CHAPTER II.

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THE NECESSITY FOR IRRIGATION IN CALIFORNIA.

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

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

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

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

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

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

A. The climatic conditions of the Pacific coast are such that crops are uncertain south of latitude 42°.
B. The orographical features of the country conspire with the climatic conditions to render crops especially uncertain in certain localities.
C. The average yearly rain-fall over the basin of the Great Valley is sufficient to insure good crops annually.
D. The rain-fall in different years is very variable, and seasons of drought and of great floods occur; and in any one season it is very unequally distributed in different sections.
E. With a proper system of controlling the waters of precipitation, and delivering them to cultivated lands when needed, annual crops may be assured.
F. The climate is mild throughout the wet or winter season, and especially well suited for all agricultural pursuits.
G. The Great Valley of California is admirably adapted for irrigation.

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

The climate of the Pacific coast west of the Sierra Nevada and Cascade Mountains is altogether different from that of the Atlantic coast, and differs also from that of the country included between the eastern slope of the Rocky Mountains and the Sierra Nevada. The ordinary form of rain-fall tables fails to exhibit its characteristic, so that upon this coast tabulated results of precipitation of rain and snow are made out for the rainy season, which extends from about October 15 to April 1. No rain, in the ordinary acceptation of the term, falls during the dry season, between April 1 and October 15, in the latitude of 38°. Northward of that latitude, and especially northward of latitude 40°, there is frequently a small rain-fall during the summer and a heavy rain-fall during the winter.

Southward of 38° the rainy season is shortened and the dry season lengthened, so that at San Diego, in latitude 32 1/2°, the rain-fall on the immediate coast averaged only 9.2 inches during twenty-three years.

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

At the extremity of the peninsula of Lower California only 3 1/2 inches fell last summer. The rain-fall at San Francisco, which may be taken as a type, averages 23.5 inches annually, distributed as follows:

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

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

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

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

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

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

This cessation does not occur at any regular epoch, so that its effect is not seen in a chart constructed only upon average quantities, but it has occurred nine years out of ten. Very frequently during this cessation of rain, the cold winds from the north, accompanied by a clear sky, blow fiercely, and blast the young growing crops; or when this dry interval is prolonged, even without these cold northers, the weather is usually clear and fine, perhaps hot, and the young grain withers and may be wholly lost, even for fodder, if the last rains of the season come late.

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

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

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

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

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

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

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

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

Nine years' observations at Pillarcitos Dam[3] give an average of 58 inches of rain, while San Francisco, distant only fourteen miles, has 23.5 inches.

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

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

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

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

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

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

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

This proposition embraces two vital questions:

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

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

We are satisfied that the proposition is correct.

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

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

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

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

			Inches.				*Inches.*
1870.	November	26	0.50	1871.	January	9	1.05
		27	0.24		February	4	0.30
		28	0.44			5	0.16
	December	17	0.10			9	0.17
		18	0.12			22	0.45
		19	0.33			23	0.50
		20	0.06			24	0.38
		21	0.28			27	0.40
		22	0.68		March	28	0.91
		23	0.15			29	0.05
		27	0.20		April	13	0.08
		28	0.98			16	0.48
		29	0.62			17	0.07
		31	0.40			27	0.13
						28	0.11
					Total inches		10.34

Throughout the southern sections of California crops have been secured when 12 inches of rain have fallen in the wet season; but the precipitation is not so reliably uniform as farther north. Farmers and stockmen claim good crops with 15 inches of rain, if it has fallen somewhat evenly

throughout the season. This amount would not be necessary to mature the crops if, at the beginning of the rainy season, the earth had not been parched several feet deep by the excessive dryness and heat of summer.

The land cannot be plowed until the first rains have moistened the earth to a sufficient depth. During May we experienced a temperature of 130° in the sun between Bakersfield and San Emedio Canyon,[4] and for months the temperature in the sun ranges over 100°. This great heat, accompanied by excessive dryness of the atmosphere and months of cloudless sky, evaporates every particle of moisture from the ground, and produces conditions which the farmers of the Atlantic States can hardly comprehend. It also demands a larger supply of water for maturing a crop than would be the case if the ground were moist when the proper season of plowing and sowing arrived.

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

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

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

At Fort Crook,[5] on the Upper Sacramento River, elevation 3,390 feet, in eight years, from January, 1858, to October, 1867, an average of 23.7 inches of rain-fall.

At Fort Reading,[6] on the Sacramento River, near Redding, in three and three-quarter years, from April, 1852, to March, 1856, 29.1 inches.

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

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

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

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

At Millerton,[7] on the San Joaquin River, in six and three-quarter years, from July, 1851, to June, 1858, 19.0 inches.

