas given for the various districts of Division No. I, are mostly obtained from the official reports of the various water commissioners to the State Engineer. The amounts reported by them are generally based upon reports to them by the various ditch superintendents, and while these can not be looked upon as strictly accurate, they have the advantage of estimates made by men who are familiar with the lands watered by the various ditches. The area given for Division I is the most reliable. Those next in accuracy being Divisions II and III. The estimates for the other divisions may be very far from the truth, but are here given as a basis for correction.

Division and district.	Stream.	Irrigated area.	
		1889.	1890.
Division I, Platte Valley:		*Acres.*	*Acres.*
1	South Platte	24,175	16,775
64	....do	24,610	*24,610
2	....do	49,419	51,006
8	....do	20,297	*20,297
3	Cache la Poudre	135,000	139,227
4	Big and Little Thompson	91,037	89,790
5	St. Vrain and Left Hand Creeks	94,013	94,565
6	North and South Boulder	77,683	81,175
7	Clear Creek	87,926	104,671
9	Bear Creek	4,965	4,893
	Bear Creek (from reservoirs)	5,191	3,201
	North Park (estimate of B. F. Sturtevant)		75,000
	South Park		25,000
	Republican River and Frenchman's Creek		*2,000
	Total	614,334	729,210

* Districts 8 and 64 considered the same as in 1889. The last two items are uncertain, being based on insufficient data.

	Acres.
Division II, Arkansas Valley:	
Arkansas River proper, under the Colorado and Kansas Canal	1,000
Amity	4,000
Black Canals	2,000
Las Animas Town Ditch	1,000
Riverside	2,000
Jones	2,000
A. R. L. R. & C. Co	35,000
Rocky Ford Ditch	4,000
Catlin	10,000
Fowler or Oxford	4,000
Private ditches	2,500
Total, Arkansas Valley below Pueblo	* 68,500
District 14, lower middle Arkansas	9,000
District 15, St. Charles	5,000
District 16, Huerfano	13,000
District 10, Fountain	20,000
District 11, Upper Arkansas	40,000
District 12, upper central Arkansas	20,000
District 18, Apishapa	6,000
District 19, Purgatoire	30,000
Total, Division II	143,000
	211,500

* The above estimates are from data furnished by J. H. Nelson, C. E., of La Junta, and Z. T. Duval, C. E., of Lamar.

Division III, the Rio Grande division:	
District 20, Rio Grande River	150,000
District 21, Alamosa	50,000
District 22, Conejos	35,000
District 24, Culebra	5,000
District 25, San Luis Creek	30,000
District 26, Saguache	30,000
District 35, Trinchera	20,000
Total, Rio Grande division	320,000
Division IV, San Juan division; total (rough estimate)	75,000
Division V, Grand River division; total (rough estimate)	195,000
Division VI, Bear River division; total (rough estimate)	50,000
Total for the State (approximate)	1,585,500

MILEAGE OF CANALS IN COLORADO.

By adding the lengths of the canals in the various districts, we obtain the following approximation to the lengths of the primary canals. With present knowledge it would be useless to make an estimate of the secondary. The estimate is quite reliable for all of division I, with the exception of district 23, or South Park, and is closely approximate for most of Divisions II and III.

	Miles.
Division I:	
Districts 1 and 64	238
District 2	217.75
District 3	340.75
District 4	236.66
District 5	250
District 6	258
District 7	255.63
District 8	240.35
District 9	62.25
District 23 (estimated, over 200 ditches)	200
Districts 46, 47, 48 (estimated, there are some 300 ditches)	500
District 65	50
Total, Division I	2,849.39
Division II:	
District 10	61.25
District 11	55.75
District 12	24.25
District 13	25
District 14	214
District 15	98.25
District 16	331.25
District 19	65
District 66	10
Districts 17 and 67	289
District 18	63
District 49	10.25
Total, Division II	1,247
Division III, Rio Grande division, San Luis Valley	1,476.75
Division IV, total (incomplete)	235.
Division V, total (incomplete)	324.50
Division VI, total (incomplete)	184.25
Total for the State	6,316.89

This is undoubtedly too small. Throughout the mountain regions are numerous ditches, mostly short, which in the aggregate would add a considerable mileage.

The following is a rough estimate of the cost of the irrigation works of Colorado. It can not be considered other than an approximation, which is based on imperfect data, but as it is almost impossible to secure the data sufficient to make a perfectly reliable estimate, the above is furnished as the best that can be had at present, and as a fair estimate probably not far from the truth. If anything, it is below the actual amount of money that has been invested, but with a more minute summation it is not likely that the sum total will exceed $15,000,000. The sums here given are based upon a personal knowledge of much of the State, and of the cost of most of the large canals. Each water district has been summed up separately, by adding the known cost of the individual canals, or the assumed cost based upon a more or less intimate knowledge of the size, length, and circumstances of construction. These have been added, and the sum is given for each of the principal water districts east of the mountains. A summation of the capital stock of the corporations would give a sum in excess of this, but their capital stock is often much greater than the actual cost. Such corporations, also, are sometimes unwilling that the true cost should be known. In the above summation it has been the attempt to estimate the actual cost.

Estimated cost of canal construction.

Division and district.	Stream.	Cost.
Division I:		
Districts 1 and 64	South Platte	$400,000
District 2	....do	300,000
District 8	....do	900,000
District 23	....do	100,000
District 3	Cache la Poudre	950,000
District 4	Big Thompson	600,000
District 5	St. Vrain	400,000
District 6	Bowlder	400,000
District 7	Clear Creek	300,000
District 9	Bear Creek	200,000
Districts 46, 47, and 48	North Park	200,000
District 65	Republican	50,000
Total		4,800,000
Division II:		
District 17	Arkansas River	1,180,000
District 14	....do	220,000
District 12	....do	100,000
District 11	....do	50,000
District 19	Purgatoire River	50,000
District 18	Apishapa	50,000
District 16	Huerfano	100,000
District 15	St. Charles	160,000
District 13	Grape Creek	20,000
District 10	Fountain	75,000
Total		2,005,000
Division III:		
District 22	Conejos River	225,000
District 21	La Jara	100,000
District 24	Culebra	40,000
District 35	Trinchera	100,000
District 25	San Luis	60,000
District 27	Carnero, La Garita	40,000
District 26	Saguache	75,000
District 20	Rio Grande	1,250,000
Total		1,890,000

Estimated cost of canal construction—Continued.

Division and district.	Stream.	Cost.
Division IV:		
District 29	Piedra, etc	$50,000
District 30	Las Animas	100,000
District 31	Pinos	75,000
District 33	La Plata	50,000
District 34	Mancos	100,000
District 32	McElmo, Hovenweep	480,000
Total		855,000
Division V, total		1,400,000
Division VI, total		400,000
Grand total for the State		10,950,000

PROGRESS IN CERTAIN LINES DURING THE YEAR.

The people of district No. 3, the Cache la Poudre, were the first to invoke the aid of the telephone in the distribution of water between the ditches. This is largely due to the foresight of Hon. B. S. La Grange, who has for a long time acted as the water commissioner of the district and saw that such a system would be a great saving of help and of water. The line is nearly 21 miles long. Telephones are placed at the principal ditches and at the gauging station in the cañon above where any canals take their water, as well as at the office of the commissioner. After one year's experience of its use, at a meeting of the associated ditches at Fort Collins November 19, 1889, the opinion seemed to be unanimous that it had paid for itself during the year and that it had now become a necessity. Patrons of the larger companies now assume that it will not be long ere such a system shall be adopted for the individual lines.

For the development and conservation of the water supply the people of this water district (No. 3) have held several public meetings to consider the questions affecting them as a body. They have proposed the formation of reservoirs to be for the benefit of the whole district, and have discussed the means by which the whole district could work together. Several reservoirs are already built in the district and are surveyed. The plan proposed by some is based on the situation, which is that most of the ditches having the earliest right to water are at the lower end of the district. During the latter part of the season these lower canals are entitled to nearly all the water, to the exclusion of the upper canals. Most of the convenient sites for storing are below the heads of these upper ditches and therefore can not benefit them directly. They therefore propose to fill these reservoirs through their canals and later in the season, when in need of water for irrigation, but not entitled to it from the river directly, to supply the demands of the lower ditches from the water stored in their reservoirs and draw an equal amount from the river for themselves; thus the lower canals would lose none of their present advantages, while the upper ones would be put in a position of comparative security. The reservoirs proposed for this purpose, and ample enough to hold all the storage supply of the year, are, in addition to those now in use, Terry Lake, north and west of Fort Collins; Long Pond, north and east; and a basin located in sections 27, 28, 33, and 34, township 7 north, range 67 west. The latter consists of two separate basins, divided by a ridge, which would be entirely submerged in high water. This would cover 649 acres on an average 15 feet deep, or store nearly 10,000 acre-feet of water. From this reservoir a line has been surveyed some 25 miles long, 10 feet wide on the bottom, 3 feet in depth, and with a grade of 2.6 feet per mile. Nothing has been done as yet on the ditch, but the small dike for the reservoir is completed and the reservoir is now in process of filling.

Another reservoir is on the southwest quarter section 15, township 6 north, range 66 west. Its area is about 37 acres, capacity 8,709,683 cubic feet. The dam for this reservoir and the ditch leading to it are now in course of construction. This is to be filled from Cache la Poudre Canal No. 2. J. D. Stannard, of Greeley, is the engineer of both of the above. Another small reservoir is situated upon section 20, township 7 north, range 67 west. A survey has been made of a site on what is known as the Little South Fork of the Poudre. It has not yet been decided that it will be built.

The Larimer County Ditch Company has already a reservoir in the mountains on the headwaters of the Poudre. It was originally a natural lake, at a point where several mountain streams meet and have formed a basin. It is known as Chambers Lake. At low water it has an area of about 110 acres, and when filled 16 feet it has an area a hundred acres greater. The embankment is comparatively short and is 22 feet in heighth. This reservoir occupies the natural bed of the stream, and has given rise to a lawsuit which has determined that a company can make such a disposition of it. The same company has intercepted at this elevation, 9,000 feet, several small streams, which flow naturally into the North Platte River, and turned them into Chambers Lake. They likewise procure some water from the headwaters of the Grand River, and late in the fall (1890) sent an outfit of men and teams to extend the last intercepting ditch, but the early fall of snow prevented the completion of the work.

Among several other proposed reservoir sites is Boyd's Lake, a basin between Fort Collins and Loveland. It is large enough to have an area of several hundred acres and is so situated that water could be run into it either from the Poudre or the Big Thompson, and the water could be drawn out so as to benefit the people near Greeley. A number of reservoirs already in service.

Claymore Lake is a body of water at the eastern base of the foothills, which has been used for several years by the Pleasant Valley and Lake Canal Company. It was originally intended to be filled by means of a tunnel, and one was constructed at a cost of some $40,000. It has since partially filled up, and the lake is filled through the regular channel. Warren's Lake is another reservoir that has been used for some years. The North Poudre Canal has several reservoirs and is developing more. This canal, which derives its water from the North Fork of the Poudre, has a late priority and in seasons of scarcity has to depend almost entirely on its reservoirs. Its reservoirs are as follows:

Name.	Depth.	Area.		Capacity.
		Lower.	Upper contour.	
	Feet.	*Acres.*	*Acres.*	*Cubic feet.*
Stuchell	8	3⅛	15¾	3,036,467
No. 4	15	47	95½	46,766,420
No. 2	20	92¼	255	145,355,180
No. 1	14	*25	76	29,345,591
No. 3	26	51	154½	111,057,813

* Estimated.

All the above are in use, Nos. 1 and 3 and the Stuchel to their full capacity, No. 2 to only a small extent this year. No. 4 will be filled some 10 feet the coming year.

The Larimer County Canal has several sites, some of considerable extent. Some are already in use.

In district No. 4, which is the district watered from the Big Thompson, several reservoirs are in use, some of considerable size, but most rather small. The Mariana Reservoir was started in 1888. It draws its water from the Rist Ditch. It covers over 30 acres by means of an embankment 1,000 feet long and 17 feet high. It is now somewhat larger, as the dam has been raised during the season of 1890. The cost of the dam mentioned was $3,400.

The Home Supply Reservoir is still larger, it covering at first 418 acres, with a subsequent enlargement.

Districts 5, 6, and 7 have constructed a large number of private reservoirs, besides improving some corporate ones. So far as the writer knows there has been no attempt in these districts to store the storm water, other than the flood water as it appears in the regular channels.

The Manvel Canal is taken from the Arkansas River, and its construction was begun in April, 1890. It is designed to be 30 miles long. At present 10 miles are constructed. At the head it is 12 feet wide, with side slopes of 1 to 1, and this width gradually decreases until at the tenth mile it is 10 feet. It is to carry 130 cubic feet of water per second. The first 10 miles have cost $4,000. Water rights will be sold at $800 per 80 acres, and will be based on a duty of 80 acres per second-foot. It has no flumes, and is of comparatively easy construction. Z. T. Duval, of Lamar, is the engineer.

The Colorado and Kansas Canal was projected by F. B. Koen & Bros., of Lamar. The incorporation papers were filed October 6, 1884. Some work was done as early as 1886, and some has been done from time to time since. A large lateral now extends to a distance of 30 miles. This was originally intended to be the main canal, but the main line has since been relocated on a grade of 1 foot to the mile, with the intention of extending into Kansas. The main line is constructed for 9 miles, or as far as Dry Creek, a few miles west of Lamar. This canal or its lateral has supplied about 1,000 acres during the past year. The lateral has one flume several hundred feet long across Willow Creek, just south of Lamar. It is 30 miles in length. At Carlton Creek there is a lateral parallel to the Manvel Canal. The canal, as projected, is to be 155 miles long, and is estimated to cost $450,000. The cost to the present has been $90,000; the main line cost $30,000 alone. The canal is to be 35 feet wide for the first 106 miles to the State line, with side slopes of 1 to 1 in natural earth and 1½ to 1 in embankment, and with a berme of 6 feet. There is also a subgrade of 1 foot. The grade is 1.056 feet per mile. The laterals, which are not planned yet, are to have grades of 1.584 feet. There are several reservoir sites along the route. Z. T. Duval, of Lamar, is the engineer of this work.

The Amity Canal takes its water from the Arkansas on the north side within the grounds of the historic Bent Fort. This canal was begun in 1886 as a small canal, but was enlarged and lengthened in 1889. Some work is still being done upon it, and there is talk of extending it to a point opposite Syracuse, Kans. At present it terminates at the first branch of Horse Creek, 63 miles from the headgate, and about 17 from the State line by the route of the canal. At the headgate the width for a short distance is nearly 40 feet, but for the first mile its width is 25 feet, with a grade of 1.584 feet per mile. Then it narrows to 16 feet in width, with a grade of little more then a foot (1.056) per mile. At the tenth mile it narrows to 10 feet, which it retains to the fortieth mile, where it becomes 8 feet wide. The grade from the thirty-third mile is 1.584 feet per mile. It has no flumes, and has apparently no more serious problems to contend with than those arising from the sand of the Arkansas. It is designed to carry 325 cubic feet per second. As at present constructed, it covers about 65,000 acres, and furnished water for some 4,000 the past season. Its water rights are based on a duty of 80 acres per second-foot. The price asked is $1,250. The cost has been about $100,000. The Amity Canal was the successor of the New Era, whose incorporation papers were filed December 8, 1885; those of the Amity were filed March 7, 1887.

The Bob Creek Canal, as it is usually known, is one of the largest of the State, and measured by the area which may draw water from it the largest, with possibly one exception. This canal draws water from the north side of the Arkansas River and covers a large area of land to the east of Pueblo. Its head is located about 16 miles east of Pueblo. It follows very closely the line of a survey made some years since by the Hon. B. S. La Grange, while deputy land commissioner. It does not get above the bluffs for some 18 miles, but when it does its line rapidly recedes from the river, and covers an exceptionally large area. The canal as planned is to be some 118 miles long, but owing to financial difficulties of the projectors it may be some time before it is completed as projected. Some 75 miles are completed, at a cost, it is said, of $350,000. There has been no irrigation carried on during the year, though some farmers put in crops with the expectation that water would be available. There are some immense reservoir sites under this canal. The largest one has an approximate area of 20,160 acres, with a maximum depth of 40 feet. Reservoir No. 4 can be filled from the preceding, and is 5,020 acres area. Number 5 has an area of 4,160 acres; No. 2 of 2,560, and No. 1, a small one, of about 200 acres.

The Otero Canal is another large one whose construction has proceeded during the year of 1890. This near the western line of Otero County, in range 59 west, and waters land on the south side of the river about Rocky Ford and La Junta. It will be some 65 miles in length. The greater part of this portion is now completed. The offices of the company are located at La Junta. J. H. Nelson is the chief engineer. Owing to failure of the principals, the work has fallen into the hands of the contractors, Messrs. Price and McGavick, by whom a new company has been organized.

The South Side Ditch is another canal, still above the Otero Canal. It is supported by the people of Rocky Ford and is designed to extend for some 80 or 90 miles. A considerable portion was constructed in 1890, but definite information has not yet been obtained.

SUPPLIES.

Artesian irrigation has been carried on somewhat during the year in the Denver Basin and also in the San Luis Valley. In the Denver Basin the wells are mostly of small flow, and the cost, considering the amount of water furnished, is relatively great. Still the demand upon the existing water supply is so great and the scarcity of water is such that many, judging from conversations with land owners near Denver, would sink wells for irrigation purposes could they strike water within a reasonable depth. These owners spoken of, being the ones having the latest rights to water, and therefore on the lands the most recently settled, are consequently largely at some distance from the valley of the river and above the limit of flowing wells. Quite a number are using the water on a small scale, and for some the artesian water forms the only source of supply. Several have connected their wells with various points with pipes, and secure a comparatively large duty.

In the San Luis Valley the flow of the wells is much larger than in the Denver Basin, and the water is obtained much nearer the surface and at a nominal cost. A flowing well often costs less than $25. The depths vary from 40 to 800 feet, but the first water is usually found within 100.

A personal visit to the valley in September confirms the estimate, presented to the Artesian Wells Investigation in June by the writer, of 2,000 wells in the valley.

This valley is blessed with a comparatively large supply of water for irrigation from other sources, and consequently has comparatively little inducement to develop artesian wells for that purpose. Some farmers are, however, using this water for irrigation, a few as their only source of supply. The effect has been good so far as known. The acreage thus watered, a personal visit convinces me, has been much less during the past year than was reported in the spring by the water superintendent of that division to the artesian wells investigation.

The wells having the greatest flow are at Alamosa. These are also the deepest wells in the valley, and passed through many water strata. One well, the town well measured by the writer, had a flow of 400 gallons per minute. The largest well could not be measured in the time at the disposal of the writer, but its flow may have been as much as 600 gallons per minute. These were both 6-inch wells. Temperature of the latter, 74.7 F.; of the former, 72 F.

The prevailing sizes of wells are those 2 inches and 3 inches in diameter. The temperature of these wells, which are nearly the same depth over a range of 60 miles, is nearly the same, and about 50 F. One 3-inch well was seen which threw a column of water 33¾ inches in an unbroken stream above the casing. This well is located nearly 20 miles due north of Monte Vista.

IRRIGATION BY PUMPING.

In places where pumping is needed additional thought and attention is being given to this method of procuring water. The Greeley Irrigation Pump Company has placed a number during the year over the western country. It is not a question of possibility with this method; it is almost entirely one of cost, which is principally due to expense of fuel. Where this can be obtained at small cost, there is no question that this method will be used to a great and increasing extent. The conditions where pumping is carried on in this State are: Where water is to be obtained from wells; from the inflow in valleys and streams; from the inflow from the seepage of ditches lying above the land; from seepage which collects in ponds, etc. Also where land is valuable, as near Denver, to supply land which is above a ditch or reservoir from such source. Then in places where the streams are of too small grade to enable ditches to be taken out, or where the banks are rather high and unfavorable to canal building, as along the Bear and Gunnison and Grand Rivers in the western part of Colorado.

Amount of water appropriated each year according to the judicial decrees so far rendered.

Water Division I, with length of canals in miles and amount in cubic feet per second of yearly appropriations of water.]

District.	Miles of canal.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.
1	238									
2	217.75		29.77		47.88	89.57	56.85	245.65	41.51	
3	340.75		24.8	24.06	127.2	8.7	78.39	43.96	78 14	169.49
4	236.66			99.62		37.14	42.73	139.92	74.45	97.03
5	250		64.12	87.61	123.03	118.43	103.9	180.18	102.12	29.06
6	258	116.85	116.03	43.74	348.82	424.65	253.66	587.57	107.86	
7	255.63		76.43	139.11	40.15	53.86	50.94	142.51	8.64	36.2
8	240.35		37	57.09	28.18	50.36	84.01	34.2	28.88	69.05
9	62.25	11.58	35.76	32.99	50.59	30.86	25.47	67.75		8.94
23	7						5.2			
*46, *47, *48, 64, 65 — No decrees granted.	*500 ... 50									
Total	2,656.39	128.43	385.91	484.22	765.85	813.57	701.9	1,837.74	511.6	409.77

District.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.
1								240.84	58.08
2		38.39	64.73	421.97	12.18	398.66	158.5	314.14	205.06
3	55.3	67.9	191.25	583.15	317.93	416.67	281.14	27.47	
4	3.77	31.51	39.04	40	13.21	250.43	12.25	143.41	103.81
5	20.28	50.65	270.25	222.3	135.72	100.87	123.42	22.93	28.7
6	238.24	6.58	199.69	388.11	323.53	928.42		312.04	163.8
7	4.3	24.77	6.31	31.94	154	118.23	138.26		
8	37.7	12.46	21.8	47.5	47.4	101.13	29.99	20.42	10.35
9	17.21	7.94	1.49	28.42			12		
23	10.4	1.6	1	3.2	2.4	6	2.4	6.4	19 2
Total	387.2	241.8	795.56	1,569.59	1,006.37	2,320.41	757.96	1,087.65	588.82

District.	1877.	1878.	1879	1880.	1881.	1882.	1883.	1884.	Total.
1	26.65	88.2				1,931.25	580.47	2,479.29	5,404.78
2	224.7	23.63	545.1		281.21	339.42		32.78	3,642.7
3	124	732,59	149.52	467.27	474.82		115.64		4,559.34
4	209.42	235.51	6.22	191.53	626.41				2,397.44
5	55.85	136.97	32.83	11.7	7.54				2,028.2
6		105.32	60.6		154.22				4,879.73
7	18.26	52.74			32.34		88.46		1,220.45
8	13.25	358.18	1,211.17	49.62	38.94	62.06			2,450.74
9		26.68			4.01	75.87			437.56
23		5.2		17 8	2.8				83.6
Total	672.13	1,765.02	2,005.44	737.92	1,622.32	2,408.6	784.57	2,512.07	27,104.54

* Estimate.

[Water Division II, with length of canals in miles and amount in cubic feet per second of yearly appropriations of water.]

District.	Miles of canal.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.
10	61.25	.74	59.9	74.53	120.49	38.36	3.22	52.15	19.56
11	55.75					7.23	27.92	259.49	36.22
12	24.25								
13	25								
14	214								
15	98.25								
16	331.25								
17	178.75								
18	63								
19	65								
49	10.25								
66	10								
67	110.25								
Total	1247	.74	59.9	74.53	120.49	45.59	31.14	311.64	55.78

Amount of water appropriated each year, etc.—Continued.

District.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.
10	44.18	10	24.16	97.02	42.08	51.74	67.31	34.36	3.67
11	25.29			7.06	14.93		144.03	259.41	10.24
12									
13									
14			7.28	5.46	6.89	.78	3.25	2.34	
15									
16									
17									
18									
19									
49									
66									
67									
Total	69.47	10	31.44	109.54	63.9	52.52	21.59	296.21	13.91

District.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	Total.
10	13.99	3.1	8.52	5.02	5.79			779.99
11	7.6	25.05	2.31	40.96	20.69	45.9		934.33
12								
13								
14		6.37	5.2	5.81				44.16
15								
16								
17								
18								
19								
49								
66								
67								
Total	21.59	34.52	16.03	51.79	26.48	45.9		1,758.48

[Water Division III, with length of canals in miles and amount in cubic feet per second of yearly appropriations of water.]

District.	Miles of canal.	1855.	1856.	1857.	1858.	1861.	1862.	1863.	1867.	1870.	1872.
20	(*)										
21	109										
22	215										
24											
25	*946	281.98	162.76	223.6	70.46	47.76	28.35	41.99	116.01	104.46	18.31
26	155.5										
27	45.75										
35	5.5										
Total	1,476.75	281.98	162.76	223.61	70.46	47.76	28.35	41.99	116.01	104.46	18.31

District.	1873.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	Total.
20											
21											
22											
24											
25	21.21	5.77	22.2	7.54	27.03	78.14	68.81	130.99	69.72	84.95	1,612.04
26											
27											
35											
Total	21.21	5.77	22.2	7.54	27.03	78.14	68.81	130.99	69.72	84.95	1,612.04

* Districts 20 and 25 are taken together.

Amount of water appropriated each year, etc.—Continued

[Water Divisions IV, V, and VI, with length of canals.*]

	Miles.
Division IV:	
District 29	6
District 30	4.5
District 31	7.75
District 32	93
District 33	7.75
District 34	116
Total	235
Division V:	
District 28	26.5
District 36	
District 37	30.5
District 38	40
District 39	56.5
District 40	11.25
District 41	15
District 42	5.25
District 45	48.5
District 50	
District 51	
Division V—Continued.	
District 52	
District 53	3
District 59	34
District 60	2.25
District 61	48.75
District 62	3
District 63	
Total	324.5
Division VI:	
District 43	50.5
District 44	38
District 54	.5
District 55	
District 56	
District 57	18.5
District 58	76.75
Total	184.25

* No water appropriated.

REPORT ON ARTESIAN WATER IN NEVADA.

BY

CHARLES W. IRISH,
Civil Engineer, of Reno,
Formerly United States Surveyor-General of Nevada.

ARTESIAN WATER IN NEVADA.

By Charles W. Irish, C. E., of Reno,
Formerly United States Surveyor-General of Nevada.

That large inexhaustible supplies of water exist beneath the surface of the earth in Nevada does not admit of a doubt. It has been proven by actual borings in many localities. I will instance very shallow wells in the Truckee Meadows, near to the town of Reno, where, at a depth of less than 100 feet, water is found with power to lift itself to the surface in a continuous stream. These wells act from a head of pressure derived from the underflow in the deep beds of the Truckee River channel, and possibly also from seepage from the slopes of the adjacent Sierra Nevada Mountains.

No deep borings have been attempted on the Truckee Meadows, for the reason that the farmers get a large supply of water from irrigation ditches which are carried out from the river.

I have no doubt but that large supplies of water can be obtained from any point in the meadows by sufficiently deep borings, and at not very great depths, either. The subsoil of the meadows was laid down by glacial ice, which, sliding from the adjacent mountains, filled up a submarine crater, which had in time become a lake. The filling consists of alternate layers of sand, gravel, bowlders, and a very hard clay, compressed by the ice pressure into a cement, almost as hard as rock. Underneath and between these cement layers is a large body of water under a very considerable pressure, for its source is in the sloping bedrocks of the mountain sides which bound the valley of the meadows.

I am thus particular in describing the formation of the water-bearing strata of the Truckee Meadows for the reason that it will apply to much of the State. Connected with the drainage of the Truckee Meadows are the circumscribed valleys called, respectively, Pleasant Valley and Washoe Valley.

The first is simply a prolongation of the meadows southward. Washoe Valley is very considerably higher in altitude, and is connected with the lower valleys by a narrow rocky cañon, which breaks through a lava dike, that in times past formed a complete barrier to the flow of water northward. Hence, as Washoe Valley is completely surrounded by high mountains, and the bed-rock in the cañon spoken of comes up to within a few feet of the general level inclosed, it might be expected that an artesian flow could be obtained by boring for it. Such is the case, as is well proven by the experiments of Hon. Theo. Winters, who has two wells bored on his farm in the valley, which, not over 300 feet deep, furnish a large and unremitting supply of pure water.

Following along the foot of the eastern slope of the Sierra Nevada from Washoe Valley southward the same conditions obtain as are already described, for in and about the capital city of Carson a number of artesian wells have been bored to water at moderate depths; and I have no doubt but that such will be the experience all along the east of that great mountain chain. For it is paralleled throughout its course by a subsidiary chain, from which many lava dikes are found to reach across the intervening valley and connect with the main chain, thus cutting the valley into rounded or oblong basins across which glacial ice has made its way, filling these inclosed basins up to various levels, underlying which is a water stratum under pressure from the absorbed water of the melting snows of the Sierras.

To a large extent the surface of the State is made up of such inclosed basins by low lava dikes thrown across valleys between north and south arranged parallel ranges. All these basins, I am sure, will furnish more or less water from artesian pressure whenever borings are made for the purpose; for all of Nevada's mountains catch snow in the winter season, more than three-fourths of the water from which is retained by absorption to percolate the strata as filter through crevices of the bed rocks, to be stored under the strata of these basins.

Twenty or 30 miles to the northwest of Reno, upon the summit of the Sierra Nevadas, is an elevated and inclosed plain called Sierra Valley. It was once a summit lake, fed by water from the crags and peaks surrounding it. Glacial ice greatly modified this lake and its basin, causing a break at first in its western wall, thus making it one of the heads of Feather River of California, and again causing a second break which was through its eastern wall and making it for a time a tributary to Pyramid Lake of Nevada. Its waters now drain into Feather River. This valley is noted for the richness of its natural grasses and for their variety. For the purpose of cultivation the soil of the valley, by irrigation from artesian wells, the land owners have joined in the purchase of hydraulic boring. Machines and individuals of the last neighborhood assist in the boring of the wells, so the cost is confined to the time spent in the boring, the money outlay for the purpose is almost *nil*. In this manner many fine farms have been improved by use of the free flowing water thus obtained, the quantity of which seems unlimited, and is not drawn down by reason of the increase of the number of wells. So far many of the wells bored in Sierra Valley are of ordinary depths ranging from 150 to 3,000 feet. But some are bored to 1,000 feet, the limit of the machines used.

The borings pass through alternate veins of cold and hot water, and these are disposed with such regularity that it is possible now, with the knowledge obtained, to have either hot or cold water as may be desired. Thus each farm is furnished with its hot and cold water pipes and it seems singular, in the light of experience elsewhere, that all the water obtained is exceptionally pure.

In Sierra Valley we have the example of strong artesian pressure on the flat summit of a great mountain ridge with very deeply cut cañons all along its western slope, the bottoms of which cañons are not less than 1,000 feet below the valley lands, and on the east side is the deep drainage of Long Valley, which is not less than 400 feet below the general level of the same lands, and in it, at a point about due east of the center of Sierra Valley an artesian boring has been made 1,000 feet deep and no water found. So it seems that artesian force is in this instance at work lifting the water of these wells to a height of not less than 1,200 feet above any chance for pressure from the sides of the valley. The average altitude above sea level at which these wells discharge their waters is 5,000 feet.

Turning now to the next example out of which has come success in artesian borings, which is at Battle Mountain, in Lander County, in this State.

At this point is the confluence of the valley of Reese River with that of Humboldt River. In the town of Battle Mountain many small wells have been bored to depths varying from 150 to 300 feet. The Nevada Central Railway has a fine one at their shops, and the Central Pacific Railway one which is used to furnish all their trains with water.

Mr. J. A. Blossom has one at his farm some 2 miles from town, and only half a mile from the Humboldt River, which is a fine one, giving much more water than is needed for all of his stock, and below Mr. Blossom's place, 5 miles, is the cattle and hay ranch of Messrs. Russell and Bradley, on which they have bored two very fine wells; any one of the large wells at this locality is, I am sure, able to furnish all the water needed for the irrigation of a square mile of agricultural land, and none of them are over 300 feet deep.

Mr. Blossom has, during the past season, bored a well in the northeast part of Battle Mountain to the depth of about 800 feet, which gives a very strong flow. As this is the deepest boring done in the vicinity, it is not known how deep the water strata may lie, but it is plain from a consideration of the country along and about the heads of both the Reese River Valley and the Humboldt, that the underflow of their beds is enormous and is inexhaustible.

The only other locality in which a thorough practical test has been made in the State is White Plains, on the Central Pacific Railway. This is in the midst of an oblong valley inclosed by mountains. It is a salt plain. The boring was carried down through various strata filled with water, variously charged with salt and other chemical matters which rendered it unfit for any kind of use. The water found also varied from cool to very hot. The well was closed up and abandoned by the company; it is 3,000 feet deep.

I have given in the foregoing a description from memory of all the artesian borings with which I am acquainted in the State. From an examination of the localities in which the work has been done, I feel sure that the flow in all cases is due to hydraulic pressure, except perhaps in the case of Sierra Valley, where it may be due to gaseous pressure. I am much inclined to believe this to be the case. However that may be, I note a singular arrangement of the springs of cold water in Nevada, which seems to point to a gas pressure as the force maintaining their flow.

While making some irrigation surveys along the eastern slopes of the Sierra Nevada, I noticed a line of growth running in pretty nearly a horizontal line at an elevation of about 1,000 feet above the levels at the base of the mountains and fully 5,800 feet above the level of the sea. This growth was of the kind of vegetation to be always found about hidden springs or those which do not quite reach the surface. It was several miles in extent (horizontally), breaks here and there, and with an occasional spring welling up with a very strong flow, so much so that the waters of these springs, which left to nature sink from sight in running only a few rods from their surface, are caught in flumes and thus carried down to the level lands of the valley, and these are used to irrigate large farms. It so happened that I had opportunity to explore this narrow wet strip throughout its extent, in doing which I came across a deep cut down into it, and across it, reaching through all the superficial deposits to bed rock, which here was granite. I saw that the water vein was an horizontal cleft in the bed rock which at this point discharged an enormous quantity of water that I estimated at 25 cubic feet per second, making as close an examination of the cleft as I could at this point I found that it sloped downward toward the center of the mountain from the side of which it issued.

I have seen many such lines of water seepage in various parts of the State and do not know of a mountain range which is free of them. In Peavine Mountain are many such veins and in all cases they furnish large and permanent springs of water used for irrigation. This mountain is an isolated peak of the Sierras, about 12 miles northwest of the town Reno, and it has a water belt reaching clear around it, but it is not continuous, the strongest flow being on the north and west sides at an elevation of about 6,500 feet above sea, and fully 1,500 feet above the levels at the foot of the mountain. But the most singular fact regarding the springs of this mountain is that one exists on the very summit at an altitude of about 8,200 feet above sea level. I am sure there can be no head of pressure to do this work.

Along the eastern faces of the mountains which overlook Pyramid Lake on its western side is a line of springs, some of which flow enormous quantities of water. There are at or near the summits of these mountains out of which they pour in rumbling cascades, the voice of which can be heard a considerable distance, but the thirsty mountain sides soon drink up the flood so that none of it reaches the lake above ground.

I some years ago made a careful examination of these springs and twice since have given them close attention. They give a permanent flow, with no fluctuations from seasonable differences in the local rainfall. The temperature of the water is about 50° F., and they are in altitude 3,000 feet above the level of Pyramid Lake. The latter is a veritable lake of boiling springs bringing up an immensity of very hot water, not a cold spring can be found in the valley of the lake.

The entire northern part of the State is furnished with such springs of cold water, high up in the mountains, and the sides and the crest of the great divide, between the Columbia River and the Nevada basin, is reeking with them, the strongest flow being on the north or Columbia River side. The streams flowing from that side are permanent, so that the salmon come to their heads each season.

There are some notable springs or rather natural wells, in the northern part of the State. Such are Deep Hole Spring, Round Hole Spring and Sheep Head Spring, all disposed along the west side of the Great Smoke Creek Desert. These springs or wells are round in contour and from 30 to 60 feet in diameter and vary about the same feet in depth. They are always standing level full of clear, cool water, and but little of it ever flows from them. Near by Round Hole Spring are two others, one strong with fumes of sulphur gas; it is called Rotten Egg Spring, the other a mile or two away, called Buckbrush Spring, and at the center of the south end of the Smoke Creek Desert is one with a strong flow of water highly charged with free soda, which is called Soda Spring. The three last named are all strong flowing springs and the water of Buckbrush Spring is good for drinking. All these wells border the desert close upon its western edge, and its arid clays and sands, bare of all vegetation and outspread to the thirsty winds and scorching sunshine, drink up their waters with unbroken avidity.

I am sure that this great bare plain of a desert overlies an immense body of water, and think, quite strongly, that in the upper strata salt water will be found.

To the east and northeast of Smoke Creek Desert is the equally extensive one called Black Rock Desert. It has not been my fortune to examine any considerable portion of it, but I know that it also has some wells on its margin and many flowing springs, and that in its widest is the great boiling spring of very hot water, discovered by General Fremont on his first journey through this region in 1844, described by him under date of January 6, 1844.

The other remarkable localities of wells and springs are to be found about the heads of the Humboldt River, and in what is called Thousand Springs Valley, in northeastern Elks County.

I have been thus particular in the foregoing description of the northern parts of the State for the reasons that, from the conditions described, I am sure that it is a great reservoir of hidden waters stored upon the highest portion of the State, the average altitude of the region being about 4,060 feet above the sea.

The mountains of the State are disposed in systems of parallel ranges, the trend of which is about north and south. Indications point to the fact that anciently the drainage of the country was from north to south. This has been since changed by upheavals and lava-rock flows, until the present condition obtains, and nearly all the drainage of the country falls into the sinks of the Humboldt and Carson Rivers and Pyramid and Walker Lakes, the average altitude of all which will be about 3,900 feet above sea. I find that about the average elevation of Lincoln and Nye Counties will be not far from 1,300 feet above the sea for the valleys and agricultural lands. This gives a fall in the length of the State from north to south of about 2,760 feet, and from the sinks and lakes mentioned of 2,600 feet. That this difference of level does send large quantities of water down from the higher regions to the southern portions of the State, is seen in the increased number of very strong-flowing springs found in the mountains and along the sides of the southern valleys.

