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HENRY LANDES, State Geologist

BULLETIN No. 14

A Preliminary Report on the Quincy Valley Irrigation Project

By HENRY LANDES, A. W. MANGUM, H. K. BENSON,
E. J. SAUNDERS AND JOSEPH JACOBS

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LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN: I have the honor to submit herewith a report entitled "A Preliminary Report on the Quincy Valley Irrigation Project," by Henry Landes, A. W. Mangum, H. K. Benson, E. J. Saunders, and Joseph Jacobs, with the recommendation that it be printed as Bulletin No. 14 of the survey reports.

Very respectfully,

HENRY LANDES,
State Geologist.

University Station, Seattle, July 1, 1912.

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INTRODUCTION.

By Henry Landes, *State Geologist.*

The Quincy Valley Irrigation Project, as at present outlined, involves a tract 36 miles by 30 miles in area, located in central Washington. The western boundary of the proposed irrigable area is Columbia River; the northern and southern limits are the highlands represented by Badger and Saddle Mountains, respectively; while the eastern boundary is placed arbitrarily in this report at the line between ranges 28 and 29. The amount of surface involved in this area of 1,080 square miles is 691,200 acres. The studies that have been made of the soil conditions and the topography have made it clear that of the above acreage at least 450,000 acres are readily irrigable, while the Wenatchee water supply is known to be ample to serve an area of at least 435,000 acres. The conversion of this large area, by far the most of it of a truly desert character, into an oasis of rare productiveness, capable of readily supporting a happy population of 100,000 people, is a matter of more than state-wide prominence, and is by far the greatest project ever proposed for the development of the state's material resources.

PRELIMINARY SURVEYS.

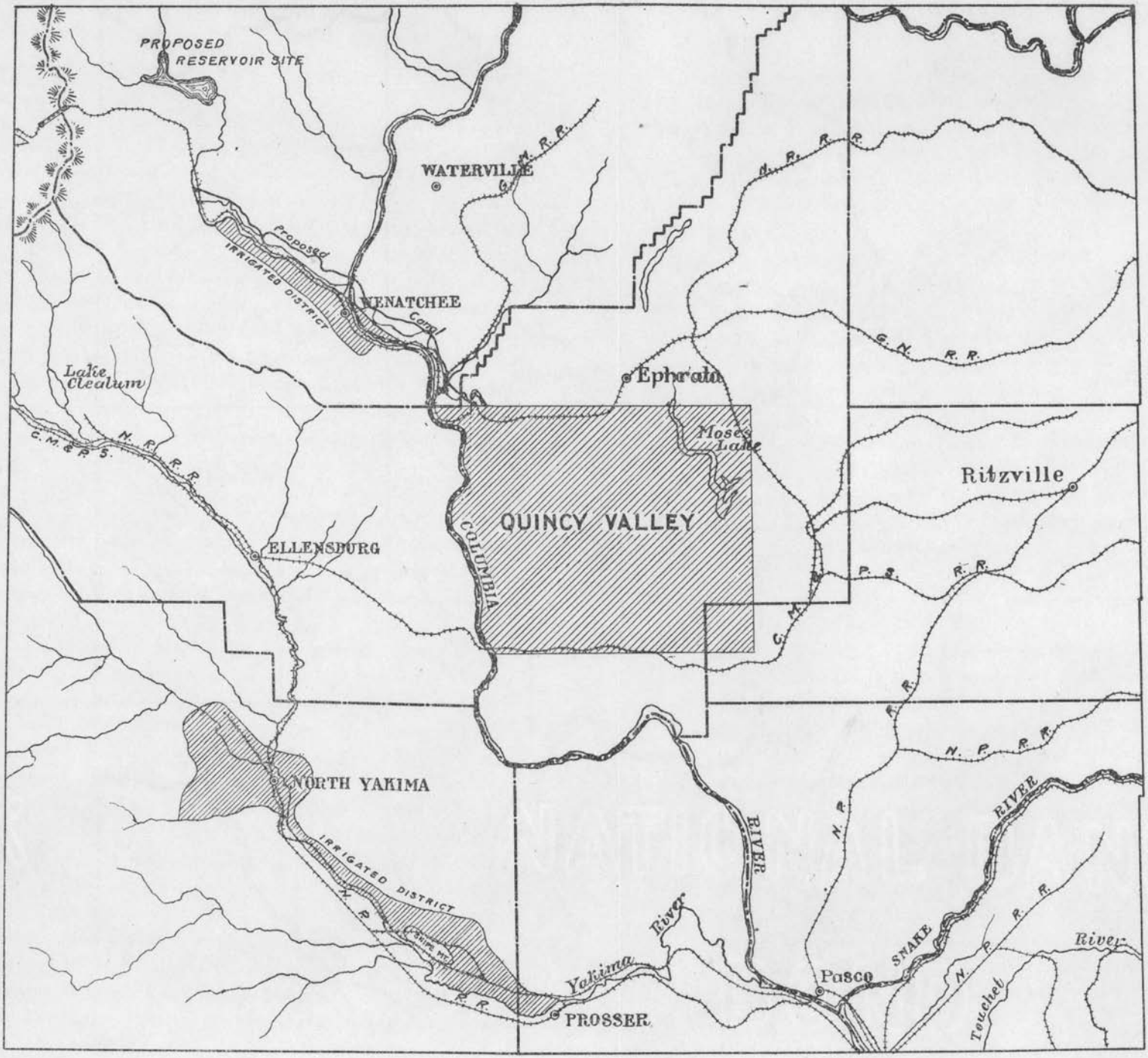
The Board of Geological Survey, at its meeting in Olympia on April 16, 1909 ,recognizing the great importance to the state of the Quincy Valley Irrigation Project, directed the State Geologist to arrange for co-operative work with the U. S. Geological Survey whereby topographic surveys might be carried on in the region in question and the country accurately mapped. Accordingly five quadrangles were mapped, viz., Quincy, Winchester, Moses Lake, Beverly and Red Rock. These have been combined on Plate 1 of this report, and it will be noted that the five quadrangles cover practically all parts of the project except four townships in the southeast corner. In a similar fashion, by co-operation with the Bureau of Soils, U. S. Department of Agri-

culture, soil surveys were made of the whole area. The different types of soils were studied and mapped, and determinations made of the percentage of alkali. A complete report will soon be issued by the Federal Bureau of Soils, containing ample descriptive matter, chemical analyses, colored maps, and all information necessary in regard to the nature of the soils embraced in the project.

In addition to the above lines of work the Wenatchee and Malaga quadrangles, lying along the line of the proposed canal from Wenatchee River to Quincy, are now being surveyed and these maps will soon be ready for use. The proposed reservoir site about Wenatchee Lake has been very carefully surveyed in detail and a topographic map prepared with 5-foot contours. A gaging station has been maintained on the lower Wenatchee River for some years and careful measurements made of the run-off of that stream. Every effort has been made by the Board of Geological Survey, with the resources at its command, and in co-operation with the Federal Bureaus, to secure necessary information bearing upon the project.

FUTURE SURVEYS.

Before the cost, as well as the complete feasibility, of such a great engineering enterprise can be determined beyond a question, it is necessary that a number of additional surveys and investigations be made. There are many questions regarding the size, location and character of the dam at the foot of Wenatchee Lake that can be settled only by careful detailed surveys. The whole route of the canal from the intake to the distributing point must be carefully studied and mapped. In particular the crossing of Columbia River will necessitate months of investigation to satisfy all the inquiries which will arise concerning such a great engineering feat. The whole scheme of distributing the water, the location of the main laterals and tributaries, will necessitate spending months of time in field surveys. In addition to all these and many other things, the entire 1,080 square miles must be examined in great detail, down to very small subdivisions to de-


PROPOSED
RESERVOIR SITE
WATERVILLE
G. M. R. R.
Proposed
IRRIGATED DISTRICT
WENATCHEE
Canal
Lake
Clealum
C. M. & P. S.
N. P. R. R.
ELLENSBURG
Ephrata
Moses
Lake
QUINCY VALLEY
COLUMBIA
Ritzville
G. N. R. R.
P. S. R. R.
C. M. & P. S.
N. P. R. R.
NORTH YAKIMA
IRRIGATED DISTRICT
N. P.
SHUPE MT.
R. R.
Yakima
River
PROSSER
RIVER
Pasco
SNAKE
RIVER
Touchet
River

termine the exact amount as well as location of the irrigable lands.

STATE AID.

It seems clear to the writer that the state should undertake the investigations and surveys just mentioned, in addition to those already made as a result of state aid. There are several reasons why the enterprise commends itself to state support. In the first place, as shown on Plate 1, there are over 31,000 acres of state land embraced in the project. Of this it is safe to say that at least 20,000 acres are irrigable. If the general story of irrigation in Washington holds true here, in its first year under water this land would be worth not less than $300 per acre; while its value after a few years, especially if fruit or alfalfa were grown, would enhance to $750 or $1,000 per acre. The story of the state lands under irrigation would be repeated for all the other lands of the project. The land which now sells generally for $15 or $20 per acre would easily become 30- or 40-fold more valuable under a successful scheme of irrigation. The profit to the state, not only in the increase of taxable property, but in the strong impulse given to every industry, and in the material advancement of its citizens, would be almost incalculable.

It is the estimate of Mr. Jacobs, in his report, that the lands of Quincy Valley can be irrigated for $100 per acre. Except for a few small irrigable tracts, it is altogether unlikely that in this state any scheme of irrigation will ever be placed in operation where the cost per acre will be less than $100. Furthermore, about all of the smaller irrigable areas have been reclaimed, so that in the future the irrigation schemes will necessarily embrace larger tracts than ever before, involving far greater capital. It becomes more and more apparent that in carrying out the larger irrigation enterprises either state or federal aid must be sought after. This seems especially necessary in the Quincy Valley Irrigation Project because it is not a case where the work can be done in sections and the land put under water as desired, but where the whole irrigation scheme must be completed before any of the land can receive benefit.