Thence, through the broadest part of the valley to Fort Tejon,[8] we have no observations except those at Visalia during the three dry winters of 1870-'71-'72-'73, as already detailed, and averaging 8.1 inches.

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

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

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

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

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

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

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

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

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

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

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

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

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

	Inches.		Inches.
At Fort Reading, (3 years,) range	37.4	to	15.9
At Sacramento, (17 years,) range	27.5	to	11.2
At Millerton, (6 years,) range	49.3	to	9.7
At Stockton, (3 years,) range	20.3	to	11.6

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

	Inches.		Inches.
At Fort Tejon, (5 years,) range	34.2	to	9.8
At Monterey, (5 years,) range	21.6	to	8.2
At San Diego, (12 years,) range	13.4	to	6.9
At Benicia, (12 years,) range	20.0	to	11.8

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

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

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

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

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

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

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

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

compelled to drive their cattle, horses, and sheep to the gulches of the mountains not only for food but for water.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table of temperatures in and adjacent to the Great Valley.

Places	Altitude above the sea.	Geographical position.		Period of observation.	Temperature.				Rain and snow.
		Latitude.	Longitude.		Mean of hottest day.	Mean of coldest day.	Range.	Mean.	
In the Great Valley:	*feet*	*o ' *	*o ' *		*o*	*o*	*o*	*o*	*In.*
Fort Reading[1]	674	40.31	122.05	4 yrs	83.0	44.0	39.0	62.1	29.1
Chico[2]	150	39.46	121.50	1 1/2 yrs	92.3	37.0	55.3	64.7	17.7
Colfax[2]	2,421	39.03	120.55	1 1/2 yrs	91.7	33.3	58.4	62.7	30.8
Marysville[3]	76	39.12	121.42	1 yr	90.0	38.0	52.0	63.3	--
Sacramento[4]	54	38.31	121.20	24 yrs	94.0	32.0	62.0	60.3	19.6
Vacaville, Solano[5]	100	38.20	122.00	1 yr	86.0	37.0	49.0	53.3	24.2
Stockton[6]	23	37.37	121.14	1 1/2 yrs	91.0	41.0	50.0	66.0	4.8
Fort Miller, (Millerton)[7]	402	37.00	119.40	5 yrs	90.0	47.0	43.0	66.0	24.5
Auburn[2]	1,363	38.57	121.02	1 1/2 yrs	91.0	34.3	56.7	62.8	17.6
Benicia[8]	183	38.08	122.14	18 yrs	80.0	44.0	36.0	59.1	22.9
San Francisco[9]	22	37.48	122.27	19 yrs	78.0	37.0	41.0	56.4	21.5
Monterey[10]	140	36.36	121.52	6 yrs	59.0	50.0	9.0	55.0	12.2
Santa Barbara[11]	300	34.31	119.38	1 yr	92.0	42.0	50.0	60.2	15.0
San Diego[12]	150	32.42	117.14	7 yrs	74.0	52.0	22.0	62.0	10.4
Fort Yuma[12]	120	32.43	114.36	6 yrs	92.0	56.0	36.0	74.0	3.2
Port Orford, Oreg.[12]	50	42.44	124.29	4 yrs	61.0	46.0	15.0	53.6	71.6

Authorities and Remarks:

1. Army Meteorological Register, 1855.
2. Engineer department Central Pacific Railroad, 1870-'71.
3. W. C. Belcher, 1858.
4. Thomas M. Logan, M.D.
5. Prof. J. C. Simmon.
6. Engineer department Central Pacific Railroad.
7. Army Meteorological Register.
8. W. W. Hays, surgeon U.S.A.
9. Henry Gibbons, M.D.
10. Army Meteorological Register.
11. J. A. Johnson.
12. Army Meteorological Register.

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

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

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

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

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

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

Months	Sacramento, 10 years	Fort Point 11 years	San Diego, 20, 10-12 years	Astoria, Ore. 11 1/4 years
	Thermometer	Thermometer	Thermometer	Thermometer
December	46.79	(52.22)	(54.11)	(40.83)
January	45.59 Winter	50.59 Winter	53.55 Winter	38.44 Winter
February	50.86 47.75	(51.81) 51.54	(54.60) 54.09	(38.78) 39.35
March	54.02	(53.15)	(57.11)	(44.24)
April	59.45 Spring	55.52 Spring	60.72 Spring	48.75 Spring
May	63.12 58.86	(57.61) 55.43	(62.59) 60.14	(53.16) 48.72
June	70.35	(58.93)	(66.68)	(57.50)
July	73.45 Summer	59.86 Summer	70.32 Summer	60.29 Summer
August	71.03 71.61	(58.84) 59.21	(72.02) 69.67	(60.77) 59.52
September	68.84	(59.31)	(69.38)	(58.30)
October	62.56 Fall	58.36 Fall	65.18 Fall	52.69 Fall
November	53.28 61.56	(56.44) 58.04	(59.04) 64.53	(46.23) 52.41
Yearly average	59.91	56.05	62.11	50.00