In a report to the Senate Committee on Arid Lands I have given an example by measurement of the flow of some of these mountain springs, and now will call attention to ash springs in the western part of the Ralston desert, which is an eastern extension of Death's Valley. This spring wells up in the wildest of ash meadows and covers the extent of about 4 miles in length by a few hundred feet in breadth throughout this extent. It is a marshy spring, giving out in the dry; rainless locality so much water as to form a running stream which, almost at all seasons, runs a full stream into the very center of Death's Valley. A counterpart of this is seen in the head of Muddy River, a confluent of the Rio Virgin which rises in another such marshy spring of great extent and flows off a steady stream of such dimensions that almost six hundred families of Mormons made a settlement upon it and live by farming lands irrigated by means of this water. From all that I have said, it will appear that upon experiment much artesian water may be found in all parts of this State, and that it will be obtained in sufficient quantities at reasonable depths, and that the greatest supply will be found in the more southern portions of the State. Of all this I am certain.

I will close by recalling the statement I have made regarding the disposition of cold water springs along the summits of the Pyramid Lake Mounta ns, and hot water springs in abundance at the level of the lake. Such disposition of the cold and hot water springs pertains to all parts of the State. I have never seen a hot-water spring up in the mountains anywhere. They are always to be found in the valleys or at the foot of the mountains, while a very large proportion of the cold-water springs is always located high up in the mountains, a very few being found in or along the valleys. I am of the opinion that boring in the vicinity of the hot springs will be failures so far as the obtaining of water fit for irrigation and potable purposes is concerned. However the value of the water to be obtained in such localities may be known by an examination of that of the adjacent hot springs.

PHREATIC WATERS IN NYE COUNTY, NEVADA.

BY

GEORGE NICHOLS,

AGENT OF THE NEVADA BOARD OF TRADE.

PHREATIC WATERS IN NYE COUNTY, NEVADA.

By GEORGE NICHOLS,
Agent of the Nevada State Board of Trade.

In reply to request for information relating to the surface and underground supply of water in this county, I would state that the subject is a very difficult one to handle, for many reasons. No accurate measurements of any of the running streams, nor the flow from the numerous large springs found in various parts of this county, have ever been made, and therefore all I can do is to furnish approximate amounts as I have had opportunity to examine them at various times and seasons in my travels through portions of the county. It would be very unfair to give an estimate of the surface waters afforded by the heavy snowfall and excessive moisture of the past winter and spring, as they were exceptional seasons in many respects. Nearly every cañon, gulch and ravine where water would run, was a rushing torrent; so great was the flow in the vicinity of the higher mountains, where the snowfall was great, that many of the valley farms were under water for months, the ground not being able to absorb the surplus for a long period, rendering large tracts of ground unfit for cultivation until very late in the season. The spring months were rendered cold by the amount of snow resting on the mountains; little of the water deposited in the valleys passed off by evaporation, but was finally absorbed by the soil and found its level in the underground water beds, and forms the source of what I term "surface artesian supply." If we had a storage or negative system in use, a vast amount of water would have been secured.

It may not be out of place to state, for the benefit of those not acquainted with the facts, that Nye County occupies a position in the central and southern portion of the State of Nevada, extending from the 36° to a little north of the 39° north latitude; that it is very irregular in form, its greatest length north and south being about 216 miles, while its width from east to west varies from 100 to 192 miles in a direct line; that the county contains an area of over 19,500 square miles, or over 12,500,000 acres; that over one-half of this area would raise excellent crops of cereals, grasses, vegetables and fruit of all kinds suited to its temperate climate, with sufficient water for irrigation; that it belongs to the arid region of the great West which requires irrigation to produce regular crops; that there are nine distinct mountain ranges in the northern end of the county whose trend is northeast and southwest (these ranges are high, some of them attaining an altitude of over 13,000 feet above sea level, and retaining snow the year round); that great quantities of snow fall on these mountains during the winter season, which furnishes our main source of water supply for irrigating purposes; that the snow as a general thing melts early in the spring, the water from which either disappears in the crevices where the country rock is much tilted, runs off and is lost in the gravelly channels of the cañons, gulches and ravines, or disappears in the loose, porous soil of the valleys; that comparatively little has been done to husband the supply obtainable for practical use, owing principally to the fact that for many years past there has been but a scant home market for farm products, having no railroads in the country yet.

The cost of hauling the products of the farm or mines to the nearest market is too great to make it remunerative. Since the depreciation in the value of silver, which has been our chief mineral product, many of the mines which furnished a home market have stopped operations, forcing hundreds of both miners and farmers to seek a livelihood elsewhere, while those who were able have engaged in stock raising, and rarely raise anything for market except beef cattle, horses, sheep, and hogs. Many indeed do not pretend to cultivate anything, even for their own use. As a consequence much valuable land formerly cultivated is now lying idle.

Having thus briefly outlined the condition of affairs in this county, I will say a few words about the quantity and quality of the land. I have stated that the acreage in the county was about 12,500,000. I believe from observations made during the past year that over 7,000,000 acres could be successfully cultivated if sufficient water could be had for irrigation. I have seen the finest kind of crops of barley, wheat, oats, alfalfa, potatoes, beets, cabbage, onions, melons, squashes, and fruit of various kinds, raised on land which I formerly considered utterly worthless for any purpose except grazing. Taking one-fifth of the above figures (7,000,000 acres) which would give us 1,400,000 acres, the amount of land I estimate could be sufficiently irrigated by proper management of the surface supply in ordinary seasons, allowing 160 acres for a farm, it would give us 8,750 farms of 160 acres each. Deducting 250 farms, or 40,000 acres, which is largely in excess of the amount claimed at present for agricultural purposes, the reclaimable would leave us farms for 8,500 families without touching the underground water supply.

As to the quality of the soil, it is rich, durable and productive, being formed from the gradual disintegration of rocks and minerals in the mountain ranges, and by decayed vegetation. In fact, Nevada ranks among the first of the States as to soil and climate. Its wheat, hay, potatoes, beef, and apples, with its mines, easily stand in the front ranks for quantity and quality.

In relation to the water supply beneath the surface, I believe it to be simply immense. Flowing wells can be found by boring a short distance in many of our valleys. Most assuredly large quantities of water could be raised to a sufficient elevation for irrigating purposes by the aid of machinery, but I have learned, however, of but one instance where machinery has been used for that purpose; that is a small windmill, which answers the purpose well. Windmills are used in other places, why not here? Steam power would be objectionable for several reasons; besides the original cost and heavy freights, fuel is expensive, and it requires a capable man to run an engine and keep it in order, besides other incidental expenses. My opinion is that some power like the vapor engine, which is cheap, light, easily transported, requires no fuel (except a can of gasoline occasionally), no water for steam, no boilers, makes no ashes, presents no danger of explosion, needs no machinist or practical engineer to run it, as any man, woman or boy of ordinary intelligence can soon learn how to manage the same, and the running cost of which, it is claimed, only amounts to 1 cent per hour per horse power. Such an engine would be just what is wanted for developing the underground water supply in Nevada, in both sinking and pumping, for both of which it seems to be peculiarly adapted. Such machinery I think will soon be in demand. When the conditions are such that the mines are in full blast again, a home market will be insured, and farming will come to the front again. The demand for a railroad will be imperative, so that needed supplies and machinery, tubing for wells, etc., can be laid down here at reasonable rates; our low-grade ores can be shipped to reduction works at a profit, and our beef cattle, etc., be transported to market without having to drive them hundreds of miles to a shipping point. As it stands at present, the freight on tubing, and nearly everything we use in this section, is greater than the original cost of the article, which is very discouraging to those wishing to make improvements.

Nature is evidently preparing this section of country for great things in the near future. Within the past 27 years, all of which time I have been a resident of this State, I have noted great changes for the better in climate, soil, and vegetation. In many places in our valleys, where formerly there was nothing to be seen but weary wastes of drifting sand and coarse gravel from mountain washes (caused principally by frequent cloud bursts) and a few scattering sage brush and greasewood. I find this sandy wash has undergone a complete change, and thousands of acres of deep, rich soil have been formed by the decomposition of the coarse sand washed down from the mountains. It is now covered with a luxuriant growth of white sage and nutritious grasses. Our great alkali flats, or dry lakes, are also being filled up to a level with the surrounding plains, and many of them are also being gradually covered with vegetation. They will soon be among our best agricultural lands, as they are formed entirely of silt, which is the richest deposits from the mountains coming down in floods and settling in the lowest parts of the valleys. Cloud bursts and high winds are becoming less frequent, and many other things are looking favorable for a brighter future.

One very important point I find I have omitted, viz, the indications for real artesian deposits. Miles upon miles of our mountain ranges are devoid of timber. The formations are much tilted from upheavals and volcanic action; this is everywhere apparent throughout. In these sections, no matter how deep the snowfall or how heavy the rain, but a very small fraction of the moisture ever finds its way on the surface to the valleys. My opinion is, founded on close observation, that nearly all the precipitation finds its way by percolation through the crevices of these tilted rocks to deep-lying cavities. If so, they must form the source of real artesian supply. This theory has yet, of course, to be tested. My attention was called to this several years ago while traveling with an English scientist. He was well posted in such matters, and expressed his surprise that no steps had yet been taken to develop artesian water where it was so much needed. In his opinion the formation of the mountains was in many places decidedly the best he had met with in his travels as feeders for subterranean water deposits, or as he expressed himself, "Many of these mountains were like huge sponges," said this gentleman, "absorbing all the moisture which fall upon them, and they have surely found a porous store-house below that is only waiting to be tapped." I had thought of this in a casual way, but had only considered it as among the possibilities until he pointed out some of the physical indications of the country, and called my attention to the tilted position and peculiar stratification of the country rock upon which he based his opinion. These I have carefully noted in my travels ever since, and am firmly of the opinion that Nye County or southern Nevada contains as fair a field for underground water exploration as any portion of the great West, at least the arid portion of it.

IMBIBITION OF ROCKS.

SPECIAL PAPER,

PREPARED FOR THE OFFICE OF IRRIGATION INQUIRY,

BY

ROBERT T. HILL,

ASSISTANT GEOLOGIST TO THE ARTESIAN AND UNDERFLOW WATER INVESTIGATION.

IMBIBITION OF ROCKS.

By Robert T. Hill,
Assistant Geologist to the Artesian and Underflow Water Investigation.

The value of rainfall in any area in its relations to the water supply can not be accurately expressed in the terms of inches per annum, but varies greatly with the characters of the rock structure upon which it falls, such as its capacity for imbibition, saturation, and percolation of moisture, and hence it is that the true value of rainfall as a source of supply for rock water can only be expressed by a coefficient representing the ratio between the character of the rock and the rainfall. If this be true it naturally follows that in studying the water conditions of any region the capacity of the rocks for receiving, retaining, and transmitting moisture is a consideration of equal importance to that of the amount, evaporation, and surface drainage of rainfall.

In the northern United States, where the amount of rainfall is abundant and the general surface conditions to the soils more uniform, this question of the capacity of structure for moisture produces no necessity of urgent consideration, although the difference is practically recognized by every farmer who deals with wet or dry soils and their improvement by drainage.

In the Southwest, however, where there is a greater diversity of rocks and accompanying residual soils, and the rainfall is diminished to or below an uncertain sufficiency, this capacity of the rocks for moisture is one of the most important problems to be considered, for often within adjacent fields the water and agricultural conditions, while ample in one are negatived in the other by the difference in rock structure, a difference which is often regional, as will be shown later.

CAPACITY OF ROCKS FOR WATER.

All rocks absorb water, but in proportions varying with their physical structure. This difference in the capacity of rocks for water can be demonstrated experimentally with familiar types of rocks, such as brick, chalk, glass, marble, and sand, which represent analogous conditions prevailing in nature. The glass, which is typical of large areas of volcanic and granite rocks, will absorb no perceptible amount of moisture. The marble will take into its pores a very slight amount; the chalk, sand, and brick, will drink in a quarter of their weight of water.

Again, if their substance be allowed to absorb all the water they can contain, they will be in a condition of saturation, and all water in excess of this amount will pass off, by aid of gravity, capillary attraction, or evaporation. It is this excess of water above saturation in the rocks which is available as a source of springs, wells, and artesian supply.

If the experiment with these materials be continued it will be found that each of these substances has a different capacity for transmission of the available water, and that this does not correspond with its capacity of absorption. For instance, a cubic foot of chalk and a cubic foot of sand may each absorb a fourth of their weight in water before they attain saturation, but after that the sand will permit the free passage of water 600 times faster than in the chalk.

These facts being true, it can readily be inferred that if we have in a vast region of comparatively uniform rainfall a diverse area of different rocks, with different capacities for water, such as chalks, sands, clays, granites and limestones, the expressed value of rainfall, as now estimated by the number of inches per annum, will be totally inadequate. This can be seen on an extensive scale in the West, especially in the Texas region of the United States, where their formations have great areal development. Approximately the same amount of rain falls upon a great diversity of country, some of which may contain great stores of available water, while others are entirely void of this essential. For instance, the mountains of the trans-Pecos region are mostly composed of hard, impervious rocks, compost limestones, quartzites and eruptive rocks. Less than 1 per cent. of the rain falling upon these rocks is absorbed, except such as finds its way into the structure by cracks and fissures or along plains of contact. As a result of this condition, the water after every shower quickly flows down the slopes to the extensive flats which occupy the valleys between the mountain ranges. These flats, as well as the entire surface of the Llano Estacado, possess a structure entirely different from the adjacent mountains, being mostly composed of loose, porous sands and gravels, so that every drop of rain that touches its surface is almost immediately drunk in, instead of flowing off in streams or rivulets. This explains the utter absence of running water over the surface of these flats, and the abundance of it stored in their structure beneath. Not only does this basin and plains formation immediately imbibe all the rain which falls upon its surface, but the great torrents, which pour down the mountain sides and canons disappear immediately upon reaching the plain, the water being quickly imbibed by the porous structure of the plain. Not only are the torrential streams thus drunk in, but many constant streams, which flow from the snow-clad peaks or mountain springs, such as the Seven Rivers, the Tularvia, and the numerous "lost rivers" of New Mexico and Texas, quickly disappear on reaching the plain.

Immediately underlying the porous beds of the Llano, which is the latest and capping formation of the area, is still another character of structure, consisting of the red and sandy clays known as the Red Beds. These are the surface formation of a large area of country east of the Llano in Texas, known as the Concho-Abiline country. This formation imbibes water more freely than the mountains, but far less than the Llano. Consequently, its surface is eroded with many dry creek beds or aroyos which for some time after a rainfall have running water, derived mostly from the base of the overlying Llano formation or the Trinity sands and conglomerate, of which more will be said later. The rainfall upon these clays quickly flows away to the rivers, and from the rivers to the sea, so that the people of eastern Texas often see the spectacle of great rivers—often disastrous overflows—of the red waters which quickly follow the rainfall in the Abiline-Concho country.

Again, to the eastward there is a vast area of country known as the Black Prairie and Grand Prairie regions. These are underlaid by chalks, chalky clays, oölites and chalky marls. All these formations, except the clays, are nearly as porous as sand, and imbibe nearly as much water. This region, too, drinks in much of the rainfall, but not as much as the Llano.

If it were possible to view this region of mountains, Llano, Estacado, Red beds, chalks and sands, while a rain was falling uniformly over the whole region, the following diverse phenomena would be seen: First, torrents pouring down the impervious mountain sides on to the plain, and there disappearing beneath its level surface; second, the level surface of the Llano would be void of streams or surface drainage, but most of the water would be imbibed almost immediately or temporarily forming on the surface in ponds or lakes, like liquids in the chemist's filter, until it can pass downward; third, the Red-bed country would be covered with rills, rivulets and torrents, laden with sediment, which would soon empty into the arterial drainage of the Red, the Brazos, or the Colorado, fourth, the rainfall upon the chalky regions and the oölites would be imbibed almost as quickly as upon the Llano, except in the clay areas; while streams flowing from the Red beds or coal measures would almost wholly disappear in that portion of their course, as shown upon the maps.

After the rain had ceased an observer would be impressed by the fact that the representative rocks of these different areas not only exhibited different capacities for imbibing water, but also for transmitting it through their structure by percolation; and would find that those rocks which imbibed the least water, like the limestones, porphyries, and quartzites of the Organ, the Guadaloupe and other trans-Pecos mountains most slowly transmitted it, so that for days, perhaps months, there would be springs and seeps flowing from the crevices and contact plains of the high mountain slopes, keeping alive delicate ferns and rare plants that one would hardly expect to find in that region. On the surface of the Llano, except where slight quantities of clay were mixed with the sandy loam, it would be found that in an hour or two there would remain little evidence in the dry surface that a shower had fallen, the water having quickly penetrated to depths beneath. The chalks, the oölites, the marls, and the sands would also exhibit similar phenomena with slight variations. The red beds and clay areas, such as the Black Waxie and Abilene countries, where there is much clay in the structure, would be wet and muddy for many days after, in exact proportion to the amount of clay they contained. These great differences are all due to the different degrees of porosity or percolation of which the different rocks are capable.

The disposition of this imbibed water is another matter of great variation and interest. This would depend not only upon imbibition and percolation but upon stratification and its arrangement. The stratification of the sandy formation of the basins and the Llano Estacado* is almost horizontal, and the water percolates downward until its further progress is arrested by the imprevious beds upon which this formation is deposited. The Llano Estacado is a great mesa or table land, of which the porous formation forms the cap or summit, as shown in the accompanying figures.

Wherever the Llano formation comes in contact with the underlying

* This formation is composed of the sediments of a great interior fresh water lake, which covered all the great plains region and surrounded the mountains in Tertiary time. It is composed mostly of the debris of the mountains and underlying formations.

beds, springs break forth and these united make the sources of the Red, the Brazos, and the Colorado. The surface and slopes of this great mesa are dry from evaporation, but its whole interior, the interstices of its component sands, is filled with water, so that to-day there are a thousand wells upon its surface which reach down to this water. This mesa cap, surmounting the impervious red beds and mountain rock can be compared to a great saturated sponge laid upon an impervious marble slab, the surface dry, but the interior full of water which finds exit at the contact with the slab. This is the theory of the sheet water of the Llano.

If this formation, instead of capping the plains and surmounting all others, should dip beneath other impervious beds, like those which underlie it, and the water should be carried beneath the lower regions to the eastward, it would constitute a receiving area for a large artesian supply. The sands of the two belts of cross timbers do incline in this manner to the eastward beneath the populous central district of Texas, and supply the water for the magnificent artesian wells of that region.

In England and Continental Europe much has already been done in this line, and for the convenience of those who wish to study the question further, I append the following extracts from a theoretical discussion of the subject by Prof. Joseph Prestwich, of Oxford University, England:

UNDERGROUND WATERS AND SPRINGS—DISPOSAL OF THE RAINFALL.

The action of the rainfall, in relation to that portion of it which runs off at once from the surface, has already been sufficiently considered. We now have to treat of that other portion of the rainfall which passes under ground and plays a no less important part in its geological bearings.

It is estimated that in these latitudes and in countries where the surface presents the ordinary variations of permeable and impermeable strata, about one-third of the rainfall is lost by evaporation, another third flows at once from the surface into the rivers, while the remaining third passes under ground to feed and maintain the underground springs. These proportions necessarily vary according to the nature of the ground—a large quantity running off at once into the rivers wherever the strata are argillaceous or hard and compact. In river basins so conditioned the rivers are consequently more torrential—overflowing in winter, but often dry in summer. Where, on the contrary, the strata consists of permeable, sandy, and free stone strata, or of fissured limestones, a large proportion of the rainfall passes under ground, and is there stored to be gradually returned to the surface in the form of perennial springs.

The foregoing definition, however, hardly expresses the actual case, for the river discharge is really composed not only of the immediate surface drainage, but also of that other portion of the rainfall which, after passing beneath the surface and remaining there for variable lengths of time, ultimately finds its way into the rivers by means of the springs just mentioned. A certain quantity of this water may pass directly through the underground strata to the sea; but this only takes place on or near the seaboard, and does not materially affect the general result. The river delivery therefore represents in fact both the rainfall at once draining into them from off the surface, and part of that which, though it passes under ground, is finally, through the agency of springs, discharged into the rivers, less the portion lost by evaporation. As a consequence of these several conditions the discharge of rivers, in relation to the rainfall, differs greatly in different areas, as shown in the following table:

Rivers.	Approximate annual rainfall.	Depth run per annum.
	Inches.	*Inches.*
Thames at Staines	26	7.31
Rhone at Avignon	41	22.86
Ganges at Benares	50	18.80
Geronne at Marmaude	47	16.23
Seine at Paris	25	6.98
Saone at Trevoux	34	19.90

While the action of the off flowing surface water is, as previously shown, mainly mechanical, the action of the underground waters is more purely chemical. It is these latter which give rise not only to ordinary springs but likewise to mineral and thermal springs, and which also have been so important an agent in all those great changes of rock structure known as metamorphism.

Capacity of rocks for water.—This is a very variable property. All rocks absorb water more or less, but the quantity of available water which the strata may contain has to be looked upon as distinct from that which a rock can imbibe. The one is the portion which the rock holds until it is lost by evaporation or driven off by heat, while the other is that which passes more or less freely through the strata. The latter is the condition which prevails when the strata are below the line of permanent saturation, and the former is that which obtains when the rock is above the line of saturation. The one may be called the "water of saturation," and the other, which is held by capillary attraction, the "water of imbibition," or the "quarry water." Percolation is a property dependent on both conditions jointly.

Saturation and imbibition.—Some experiments show that while the presence of a small quantity of clay does not diminish the amount of saturation, it materially affects percolation.

	Water of saturation per cubic foot.	Percolation per hour.
	Gallons.	*Cu. inches.*
Thanet sands, fine and slightly argillaceous	2.80	1.5
Woolwich sands, fine-grained, quartzose	2.60	5.1
Upper green sand, slightly argillaceous, quartzose	3.00	3.6
Lower green sand, very coarse	2.18	8.4
Lower green sand, coarse and ferruginous	2.56	14.4
Garden soil	2.60	....

Chalk was found to absorb and hold about 2 gallons of water per cubic foot

More recently M. Delessee made a series of experiments on the water held in a great variety of rocks fully saturated; the following are some of the results which he obtained with the materials in fragments:

	Water in 100 parts of rock.
Sandstone (Gres de Beauchamp)	13.15
Sandstone, another specimen	4.37
Calcaire grossier (a calcareous freestone), average of five specimens	18.03
Lower tertiary sandstone, pure quartzose	29.00
Upper chalk, Issy	24.10
Dark coal shale	2.85
Devonian limestone, Boulogne	0.08
Siberian slate, Angers	0.19
Granite (fine-grained), Brittany	0.12
Granite (hornblendic)	0.06
Porphyritic trachyte, Mont-Dore	3.70
Basalt, Haute Loire	0.83

M. Delesse gives the proportion of quarry water, or, as I would propose to call it, the "water of imbibition," of the following rocks taken from above the line of water level:

	Water in 100 parts.
Upper chalk, Meudon	19.30
Chalk, flint	0.13
Plastic clay, Issy	19.56
Light-green magnesian marl, Bagneux	27.99
Large-grained granite, Semur	0.37

The absorbent power of various rocks as building stones was also carefully determined by the commissioners appointed to select the stone for the houses of Parliament. The following are a few of the many cases they give:

	Proportions of water absorbed by 100 parts of stone.
Limestone, Portland, Chilmark	5.30
Great oolite, Bath	31.20
Great oolite, Ancaster	18.00
Great oolite, Barnack	24.40
Magnesian limestone, Bolsover	18.20
Magnesian limestone, Park Nook	24.90
Sandstone, permian, Mansfield	15.10
Sandstone, carboniferous, Craighleigh	14.30

Mr. E. Wetherel has recently made a series of observations on the porosity of other classes of rocks, with respect especially to their water-bearing characters. The following are some of the results:

	Proportion of water absorbed by 100 parts of stone.	Gallons per cubic foot of rock.
Inferior oolite, freestone, Cheltenham	23.98	1.50
Inferior oolite, limestone, Cheltenham	12.15	0.76
Magnesian conglomerate, Clifton	5.28	0.33
Magnesian limestone, Clifton	16.33	1.02
Millstone grit, Bristol	0.93	0.06
Millstone grit, Sheffield	7.54	0.47
Carboniferous limestone, Clifton	0.70	0.04
Old red sandstone, Gloucestershire	11.60	0.72
Old red conglomerate, Gloucestershire	13.53	0.84
Old red flags, Caithness	1.39	0.09

It will be seen that the quantity of water absorbed by the different strata is very variable. It is small in compact sandstones and limestones; large in soft sandstones and oolites, the largest in pure quartzose sands. But the full absorbent power of a rock, which represents both the water of imbibition and of saturation, does not represent its value as a water-bearing stratum. Clay can absorb a large quantity of water, but transmits none. Chalk absorbs freely, but transmits slowly, and in small quantities. A sand of the upper greensand, although when saturated 3 gallons per cubic foot, only transmitted in consequence of the presence of a small relative proportion of argillaceous matter, 3½ gallons per hour, where as purer sand of the lower greensand, although only holding when saturated 2 to 2½ gallons, transmitted at the rate of 8 to 14 gallons of water per hour.

Laboratory experiments, moreover, are made on compact, unfissured places in the several rocks, whereas in nature of the chalk, oolites, and sandstones are traversed by joints and fissures, which hold and transmit water freely. Even compact, impermeable limestones, for this reason, will form high waterless tracts, with strong springs issuing in the valleys. The value of the strata as water-bearing strata is in direct ratio to the capacity of saturation and in inverse ratio to the power of imbibition. Thus, although solid chalk and loose sands may hold the same quantity of water, the resistance to the free passage of water in the former is to the latter in proportion of about 600:1. In impermeable strata, such as quartzites, slates, granites, clays, etc., saturation and imbibition are more or less nearly balanced.

If, with strong imbibition, the rocks are also compact, percolation is very slow, as in the case of deep-seated and undisturbed chalk; but if they are fissured, the cracks and fissures serve as channels and conduits to facilitate the passage of water. In oolitic strata and soft sandstones fissures and joints prevail as a rule.

But while the power of imbibition interferes with percolation, it is of the highest value in its geological aspect; as apart from free percolation, it tends to the transmission and retention of water to great depths under ground, and has ever been powerful agent in metamorphism. It is a force due to capillarity, and in part is the affinity of certain substances, alumina, especially for water—not chemically, but hydrometrically.

The preceding examples of the habits of water are given to illustrate the difference in value of rainfall upon dissimilar geologic structure; and it will be readily seen that it would require vastly different amounts of rainfall to charge these different rocks with relatively the same amount of moisture, and to produce an accompanying similarity in water conditions of the different areas. In the light of this difference in the capacity of rocks for absorbing or imbibing, transmitting and retaining moisture, the whole question of water supply in the arid region must be studied, and the present classification of all natural conditions upon the annual inches of rainfall be greatly modified. By the study of these relations of rainfall to structure alone can the water capacity of the great West be ascertained.

The study of the relation of structure and rainfall also opens up a large and legitimate field of agricultural inquiry. If a small amount of clay in a sand will decrease the percolation, without diminishing its capacity for imbibition, it is important to study the artificial mixture of clay to produce this effect in arid sandy soils. Likewise will it be proper to reverse this method, and mix sand with clay soils to increase their capacity for imbibition.

CULTIVATION OF THE RAISIN GRAPE BY IRRIGATION.

CALIFORNIA DISTRICTS.

CULTIVATION OF THE RAISIN GRAPE BY IRRIGATION.

CALIFORNIA DISTRICTS.

[This statement is condensed from a recent publication by Professor Gustav Eisen, Fresno, California.*]

While the planting of raisin grapes and the production of raisins in California dates back some 30 odd years, the raisin industry can not be said to be yet 20 years old. Already, in 1851, Col. Agoston Haraszthy grew Muscatel vines from seeds of Malaga raisins. On the 25th of March, 1852, he imported the Muscat of Alexandria, and 10 years later during a visit to that place on September 27, 1861, he selected cuttings of the Gordo Blanco, which afterwards were grown and propagated on his San Diego County vineyard. The same year he imported Sultana vines from Malaga and white and red Corinth from Crimea. Colonel Haraszthy was, therefore, the first one to introduce the raisin vines in California. Another importation of the ovoid Muscat of Alexandria was made in 1855 by A. Delmas and planted at San José, according to a statement made by his son, D. M. Delmas †, a prominent San Francisco lawyer. G. G. Briggs, of Davisville, also imported Muscatel grapes from Malaga in Spain, while R. B. Blowers, of Woodland, Yolo County, started his raisin vineyard in 1863 from Gordo Blanco cuttings received from Colonel Haraszthy. In 1876 W. H. Chapman imported the best Muscatels from Spain for his colonists in the central California colony in Fresno, which proved in no way different from those already growing there. Who produced the first raisins in California will probably never be known. According to page 88 of the report of the State Agricultural Society of California, 1863, cured raisins were exhibited by Dr. J. Strentzel at the State fair in 1863.‡ The first successful vineyards in the State were those planted by G. G. Briggs, at Davisville, in Solano County, and by R. B. Blowers, at Woodland, in Yolo County. Both these gentlemen grew the raisin grapes on a large scale and shipped raisins extensively. The Briggs vineyard consisted mainly of Muscats of Alexandria, while the Blowers vineyard contained the Gordo Blanco. Both these vineyards produced raisins as early as 1867, but it was not until 1873 that their raisins cut any conspicuous figure in the market. That year 6,000 boxes were produced in the State, the majority by far coming from these two vineyards.

In 1873, in the fall, the Muscat vines were first brought to the Fresno raisin district where 25 acres of the Muscat of Alexandria were planted

* *The raisin industry.* A practical treatise on the raisin grapes, their history, culture, and curing. By Gustav Eisen, S. F. H. G. Crocker & Co., 1890.

† See also Wickson's California Fruits, p. 357.

‡ Same, p. 79.

in the Eisen vineyard. A few years later, or in 1876 and 1877, T. C. White planted the Raisina vineyard in the central California colony near Fresno, from Gordo Blanco muscatels brought from R. B. Blowers's vineyard at Woodland. The following year, or in 1877-'78, Miss M. F. Austin began improving her Hedgerow vineyard, also in the same colony, with grapes of the same kind as Messrs. White and Blowers. Robert Barton had also planted some 25 acres of Muscat grapes, but did not make raisins until later. The year 1879 saw the first planting of the A. B. Butler vineyard, now the largest vineyard in the State. J. B. Goodman had begun improving his place at the same time, while Col. William Forsyth entered upon raisin-grape growing between 1881 and 1882, most of his grapes, however, being planted a year or two later. From that time the raisin vineyards in Fresno multiplied rapidly, and about 1886 and 1887 raisin production became recognized as the principal industry of the district.

The history of the development of the raisin industry in the other districts of the State runs very much the same. Riverside had entered the field in 1873, when the founder of that colony, Judge John Wesley North, planted the first raisin vines of the Muscat of Alexandria variety. In El Cajon Valley, in San Diego County, the first raisin vines of the Muscat of Alexandria variety were planted there by R. G. Clark in 1873, but the raisin industry did not get a good start until 6 or 7 years ago, while most of the vineyards were planted from 1884 to 1886. In Orange County raisin grapes were planted at the same time as in Riverside and El Cajon by McPherson Bros., near Orange, now called MacPherson. The raisin industry developed rapidly, and Robert MacPherson, the largest grower and packer in the district, and at one time in the State, handled yearly over 100,000 boxes, while the yearly crop of the district rose to 170,000 boxes.

In central California the raisin industry is gradually spreading from the original center around Fresno, the greater freedom from rain and the better facilities for irrigation offering great inducements for the settlers to engage in the growing and curing of the raisin grapes. The San Joaquin Valley is specially adapted to the raising of raisins, the Fresno raisin districts being by far the largest, and now producing about one-half the raisin crop of the State. In San Bernardino County and district the raisins are also grown to great profit and with great facility, and are of equal quality with those of the interior of the State. But the raisin industry is here gradually giving way to the culture of oranges and other citrus fruits, and the increase in the raisin acreage has, therefore, not been so great as in the San Joaquin Valley. In El Cajon irrigation is not used, and the raisins produced there are very similar to the Malaga raisins, but through absence of irrigation the crops are smaller than in any of the other districts of the State. In Los Angeles and Orange County district the raisin industry has suffered immensely from the ravages of the vine plague, and the output of raisins there has dwindled down to almost nothing.

In the interior of California, north of Solano and Yolo Counties, large quantities of raisin grapes have been planted during the last few years, both in the foothill valleys, out on the plains, and in the bottom lands of the Sacramento, Yuba, and Feather Rivers, etc. Raisins of very good quality have been produced in that part of the State for years in limited quantities, but it is yet a question to what extent that part of the State can compete with the central and southern parts. In Sutter County, around Yuba City, the cultivation of a seedless raisin grape is advancing rapidly, the raisins made from it being of excellent quality and finding a ready market.

Acreage and crops.—The quantity of raisin vines planted can not be estimated correctly, but it is certain that at least 65,000 acres of Muscat vines are now set in the State, including grapes in bearing as well as vines lately set out.

California enjoys a climate peculiarly adapted to the culture and curing of the raisin grape. The summers are warm and rainless; the winters moderately rainy. The interior is free from injurious fogs and heavy dews, while the most southern coast is only visited by warm fogs which are not greatly harmful to the grapes. Irrigation is practiced almost everywhere except in the El Cajon Valley and in some northern districts of the State, but even there I think judicious irrigation would be beneficial to the crop and greatly increase it. The demand for California raisins has kept pace with the improvements in curing and packing, and has steadily increased from year to year.

The irrigation of the raisin grapes was for several years considered a practice entirely peculiar to California, but as knowledge extended it was found that far from being anything at all new it had been practiced for centuries in some of the Mediterranean countries. Irrigation is customary both in the Valencia and Denia districts as well as in Greece. It is evident that irrigation there is only limited by the supply of water, and that there is no question about its usefulness. As to methods, the following points are of more general interest to our California growers: Necessity of irrigating the raisin vines; the health of irrigated vines; the bearing quality of irrigated vines; the quality of the irrigated grape; supposed unhealthfulness of irrigated vineyards; irrigation by flooding; irrigation by furrowing; sub irrigation; seepage; drainage; irrigation, and its influence on the soil.

When the irrigation of raisin grapes was first attempted in Frenso and Riverside hardly anyone was acquainted with or knew that irrigation had ever been used for such a purpose before, and irrigation was considered as a venture which did not promise well for the future. Later on it was found that the raisin grape really would grow and do well in some localities without irrigation, and irrigation was accordingly condemned. To-day, however, the practical knowledge of irrigation is greater and more generally distributed, and it is now fully understood that irrigation is not only not injurious but beneficial and necessary in localities where the raisin vine will not grow or bear sufficiently without it. The questions then arose: When is irrigation necessary, and how much irrigation is required? The first object in raisin growing is the profit; a secondary object is how to treat the vines that they may last as long as possible. When a larger quantity of good raisin grapes can be grown with irrigation than without it then irrigation is necessary and justifiable. In Spain, especially in the Denia district, irrigation of the raisin grapes is practiced wherever the water can be had, and the same is the case in Greece and Italy.

In California the tendency now is to irrigate wherever water can be had, and wherever it is profitable to procure it. In Fresno, Tulare, and Kern Counties raisin grapes could not be grown without irrigation. These same conditions are also found in San Bernardino County, while in Los Angeles and Orange Counties all the best vineyards are irrigated, and only occasionally do we find the conditions such as to render irrigation not absolutely necessary. In northern California raisin vines may be grown without irrigation, but the latter is considered of such advantage that expensive pumping works have been erected in places where no other means could be had for irrigating the vines. In San Diego County, especially in Cajon and Sweetwater Valleys, irrigation is not absolutely necessary; in fact it is not practiced there at all although water could be had, but as a consequence the crops there are not as large. In Smyrna, in Asia Minor, the largest raisin center in the world, the raisin vines receive no irrigation, but the usual heavy rainfall of this section makes the want of irrigation less felt. Of course, outside of the raisin districts proper, Muscatels or other raisin vines may be grown, and are grown to good advantage without irrigation, but the climate in those places is generally unsuited to the drying of the grapes.

If the inquiry be made why raisin grapes may in some localities be grown and actually prove profitable without irrigation, it will be found that it depends not alone upon the rainfall of a locality, but principally upon such other circumstances as dew, fog, the nature of the subsoil, and the moisture of the air. In Smyrna the rainfall of the wet season is from 24 to 36 inches annually, which is greater than in any other raisin district. In El Cajon, San Diego County, Cal., the rainfall is only half that much, and the moisture in this case must be sought partly in the subsoïl, which is especially retentive of moisture, as well as in the dew and the warm fogs from the ocean. The subsoil has the greatest possible influence, as in other valleys near by where the fog and the dew are the same; but where the subsoil is different no raisin vine can be grown without irrigation. Malaga is, in this respect, very similar to El Cajon and Sweetwater Valleys; but it enjoys more rainfall than the latter places, while the dew and fog are about the same. Still, in Malaga, irrigation is made use of in a few isolated localities, where it can be obtained, the nature of the country being such that no general irrigation system is possible, and this is probably the reason more than anything else why the vines are more generally irrigated there. In Chili, in the valley of the Huasco, the Muscat vines are grown both with and without irrigation, the conditions there appearing to be very similar to those in El Cajon Valley, in San Diego County. From the above might be drawn a general conclusion that wherever the raisin vines can not grow without irrigation, and wherever water can be had in sufficient quantities, irrigation is practiced in order to increase the crops and to make the business more profitable.