While the cost per acre to irrigate the land is moderate and a charge which the land would easily and readily assume, yet the large acreage involved makes the total engineering cost so high that the whole sum of money involved seems stupendous. In any plan of bonding, however, where the repayment of the cost is extended over a period of 20 or 30 years, the annual charge per acre is small and even insignificant when contrasted with the earning power of the land.

ACKNOWLEDGMENTS.

For this bulletin articles have been contributed by Mr. A. W. Mangum, Prof. H. K. Benson, Prof. E. J. Saunders and Mr. Joseph Jacobs. Mr. Mangum has had charge of the soil surveys and in this report submits a brief abstract of his full account, which will be ready for distribution about December 1, 1912. Prof. Benson has selected samples of the typical soils of the valley and in his article gives their analyses, as well as a brief discussion of soil characteristics. A more complete chemical report accompanies the soil report above mentioned. Applications for the fuller report, with descriptive matter, colored maps, analyses, etc., should be made to the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C., or to the State Geologist, University Station, Seattle, Washington.

Prof. Saunders has submitted a report upon the general weather and climatic conditions of Quincy Valley. This is a topic of great importance in considering the nature of the crops that may be grown. Mr. Jacobs, who has given this irrigation project much attention, and who is well informed about every phase of it, has prepared an important article upon the engineering problems involved. He has gone into the subject as thoroughly as possible with the data at his command. It will be recognized by everyone that any engineering report at this time is wholly preliminary, and that many months of detailed work will be necessary before the final plans and estimates can be submitted.

SOILS OF QUINCY VALLEY.

By A. W. Mangum.*

The soils of the Quincy area may be separated broadly into six groups: (1) The compact fine sandy and silt loams that cover the underlying basalt to a depth of from 10 to more than 30 feet; (2) the sandy and fine sandy loams underlain at an average depth of from 2 to 6 feet by a thin layer of limestone which in turn rests upon the basalt; (3) the stony and gravelly soils underlain by compact deposits of gravel and rounded bowlders; (4) the areas of drifting sands; (5) the rough stony lands; and (6) the recent alluvial soils.

The soils of the first group occupy a large area in the northwestern part of Quincy Valley. The finer textured types, consisting of a silt loam, a silty fine sandy loam, and a fine sandy loam, occupy a large area southwest of Quincy and also the greater proportion of the country surrounding that town. A large area of the silty fine sandy loam belonging to this group occurs south of Frenchman Hills, embracing the northern part of T. 16 N., ranges 25 and 26 E., and the southern part of T. 17 N., ranges 25 and 26 E. There is a large area of sandy loam occupying the country around Morrison postoffice, which is also included in this group. In this particular locality the soils are underlain by a compact deposit of sands and fine gravel.

The soils of this group have a deep compact subsoil and when thoroughly cultivated are among the most productive types in the area. South and southeast of Quincy, they become more sandy, and the surface becomes more hummocky, as the loose sandy soil has been drifted into series of small mounds and ridges with shallow basins intervening. The level topography of this group as a whole makes these types well adapted to irrigation. Where dry farming is practiced, wheat and rye are the principal crops grown. The average yield of wheat is

*Bureau of Soils, U. S. Department of Agriculture.

about 8 or 10 bushels per acre, but yields of 20 to 25 bushels per acre have been secured during favorable seasons. When irrigated, these soils produce very profitable yields of melons, potatoes, small grains, and fruits. Oats and alfalfa have also been successfully grown on a limited acreage of irrigated land.

The soils of the second group occupy a large area north of Frenchman Hills, in the vicinity of Burke. Another large area occurs between Frenchman Hills and lower Crab Creek Valley, occupying a large proportion of the level to gently rolling uplands between Low Gap and Beverly. They consist of compact fine sandy loams and fine sands, underlain at a depth of from 12 inches to 6 feet by a thin layer of limestone. In some localities the shallow surface soils have been almost entirely removed by the action of winds, and the underlying limestone occurs so near the surface that the weathered material is frequently turned up with the plow. The topography of the soils of this group varies from almost level to very gently rolling, and the greater proportion of the area occupied by them lies well for irrigation.

During a favorable season they produce very good yields of small grains, but the crops grown on the more shallow areas, where the underlying limestone occurs within 3 feet of the surface, are usually damaged by drought, as the shallow soil is unable to conserve a sufficient amount of moisture. The small areas under irrigation have demonstrated that under favorable moisture conditions, the soils of the second group are very productive.

The soils of the third group occupy a large area south and southwest of Ephrata, embracing the greater part of the country around Moses Lake. They consist of sandy loams and fine sandy loams which contain a variable amount of gravel and small bowlders. It is usually necessary to remove a large quantity of stones from the surface before the land can be profitably cultivated, and in some localities small areas occur which are of such a stony character as to make cultivation impracticable. Areas occur, however, throughout the region occupied

by these types where the surface soils, to a depth of 12 to 15 inches, are comparatively free from either gravel or small bowlders. The soils are underlain to a considerable depth by a compact deposit of gravel and small, rounded bowlders, which insures good natural drainage. Some of the best orchards in the area are located on these soils and when irrigated and thoroughly cultivated the trees do exceedingly well. The irrigated areas produce very profitable yields of all crops grown in Quincy Valley.

The soils of the fourth group consist of loose incoherent sands and fine sands which have been drifted into mounds and ridges by the action of winds. These soils occur south of Moses Lake and north of Frenchman Hills, extending westward to a point within a few miles of Burke postoffice. The loose structure of the soils causes the surface material to be constantly shifted by the wind, and the open porous character of the subsoil causes the natural drainage to be excessive. A large proportion of this land could be irrigated and utilized for agricultural purposes, although there would probably be a considerable loss of water by seepage, and the hummocky topography would make it very difficult to get the land into suitable shape for irrigation.. There is a large area of sand dunes included in this group, which are of little or no agricultural value. These dunes occur principally south and southwest of Moses Lake. The topography of this region consists of high, rounded dunes with shallow "pot holes" or basins intervening, or long, narrow ridges with troughlike valleys between them. These topographic features make it impracticable to attempt the irrgation and agricultural development of this region, as the dunes and ridges have a height of from 20 to more than 60 feet and the loose sandy soils are being shifted continually.

The fifth group comprises the extensive areas, locally known as "scab lands," and the precipitous, rocky bluffs which border the valleys of Crab Creek and the Columbia River. The larger areas of "scab land" border the valley of Crab Creek. They consist of small areas of sandy soil, varying from a few square

rods to several acres in extent, occurring at intervals over more extensive areas whose surface consists mainly of bare rock outcrop. Only a shallow covering of soil rests upon the bed rock and large quantities of rock fragments are frequently scattered over the surface or mixed with the sandy soil. A large proportion of these "scab lands," however, consists of areas of bare outcrops of basaltic rock.

The rough stony lands found along the northern slope of Saddle Mountain and the bluffs bordering the valley of Columbia River are too steep and rocky to be of any agricultural value. Small areas occur throughout the "scab lands" where the sandy soil has a sufficient depth to enable it to be used for agricultural purposes, but these areas are of such limited extent and are surrounded by such extensive areas of non-agricultural lands that it is impractical to attempt to irrigate them.

The sixth group embraces the recent alluvial soils lying along the courses of Columbia River and Crab Creek. Many of these soils have been modified to some extent by materials deposited on the surface by the wind. Along Columbia River the alluvial soils occupy a comparatively level strip of land between the steep bluffs of the adjacent uplands and the channel of the stream. The soils consist of fine sands, sandy loams, and gravelly sandy loams. The subsoils are uniformly composed of compact masses of rounded, waterworn gravel, which insures good natural drainage. The areas occupied by these soils have only a slight elevation above the level of the stream at high water, but with the exception of a small area bordering the river, none of the land is subject to overflow. A few small areas occur where gravel and small, rounded cobbles are present in sufficient quantities to interfere with cultivation, but these areas are of small extent and the greater proportion of this land is well adapted to agriculture. The topography varies from level to gently undulating and a very large percentage of these alluvial soils could be irrigated and developed agriculturally without difficulty. The soils occupying the narrow valley bordering the channel of Crab Creek consist principally of sandy loams,

gravelly sandy loams, and clay loams. They are, as a whole, poorly drained and frequently contain alkali in harmful amounts.

The failure to secure profitable yields in Quincy Valley is often due as much to the drifting of the dry sandy surface soils as to the lack of a sufficient amount of soil moisture to mature the crops. This is true of almost every type of soil suitable for agricultural purposes. On many of the more sandy types the soil is blown away from the roots of the plants while the crops on adjacent fields are covered by shallow sand drifts. Where irrigation is practiced extensively, trees, to serve as windbrakes, should be set along the fence lines or ditches.

Most of the soils are at present entirely free from any harmful accumulation of alkali. Small areas occur, however, in Crab Creek Valley, in the bottoms of Willow Creek and several other large coulees, and in the deep depressions or pot holes surrounded by areas of rough stony lands where the soils contain as much as two-tenths of one per cent. to more than three per cent. of alkali. The majority of these alkali areas are of very small extent and occupy low depressions or poorly drained basins which receive the drainage water from the surrounding lands.

The soils over the remainder of the valley are at present free from alkali, but if any extensive acreage were put under irrigation a more thorough drainage system would be necessary in many localities to prevent the accumulation of harmful salts. If the seepage water were allowed to collect and evaporate in the shallow depressions which occur at intervals over almost every type of soil, there is danger that these poorly drained areas would eventually contain enough alkali to injure crops.