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

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

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

To show its relation to the State of California and of Nevada, we append the map of the State geological surveys; and to exhibit it in greater detail, we append the map of the valley on a larger scale as drawn in the office of the geological survey, with additions under the direction of the commission. It lies between latitudes 34° 50' near Fort Tejon, and 40° 41' near Shasta, giving an extreme length of four hundred and fifty miles, and an average width of forty miles, including the foot-hills of the mountains. The general trend of its longer axis is north-northwest and south-southeast, lying parallel to the Pacific coast line, from which the middle line averages a distance of eighty-five miles.

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

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

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

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

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

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

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

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

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

The only streams that carry water in summer are Puta Creek, Cache and Stony Creeks, but in summer these lose their waters beneath their beds soon after leaving the hills. On the western side, north of Knight's landing,[9] the plains are destitute of trees.

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

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

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

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

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

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

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

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

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

One of the features of this part of the valley is the large lakes, Kern, Buena Vista, and Tulare,[10] which receive the drainage of the streams at the southward, King's, Kaweah, and Kern.

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

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

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

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

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

In the southwestern section of the valley, between Firebaugh's and Hill's ferries,[11] the levelings show that the ground falls from the foot-hills to within four and a half miles of the river at the rate of 6 feet per mile, thence it is nearly level to within a half mile of the river, which it then approaches with an ascent of 1 1/2 feet per mile.

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

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

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

This river drains the highest and wildest part of the Sierra Nevada, and its course is said to be marked by deep canyons, above each of which

there may doubtless be opportunities to establish large reservoirs, while advantage can be taken of forming reservoirs in the hills to hold the water of all the minor streams. These are, of course, propositions for the future.

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

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

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

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

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

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

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

Thence to the northward as far as Corral Hollow Creek[12] the total area of catchment is five hundred and thirty-three square miles.

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

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

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

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

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

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

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

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

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

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

In some of the localities visited by us, more especially in the southern section of the valley, small areas of otherwise fine land showed the presence of "alkali;"[13] and east of Kern Lake a rude manufacture of salt had been attempted by the evaporation of water obtained from shallow wells.

Broad belts of "adobe"[14] are found throughout the southern section of the valley, while loam occupies the larger part of the main depression through which the rivers and lakes drain.

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

Along the eastern side of the valley, close under the foot-hills, there are considerable areas of good soil of small depth underlaid by what is locally known as "hard pan." Over other areas the soil is of moderate depth over gravel deposits. But throughout large areas of the valley and on the eastern side, extending in many places from the foot-hills to beyond the line of the Southern Pacific Railroad, the surface of the soil is peculiarly marked by innumerable and contiguous nearly circular mounds,

locally known as "hog-wallows." These mounds, lying without perceptible symmetrical arrangement, are moderately uniform in shape and size; ranging from 6 inches in height to as much as 3 or 4 feet, although by far the greater number average about 1 to 1 1/2 feet, as exhibited in the railroad-cuttings, and from 20 to 50 feet in diameter. The largest we saw were on the Kaweah, above Visalia, and were composed of gravel, &c.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHAPTER III.

1. Necessity of surveys--The funds at the disposal of the commission would not authorize surveys--Necessity of an instrumental reconnaissance and of detailed surveys.
2. System of irrigation--No continuous canal on the eastern side of the Great Valley--Each river may have one or more dams and canals--The San Joaquin and King's River Canal--Other canals--Some portion of the plain cannot be thoroughly irrigated--Canals on the western side of the Sacramento River--Main canal may be navigable--Clear Lake and its contents.
3. Influence of irrigation on the navigation of rivers--This influence is small--Experience in Italy and in India--Argument to show that this influence will be small on the navigation of the Sacramento and San Joaquin Rivers--Compensation by making some canals navigable.
4. What is irrigation?--Mistakes that have been made--Description as to how water is to be taken from a river and distributed over the land by dams, head-works, and canals--Examples taken from the San Joaquin and King's River Canal Company.
5. Existing and hypothetical canals--Existing canals at Bakersfield and Visalia--Canals from the King's River--The Chapman Canal--The Fresno Canal--Small canals--Hypothetical canals shown on the map.