As regards the health of the vines, the old idea in this country that the vines would suffer from irrigation is decidedly erroneous. The vines of Denia, in Spain, have been irrigated for 80 years or more, and are to-day the healthiest vines in Spain. Similarly in Fresno, where the water level is, as in Denia, only from 5 to 10 feet below the surface, the vines show no signs of decay, while many of the raisin vines in other parts of the State, especially when planted on the hillsides, show diseases which baffle the cultivator. I do not, of course, mean to say that irrigated raisin vines are entirely free from disease, but only that so far the healthiest and strongest raisin vines in the world are those which are irrigated and which have always been irrigated. Of course in this respect the Muscat grapes, as well as the currant vines, differ materially from certain wineh grapes, which as a rule have originated on drier soils, and which, if grown with irrigation, deteriorate and yield inferior fruit. The raisin vines require much moisture, and if this is not supplied in one way or another they will suffer and prove unprofitable. The same is observed in soils which rapidly lose their moisture. In such soils the Muscat is not at home, and its health and vigor are seriously impaired.

As to the bearing quality of the raisin grapes under irrigation, we know with certainty that the irrigated raisin vines yield by far the most. In Valencia and Denia the vines yield from 5 to 10 tons per acre, and so do those of Riverside and Fresno, while the El Cajon unirrigated vines yield only from 1 to 2 tons per acre. If the latter place would irrigate judiciously its Muscat vines they would no doubt bear as well as those of any other locality.

The quality of the irrigated raisin grape is increased by judicious irrigation. This is readily seen in all irrigated districts, where those vines which receive their proper share of water produce the largest bunches and berries; but it is also evident that too much water will cause a deficiency of sugar in the grapes as well as a lack of flavor, by which the irrigated grapes can always be distinguished from those grown with natural moisture. Grapes too frequently irrigated are wanting not only in sugar, but also in color. Such grapes remain green to the end of the season, and never assume that amber color so valued in grapes and which always indicates what kind of raisin will be produced when properly dried. In the interior valleys of California, where the sun and the wind sometimes produce sun scald of the berries, which cause them to dry up or fall off long before they are properly ripe, this defect is observed much more frequently on vines which suffer from want of water than those which have had enough. When the soil is not sub-irrigated, it is therefore advisable to irrigate the vines at the end of June, just before the hottest part of the summer arrives. Similarly, irrigation will help to swell out the berries, if applied just before they commence to ripen.

In conclusion, it might with truth be said that the raisin grapes may in many localities be grown without irrigation, but that in California, in Greece, and in Spain the largest and most prosperous districts are those where the raisin vines are liberally irrigated. The Muscat grape seems especially to love water, and in the real raisin districts the healthiest vineyards are those that are best irrigated. The berries and bunches are also increased in size, but not in flavor and aroma by irrigation. In places where the raisin grapes will not bear without irrigation the latter of course is a necessity. There are always naturally sub-irrigated parts, where irrigation is unnecessary. But these parts are generally confined to river bottoms or natural sinks, which so far have played no important part in the raisin industry. Considered from a practical standpoint, irrigation of the raisin vines is necessary in California, and should it from some reason or other be made impossible, the raisin industry would not prove profitable or even possible except in a few very limited localities. Much has been written as to the supposed unhealthiness of the irrigated vineyards. The malaria prevalent in some vineyards is no doubt caused by irrigation, but it has been amply proved in Fresno and elsewhere that if the grower would know from the beginning how to so prepare his lands that there would be no stagnant pools, no waste water, and no swampy grounds, the so much talked of malaria would be as rare in the irrigated vineyards as anywhere else. It is not the irrigation, but the waste of the water, the carelessness of the irrigator, and the faultiness of the badly constructed irrigation works. After the vineyard has been irrigated a few years the malaria leaves it entirely. This is the experience in Fresno, where the vineyards after years of irrigation have become perfectly healthy.

In the old irrigated districts water can now be found from 6 to 10 feet from the surface in the driest season, while formerly the wells had to be from 50 to 70 feet deep. In the older vineyards and even in many of the younger ones, no more surface irrigation is used; all that is now required is to allow the water to run in the main ditches, in which the water sinks sufficiently to keep up the supply of the evaporation of the ground outside. Large tracts of land which have never been surface irrigated are now sufficiently moist to grow vines to the greatest perfection, and many of the best vineyards have never been irrigated at all; in fact, nothing but drainage ditches have ever been made on the land. Whenever such sub-irrigation exists the water level will be found higher in the winter than in the summer, and drainage should accompany sub-irrigation in nearly every instance. A sub-irrigation like the above exists in Denia and other of the Spanish districts. Sub-irrigation may also be caused by either impervious subsoils, such as hardpan and clay, or by spongy subsoils, which keep the water like a sponge. Such is the case to a limited extent in parts of San Bernardino County. At Redlands, for instance, much less irrigation is now used than when the vines were first planted, and this fact is attributed to a spongy subsoil peculiarly retentive of water. A similar sub-irrigation exists in the Mussel Slough country, where the water rapidly fills the land and keeps it moist throughout the summer. The phenomenal moisture of the El Cajon land is probably also produced by some kind of sub-irrigation, either on impervious or through retentive strata; the waste water from the surrounding hills no doubt supplies much of the water appearing in the lower lands of the valley. Other valleys close by do not show this moisture, the underlying strata probably making sub-irrigation impossible with the present amount of rainfall.

Seepage is the quality of the soil to attract moisture and retain it. Seepage soils attract the water from a ditch run through the land, the water spreading all through the soil toward all sides instead of sinking only vertically down. There is a distinct difference between such seepage soils and those which do not seep, although there is a gradation in the degree of seepage, some soils seeping more than others. Thus the Fresno soil or the soil of the Fresno Plains, especially the red and sandy soils, do not seep or percolate. Vines planted on the sides of the ditches, or a foot or two from their banks, will die or dry up if not specially irrigated by bringing water to their very roots. Other soils, especially the river-bottom soils or the alluvial soils, seep or percolate in a great or less degree. They act like a sponge, attract water and give it away slowly, and the soil will be found wet for long distances from the ditch. This seepage capacity of the soil is partly caused by an abundance of humus or vegetable matter. The seepage capacity of the soil greatly increases by admixtures of green vegetable matters, through the plowing under of green crops, such as alfalfa, pease, beans, grain, etc. The value of seepage soils is seen especially where some uneven ground is scraped off and the soil removed to low places. Such ground often becomes useless for years afterwards, especially if the quantity of humus in the lower soils is small. Frequent irrigation will not serve to keep such soils moist, as the water sinks rapidly down, leaving the poor topsoil dry. Vines planted in such places never do well, and even heavy manuring will not suffice to bring on a strong healthy growth. Such humus-wanting soils must be treated with green crops, as stated above, in order to become fertile and moist. Thus seepage and sub-irrigation are often confounded. The former is caused by the retentive and communicative quality of the soil, while the latter is caused by the natural or artificial distribution of the underground water.

Sub-irrigation and seepage combined make the most perfect irrigation for a raisin vineyard, with advantages that can in no other way be attained; absence of distribution ditches, which take up valuable land and which cost money to keep free from weeds; less growth of weeds on the surface of the ground; greater mellowness of the topsoil and less work in plowing generally; a greater and more uniform supply of moisture, which instead of being near the top of the ground is accumulated deeper down, thus causing the roots to go down instead of spreading near the surface; no expensive irrigation which will require plowing every time after the water is spread on the surface; a greater coolness of the ground and a lower temperature generally, which shows itself in the more vigorous growth of the vines, a greater supply of grapes, and less danger from sunburn—these and many more are the advantages of sub irrigation and seepage combined. To attain them in a raisin vineyard no labor and reasonable cost should be spared.

Drainage is necessary in all vineyards where large quantities of water are used for irrigation, and principally at the very time when sub-irrigation begins. Thus in Fresno County the best raisin vineyards are those in which the land is both sub-irrigated and drained. When irrigation commences in any certain district no one thinks of drainage as a possibility, and great carelessness is shown in locating ditches and other irrigation works. But in a few years when the soil is full of water which finds no outlet, drainage becomes both necessary and desirable. A very successful and highly necessary drain has been constructed through a part of the Fresno district, which so filled up with water during the rainy winter of 1883–'84 that much of the ground could not be plowed until late in the spring. The drain remedied the evil and drained the soil, and the vineyards grown there are now counted among the best and most profitable. The water thus drained off lowered the water level from 6 to 7 feet. In very dry seasons this ditch is filled with water, and serves then to keep the soil moist through seepage or sub-irrigation.

It is thought by many that irrigation helps to fertilize the soil. The spring and flood water contain great quantities of mud and humus, which, when spread over the land, will greatly increase its fertility. Even ordinary river water contains salts and other ingredients which will fertilize the soil to no small degree. Another cause of the increased fertility of subirrigated soils is that the water which constantly evaporates carries with it salts, etc., from the lower strata up towards the surface and makes them accessible to the roots of the vines. But, on the other hand, if the water or the soil contain alkalies or other destructive substances, these also are deposited on the surface to the great detriment of the vines, and often to such an extent that the vines will die or become sickly. Too abundant flooding may also leach out of the soil its soluble salts and carry them deeper down in the ground. But if this soil after a while fills up with water and becomes subirrigated, the evaporation of water from the surface will gradually carry these salts back to the surface, when they will increase the fertility of the soil. Where drainage is very perfect constant irrigation will gradually rob the soil of many of its soluble salts and carry them to places where they will forever be out of the reach of the vines. To ascertain these facts and conditions, every vineyardist should have the soil analyzed about every 5 years, and too great care can not be taken to keep the soil of proper strength.

Another influence of irrigation on the soil may also be mentioned: Some of the soils in the irrigated districts which were formerly very hard and difficult to work have, in course of time, changed and become mellow. The water has undoubtedly caused a chemical and mechanical decomposition of the components of the soil, which has caused it to continually improve. Even certain kinds of hardpan have been known to dissolve when irrigated, and to change into useful and mellow soil, in which the vines can find nutriment. Such hardpans are generally those which are generally found in very dark red soils; those in lighter soils are not so easily dissolved. Professor Eisen says:*

IRRIGATION AND THE CULTIVATION OF CURRANTS.

California has so far not cut any figure as a currant-producing country, not because the currants will not grow, but because no one has ever seriously engaged in their culture. Currant grapevines are scattered all over the State, but I know of no plantations larger than an acre or two. In Fresno a few acres of currants are found in the Mirabelle vineyard east of town, and a few hundred vines are also grown on the Raisina vineyard in the central colony. Outside of these there are only scattered vines, as far as known. These currants are all of the white variety, which is considered inferior to the black currant of Zante and the mainland of Greece. When dried they produce a most beautiful semi-transparent raisin, entirely seedless, with a very thin skin and of a very fine flavor. The yield, however, has not been equal to expectations. Until we import the true black currant from Zante, and find the most fovorable locality to grow them, it is not likely that currant culture will make much headway in this country. We have no doubt, however, that with our various climates many places will be found in California where the currant will yield enough to pay, provided our raisinmen will be satisfied with a reasonable profit.

He gives the following account of the conditions necessary:

The soil best suited to the currant grape is a calcareous marl, which must be of good depth, loose, and easily worked. Such marls are also greatly prized for their great power of retaining moisture. But vineyards are planted in Zante, Cephalonia, and Ithaca in the most different soils and situations. They are found in gray marls, in red clay, on the plains, and among the hills, in fact in the most widely different situations. The soil of Zante contains a small percentage of sulphate of lime or gyp sum, which is by many considered indispensable for the successful and profitable cultivation of the currant vine. The currant vine thrives especially in low and rich land which can be irrigated, and irrigation is quite essential to the perfect development of the grapes. Many vineyards, however, are not irrigated, the irrigation of course being only practicable on the plains. The irrigation is practiced from October to the end of December, often while the natural rainfall supplies the artificial watering. The lands are generally small freeholdings, owned by the peasants. The most valuable currant vineyards are situated on the rich and level valley lands.

The preparation of land for a currant vineyard is expensive, as the land is hardly ever level enough to admit of the vines being immediately planted. The surface is therefore first leveled and divided up in smaller checks or flats, each one surrounded by a bank. The whole is covered with a network of ditches, which are necessary for the perfect irrigation of the soil. Where there is water enough the vineyards are irrigated in November and December, and are then flooded as often as practicable, the water sometimes standing on the ground for weeks in succession. In perfectly irrigated vineyards the water is so arranged that it flows from one check to another, and is first shut off at the advent of the new year, when the pruning and cultivation begins. By this plentiful irrigation the ground becomes thoroughly soaked, and remains saturated until the next season, when the rain again sets in and fills the irrigation canals. No summer irrigation is used in old vineyards, and in young vineyards only in cases of great necessity.

In the Grecian Islands and the Morea the best vineyard land varies between $80 and $125 per acre for unimproved land. To prepare the land for the vineyard and irrigation it will cost in extreme cases from $20 to $50 more. The first year's cultivation and care of the young vines is of course different according to the locality, but the average is seldom less than $50 per acre. The value of already planted property or a vineyard in good bearing is seldom less than $320 per acre, and often as high as $650 per acre—four stremmas. Strange enough in calculating the cost of a vineyard in Greece no one ever takes in consideration the price of the plantation as the capital invested. The interest on the same is never considered by the natives. In this respect they resemble or own farmers, who, in calculating the expenses of their farms never take into consideration the labor of themselves and family. Of course it is al-

* The Raisin Industry, San Francisco, 1890.

most impossible to obtain exact calculations of profits. The following will serve as a sample. An acre of vineyard planted to currants yields 3,200 pounds. The price obtained for the same is 2 cents per pound or $64. The labor of the year on 1 acre is estimated at $45, leaving a yearly profit of $19 per acre. In reality, however, this is not a true statement, as it does not consider the interest on the capital. If the same should be added it is evident that there would be little or no profit in the growing of currants. The industry simply enables the peasant to live and support his family, and possibly to pay his taxes. Only the very best land and the best vineyards can pay enough to enable its owner to save a capital, generally a difficult thing in Greece for anyone but a merchant or government officer.

As a rule the cost of producing 100 pounds of currant raisins is not less than $1.35. Whatever the merchant pays above this to the producer will be for the benefit of the producer. But as a rule this way of buying direct is not in use. The merchant sells on commission, and what this means we who have had experience in the raisin business in California will know. We will see how a calculation of an acre of currants will look when all the expenses are taken into consideration:

One acre of currants equals 3,200 pounds, at 3 cents per pound	$96.00
Expense on 3,200 pounds, at $1.35	43.00
Packing and hauling	7.50
Freight, insurance, duty, etc	22.50
Interest on capital invested	15.00
Merchant charges, say	8.00
	96.00

In this instance the poor currant raiser has had no other profit than the 5 per cent. interest on his capital invested; he has, in other words, come out even. But figures sometimes are apt to lie. The profit no doubt is small to the producer, but it must still be some. He makes no doubt fair wages according to his own ideas, and as he has paid for his capital in labor and probably never handled a dollar of the same he considers himself comparatively well-to-do. But as currant vineyards sometimes sell, and sell high, too, it is simply unaccountable that the interest is never taken into consideration in estimating the profits of the grower. The currant industry is, I believe, the only one in the world in which this is not done. I have thus extensively dwelt upon the profits and expenses of this industry in its native country on account of the many attempts to introduce the growing of currants in California. The question is, will it pay? One advantage in California is that currants would be protected, but it is very doubtful if currant plantations would ever pay enough to warrant their cultivation. The price paid at present is too low, and as long as Muscatels bring a higher price, it will probably be the favorite grape with us.

IRRIGATION IN AUSTRALIA.

RECENT INVESTIGATION, LEGISLATION, AND ADMINISTRATION BY THE COLONIES OF VICTORIA AND NEW SOUTH WALES.

BY

RICHARD J. HINTON.

IRRIGATION IN AUSTRALIA.

RECENT INVESTIGATION, LEGISLATION, AND ADMINISTRATION BY THE COLONIES OF VICTORIA, NEW SOUTH WALES, AND QUEENSLAND.

By Richard J. Hinton.

INTRODUCTORY.

On the island continent of Australia the two leading colonial communities, New South Wales and Victoria, have been for the past decade, or since 1882–'83, making special efforts in the direction of water conservation and the reclamation of arable lands by means of irrigation. In 1884 both colonies appointed what are termed "royal commissions" to investigate the whole subject. In 1885 the Victorian commission, consisting of Hon. Alfred Deakin, M. P., then attorney-general of that colony, Mr. Dow, a well-known agricultural writer and journalist, who had been in California the year preceding, and Mr. Derry, a well known civil engineer, visited this country, making quite a thorough examination of our Western States and Territories and afterwards published a series of valuable reports. Mr. Deakin also visited Egypt, India, and Italy. He became minister of the department of water supply, which post he held until the summer of 1890, when a change in policy caused the retirement of the ministry, of which he was so prominent a member. The New South Wales commission did not send its representatives to other regions, but made diligent inquiry, examining many witnesses and getting together much valuable evidence. Indeed, the reports, testimony, and maps published by the two colonies form a most important part of the literature of irrigation—a specialist bibliography, which is growing rapidly in value, titles, and ability. The New South Wales commission gave in its first report, printed at Sydney in 1885, the evidence of 137 witnesses, examined at 99 sessions, with an elaborate review and suggestions as to the legislation to be adopted. Some of these are of value to us in considering our own problems, and should be examined.

AUSTRALIAN LAWS OF WATER.

The colonial government, in leasing or selling public or crown lands, reserved of late years land deemed essential for the purposes of water supply present and future. This has brought up the whole question of "riparian" rights. The surveyor-general required his assistants to select and recommend for reservation and public use "permanent water-holes, springs, and parts of rivers desirable for water supply."

These instructions have been reasonably well followed, but the commission consider that more intelligence and discretion would have resulted beneficially in securing a larger reservation of water-bearing and storage arrears. In order to avoid the conferring of riparian rights more or less definite in character the official also requires his subordinates to omit meanders and contours in the matter of swamps, lakes, ponds, or lagoons, found within lands to be alienated from the Crown. The survey is to be run on right lines, thus avoiding all boundary issues. "The doctrine of riparian rights, which obtains under the common law of England, is not applicable to the conditions of Australia," the commission reports, and "it is calculated to be a very serious obstacle" to Australian progress. The colony of Victoria, having by enactment reserved from sale all river or stream frontages, is relieved from the dread which riparian claims always produce in an arid country. In New South Wales, however, these difficulties have arisen. The commission recommended state in place of private ownership of all riparian rights. It illustrated this view as follows:

> We do not imagine that the rights of riparian owners, when water is provided for their requirements, can give any claim to compensation. If, however, we had reason to think otherwise we should still be of opinion that state ownership of all the rivers and water courses is so essential in providing and supplying water as to make it desirable that the Government should resume the title to ownership by giving compensation. Public policy in Australia has hitherto jealously asserted the right of the state, or of municipal bodies delegated by the state, to all the main arteries of communication, such as roads, streets, etc.; * * * and when the value of the water courses of the country come to be properly estimated it will be seen that the policy which is designed to protect the interests of the community as a whole against the exactions of private monopolies should be applied to water conservation as it has been to roads, railways, and telegraphs, to which it is quite as applicable, if not indeed more so.

In the matter of legislation the New South Wales commission made recommendations in the form of a drafted act, which has since become law. This act defines "water rights, national administration, district administration, water trusts, drainage works, navigation matters," and "offenses and penalties." In the preamble it is declared that the measure is designed to "define the public right" in rivers and streams and their natural courses in still waters, similarly conserved, and to create a system for the "conservation and distribution" of the waters flowing or contained, whether above or beneath the surface of the ground. Special terms used in the drafted act are defined as follows:

"Trust" or "water trust:" Any local council appointed thereby "to design, construct, administer, or maintain local works for water conservation and utilization, or for drainage." "Trust district:" Such portion of the colony as may be within the jurisdiction of a legally constituted water trust. "Water rights:" The right, title, and interest to a supply of water from any source, whether above or beneath the surface. "Rivers" are defined as both "perennial and intermittent," having a natural course, whether "above or beneath the ground." "Lake" is defined as any collection of "still water * * * permanent or temporary" in character, and found "above or beneath the surface." "Water course" is defined as any stream smaller than a river. The same definition is given as to a surface or other character. "Domestic use" provides for all household and personal uses, but not for watering stock or washing sheep.

The definition of "water rights" made by the New South Wales commission is of sufficient importance to warrant quotation:

To the crown belong—

(a) The water flowing or contained in every river, stream, creek, or water course, whether the same be permanent or intermittent, and whether or not the land through which it flows belongs or not wholly to the crown.

(b) The water contained in every lake, swamp, lagoon, or other collection of still water, subject to the same conditions as rivers, etc.

(d) All springs situated within crown lands, and all springs, whether so situated or not, which have overflowed into or contributed water to any river, stream, or lake belonging to the government.

(e) The right to control for the purposes of the act, land covered in any way by the water of any river, creek, stream, or lake.

These are in substance the public rights. They are the same substantially in terms and effects as those embodied in the laws of Italy, Spain, France, India, in some of our own arid States, and elsewhere in the world, either by statute law or by community regulation and custom. The Spanish "law of waters" (article 33) declares that—

There pertain to the public or public property:

(a) The waters which spring or intermittently flow within the public lands.

(b) Those of the rivers.

(c) Those * * * of springs and torrents which flow through their natural channels.

The Italian civil code (article 420) declares:

The rivers and torrents are considered as dependencies of the royal domain.

The chief canal and drainage law enacted for India declares in its preamble over the area embraced that—

The Government is entitled to use and control for public purposes the water of all rivers and streams flowing in natural channels, and of all natural collections of still waters.

The water rights belonging to private parties are defined in the drafted act to be—

(a) The whole of the rain which falls on such land, except where occupancy rights have been acquired.

(b) So much of any river, etc., adjoining such land as is required by the owner, etc., for domestic use and for watering of stock, provided always that no owner, etc., of such land shall have a right to a larger supply of water than at the rate of 2,000 gallons per day for every mile of river or lake frontage.

(c) Any rights, whether permanent or temporary, which have been acquired under any other act or regulation in force prior to the passing of this act.

(d) The exclusive right to the use of any spring of water situated on such private land, if no other person nor the Government has acquired by use and occupancy for 20 years the right thereto.

(e) All surface waters; the owner of land may also make lawful use of any underground supply, but such use must not affect injuriously any adjacent well, boring, or supply.

These provisions are framed on the lines of the Spanish law of waters, article 30 of which code says:

There belongs to the owner of an estate the rain water which falls or is collected on it while passing through it; he may, in consequence, within his own property, construct cisterns, tanks, ponds, or reservoirs to preserve it, always providing it does not injure the public or third parties.

Also—

Whoever has a spring on his estate may use it at his pleasure, saving the right which the owner of lower one may have acquired by title or prescription.

This, the Spanish law, has been from the date of discovery and occupation the governing condition of Florida, the Louisiana purchase, all of Texas, California, New Mexico, Arizona, with portions of Nevada, Colorado, and Kansas—in fact, nearly all of our arid region and very much also of the lower Mississippi Valley section.

The right of use through 20 years' occupancy is, by the New South Wales code, limited to domestic and stock purposes. An appeal is allowed a land owner where occupant right has been acquired to limit the use of said right as provided. If any actual damage has been done anyone entitled to a legal use of water "by the construction of any canal, channel, cutting, well, or boring," compensation shall be allowed on sufficient proof of such alleged damage being given.

A board of control, to be known as the "National Administration Board," is provided for, withr the management of "all rivers, streams, creeks, lakes, springs, and underground supplies of water in the colony." The president and associate officers are permanent, devoting their time to its duties; that of the commissioners, however, extending only to the meetings and business brought before the board. An engineer and such staff as is needed is also appointed. The board controls, under legislation, the boundaries of water districts, sanctions or otherwise, the works locally proposed; examines all applications for loans to carry forward proposed works; no such construction can be undertaken without the sanction of the board; all tenders therefor to be by public advertisement; all contracts to be approved by the board; vouchers, accounts, etc., must be open to the inspectors of the board; its staff may, on sanctioned emergencies, make surveys and carry on needed works. The powers presented are ample for all purposes of control, adjudication, and management.

The objects aimed at are uniformity and completeness on the part of the general or "national administration," while the organization of national water trusts is expected to provide "for local wants and the economical treatment of details and maintenance." The New South Wales board is similar in character to the irrigation or water-supply department of Victoria. The town and village communities of civic administration stand for the local water trusts. In southern France all irrigation works but the Marseilles Canal, which is constructed also for navigation uses, are under control and construction similar to the Australian system. In many respects it may be said that the irrigation districts, now becoming operative in California, under the Wright irrigation laws, are similar in character. Local conservation of water and works is also practiced in India and New Zealand. Indeed, however widely applied, it will be found to be the ruling principle of all ancient water codes, and has steadily descended through clans, gens, tribes, communities, states, and peoples, to all primeval and still existing native associations and governments in Asia, Africa, Europe, and America; wherever, indeed, irrigation has been and still is extensively practiced.

THE LOCAL ADMINISTRATION.

The powers of the "district administration" in the formation of "local water trusts" are quite extensive. These "trusts" are formed on petitions of land owners or lessees, and after investigation by the board of "the feasibility and propriety of the proposed works." The "trust," when constituted, consists of members, who, if in the western division of the colony, shall either be owners of 640 acres or lessees or occupiers of not less than 10,000 acres of land; if residents of the central division, they must own 160 acres or lease or occupy not less than 2,500 acres; while in the eastern division each man must own 40 acres or lease or occupy not less than 640 acres of land. These divisions, as to geography, ownership, or occupancy, represent very fairly different stages of social, economic, agricultural, and pastoral development and growth.

They practically explain themselves. In constituting a "trust" the administration is guided by watershed lines and other hydrographic features of the territory to be embraced, so as to include as far as practicable a complete catchment area.

The details of administration are very fully, even minutely, arranged. Every local water trust is made a body corporate, with the usual powers as to purchase or sale and control. With the Government sanction, its powers of administration may be delegated to agents. Actions and appeal may be taken and lie against the trusts to the water supply department itself. Compensation claims are provided for. All local works must first be sanctioned by the national board. In case of flood or other sudden dangers the local trust can take the needed responsibility, reporting their action. Transfers of water supply can not be permitted without the sanction of the trust. All supplies provided by such local trust are made subject thereby to the general act and by-laws provided under it. The right of purchase or the lease of a right of way through any land can be made. Condemnation and compensation are also provided, and no vested interest in the water supply can ever accrue to the land owner. The water trust also fixes the rates for supply. These are ordinarily for domestic and stock use, for irrigation, and for power. Stock may be supplied by measure or per head. Loans for construction are arranged for after full local examination, report to national board, and sanction therefrom. The loan may be direct from the Government or by the creation of a bonded debt, the Government guaranteeing the interest. The security shall be the rates for supplies that are to be levied, or that of the land and works belonging to the trusts. The rates when levied shall be used as follows: (*a*) For payment of interest; (*b*) for maintenance, repairs, and management; (*c*) to create a sinking fund; (*d*) for useful extension and development of water works.

Liabilities are not to exceed two-thirds of the enhanced value, as officially to be estimated, of the works and lands to be constructed and served. Trusts borrowing in excess, or otherwise in contravention of law, render their members personally liable for payment of principal and interest.

Drainage works are also similarly provided for, as also when required, those for navigation purposes.

The whole code is thorough. It appears well calculated to accomplish its chief purposes. These are to insure:

First. The public control and ownership of all natural waters above or below the earth's surface.

Second. The national or general supervision of the same by properly equipped authority.

Third. The direct cost, construction, management, and maintenance, by local authority, consisting of the representatives of those directly interested and to be directly benefited by the conservation and storage of water, and its artificial distribution and utilization for domestic, stock, farm, and manufacturing purposes.

Stringent provision as to waste or deterioration of supply, or of injury to works, etc., are also included. The Government, by the Royal Commission Report of 1885, was recommended to protect itself for loans by taking mortgages on trust works and their revenues; also to require the creation of a sinking fund, to require maintenance in good of all such works, to correct the rates itself if any default of a trust should occur, and to provide also for annual auditing of all trust accounts. It is believed all these provisions have since been adopted. Government farms and forests are also a part of the system in vogue in New South Wales. A very complete engineering and hydrographic office is conducted on excellent lines, and the colonial plans for observations of climate and meteorology are also linked with the water supply service and department. The unique system of pastoral water supply, stations, and stocks roads are also part of the same administration. Reference thereto will be made in this paper. The reports and maps issued by the Australian colonies of New South Wales, Queensland, South Australia, and Victoria, especially the first and last, are among the very best of technical and expert papers relating to water supply, irrigation, hydrology, etc., published by any government in the world. They are in many respects equal to the best of station reports.

PHYSICAL DATA AND HYDROLOGY.

The eastern watershed of the colony of New South Wales is a narrow strip, shut in by sea and low mountain ranges. This plain is traversed by many small rivers, with rapid flows and short courses. The western section is a great basin with moderately high table-lands, traversed by a great many rivers having long courses with slow flows therein. The fluvial system of the Murray, which is the greatest of these basins, carries into the Southern Ocean through South Australia the drainage of an immense area, which includes western New South Wales, a large part of Queensland, and the northern section of Victoria. It has a total course of 1,719 miles, of which 1,132 miles are in New South Wales. The river is navigable for 1,590 miles and its source is 5,000 feet above sea level. There are no very high ranges in the Australian continent, and the snowfall forms but a moderate proportion of its precipitation. Other large drainage basins are found by the Murrambridge (1,350 miles), the Darling (1,000 miles), and other smaller streams, forming altogether a navigable network of about 4,500 miles. The coastal rivers or drainage basins have a total area of over 42,000 square miles. There are 20 rivers of a total length of 2,000 miles. The western basins drain at least 100,000 square miles. The river channels have a total length of about 4,500 miles, of which nearly 4,000 are navigable. This statement does not embrace the mileage of the minor streams. There are but a few lakes in the colony, the largest being Lake George, which has no outlet and a surface area of 93 square miles.

The mean annual rainfall is given by divisions as follows:

	Stations.	Rainfall.
		Inches.
The coastal region	8	48.08
The western basin	5	19.075
The table-lands or central section	15	39.08

The mean annual temperature of the several divisions in the same order is given as follows:

	Annual mean.	Summer.	Winter.
	° ′	° ′	° ′
Coastal	64 3	71 6	53 7
Western	62 8	76 7	49 0
Central	50 6	64 6	40 0

The underlying foundation over a larger portion of New South Wales is of a cretaceous character, and hence of water-bearing quality. The problems of irrigation are therefore to be advanced largely to a prosperous solution by the success achieved in finding and utilizing a large subterranean water supply, whether the same be of true artesian character or from the drift drainage lying near the alluvial surface. Over what area systematic irrigation, from a surface supply, may be carried on has not yet been ascertained. Coghlan's Wealth and Progress of New South Wales, 1888–'89, says: "It may not be considerable, owing to the comparatively small volume of the rivers and the regularity of their flow," as well as the want of perpetual snows. How much this opinion is influenced by the peculiar plan of land distribution policy in vogue and the enormous extent of the cattle and sheep ranches to which it gives rise, is not for us to say, but this judgment sounds suspiciously like that which in our own land has declared in various official and nonofficial ways, during the past decade, that the arable portions of our public domain is almost exhausted, and which has therefore deliberately sought to relegate an area embracing two-fifths of our national domain and two-thirds at least of our remaining pualic land areas to the sole use, (outside mining), of the cattle and sheep rbnches.

LAND SYSTEM OF NEW SOUTH WALES.

The character of the colonial land tenure system deserves a brief outlining. It originally embraced only grants of crown lands in large bodies. It then provides for sales of the same, equally unrestricted as to extent. In 1861 the policy of "free selection" by settlers was adopted. Then came the sale of such selections. Leases are also in use. In 1884 all crown lands remaining unoccupied were thrown open to "free selection," which may be considered, except as to area, analogous to our preemption system. The total area of the colonial * public domain was 195,882,150 acres. There remains (1885–'86) a balance of but 13,998,201 acres. Only one half of 1 per cent. of the area is cultivated. The average of such farm holdings is stated at 850 acres. The pastoral ranges are, however, enormous in their extent. They are largely held under crown leases or sold conditionally at $1 per acre. Up to 1884–'85 there had been actually sold some 40,157,562 acres. The area of pastoral leases, etc., was 139,500,800 acres. In 1889 the total number of cultivated acres was only 999,298. Wheat generally produced about 13 bushels per acre; on an average, rainfall in seventeen subdistricts was 18½ inches per annum. The total area (1888) in pastoral leases was 67,098,880 acres. The number of such leases was 1,613, or an average of 41,600 acres per lease. There were 407 "conditional" leases covering 9,779,840 acres, or 6,741 each. Of these, given as "homestead" leases, there were 392, averaging 9,609 acres, or a total of 3,766,728 acres. These figures illustrate the controlling ideas of the colonial land system, and explain, probably, the small interest really, so far, taken in irrigation progress.

THE PASTORAL INTEREST.

The arid characteristics of the pastoral ranges and the powerful interest they represent in colonial affairs has, however, caused the adoption of an extended system of water conservation, sedulously aided and fostered by the Government in later years. The pastoral interest in its importance is illustrated by the following figures:

* New South Wales.

Number of sheep and cattle in 1888.

	Sheep.	Cattle.
New South Wales	46, 503, 469	1, 622, 907
Victoria	10, 805, 682	1, 341, 069
Queensland	10, 444, 005	4, 654, 932
South Australia	7, 150, 000	430, 000
West Australia	2, 112, 392	95, 822
Total	57, 014, 548	8, 144, 730

In New South Wales there were in 1888 the following works for obtaining and conserving water for pastoral purposes:

	Number.	Value.*
Tanks	24, 741	$23, 414, 150
Dams for storage	23, 330	10, 205, 000
Wells, bored or dug	3, 131	3, 220, 000
Total	51, 202	35, 830, 150

* Stated at $5 on the pound sterling.

PUBLIC WATERING PLACES.

The public conservation and use of water in connection with pastoral purposes has been more extensively carried on in New South Wales than elsewhere. A branch of the colonial department of mines, known as the "public watering places," has general charge. In a report received through United States Consul Griffen, of Sidney, under date of October 17, 1889, it appears that the object of such water conservation is to furnish supplies for the "traveling stock routes" used for stock in passing to market, and in dry seasons as means of changing pastures. Domestic supply is also obtained thereby for the outlying stock stations or ranges, wholly dependent on the scant rainfall. The means of storage supply are tanks, wells, dams, and bores, of which there are about 153 completed and about 40 in process of construction. These are public works, and the department of mines decides as to the necessity, upon reports from stock inspectors, who are also overseers of public watering places. The location of a well or tank being approximately determined upon, the work proceeds. A weekly list of all routes with well, *et al.*, locations, is published. This list shows road, depth of water in well or tank, estimated weekly rainfall, and condition of pasture. It is then distributed for the drovers' information. The average cost of the tanks, usually excavations partly dug under the surface to prevent evaporation, is $946 each; that of the dams, small works as a rule constructed at any point where a supply promises to make a convenient watering place, is $435 each. The average cost per well is $996.24. The average capacity of these cattle tanks is from 2,000 to 3,500 gallons each; with embankments they will hold 3,500,000 gallons as a rule. The total storage is equal to 600,000,000 gallons. The wells will range from 70 to 400 feet in depth. There are 51 steam pumps, 48 with horse-power and 1 with a caloric-engine, in use in distributing the water thereof.

Up to 1888 there were in New South Wales 248 artesian well borings. Of these 134 flowed fresh water, 77 had saline flow, 11 were brackish, 2 were mineral, in 19 cases coal was struck, and of 7 no record is given. A later return (1889) gives for this colony, in public works, 110 tanks, 27 artesian wells, 9 dams, and 7 other works; 153 in all. In process of construction were 52 bored wells, 21 tanks, 3 dams, and 1 weir; 77 under way, or 230 works in all. The expenditures made by the colonial government direct for pastoral waters up to 1888 have amounted to about 17,500,000. This includes the laying out and maintenance of 2,000 miles of cattle roads or routes. As to the results arising from and value of such outlays, the report made in 1885 by the Royal commission for the conservancy of water (New South Wales) says:

During the last 15 years great waterless districts to the west and north of Darling have been reclaimed from their normal condition, in which neither man nor beast could live except immediately after rain, and have been made to contribute to the pastoral production of the colony.

The principal means by which this important extension of the habitable boundaries of New South Wales has been accomplished, has been by the excavation of tanks and the construction of dams, wherever the configuration of the colony admitted these means of storage.

A public watering place in New South Wales consists of 2 areas—each of 640 acres; one is leased to a tenant who keeps the other in order—that is, the watering, camping and feeding place. No charge for grazing on the government section is made; for watering per capita rates are collected. If there be no tenant, a caretaker is placed in charge. The lease is usually for 5 years and the rents received from the watering places range from $30 to $730. A minute and well-arranged code has been adopted.

The earlier attempts to find water by boring for pastoral purposes were largely failures. Recently, considerable success has attended the experiments. To the northwest of the Darling River a great extent of artesian water-bearing stratum has been discovered. On several "runs"—that is the cattle ranges—such flows have been struck at from 600 to 1,200 feet deep. The flow ranges from 200,000 to 600,000 gallons per diem. The department of mines has now under way 39 experimental borings, whose minimum depth will be carried 2,000 feet in each case, if necessary.

The nature and quantity of the supply may be estimated by a summing up from one inspectorial report, covering certain routes with the number of works, etc., on each as follows: thirty-four works of various kinds; covering 734 miles; comprising 355,000 cubic yards of tanks, etc.; furnishing 59,642,000 gallons of water.

The number of head of live stock served by these routes during the season was—sheep, 1,410,000; cattle, 72,000; a total of 1,482,000 head.

COST OF IRRIGATION WORKS.