CHEMICAL ANALYSES OF THE SOILS OF QUINCY VALLEY.

By H. K. Benson.*

Much stress in the past has been placed upon the chemical composition of soils. More recently the efforts of soil chemists have been directed toward showing that soil fertility is more largely a matter of control or soil management. This assumption is based upon the belief that the chemical elements become available for plant growth only under certain conditions which it is necessary to obtain and maintain during the growing period. These conditions may be broadly stated as a proper physical condition of the soil at to fineness and crumbling or tilth; sufficient moisture or water holding power; a suitable temperature; and the absence of certain plant poisons or toxic substances secured by crop rotation.

Nevertheless there has been a rather close relationship between the chemical compostion of soils and the specific crops which have been found especially prolific. For example, the soils of the Palouse region are high in phosphoric acid and are also well adapted for grains, while in the fruit belt of central Washington the soils are usually high in the content of potash.

The manner in which chemical elements enter into the mechanism of plant growth is not fully understood. It has come to be generally recognized that the mineral elements in the soil which are of the most interest to the agriculturist are calcium, potassium, phosphorus, and nitrogen. For technical reasons these are generally spoken of as lime (calcium oxide), potash (potassium oxide), phosphoric acid (phosphorus pentoxide) and nitrogen. These constituents are the ones which it is thought to add to the soil in commercial fertilizers.

The action of lime is probably quite complex in most cases, neutralizing any acids which might be present, inducing a much better flocculation, or crumbling of the soil, improving its tilth,

*Professor of Industrial Chemistry, University of Washington.

aeration etc., which functions are most important for the growth of desirable kinds of bacteria in the soil, especially those kinds which gather nitrogen from the air and grow in association with leguminous crops as alfalfa, vetch or clover. It is possible also that lime may have a specific effect on some plants and it is held by many fruit growers that an ample amount of lime will cause the production of a sweeter fruit. Potash is believed to be of especial importance in the production of starch in growing plants, and phosphoric acid to be important mainly in the formation of seeds or grain, although undoubtedly having other functions in the growing plants. Nitrogen is believed to be taken from the soil, mainly in the form of nitrates, and is elaborated or made over in the plant into various substances, especially the proteids, substances which are best known in the muscular tissues of animals. No substance in the soil produces a more rapid or decided response in the crop than does nitrogen. A ready supply of nitrates is of the utmost importance to green crops, especially during the periods of most rapid growth, and it is desirable to have nitrogenous organic substances in the soil to furnish nitrates by the process of decay, especially for crops other than leguminosae.

The six groups of soils noted below may have certain typical compositions assigned to them. It is of course, evident that no two samples of any one soil will give the same analytical results on account of the variations which exist in the history of a soil. All that can here be done is to represent within reasonable limits the approximate composition of the respective groups as determined by the analyses of a number of carefully selected and typical samples. The interpretation of a soil analysis is also a matter of some difficulty. Agricultural chemists vary in their manner of classifying a given soil as good or poor.

Hilgard in his text book (page 377) states the average composition of virgin soils taken from arid regions as follows: lime 1.43%; phosphoric acid 0.16%; potash 0.67%; and loss on ignition 3.15%. Professor Maercker of the Halle Experimental Station, Germany, has formulated a classification which often

serves as a guide in judging the capabilities of a soil (under a proper system of management) from the analysis of the virgin or uncultivated soil.

Grade of Soil	Potash	Phosphoric acid	Lime in sandy soil	Total nitrogen
	Per cent.	Per cent.	Per cent.	Per cent.
Poor Soil	Below 0.05	Below 0.05	Below 0.05	Below 0.05
Normal Soil	0.15—0.25	0.10—0.15	0.15—0.20	0.10—0.15
Rich Soil	Above .40	Above .25	Above .30	Above .25

CHEMICAL COMPOSITION OF THE QUINCY SOILS.

Group I. Fine sandy and silt loams.

Lime	1.00—1.15%
Phosphoric acid	0.08—0.13%
Potash	0.30—0.45%
Loss on ignition	4.00—6.00%

Group II. Sandy and fine sandy loams.

Lime	1.20—1.30%
Phosphoric acid	0.04—0.12%
Potash	0.30—0.90%
Loss on ignition	2.80—4.40%

Group III. Stony and gravelly soils.

Lime	1.02—1.20%
Phosphoric acid	0.10—0.15%
Potash	0.37—0.46%
Loss on ignition	4.30—4.90%

Group IV. Drifting sands.

Lime	0.50—1.00%
Phosphoric acid	0.03—0.07%
Potash	0.30—0.35%
Loss on ignition	1.10—2.60%

Group V. Stony soils from "Scab" land. (No analyses.)

Group VI. Recent alluvial soils.

Lime	0.91—0.96%
Phosphoric acid	0.10—0.13%
Potash	0.48—0.80%
Loss on ignition	1.70—4.00%

Inasmuch as all of the soils were either light colored or gave a low loss on ignition (except those containing calcium carbonate), it was apparent that generally speaking the soils are deficient in nitrogen and very few determinations of this element

were made. One of the first steps in improving the agricultural value of the virgin soils of this region will therefore consist in supplying organic and nitrogenous matter to the soil by the usual method of green fertilization.

The following table gives the analytical data and geographic location of a portion of the samples analyzed:

LOCATION	Lime	Phosphoric acid	Potash	Loss on Ignition
Section 19, Tp. 20 N., R. 23 E.	0.70%	0.14%	0.31%	4.80%
Section 16, Tp. 16 N., R. 23 E.	0.91	0.13	0.48	1.70
Section 25, Tp. 16 N., R. 28 E.	1.04	0.09	0.43	3.70
Section 33, Tp. 16 N., R. 26 E.	1.63	0.19	0.87	6.20
Section 20, Tp. 19 N., R. 24 E.	0.91	0.11	1.00	3.90
Section 35, Tp. 17 N., R. 24 E.	1.27	0.05	0.25	2.80
Section 23, Tp. 19 N., R. 27 E.	1.02	0.04	0.42	4.80
Section 27, Tp. 20 N., R. 26 E.	0.96	0.08	0.42	4.90
Section 26, Tp. 18 N., R. 23 E.	1.29	0.137	0.316	4.40
Section 8, Tp. 20 N., R. 24 E.	1.06	0.12	0.50	6.10
Section 26, Tp. 20 N., R. 24 E.	0.95	0.07	0.35	3.00
Section 31, Tp. 19 N., R. 24 E.	1.13	0.07	0.31	1.10
Section 34, Tp. 29 N., R. 23 E.	0.83	0.11	0.41	4.70
Section 1, Tp. 16 N., R. 26 E.	0.95	0.119	0.273	3.80
Section 6, Tp. 18 N., R. 26 E.	1.04	0.10	0.33	2.40
Section 20, Tp. 16 N., R. 26 E.	1.15	0.04	0.23	2.00
Section 16, Tp. 17 N., R. 25 E.	0.47	0.03	0.31	2.60
Section 27, Tp. 19 N., R. 24 E.	0.93	0.10	0.40	4.00

CLIMATE OF QUINCY VALLEY.

By E. J. Saunders.*

CLIMATIC CONDITIONS.

The Quincy Valley, situated east of the Cascade Mountains in the Columbia River Basin, although in the same latitude, and not far removed from Puget Sound Basin, has a climate as different from that west of the mountains as if it were in an entirely different part of the continent. The influences of the topography and of the prevailing winds are remarkably well shown here. This area is practically shut off from the moderating effects of the ocean winds by the high Cascades to the west, and it also lacks the protection of these mountains from the continental extremes of climate, especially the cold waves of winter that spread from the east over this section of the country. But being near the ocean the westerly winds prevent, or break up, the cold waves so that this section is not subject to the prolonged winter conditions or heavy snows to which the states of the middle west in the same latitude are exposed.

The interception of the moist ocean winds by the Cascade Mountains gives this valley a very low annual precipitation, and the region of which it is a part is called the arid belt of the state. The air in its forced ascent loses most of its moisture on the western slope and near the summit of the Cascades, and in descending the eastern slope it is dynamically warmed so that it blows over the Quincy Valley as a dry wind, able to take up moisture rather than to cause precipitation.

PRECIPITATION.

The average annual precipitation for the Valley is less than eight inches. Of the Weather Bureau Stations which supplied data for this report, Wenatchee has the greatest average rainfall, 14.33 inches, and Kennewick the least, 6.34 inches. (See table.) This very low precipitation, as compared with that on the western slope of the Cascades, as already stated, is ac-

*Assistant Professor of Geology, University of Washington.

counted for by the fact that the air is cooled to such an extent by forced ascent in passing over the Cascade Mountains that the greater part of its moisture is deposited on the western slopes. In descending the eastern slopes the air is dynamically warmed by increase of pressure at lower levels, and its capacity for moisture rapidly increases, thus favoring clear skies and scant precipitation. As a result of this decided change in relative humidity the annual rainfall gradually decreases as the air seeks lower levels toward the Columbia River, and Quincy Valley may be considered as located in the rain shadow of the Cascade Mountains.

The monthly distribution of rainfall as shown on Plate IV is of greater importance than the average annual precipitation. In Quincy Valley a wet season from November to March, inclusive, and a dry season from April to October, inclusive, prevails and shows the effect of proximity to the western coast. But the contrast between the two seasons is much less marked than on the coast, and the summer months usually show a secondary maximum rainfall period in May and June, but not with as heavy precipitation as the winter months. This increased precipitation in May and June is very favorable to dry farming, and is a great aid to all lines of agricultural development of the country.