The full cost of Australian colonial works (1888) for water supply and sewerage is as follows:

New South Wales	$19,198,485
Victoria	26,725,750
Queensland	2,705,110
Total	48,629,345

The debt thus incurred is distributed according to population (1888) as follows:

	Population.	Cost per capita.
New South Wales	1,085,700	$17.52
Victoria	1,090,869	25.12
Queensland	387,463	7.16
Western Australia	313,065	....
Southern Australia	42,137	43.48
Total population	2,917,224	....

The colony of Queensland has but just commenced the work of water conservancy, and the lines of its policy shape themselves for both pastoral and agricultural supply. In New South Wales the public exertions and aid have been in the direction of town and pastoral supplies. In Victoria, besides large town works, the trend is directly in aid of agricultural irrigation. In Queensland (1888) there were 6 public artesian wells completed, 1 having a depth of 180 feet, while the other 5 were drilled from 691 to 1,663 feet before a flow was obtained. The Banaldine well (691 feet deep) has a 10-inch casing, with pressure sufficient to force the water 30 feet above ground. It flows 240,000 gallons per 24 hours, and cost $3,875. There were, in the year given, 26 more well-bores in process, while 2 had been abandoned. Of private borings, there were 17 in progress, 1 of which was 2,485 and another 1,875 feet deep.

Table of bores completed.

GOVERNMENT BORES.

Name of bore.	Depth.	Yield per diem.	Temperature.	Pressure per square inch at surface.	Remarks.
	Feet.	*Gallons.*	*Fah.*	*Pounds.*	
Barcaldine	691	175,000	102	12	Add 5 pounds to each of these pressures.
Saltern	978	17,200	115	33	
Blackall	1.663	300,000	119	60	
Tambo	1,002	200,000	38	*7	
Cunnamulla	1,402	540,000	106	180	
Back Creek	180	72,000	70	5	Railway department.

PRIVATE BORES.

Name of bore.	Depth.	Yield per diem.	Temperature.	Pressure per square inch at surface.	Remarks.
Manfred	678	50,000	106	....	All information obtained from private sources.
Saltern	1,130	175,000	....	....	
Do	*1,500	*30,000	....	....	
Coreena†					
Weelamurra	1,589	150,000	113½	150	
Thurulgoonia	1,080	3,000	....	....	
Do	1,243	1,000	....	....	
Do	1,216	1,000	....	....	
Do	718	1,200	....	....	
Do	831	8,000	....	....	

* Approximate. † Bores not overflowing.

In a table furnished by the New South Wales Report of 1885, the area of the seventeen organized trusts is given with the population thereof. It was as follows:

Total land areas (acres)	13,346,000
Total population	56,167

The character of the works constructed are distributing ditches or "channels," weirs for storage and "off-take" purposes, tanks—iron and earth, reservoirs, dams, reticulation pipes, steam pumps, and other machinery.

There is a large number of artesian wells, positive and negative, drilled and bored, 30 of which in 1888 were used for irrigation purposes, and 111 more were in process of sinking, for the same purpose. There were 20 deep flowing wells used for town supply, and 10 more in process of drilling. In all of bored wells in which the water rises there are about 1,000 in the colony of Victoria. These wells range from 74 to 1,600 feet deep. In all, the colonial Governments had made, up to 1887, about 350 bores in search of artesian water, of which 199 were reported in successful operation. There were besides nearly 300 more such wells bored and operated by private persons or corporations. The several colonies' reports and dates give the number of drilled and bored wells as follows:

	Date of report.	Average depth.	Total bores made.	Fresh water struck.	Salt or alkaline.	No water.
		Feet.		*No.*		
Victoria	1885	837	330	56	167	106
South Australia	1884	297	26	6	11	2
New South Wales	1887	494	400	136	....	....
Queensland	1888	609	252	*10	....	....

* Artesian flow only.

THE WATER SYSTEM OF VICTORIA.

The average rainfall in Victoria for 20 years has not exceeded 25½ inches,* but it ranges according to districts from less than 10 to 50 inches per annum. Attention was first turned to irrigation by causes exactly similar to those which influenced the people of our subhumid region, viz, opening of public lands, rapid expansion of settlements, years of good rainfall and large harvests, followed by drought, loss of crops and great suffering. The storage of water for pastoral purposes, which had already been largely achieved, pointed to the same means on a large scale as the only security for agriculture. As a result of the subsequent agitation came the formation of a commission and the investigation made of irrigation in Italy, Egypt, India, and the United States, with consequent passage of laws on the subject by the Colonial Parliament. The Victorian trust system is very similar to that of New South Wales, already outlined.

The total area of the colony is 87,884 square miles. All of this, with the exception (1886) of 4,673 square miles, is divided into municipal bodies, such as counties, villages, towns, and cities, making a complete system of local self-government. In the other colony administration is more centralized. Victoria has local home rule, as well as other American characteristics, to a large degree. The aid granted for municipal purposes by the colonial government is granted through these bodies. Up to 1883 the local aid amounted to $1,550,000. The water-trust system then came into existence, and the laws thereon aim to coöperate with the local bodies in cost and responsibility. After plans and reports are made and approved the governor in council can approve

* Report of Secretary Charles Robinson, New South Wales, Royal Commission on "The Conservation of Water," 1885.

of a law, with a rate of one-half per centum as interest. The area of the trust is proclaimed and the character of principal works is announced. Commissioners, auditor, and other officers are appointed. The general powers of a Victorian water trust are thus defined:

It may enter upon described lands, set out such parts as are necessary, make trenches, dig up the soil, etc.

It may enter on, appropriate, and condemn all land necessary for construction and improvement works.

It may lease or purchase existing works, erect or construct others, bore wells, sink shafts, maintain or discontinue reservoirs, and do all necessary work.

It may divert waters from one place to another; it may also alter the direction of water-courses if necessary, construct weirs or dams in any river, cut, drain into, enlarge, widen, or deepen any lake, lagoon, swamp, river, or stream; and it may enter streets or roads at any time for repairs of water-courses or works.

In 1888, there were 50 water trusts in Victoria, 30 urban water districts, and 11 others proposed and forming. Of the town trusts, 20 were of a local character; 10 others were constructed by the colonial government. There were 6 other works formed of swamp districts. These covered in all about one-fifth of the area of Victoria, or some 17,000 square miles. Up to the close of 1885 the accounts of the colonial department of water supply stood as follows:

Amount of authorized loans	$3,988,840
Amount paid to corporations	3,980,846
Cost of maintenance	447,971
Interest due	323,648
Revenue received to date	1,397,083
Principal of loans repaid	301,904

The spirit in which irrigation is dealt with among our Australian cousins can be estimated by the following excerpts on a report on "tanks," made by an official of the New South Wales commission for water conservation. Mr. Frederick B. Gipps, civil engineer, sums up his recommendations for legislation as follows:

That experimental or agricultural farms should be established in each river basin for testing all kinds of crops under irrigation and for forest nurseries; that the damming back of any of the main rivers below their continuous rocky banks and beds by fixed weirs would be highly injudicious; that owing to the excessive evaporation on shallow pools, tanks should be excavated fully 20 feet deep; that the prosecution of well boring should be conducted on systematic principles in order to fully develop its application for water supply and irrigation; that by excavation and low embankments a large number of lakes might be converted from shallow evaporating pans into magnificent impounding reservoirs; that after the survey and investigation of all the features of the different river basins by civil engineers, the control of all future works on them should be handed over to river trusts, who should have powers to raise loans, etc., for carrying out any engineering works for water supply or conservation, after their approval by a central board of engineers; that all vested water rights are highly antagonistic to the public interests, with exception of tanks and wells, and should therefore be disallowed for the future, while all present rights should be gradually resumed as required by the public under equitable conditions. the hydrographical maps show the area of each river basin in acres and the average rainfall over each area. Supposing only one-twentieth of the rainfall could be conserved, it would be sufficient to irrigate, in an aggregate of the river basins, no less than 20¼ million acres. The Murray Basin, of about 39,351,000 acres, would supply by one-twentieth of its rainfall 5,328 cubic feet per second. The Murray Bridge Basin, with an area of 15,430,720 acres, would supply by one-twentieth of its rainfall 1,624 cubic feet per second, and the Darling Basin, with an area of 191,343,000 acres would supply 11,482 cubic feet per second, capable of irrigating, at 1,000 acres per cubic feet per second, no less than 11,482,000 acres.

It is utterly impossible to estimate the value of irrigation in the interior for promoting settlement and increasing population, though it may be partially realized by those who travel in India, Europe, and America. In every instance the influence of irrigation has tended directly to establish small farms.

In reviewing Australian discussion and legislation, one of the most important propositions that has been made seems appropriate to some of our own conditions. The colonies of Victoria and New South Wales are in large part divided by the great water course of that region known as the Murray River. The channel of that river is for a greater part of its extent within the borders of New South Wales, but the drainage basin embraces also a great area in Victoria. For the conservation, administration, and subsequent distribution of the waters of this great basin, the following propositions were, after a joint conference, submitted by the commissions of both colonies:

The resolutions of the conference appear to us to be sufficiently perspicuous not to require further explanation, and we therefore submit them with our recommendation that they may form the basis of a treaty between New South Wales and Victoria. They are as follows:

1. That a joint trust shall be constituted, equally representative of the colonies of New South Wales and Victoria, in which shall be vested the control of the whole of the Murray River and its tributaries from its source to Howlong, to be known as the Upper Murray; and of the whole of the Murray River from Howlong to the eastern boundary of the colony of South Australia, to be known as the Lower Murray; and such trust shall have power to regulate all diversions of water from the river and tributaries within its jurisdiction.

2. That the waters of the tributaries of the Lower Murray, except such proportions thereof as shall, under the direction of the trust, be required as compensation water for the main river, may be diverted and used by the respective colonies through which they flow.

3. The whole of the waters of the Upper Murray and its tributaries and the whole of the waters of the Lower Murray shall be deemed to be the common property of the colonies of New South Wales and Victoria. And subject to the reservation of such compensation water as the trust may from time to time determine, each of the said colonies shall have the right to take and divert one-half of such water at such point as may, with the sanction of the trust, be fixed on as most suitable for the requirements of such colony: *Provided always*, That the totals of the quantities so divided by the two colonies, when the surplus (after providing compensation water as above) is utilized, shall be equal.

4. That all natural diversions of water from the Murray shall be gauged under the direction of the trust, and the portion of such diversions not returned to the channel of the main river shall be debited to the colony into which such water is diverted, in the same manner as if such diversion had been made under the last preceding action.

5. That the trust may fix and determine levels to be known as the high-flood levels of the Murray, and may make such regulations for the disposal of water flowing above such levels as to it shall seem expedient.

6. That works for the storage and regulations of the waters of the Marray may, under the supervision of the trust, be continued at the joint cost of the colonies of New South Wales and Victoria, such cost to be borne by each colony in proportion to the benefits derived by it from such works.

7. That, so far as possible, the two colonies shall take united action in respect of all works intended to provide for the utilization of the Murray waters.

8. That the trust shall consist of not more than six members, three of whom may be appointed by the Government of New South Wales and three by the Government of Victoria, such members to hold office for terms of not more than five years. The expenses of the trust and its officers to be defrayed by the two colonies in equal proportions.

9. That a bill embodying the above resolutions shall be prepared, under the supervision of the water supply commissions, for submission to the parliaments of New South Wales and Victoria. The Government of each colony, having approved of the measure, shall be requested to secure for it the earliest possible consideration by its legislature.

10. That the Government of the respective colonies of New South Wales and Victoria shall be requested to hold themselves bound, *ad interim*, by the provisions of the above resolutions, until they shall be dealt with by the legislatures of both colonies.

There is in this paper something worthy of consideration by such of our own States as are already at the threshold of a great discussion and conflict in relation to the proper conservation and distribution of what may be termed interstate waters. Within Montana, for example, are located the headwaters of one of our greatest river systems, that of the Missouri. On their western flank also, its mountains embrace the sources of considerable confluents and tributaries of the Columbia River. California holds within its Sierras the larger portion of the drainage supplies which by physical configuration belong to the mountain and hydrologic basin of Nevada, and without the use of which waters that State may finally perish. Colorado holds within her borders river sources whose channels also feed and drain large portions of Kansas and Nebraska, of New Mexico, and western Texas. Wyoming, with Colorado, embraces also the sources of the Great Rio Colorado, forming a service of drainage areas whose waters are yet to quicken and give life to vast sections of fertile lands now arid and waste. Perhaps the example of the Australians may point the way to an equitable solution of the problems involved in this important subject of interstate waters

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NOTES OF AN IRRIGATION CONFERENCE HELD AT MELBOURNE, VICTORIA.

OBJECTS.

The first irrigation conference of the Victorian water supply department assembled on the call of the Hon. A. Deakin, then minister of water supply at Melbourne, on the 25th, 26th, and 28th of March, 1890.

The experience of any class of irrigators must of necessity interest the great mass, and therefore the following is given as the results of those deliberations. The object was to ascertain the most approved local opinion as to—

(*a*) Methods of laying out land for irrigation for annual crops, such as grain; for permanent crops, such as fruit trees; and for meadows and pastures.

(*b*) Methods of applying water to different soils and crops, frequency of watering, drainage, etc.

(*c*) Various products and their treatment under irrigation.

(*d*) Management of trusts (water or irrigation district), and the collection of water rates.

METHODS IN USE.

The general plan of the preparation of farm land for irrigation in Victoria is that it should be divided into drains, roads, and channels; the smaller the divisions the better. The most desirable waterfall is about 2 feet per mile towards a main drain, except when the subsoil is porous, and then drainage is not so important; but the frequency of water application is—the main object of drainage being to keep the subsoil moist but not water-soaked. An all-important necessity is, therefore, the loosening of the sub-stratum to the depth of 15 or 18 inches. This preparation of the subsoil, with a fall as above stated, will need drains of only small section, as the surplus of water when properly applied will be small, and the absorption to the moisture point will take up nearly all the water run upon the land.

Roads.—The distance these should be apart will depend on the size of the blocks into which the country is subdivided, as every block should have a road frontage. In valuable lands adjacent to towns, roads 15 chains apart, with a supply channel midway between, is a good formation. They should be 1 chain wide, with a center raised 9 to 12 inches, sloping to water tables 15 feet on either side.

Channels.—These and their branches should be constructed as subsidiary storages, as it is desirable to have a small supply always on hand, and the main channel should bisect the irrigated area.

For irrigation the soil should be thoroughly broken and leveled. With the proper slope this may usually be accomplished by use of the plow, roller, and scarifier. If land can not be graded to an even surface, it is better to run the plow furrows crosswise to the water flow to prevent drainage of the upper and flooding of the lower portions, otherwise the furrows should run with the water.

Supply channels should be banked about 18 inches above ground, 2 feet below surface, and about 4 to 6 feet wide. The distributing channels are mere plow furrows drawn along each row in an orchard or vineyard and plat of ground in cereal cultivation to water them. To obviate the necessity of breaking the supply-channel bank temporary head channels are recommended parallel to the supply. These temporary supply channels should be well filled before opening, and then a man with a long-handled shovel can regulate the flow by the mere placing of a clod in any distributary when the head is too great.

The grade must in all cases regulate the methods of irrigation. Mr. F. W. Shaw stated his method as that of running a 1½-inch pipe from a bank level with the tops of the trees down the center between an orchard and a vineyard of 6 acres each, a distance of 14 chains, with 1½-inch taps at suitable distances. The trees are watered by a 3 inch canvas hose, longer than the distance between the trees, giving about 100 gallons of water for trees and 10 gallons for grapes twice during the year, except late peaches, which require an extra watering. He also floods the orchard and vineyard during winter from the creek.

Another gentleman, Mr. Vince, applied his water in individual tree storage, as it might be termed, by raising the ground in a circle about each tree and applying the water with a hose. After watering a little soil is sprinkled on the moist surface. This method leaves large basins between the trees capable of holding a hogshead or two of water, which is locked in by a small cutting on the lower side.

The advocates of all these systems, however, unite in the absolute necessity of thorough cultivation. The upper crust must always be in a pulverized state. It being the general opinion that cultivation is possible without irrigation, but that irrigation must always fail in its absence.

The season, climate, and state of the plants should always regulate the time and amount of water. One to 1½ cubic inches, or 20,000 or 30,000 gallons per acre, will in general be sufficient. But it will be found that an irrigated orchard or other crop will require less and less water each year, and the beneficial effect of a shower is greatly augmented on such than on non-irrigated.

The various products and their treatment is always a question for local decision. Orchard and vineyard irrigation, when each plant must be treated in some sense separately, differs from the cultivation of grain and forage only in this individuality. A proper distribution, by supply channels and distributaries, is applicable to both. Mr. A. Lane, of Benjeroop, recommends grain land to be laid out into blocks of 25½ chains by 120 chains, and divided into paddocks of from 15 to 50 acres in extent and the various paddocks divided into sections of from 4 to 10 acres by check banks, the water in all cases being permitted to flow on the higher sections and drain onto the lower levels, so as to insure equality in watering.

With local variations this is the general plan throughout Victoria.

METHODS OF WATER SUPPLY.

These are as various as the location. In some few instances the simple dam or weir, emptying immediately into the supply channel; others, tanks filled by means of chain buckets, centrifugal pumps worked by windmills, horse power, or steam. The windmill is always recommended as of less ultimate cost than any of the others. Animal power for small irrigations is desirable; wind power for large storage, at elevations sufficient for resulting gravitation, is very profitable, and the same may be said of all water wheels and power. An undershot wheel or turbine with 3 to 4 foot dam is the ideal method for local irrigation. By its use plentiful power is developed and the first cost, which is the principal item of expense, is about the same as any other practical mode. With regard to steam power, the most authoritative paper before the conference on the subject, that of Mr. J. Tipping, civil engineer, recommends the "Galloway" type of boiler, as against the tubular generators, for the reason that the mud accumulations, necessarily consequent to the use of river water, has a bad tendency with the latter. The daily expense, however, must always be seriously considered.

At the date of the conference irrigation in Victoria was yet in its infancy, being only of 5 years' growth, yet so enthusiastic had been the progress that there were then projected twenty-five irrigation trusts or subsidized water-supply companies, but of which number five only had water to sell, four of them being among the smallest in the colony. There were also five million dollars' worth of national works then under way. The only practical irrigation was the result of private enterprise and could not be ranked as regional. The whole amount expended was about $1,415,000. The ultimate sum then proposed to be spent out of the colonial treasury on national and trust works was $10,000,000. Such irrigation, therefore, as had been made workable was the result of individual enterprise, and presents a wide divergence in its methods, works, and power used. The tendency here, as elsewhere, has been to break up the large holdings of 1,000 acres and run into small farms owned and worked by the farmer and his family. It is a lesson to the new States of our own arid region that already the demand for labor in Victoria is much greater than the supply. The Colonial Government looks to irrigation to populate its fields, to cultivate the waste places, and build up cities and towns with the resultant manufactures. In a word, they hope to create a home market for home products. Irrigation is too young in Victoria to present any reliable statistics as to the cost of water, but no man who has once adopted a system of irrigation in that country has expressed a doubt of its profit or contemplates any abandonment of his works unless for more perfect methods.

Hon. Alfred Deakin, minister of water supply,* in opening the conference gave the number of irrigation trusts as twenty-five. Five of these only had water to sell last season. No trust was able to sell water before them, because none of them had works in such order as to warrant their ability to deliver the same. Of the 5 that had water in uncertain quantity, 4 were the smallest in the colony. The only irrigation carried on in the colony was by private persons and in a small way. The trusts had received advances amounting to £283,000. This is all they have received from the public treasury. For national irrigation works, to some extent, it has been £186,000. Messrs. Chaffey Bros. have spent as much on two small colonies on the Murray River. They received a land grant of 500,000 acres.

The season of irrigation for 1891 will probably see a great improvement. Several trusts will be able to deliver water. In 1892 about one-half of the 25 will do so. The total advances that will be made if they carry out their improvement will be only £1,158,000. The security will be 1,440,000 acres of land, worth without irrigation £4,000,000, with irrigation double that sum. The national works will cost about £1,000,000. The total expenditure, therefore, will be about £2,000,000 sterling. The colony has a revenue of £8,000,000. It has expended £30,000,000 on railways. The expenditure of £5,000,000 will reclaim land worth £11,000,000, covering about 3,000,000 acres.

Speaking of American irrigation, Mr. Deakin said:

In all the States in the Union which I had the opportunity of visiting 5 years ago, irrigation has not since receded by 1 acre. * * * In some States it is double what it was 5 years ago. * * * Our cousins make a profit where we with apparently the same energy and manhood can only make a loss. Surely such an apprehension is without the shadow of justification. * * * It is the men of no experience who raise doubt. The practical men of Victoria, like the practical men in America, have only given one verdict. I know of no man in Australia who has commenced irrigating and afterwards abandoned it. I know no man * * * who has not increased his area as fast as opportunity permitted.

In reference to the service and value of water in agriculture, Mr. Deakin made these sagacious suggestions:

Water is a splendid servant, but is just as bad a master as fire if the farmer permits it to overflow his fields. He has not only to put water on his fields, but to put it on them in the right way, at the right time, and in the right quantity, and to remove the surplus without injury to himself or others. * * * What irrigation wants is not the mere water which it enables you to use, but the intelligence that will enable you to produce its best results. * * * In irrigation the farmer becomes in a sense his own providence, for he decides when it shall rain and when it shall not, and what amount of rain shall fall upon each of his crops. Each of these operations requires to be controlled by skill and trained intelligence.

THE PREPARATION AND PLANTING OF IRRIGABLE ORCHARDS AND VINEYARDS.

Mr. J. W. West, of Moorapoona, in relating his experiences with orchard and vineyard irrigation, holds one of the chief purposes of irrigation to be in that direction. The first operation after breaking up the soil is to obtain a uniform level surface to evenly and economically distribute the water. His own orchard of 20 acres, all irrigated, was (except a couple of small hollows filled with a scoop) all prepared with

*A change in the ministry has since occurred, and Mr. Deakin is now retired.

plow, roller, and scarifier, care being taken to plow in the direction the water was to run. Land with even a couple of inches fall to chain gives trouble. If land can not be graded to an even surface, it is better to run the furrows crosswise to the water flow, to prevent drainage on the upper and flooding of the lower portions.

Supply channels.—Such channels should be at least 4 to 6 feet wide, 2 feet below surface level, and banked about 18 inches above ground. They should be strong and not too wide apart. Five chains is as far as water should be distributed by furrows. A V-scraper or delver plow is the greatest labor-saver in constructing supply channels. It operates as follows: A sod is turned with a single furrow plow, and the V-scraper then not only removes the sod but places it properly to form the bank. This operation is repeated until the channel is complete.

Distributing channels.—These are plow furrows drawn along each row of trees or vines to water them. For young trees there should be one on each side, 2 feet 6 inches away, and the distance gradually increased until full growth, when one good furrow midway between the rows is all that is required; and they should be gone through twice, throwing the sod on each side, preventing the spread and waste of the water. To obviate the necessity of breaking the banks of the permanent channels, a temporary head channel is made parallel thereto; from this the water is let out into as many distributaries as we can conveniently manage. In light soils a horse hoe fitted temporarily with a pair of moldboards is a good implement for drawing distributing channels.

Watering.—To do this with a properly leveled orchard or vineyard is not a difficult process by means of stop bars at convenient places, made by driving three posts about 2 feet 6 inches apart in each bank, the post on either side highest upstream being set a foot farther back to form a wing; slabs are nailed to these and a floor put down. When the shutter is put down and a few shovels of soil thrown in front of it, very little water escapes. The sides, wings, and bottom require to be well puddled. Sacks filled with straw are just as effective and more convenient than sand bags to construct temporary dams.

The supply channels should be well filled before opening, and one man with a long-handled shovel may control a dozen distributaries by placing a clod here and there to obstruct the too-full flow in any one furrow, and the flow from the supply channel may be similarly checked. Both men and boys find the work light and pleasant and by this method have a perfect control over all the water.

The season, the state of the plants, and the climate should regulate the time and amount of water. For trees about 1 to 1½ cubic inches, or 20,000 to 30,000 gallons per acre per annum, is good watering; for young trees and vines less will do. Vines must be protected against fungoid diseases bred from overwatering. An irrigated orchard requires less water each year, and an ordinary shower is more effective on such than on unirrigated.

Drainage.—It is sufficient to drain the surplus water from the surface, and channels 18 inches to 2 feet below surface level will answer admirably. During excessively wet periods open plow furrows draining into supply channels will be ample protection.

Cultivation.—This must go hand in hand continuously with irrigation to secure practical benefit. The soil should be frequently stirred, as this is a first essential to healthy plant life during the summer season. This is required with ordinary cultivation, but under irrigation is absolutely necessary, unless failure be openly courted. After watering, the horse hoe or scarifier should be run through, and the furrows and temporary head channel obliterated, which all have to be drawn again when required. To allow the furrows and soil to bake hard would nullify the effect of watering.

Mr. West further stated that he finds reasonably close planting, say 18 feet apart for orchard trees, beneficial, as the orchard sooner becomes self-protecting. His superfluous water is drained back to trust or company channel; but he notes "that when you get down 2 feet or 2 feet 6 inches the water does not lie then at all—it drains away."

In plowing for a 2-foot channel, Mr. West recommends that the first sod be all plowed one way, and the next the other, and then by the use of moldboards on the scraper the earth can all be removed without the use of a shovel.

LAYING OUT LAND FOR IRRIGATION.

J. D. Derry, M. I. C. E., said that the lands should be divided by drains, roads, and channels, and the smaller these divisions are the better. The engineer has to deal with the primary subdivision.

The land should have a slope of 2 feet per mile towards the main drain, except when subsoil is porous, and then drainage is not important, but water has to be applied more frequently. A clay subsoil prevents loss in the channels, especially when these are constructed to act as local storages. Subsoil must be kept moist, and not water-logged, and therefore such a subsoil must be intersected by drains at least 2 feet deep to carry off surplus water. "Subsoiling," or loosening of underlying clay, should be from 15 to 18 inches deep—an all-important necessity.

The slope and condition of the soil should always be studied before laying out for irrigation, as air and warmth are a necessity for the plant roots; as the water—rain or irrigated—drains away or evaporates, air takes its place, and with this in view about 7 chains' length of land is about proper for draining when the slope is 2 feet per mile.

Drains need not be of large section, as with skillful irrigation there should be no surplus water. Rainfall drains need only be capable of carrying off the precipitation in 24 hours, as such submersion is not injurious.

The distance that roads should be apart will depend on the size of the blocks, because each block must have a road frontage; and the roads in valuable lands, near towns, should be 15 chains apart with a supply channel midway between them. Roads should be 1 chain wide, the center raised 9 to 12 inches, sloping to water tables 15 feet on either side. The tributary drains should be constructed 1 foot from the road boundaries, and the water tables be connected with them every 25 feet by cross drains, thus forming plots 25 by 12 feet. The whole plot should be plowed and a tree planted in the middle of each plot, and the water tables should be used to irrigate these trees. The main channel and branches should be constructed to act as storages, and the main should, if possible, divide the area irrigated, as it is very desirable to have a small supply constantly on hand.

THE DEVELOPMENT OF SPRINGS.

Mr. G. Hunt, of Castle Creek, said as long as he could "get water and sun" he could "grow anything with irrigation." His land is hilly and he opens springs where ever they can be found, putting timber in the bottoms and then filling over. In 5 years he has developed in one part of his land 4 continuous streams. He cuts races on the highest levels and has now four of them, one above the other, three running one way and one to pick up the overflow from them. Every man could open similar springs and races; then he would have all the water he could get free of charge.

IRRIGATION FROM WELLS.

Mr. James Mussen, secretary of Lowanshire Water Works Trust, while speaking of irrigation from single wells, said that in his company's district, an area of 2,000 square miles, there is no natural water supply from creeks. Before the trust was formed, the only use was that made by the pastoral tenants of the crown. In 1883 the trust was constituted and most of the then wells and dams were taken by the trust, who have opened numerous new wells, and are still striving to meet the demand for water. An unlimited supply of water has so far been developed at from 100 to 200 feet throughout the district. This water is raised by wind pumps to tanks of 6,500 gallons capacity, and also pumped from earth tanks into troughing. After discussing various propositions for restoring water to the surface, Mr. Mussen gives the opinion that 4 acres is sufficient for one holder to irrigate at starting, and that sandy loam with a subsoil about 12 to 14 inches below surface is best for fruit and forage crops. The land should have a gentle slope from the well. Plowing to break the "pan" or subsoil is recommended, and land should be well saturated when first prepared. Forage crops require most water, and such crops should be attended to for the sake of the general return from the place. Lucerne has been known to fade away as irrigation ceased. Constant moisture by a system of channeling and not flooding is the desideratum. Opinions have been expressed against well water for irrigation, but his experience is favorable to such supply.

The cost of a well 150 feet deep, with windmill, tank of 1,000 cubic yards capacity, split timber, pump, and piping with valves and outlets complete, is stated at £230, or about $1,000. Horse power is cheaper at first, but the windmill is finally the most economical. With the tank once filled, and the mill at work, a constant supply can be depended upon.

"Single well" irrigation may appear unique to many, but if persevered in will enable this large region to raise the more lucrative fruit crops in great abundance, and to some measure abandon the now universal staple of wheat. The depth of these wells varies according to elevation of the surface.

IRRIGATION BY SHOWERS.

W. Brown, principal of Lougerenony Agricultural College: Recommends for the purposes of shower irrigation a hand force pump on a 4,000-gallon tank in the ground, with iron pipes along edges of crop plots to which rubber hose are attached with portable sprinklers, one man with two sprinklers can shower a diameter of 40 feet each, irrigating at the rate of 1 inch to the acre, 22,600 gallons of water in 3 hours. The cost of the whole plant of Lougerenony Agricultural College, Australia, is only $200.

He said that—

> To say that we are limited to "flooding" and furrow as systems of applying water is to acknowledge a limitation of the art and our own unprogressiveness.

Water applied only to the roots, and the sudden changes of temperature, are unnatural, and with "highly organized" plants must be a source of danger. Irrigation by showers in certain localities would arrest frost. As yet the system thus described is only available for limited areas. On large plantations little could be done.

METHODS OF IRRIGATION.

C. L. McGuirk, Mildura, argued that land must be thoroughly graded and leveled after plowing and all crops should be drilled, so that horse, hoe, and cultivator could be worked after watering.*

Fruit trees should be watered by furrows run each side and closed after each watering. The water is run right through them one-half or two-thirds, and the smaller streams allowed to run until thoroughly soaked. No two tracts can be watered the same unless the grades are equal, and the irrigationist must watch his land and apply water on the first sign of choke.

Drainage, when required, is easy by the use of stones, dead wood, heath, or saplings laid at bottom of drain and covered with sods; but many irrigators hold that drainage is unnecessary except when the land has a deep fall.

Mr. McGuirk has under cultivation by irrigation: Apples, 35 sorts; apricots, 9 sorts; almonds, 2 sorts; cherries, 10 sorts; peaches, 13 sorts; plums, 25 sorts; pears, 4 sorts; also quince, mulberry, raspberry, and strawberry. His vines also, of various kinds, have all done well under irrigation. He also declares that "the smaller the area worked by one man the greater will be the results and the more got from the land in proportion."

IRRIGATION OF ORCHARDS.

F. W. Shaw states that, as to the quantity of water required for a 12-acre orchard or vineyard, a supply tank of 4,000 yards, excavated out and placed around 8 chains 1 rod of land 5 feet high, will give, after allowing for evaporation and seepage, 1,338,000 gallons of water. To water 6 acres of trees 16 feet by 16 feet, and 6 acres of vines 7 feet by 7 feet apart, it would require 309,480 gallons of water. I have an elevated tank of 2,000 gallons filled in 12 minutes by a 4-inch centrifugal pump driven by 2 horses. The same power is used for farm purposes, cutting chaff, crushing corn, etc. The bottom of this tank is level with the tops of the trees, so that the trees may be sprayed. From this tank a 1½-inch main pipe runs down the center, between the orchard and vineyard, a length of 14 chains, with 1½-inch taps on standards at suitable distances, a 3-inch canvas hose is attached. From this hose the stem of each tree may be watered about 3 feet all around. While that is running I lay down the next hose, and so on to the end of the row, and then coming back irrigate two trees at a time, and also finding time to support with props the trees that are heavy laden with fruit. Each tree gets 100 gallons of water in two waterings during the year. Late peaches require an extra watering. Wine grapes do not require any water during the growing season.

D. R. Vince plants trees any distance from 16 to 30 feet one way and 10 to 12 feet between the rows. The subsoil must not be turned up, but after plowing the land once and thereby getting the soil about a

* This seems to be the general idea in Australia, great stress being laid on the mellowing of the soil by pulverization. Aëration seems to be as much sought as moisture

foot higher on the crown than in the furrow, he goes back again about 3 feet from the crown, which makes a furrow of about 9 inches deep. A load of maiden soil is required for each tree. By planting them about 10 or 12 feet apart, if the garden were a mile long every tree is shaded. After each watering a little soil should be sprinkled on the watered area. About the third year we heap a little dirt and water around the stem of each tree, making a basin about 3 feet around it. As we go along we leave a basin to hold about a hogshead or two of water locked by a little cutting on the lower side. Under this theory all the ground must not be watered but only the space in these holes. Mr. Shaw notes an instance where the water was run all over the surface, with a fatal effect on all the trees, some of which had been growing for 25 years. For drainage he uses a 6-inch earthen pipe. His plant cost £1,000, including pump. For vines he runs two taut wires the same as in a fence, and trains the vines on the lower one, on the top wire he ties the growing wood. We prune back to 2 or 3 inches so that the vine has nothing to support but the year's growth.

When the yield of fruit diminishes from constant bearing he cuts off about two-thirds of the tree, from a 15-foot tree he takes 10 feet, and the following year gets a heavier yield from the 5-foot tree than from the 15-foot.

G. Eason, discussing the irrigation of garden and orchard, said that the preparation of the land is as usual.

In applying water to apples he runs the water down furrows between every alternate rows of trees, then also bring a covered drain down the same. Apples do well on a light surface soil with clay subsoil. Plums, pears, and raspberries are planted in deep black soil and require little water. Stagnant water must not be allowed to remain. A plant standing in stagnant water 12 hours is likley to die. Cultivation may be a success without irrigation, but that can not take the place of cultivation, therefore drainage and the working of the soil is absolutely necessary.

Cabbages grown without irrigation are worth in the Ballarat market about 2 shillings per dozen, not more than half being fit to cut, while the irrigated product is worth 3 shillings per dozen, and about 1,000 dozen are raised per acre. Irrigated land is worth from four to five times the value of nonirrigated.

Hans Larem said that he plants fruit trees not less than 24 feet apart, with early bearing fruits between to be removed as the permanent trees require space. Trenched embankments with properly graded drains are recommended for facility in watering, the water to be confined therein and not allowed to run over the surface. These trenches should be underdrained and the water conserved in reservoirs for use on lower levels.

IRRIGATION OF VINEYARDS.

T. Haig, discussing this subject, said that: A vineyard planted 27 years ago without irrigation yielded 200 gallons per acre. Mr. Haig desired to irrigate but had neither creek, spring, nor well on his ground, although he had gone down 70 feet for water. He bought a piece of morass about half a mile from his place and sank an open channel about 70 to 80 feet deep at the foot of it, getting a little water and finding solid rock into which he drove 60 feet with dynamite at the rate of a foot a day. At that point he got water enough to double his yield. From a dam erected at the water site, he brought a $1\frac{1}{2}$-inch pipe to the vineyard and laid down branch pipes of 1 inch with plugs about every

12 feet. The only labor of watering being the removal and returning of these plugs.

The ground thus irrigated has a fall of 1 in 8 feet and the water is run from the pipes into little excavations about 15 or 18 inches deep; the idea being to get it to the subsoil. This irrigation is done with a flow of only 5 gallons per minute, but the return is marvelous. The cost of the plant was $2,500, but in 2 years the increased products paid the cost and the vines are now bearing six times more fruit than before water was brought to them, and the wine is of a better quality.

IRRIGATION OF HOPS AND FRUIT.

H. A. Crawford states that the water he uses for the irrigation of hops is taken from a river (Owens) by 9-inch and 7-inch centrifugal pumps and a 20-foot undershot water-wheel. The rise is about 20 feet into a receiving box, and is distributed from thence by a 9-inch galvanized iron pipe, with openings at proper intervals, to which I tie calico hose divided into 10-yard lengths. At one end of the hose an iron ring is placed, and at the other end a string of tape with which I tie the hose to the hole in the pipe. The two pumps have a capacity of 8,000 gallons per minute. This plant irrigates 100 acres.

Hops require more water in the early part of the season than they do later on. After they commence to ripen water retards their maturing and produces a green color that is objectionable.

Fruit trees should be planted at least 6 or 8 inches above the adjoining ground to prevent collar rot. This is the practice in southern California.

Out of 830 lemon trees I planted last year according to this method all are growing remarkably well. Speaking of the general benefits of irrigation at Los Angeles, in 1876 these regions were alkali deserts, but now under irrigation a man who owns 10 acres is comfortable and the owner of 20 acres is independent. If irrigation has the same effect in Victoria it is destined to be one of the richest countries in the world.

IRRIGATION OF MEADOWS AND PASTURES.

T. Edol's plan to irrigate grass land is to hoe or plow large drains to conduct the water, and have the ground laid out in "lands" of width conforming to the topography and the area to be watered; and a section properly irrigated will pasture 10 sheep to the acre. He was also in favor of the storage system of semi-artificial reservoirs made by damming the rivers at the mountain gorges.

CULTURE OF AMBER CANE SORGHUM.

A. D. Jeffrey states that amber cane sorghum is one of the most valuable of summer and autumn fodder crops. The land is plowed in autumn about 9 inches deep and sown with wheat for hay in April or May. This is watered about 2 inches at the end of August and cut early in October. Then the land is cross-plowed about as deep as before, then harrowed, rolled with a porcupine roller, and worked with a cultivator until thoroughly pulverized. After leveling and grading furrows are opened with a plow about 2½ feet apart, the main channel being at the higher end. The furrows are filled with water and the land thoroughly soaked, and as soon as the soil is fit to work the sorghum seed sown about 12 pounds to the acre. The furrows are filled in with a leveler and 2 days afterwards given two strokes with a harrow, this last process being important, as it leaves the land in the best possible condition to retain moisture. A horse hoe is worked through the rows and the young shoots earthed up when about 6 inches high, and every second furrow prepared for a water channel by dragging a small stump through it. About the middle of December water is given according to the previous rainfall, and the channels scarrified to the depth of about 3 inches. From Christmas time until May* it is fed to stock, yielding about 50 tons of this nutritious green food per acre. In gathering only the thick, well-grown stalks are cut, leaving the rest to ripen, and about six cuttings per crop are made; and after that sheep or swine may be turned in, which will eat the remaining shoots level with the ground. The land may be made ready then for spring tomatoes, as the cane leaves the soil in nice friable condition.

CULTIVATION WITH IRRIGATION.

T. K. Dow, who is well known in the Western States, as well as in Australia, as an agricultural writer and traveler, said that the importance of cultivation is too often imperfectly understood by farmers who depend upon rainfall for moisture, and it is seldom that in adopting irrigation the degree of increased attention to the working of the soil is given which the new conditions demand.

Deep cultivation must be distinguished from plowing. The terms are not the same. It is possible to cultivate without plowing, and it is well known that deep plowing of new ground often gives unsatisfactory results, exposure to sun and air being necessary before the soil brought up becomes productive. Even in a moist climate a deep bed of cultivated soil is advantageous; but with irrigation this is of the first importance. The layer of cultivated soil is all that the irrigator has to take in and hold the water supply for his growing crops. Well-cultivated soil takes in water like a sponge and like a sponge holds it. A deep layer of soil will hold more than a shallow one. Moisture to the depth of 3 or 4 inches is quickly drawn from the earth, and if cultivation extends no deeper there is nothing left to support a crop. An inch of such soil at the bottom is worth two at the top, and it is bad policy to put water on a thin layer of soil to be quickly evaporated. A stratum of hard lumps will not absorb or retain water; what is wanted is a soil well worked, and the greater the depth of this the better to hold water.

A frequent stirring of the surface is as necessary as deep cultivation, as this process resolves the upper layer of soil into a loose tilth filled with air spaces which prevent evaporation. After a shower or irrigation, a thin crust or skin forms, which is nature's medium for evaporation. Cultivation breaks up this medium and pulverizes the soil so as to form a sort of blanket between the atmosphere and the water-bearing stratum of soil. Just as when an empty sack, or plank or some straw is sometimes found in a field, and although all the remaining land is dry the underlying soil is moist and fit for growing, so with this thin covering of pulverized aërated earth, the moisture of the underlying soil is conserved. An instance is noted of an orchard that was irrigated and then cultivated, and upon removing about 2 inches of soil, the ground was found moist and mellow. At one corner of the orchard the channel had overflowed and irrigated this part of the orchard a second time, but no cultivation had followed; and the result was a striking lesson;

* The antipodeal difference between American and Australian seasons should be noted.

the surface was hard and cracked, and I had to dig 5 or 6 inches before uncovering moist soil. Frequent cultivation in reality is forming a mulch with the surface soil, and the advantages of mulching to check evaporation are too well known.

There were present at this conference 72 representative farmers, and 62 papers were read; ways and means were intelligently discussed, and each paper was followed by an exchange of views that must result in much practical benefit. The foregoing are merely abstracts, and the limited space allowed in this report must excuse the omission of much valuable matter. It is only necessary to allude again to the fact that while Victoria is alive to the benefits of irrigation, and under the kindly influence of its waters is bringing a new bloom to the face of nature, the absolute necessity of intensive cultivation in connection therewith is never lost sight of. An irrigable farm gives a sure return to labor.

NOTES ON THE EXPERIENCE OF OTHER COUNTRIES IN THE ADMINISTRATION OF THEIR WATER SUPPLY.

BY H. G. MCKINNEY, M. E., C. E.

[Read before the Royal Society of New South Wales July 26, 1887.]

The countries from which the most useful lessons in water administration can be obtained are Spain, Italy, India, France, and the colony of Victoria, while America and England furnish striking instances of mistakes which we should do our utmost to avoid. There are other countries from which some useful hints can be obtained and which will be incidentally referred to, but those enumerated will supply nearly all the information now brought forward.

The scanty rainfall and high temperature in Spain early led to the introduction of irrigation in that country, while the smallness of the available supply of water necessitated the framing of regulations for its use. Hence we find that during the occupation of Spain by the Moors irrigation was widely practiced, works for this purpose having been constructed then which even now occupy an important position both from an engineering and from a utilitarian point of view. The value of the customs and laws under which irrigation works were managed by the Moors was fully recognized by their conquerors. An excellent instance of this occurred early in the thirteenth century, when the King of Aragon, by whom the Moors had been expelled, issued a decree that the customs observed by them in regard to the utilization of water should be adopted and adhered to. In short, the Spaniards were indebted to the Moors not only for their irrigation works, but for their system of administration and their sound and practical methods of dealing with the water rights.

The Spanish law of water, which was passed in 1366, and which is probably the most comprehensive act of its kind in existence, is little more than a codification of previously existing laws and a legalization of established customs. Generally speaking, every irrigation work in Spain has a code for its management, and the administration of these rules is in the hands of the irrigators. The law of water deals with the general question of the rights of the State and of individuals to water, and is sufficiently wide in its scope to provide as well for the most ancient irrigation works in the land as for those recently carried out by the English companies. This law consists of three hundred articles or clauses; but the first twenty-nine of these relate to the waters of the sea and deal with coastal works and with the belt of sea throughout which Spanish jurisdiction extends. In the remaining two hundred and seventy-one clauses the subject of rights to rain-water and to rivers, lakes, and subterranean supplies is treated exhaustively. The basis of this law, briefly stated, is that all large natural supplies of water are public property.

Article 31 declares that—

There pertains to the public property the rain-water which flows through torrents or water-courses, the channels of which belong to the same public property.

Article 33 proclaims that—

There pertain to the public or public property: (1) The waters which spring perennially or intermittently within the public lands. (2) Those of the rivers. (3) Those, whether perennial or intermittent, which flow through their natural channels.

Article 44, dealing with the stagnant water, declares that—

There pertain to the public property the lakes and marshes formed by nature, covering public land and fed by public streams.

In the case of subterranean waters, these belong to the owner of the land under which they are obtained.

Article 45 on this subject states:

There pertain to the owner of an estate in full possession the subterranean waters which have been obtained in it by means of ordinary wells, whatever may be the apparatus employed to draw it.

Among the numerous points provided for in the Spanish law of water one of the most important is the power to obtain a right of way for water for irrigation purposes. It is at once obvious that in a case where extensive irrigation works are constructed it is absolutely necessary that all persons owning property within a reasonable distance of the works, and to whom it is desirable that a supply of water should be afforded, should have a right to construct the necessary channels on payment of fair compensation to the owners of the land through which these channels have to be taken. Another very important subject dealt with is the provision of regulations under which concessions can be granted to companies or to individuals for the construction of works for irrigation or for water supply to towns. As an instance of the terms on which concessions have been granted, the case of the Iberian Irrigation Company may be quoted. The principal conditions under which the concession was granted this company were that it would at its own cost and risk construct canals for irrigation purposes, that it would not have authority to charge at a higher rate than 28*s*. per acre of land watered, and that after 99 years the canals would become the property of the State, to which they should be made over in good working order. The following remarks of Moncrieff on this concession are suggestive:

In return for all this what the Government gives is the use of a river running to waste and which they themselves could not employ; and this use is in order to benefit their own country, increasing the general prosperity of the district, and directly swelling the revenue by enabling them to impose on the watered lands a heavier assessment.

Legislation on the subject of water rights in the various States which are now combined in northern Italy dates back in some instances as far as the tenth century. The laws and customs of these States have been altered and improved on as occasion required; but the general basis of the enactments in force is that the state is the owner of the rivers and of all their tributaries of any importance. This point is enunciated in the Code of Victor Emmanuel, which was passed on the union of the Italian States and which proclaims that the rivers and torrents form part of the public domain. Starting with this position, most complete regulations are laid down in regard to the utilization of the national supply of water. All owners and occupiers of land are bound to obtain sanction from the authorities before any works can be constructed by them for this purpose. The works must be carried out and the water used in the manner sanctioned, and no alteration of existing works can be made without first obtaining approval. The owners or users of canals are bound to maintain them in good working order and have to provide for the escape of all surplus water, which, if not required for use by other irrigators, has to be allowed to flow to the river from which it originally came.

The portion of the Civil Code of Italy which treats of water rights is very comprehensive and holds a corresponding position there to that occupied by the law of water in Spain. The conditions existing in these two countries differ materially, and the legislation to provide for these conditions naturally exhibits a corresponding difference. In Italy the rainfall is much higher and the supply of water in the rivers more abundant and more regular. Hence the necessity for drainage works in connection with the irrigation in northern Italy is felt in a degree unknown in Spain. On this account the subject of drainage is dealt with more exhaustively in the Italian enactments. Among points relating to drainage provided for in these the most important are (1) the right of way for drainage water, (2) the obligation to keep drainage works in repair, and (3) the right of an owner or occupier of land to enter the lands of others in order to repair any drainage work, from the condition of which he has reason to apprehend danger or loss. Under the Italian laws no man has a right to waste water. When a supply of water is granted to any person for the irrigation of a certain plot of land, the surplus left after that land is watered belongs to the person or authority from whom that supply was obtained.

The same reason which in Italy called for special provisions regarding drainage also necessitated comprehensive regulations in regard to right of way for water. Not only is a right of way for water through public or private lands and over or under canals provided for, but even cases in which it may be desirable to conduct water into and for a certain distance through a canal or channel already in operation has not been overlooked.

The canals of Italy having been constructed under a great variety of conditions, and in most cases many centuries ago, there is considerable diversity in the nature of their ownership. Hence we find that some of these works are the property of the Government, others of corporations or associations of irrigators, and others of private individuals or companies. Since the union of the Italian States the principle of having irrigation and drainage works constructed and managed by the persons interested has been fostered and encouraged. Still, the only great irrigation work constructed within a comparatively recent period—namely, the Cavour Canal—was carried out by an English company under a special concession from the Government. But the system of management by associations, which corresponds closely with what we should term "irrigation trusts," is in full operation and works very satisfactorily, as might be expected. The Italian civil code not only sanctions voluntary associations for the management and drainage of irrigation works and prescribes regulations for their guidance, but it provides for the compulsory formation of associations of this description for the public benefit when a majority of the landholders of a district so desire. It is necessary to add, that in cases of the latter description an association can be formed only when the majority of the landholders who are in favor of it represent more than half of the total interest involved.

The procedure laid down for cases in which a supply of water from a river or lake is required is, in the main, similar to that adopted in France, as will presently be explained. Applications for such supplies have to be made to the Government through the local authorities, and every application must state the nature and extent of the concession asked for, explain the objects in view and show their utility, and must be accompanied by plans and sections in explanation and support of the claims advanced. To deal with such proposals and with the management of the water supply generally, there is a staff of highly trained hydraulic engineers in the service of the Government. Projects for the diversion of water from the rivers, or for drainage, or for the alteration of existing works for drainage or irrigation purposes, are referred to those engineers, who have to inquire into not only the engineering aspect of the proposed works, but also as to the benefits likely to arise from them, and the actual or possible objections to their construction. The local authorities are also called on to furnish their opinions. The information and opinions thus obtained are considered by the Government, and if it be decided to grant the concession asked for, the terms on which it can be allowed are arranged in detail.

The Cavour Canal, which has already been referred to, being a national work in importance, magnitude, and cost, was to have been constructed by Government; but owing to the state of the public finances an advantageous offer made by a company, composed chiefly of Englishmen, to carry out the works was gladly accepted. The terms of the concession were so favorable to the Government that, as has been stated by Moncreif, the canal has proved a source of wealth and prosperity to all connected with it, except the shareholders. The principal points in the agreement were that the company should, within a given period, carry out a project the main features of which had already been determined on for the construction of a canal from the river Po, that this canal should be capable of discharging a stated quantity of water, and that its main object should be to augment the supply in several existing canals. The company was to manage and maintain the works and to receive the revenue from them for 50 years, after which period it was to hand them over in good repair to the Government. The charges for water made by the company were not to exceed rates which had obtained the approval of the Government; but the latter guaranteed a return of 6 per cent. on what it recognized as the capital of the company. It is manifest that an agreement of this description carries with it a certain advantage free from risk to the Government which makes it, and to the landholders on whose behalf it is made, while the risk all falls on the company which undertakes to construct and maintain the works.

In France, questions relating to irrigation and navigation have to be considered together when dealing with the rivers. The system of inland navigation in that country has long been one of the most important in the world and holds a very prominent position in promoting trade by reducing the cost of carriage. The extent to which the value of the rivers and canals of France are appreciated may be judged from the fact that not many years ago the sum of forty millions sterling was voted for their improvement and development.

Although irrigation is practiced in almost all parts of France and over extensive areas, and although its general effect is to raise the value of land 50 per cent., still it is not of such vital importance as in Spain, nor is it even so much of a necessity as in Italy. Hence it is not surprising that the laws of France relating to water supply, having to deal with all the requirements of both navigation and irrigation, are more complicated than those of Spain or Italy. But the principal of the State right to streams is made sufficiently clear and the rights of the public are so defined as to prevent the obstruction of useful works. The code of Napoleon declares that rivers and streams which will carry floats or rafts are considered as dependencies on the public domain, and a subsequent enactment specifies the streams and parts of streams which were to be deemed navigable or raftable. In cases where rights to supplies of water had been acquired previous to the passing of these enactments, compensation was allowed to the owners of these rights. Subject to such conditions, the Government also reserves to itself the right to declare streams or parts of streams navigable or raftable in addition to those already proclaimed.

When any private individuals or syndicates propose to obtain a supply of water from a river, the matter has to be referred to the prefect of the district in which the supply is required. Investigations are made by him into the circumstances of the proposal, and the subject is then made over to the engineer of the department, who reports on the merits of the project from an engineering standpoint. As in Italy, applications for water privileges must be accompanied by plans and sections, and also, as in that country, the engineer to whom they are made over for report is a highly trained government officer. Having investigated the application, the engineer returns it, with his report, to the prefect, who adds any remarks he may consider necessary, and then forwards all the papers to the Central Government, where they are considered by the council of state. If the application be granted, the proposed works must be carried out under terms prescribed by the Government and subject to the supervision and approval of the Government engineers.

The foregoing is the procedure in the case of large works or claims, but for water privileges of minor importance the prefect has discretionary powers to grant claims which are recommended by the engineer.

The fact that the State does not lay claim to rivers and streams which are not navigable has led indirectly to difficulties in the way of irrigation enterprise. Another cause of injury to irrigation prospects has been the difficulty and expense attendant on obtaining a right of way for water and a right to abut a dam on the property of others. These difficulties have, in a great measure, been surmounted by the system of having works constructed and managed by syndicates or associations composed of persons directly interested in them. Two kinds of such syndicates are recognized by the laws, and one termed "free," because its members, in all cases, join it voluntarily, and are at liberty to leave it if they desire; the other termed "authorized," because it is empowered by the State to exercise certain rights, and among others to acquire any land which may be necessary for its purposes. On the whole, a free syndicate bears to an authorized syndicate nearly the same relation as a progress committee in this colony bears to a municipal council. The main principle of either kind of syndicate is purely that of local government, the construction and management of irrigation, and other kindred works being in responsible charge of a body elected by those directly interested.

In Upper India the canal act of 1873 deals in a concise, as well as comprehensive, manner with the question of water conservation and supply. This act is the outcome of two excellent reports which were furnished to the Indian Government at different times by two engineers, who were specially deputed to visit irrigation works in the south of Europe, and to report on their character and administration. The countries drawn on for information and experience were Italy, Spain, and France, and there can be no doubt that these were the countries which could furnish the most valuable suggestions and present examples most worthy of imitation.

The Northern India canal and drainage act commences with the announcement of the right of the State "to use and control for public purposes the water of all rivers and streams flowing in natural channels, and of all lakes and other natural collections of still water. Part I of this act is of a preliminary nature, and furnishes a statement of the territories to which it applies, specifies the previous acts which it supersedes, and defines the application of the terms used in it; part II, relating to the application of water for public purposes, describes the procedure to be adopted when a supply is proposed to be utilized, and states the powers of canal officers, the conditions under which compensation may or may not be awarded, and the method of inquiry into claims; part III, dealing with the construction and maintenance of works, gives to canal officers the power of entry on private lands, and describes the procedure followed when granting supplies of water from a canal, and the responsibilities of the persons to whom such supplies are granted; part IV, on the supply of water, describes the cases under which a supply may be stopped, forbids the subletting of such supply, and ordains that any contract for water between the Government and a landholder shall be transferable with the land; part V, dealing with water rates, distinguishes between the occupier's rate and the owner's rate, and describes the mode of treatment of each. The remaining six parts, into which the act is divided, deal respectively with canal navigation, drainage, obtaining labor for canal and drainage works, jurisdiction, offenses and penalties, and subsidary rules.

It is well to call attention here to the title of this act, which shows that it applies only to Northern India. Madras, which has a governor and government of its own, is much behind the northern provinces in regard to such legislation, and in this respect, at least, justifies the name of the "Benighted Presidency," which is frequently applied to it.

For the administration of the act described, the engineers in charge of canals in full operation are required to pass a qualifying examination to show that they have required the requisite proficiency in knowledge of canal law and of the code of criminal procedure. On passing this examination they are gazetted as canal magistrates, with powers to try and pass judgment on offenses against the canal act. Appeal can be made in such cases to the district magistrate, but this is very seldom resorted to. The position of canal engineer is thus one of very considerable responsibility, as he has not only to see that the main canals and distributaries are in thorough working order, but he has to supply the water without fail to the cultivators according to an appointed rotation, to punish any attempt to interfere with this rotation, to decide regarding applications for new supplies or for the transfer of the position of outlets, and to prevent any kind of waste. The canal engineers, whether they be royal engineers or civilians, are the outcome of the competitive system, the only exceptions to this rule being furnished in the cases of a few civilians and staff corps offices of long service. For many years past the first step towards the attainment of an appointment in the department of public works in India, whether the candidate proposes to enter the service as a royal engineer or civilian, is the passing of an open competitive examination. The course of training necessarily differs, as the curriculum for civilians includes only civil and mechanical engineering and subjects bearing on these, while that of the military cadet, though involving these subjects to an important extent, embraces also the subjects necessary to qualify for the higher scientific branch of the military service.

The canal and other great irrigation works in India are in all cases constructed by Government and managed in the manner described. The success of the system of canal administration in Upper India is beyond question, though the attempt to engraft the principle of local government on it proved a failure. The management of branch canals and distributaries will probably be placed in course of time with satisfactory results in the charge of local associations of landholders. It does not, however, seem surprising that a nation that has been the victim of successive conquests from time immemorial, and which has never hitherto been permitted to have a voice in the administration of its own affairs, should be slow to develop a talent for governing itself. The present system is undoubtedly that best suited to the conditions of the people, though it is not altogether in accordance with the present tendencies of European nations. Hence, while we can learn useful lessons from the principles of Indian canal law, there are many points in its administration which we are not likely to imitate. The great principle which lies at the root of the legislation in Northern India, as well as in Spain, Italy, and France, is that all great natural supply of water belong to Government, and that it is the duty of the Government to deal with them in the manner most advantageous to the public. This was the principle on which was based the draft bill given in the first report of the late royal commission on the conservation of water in this colony. It is the principle adopted (avowedly from the draft bill) in recent legislation in Victoria, and, so far as can be judged from the experience of other countries, it is the only sound basis on which the natural water supply of a country can be administered.

Spain, Italy, France, and India take the leading positions in regard to administration of rivers and other sources of water supply, and furnish the best examples for our information and guidance. But there are other nations which afford corroborative evidence of the soundness of the systems which they follow. For instance, in Prussia, Bavaria, and Saxony, the Government claims absolute ownership of the rivers, and will not permit even the tributary streams to be interfered with until sanction has been granted. he general principles adopted in the management of the rivers in these countries bear much resemblance to those acted on in France, and the result is equally satisfactory.

IRRIGATION THEORIES AND PRACTICES.*

PURPOSE OF IRRIGATION, ITS IMPORTANCE, EXPLANATION OF ITS EFFECTS—THE PART WHICH WATER PLAYS IN VEGETATION—DISTINCTIONS NECESSARY TO BE LAID DOWN.

Definition.—To irrigate a soil is to moisten it by spreading water on its surface so as to produce, by artificial means, a similar effect to that caused by rain. The employment of a watering pot requires an enormous amount of manual labor, not merely for the scattering of the water, but still more for its conveyance from the reservoir which supplies it to the place where it is made use of. For this reason it is now attempted, even in gardens, to substitute more economical plans as much as possible. In cultivation on a large scale, watering by manual labor can not be even dreamed of. Happily, the greater part of manual labor can be avoided by a suitable system of ditches or trenches. These, by a properly arranged fall, conduct the water by gravitation from the off-take point to the land to be irrigated. This economical process constitutes "irrigation." In every case, a limited quantity of water, spread at a given moment over a given portion of cultivated soil, is for such portion what is called a "watering" (arrosage).

Importance of irrigation.—In France the land, which is unirrigated but suitable for that process, is calculated to amount to 3,000,000 of hectares (nearly 7,500,000 acres), and it is probable that this estimate is below the truth. The fact is recognized elsewhere, in countries where irrigation is a general practice, that it increases the value of land at least 50 per cent. beyond its original value, and that it oftener triples or quadruples that value, and that sometimes it multiplies it even tenfold. What an inexhaustible spring of riches it would be, what an increase to the public estate, if all the advantage possible were taken of this marvelous aid to production.

Water, the indispensable factor of vegetation.—Water, it is known, is indispensable to cultivation and vegetation. A soil completely deprived of water must either become reduced to a dust incapable of affording the requisite support to the roots of plants, or would form a mass very difficult to be broken up by agricultural implements, and altogether impenetrable by the young extensions of the roots of plants. Further, it is water which, aided by the atmospheric gases with which the earth is ordinarily impregnated, attacks the mineral constituents of the soil, and by their dissolution sets free the useful elements which the plants very soon appropriate. It is water which serves as a vehicle for all the active properties of manure; and it is water, in one word, that forms the principal portion of the sap.

The sap absorbed by the spongioles or suckers of the rootlets rises to the green parts of the plant, and especially to the leaves; there it is elaborated, and assimilates carbon, which it borrows from the carbonic acid of the atmosphere; it then becomes concentrated by a considerable evaporation of water, and finally descends again and distributes itself through the substance of the plant, causing the increase or growth of its various organs. We know that the transpiration, by

* A translation from "Notions Elémentaires Théoriques et Pratiques sur les Irrigations appliquées aux terres en culture, aux jardins et aux prairies, par J. Charpentier de Cossigny, Ingénieur Civil, ancien élève de l'école Polytechnique, etc. Ouvrage couronné et publié par la Société des Agriculteurs de France." Paris, 1874. This paper is adapted in part from a report made in 1887, by the Hon. Alfred Deakin, M. P., chief secretary of the department of water supply, Victoria, Australia.

which plants lose a portion of the water they contain, takes place chiefly during the heat of the day, and that it is greater in proportion as the air is drier and the soil is more saturated with water. However, this evaporation, in each species of plant, can not diminish beyond a certain limit; it becomes, on the contrary, enormous under the combined action of dry winds and sunshine. Physiologists calculate that, approximately, as a general rule, the daily evaporation is equal to half the weight of a plant. It was by starting from a datum of this kind that Hales supposed that 1 hectare (2½ acres) of cabbages could lose by transpiration 20,000 kilogrammes (over 42,000 pounds) of water during 12 hours of the daytime. It can be at once understood that the general activity of the vegetative functions is proportionate to the abundance of this transpiration, but with this condition always, that the soil is able to supply a sufficient flow of sap as required to maintain this incessant consumption of water. As soon as the moisture of the soil becomes insufficient, the current slackens, and the plant remains in a stationary condition. It is true that the transpiration has diminished also, but it can not nullify itself altogether, so that, if the quantity of water supplied by the soil continues to diminish, the plant droops, withers, and finally dies.

Frequent insufficiency of rain.—Rain is distributed over the days of the year in the most unequal and capricious manner. If at certain times the water is so abundant in the fields that the farmer is obliged to apply himself to providing an escape for it, on the other hand, there are frequently periods without rain, when vegetation remains languid, and as it were in suspense. Even if the rain were distributed evenly it would be very far from sufficient, at least for porous soils, and where plants are cultivated, whose roots pierce only to a little depth, for the support of a continually active and vigorous vegetation. It is then that irrigation operates in the most advantageous manner, and we can easily understand that it is especially in climates where the heat and light excite to the highest degree the power of assimilation in the organs of plants, and where an important leaf evaporation demands a proportionate current of ascending sap, that water produces wonderful effects. Who has not remarked that years of abundance depend very much on a fortunate distribution of showers coming on at opportune times? To have water always at our disposal, it is evident, is the only way to have a truly vigorous vegetation, and harvests at once regular and abundant.

Mineral substances in solution in water.—Water does not exist in nature in a pure state; as it flows, whether on the surface of the ground, or in the substance of the more permeable of the strata of the earth, or finally in the deep chasms from which it comes forth in the form of springs, in all these cases it is charged, by means of solution, with the numerous mineral substances composing the rocks with which it has happened to come in contact. The most common and most abundant substances in waters, are lime, magnesia, alumina, oxide of iron, generally united with silica, and carbonic and some other acids. The majority of these substances are such as necessarily form part of the tissues of vegetables, and which can be found in their ashes.

Mineral substances conveyed in water will have an especially great importance, when they are such as the irrigated land had previously been almost entirely deficient in, and such a case may occur tolerably often. For instance, it has been found that waters issuing from ground considered exclusively calcareous hold in solution important quantities of silica. On the contrary, I have several times had to remark, in places where the arable land is almost completely destitute of lime, that the water of the springs was highly charged with calcareous salts, a fact very easily explained in this case by the existence of immense beds of chalk in the subterraneous country traversed by those waters. Such waters employed for watering not only furnish the crop with its necessary food, but in the course of time modify the nature of the soil, and produce the effect of actual manuring. M. Hervé Mangon, who has tried many and very interesting experiments with these waters, has found in every case which he had an opportunity of studying, that the influx of mineral substances was greater than their consumption by the crops.

Among the mineral substances there are two which are the most valuable of all, on account of their necessity to the plants, and of the niggardliness with which nature has doled them out to arable lands; these two are potash and phosphoric acid. Potash does not occur in many analyses of waters, especially when they are rather old; and as for phosphoric acid there is perhaps not one single analysis made up to the present day (1874) in which mention is made of it. We should not, however, conclude from the foregoing that these substances are absolutely wanting in the majority of natural waters. We must remember that it is only lately that their importance has been duly appreciated from an agricultural point of view, and to take into account also the difficulty that is presented by the proportioning of very small quantities of potash, and still more of very small quantities of phosphoric acid. These are operations in fact which exact the employment of the latest and most delicate processes of chemistry, as well as all the skill of an expert analyst. It has been confirmed on several different occasions that rain water dissolves by degrees the potash contained in granite soils. It is no less certain that these waters attack the phosphate disseminated through many soils, but especially abundant in rocks of volcanic origin. We can not, therefore, doubt the existence of small quantities of phosphoric acid in almost all the waters of springs and rivers. I would say, to sum up, that all the waters which we generally can make use of for irrigation contain, in greatly varying proportions, all the mineral elements which are necessary to the formation of the organs of plants, not excepting even potassium and phosphorus; * and that these elements, even when they exist in the water in only infinitesimal quantities, do not fail, on account of the influx incessantly renewed, to constitute a very real and very appreciable agricultural value, of which it is only right to take account. In some cases, according to the nature of the water, and that of the land watered with it, one mineral substance or another may be introduced into the soil in a quantity more than the crop requires, and in such cases it is possible to cause a permanent increase in the fertility of the land. But, on the other hand, it may happen that certain mineral elements are not brought in by the water in sufficient quantities for the production of abundant harvests, in which case it is necessary, in order to obtain the greatest possible advantage from irrigation, to supply this partial deficiency by the judicious addition of some suitably chosen manure or fertilizer.

Nitrate of ammonia and nitric acid in irrigation waters.—We know that nitrogen has such an influence on vegetation, and so great an agricultural value, that it is often admitted that the quantity of nitrogen contained in any fertilizing matter suffices in itself to give an approxima-

* Potash is a compound of potassium and oxygen; phosphoric acid is a compound of phosphorus and oxygen.

tion to its agricultural value. Nowadays, also, it is admitted, and on very good grounds, that the form of nitrate is one of those which nitrogen assumes for the purpose of penetrating along with the sap into all vegetable organisms. We have then in waters, nitrogen in the condition most easy of assimilation, and in irrigation we ought to take into account the fertilizing power of this element, in addition to that of other mineral substances which we have already considered. Nitrogen is found usually in the form of nitrates. In certain waters it may also be found in combination with hydrogen under the form of ammonia, and that it is just as easily assimilated under this second form.* The waters, which contain animal matter in a state of putrescence, are very markedly ammoniacal.† Rain water itself, although the purest of all, contains, at Paris, according to M. Barral,‡ from 1 to 3 milligrammes of ammonia per litre, and almost as much nitric acid. The waters supplied by the drainage of cultivated land are very much richer in nitrogen than those of springs and rivers, as M. Barral was the first to observe. Taking the mean of eighteen analyses of drainage waters, reported on by this agricultural chemist,§ we find—

Mean per cubic metre of water:	gr.	c.		gr.	c.
Ammonia	2	00	containing nitrogen	1	64
Nitric acid	67	00	containing nitrogen	17	37
			Total nitrogen	19	01

which gives for a season's irrigation on one hectare, in the same proportion as already supposed, *i. e.*, 15.552 metres, an equivalent of 73,000 kilogrammes of stable manure.

Gas held in solution by water.—All waters, but especially those of running streams, absorb air in their prolonged contact with the atmosphere. We can prove this easily by raising water to the boiling point, when the gases at first held in solution escape with the steam, and can by the aid of very simple arrangements be recovered and analyzed. Everybody knows that atmospheric air is a mixture, and not a combination, of two gases principally, namely, oxygen and nitrogen, in the proportions approximately of 21 of oxygen to 79 of hydrogen by volume. The air contains besides from 4 to 6 millimetres of carbonic acid gas. The volume of all the gases which are found thus dissolved in water is variable. But one thing worth remarking is that, oxygen and nitrogen being, as I have just stated, uncombined, behave each of them as if it were alone, and they act respectively on the water in accordance with their several affinities with that fluid, so that it is always found to have absorbed more oxygen than nitrogen.

* The acid resulting from a certain combination of nitrogen and oxygen is called indifferently nitric or azotic acid. This nitrogen or azote uniting with bases, such as lime, potash, soda, etc., produces salts called nitrates or azotates.

† See, on this point, the interesting table given by M. Bobierré, in p. 61 of his "Lecons de chimie agricole." I would remark that this table shows certain quantities of ammonia in the waters of the Seine and Loire, whilst the table on p. 38 gives analyses of these same waters in which ammonia does not occur. We must apply, in fact, to ammonia what I have already said relative to potash and phosphoric acid. The search for substances in such very small quantities could only form portion of a study undertaken specially for that object. But, besides, it must be recognized that but little light can be thrown upon the present question by analyses which have been made merely for an agricultural purpose, and which give only those mineral substances of which the greatest abundance exists in solution in the samples of water.

‡ Barral, "Recherches Analytiques sur les Eaux Pluviales."

§ Barral, "Drainage, Irrigation (Liquid Manures), Engrais Liquides," 2d edition, vol. 4, pp. 677 and 680.

Let us see what part is played by this gas introduced by water into arable soil. Oxygen should not be considered so much a food for plants as one of the principal agencies in those complex phenomena by which the sap is prepared in the bosom of the soil. It slowly burns organic substances of vegetable or even animal origin which chance to be mixed with the earth; it thus transforms little by little insoluble organic matter into soluble humus capable of assimilation. Besides oxygen keeps, and, if necessary, restores sulphur to the form of sulphates, inoffensive salts, with the exception of the sulphurets, and notably of sulphurets of hydrogen, which are frequently produced by putrefactive decomposition, and which are poison to plants. Finally this same gas (oxygen), the principal cause of life, in company with any calcareous or alkaline substances, causes the nitrogen contained in the soil to pass little by little into the condition of nitrates, and these nitrates are known to be the richest and most essential food for all cultivated vegetables.

As for nitrogen, which is also introduced into soils by the agency of water, we do not as yet possess any experience sufficient to establish in a very decided manner what is its action in connection with crops. And we can only base our conjectures on reasoning. Must this nitrogen escape finally into the atmosphere? This appears reasonable enough for that portion combined with the water which may be evaporated from the surface of a soil under the combined action of the sunshine and wind. But this is only a small part of the water of waterings; and independently of that which sometimes penetrates the land to great depths, we have seen that there is another portion which is restored to the atmosphere by the transpiration of plants, after traversing their organs with the flow of the sap. But vegetables we know do not exhale nitrogen; there is, therefore, good grounds for believing that the portion of nitrogen in the water of transpiration, of which I now treat, must become fixed, either by the soil just before the water penetrates into plants by their roots, or it may be by the plants themselves while the water is flowing through them. In the first case there is no impossibility in this that under the action of oxygen, and of the alkaline substances which are also contained in the water, nitrification of the nitrogen had taken place previous to its absorption by the plants. This would be all the more likely, as a gas held in solution by water is in a state of true liquefaction, and its atoms are infinitely more condensed than in the gaseous state, which singularly increases the energy of its physical forces. Who has not remarked, for instance, that the oxygen of the air, which is completely inactive, in its dry state, on iron and the majority of metals, oxidizes them at once by the intervention of water? Is it not to be admitted that, by an effect of the same kind, nitrogen ordinarily inert becomes much more apt to react chemically when it is in solution?

The preceding arguments may perhaps be rendered more clear by applying them to a case in point. I take the first of the remarkable experiments by M. H. Mangon on irrigation waters. He watched the irrigation of a field during an entire season. When each watering was given, he measured exactly the quantity of water let in on the field, as also that which drained off without being absorbed. He drew up an exact account, by means of numerous analyses, of the water which was allowed to flow on the field and of that which came from it. He weighed and analyzed the manures put on the field. He also weighed and analyzed the crop of fodder harvested. The results of this long and patient research is summed up, as far as nitrogen is concerned, in the following table, in which all the quantities are reduced to a surface of one hectare:

	Kilos.
Nitrogen borne along by irrigation water in the form of ammonia or nitric acid	23.442
Nitrogen in manuring	121.884
	145.326
Nitrogen in the hay crop	184.345
From which take	145.326
Difference	39.019

I would first remark, cursorily, that the amount of nitrogen supplied by manuring can be known approximately only. In fact a manuring is not used up during the exact time that the crop takes to ripen. If we take the above figures to represent the amount of nitrogen furnished to the crop by manuring, we must take for granted that the remains of former manurings exactly balance the unconsumed portions of the last dressing at the time of the removal of the crop, which doubtless is not always the case. Still this remark, which bears only on the absolute value of one figure, has no special importance as regards the general conclusions to be drawn from the experiment we are now considering.

There is then in the fodder something like 39 kilogrammes of nitrogen, which comes neither from the manure nor from the saline matter supplied by the water. I might say that there ought to be even more than 39 kilogrammes, as the manure (another fact of which an analysis can take no account) must lose more or less nitrogen, either by being carried away into the subsoil or by passing off into the atmosphere. Now this nitrogen can only come from the atmosphere, from which it passes into the plant after undergoing an unknown series of transformations. In any case, is it not in the highest degree probable that it is rather to the nitrogen existing in the soil in a state of solution that the roots have borrowed the amount in question? I will not assert that all the nitrogen in solution in irrigation water has been of service to the crop, for this nitrogen, in the present case, amounts to no less than 200 kilogrammes, which is evidently much more of that gas than the crop contains. But it remains no less probable, in my opinion, that the presence of this liquefied nitrogen in the substance of the soil is one of the necessary conditions of the nitrification, or some other similar reaction by which the nitrogen of the crop is made up. Thus, although it may be impossible to assign an exact value to this nitrogen in solution in the water, it is yet no less proper to take account of it in computing the value of irrigation water.

Finally, before quitting this subject, we should note that M. H. Mangon has repeated experiments of the same kind on several pieces of land containing crops of different sorts, and that all the results tended to exactly the same conclusions.

Water holds in solution not merely oxygen and nitrogen, but also contains carbonic acid in variable proportions. It must be fully acknowledged that the few thousandths of carbonic acid which are disseminated in the atmosphere would hardly suffice to account for large quantities of this gas in the waters. In fact, carbonic acid emanates, so to say, from all parts of the depths of the earth; it is the constant and most abundant product of volcanos, and it is given out from the majority of very deep excavations. It is then in its passage across certain fissures in the soil that rain water becomes more particularly charged with the gas we are now treating of. The subterranean caverns in which this passage takes place sometimes form an arrangement something like a reversed syphon; the water flowing in by the longer leg, issues by the shorter one. If the part which corresponds to the bend of the syphon is of very great depth, the pressure exercised in that part by the column of water is singularly favorable to the solution of the gas, and the water might then come to the surface, containing in a condensed form many times its own volume of carbonic acid; this latter has a tendency to escape as soon as it has no longer to bear the pressure in excess of that of the atmosphere, and in such a case we have a spring of ærated water.