The winter maximum is accounted for by the larger number and greater activity of the cyclonic or storm areas during that season, the movement of the warm moist air from the ocean over a cooler continent, and the fact that although deprived of most of its moisture in its passage over the Cascade Mountains, the air is cooled to a still lower temperature in moving towards the interior and thus yields additional precipitation. The secondary summer maximum is explained by the occurrence of summer convectional or thunder storms, causing heavy showers and occasional cloudbursts in this section. These showers bring the summer average up much higher in comparison to the winter average than it is on the coast, and as we go farther inland we find the summer precipitation greater than the winter precipitation. In this particular case then we have evidence of the two con-

trols, the oceanic with a winter maximum, and the continental with a summer maximum, the former being more pronounced because of the proximity of the Valley to the Pacific Coast.

The average snowfall throughout the Valley is from 10 to 24 inches, but is higher for some of the stations used in the table, e. g., Wenatchee having 63.4 and Ellensburg 29.2 inches. The greatest snowfall recorded at Wenatchee is 114.5 inches, while at Kennewick the highest is 19.5 inches. Occasionally a winter will pass with scarcely any snow at the southern and lower stations. The snow remains on the ground for a comparatively short time and thus is not a very important factor in the general climatic conditions of the Valley.

A rather important factor in the climate of Quincy Valley, especially in the ripening and coloring of fruits and grain, is the great number of clear days. The average year will consist of about 190 clear days, 79 partly cloudy days, 96 cloudy days, and only 36 days on which more than .01 inches of precipitation may be expected. Thus there will be at least 270 days per year with abundant sunshine, and of the remainder a number recorded as cloudy will be only partly so.

TEMPERATURE.

The mean annual temperature of the Valley is about 50 degrees and there is a very slight difference for the various stations. But this tells us little about the yearly temperature conditions. It is from the study of the annual, monthly and daily ranges that we get some idea of the true temperature conditions.

The average temperature for the coldest month varies from 25.3° at Ellensburg to 31.2° at Kennewick, giving a winter average for the district of about 27°. The average for the warmest month varies from 77.3° at Wahluke to 72.1° at Odessa, giving a summer average of about 75° for the district. This would give an average yearly range of 48° for the region or more than twice as great a range as in western Washington, where the difference from season to season is about 20°.

The highest and lowest temperatures recorded at the various stations often show an absolute annual range of 110° or from

100° to -10°, and temperatures have been registered as high as 106° at Ephrata, 107° at Wahluke, and 115° at Kennewick, and as low as -21° at Kennewick and -29° at Ellensburg. These extremes occur only during very hot spells of summer and cold waves of winter and are of short duration. On account of the low relative humidity of the air the temperature extremes are not felt to the same extent as if the air were moist, and during the warmest weather the nights are cool and pleasant, and in the coldest spells of winter the days are bright and clear.

The cold waves of winter are due to the extension of high pressure areas, with their low temperatures, from the northeast over this region, and are usually accompanied by a slow drift of air from that direction. The warm waves of summer are also due to the pressure of a well developed high barometer area to the east, causing the highly heated air from the interior to move westward over this region. These warm spells are frequently broken by strong winds from the west causing a rapid fall in temperature.

The daily range of temperature is high, especially in the summer months, with an average daily range of about 35° and a somewhat lower range in the winter months of about 15°.

The explanation of the high annual, monthly and daily ranges of temperature is, first, the slight moderating influence that the ocean winds exert here on account of being intercepted by the Cascade Mountains; second, the fact that this district lacks the protection of high mountains from the extremes characteristic of the interior; third, the air, deprived of most of its moisture in passing over the Cascades, is usually clear and allows of much greater radiation of heat during the night and during the winter, thus increasing the daily and annual range of temperature.

KILLING FROSTS.

The dates on which first and last killing frosts occur, being governed by the passage of well developed high pressure areas, will vary considerably from year to year. The dates in the table give approximately the times between which frosts may be expected at any station. In general the higher uplands are sub-

ject to frosts earlier and later than the lower areas, but frequently the low flat valleys will have heavy frosts when the adjacent slopes and uplands are free from frost because of the drainage of the cold heavy air down the slopes and its collection in the lower valleys.

In some sections of the district frost may be expected as early as September 15, while in other parts it is not liable to occur before October 20. On the other hand frosts have occurred as early as August 23 at Ephrata, September 10 at Odessa, and October 7 at Trinidad.

The latest frosts in the spring may be expected at Trinidad about April 5, at Odessa about May 17, and at Hatton about May 25; but killing frosts have occurred at Trinidad as late as April 17, at Odessa as late as June 3, and at Hatton as late as June 15.

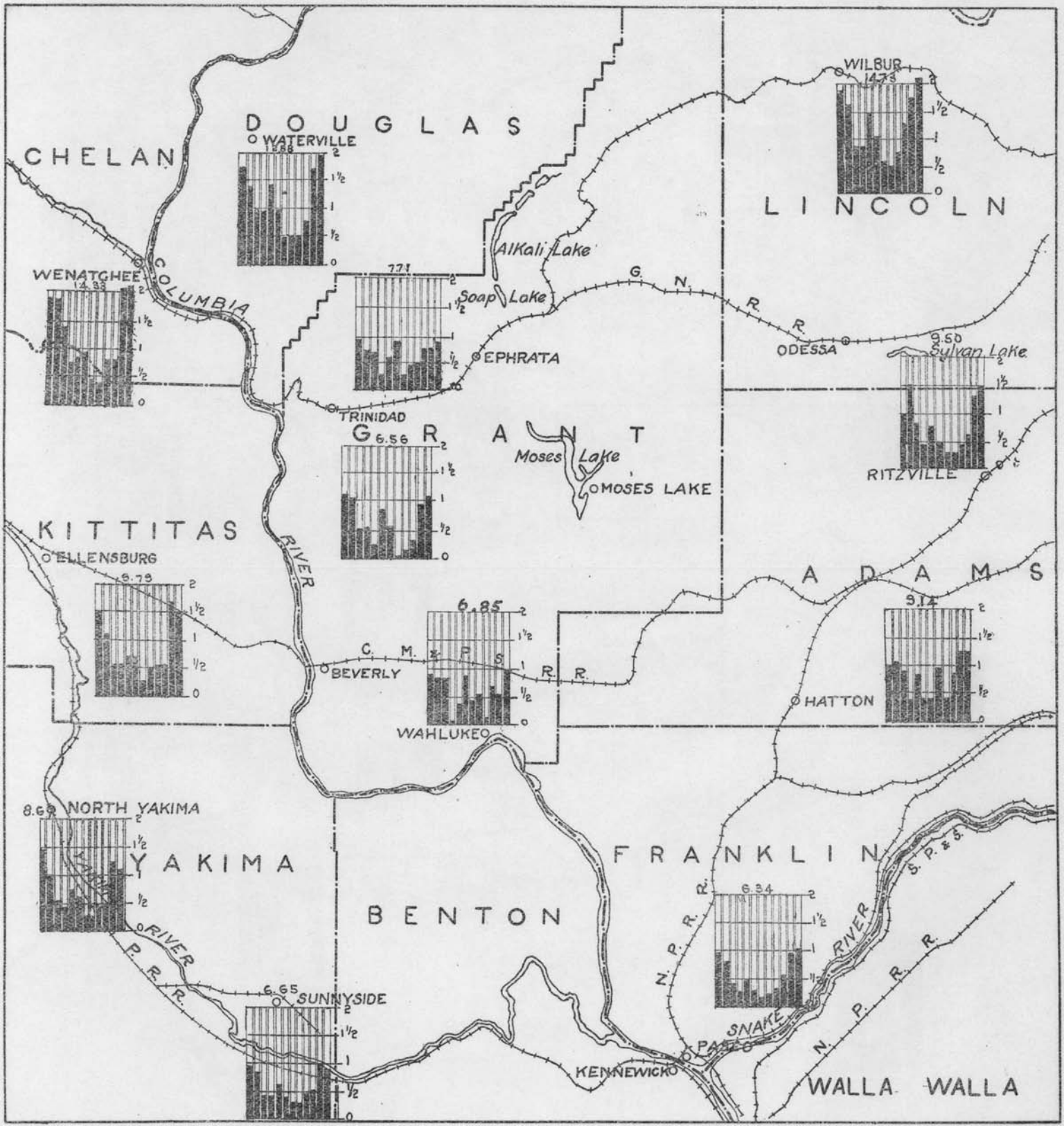
TABLE A. CLIMATIC CONDITIONS IN CENTRAL WASHINGTON.

	Elevation	Total precipitation in inches	Snowfall	Days with more than .01 inches precipitation	Cloudy days	Partly cloudy days	Clear days	Latest frost	Earliest frost	Days without frost
	Feet		Inches							
Ephrata	1,265	7.71	12.0	30	94	37	197	Apr. 23	Sept. 28	158
Ellensburg ...	1,570	9.79	29.2	61	92	68	205	May 23	Sept. 21	121
Hatton	1,100	9.14	13.5	67	120	83	162	May 25	Sept. 8	106
Odessa	1,540	.....	.....	.....	104	101	146	May 17	Sept. 25	116
Trinidad	900	6.56	23.8	32	67	79	219	Apr. 5	Oct. 20	198
Wahluke	410	6.85	11.5	34	94	80	185	Apr. 21	Oct. 4	166
Wenatchee ... (near)	1,169	14.33	63.4	82	103	90	172	Apr. 30	Oct. 21	174
Kennewick ...	367	6.34	10.8	48	78	90	193	Apr. 28	Oct. 15	170
Sunnyside ...	740	6.65	8.2	50	106	73	186	May 7	Oct. 8	154

WINDS.

The prevailing direction of the winds varies considerably at different stations, due to topographic irregularities, but in general the winds are either west, northwest, or southwest, and only occasionally from an easterly direction, when they bring with them the cold spells of winter or the warm waves of summer.

During the fall and spring months, occasional strong and disagreeably cool dry winds blow from the mountains over the


CHELAN
DOUGLAS
LINCOLN
GRANT
KITTITAS
ADAMS
YAKIMA
BENTON
FRANKLIN
WALLA WALLA
WATERVILLE
1.58
WILBUR
1.473
WENATCHEE
1.435
COLUMBIA
RIVER
Alkali Lake
Soap Lake
EPHRATA
TRINIDAD
G. N. R. R.
ODESSA
9.50
Sylvan Lake
RITZVILLE
6.56
Moses Lake
MOSES LAKE
ELLENSBURG
6.79
6.85
C. M. & P. S. R. R.
BEVERLY
WAHLUKE
9.14
HATTON
8.60
NORTH YAKIMA
YAKIMA RIVER
P. R. R.
6.65
SUNNYSIDE
6.34
N. P. R. R.
S. P. & S.
SNAKE RIVER
PASCO
KENNEWICK
N. P. R. R.

plains toward the east, the direction at different stations depending somewhat on the local topography. The air seems to glide rapidly down the eastern slope of the mountains after several warm days, and the winds will continue to blow for several days at a time, often attaining a velocity of thirty or forty miles an hour. When the winds first begin, usually along about noon, or late in the afternoon, the temperature will fall 10° to 30° in a short time and the first part of the blow often creates a dust storm. The winds are quite a relief after a few days of real hot weather, which in summer they frequently follow.

During the winter months there is very little strong wind, but occasionally, following the passage of a cyclonic area to the east, the air, moving into it from the southwest, comes down the eastern slope of the Cascades and is warmed dynamically by increased pressure, due to its forced descent. Having lost most of its moisture as it passed over the mountains, it blows over the valleys east of the mountains as a warm, dry wind called the "Chinook," often causing the sudden breaking up of a cold stormy spell of weather and rapidly melting or vaporizing any snow or ice that may be present.

SUMMARY.

The climate of this section of the Columbia River Basin seems to be the result of a combination of oceanic, continental, and mountain influences. The winter maximum of rainfall, the fact that the summer warm waves and the winter cold waves are not as severe, nor of as long duration as those farther east, are evidences of the oceanic influence. The high temperatures of summer, the low temperatures of winter, and the summer maximum of rainfall in May and June, which is of immense importance to the wheat growing sections of the country, are all interior characteristics. The clear, dry, exhilarating air and the strong mountain winds, are the results of the situation of the section on the east slope of the Cascade Mountains.

These conditions all combine to give the Quincy Valley one of the best agricultural climates on the continent, although the low rainfall makes irrigation necessary for the most advantageous crops and for fruit growing.

IRRIGATION PROBLEMS OF THE QUINCY VALLEY PROJECT.

SOURCE OF WATER SUPPLY, STORAGE, DELIVERY AND DISTRIBUTION, DUTY OF WATER, LENGTH OF IRRIGATION SEASON, COST DATA, ETC.

By Joseph Jacobs.*

In complying with the request of the State Geologist that I prepare a chapter on the engineering aspects of the Quincy Valley Project, I would point out that in a pamphlet of this character, intended as it is for general distribution and largely for lay readers, a purely technical discussion of engineering problems would be manifestly out of place, and I do not feel at liberty to consider these matters as exhaustively as was done in my initial report on the project to the Quincy Valley Water Users' Association.

Furthermore, a comprehensive engineering consideration of any irrigation project embraces far more than mere detail of construction and design, dealing as it necessarily must with soils, crop and climatic conditions, with water-supply, water-rights and transportation, and in fact with all those elements which affect the commercial as well as the physical feasibility of the project.

No attempt therefore will be made to record here, in detail, all the engineering data that have been secured in pursuit of the studies of this project, and such presentation as is here made will be confined to a general description of what the scheme contemplates, a discussion of its more important engineering features and a recital of the character of the investigations that have thus far been made.

The writer has been concerned with the study of this project since the fall of 1909 when he was requested by the Quincy Valley Water Users' Association to make an investigation and to render a report upon the most feasible and economical source of

*Consulting Engineer, 406 Central Building, Seattle.

water supply for irrigation of the so-called Quincy Flats. Except as limited by the funds available for the work, no restrictions were imposed as to the scope of the investigation and he was therefore permitted to and did in fact examine every possible source of water supply that might be brought into service for these lands. These possible sources were as follows:

1. Pend d'Oreille River and Pend d'Oreille Lake.
2. Spokane River and Coeur d'Alene Lake.
3. Columbia River.
4. Moses Lake and Crab Creek.
5. Ground water and artesian supply.
6. Wenatchee River and Wenatchee Lake.

Of the water supply sources above listed it is my purpose to discuss in detail only the one finally adopted, namely Wenatchee River and Wenatchee Lake, but before proceeding with that I would state briefly the causes which lead to the abandonment of the other supplies.

Nos. 1, 2 and 3 were abandoned by reason of prohibitive cost, though incidentally No. 2 was also rendered untenable by reason of the complicated water-right situation involved.

No. 4 was abandoned by reason of its entire inadequacy to serve a project of the magnitude contemplated, though for a project of lesser magnitude, or under certain conditions to serve a small portion of the proposed project, it was well worthy of consideration.

No. 5 was abandoned on account of the uncertainty of the supply, on account of its inadequacy to serve the area contemplated for irrigation, and finally because the capitalized value of the annual maintenance cost for pumping was, except for low lifts, in excess of the estimated ultimate cost involved in the gravity scheme adopted.

Serious consideration was given to this scheme of pumping from ground waters, by reason of the ease and cheapness of its initial installation and the fact that development could proceed as rapidly or slowly as general business conditions seemed to warrant.

In my initial report this matter was discussed at length and in detail, and I believe showed conclusively that, for the irrigation of an area as large as that contemplated in this project, it would be foolhardy to depend upon an artesian supply, the existence of which has not been proven and which in all probability does not exist, or upon pumpage from a ground water supply whose quantity and extent is at best conjectural.

Despite my positive views, however, as to the final insufficiency of this source of water supply, I recognize the practical aspects of the present installation of wells, where the pumpage lift is not excessive, in that such development serves to establish the agricultural excellence of the district and to enhance land values, and because these installations may be replaced with the gravity supply when the same becomes available.

This now brings us to a discussion of the project proper as dependent upon the Wenatchee source of water supply.

CHARACTER OF INVESTIGATION.

The investigations thus far made are as listed below and have been wholly of a reconnaissance nature, unless otherwise stated.

1. An examination of the irrigable area as to topography and soil characteristics.
2. An examination into the character of land ownership.
3. An examination of water-rights on Wenatchee Lake and Wenatchee River.
4. An examination of route of main canal.
5. An examination of Wenatchee River for possible dam sites.
6. An actual survey of the Lake Wenatchee reservoir site.
7. An examination and compilation of all available data, published and unpublished, of the hydrography of the streams involved and of the topography of the lands involved in the project.

LOCATION.

The lands to be irrigated are situated in Grant county, in the north central part of the state (see map), and are embraced in the territory roughly bounded as follows: On the north

by the Great Northern Railway, on the east by Moses Lake, on the south by Crab Creek and the Chicago, Milwaukee & Puget Sound Railway, and on the west by the Columbia River. The tract described contains about 550,000 acres of which it is estimated that about 80 per cent. is irrigable and it is also estimated that there is sufficient water for about that amount of land.

TOPOGRGAPHY.

The lands vary in general altitude from about 700 feet above mean sea level along their southerly extremity to about 1,300 feet above mean sea level along their northerly extremity, with, however, a narrow zone of higher land in between. Extending easterly and westerly across the valley, along a line about nine miles from the southerly boundary and about eighteen miles from the northerly boundary, there is a low, sandy ridge known as Frenchman Hills, which at certain points along its crest rises to elevations of from 1,700 feet to 1,900 feet above mean sea level, the lowest point in the ridge being only 1,500 feet above mean sea level. Along the easterly edge of the tract the lands slope gradually to the level of Moses Lake, at an elevation of 1,038 feet, while along its westerly edge the general plateau elevation is maintained to the rim of the Columbia River bluffs where it drops abruptly to the river grade at an approximate elevation of 600 feet above mean sea level. The main body of irrigable lands, namely that lying northerly from Frenchman Hills, constitutes a slightly rolling plateau practically free of marked surface irregularities, while to the southward the lands slope rapidly but with fair regularity from the Frenchman Hills to the low basaltic bluffs immediately facing Crab Creek bottoms.

Not all of these lands are irrigable, certain areas being classed as non-irrigable, by reason of their being too steep, as along the Columbia River bluffs, or too high for gravity irrigation as are the higher portions of the Frenchman Hills, and certain small areas also would be classed as "scab land," i. e., having such surface exposure of rock as to render their reclamation impracticable.

SOIL.

This has been made the subject of a special chapter which will be found in another part of this bulletin and I will therefore state here but a few words in relation thereto. As to quality the soil may be classified as a basaltic loam, a type of soil characteristic of a great portion of central Washington and universally recognized as of high value. It appears to be somewhat heavier, but in kind related to the soil of the Yakima Valley, and perhaps even more nearly identical with that of the Sunnyside District, which alone would prove its fertility. As indicated by a great many wells already put down for domestic and irrigation purposes the soil depth varies generally from 25 feet to 100 feet or more.

CLIMATE.