Some other causes, as yet but imperfectly studied, doubtless contribute to augment the proportion of carbonic acid in water.

M. H. Mangon, in his analysis of irrigation water which had flowed in a thin sheet over the surface of a meadow, found it invariably more charged with carbonic acid than it had been before passing over the meadow.* Will it not be by means of a similar phenomenon, which occurs during heavy rains on the surface of each field, that river water is much more highly charged with carbonic acid gas at the growing season than it is when the crops are ripe and dry? †

Whatever there may be in these phenomena, the explanation of which has drawn me a little away from my subject, carbonic acid plays an important part and a very special one in the phenomena which affect vegetation. It is by its assistance that water attacks solid rock, sand, and clay, and that it derives from these inert matters the elements which the plants can assimilate. Water charged with carbonic acid as it sinks into the earth carries with it therefore an instrument which can disengage such rare substances as potash and phosphoric acid, which perhaps but for it would not be found in sufficient quantity either in the water itself or in the manure.

It has been objected that carbonic acid is formed in sufficient quantity in the soil, by virtue of the slow combustion of organic matter by oxygen, as I have mentioned already. This objection, which might have some foundation as regards soils very rich in humus, falls to the ground of itself when it is a question of those hungry soils which contain hardly any organic matter; and I regard it as likely that flowing in with (arrosage) water is useful in the majority of cases.

Solid matter in suspension in water.—It now remains for us to examine the waters from a last point of view, as to the very minutely divided particles of solid bodies which they contain and carry with them in their courses. The quantity of matter thus borne along is extremely variable. In the impetuous torrents which descend from mountains their proportions may become enormous, and so to say unlimited.‡ But the bowlders, gravel, and sand become deposited successively according to the diminution of the swiftness of the current; and in the gentler rivers which flow through the valleys below there are only at most some impalpable matter which affects more or less the transparence of the water. It is only this latter which will settle in the form of mud on the irrigated soil with which we are here concerned. In the same river, and at a given point, the quantity of mud varies incessantly; it increases during floods and diminishes when the water is low.

As for their composition, the muds deposited by rivers are mixtures of impalpable sand, clay, and carbonate of lime, of divers other miner-

* M. Hervé Mangon "Experiences sur l'emplai des eaux dans les irrigations," p. 81. See also the tables on pages 78, 88, 100, 108, and 118.

† Bobierré's "Leçons de chimie agricole," p. 56.

‡ The torrents from the lofty portions of the Alps sometimes dilute crumbling earth to such an extent that it no longer forms anything but mud; and incidents have been observed of currents of apparently fluid matter, which contained in reality less water than it did of earthy substances.

als reduced to the last stage of subdivision, and finally organic matter, almost always nitrogenous. The exact proportions of these different substances are so variable in different water courses, and even from day to day in the same river, that any examples of analyses I might transcribe here would be, I think, of but little use to irrigators. What there is which can be depended upon is that these muds are coincident with the most fertile lands, and include almost all the mineral or other elements which can be useful to vegetation.

Nitrogen contained in muds.—The mud held in suspension in irrigation waters and deposited by them on the surface of the soil after each watering can not in any case fail to increase the fertility of the soil. One element especially above all others merits our particular attention. That is nitrogen.

If we remember, in fact, that the dunghill, taken as a type, contains 0.004 of its weight in nitrogen, we will perceive that there are rivers whose poorest muds are as rich in nitrogen as dunghill manure, and ought to be considered as true manures. The muds of Alpine rivers are less rich in nitrogen than those of the other rivers I have just quoted; and yet the total quantity of nitrogen provided for the land by the repeated application of these muds are still important even in the case of the latter rivers, and evidently in all cases add themselves to the nitrogen which we have already found in the substances contained in the water in a dissolved condition.

Special uses of muddy sediments.—The mud deposited in successive layers by the impure waters that are let in frequently on the same piece of land may pretty soon attain a very considerable thickness, especially if the water is abundantly used. Thus a layer of fertile mud can be obtained, which will serve to fertilize a soil too barren by itself, such, for example, as a soil altogether sandy. One can even go further and flood a piece of land with muddy water diverted from a swollen river; let this water flow off when it has deposited its sediment, and then repeat the operation a great many times. One would in this way, bit by bit, create a true agricultural soil of the very greatest richness, whilst raising a piece of land that was too low, and thus transforming, for instance, a swamp or a place liable to flooding at any moment into a field infinitely better adapted for agriculture.

Double manner of action of water.—To sum up all the preceding, I would mention that irrigation has two sorts of effects, very distinct, although equally important. The first is to supply to the soil the water which the rainfall has not distributed over it in sufficient quantity. Secondly, to deposit in the soil the fertilizing elements which water contains in abundance, and which following the courses of the streams and rivers would naturally flow to waste itself in the sea.

Irrigation in summer and irrigation in winter—Irrigation of farm lands and irrigation of meadows.—The two advantages which I have just related can, in many cases, be obtained together. But it more frequently happens that, on account of the circumstances in which the farmer is placed, one of the two modes of action is more particularly profited by. It must also be noted that, in one of the cases, it is only necessary to use the water during the dry season; whilst, in the other, irrigation may be successfully practiced at all seasons of the year. We can therefore separate summer and winter irrigation—the first intended principally to supply water to vegetable production; the second having for its object and almost sole result the utilization of water at the time of its greatest abundance, and the fertilization of the soil by means of it. But the practical methods adopted in irrigation depend principally on the position of the places and the state of the surface of the soil which it is proposed to water. In order to explain what follows I shall have to lay down two great divisions, one comprising the *irrigation of arable land*, the other the *irrigation of permanent meadows.*

Independently of ordinary case, and of waterings properly so called, there are many special operations in which irrigation may be profitably employed, notably in the reclaiming of poor land by the mud dressing; the raising, generally called colmatage,* of lands too low-lying, and subject to be flooded (two operations which I have already mentioned); the removing of the salt from lands rendered unfertile by the abundance of sea salt; the economical transport and spreading on the surface of the soil of liquid manures and many other fertilizing substances; the moistening of fields in order to facilitate plowing or agricultural work, which, without this plan, could not be executed at the proper time, on account of the hardness acquired by the soil under the influence of drought.

All these different operations shall be described in turn in the following chapters.

Importance of the results of irrigation.—I can not close this chapter without again insisting on the importance which irrigation proper and colmotage might acquire if they became in general use and were applied on a grand scale. How shall I avoid relating, for the story is an old worn-out one, that the valley of the Nile in Egypt owes its inexhaustible fertility for so many ages solely to the periodical overflows of its river, laden with mud, of which, moreover, the advantages have been lately considerably extended by the aid of a vast system of canals and reservoirs constructed by the hand of man? Shall I quote the clever comparison made by an illustrious English geologist, Lyell, who, on the basis of the experiments by Everest on the water of the Ganges, calculated that that river bore annually to the Indian Ocean a quantity of mud of extraordinary fertility, of which the weight would be equal to sixty times that of the greatest pyramid of Egypt? †

Without seeking so far from us for other examples, I will finish by quoting some eloquent passages which I have taken word for word from the fine work by M. Hervé Mangon, from whom I have already quoted, and from whom I shall still have to quote more than once:

> The mud which rivers bear away to the sea is stolen from cultivated, or at least from the bared surface of the country, and agriculture, in not putting a stop to it, abandons a most precious portion of her capital, and permits a part of her domains to escape her; in the second case she suffers a loss of profit, and abandons the victory which nature so generously places at her disposal.
>
> The Durance transports, every year, 11,000,000 cubic metres of mud, containing as much available nitrogen as 100,000 tons of excellent guano, as much carbon as could be supplied by a forest of 49,000 hectares in extent. The Durance is, of all our rivers, the one whose waters are most utilized, and yet agriculture profits by only one-tenth part of its mud.
>
> The weight of the mud carried by the Var during one year would form a mass of 12,222,000 cubic metres, which would suffice for the raising (colmotage) of more than 6,000 hectares, by a thickness of 20 centimetres.
>
> A small canal fed by diverting water from the Var, and carrying only one cubic metre of water per second, and suitably designed, is able to raise (colmoter) per annum to a thickness averaging from 50 to 60 centimetres, a dozen hectares of barren

* *Colmotage.*—This plan for raising low lands was employed in Italy before it was in France. It is a very long time ago since it was put in practice on a great scale on the banks of the Po, the Arno, and other rivers. The Italians called this operation "una colmata," literally a "heaping." M. Nadault de Buffon has derived from that the new word "colmatage."

† The great pyramid is 146 metres high; that is 4 metres higher than Strasburg steeple, or three times the height of the column of the Place Vendôme.

land, and in consequence to create an annual value of 30,000 or 40,000 francs (£1,200 or £1,600).

The Var sweeps away with it to the sea every year 22,000 to 23,000 tons of nitrogen.

If we add the weight of the soluble substances to the weight of the mud carried away * * * * we will perceive that the Seine at Paris draws off under our eyes, and without our noticing it, so to speak, 2,117,984 tons of solid matter, very nearly equal to that of the total quantity of merchandise borne on the river to Paris.

Every 200,000 cubic metres of water thoroughly used in irrigation, says the same author elsewhere, would produce in alimentary products as much as would equal the value of an ox fit for the shambles. Thus the water of the Seine, wasted without having served for watering land, casts into the sea one head of fat cattle every two minutes, or 720 head in 24 hours, or 260,800 head of cattle in the year.

Result of Letheby's analyses of the water of the Nile during a year (for 1874–'75), giving the constituents per million parts.

	June 8.	July 10.	Aug. 12.	Sept. 20.	Oct. 12.	Nov. 12.	Dec. 12.	Jan. 23.	Feb. 12, at Dam.	March.	April.	May 13, at Bulak.
Dissolved matter:												
Lime	41.67	39.92	44.22	42.60	23.09	43.04	42.64	44.68	40.57	46.31	47.63	51.78
Magnesia	16.23	51.13	10.30	6.17	4.83	11.32	9.26	10.29	8.74	9.77	8.23	10.29
Soda	12.01	7.44	5.87	3.01	5.04	3.18	3.69	3.47	3.07	8.94	8.30	13.01
Potassa	24.75	10.62	5.01	41.20	23.48	13.29	10.02	8.31	9.34	7.28	6.09	4.04
Chlorine	16.43	8.51	6.28	2.09	4.91	2.07	2.76	2.42	2.81	6.13	9.16	17.37
Sulphuric acid	28.08	28.38	18.37	19.96	19.08	19.11	17.64	19.60	18.13	22.63	20.09	29.31
Phosphoric acid	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace.	trace	trace.
Nitric acid	..do	..do	..do	..do	..do	..do	..do	..do	..do	..do	..do	..do
Silica, alumina, and oxide of iron	7.01	7.13	11.29	12.57	18.43	9.86	8.19	8.57	7.29	12.71	7.14	6.71
Organic matter	15.00	10.57	11.86	19.29	24.14	13.43	9.20	12.86	15.86	20.86	25.86	31.29
Carbonic acid, and loss	41.82	36.10	42.81	47.54	35.57	34.27	32.74	34.51	41.20	46.51	49.36	40.91
Total solids	263.00	163.86	166.01	194.43	858.57	149.57	136.14	144.71	146.71	178.14	181.66	204.71
Saline ammonia	0.057	0.129	0.043	0.100	0.071	0.064	0.049	0.087	0.048	0.036	0.035	0.014
Albuminoid ammonia	0.114	0.100	0.071	0.171	0.143	0.114	0.108	0.143	0.116	0.086	0.107	0.118
Suspended matter:												
Mineral	60.86	87.29	1,307.43	483.43	332.14	306.86	269.71	148.99	114.86	46.29	61.14	38.29
Organic	8.29	91.14	184.14	59.14	45.86	36.86	19.43	19.14	10.86	6.86	5.14	9.43
Total solids	69.15	178.43	1,491.57	542.57	378.00	343.72	289.14	167.43	125.72	53.15	66.28	47.72

The remarks of Dr. Letheby on his own results are:

(1) That the dissolved matters increase gradually from December to June, and diminish from June to September, excepting in September.

(2) That the azotose matters are very large compared with those of European rivers.

(3) The sulphates and carbonates and chlorides of lime and magnesia and soda are not in excess; thus the water is well suited to domestic purposes.

(4) The carbonates and silicates of potash are large in amount, especially in June, September, and October, when the soluble constituents have most fertilizing qualities.

As to the slime or suspended matters—

(1) The suspended matters are the chiefly fertilizing ingredients in Nile water. These are most abundant in August and September.

(2) The potash and phosphoric acid of the slime constitute the manurial value; and these are in greater proportion in the samples of August and September.

(3) The high floods from August to October hence supply the qualities most valuable in irrigation.

The following results of analyses of well waters from the valley of the Nile show large proportions of sulphates and carbonates of lime and magnesia, also of alkaline chlorides. They have very little fertilizing quality, and are unsuited for domestic use. They hence contrast markedly with Nile water:

Constituents of water from Egyptian wells in 1874, *per million parts.*

	Brombel, June 28.	Umfast, June 17.	Steined Well at Shubrawent, August 3.
Dissolved matter:			
Lime	145.93	166.81	183.94
Magnesia	28.15	28.67	79.11
Soda	87.27	51.32	107.51
Potassa	3.48	1.99	6.57
Chlorine	72.86	81.16	254.06
Sulphuric acid	86.73	39.20	51.94
Phosphoric acid	....	....	....
Nitric acid	1.69	1.87	1.45
Silica, alumina, and oxide of iron	17.28	18.01	18.83
Organic matter	4.29	6.14	7.57
Carbolic acid, and loss	123.61	135.40	138.88
Total solids	571.29	530.57	849.86
Saline ammonia	.057	.043	.071
Albuminoid ammonia	.071	.057	.071
Suspended matter:			
Mineral	6.57	11.00	3.14
Organic	34.56	87.14	7.43
Total solids	41.13	98.14	10.57

NOTE.—Mr. Butler, civil engineer on the staff of the Egyptian irrigation service, having carried forward a series of careful experiments and observations, computes that the movement through the sand stratum of seepage from the Nile direct and at right angles from the river channel is at the rate of 1 mile per each 7 days.

IRRIGATION IN FRANCE, ITALY, AND SPAIN.

Italian, French, and Spanish experience all tend in one direction. The interest embraced by irrigation works and enterprises are so varied and bound up with the public welfare that State control seems to be imperatively necessary. For the protection of their citizens at least it is considered that no monopoly can be permitted which would separate property in water from property in the land to which it is to be applied. A general control by the State from a central administration is the essential rule, yet the business management and distribution of the water is considered as better placed under local authority. This is more efficient in its supervision and more economical in its administration. The establishment of a comprehensive system of irrigation by private enterprise, in the countries named, is deemed possible only under unusual conditions.

The capital required is large; the returns therein are not rapid enough; and yet benefits secured by the fuller occupation and utilization of considerable areas are so diffused that the State must and does reap those benefits in unnumbered ways. These considerations justify the assuming such large responsibilities. Such carefully matured schemes, as for example, in Italy and Egypt, insure an enormous agricultural production and the stable prosperity of a large number of producers. It may safely be asserted, then, that irrigation is one of the soundest collective or State investments, where engineering ability executes works which are afterwards taken over under local control. They must be guided by wise codes of water laws and regulations. The land whose production is thus enhanced remains charged, of course, with the interest upon the capital expended in supplying it, and also with the final payment of the debt incurred for its permanent reclamation.

The water supply in Italy is much larger than those portions of our own domain in which, without irrigation, agriculture remains practically impossible. In the south of France, where desiccating or hot winds like our own prevail at certain seasons, the evaporation is so much increased that the duty is appreciably lessened. But that steady extension of the area commanded by a given stream of water, which is one of the marked results of American irrigation, appears to be almost unknown in Europe; on the contrary, the area of service appears to be stationary year after year. The remarkable degree of economy reached by our California horticulturists is without precedent elsewhere in the world. "An acre of meadow, of beans, or of potatoes in France takes half as much again in a fortnight as an acre of olives requires in a year," says Alfred Deakin; "so that, as the irrigating season for the former lasts 6 months, the grass or beans consume about eighteen times as much water as the more valuable crops. Yet the deduction is not drawn that they should avoid such thirsty crops, or at least encourage those which are profitable with little water."

Our own rainfall, beyond the one hundredth meridian of west longitude, is very much less when compared with Piedmont, 38 inches in Lombardy, and 32 inches in Bouches-du-Rhone. It is much less also in the irrigating season, when Piedmont receives 28 inches, Lombardy 22 inches, and Bouches-du-Rhone 13½ inches. Our own precipitation for the same period will range from 12 down to but 2 inches of rainfall. Direct precipitation is, however, a secondary consideration, when the supply from other sources remains sufficient. The finest irrigation in Spain is in Valencia, which has a fall of only 4.6 inches in the hottest half of the year, and yet has over 100,000 acres watered and splendidly fertile. In our own country much rain is regarded by some irrigators as a disturbing element. One fact remains clear in all lands, and that is that the more water there is available the more it is used. Most of the best results are obtained, however, with moderate quantities.

The agricultural opulence, commercial stability, and successful industrial enterprise of the people of northern Italy are chiefly due to the irrigation system which they built up and maintained under economic and other conditions of the most adverse order. "A town of 20,000 people, in the irrigated Milanese, has more appearance of prosperity than a town of 50,000 people in France," says M. Herison, according to whose calculation irrigation has added $330,000,000 to the national wealth of that country. It has proved also a steady stream of indirect national revenue. Taxation upon the land itself amounts to between 25 and 30 per cent. of the rent, while the tenant farmer pays, in addition, something like 13 per cent. of his earnings, calculated at one-fifth of his gross receipts, and certain of his products are taxed as well. The great strides which Italian manufactures and Italian commerce have made during the last 15 years are largely tributary to the regular returns produced by its irrigated agriculture. The southern provinces of France have of recent years suffered terrible reverses. The yield of wine in Vaucluse fell 11,000,000 gallons in the 10 years from 1865 to 1876 owing to the phylloxera, while the loss owing to the displacement of madder by aniline colors derived from tar was reckoned in the same province at $5,000,000 a year.

What has helped to sustain French agriculture under such shocks has been irrigation. "Though population has remained stationary," says Mr. Deakin, in his Royal Commission Report of 1887, "numbers have moved to the districts in which irrigation is practiced. The area of cultivation has had a parallel change. Its gross increase has been trifling, but, nevertheless, there has been a large addition to the artificially watered portion. The courage and resources of the population have been equal to their trial, and, in spite of its severity, they appear to have overcome it. It is a significant fact that, in spite of Asiatic and American competition, irrigated fields are being multiplied both in France and in Italy. No land once watered has returned to dry farming, no canal has been closed, and no waters have been suffered to run to waste. Wherever irrigation has been introduced it has been maintained; and though conditions have altered and products have varied, it has steadily increased its area and the capital invested in it, the produce raised by it, and the numbers of those engaged upon it and supported by its means."

DISTRIBUTION OF WATER FOR SUMMER IRRIGATION FROM APRIL TO SEPTEMBER.*

ART. 1. For the year 1877 and following years to all 1883, the normal price of a continuous supply during the summer period is fixed at £92 per Italian modulo (23 gallons per second).

ART 2. The above price, for a determined quantity, and for a term not larger than the above-mentioned one, may be reduced by the administration to £60 in favor of those companies who had in the preceding years a "trattamento di favor" (lit. "agreement of favor") in view of the pecuniary aid lent for the construction of tributary or sub-tributary canals or for the expenses incurred for the construction of secondary basins.

ART. 3. A rebate of 20 per cent is allowed on the normal price of continuous water which is employed for the first time, or for the two following years, for the summer irrigation of land not yet irrigated.

ART. 4. The contracts for concessions, conformably with the two preceding articles, must be stipulated by joint agreement.

ART. 5. When special circumstances demand it, there may be admitted in favor of an irrigating company or of several clients united in coöperation, even for a single season, the alternate supply of several offtakes of a determined course of continuous water, or of part of same, subject to the following rules:

(*a*) The collective demand must remain unaltered and continual.

(*b*) The mode of division of the whole body of water among the various offtakes, the duration of the distributing turn, and the "erario" of such mouth must be declared in the requisition for water, and remain unaltered during the whole season.

(*c*) For such mouth, when the alteration takes place, the demand must not be less that a tenth of an Italian modulo (modulo=one-tenth of cubic metre).

(*d*) The recipient must defray the expenses of extra watching required for the turn, which would equal an increase of 5 per cent on the normal price of the water.

ART. 6. Distributions "a bocca libera" (by free mouth) are admissable only under certain conditions of elevation or position of depth of soil, to be estimated by the administration, when, however, the drainage and residue waters fall naturally or are artificially conducted in favor of the Government.

For such irrigation the equivalents remain fixed as follows:

	£.	*s.*	*d.*
Rice fields per hectare	4	0	0
Meadow land per hectare	2	8	0
Turkey corn per each flooding	0	12	6

These distributions can only be granted when the supply of water in the canals exceeds the requirements for the regular service.

DISPENSION OF WATER FOR THE WINTER SEASON (FROM OCTOBER TO FEBRUARY).

For each Italian modulo of continual water during the winter season, for uses limited to irrigation, the price is fixed at £7 5*s*.

Recipients of water are allowed, without extra charge, to make use of winter water for the forming of ice for their own use.

The concessions to nonusers of winter water for making ice will be granted by the administration at a charge of 8*s*. 4*d*. for each area.

The daily (extra) distributions will only be granted when there is water at disposal in the canals, after satisfying the continuous distribution, both of regular service and that "a bocca libera" (by free mouth).

The price for each modulo in such cases will be 33*s*. per day.

* Rules and regulations in vogue in Italy at dates named. No material changes have been adopted.

CONCESSIONS OF WATER BY MOTIVE POWER FOR RURAL USE.

ART. 9. For each horse-power of motive power developed from water in the canals in the summer season as well as in the winter, the recipient will be charged 4*s*. 2*d*. per mouth, on the condition also that the water is restored in full at useful points for fresh distributions, each fraction of a mouth being charged as a whole mouth.

After August 20, and for the whole winter season, the water used by motive power for agricultural purposes will be granted without making the restitution obligatory, provided always there is sufficient at disposal, and that the recipient is in a position to show that it is discharged into water courses whence no one can derive profit, and he is responsible for any damages.

ART. 10. *General conditions.*—The year for concessions of water begins with April 1 and terminates with March 31 of the following year, and is divided into two seasons—the summer from April 1 to all September, and the winter from October 1 to all February. The month of March is devoted to spring cleansing.

ART. 11. The concessions stated in the present tariff can only have effect within the term to which the tariff is limited.

When there is a question of concessions of a longer duration by motive power for industrial purposes, the settlement is reserved for the decision of the minister of finances. The demand for concessions, according to terms of the tariff, must, conformably with the copy which will be distributed, be made out on paper stamped with 50 centimes (5*d*.) and directed to the central office of the canals during all January for continual distribution of summer water, and during all August for that of winter water, and for casual demands according as it is wanted.

Late demands for continual water will be placed secondary to those sent in due time. No demand will be recognized for less than a tenth of an Italian modula (10 litres per second.

ART. 13. In applying for water "a bocca libera," the applicant must indicate the region at which the area to be irrigated is situated, and the superficial extent.

When the declared area is more than a tenth less than the area irrigated, the applicant is subject to the expense of measuring the water, and must pay double the charge fixed in III. for the extra area irrigated.

ART. 14. Concessions are made by duplicate receipt forms torn off the original, which latter, signed by the applicant, is held as a bond for the observance of the regulations as per present tariff. The expenses for stamping and registration are chargeable to the applicant.

ART. 15. New dispensations of water will not be made otherwise than by means of fixed works of derivation.

Such works must be constructed and maintained by the party using the water, according to directions and under the surveillance of the official agents, in whose keeping must remain the keys of the "modellatori" when the water is flowing.

The expense and care of deriving and transferring to its destination water granted at the banks of the canals must be borne by the applicant.

ART. 16. With the concessions named in the present tariff the administration does not contract toward the parties applying other obligation than that of distributing among them the water at disposal in the canals, after satisfying all prior engagements.

But at their expense lie the consequences of scarcity, also of interruptions in the distribution, only in case of continued total interruption for over 15 days, exclusive of any other indemnity. (Recipient gets back a pro rata sum for any period of interruption over 15 days.)

ART. 17. In cases of prolonged scarcity, the administration may, without incurring responsibility of any kind, close alternately the distributing mouths to unite the water at disposal, so as to grant it in rotation to the various applicants, but must restore the ordinary service immediately the capacity of the canal permits.

ART. 18. The administration reserves to itself the right of refusing any applicant where hurtful filtrations are to be feared, and wherever questions of indemnity might be involved, unless the applicant formally holds himself responsible, and holds the administration harmless of whatsoever injury.

ART. 19. The administration reserves the right of disposing of any residue water abandoned by the recipient, to collect and utilize same for themselves or in favor of third parties.

ART. 20. The charge for summer water must be paid in two equal installments, October 15 and December 15 of the same year in which the relative distribution takes place.

The charge for winter water must be paid in full on December 15.

Motive power and extra demands must be paid for in advance for the period declared.

ART. 21. The above rule (20) is final, and constitutes a debtor *de facto*, without necessitating notice, intimation, or equivalent act. If not paid within 10 days after fixed periods, the debtor is liable to a fine of 4 centesimi (5 centesimi = ½*d*.) for every lira (10*d.*) not paid, in excess of amount owing. If an extra 5 days elapse after the 10 days overdue, from the sixteenth day, interest on the principal and fine added will be charged at 6 per cent, besides contingent expenses, in terms of the law.

ART. 22. Besides price of water, fines and contingent expenses, 1 per cent for costs of recovery is chargeable jointly with the above.

ART. 23. The administration reserves the right of refusing, the year following, any dispensation of water for irrigating lands whose holders have been tardy in paying for the previous year's dispensation.

ART. 24. The regulations of article 5 of tariff, March 23, 1872, remain in force till the expiration of the present quinquennium in favor of those using the Casalese Canal, inasmuch as they are in enjoyment of privileges accorded them in observance of fourth agreement of the convention, May 4, 1872, with the municipality of Casale Monferrato.

ARTS. 25, 26. Regulations of March 28, 1861, remain in force in respect of distribution of water from Salterana and Gamana tributaries, and their subtributaries in Lowellina.

ART. 27. All works of derivation must be constructed and maintained at the expense of recipients, under the direct surveillance of official agents, who keep possession of the keys of the "modellatori" when the water is flowing.

TILLAGE AND PRODUCTS OF THE SOIL ON IRRIGATED LANDS.*

INTRODUCTION.

Methods of irrigation.—There are many methods of irrigation. The various conditions of water supply, climate, understrata, character of soil, drainage, surface formation, chemical properties of earth and water, and the crops desired to be grown, have all to be considered in the application of the water to the land.

The experienced irrigationist understands the word irrigation to mean not only to wet or flood the land, but rather to run the water by soakage into the soil, and by close culture of the surface to retain it there as long as the nature of the soil will permit.

Where the soil is sufficiently porous to allow the water to sink quickly, the land can be flooded between the tree rows, and a furrow on each side will enable the irrigator to control the fluid. In California and Mexico the land is sometimes ridged into squares and the water allowed to fill one square, and then given an outlet to another, and so on, until the section requiring moisture is irrigated.

Another plan is the basin system, where basins are made around each tree and the water allowed to run until each circle is filled. This system has many disadvantages, and frequently causes diseases to the tree and the hardening or baking of the soil about the roots.

Another method, and perhaps the best, where a true grade can be obtained, is to allow the earth to absorb the water, by soakage, traveling through furrows. The gravitation that will allow of the slowest movement is the most desirable. The furrows, if for tree watering, should be about 3 feet apart, and the same distance from trunk of tree. The ground becomes moistened by soakage in the course of from 6 to 24 hours, according to the character of the soil.

Sub-irrigation can also be adopted, but the writer anticipates it will not become general in Victoria, on account of the great cost in laying the requisite plant; and another reason, because of the plentiful supply of water obtainable in the colony. On lands having an abrupt slope and porous soil what is known as the mesa system is best. The water is applied direct to basins made about the trees.

* Adapted from a paper (1887) by Stephen Cureton, of Melbourne, Victoria, addressed to the Hon. Alfred Deakin, minister of water supply in that colony.

The barrel or tank-wagon method is in vogue where pipes or flumes are not available, and consists of the water being drawn on wagons, with hose attached to each receptacle or water carrier. This primitive mode is slow and expensive, and should only be adopted where other systems are not applicable.

Where the basin method is employed, dry earth can be used to cover all the moist soil, and a light cultivation afterwards will materially assist in holding the water in the ground. If the flooding or furrow system is adopted, cultivation should be thorough, and must invariably follow.

It requires experience to tell when the exact time for cultivation after irrigation should take place. Light sandy soils do not require the same period of time before stirring that heavier and clayey soils do. The danger to be apprehended is allowing the moisture to escape if left too long, and breaking the earth into lumps and clods if done too soon.

No fixed method or rule can be laid down that will apply to all the various products of the soil. For instance, the cultivation and irrigation of wheat has to be done in an entirely different manner to that required by lucerne. Or, again, the treatment of the vine would be injurious to the orange. Root crops, such as the potato, turnip, carrot, etc., all require a separate treatment, in the quantity of water and the frequency of its application.

The quantity of water is not such an important factor as the knowledge of when and how to apply it in such volume as the product under treatment requires. The irrigator must be governed by circumstances, and remember the better he cultivates the more he conserves the moisture he has artificially applied to the ground.

CULTIVATION.

The tillage of the soil by steam has many advantages over cultivation by animals, apart from rapidity, thorough work, and cost. It leaves the land in a better state to be acted upon by the atmosphere. Aëration of the soil is one of its best features and objects. It breaks up the surface, and allows it to remain in a loose state. The atmosphere can more quickly act upon the subsoil, as well as on the surface, and thereby raises the temperature, pulverizes the whole with equability, and better prepares it for the reception of the product. Injurious tramping by animals is avoided, and the moisture can obtain a quicker and better access to the subsoil.

Almost any depth desired can be obtained. Once done, the after-tillage and drainage is reduced in cost and labor.

AN ORANGE ANALYZED.

The skin weighed 67.5 grammes, which is 23.53 per cent.; the seeds weighed 6 grammes, which is 2.84 per cent.; the pulp weighed 182 grammes, or 73.83 per cent.; the skin contained in 100 parts—water and volatile oil, 78.00; organic matter, 21.40; ash, 0.84. The pulp contained in 100 parts—grape sugar, 4.3; cane sugar, 4.2; in free acid, 1.0. The free acid consisted of about equal parts of malic and citric acid. The ash constituents of the orange were—potash, 38.9; soda, 7.6; lime, 23.0; magnesia, 6.5; ferric phosphate, 1.7; sulphur, 2.9; silic, 6.2; phosphoric acid, 14.1.

FRUIT SEEDS.

Fruit-tree seeds do not produce the same varieties as the parent tree, but generally give a hardy though inferior sort, and upon these seedlings are grafted or budded the finer varieties. The seeds may be planted in the autumn, in rows 2 feet apart, or they may be planted in early spring, but in that case the seeds require to be first mixed with damp sand, after which care must be taken that they do not become dry before planting. As soon as the plants are up they should be well cultivated, and every effort made to secure a vigorous growth the first season; and as soon as large enough may be budded in the summer, or grafted in the spring. This applies to such products as the apple, cherry, pear, peach, plum, and quince.

TRANSPLANTING TREES.

Do not expose the roots to the wind, sun, or frost; shorten the tops well and cut off all broken or bruised roots with a sharp knife. When but few trees are to be set, dig large liberal-sized holes. If the soil is poor, improve it with mold from beneath old trees, or with well-rotted stable compost and some ashes and a little slacked lime; but all must be thoroughly mixed and worked together before planting. When ready, fill the hole a depth to receive the roots, so as not to set deeper than grown in nursory. Set the tree and fill in, spread the roots out laterally, fill all the crevices with the soil gently at the trunk, more firmly at outer edge, and slop in one or two pails of water according to size of tree.

If the tree has the roots balled don't spread roots or disturb soil around them. Plant the sack, first cutting the string at the crown. The sack will soon rot away, and is not injurious, rather an advantage. Wrapping the trunk the first season with sacking will assist its growth. Slopping a little water about the surface, no matter how often, is the worst kind of irrigating; good, frequent working of the soil is much better. If irrigation is needed, let it be less frequent but in copious quantity when done. This leads the roots down away from the sun instead of near the surface, as the slopping system does. Don't fail to cut back the top when you transplant. If irrigation is not required pack your soil with the foot.

MODES OF PROPAGATION.

The following schedule is adapted to the propagation of the different trees and fruit-bearing shrubs:

Apple and pear.—Budding and grafting.

Cherry.—Mostly by budding, but succeeds well by grafting if done very early.

Peach and nectarine.—By budding and grafting.

Plum.—By grafting; also by budding if the stocks are thrifty.

Apricot.—By budding; occasionally by grafting.

Almond.—By budding; occasionally by grafting.

Chestnut.—By early grafting.

Walnut.—By early grafting and by annual budding.

Quince.—By cutting and grafting.

Filbert.—By suckers and layers. The finer sorts may be grafted on the more common, which reduces the size of bush and makes them more prolific.

Grape.—By layer and cuttings, and in some instances grafting is advantageously employed for new and rare sorts on old or wild stocks, producing rapid growth and early bearing.

Raspberry and blackberry.—By suckers, cutting off roots, and layers.

Gooseberry and currant.—By cutting, and sometimes by layers.

Distances for planting.

	Feet apart.
Apricots	24
Apples	18 to 20
Pears	18 to 20
Cherries	18
Plums	20
Peaches	20
Nectarines	20
Dwarf apples and pears	10
Grapevines	8 by 8
Raisin vines	10 by 10
Currants and gooseberries	3 to 4
Strawberries, for field culture	1 to 1½ by 3 to 3½
Strawberries, for garden culture	1 to 2
Raspberries and blackberries	3 to 4 by 5 to 7

ARRANGING AN ORCHARD.

There are three popular systems for the arrangement of trees in an orchard:

First. The square system.

Second. The quincunx system.

Third. The septuple system.

Adopt the septuple system for distances over 20 feet apart; under 20 feet the square system is best.

Number of trees to an acre.

Apart each way in feet.	No. of trees.	Apart each way in feet.	No. of trees.
30	50	10	435
25	70	8	680
20	110	6	1,210
18	135	5	1,745
15	205	4	2,725
12	300	3	4,840

CAPACITY OF CISTERNS.

[For each 10 inches in depth, American standard.]

Diameter.	Capacity.	Diameter.	Capacity.
Feet.	*Gallons.*	*Feet.*	*Gallons.*
25	3,059	9	396
20	1,958	8	313
15	1,101	7	239
14	959	6	176
13	827	5	122
12	705	4	78
11	592	3	44
10	489	2	19

HOW TO NEUTRALIZE ALKALI.

Gypsum, or plaster of Paris, applied at the rate of 4 or 5 tons to the acre, will neutralize alkali, so prevalent in some soils, and at once render it capable of producing almost any kind of crop.

NOTES.—Irrigation is the best and cheapest of all fertilizers. One cubic mile of river water contains 762 tons of dissolved matter.

Alfalfa, properly irrigated and cultivated, is the most prolific and best product for raising and fattening stock.

Small holdings are cheaper to work and pay a better remunerative return than large ones.

All soils, loose and compact alike, form a crust upon the surface under the action of rain and sunshine; break this and save the moisture beneath.

If you see that a tree is suffering, as indicated by curled or wilted and leathery leaves and drooping stems, irrigate at once.

SUB-CANAL OPERATIONS AT DODGE CITY, KANS.

The canal covers 25,000 acres of land lying south of the river from Dodge City, in Ford County. The head of the canal is 8 miles up the river from Dodge City. Canal is 25 miles long and 20 feet wide at the bottom, and receives its supply from the sheet or subterranean waters of the Arkansas valley. There is a grade of 1.7 feet per mile. The canal is cut from the surface, going towards its head on a grade, the bottom of which, when the upper end is reached, will be 6 feet below the bed of the river opposite that point. At present the lower end of the canal has been constructed, and about one-half of that portion of the canal below the bed of the river is finished. At that point in the excavation, which was 2 feet below the river bed, the excavation is about 45 feet wide at the bottom, and gradually widening to 60 feet on the bottom for a distance of 1,700 feet. This portion of the canal is protected on its sides by the driving of oak piles 12 feet long into the ground 16 feet apart, and framing a stringer at the top 4 by 4, and pilings 2 by 8 and 12 feet long are driven on the outside of this, this being done before the dredging machines were put into operation.

The surface of the excavation down to the water line was excavated by scrapers, and the balance of the excavation under the water is being excavated by a clam-shell dredging machine. One-fourth of the estimated amount of work to be done in running up to the river bend was done last fall—the work having been discontinued on it during the winter—the other one-fourth being done this spring, since April 1. The amount of water discharged from the opening does not seem to be increased by the rise in the river. A measurement taken last fall (1889) showed the standing water in the excavation about 1 foot higher than the river at that time, which was practically dry. At present the surface of the water in the excavation is 2 feet lower than the surface of the high water, which is now what is commonly known as the river "banked full." The amount of water has not yet been measured. The excavation under water is done by contract at 20 cents per cubic yard.

At a later date (August 11, 1890) Mr. Gilbert, executive of the Kansas Waterworks and Irrigation Company, writes that 1,500 feet had been excavated and the discharge into the subcanal was 25 cubic feet per second; there was no water on the surface of the river at that date, which makes a good showing for the new system of underflow conservation.