This too has been made the subject of a special chapter and I shall therefore say only a brief word in relation thereto. Like all central Washington this region has insufficient rainfall to insure profitable agriculture without irrigation. The warm moisture laden winds of the Pacific are nearly sapped of their water vapor in passing over the Cascade Mountains, so that there is a wholly deficient precipitation for successful agriculture when the Columbia River Valley proper is reached.

The irrigable area under consideration has long summers with very warm days and cool nights, and winters that are not excessively cold. The nearest Weather Bureau stations are at Ephrata, at an elevation of 1,265 feet, and Trinidad, at an elevation of 900 feet, near the eastern and western boundaries, respectively, of the project, these stations having been established in 1903. On account of Trinidad being somewhat under the general upland level and on the slope dropping down to the Columbia River, the record at Ephrata is more nearly representative of the climatic character of the entire Quincy Valley and in deducing the table which follows a little further on, a slightly greater weight was given to the record of that station.

As best indicative of the character of climate enjoyed by Quincy Valley it is of interest to compare its more important

climatic features with those of the Wenatchee, Sunnyside and Yakima districts, which are in neighboring territory and all of which have already won fame for their exceptional adaptability to fruit culture and for the resulting high values of land attained.

In the following table all data were deduced from published records of the United States Weather Bureau and are intended to include only those factors which have direct bearing upon agriculture and irrigation.

TABLE B. MEAN WEATHER CONDITIONS—VARIOUS STATIONS. (a)

ITEM	Quincy Valley (b)	North Yakima	Sunnyside	Wenatchee (near)
Elevation above sea level	1,200′	1,000′	764′	1,169′
Length of record (years) (c)	4 to 8	12 to 13	9 to 12	11 to 12
Mean annual precipitation	6.77″	8.43″	6.65″	14.33″
Precipitation—July, August and September	1.05″	1.05″	0.81″	1.61″
Mean annual temperature	52.4°	49.8°	50.8°	47.9°
Maximum annual temperature	106.°	103.°	102.°	97.°
Minimum annual temperature	—2.°	—6.°	—2.°	—2.°
Last killing frost in spring	Apr. 22	May 20	May 7	May 1
First killing frost in autumn	Oct. 12	Sept. 19	Oct. 7	Oct. 22
Length of frost free period (days)	173	122	153	174

(a) The above records are to 1910, inclusive, the compilation for 1911 not yet having been issued by the Weather Bureau.

(b) This column is made up from the records for Trinidad and Ephrata, a slightly greater weight being given to the latter station.

(c) Observations for the various phenomena were not begun simultaneously at any station, hence the two figures for length of record.

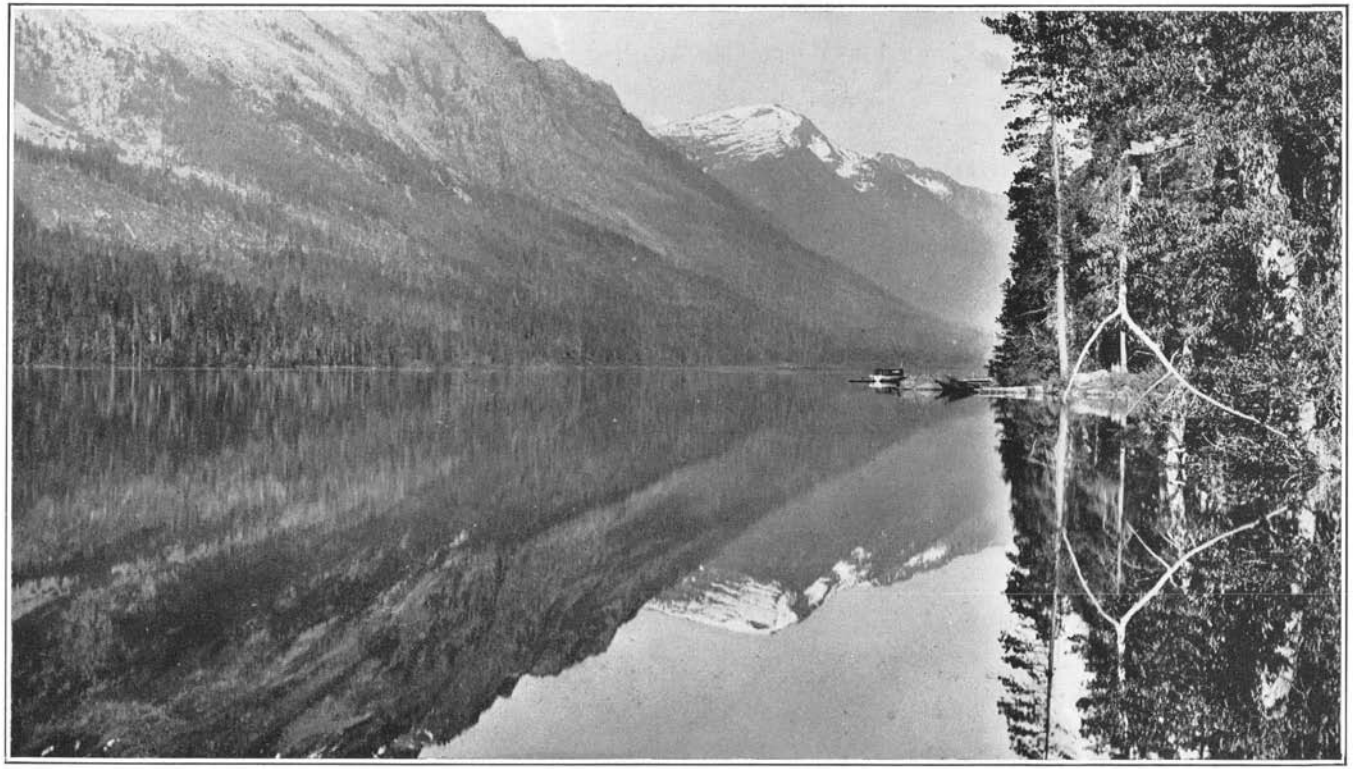
From the above tabulation it is apparent that Quincy Valley has certain climatic advantages over the Yakima, Sunnyside and Wenatchee districts, its salient features being that its weather is somewhat warmer and that, excepting Wenatchee, its frost free period is appreciably longer, which factor is important in its relation to fruit culture for it approximately measures the growing season for crops. It is true that two of these districts show a slightly greater annual precipitation than does Quincy Valley, but it will be noted that the summer precipitation in the Quincy Valley is surpassed only by that of Wenatchee. The record as a whole shows up exceptionally well for the Quincy Valley country.

CROPS.

At the present time, on account of the deficient rainfall and because no water is available for irrigation, practically the only crops attempted to be grown are hay and grain, and thus far these have scarcely maintained the rancher. Exceptions to the above are occasional small tracts where irrigation by pumping or from springs has been successfully applied to fruit raising, as for instance the Keigly 25-acre tract at Quincy, the Tolliver 20-acre tract at Ephrata and notably the Techacek orchard tract on the shores of Moses Lake. From the results obtained on these tracts and from the climatic conditions as disclosed in the records hereinbefore quoted, there can be no doubt that this valley will successfully grow all the fruits grown in the Wenatchee and Yakima valleys. That all forage crops such as timothy, alfalfa, wheat, oats, rye, etc., will flourish here when water is available has been abundantly proven. It goes without saying that a certain area will always be devoted to these forage crops, but on account of the great adaptability of the valley to fruit and vegetable culture and because of the high values of land attainable under such culture, it is believed that when irrigation water is provided at least the major portion of the lands will be devoted to this class of farming. As an evidence of the value of the soil in producing fruits and vegetables, it may be stated that Quincy Valley has already won several first prizes for this class of culture, not only at the successive annual competitions of the Spokane Interstate Fair, which embraces the states of Idaho, Oregon and Washington, but also at the Alaska-Yukon-Pacific Exposition of 1909, which was international in its scope.

TRANSPORTATION.

The transportation facilities of Quincy Valley are good. As will be noted on the index map the Great Northern Railway traverses the entire north boundary of the tract, the Chicago, Milwaukee & Puget Sound Railway the south boundary, the Connell Northern branch of the Northern Pacific Railway lies just east of its eastern boundary and the Columbia River forms



its western boundary. In addition to the above the Chicago, Milwaukee & Puget Sound Railway has about ready for operation a branch from its main line to Moses Lake and the Northern Pacific cut-off from Ritzville to Ellensburg has partially been constructed and this line traverses the very heart of Quincy Valley. Furthermore the open and level character of the country lends itself to cheap highway construction so that on full development of the project the remotest ranch would need be scarcely more than a two or three hour drive from a railroad.

LAND OWNERSHIP.

Practically the entire project is included within the land grant limits of the Northern Pacific Railway, a land grant by which the railway received from the government title to every odd-section of land. It appears that, excepting a few sections bordering on Moses Lake, the railway company has disposed of these lands to individuals, title however remaining in the name of the company until all payments on the purchase contract have been satisfied. Counting such lands, however, as in private ownership, the character of land ownership of the entire irrigable area is approximately as follows:

Government land	6%
Private land	85%
State land	7%
Railroad land	2%
Total	100%

DUTY OF WATER.

Experience with existing irrigation practice in central Washington, as indicated both by crop experiments and by the amount of water guaranteed in the water-right contracts of various irrigation companies, shows the water requirements for different crops to be about as stated below, the amounts given being the vertical depth of water delivered to the land during the irrigation season:

Alfalfa and forage crops in general	32″ to 36″
Vegetables	30″
Fruits	24″

With more careful cultivation of the soil and with a general improvement in irrigation methods the tendency is and will continue to be to decrease the amount of water applied to the land, so the above figures may be assumed to be at least a conservative maximum of what would be required for this project. It may be assumed that all the lands will not be devoted to fruit culture and I have therefore assumed as a basis for all my preliminary estimates an average duty of 30″ of water delivered to the land. In the distribution system, the laterals being unlined, I have assumed a loss of 16 2-3%, thus making the requirement at the head of the distribution system, i e., at the lower end of the main canal, 36″.

The seepage and evaporation losses from the main canal will depend upon its total length and upon the relative lengths of lined and unlined portions, none of which can definitely be determined until final surveys are made. The major portion of the main canal, however, we know will need to be lined and I have therefore assumed its seepage losses at 15%, thus making the resultant diversion duty of water 42″ at the intake of the main canal.

IRRIGATION SEASON.

The irrigation season should extend from April 1st to October 31st, and the distribution throughout the season would be about as follows:

During April	7% of total supply.
During May	15% of total supply.
During June	17% of total supply.
During July	19% of total supply.
During Aug.	20% of total supply.
During Sept.	15% of total supply.
During Oct.	7% of total supply.
Total	100%

The maximum draft, i. e., the requirement for the month of August, will of course determine the necessary capacity of the main canal.

WATER RIGHTS.

Before proceeding with a description of the water supply, which as already stated would be from Wenatchee Lake and Wenatchee River, brief reference should be made to existing water rights.

The only water rights which at the present time have any bearing on the project are those for existing irrigation systems in Wenatchee Valley and for the few power plants at and above the town of Wenatchee.

The Great Northern Railway Company's Tumwater Power Plant, located about three miles above Leavenworth on Wenatchee River, claims a water right of 525 second-feet and has an installation practically sufficient to utilize that amount of water. As the main canal diversion for the Quincy Valley Project must be well above the intake for this power plant, the storage operations of the scheme must be such as not to affect the normal discharge of the river when the same falls below 525 second-feet at the power penstock intake. There are other power plants on Wenatchee River, but as the Tumwater plant above described is highest up on the river and requires the largest flow of water for its operation, any provision made for it would more than provide for the smaller plants below.

The present area under irrigation in Wenatchee Valley does not exceed 20,000 acres and with possible future development of existing canals either by gravity extensions or by pumping, the gross irrigable area will probably not exceed 25,000 acres. This acreage would require less water than that demanded by the Tumwater Power Plant and as the latter is above practically all present diversions for irrigation its requirements would remain the criterion as affecting storage operations of the Quincy Valley Project.

WATER SUPPLY.

Wenatchee River, including its tributary, Chiwawa Creek, has a drainage area of 560 square miles above the proposed reservoir dam site hereinafter described. It drains the eastern slope of the Cascade Range, reaching an altitude of 8,100 feet at the

head of White River, the mean altitude for the entire basin being about 5,000 feet. Its drainage area is all mountainous and fairly well forested with fir, pine and cedar and it is in fact included within the Wenatchee National Forest. There is practically perpetual snow on the highest peaks along the western rim of the basin and over the entire water shed a heavy annual precipitation prevails.

The water supply records available at the time my initial report on this project was prepared was for a single station (Cashmere) and covered only a period from July, 1904, to December, 1906, inclusive, the data subsequent to that date having been withheld by the United States Geological Survey pending additional observations to establish the accuracy of the original records. At the present time, however, we have available actual published records of the United States Geological Survey up to and including the year 1909 and the unpublished provisional data for the years 1910 and 1911.

Realizing the importance of having a gaging station near the proposed reservoir dam site, the Quincy Valley Water Users' Association established, in December, 1910, such a station at a convenient point about three miles below the said dam site, which station has been and is now regularly observed and records of the same maintained by the United States Geological Survey, in co-operation with the State Geological Survey.

The data for these two stations, namely the one at Cashmere and the one recently established and designated as being near Leavenworth are submitted herewith in complete tabular form and if comparison is made with previously published records it will be noted that the government has revised its original figures, the records now indicating a greatly increased discharge of Wenatchee River. This increase in Wenatchee River run-off permits an accordant increase in the area that may be reclaimed by irrigation.

TABLE C. DISCHARGE OF WENATCHEE RIVER AT CASHMERE, DRAINAGE AREA, 1,250 SQUARE MILES.

Month Year	January	February	March	April	May	June	July	August	September	October	November	December	For Year or Prior
							(a)						
							4,260	3,180	1,480	1,280	1,940	1,590	
1904							3,180	1,280	830	730	690	1,030	
							3,780	2,080	1,080	855	1,100	1,300	
							37,500	128,000	64,300	52,600	65,500	79,900	428,000
	1,100	1,700	6,040	11,400	11,600	14,900	7,200	2,350	1,820	8,760	1,940	1,280	14,900
1905	730	650	1,820	2,210	4,740	6,900	2,500	1,030	890	1,190	1,190	780	650
	900	990	4,370	4,710	6,550	10,500	4,450	1,560	1,090	2,950	1,400	965	3,380
	55,300	55,000	269,000	280,000	403,000	625,000	274,000	95,900	64,900	81,000	83,300	59,300	2,450,000
	1,700	1,940	3,180	9,960	11,600	8,760	6,320	1,480	1,700	12,400	19,200	1,480	
1906	780	1,190	1,190	3,000	4,740	3,800	1,590	890	830	830	(b) 1,940	(c) 1,380	
	1,040	1,520	1,450	5,860	7,860	5,390	3,260	1,160	1,000	2,420	4,070	1,420	
	64,000	84,400	89,200	349,000	483,000	321,000	200,000	71,300	59,500	49,000	113,000	141,000	2,000,000
	1,380	4,260	2,660	7,500	18,500	19,000	6,600	2,660	1,700	1,110	2,500	2,350	19,000
1907	890	960	1,280	1,820	6,320	5,500	2,500	1,110	890	1,110	1,120	1,190	890
	1,040	2,420	2,040	4,670	12,500	9,500	4,320	1,650	1,220	1,110	1,300	1,730	3,620
	64,000	134,000	125,000	278,000	769,000	565,000	266,000	95,900	72,600	68,200	77,400	106,000	2,620,000
	1,700	1,480	3,580	8,760	9,780		13,200	3,800					
1908	960	890	1,380	2,070	5,760	6,320	3,800						
	1,390	1,210	2,380	4,560	8,050	11,500	9,590	2,060					
	85,500	69,600	146,000	271,000	495,000	684,000	590,000	127,000					2,470,000
				5,500	11,600	21,400	9,440	1,940	1,380	1,480	20,800	17,100	
1909				(d) 4,380	4,380	7,800	2,660	1,030	730	940	1,040	1,640	
				4,970	7,420	13,600	5,510	1,510	930	1,090	5,240	4,030	
				49,300	456,000	809,000	339,000	92,800	55,300	67,000	312,000	248,000	2,430,000
	2,660	1,600	10,500	20,500	20,000	12,200	6,680	2,490	1,020	4,840	13,200	2,940	20,500
1910	1,210	1,070	1,600	2,580	7,920	5,080	2,580	940	725	750	1,800	1,320	725
	1,590	1,390	4,550	7,270	13,100	7,700	4,710	1,680	873	2,870	4,100	1,750	4,320
	97,800	77,200	280,000	433,000	806,000	458,000	290,000	103,000	51,900	76,000	244,000	108,000	3,120,000
	1,620	1,110	3,290	6,710	11,700	19,300	5,740	2,020	1,940	775	6,560	1,800	19,300
1911	940	780	780	2,020	4,130	5,150	2,020	940	800	620	620	940	620
(e)	1,250	934	1,600	3,620	6,160	10,700	3,800	1,290	1,110	682	1,900	1,340	2,870
	76,900	51,900	98,400	215,000	379,000	637,000	234,000	79,300	66,000	41,900	113,000	82,400	2,074,800

TABLE C. DISCHARGE OF WENATCHEE RIVER AT CASHMERE, DRAINAGE AREA, 1,250 SQUARE MILES.—Concluded.

Month Year	January	February	March	April	May	June	July	August	September	October	November	December	For Year or Prior
For Period	2,660	4,260	10,500	20,500	20,000	21,400	13,200	3,800	1,940	12,400	20,800	17,100	21,400
	730	650	780	1,820	4,130	3,800	1,590	890	725	620	620	780	620
	1,200	1,420	2,730	5,100	8,810	9,850	5,060	1,610	1,040	1,710	2,420	1,910	3,580
	73,900	78,700	167,900	303,700	431,600	585,600	311,400	99,200	62,100	105,100	144,000	117,800	2,591,000

(e) DISCHARGE OF WENATCHEE RIVER NEAR LEAVENWORTH, DRAINAGE AREA, 590 SQUARE MILES.

1910												1,780	
												910	
												1,130	
												69,600	69,600
1911	1,060	750	1,820	3,910	6,130	8,250	3,620	1,600	1,380	670	4,060	1,540	8,250
	710	490	490	1,600	3,130	3,480	1,710	920	670	520	520	830	490
	841	625	891	2,220	3,950	5,470	2,740	1,150	957	582	1,430	1,090	1,830
	51,800	34,700	54,800	132,000	243,000	326,000	168,000	70,700	56,900	35,800	85,100	67,000	1,325,800

These data are deduced from the published records (to 1909 inclusive) and the unpublished records (1910-1911) of the United States Geological Survey under whose direction the gagings are maintained. The first three lines for each year indicate respectively, maximum, minimum and mean discharge in second feet; and the last line indicates the run-off in acre feet for the month, year or period as the case may be. (a) For period July 27-31; (b) Nov. 1-14; (c) Dec. 27-31; (d) Apr. 26-30; (e) This record is for Dryden Station, located a short distance above Cashmere Station, which it is intended to replace, the latter station having been abandoned in September, 1911. (f) This gaging station located in Section 12, T. 26 N., R. 17 E., W. M., being about three miles below the upper dam site of proposed Wenatchee Lake Reservoir.