The bottom of the excavation was then 8 feet below the bottom of the river, and observation proves that more water is obtained for the money expended by not going any deeper. They will run up the river with the excavation at this depth, and keep it just wide enough to carry the amount of water required by the canal. In other words, after the construction of the canal is commenced at the east end of the reservoir, give it a fall of 3 feet to the mile until a point is reached where it is 8 feet below the bed of the river, and then give the canal the same fall of the river, which at this point is about 7 feet to the mile. After reaching a point where the excavation is 8 feet below the bed of the river there will be a gain of about 15 cubic feet per second for every mile of excavation. If a slope of 3 to 1 is given the sides, there is no necessity of protecting the sides with sheet piling.

The company started in to build what we termed a reservoir, making it much wider than the canal. This is now regarded as being unnecessary.

UTAH WATER COMPANIES.

The total number of companies incorporated in Utah Territory for irrigation purposes since July 1, 1889, and up to October 15, 1890, and the total amount of capital recorded by each company, is as follows:

Alturus Land and Irrigation Company	$500,000.00
Bear River and River Water Works and Irrigation Company	2,100,000.00
Buckhorn Reservoir and Canal Company	100,000.00
Bear River City Irrigation and Manufacturing Company	25,000.00
East Canyon Water Company	5,000.00
Glasgow Canal and Irrigation Company	2,000,000.00
Hydraulic Canal Company	150,000.00
Newton Irrigation Company	10,000.00
Northwest Field Canal Company	10,000.00
Payette River Canal and Land Improvement Company	100,000.00
Snake River Canal and Power Company	1,000,000.00
Tooele City Water Company	25,000.00
Utah Water Company	3,000,000.00
Wellington Irrigation Company	10,000.00

KANSAS WATER COMPANIES.

[Incorporated between July 1, 1889, and October 15, 1890.]

Dodge City Canal Company, Dodge City, Kans.
South Dodge Canal Company, Dodge City, Kans.
F. X. Aubrey Irrigating Company, Kendall, Kans.
Des Moines and Western Irrigating and Land Co., Medicine Lodge, Kans.
Southwestern Irrigating Company, Leoti, Kans.
Consolidated Irrigating and Water Power Company, Dodge City, Kans.
Interstate Irrigating Company, Leoti, Kans.
Smoky Hill River Irrigating Company, Russell Springs, Kans.
Garden City Irrigating Company, Garden City, Kans.
Irrigating Land Company, Topeka, Kans.
Smith-Buck Irrigating Company, St. Francis, Kans.

Prior to that date there had been fifty-seven irrigating companies chartered by this State.

All the above-named companies were chartered prior to October 15 of this year

NEVADA WATER COMPANIES.

Incorporations formed in the State of Nevada, wholly or in part for irrigating purposes, from July 1, 1889, to October 15, 1890.

Date of incorporation.	Name of incorporation.	Capital stock.
1889.		
Sept. 5	Washoe Lake Reservoir and Galena Creek Ditch Company	$20,000.00
Sept. 25	Reno Water and Irrigation Company	200,000.00
Nov. 11	Reno Water, Land, and Light Company	300,000.00
Dec. 20	Nevada Land, Mining, and Water Company	7,500,000.00
1890.		
Jan. 8	Ophir Land, Wood, and Ice Company	100,000.00
June 16	Nevada and California Land Company	50,000.00
July 28	Russell and Bradley Land and Cattle Company	350,000.00
Aug. 9	Spanish Spring Ditch, Land, and Water Company	500,000.00
	Total amount of capital stock	9,020,000.00

ARIZONA AS PRESENTED IN CENSUS BULLETIN No. 35.

While this report was being printed, there was issued by the U. S. Census Office a report entitled "Census Bulletin, No. 35, Washington, D. C., February 27, 1891—Agriculture: Irrigation in Arizona"—in which appears a communication from Superintendent Robert P. Porter, dated February 24, 1891, stating that said bulletin was "prepared by Mr. F. H. Newell, of the U. S. Geological Survey, special agent of census for the collection of the statistics of irrigation, under the direction of Mr. John Hyde, special agent in charge of the division of agriculture, A."

From the said bulletin the following statements are taken:

Total area in Arizona on which crops were raised by irrigation in the census year ending June 30, 1890, 65,821 acres, or 102.8 square miles; less than one-tenth of 1 per cent. of entire area.

Aggregate number of farms, 1,448; depending upon irrigation, 1,075 (or 74 per cent.); remaining 26 per cent. being stock or other farms, where crops are raised by "dry farming." Average size of "irrigated farms" (by which is meant portions of farms only on which crops are raised by irrigation), 61 acres.

Irrigated farms of—

640 acres or more	7	
320 to 640 acres	15	
160 to 320 acres	57	
		79
Under 160 acres		996

The 79 farms contain an average of 287 acres each, and a total area of 22,656 acres (or 34 per cent. of "entire amount watered in Territory." The 996 farms (under 160 acres) average 43 acres each, and comprise only 66 per cent. of the total irrigated area. "In other words, 7 per cent. of the farmers of the Territory owned over one-third of the productive land, and the remaining 93 per cent. of irrigators owned an average of 43 acres each

Table of irrigators, areas, farms, and products.

Counties.	Number of irrigators.	Total irrigated acreage in crop.	Average size of irrigated farms, in acres.	Average value of products per acre.
Apache	182	5,545	30	$13.36
Cochise	52	2,372	46	26.93
Gila	18	815	.45	23.85
Graham	199	7,556	38	16.06
Maricopa	327	35,212	108	9.26
Pima	85	3,085	36	30.36
Pinal	115	6,919	60	11.25
Yavapai	91	3,762	41	31.00
Yuma	6	552	93	10.50
Total	1,075	65,821	61	13.92

Estimated average cost of water right (taking all counties), $7.07 per acre (which includes cost of digging ditch, or the purchase of water right from some company or carrier); selling value of right as placed by farmers, $12.58; average annual cost per acre (for maintenance, etc.) or assessment or rental, $1.55; estimated cost per acre of preparing land for irrigation, clearing, leveling, etc., $8.60.

Recapitulation.

Original purchase price of land per acre	$1.25
Cost of preparation of land per acre	8.60
First cost of water right	7.07
Total cost	16.92

Average valuation placed by owners of land irrigated, including buildings, fences, and other improvements, $48.68 per acre; showing an apparent profit, less cost of buildings, of $31.76 per acre.

Average annual value of farm products	$13.92
Annual outlay for water	1.55
Leaving for farmer per acre per annum	12.37

In general, "the value of products per acre increases as average size of farm diminishes." In Maricopa County, average size of farms, 108 acres; average product value per acre $9.26. Yuma County, average farm area, 93 acres; product average, $10.50. Pinal County, average farm area, 60 acres; product average, $11.25. On the 996 farms, having an average area of 43 acres, the average value of product is placed at $16.75 per acre, showing that these farmers were "supported and made these profits out of gross earnings averaging $720 per annum each."

The data relative to above was acquired by census enumerators and by correspondence, blank schedules being left with each farmer, and letters sent to canal companies, etc.

Statistics such as these are important if entirely or approximately correct. There is a very wide discrepancy between the areas "cultivated" and reclaimable by irrigation methods within the Territory of Arizona in the figures put together in "Census Bulletin No. 35" and those presented in this progress report. There is a wide difference also between the estimate Mr. Newell prepared in December, 1889, for the use of the Senate Special Committee on Irrigation, and published as part of the testimony.*

In that statement Mr. Newell estimates the area under irrigation in Arizona as 175,000 acres, a total which must be much nearer the facts than the census figures of but 65,821 acres. Mr. Farish, the Territorial commissioner of immigration, at that date gave the total area "irri-

* Senate, Fifty-first Congress, first session, Report 928, Part V, p. 7.

gated" at 203,080 acres, and that "under ditch" at 455,600 acres. The Board of Trade of Phœnix, Maricopa County, presented to the same committee a statement to the effect that there were in that county alone in September, 1889, 125,000 acres "annually cultivated," while the area actually reclaimed reached 187,500 acres.

The statements presented in this report are taken from the official report of the acting governor of the Territory, from other Territorial and county officers, from agents of this Department, from engineers and other residents, and from unpublished data gathered by the United States Weather Service. The circulars sent out by this office also supplemented these sources of information. The Annual Report of the Department of Agriculture for 1889 (covering the preceding year) gives the following totals for Arizona of crops named, all of which must have been irrigated:

Products.	Quantity produced in 1888.	Average yield per acre.	Number of acres in each crop.	Value per unit of quantity.	Total valuation.
Wheat .... bushels.	370,000	15.0	24,695	$0.90	$333,000
Barley .... do..	459,000	18.3	25,086	.65	298,398
Potatoes .... do..	110,000	76	1,441	.68	74,471
Hay .... tons.	35,343	1.10	32,130	11.00	388,773
Total..........	....	....	83,352	....	1,094,642

The wheat acreage, as per monthly crop report for December, 1890, is given at 25,930 acres, increase of 1,235 acres.

The following tables of ditches, irrigated areas under them, and cultivated thereby, was forwarded to this office by J. H. Martineau, civil and hydraulic engineer, of Tucson, Ariz., who is well known in connection with irrigation enterprises. They were received too late for use in the body of the report.

Incorporated irrigation ditch companies in Arizona.

County.	Name.	Mileage of ditch.	Acreage irrigated.	Source of supply.
Maricopa	Arizona	42	50,000	Salt River.
	Buckeye	39	20,000	Gila River.
	Citrus	14	5,000	Do.
	Enterprise	12	6,000	Do.
	Farmers'	5	21,000	Salt River.
	Gila River	8	5,000	Gila River.
	Grand	27	....	Salt River.
	Highland	22	18,000	Do.
	Maricopa	26	45,000	Do.
	Palmer	22	12,000	Gila River.
	Tempe	19	25,000	Salt River.
	Utah	6	10,000	Do.
Pinal	Alamo Aramilla	7	1,000	Gila River.
	Florence	43	60,000	Do.
	Mesa	9	13,000	Do.
	Montezuma	6	1,000	Do.
Yuma	Farmers'	13	10,000	Do.
	Mohawk	35	40,000	Do.
	South Gila	22	12,000	Do.
	Salt River Valley	26	....	Salt River.
	Toltec	3	10,000	Gila River.
	Purdy	10	7,000	Do.
	Saunders	10	4,000	Do.
		417	375,000	

NOTE.—Pima County has about 50 miles of canals serving about 4,500 acres. About 20 miles of small ditches at Fort Thomas in Graham County.

Carrying capacity of Yuma County canals.

Name of canal.	Cost.	Carrying capacity.
		Inches.
Antelope	$10,000	2,000
Araby	35,000	3,500
Contreras	9,000	3,000
Farmers'	15,000	5,000
Mohawk	150,000	11,000
Purdy	25,000	9,000
Saunders	25,000	5,000
South Gila	45,000	8,000
Toltec	15,000	30,000
Redondo	8,000	600
Total	337,000	....

Partial table of private ditches in Arizona.

County.	Name.	Mileage.	Area irrigated.	Source of supply.
Graham	Central	4	200	Gila River.
	Curtis	5	400	Do.
	Darby	3	200	Do.
	Dodge	4	200	Do.
	Gonzales	2	200	Do.
	Graham	4	500	
	Justran	2	200	San Pedro River.
	Kempton	3	400	Do.
	Mathews	4	400	Gila River.
	Mejia	2	500	Do.
	Michelena	5	600	Do.
	Montezuma	10	800	Do.
	Oregon	5	1,200	Do.
	Smithville	6	400	Do.
	Sunflower	2	400	Do.
	Union	8	1,200	Do.
Pinal	Adamsville	4	1,000	Do.
	Bates	1½	160	San Pedro River.
	Brady	4	1,000	Gila River.
	Brannaman & Co.	1¼	320	Do.
	Brash	4	400	Do.
	Brown	1¼	160	San Pedro River.
	Cook	1½	200	Do.
	Dodson	2	320	Do.
	Harrington	1¾	480	Do.
	Latham	1	80	Do.
	McClellan	3	300	Gila River.
	Moore	3	300	Do.
	Pat Holland	7	1,000	Do.
	Pusch	2	640	San Pedro River.
	Sharp	3	160	Gila River.
	Shields	2½	480	Do.
	Swingle	2	480	San Pedro River.
	Stiles	4	300	Gila River.
	Swiss	2	200	Do.
	Walker and Dempsey	3	300	Do.
	Waterman No. 1	1½	320	San Pedro River.
	Waterman No. 2	1½	320	Do.
	White	3	200	Gila River.
	Winkleman	1½	480	Do.
	Z. Gonzales	4	800	Do.
Yuma	Antelope	7	2,500	Do.
	Araby	8½	2,000	Do.
	Contreras	7	2,000	Do.
	Redondo	5	1,500	Do.
		161¾	25,400	

This gives an average per ditch of nearly 160 acres per mile of ditch.

An act "to repeal timber-culture laws, and for other purposes," was passed and approved by the President, in the closing hours of the Fifty-first Congress. The following sections are of direct importance to all proposing to enter desert land, to construct ditches, and to maintain reservoirs for purposes of irrigation.

SEC. 2. That an act to provide for the sale of desert lands in certain States and Territories, approved March 3, 1877, is hereby amended by adding thereto the following sections:

"SEC. 4. That at the time of filing the declaration hereinbefore required the party shall also file a map of said land, which shall exhibit a plan showing the mode of contemplated irrigation, and which plan shall be sufficient to thoroughly irrigate and reclaim said land, and prepare it to raise ordinary agricultural crops, and shall also show the source of the water to be used for irrigation and reclamation. Persons entering or proposing to enter separate sections, or fractional parts of sections, of desert lands may associate together in the construction of canals and ditches for irrigating and reclaiming all of said tracts, and may file a joint map or maps showing their plan of internal improvements.

"SEC. 5. That no land shall be patented to any person under this act unless he or his assignors shall have expended in the necessary irrigation, reclamation, and cultivation thereof, by means of main canals and branch ditches, and in permanent improvements upon the land, and in the purchase of water rights for the irrigation of the same, at least $3 per acre of whole tract reclaimed and patented in the manner following: Within one year after making entry for such tract of desert land as aforesaid the party so entering shall expend not less than $1 per acre for the purposes aforesaid; and he shall in like manner expend the sum of $1 per acre during the second and also during the third year thereafter, until the full sum of $3 per acre is so expended. Said party shall file during each year with the register proof, by the affidavits of two or more credible witnesses, that the full sum of $1 per acre has been expended in such necessary improvements during such year, and the manner in which expended, and at the expiration of the third year a map or plan showing the character and extent of such improvements. If any party who has made such application shall fail during any year to file the testimony aforesaid the lands shall revert to the United States, and the 25 cents advanced payment shall be forfeited to the United States, and the entry shall be canceled. Nothing herein contained shall prevent a claimant from making his final entry and receiving his patent at an earlier date than hereinbefore prescribed, provided that he then makes the required proof of reclamation to the aggregate extent of $3 per acre: *Provided*, That proof be further required of the cultivation of one-eighth of the land.

"SEC. 6. That this act shall not affect any valid rights heretofore accrued under said act of March 3, 1877, but all bona fide claims heretofore lawfully initiated may be perfected, upon due compliance with the provisions of said act, in the same manner, upon the same terms and conditions, and subject to the same limitations, forfeitures, and contests as if this act had not been passed; or said claims, at the option of the claimant, may be perfected and patented under the provisions of said act, as amended by this act, so far as applicable; and all acts and parts of acts in conflict with this act are hereby repealed.

"SEC. 7. That any time after filing the declaration, and within the period of four years thereafter, upon making satisfactory proof to the register and the receiver of the reclamation and cultivation of said land to the extent and cost and in the manner aforesaid, and substantially in accordance with the plans herein provided for, and that he or she is a citizen of the United States, and upon payment to the receiver of the additional sum of $1 per acre for said land, a patent shall issue therefor to the applicant or his assigns: But no person or association of persons shall hold by assignment or otherwise, prior to the issue of patent, more than 320 acres of such arid or desert lands; but this section shall not apply to entries made or initiated prior to the approval of this act: *Provided, however*, That additional proofs may be required at any time within the period prescribed by law, and that the claims or entries made under this or any preceding act shall be subject to contest, as provided by the law relating to homestead cases, for illegal inception, abandonment, or failure to comply with the requirements of law, and upon satisfactory proof thereof shall be canceled, and the lands, and moneys paid therefor, shall be forfeited to the United States.

"SEC. 8. That the provisions of the act to which this is an amendment, and the amendments thereto, shall apply to and be in force in the State of Colorado, as well as the States named in the original act; and no person shall be entitled to make entry of desert land except he be a resident citizen of the State or Territory in which the land sought to be entered is located."

SEC. 3. That section 2288 of the Revised Statutes be amended so as to read as follows:

"SEC. 2288. Any bona fide settler under the pre-emption homestead, or other settlement laws shall have the right to transfer, by warranty against his own acts, any portion of his claim for church, cemetery, or school purposes, or for the right of way of railroads, canals, reservoirs, or ditches for irrigation or drainage across it; and the transfer for such public purposes shall in no way vitiate the right to complete and perfect the title of his claim."

SEC. 17. That reservoir sites located or selected and to be located and selected under the provisions of "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1889, and for other purposes," and amendments thereto, shall be restricted to and shall contain only so much land as is actually necessary for the construction and maintenance of reservoirs; excluding so far as practicable lands occupied by actual settlers at the date of the location of said reservoirs, and that the provision of "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June 30, 1891, and for other purposes," which reads as follows, namely: "No person who shall, after the passage of this act, enter upon any of the public lands with a view to occupation, entry, or settlement under any of the land laws, shall be permitted to acquire title to more than 320 acres in the aggregate under all said laws," shall be construed to include in the maximum amount of lands the title to which is permitted to be acquired by one person only agricultural lands, and not to include lands entered or sought to be entered under mineral-land laws.

SEC. 18. That the right of way through the public lands and reservations of the United States is hereby granted to any canal or ditch company formed for the purpose of irrigation and duly organized under the laws of any State or Territory, which shall have filed, or may hereafter file, with the Secretary of the Interior, a copy of its articles of incorporation, and due proofs of its organization under the same, to the extent of the ground occupied by the water of the reservoir, and of the canal and its laterals, and fifty feet on each side of the marginal limits thereof; also the right to take from the public lands adjacent to the line of the canal or ditch, material, earth, and stone necessary for the construction of such canal or ditch: *Provided*, That no such right of way shall be so located as to interfere with the proper occupation by the Government of any such reservation; and all maps of location shall be subject to the approval of the Department of the Government having jurisdiction of such reservation, and the privilege herein granted shall not be construed to interfere with the control of water for irrigation and other purposes under authority of the respective States or Territories.

SEC. 19. That any canal or ditch company desiring to secure the benefits of this act shall, within twelve months after the location of 10 miles of its canal, if the same be upon surveyed lands, and if upon unsurveyed lands, within twelve months after the survey thereof by the United States, file with the register of the land office for the district where such land is located a map of its canal or ditch and reservoir; and upon the approval thereof by the Secretary of the Interior the same shall be noted upon the plats in said office, and thereafter all such lands over which such rights of way shall pass shall be disposed of subject to such right of way. Whenever any person or corporation, in the construction of any canal, ditch, or reservoir, injures or damages the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage.

SEC. 20. That the provisions of this act shall apply to all canals, ditches, or reservoirs, heretofore or hereafter constructed, whether constructed by corporations, individuals, or association of individuals, on the filing of the certificates and maps herein provided for. If such ditch, canal, or reservoir has been or shall be constructed by an individual or association of individuals, it shall be sufficient for such individual or association of individuals to file with the Secretary of the Interior, and with the register of the land office where said land is located, a map of the line of such canal, ditch, or reservoir, as in case of a corporation, with the name of the individual owner or owners thereof, together with the articles of association, if any there be. Plats heretofore filed shall have the benefits of this act from the day of their filing, as though filed under it: *Provided*, That if any section of said canal, or ditch, shall not be completed within five years after the location of said section, the rights herein granted shall be forfeited as to any uncompleted section of said canal, ditch, or reservoir, to the extent that the same is not completed at the date of the forfeiture.

SEC. 21. That nothing in this act shall authorize such canal or ditch company to occupy such right of way except for the purpose of said canal or ditch, and then only so far as may be necessary for the construction, maintenance, and care of said canal or ditch.

ALKALI SOILS AND WATERS IN CALIFORNIA.

ALKALI SOILS AND WATERS IN CALIFORNIA.

The following statements and analyses are copied or condensed from the reports of Prof. E. W. Hilgard, University of California, 1888–'89. It is believed they will be of service in estimating the value of artesian wells in connection with irrigation.

WATERS AND WATER SUPPLY.

Analyss of the waters of Lake Tulare, three periods (in grains per gallon).

[Date of taking sample, January, 1880; June, 1888; February, 1889.]

	1880.	1888.	1889.
Total solid contents	81.80	204.7	303.07
Soluble after evaporation	71.16	186.7	279.97
Sodium chloride (common salt)	22.77	....	95.79
Sodium sulphate (Glauber's salt)	17.23	....	73.76
Sodium carbonate (sal-soda)	27.92	74.3	94.74
Potassium sulphate	3.24	....	15.68
Insoluble after evaporation	8.36	.37	6.97
Calcium sulphate (gypsum)	....	....	1.47
Calcium carbonate	2.97	....	1.07
Magnesium carbonate	4.95	....	2.55
Silica	.44	....	1.87
Organic matter and water	2.28	14.1	16.12

The most noticeable item of the above comparison is the rapid increase of the solid contents of the water between the last two dates, as compared to that "between the first and second dates." The following is quoted from Professor Hilgard's report, 1888–'89:

It should be noted that these 8 months were remarkable for very great evaporation elsewhere * * * and that they formed the end of 3 years of rather deficient rainfall in the State. The more abundant moisture of the season just passed may have stopped or perhaps even reversed the process, a point which will receive attention within a short time. It will then be possible to predict with some degree of approximation how nearly the condition of natural equilibrium between the evaporation from the lake surface, and the seepage from the streams and irrigated plains * * * is being approached, and to forecast the future of the lake. * * * Whether or not it will be expedient to interfere with the natural course of events, either for the establishment of a great irrigation reservoir * * * or for the reduction of the lake to a mere waterway in order to reclaim the lands now covered by it, * * * will in a measure be detrimental by the decision of another question, viz., whether the increased saline strength of the lake water is due wholly to evaporation, or in part to concentrated solutions of alkali extracted from underlying beds, by the inward seepage. If a consideration of the area and depth lost by the lake within the last year shall show that there has been a distinct accession of alkali salts from the outside, the use of the drained lake bed as an irrigation reservoir will be of very doubtful practicability, as it would imply an annual addition of such salts to those already contained in the natural soils irrigated therewith.

The importance of the latter consideration is made apparent from the results of an examination of a sample of "dry bog soil" taken from the reclaimed "swamp or overflowed" land on the east side of Tulare Lake, inclosed by a levee and being below the high-water mark.

ANALYSIS OF "DRY BOG" SOIL FROM NEAR TULARE LAKE.

When sampling the soil (after being left uncovered 18 months by the receding of the lake), it was found to be baked quite hard for the first 6 inches; from that line down 20 inches, at which depth the sample was taken, it was boggy and soft. The soil * * * is a somewhat bluish gray clayey sediment, containing small gravel and shells. Its reaction is alkaline though not sharply so.

MECHANICAL ANALYSIS.

	Per cent.
Gravel and shells above 0.6 millimeter in diameter	4.1
Fine earth	95.9

MECHANICAL ANALYSIS OF FINE EARTH.

Clay	29.793
Sediment of—	
0.25 millimeter	13.840
0.25 millimeter	1.567
0.5 millimeter	2.195
1.0 millimeter	8.183
2.0 millimeter	8.622
4.0 millimeter	9.722
8.0 millimeter	6.641
16.0 millimeter	2.115
32.0 millimeter	2.407
64.0 millimeter	1.275
	*86.360

According to this analysis this is a clay soil, which, however, should till well, in consequence of the uniform distribution of the sediments. It seems, however, to acquire tilth with some difficulty at present.

CHEMICAL ANALYSIS.

	Per cent.
Insoluble residue	67.34
Potash	1.05
Soda	.84
Lime	6.51
Magnesia	3.96
Br. or. manganese	.04
Ferric oxide	5.05
Alumina	7.97
Phosphoric acid	.32
Sulphuric acid	.08
Organic matter and water	3.71
Carbonic acid	4.42
	101.29
Humus	.468
Available inorganic	2.184

This shows the general composition of the soil to be excellent, so far as the important ingredients of plant food are concerned. The amounts of potash and phosphoric acid are equal to those in the most productive soils of the Mississippi bottom, and the large percentage of lime should insure its thriftness and kindly tillage; but it is evident, from its alkaline reaction and the large percentage of soda shown, that it contains enough of the true "alkali" to interfere seriously with tillage as well as with the welfare of vegetation. At the same time the solution formed by hydrochloride acid showed the want of aëration in giving an

*The low summation of this analysis is due to the dissolution of lime and some alkaline salts in the large quantity of water employed, the clay at first failing altogether to diffuse until these salts had been washed out. The loss bears mainly, of course, upon the fine sediments.

indication of iron protoxide. These inferences are, moreover, corroborated by observation showing that wheat made some fine ears on the upper portion of a part of the levee where of course the rain had washed out the soda and the air had ample access. On the basis of these facts the following advice as to the treatment of the land was given:

First of all, give the soil a dressing of at least 600 pounds of plaster per acre. You will then find that it will till better, and that weeds will grow on it different from those it now bears.

The soil evidently has not had sufficient time and tillage to get thoroughly aired after its reclamation from the waters of the lake. It evidently needs greatly a summer's fallow, and that to the greatest depth that a big plow and a strong four-horse team can go.

If I understand correctly that it was "boggy" at a depth a little below 6 inches, it is too full of water yet to allow of the healthy life of crop roots. This implies drainage of some kind and protection against the backwater of the lake.

It would seem, from the account given of the condition of crops near the lake, that the same conditions do not exist everywhere on the present and ancient lake border. Such differences doubtless arise from location near to or away from the mouths of streams, as against that in bays or inlets or along the general shore line. But while these various soils may differ in respect to their mechanical composition, there can be little question of their eminent intrinsic fertility when reclaimed from the water and cultivated with due regard to the avoidance of the "rise of the alkali," which not only exists within the sediments themselves, but also (as has been often observed) at some points exists in solid form deposited at some distance beneath the surface. It will therefore require special precautions to cultivate these lands successfully, but their immense stock of native fertility will amply repay considerable care in their management, which can undoubtedly prevent injury from or perhaps even permanently cure the surplus of the alkali. It should not be overlooked that the latter contains among its ingredients so large a proportion of potash salts that the cultivator will probably be relieved of the need of replacing this portion of the drain caused by cropping for an indefinite length of time.

In view of the practical as well as theoretical interest attaching to the subject, we intend to pursue it into its various ramifications as rapidly as time will permit. For the present we present only one instance in which a change now going on on a large scale in nature is at once explained by even the preliminary experiments reported above.

The three lakes of the upper San Joaquin Valley—Kern, Buena Vista, and Tulare—were once connected, and the alkali contained in their waters is manifestly of the same origin. Evaporation has for years past gradually concentrated their waters, for want of their natural influx (Kern River) now diverted by irrigation ditches. But analysis showed that, apart from concentration, a change in the ratio between the soluble salts has been going on as evaporation progressed. The cause of this change was not obvious.

The table below gives the results of the analyses made in 1880, and one lately made of the water of Tulare Lake, which has likewise been seriously diminished by evaporation so as to more than double its solid contents, shows a difference has occurred corresponding to that which in 1880 existed between Kern and Tulare Lakes. That is, the relative proportions between sodic carbonate on one hand and common and Glauber's salts on the other, have changed and are tending toward the same ratio that then existed in Kern Lake, evidently as the result of concentration. There has been a relative diminution of the sodic carbonate; in conformity with the rule shown in our experiments, above reported, that as the amount of neutral alkali salts is increased, a relatively smaller amount of carbonate is formed. The calcic carbonate required for the reaction is abundantly present both in the waters and in the deposits of the lake.

Table showing the increase of alkali carbonates by concentration.

Locality.	Year.	Total residue.	Carbonate of soda.	Common and Glauber's salts.
Tulare Lake:				
Near mouth of Kings River	1880	38.55	1	1.11
Middle	1880	81.83	1	1.29
South end	1880	81.49	1	1.35
Middle	1888	204.00	1	1.58
North end	1889	303.07	1	1.94
Kern Lake	1880	211.50	1	1.78

Doubtless a host of similar examples can be found within arid regions. It may be necessary to remark that while the above table shows no constant ratio between concentration and the proportion of alkali carbonate in solution, the discrepancies are readily accounted for by the possible presence of other conditions that undoubtedly influence the relations between the earthy and alkali carbonates; among these, the prevailing temperature and the relative proportion of lime carbonate in direct contact with the water are probably the most important factors.

Table showing composition of alkali salts in San Joaquin Valley.

	Goshen (surface soil).	Tulare County. People's Ditch (alkali crust).	Tulare County. Near Lake Tulare (surface soil).	Tulare County. Visalia (surface).	Lemoore (alkali).	Tulare Express Station (alkali crust).
Soluble salts in 100 parts soil	1.40		.83	1.26		
Potassium sulphate						
Potassium nitrate*						Small.
Potassium carbonate (saleratus)				18.80		Small.
Sodium sulphate (Glauber's salts)	44.24	1.22	†31.30	13.4	Chiefly	32.8
Sodium carbonate (sal-soda)	32.98	88.09	18.2	45.3		36.16
Sodium chloride (common salt)	16.74	1.00		4.4	Little	31.16
Sodium phosphate†	1.97		.22	10.4		
Calcium sulphate (gypsum)					Little	
Magnesium sulphate (Epsom salts)				8.1	Moderate.	
Organic matter	1.57	9.21	7.5			5.37

*Very generally present, but not always in quantities sufficient for determination.
†Common and Glauber's salts.

Analysis of water from spring 30 *miles north of Visalia, slightly alkaline.*

[From report of Professor Hilgard.]

	Grains per gallon.
Total solid contents	18.22
Again soluble after evaporation	8.29
Insoluble after evaporation	7.01
Organic matter and water	2.92

Amount of mineral matter not excessive or noxious; soluble parts essentially common salt and Glauber's salt. Insoluble part mainly lime carbonate with a little magnesia and silica.

Analysis of water from spring in the foothills of the coast range, in the western portion of county.

[Taken from same report.]

	Parts in 10,000 grains	per gallon.
Total residue by evaporation	35,680	208.4
Again soluble after evaporation	22,600	132.2
Insoluble after evaporation	8,762	51.1
Silica	1,644	9.6
Organic matter and combined water	4,300	25.1

This water is clear, odorless, but with flat, brackish taste. Strong alkaline reaction. Fit only for medicinal uses.

Analyses of artesian waters from different points in Tulare County.

[From report of Professor Hilgard, Agricultural College, California.]

	E. Jacobs.	E. M. Dewey.	D. Madden.	T. Paige.	Hoskins.	E. Jacobs (Lemoore).	D. Rhodes (Lemoore).
Total solid residue by evaporation	21.6	9.99	5.75	12.05	7.80	26.75	26.98
Again soluble after evaporation	17.27	7.18	3.24	10.60	5.00	21.49	23.01
Insoluble after evaporation	2.39	1.61	1.53	1.45	1.20	.87	.76
Organic matter and water	1.93	1.20	.98	....	1.60	4.38	3.21
Sodium silicate:							
Potassium sulphate	....	....	.22	.74	....	....	....
Potassium carbonate	....	3.36	.06	.38	....	(*)	....
Potassium chloride	....	....	....	....	....	....	....
Sodium sulphate	.67	1.02	....	....	(†)	....	....
Sodium carbonate	16.61	2.80	2.96	8.55	(*)	19.30	(†)
Sodium chloride	....	....	....	.40	(†)	(‡)	(‡)
Calcium sulphate	....	.02	.03	....	....	....	....
Calcium carbonate	1.18	.40	.97	.45	(†)	(†)	(†)
Calcium phosphate	....	....	....	....	....	....	....
Calcium chloride	....	....	....	....	....	....	....
Magnesium carbonate	.63	1.19	.06	.70	(§)	....	....
Magnesium chloride	....	....	....	....	....	....	....
Magnesium sulphate	....	....	....	....	....	....	....
Iron and manganese carbonate	....	....	....	....	....	....	....
Silica	.58	....	.47	.80	(§)	....	(§)
Organic matter	1.93	1.20	....	....	....	(‡)	....
Total grains per gallon	21.6	9.99	5.75	12.02	....	....	....

* Some. † Chiefly. ‡ Much. § Little.

Analysis of artesian water from well bored near Lemoore, Tulare County.

[From Professor Hilgard's report.]

Depth, 442 feet; water slightly yellowish but clear; strongly alkaline to test paper.

	Grains per gallon.
Total residue by evaporation	26.75
Again soluble	21,49
Carbonate of soda	19.30
Insoluble	.87
Water and organic matter	4.38

The soluble part is intensely alkaline. It contains chiefly carbonate of soda, with a little common and Glauber's salts.

Analysis of artesian water from well 900 feet deep, in same portion of country:

	Grains per gallon.
Total solid contents	26.98
Again soluble after evaporation	23.01
Insoluble after evaporation	.76
Organic matter and water	3.21

Soluble part alkaline, mostly carbonate of soda, and small amount of common salt. Insoluble part very small, is carbonate of lime and small amount of silica. Water from both wells used generally for drinking.

Analysis of water from the bored well at experimental station near Tulare City; depth of well 60 feet.

	Parts in—		
	100,000 of water.	100 of solid residue.	10 of soluble salts.
Potassium sulphate	.026	1.3	5.5
Sodium sulphate	.049	2.5	10.5
Sodium chloride	.066	3.4	13.9
Sodium carbonate	.334	17.0	70.3
Lime carbonate	.893	45.6	....
Magnesium carbonate	.258	13.1	....
Silica	.239	12.2	....
Organic matter	.096	4.9	....
Total	1.961	100.0	100.0

Total solid contents 1.96 parts in 10,000, 11.5 grains per gallon; permanently soluble 2.8 grains.

The water used in above analysis was taken December 10, 1889, after a very unusual rainfall, and therefore the quantity rather than the quality of its ingredients for the irrigation season is shown.

The amount of soluble "alkali" in the waters from this and the other wells of like character in that part of the county is less than that carried by Kern River at its issue from the Sierras, and can be used without fear of material increase of alkali in the soil irrigated.

Profile of well bored at the experimental station near Tulare City.

	Thickness.	Total depth.
	Feet.	*Feet.*
Black sandy loam	2	....
Hardpan	½	2½
Surface water:		
Sandy loam, light-colored	9½	12
Clay	5	17
Second water:		
Gravel and sand mixed	4	21
Hard clay	6	27
Crumbly hardpan	14	41
Sand	11	52
Clay	4	56
Third water, coarse gravel to clay	4	60

Water rises to within 11 to 13 feet of surface.

This well is used for irrigation. Its output, by means of pumping (triple-action suction, two-horse power), is about 70 gallons per minute, equal to 42,000 gallons for working day of 10 hours. This amount is equivalent to nearly 7.8 miners' inches (4-inch pressure), and would irrigate 40 acres if run the whole 24 hours. One of these wells should be sufficient to irrigate 20 acres of fruits.

APPENDIX.

COPIES OF CIRCULARS AND GENERAL LETTERS SENT OUT BY THE OFFICE OF IRRIGATION INQUIRY.

I.

LAW CREATING IRRIGATION INVESTIGATIONS.

[From deficiency bill, public, No. 315, first session, Fifty-first Congress. Approved September 30, 1890.]

Irrigation investigations: To enable the Secretary of Agriculture to continue to completion his investigations for the purpose of determining the extent and availability for irrigation of the underflow and artesian waters within the region between the ninety-seventh degree of longitude and the eastern foot-hills of the Rocky Mountains, and to collect and publish information as to the best methods of cultivating the soil by irrigation, forty thousand dollars:

Provided, That no part of said sum shall be expended under this paragraph unless the entire investigation, collection, and publication contemplated herein, including the report thereon, can be fully and finally completed and finished before July 1st, eighteen hundred and ninety-one, without any additional expense, cost, or charge being incurred.

II.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION, UNDERFLOW,
AND ARTESIAN WELLS INVESTIGATIONS,
Washington, D. C., ————, 1890.

DEAR SIR: By a recent provision of law, this Department has been charged with the collection, preparation, and publication of information relating to irrigation and the cultivation of the soil thereby.

The Department has decided to prepare a progress report for submission to the next session of Congress. In furtherance of this work, the inclosed circular is forwarded with the request that the same be filled out at the earliest moment and returned in the inclosed penalty envelope. The pasters are for use in sending reports or other printed matter.

Very respectfully,

RICHARD J. HINTON,
Special Agent.

Approved.
EDWIN WILLITS,
Assistant Secretary.

COUNTY AND LOCAL CIRCULAR.

[Please fill out the following blanks as fully as possible and mail in return envelope sent herewith.]

1. No. of irrigation works in your county October 1, 1890? ————.
2. Mileage of main canals? ————; of distributories and laterals? ————.
3. No. of reservoirs, if any? ————.
4. No. of dams? ————; head gates? ————; weirs? ————; wing dams? ————; other works? ————.

5. Cost of such irrigation works whenever possible, either actual or approximate? ———.

6. Acreage served by such works? ———.
7. Character and yield of crops (general)? ———.
8. Acreage, character, and yield of fruits, etc? ———.
9. Other special crops, if any raised? ———.
10. Assessed value (per acre) if irrigated? ———.
11. Actual or selling value? ———.
12. Assessed value of non-irrigated land per acre? ———.
13. Actual or selling value? ———.
14. Are there any artesian wells (that is flowing wells) in your county used for irrigation, farm, or stock purposes? If so, state their number and location ———.
15. State the acreage such wells serve ———.
16. Other wells, as bored, gang, driven, or dug, used for farm, stock, and irrigation purposes. If so, how many? ———.
17. What acreage or other farm use, if any, do they serve? ———.
18. Are there any springs, tunnels, lakes, ponds, lagoons, or other earth water supplies, used for irrigation purposes? If so, please state character and location ———.
19. In the use of underground, underflow, artesian, or other earth waters, for irrigation and farm purposes, please state, if known, whether or no mechanical means are needed and used to lift and distribute the said water over the surface; and if so, what is the character of such power in general use? ———.
20. Any other data or remarks? ———.

Name, ———; post-office, ———; county, ———; State, ———.

III.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION, UNDERFLOW,
AND ARTESIAN WELLS INVESTIGATIONS,
Washington, D. C., November —, 1890.

SIR: This Department is desirous of obtaining a full history of every irrigation colony enterprise and of all other irrigation and water land companies and projects which have been located within the arid region. To that end it respectfully asks an early reply to the following questions; also any other information, copies of reports, pamphlets, maps, etc., which you may be able to forward.

Return penalty envelopes, and pasters for packages of papers, are herewith inclosed.

Very respectfully,

———,
Special Agent.

Approved.

———,
Assistant Secretary.

IRRIGATION ENTERPRISES.

Give name and location of enterprise: ———, town, ———; county, ———; State or Territory, ———.

State whether colony is coöperative or associated, or organized by land owners, private capitalists, or companies, ———.

When organized, year and month? ———.

Number of original settlers or occupiers? ———.

Present population? ———.

Area of land originally settled or embraced in enterprise? ———.

Present area in acres? ———.

Value of land per acre before settlement? ———.

After the same by years, if possible? ———.

Present value per acre improved? ———; unimproved? ——— per acre.

Value with water supply? ———; without? ———.

Sources of water supply? ———.

Give name and location of river, stream, lake, or pond? ———.

General character of works employed? ———.

State other sources of supply, if any; such as wells, flowing, gang, or dug; underground streams, springs, seepage and drainage waters, marshes, lagoons, or ponds, ———.

Service of water, by inches or feet, per acre? ———.

Cost or rental of same? ———.

Whether in perpetuity or by annual payments? ———.

Legal relations of water and land? Please state. Is water public property, inalienable from the land, or not? ———.

Nature of purchase, lease, lien, rental, transfer, or occupancy? ———.

State character of crops raised by irrigation: ———.

Different values of same? ———.

Compare with non-irrigated crops, either in vicinity or in former homes? ———.

General size of holdings? ———.

State what, in your judgment, are the crops best adopted to local and regional conditions? ———.

Remarks: ———.

Please return reply at your earliest convenience.

OFFICERS OF AGRICULTURAL SOCIETIES, ETC.

IRRIGATION INQUIRY.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., ———, 189–.

SIR: Under a recent appropriation the Department of Agriculture has been charged with an inquiry into irrigation and the cultivation of the soil thereby, with the view of publishing reports on the same.

Your extensive interest in, and acquaintance with, this subject in your own State and neighborhood warrants a request for such recent information as you can give. This office wants a record of all canal companies, colony and other land and water enterprises; their area, value, cost, etc.; of the acreage of irrigated and irrigable lands for the past year; the extent and mileage of all irrigation works; of climatic and hydrographic observations; generally, indeed, of such data as may be accessible; also copies of reports, maps, local agreements, leases, regulations, etc., which show the methods of conserving and distributing, selling, and renting water for irrigation purposes.

Your own views as to these subjects, especially in relation to the water supplies in sight above and those below the ground, will be esteemed a favor.

Yours, very respectfully,

———,
Special Agent.

EXECUTIVE OFFICERS, STATES AND TERRITORIES.

IRRIGATION INQUIRY, UNDERFLOW AND ARTESIAN INVESTIGATION,
Washington, D. C., ———, 189–.

To the Governor of ———
———:

SIR: At its recent session Congress authorized this Department "to collect and publish information as to the best methods of cultivating the soil by irrigation," as well also as to continue to completion the investigation into "underflow and artesian waters, their extent and availibility for irrigation."

The Department and this office will be greatly obliged by the receipt of any information and documents bearing on these subjects; and reports, maps, etc., will be of value. If an executive request for such information and aid to inquiry could be sent to State and county officers, it would unquestionably secure valuable responses.

Return envelopes and pasters for papers are herewith inclosed; more will be sent if desired. Data for the past 12 months and the latest reports are respectfully asked for.

Very respectfully,

———,
Special Agent.

To the Secretary of State of ———,

———:

Dear Sir: This office has been directed to prepare a progress report on irrigation for submission to Congress at its next session.

To that end it will be of great service to learn the following facts:*

(*a*) The total number of companies incorporated in your State for irrigation purposes since July 1, 1889, up to October 15, 1890.

(*b*) The total amount of capital recorded by such companies. Also, if possible, the total divided by sources of supply, as

First. Surface waters, such as creeks, streams, rivers;

Second. By reservoirs;

Third. From underflow or other subterranean sources.

The names and localities are not absolutely needed, though that information would be of value. What is more especially desired is the numbers, etc., in order to show activity in this form of enterprise.

Yours, very respectfully,

———,
Special Agent.

RAILROAD OFFICIALS.

U. S. Department of Agriculture,
Office of Irrigation Inquiry,
Washington, D. C., ———, 189–.

Dear Sir: By the inclosed slip you will be informed of the duty Congress has placed upon this Department.

In furtherance of this public service, then, this office asks your assistance, as the road of which you are the executive, in whole or large part, passes through the arid region and is interested in the development of irrigation and the reclamation thereof. Will you, therefore, as early as may be, assist in securing information, etc., as to the following points among others:

(1) Is your corporation, in relation to its land grant (if any), taking any steps towards conserving and utilizing water supplies for present or future use in irrigation? If so, please forward particulars.

(2) What is the character of your water supply within the arid sections of your territory? If such facts have previously been forwarded to this office or to the United States Senate Committee on Irrigation, please give such additional information as will cover the period from July 1, 1889, to October 1, 1890.

(3) Copies of maps, folders, pamphlets, reports, etc., bearing upon the water supplies, etc., will be of great value.

(4) Can you furnish this office with profile map of your road and its branches within the territory west of the ninety-seventh degree of west longitude?

Any information bearing on these questions will be of value.

Penalty return envelopes and pasters (the latter for use on papers, reports, maps, etc.) are herewith inclosed.

An early reply will be of great importance.

Yours, very respectfully,

———,
Special Agent.

COUNTY OFFICERS.

U. S. Department of Agriculture,
Office of Irrigation Inquiry,
Washington, D. C., ———, 189–.

Dear Sir: Will you please oblige this office with copies of your latest reports of assessments and valuations, also showing areas of cultivation, crops raised, stock owned and pastured. In preparing progress report on irrigation this office desires official data on all these points, and others of interest, that will show the growth of the arid sections of our country and the progress and means for reclaiming the same. Accounts of all irrigation enterprises and of all water supplies will be of great value.

Return penalty envelopes and slips are herewith inclosed.

Very respectfully,

———,
Special Agent.

DIRECTORS OF AGRICULTURAL EXPERIMENT STATIONS.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., ———, 189–.

SIR: By the terms of inclosed law you will see that this Department is charged with further inquiry into irrigation and water supply. Your own work must necessarily embrace much of interest in relation to "the cultivation of the soil by irrigation." It is proposed to prepare a progress report for submission to the next session of Congress. To facilitate that work the Department and this office asks your aid:

(1) By the forwarding copies of any reports, papers, plans of works, analyses of soils and water, etc., which may be of service;

(2) Accounts of experiments, if any, that may bear on this subject;

(3) In general, your own views, and any other data than that named bearing upon the subject of irrigation and water supplies, especially those from artesian and underflow sources. Return envelopes and pasters for return postage are inclosed. An early reply will oblige,

Respectfully,

———,
Special Agent.

Approved.

———,
Assistant Secretary.

TO EDITORS.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., ———, 189–.

DEAR SIR: Inclosed find copy of recent provision of law under which this Department and office are now operating. Your journal must of necessity discuss the matters involved. It is of great importance to your readers and the Department also that such data as you publish and consider should be in possession of the office. Will you, therefore, as a matter of public service, forward copy of articles, news items, statistics, etc., which may appear in your columns? All such material as relates to the past 12 months will be of special value. Return envelopes and pasters for packages are inclosed.

Respectfully,

———,
Special Agent.

FOR LAND MORTGAGE AND LOAN COMPANIES.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., ———, 189–.

DEAR SIR: By the inclosed copy of a provision of law, passed at the late session of Congress, you will comprehend the work imposed upon this Department and office.

Your large business interests necessarily make you acquainted with the imperative nature of the demands made by the people of the great plains region for an artificial increase of the water supplies thereof. The appropriation made and its provisions are, you will perceive, small in amount and limited as to power. The chief engineer and chief geologist of this Department are now in the field, and will remain there as long as the weather will permit, making such deductions and plans as the law and their observations will warrant.

Coöperation on the part of all interested—settlers on the lands and capitalists whose means have allowed them to remain there—with officers of the Government and this Department is certainly most desirable. The advantage of your knowledge and extended information is asked for as part of such coöperation. The field officers of the Department, as well as this office, will be found ready to confer with yourself and others interested. The Department would like to receive your views as to the possibilities of obtaining and conserving water supplies, and of the utilizing the same for the cultivation of the soil within the region covered by the artesian wells investigation. Any information or suggestions in relation to irrigation will be welcomed.

Very respectfully,

———,
Special Agent.

Approved.
EDWIN WILLITS,
Assistant Secretary.

CALIFORNIA IRRIGATION DISTRICTS.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF IRRIGATION INQUIRY,
Washington, D. C., ———, 189–.

Secretary of Irrigation District,
———,
———,
California:

SIR: This Department has been charged under recent legislation with an inquiry into irrigation and the cultivation of the soil thereby. It needs no argument to prove to you the advantage of a clean and clear statement in relation to your district.

May I ask, therefore, an early reply to the following questions and such other information, copies of reports, maps, etc., as you can forward?

(1) Name, boundaries, area, location of your irrigation district, post-office address of executive, name of county, etc.?

(2) Area of district; area cultivated, with or without irrigation; area irrigable; sources and extent of water supply?

(3) Amount of bonds issued, annual interest, period running; amount, if any, now negotiated?

(4) Character of works proposed and under construction, cost of same? State miles of canals now in use or to be constructed, number of reservoirs, number of dams, number of weirs, head-gates, wing-dams, etc.?

(5) State if artesian water by wells or springs or any other underground supplies are utilized.

(6) Annual rental of water, permanent cost per acre, service of water per acre?

Return envelopes and pasters for packages are inclosed. A prompt reply will greatly oblige,

Yours, respectfully,

———,
Special Agent.

DIVISION CIRCULARS.

The following were distributed by the special agent sent to investigate irrigation in Montana, Idaho, Eastern Oregon, and Washington:

1. Will you please to describe any irrigating canals which have been completed since the visit of the Senate committee, and the results already secured by means of such works? In replying to this inquiry, will you please to state the length of canal, its breadth at surface and at bottom, its depth and quantity of water which it is capable of carrying, and when it was completed?

2. Will you please to mention all artesian wells in your State or section of the State which have struck artesian water since the visit of the Senate committee, stating diameter of well, *i. e.*, of tubing, depth at which water was obtained, whether flowing or not, and if flowing, in what quantity per hour?

3. Will you please to mention all artesian wells now in progress, but which have not yet struck artesian water?

INQUIRIES RELATING ESPECIALLY TO THE YELLOWSTONE VALLEY.

The following inquiries are addressed to persons residing in or especially informed in regard to the Yellowstone Valley, and particularly to civil engineers and other persons who have made some study of hydraulic engineering or who have had some experience in the construction of machinery for elevating water. These inquiries, of course, relate to the possibilities of future development rather than to what is now desirable:

1. In your opinion, is it practicable to throw water from the Yellowstone River upon the mesas or table lands by means of power furnished by the river, either from canals used for irrigation or from canals constructed for the especial purpose of furnishing water-power?

2. Do you think it practicable to utilize the waters of the Yellowstone River upon the mesas or table lands by employing a series of small reservoirs upon such high lands, the work of pumping to begin early in the spring and to continue through the period of irrigation, such reservoirs to be of a capacity to irrigate, say, from 160 to 1,000 acres of land?

3. Is the coal or lignite found in the Yellowstone Valley cheap enough, and has it the requisite steaming quality in order to render it practicable to throw water from

the Yellowstone Valley into the reservoirs, such as those mentioned in the preceding question, by steam-power, for the purpose of irrigating the mesas and high table lands?

4. In your opinion, could a sufficient supply of water be drawn from the Yellowstone River to irrigate the valley lands, and the available mesas and other high table lands, within a distance of 5 miles from the river, without having recourse to great reservoirs at the head of the Yellowstone River and its principal tributaries, involving also canals of large dimensions and carrying capacity?

GENERAL INQUIRIES IN REGARD TO THE VALLEY OF THE YELLOWSTONE.

1. Please to describe all new works completed or in progress in the Yellowstone Valley since the visit of the Senate committee to Montana in the year 1889; also state what results have been realized from completed works.

2. Will you please to state the number of artesian wells in your vicinity, the depth of each, the diameter of each, and the quantity and quality of the water delivered by each, stating whether they are pumping or flowing wells?

3. What is the fall of the Yellowstone River per mile at Big Timber, at Billings, at Miles City, and at Glendive?

4. What is the average volume of water per second which flows past a given point at Billings and at Miles City during the months of May, June, and July?

5. What is the average volume of water per second which flows from the mouth of the Big Horn River during the months of May, June, and July?

EASTERN WASHINGTON.

The following inquiries are addressed to persons residing in the State of Washington and to others who have practical knowledge in regard to the practicability of reclaiming that vast area of the State of Washington lying east of the Cascade Range, or any portion of it, by means of irrigation:

1. Please to state any facts of interest which you may be able to communicate in regard to the possibilities of reclaiming arid lands in that vast area lying east and south of the Columbia River, north of the Snake River, and embraced almost entirely in the counties of Spokane, Douglas, Lincoln, Adams, and Franklin. In this connection the following facts will be of especial value:

(*a*) The location of irrigable areas.

(*b*) The probable area of such irrigable areas.

(*c*) The sources of water for irrigation.

(*d*) Any facts which you may be able to communicate in regard to the probable location of reservoirs and the probable capacity of such.

2. Facts in regard to the nature of the soil.

3. The prevailing natural growth of nutritious grasses or shrubs, and particularly as to the growth of sagebrush and greasewood.

4. Please to state any facts of interest known to you in regard to the practicability of carrying the waters of the Columbia River upon lands in the counties of Spokane, Lincoln, Douglas, Adams, and Franklin.

5. Please to state any facts of interest known to you in regard to other water supplies available for irrigation in the counties of the State of Washington just mentioned, viz, tributary streams, elevated lakes, underflow or subterranean reservoirs, or artesian waters.

6. Please to state any facts of interest in regard to progress made in the general work of irrigation.

7. The Department of Agriculture is especially desirous of gaining as full and accurate information as possible in regard to agriculture by irrigation in the valleys of the Yakima River and its tributaries.

8. The Department of Agriculture also desires to pay particular attention to that large and productive area known as the "Walla Walla country" and the "Palouse country," in the southeastern part of the State of Washington, which section embraces also a considerable area in northeastern Oregon. This entire area, although highly productive without irrigation, still, like the provinces of Lombardy and Piedmont, in Italy, has a very important relation to the subject of irrigation. Facts which have come to the notice of the Department of Agriculture seem to indicate that the productiveness of this area can be greatly increased by means of irrigation. The following inquiries relate especially to this area:

(*a*) What is the average wheat product of particular lands to which you may refer, during a season of unusual drought and when no rain falls from the time of planting to the time of reaping, and what the average wheat product of such lands during the years of greatest rainfall?

(*b*) Please to state any facts of interest in regard to maximum and minimum crops, other than wheat, on account of extreme drought or unusually large rainfall during the season of vegetable growth.

(*c*) Please to describe the results of irrigation wherever it has been practiced in this region which is not absolutely dependent upon irrigation.

(*d*) Please to state any facts known to you as to the possibility of carrying water upon the lands of the "Walla Walla country" and the "Palouse country" generally, from what sources water can be obtained, and by what means.

(*e*) Please to state any well-established facts known to you in regard to the peculiar chemical properties of this land.

EASTERN OREGON.

But little is known in regard to the practicability of irrigating the lands of that vast area in the State of Oregon lying east of the Cascade Range, south of the Columbia River and south and west of the Blue Mountains and the Powder River Mountains. The irrigating works of Baker County and Klamath County, which counties are far apart, are the only ones of any magnitude in Oregon now known to the Department of Agriculture. The following facts having a bearing upon the subject of irrigation in Eastern Oregon are desired, in order that the Department of Agriculture may make them the basis of a future and more specific investigation of the resources of that area:

1. The topographical features of the country.
2. Its rainfall.
3. The location of irrigable areas and the boundaries thereof.
4. The probable area of such irrigable areas.
5. The available sources of water for the purpose of irrigation, describing streams or lakes available for that purpose.
6. Any facts known to you in regard to an underflow of water or to subterranean reservoirs or artesian waters in this section of the State of Oregon.
7. Any facts which you may be able to communicate in regard to the probable location of reservoirs and the probable capacity of each.
8. The quality of the soil.
9. The prevailing natural grasses, and particularly as to the growth of grease wood and sage brush.
10. The following inquiries relate to that large and productive section in the northeastern part of Oregon which constitutes a part of what is known as the "Walla Walla country." Although highly productive without irrigation, it is believed that, like the provinces of Lombardy and Piedmont in Italy, this area could be greatly benefited by irrigation. At least such is the purport of facts which have come to the notice of the Department of Agriculture. The following special inquiries are therefore submitted:

(*a*) What is the average wheat product of lands to which you may refer during a season of unusual drought and when no rain falls from the time of planting to the time of reaping, and what the average wheat product of such lands during the years of greatest rainfall?

(*b*) Please to state any facts of interest known to you in regard to maximum and minimum crops, other than wheat, on account of extreme drought or unusually large rainfall during the season of vegetable growth.

(*c*) Please to describe the results of irrigation wherever it has been practiced in this region which is not absolutely dependent upon irrigation.

(*d*) Please to state any facts known to you as to the possibility of carrying water upon lands of the "Walla Walla country," from what sources water can be obtained, and by what means.

(*e*) Please to state any well-established facts known to you in regard to the peculiar chemical properties of the land of the "Walla Walla country."

IDAHO.

The Department of Agriculture is desirous of supplementing, in so far as may be practicable, the valuable information in regard to the possibilities of irrigation in the State of Idaho secured by the Senate Committee on Irrigation during the summer of 1889. For this purpose your attention is invited to the following inquiries:

1. To what extent is irrigation necessary in the Panhandle region of Idaho, and to what extent would it be helpful to agriculture where the possibility exists of culture without irrigation?
2. Please to describe the waters of the Panhandle region of Idaho which are available for irrigation.

3. Please to present the following facts in regard to the Panhandle region of Idaho; also in regard to other parts of the State:

(*a*) Its rainfall.

(*b*) The location of irrigable areas and the boundaries thereof.

(*c*) The probable area of such irrigable areas.

(*d*) The available sources of water for the purpose of irrigation, describing lakes or streams available for that purpose.

(*e*) Any facts known to you in regard to an underflow of water or to subterranean reservoirs or artesian waters in the State of Idaho.

(*f*) Any facts which you may be able to communicate in regard to the probable location of reservoirs and the probable capacity of each.

(*g*) The quality of the soil.

(*h*) The prevailing grasses, and particularly as to the growth of grease wood and sage-bush.

4. Information in regard to the location, boundaries, and area of lands in Idaho, Nevada, and Oregon which may be irrigated by the waters of the Owyhee River and its tributaries.

5. Information in regard to the methods of cultivation and irrigation in southeastern Idaho. In this connection the following special inquiries are submitted:

(*a*) The average size of farms.

(*b*) The sources of water for irrigation.

(*c*) The manner of conducting water upon the lands.

(*d*) Methods and economies practiced in the division and distribution of water.

(*e*) The location and capacity of reservoirs.

(*f*) Any questions which have arisen in regard to the appropriation of water for the purposes of irrigation.

6. Any facts which you may be able to communicate as to the possibility of utilizing the waters of the Snake River for the purposes of irrigation in the States of Idaho, Oregon, and Washington.

7. Progress made in the general work of irrigation since the visit of the Senate Committee in 1889.

FRUIT CULTURE BY IRRIGATION.

All persons who have made a specialty of fruit culture by means of irrigation are earnestly requested to present as full a statement as practical in regard to their experience in this special branch of industry, as follows:

1. Where success has been attained, the means of irrigation adopted.
2 Kind of fruit raised.
3. In what year after trees were set out did they begin to bear.
4. Yield of such trees.
5. Facts in regard to the culture of the small fruits, such as strawberries, raspberries, and blackberries, by means of irrigation.
6. To what extent the bearing season of fruit trees, and more especially of the smaller fruit plants, can be controlled or made to yield two crops in a single season.
7. In cases of failure in the attempt to raise fruit by means of irrigation, please to state the cause or causes of such failure, in so far as it can be determined.

PASTORAL OR GRAZING LANDS.

By "pastoral or grazing lands" reference is here had to lands so far removed from water where cattle may drink during the summer season as to render such lands unavailable for pasturage.

1. Will you please to mention any instances known to you of water being supplied to cattle on lands here especially referred to by means of artesian wells or by conducting water from streams or elevated lakes?
2. Will you please to state any facts which may lead you to believe that such reclamation of lands for pasturage is practicable, the location of such lands, and the means whereby, in your opinion, water can be conveyed to such lands for the use of cattle.
3. In your opinion what acreage of lands can thus be reclaimed for pasturage in each specific case which you may mention.

IMPROVEMENTS IN IRRIGATION.

1. Please to describe any recent improvements in the construction of irrigation works which may have come to your knowledge, stating particularly the points of difference between the old and the new methods of construction.
2. Please to describe any recent inventions or improvements in the method of measuring water.

3. Please to describe any recent inventions or improvements in the methods of distributing water to the land of different proprietors.

EXCESSIVE IRRIGATION AND THE DRAINAGE OF IRRIGATED LANDS.

1. Will you please to mention any instances of excessive irrigation which may have come to your notice, stating the indications of such excessive irrigation and the effects thereof upon the different crops?
2. To what extent are irrigated lands drained in your vicinity?
3. In what manner is such drainage affected, and at what cost per acre?
4. Is it your opinion that as a rule some system of drainage must accompany every system of irrigation in order to realize the best results and to prevent the deterioration of irrigated lands?

MARKETS.

1. Will you please to state what proportion of the total value of the products of agriculture by irrigation in your section are marketed in your State or in an adjoining State, and the particular towns and cities in which they are sold?
2. Will you please to state what products are sold exclusively in markets near the place of production?
3. Will you please to state the products of agriculture in your vicinity which are sold both in near-by markets and in remote markets, and the proportion shipped to remote markets?
4. Will you please to state what changes are taking place as to the markets to which products of irrigated lands in your vicinity are shipped, and the causes of such changes in the course of trade?

GENERAL INQUIRIES.

1. Please to state any facts of interest which may occur to you touching the increased value of lands in your vicinity in consequence of irrigation.
2. What are the comparative results of spring and fall plowing with respect to the different crops in your vicinity?
3. To what extent, by what means, and in what manner are fertilizers applied to irrigated lands in your vicinity; and with what results?
4. Please to state the average period of growth from planting to reaping or harvesting of the various crops under irrigation in your vicinity.

TECHNICAL INQUIRIES IN REGARD TO IRRIGATING WORKS.

1. Please to state any facts which may have come to your observation in regard to particular canals, as to the grade below which sediment will accumulate in the beds of such canals.
2. Please to state the maximum grade which can be given to particular canals, or to various sections of such canals, without causing undue wash of the sides or bottoms of such canals.
3. Please to describe in general terms the manner in which and the extent to which the sides or bottoms of particular canals are revetted in order to prevent wearing away.
4. Please to describe the manner in which and the extent to which puddling is resorted to in the construction of particular canals.
5. Please to describe the extent to which terra cotta or other impervious earthen pipes have been employed to carry water from higher to lower levels, where the construction of canals or ditches is impracticable.
6. Please to state the cases which have come to your notice where the loss of available water for irrigation purposes by seepage or the sinking of the water in the earth, has been prevented by the use of flumes or earthen pipes.
7. Please to state any specific facts which may have come to your notice as to the cost of such works for preventing the loss of water by seepage.
8. Please to state any facts which may have come to your notice as to the facilities which exist for the manufacture of impervious pipe in your vicinity, and the cost or probable cost of such pipe.
9. Please to present any facts which may have come to your knowledge, either in writing or in print, as to the fertilizing properties of particular waters of irrigation, *i. e.*, as to the fertilizing silt which they are said to convey to the lands.
10. Please to mention the elevation above sea level of all irrigated lands to which you may refer, in so far as that may be practicable.

11. Please to present to me or refer me to data as to the capacity to deliver water of canals of different cross-sectional size and of different grades.

12. Please to mention failures to secure good results from irrigation and the cause or causes of such failures.

13. Please to state when "flooding" is resorted to and when water is served to the land "in the row."

14. Please to describe the best means of measuring the quantity of water supplied by irrigation which have come to your observation, or refer me to printed description of such works with drawings of the same.

15. Please to state any facts of interest which may have come to your notice as to the irrigation of land which has been terraced.

16. Will you please to mention instances in which underlying waters have been found in sinking artesian wells, which waters furnish evidence of an underflow, or of a subterranean reservoir above bed rock.

The duty of water.

By the expression "duty of water" is meant the quantity of water which is necessary for the irrigation of an acre of land during the season of vegetable growth. This in practice varies from year to year on account of the rainfall. During a season of large rainfall the duty of water will be much less than during a very dry season. Again the duty of water varies with the quality of the land, a loose, porous soil from which much water passes off by seepage, requiring much more water than a heavy soilwith an impervious subsoil.

1. Please to state the average duty of water in the particular localities to which you may refer with respect to the following crops, or vegetable growth:

(*a*) Wheat.
(*b*) Corn.
(*c*) Rye.
(*d*) Potatoes and other root crops.
(*e*) Strawberries, raspberries, and blackberries.
(*f*) Fruit trees.

2. Please to state how much more water is required for irrigation during seasons of extreme drought than during seasons of greatest rainfall.

3. Please to state any other facts in regard to the duty of water which may occur to you, and any improvements of method or of mechanical means whereby the duty of water is economized.

Underflow and underlying waters.

The waters of almost all streams are to a greater or lesser extent subject to underflow, *i. e.*, their waters sink into the earth and flow through sand, gravel, or other pervious stratum, reappearing below in the bed of the same stream or at some remote point. This is due to two causes—first, the nature of the deposit or strata over which such streams flow, and second, to the fact that the beds of such streams have not become perfectly puddled or rendered impervious to water by the sediment which they deposit. Again, there are in particular localities underlying storm waters held in natural reservoirs beneath the soil, in regard to the location and physical characteristics of which reservoirs but little is yet known.

1. Please to state any facts which may have come to your notice in regard to the underflow of the water of large or small streams, or in regard to underlying waters or subterranean reservoirs.

2. It has been found that in certain instances water carried in canals along the sloping sides of high lands has seeped through the bottoms of such canals and by percolation has found its way beneath the soil of valleys below. This is proven by the fact that wells sunken to great depths before such seepage took place failed to reach water, whereas after such seepage has gone on for a term of years water has been found at quite moderate depths, and in certain instances has arisen to the surface as flowing wells. You are respectfully requested to state any facts of this character which may have come to your notice.

3. This whole subject of underflow and underlying waters is one in regard to which little is known. It has an exceedingly important bearing upon the subject of irrigation. Any exact facts, therefore, or phenomena which you have noted in regard to this subject will be of especial value at this time.

Natural subirrigation.

By natural subirrigation is meant the supplying of moisture from the underflow or other underlying waters. Such subirrigation takes place through the evaporation of underlying waters, and the absorption of moisture from such waters by the dry ground at the earth's surface. Evidences of such subirrigation are found not only in valleys but also on mesas lands and the higher plateaus.

1. Will you please to state to what extent valley lands in your vicinity are irrigated by means of natural subirrigation?

2. If in any instances known to you, high lands are subirrigated from the underflow or accumulation of water from the natural rainfall, will you please to describe such cases?

3. In each case of natural subirrigation mentioned by you, will you please to state the nature of the surface soil, the depth to water, and the thickness of the layer of sand or gravel through which subirrigation takes place?

4. Please to state any facts of interest which you may be able to secure as to the time of plowing such subirrigated lands, and the successes and failures which have attended the attempts made to cultivate the various crops upon such lands?

5. Please to state any facts of interest which you may have observed in regard to the subirrigation of high lands from underlying storm waters which are held in a natural subterranean reservoir.

Artificial subirrigation.

By artificial subirrigation is meant the carrying of the water or irrigation underground in pipes, through which water freely circulates, or by other means of conveying water. Such subterranean conduits also operate as drains, carrying off surplus water.

1. Will you please to state any instances which have come to your notice in your immediate vicinity, or in your State, where subirrigation is practiced and with what degree of success?

2. By what means is the water conveyed underground for the purpose of irrigation, stating, if you please, the distance of the conduits apart, their size, and the grade upon which they are laid, also how far below the surface of the ground.

3. Will you please to state any facts of interest which may occur to you as to the time of plowing such subirrigated lands and the successes and failures which have attended the attempts made to cultivate the various crops upon such lands.

Hydraulic machinery for elevating water for the purpose of irrigation.

1. Will you please to describe any works which may have come under your observation for throwing water from lower to higher levels for the purpose of irrigation by water power stating particularly—

(*a*) The location of such works.

(*b*) Description of works, embracing facts in regard to the source and manner of using water as a pumping power.

(*c*) The name and address of the constructors of such machinery.

2. Will you please to describe any works which may have come under your observation, or which may have been projected for throwing water from lower to higher levels, for the purpose of irrigation by means of steam power, stating particularly—

(*a*) The location of such works.

(*b*) Description of such works.

(*c*) Cost of coal or lignite used in generating steam, and where produced.

(*d*) Describe the coal or lignite used, especially as to its steaming quality.

(*e*) The name and address of the constructors of such machinery.

CLIMATOLOGY.

Information is solicited in regard to average monthly temperature, rainfall, and hours of sunshine, and the occurrence of latest spring frosts and earliest autumn frosts for a series of years. It is expected that this sort of data will be procured chiefly from the records of the United States Signal Service at Washington or its agents in various parts of the country; but it is believed that many facts of interest in regard to the influence of climatological conditions can be procured throughout the arid region.

1. Will you please to present such data as you may be able to obtain in regard to the average monthly rainfall at any particular point or points in your State for 10 years or less, and in so far as you may be able to do so?

2. Will you please to present such data as may be available to you in regard to the average monthly temperature at any particular point or points in your State for 10 years or less, and in so far as you may be able?

3. Will you please to present such data as may be available to you in regard to the number of hours of sunshine during each month of vegetable growth, say from March 1 to November 1, at any particular point or points in your State for 10 years or less, and in so far as you may be able?

4. Will you please to give data as to the latest spring frost and earliest autumn frost destructive of vegetable life at any particular point or points in your State for 10 years or less, and in so far as you may be able?

5. Any well-established facts of interest which you may be able to communicate in regard to the comparative influence of climatological causes upon vegetable growth in the humid and in the arid region will be of interest.

6. Will you please to state the elevation above sea level of each locality to which you may refer in so far as that is practicable?

PHENOMENAL RESULTS.

In certain localities and in certain instances, the results of agriculture are so much in excess of the general or average results in the same section or State as to be properly regarded as phenomenal. Exact facts in regard to such results usually afford valuable lessons. A wheat crop of 60 bushels or in excess of such yield would be regarded as phenomenal.

1. Will you please to mention any phenomenal results of irrigation which have come under your observation with respect to agricultural crops generally, or with respect to some particular crop or crops?

2. Will you please to state as specifically as possible the following facts in regard to such phenomenal results:

(*a*) The quantity of each crop harvested, and the quality of such products in any one year.

(*b*) Facts of interest in regard to plowing and to culture generally.

(*c*) How many times were such lands irrigated during the season, in what manner was the water applied and in what quantity applied each time?

(*d*) Nature of surface soil.

(*e*) Nature of subsoil.

(*f*) Was any fertilizer applied to the soil, and if so, what kind, at what time or times, and in what quantity?

3. Please to state the elevation of such lands above sea level, and their situation with respect to direction of slope, also the grade or fall per 100 feet as nearly as you may be able to state that fact.

OFFICERS OF RAILROAD COMPANIES AND OTHER LARGE CORPORATE OWNERS OF LAND.

1. What has your company done in the way of reclaiming arid lands by means of irrigation, or what plans have you in view for securing that object? In speaking of works completed or in progress, please to give their location, capacity of reservoirs, length of canal, breadth of canal at surface and at bottom, depth of canal, and other facts of interest in regard to its construction. Also, please to state the cost of such works, the cost per acre of land expected to be reclaimed by them, and the cost per acre of irrigating lands.

2. Will you please to send me in duplicate all statements in print embracing the rules and regulations which you have adopted for the management of such works, and describing the manner in which your irrigation service is administered?

3. Of the total acreage of lands irrigated, or which may be irrigated by your company, what is approximately the acreage owned by it, what the acreage owned by individuals or corporations, and what the acreage which is still a part of the public domain?

4. Please to state your views in regard to the line of policy which should be pursued by the National Government and by State governments touching the general question of reclaiming the lands of the arid regions by means of irrigation. In this connection you are respectfully requested to state your views in regard to the construction of works of great magnitude involving interstate administration, also works of smaller and merely local importance; also your views upon any question of public policy involved in the general subject of the reclamation of the lands by the various means of irrigation for the purposes of agriculture or of pasturage, with special reference to the disposition of the lands belonging to your company or to the United States Government.

IRRIGATING WORKS.

In describing particular irrigating works will you please to give the following data?

1. Address of proprietor or of chief manager in case the works are owned by a firm or corporation.

2. The name of the river or creek from which water is taken.

3. The point where the water is taken out and location of lands to which it is served.

4. The length of main canal.

5. The breadth of canal at surface and at bottom, and depth of canal.

6. The grade of the main canal, *i. e.*, average fall per 100 feet.

7. A description of the arrangements for distributing the water upon the land to be irrigated, describing particularly the construction of ditches, checks, etc., and the operation of conveying the water to the land.

8. The total cost of constructing such work, and cost per acre.

9. The total acreage of land which is or may be irrigated by such work, and cost of irrigating the same.

ERRATA.

On pages 18, 259, and 267, read "distributories" instead of "distributaries."

On page 38, in line 1, instead of "6,423.25," read "6,453.25"; in line 5, instead of "550,400," read "551,761"; in line 7, instead of "1,100,800," read "11,035,200"; in line 10, instead of "220,800," read "2, 758,805."

On page 41 read "Trans-Missouri," instead of "Trans-missouri."

On page 60 last line in table, read "Washington," instead of "Wyoming."

On page 92 read "Sacramento," instead of "Sacremento."

On page 92 read "salable," instead of "saleable."

On page 96 read "sub-canal work," instead of "subcanalling work."

On page 99 read "financiering" instead of "financeering."

On page 101 read "wastefulness" instead of "wastefullness."

On page 108 read "corollary" instead of "corrolary."

On page 128 read "parallels" instead of "parellels."

On page 152 read "Otter" instead of "Ottar."

On page 155 read "stratum" instead of "strata."

On pages 183 and 184 read "Cache la Poudre" instead of "Cache a la Poudre."

On page 186, in total to table of Division II, read "1,643,30" instead of "1,648.30."

On page 187, in first table, read "614,316" instead of "614,334," and "732,216" instead of "729,210" as totals. In first total fór table for Division II read "67,500" instead of "68,500." In final total for same table read "210,500" instead of "211,500."

On page 188, in final total for Division III, read "1,582,710" instead of "1,585,500."

On page 195, in first table in column under 1860, read "total of 383.91" instead of "385.91": in column under 1864 read "total of 701.15" instead of "701.9;" under 1865 read "total of 1,441.74" instead of "1,837.74"; under 1866 read "441.6" instead of "511.6"; under 1871 read "1,769.59" instead of "1,569.59"; under 1876 read "589.00" instead of "588.82."

On page 204 read "A horizontal" instead of "An horizontal."

On page 206 read "a failure" instead of "failures."

On page 227 read "Fresno" instead of "Frenso."

On page 243 read "ranches" instead of "rbnches."

On page 244 read "Griffin" instead of "Griffen."

On page 255 read "wherever" instead of "where ever."

On page 258 read "likely" instead of "likley."

On page 261 read "M. I. C. E." instead of "M. E., C. E."

On page 274, in note, read "Expériences sur l'emploi" instead of "Experiences sur l'emplai."

On page 297 read "analysis" instead of "analyss."

Many compounds are used in this report, which in printing should have been so indicated by the use of a hyphen. This use is proper, because the compound is both new and technical. A proper understanding requires them to be indicated as follows:

> On page 45 read "sub-ditch" instead of "subditch."
> On page 51 read "semi-tropics" instead of "semitropics."
> On pages 52 and 128 read "semi-arid" instead of "semiarid."
> On page 98 read "sub-canal" instead of "subcanal."
> On page 147 read "extra-territorial" instead of "extraterritorial."
> On page 159 read "non-irrigating" instead of "nonirrigating."
> On page 161 read "non-irrigable" instead of "nonirrigable."

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