From the above table it will be noted that for the year 1911 the discharge at the upper gaging station, with a drainage area of 590 square miles, is about 64% of that for the Cashmere gaging station with a drainage area of 1,250 square miles. Assuming that this same ratio would hold for mean years and that the discharge at the reservoir dam site, including the discharge of Chiwawa Creek which it is proposed to divert into the reservoir, would be slightly less than that at the upper gaging station, I have deduced the following as the actual or the estimated mean annual run-offs at those critical points which must be considered in determining the area that can be irrigated on the basis of the water supply, and the amount of storage required therefor:

At Cashmere, 1,250 square miles (record) ..... 2,600,000 acre-feet
At Great Northern Power Dam, 700 square miles (estimated) ..... 1,920,000 acre feet
At Diversion Site hereinafter described, 280 square miles (estimated) ..... 1,880,000 acre-feet
At Reservoir Dam Site, including Chiwawa Creek, 560 square miles (estimated) ..... 1,640,000 acre-feet

After making allowance for evaporation losses from the proposed reservoir hereinafter described (22,500 acre-feet) and for a continuous flow of 525 second-feet, to satisfy the requirements of the Great Northern Railway Power Plant, which latter would also satisfy all present power and irrigation rights in Wenatchee Valley, I estimate that there will be available for irrigation in mean years about 1,520,000 acre-feet of water, or an amount sufficient to irrigate 435,000 acres, assuming, as hereinbefore set forth, a diversion duty of 42″ and a delivery duty of 30″.

It may be noted here that if a delivery duty to the land of 27″ instead of 30″ be assumed there would be sufficient water to irrigate 475,000 acres. In this connection I would state that the area actually to be irrigated can be determined only by a careful examination of the entire body of land, classifying it section by section as irrigable or non-irrigable, and such a survey has not as yet been made.

STORAGE.

It will be noted in the tabulation of run-off previously quoted, that even at Cashmere which is far below the point where our diversion must be made, the normal discharge of Wenatchee River is not sufficient for a project of the size contemplated and it is therefore essential to secure the maximum storage possible.

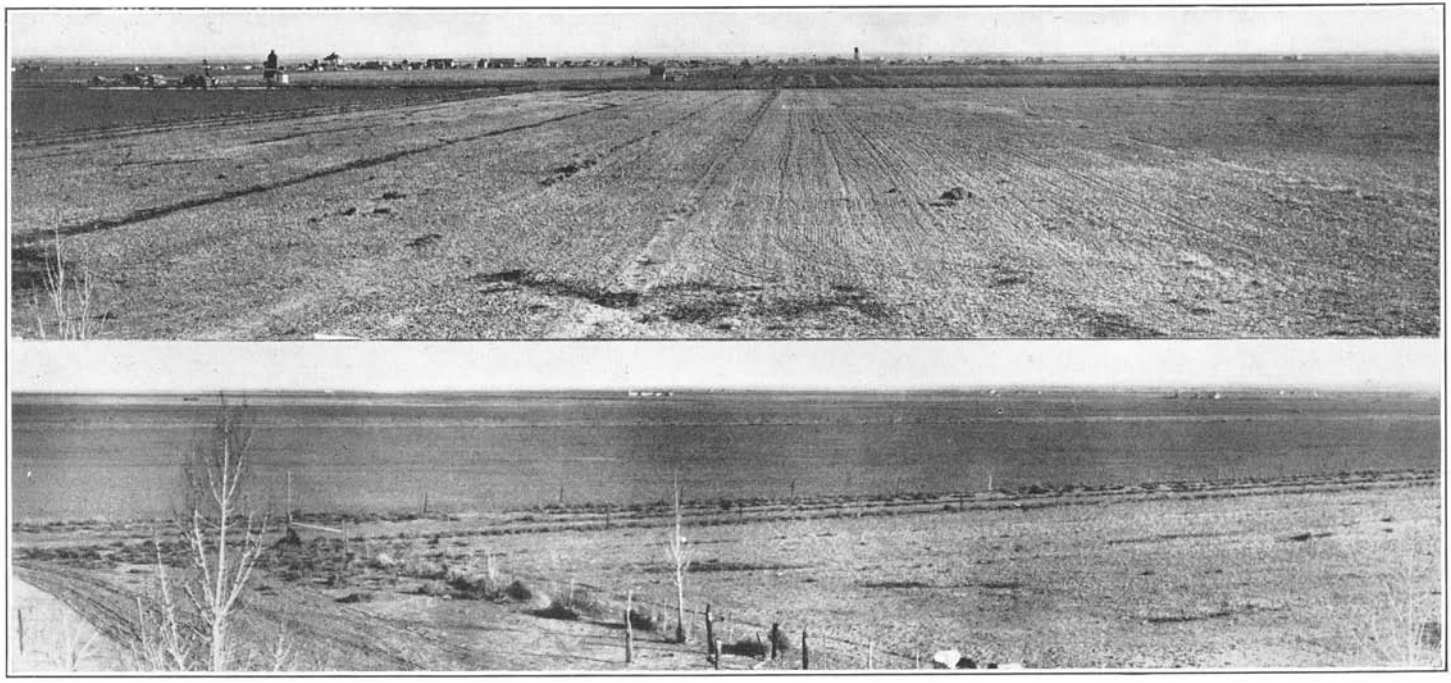
I estimate that the normal storage requirement, i. e., in years of mean run-off, will be about 637,000 acre-feet, but to provide for years of minimum run-off, taken as 60% of mean run-off, the approximate maximum storage requirement is 1,142,000 acre-feet for an irrigated area of 435,000 acres.

WENATCHEE RESERVOIR.

Wenatchee Lake, at an altitude of 1,870 feet and with an area at mean stage of about 2,400 acres, affords a very favorable reservoir site. It is sufficiently high to command the lands to be irrigated and is located on the best part of the Wenatchee River drainage (See Plate II). At its outlet its width narrows to form the regular channel of the river and this point affords a fair site for a low dam, but a low dam would not provide the storage required and a high dam at this point, on account of its great length, would be impracticable.

A far more favorable site for a high dam is found in sections 26 and 35, Tp. 27 N., R. 17 E., which site has the important advantages of increasing the size of the reservoir and of including the Nason Creek drainage of 121 square miles.

Other possible dam sites exist further down the canyon, surveys of which have not yet been made, but before any final decision is reached as to the best location for a dam the entire canyon must be carefully examined and all possible sites accurately surveyed. A favorable site below the mouth of Chiwawa Creek for instance would involve but little increase in height of dam and would at the same time avoid the artificial diversion of that stream into the reservoir as will be necessary if the upper site is adopted.



For the present and until definite surveys and studies of this lower dam site are available, all estimates are made on the basis of the adoption of the upper dam site.

It is proposed to build here an earthern dam to an elevation of 2,000 feet above mean sea level, being a maximum height of 146 feet above the stream bed. The top length of this dam will be 4,446 feet and with upstream and downstream slopes of 3 to 1 and 2 to 1 respectively, and with a top width of 20 feet, it will have an earth volume of 4,600,000 cubic yards. It is proposed to protect both faces of the dam with riprap 18″ thick and it is also planned to carry two lines of concrete cut-off walls extending the entire length of the dam, these walls to go down and into the bed rock and project about 5 feet into the main body of the dam. It is proposed also to construct a concrete lined spillway of 25,000 second-feet capacity around the southerly end of the dam.

SURVEY OF RESERVOIR.

Pending an actual survey of the reservoir site and recognizing its strategic relation to any general scheme of irrigation in central Washington, the government withdrew from public entry all lands within the Wenatchee reservoir site, the President of the United States having issued such order through the Secretary of the Interior under date of January 17, 1911. This order withdrew from entry 18,553 acres, embracing lands both within and without the reservoir site, reserving the same for use in connection with irrigation only.

During the summer of 1911, the Quincy Valley Water Users' Association made, under my direction, a complete survey of the Wenatchee Lake reservoir and dam site and I am permitted by that organization to give in Table D complete data as to the areas and the capacities of this reservoir for varying heights of storage.

TABLE D. WENATCHEE LAKE RESERVOIR.
(From Surveys Completed September, 1911.)

CONTOUR ELEVATION.	Area. Acres.	Capacity between contours. Acre-feet.	Capacity to any contour. Acre-feet.
1,855 feet	0		0
		115	
1,860 feet	46		115
		36,320	
1,880 feet	3,686		36,435
		94,510	
1,900 feet	5,865		130,945
		134,750	
1,920 feet	7,610		265,695
		176,290	
1,940 feet	10,019		441,985
		213,430	
1,960 feet	11,324		655,415
		239,420	
1,980 feet	12,618		894,835
		63,335	
1,985 feet	12,715		958,170

REMARKS.—Elevation of river bed at dam site, 1,854 feet. Proposed top of dam elevation, 2,000 feet. Proposed spillway elevation, 1,985 feet. Proposed spillway capacity, 25,000 second-feet. Maximum water surface elevation in flood, 1,995 feet.

As will be noted from Table D the survey indicates a storage capacity of about 960,000 acre-feet to the proposed flow-line of the reservoir at an elevation of 1,985 feet, this being the elevation assumed for the crest of the spillway with height of dam at an elevation of 2,000 feet. Although this storage capacity is somewhat less than the apparent maximum storage requirement, under extreme conditions, as hereinbefore set forth, yet it is believed that it will prove sufficient, or at least that greater storage need not be provided at this time and for the following reasons, to-wit:

(a) It will take at least 15 years after water is delivered to settle up the entire irrigable area, by which time improved irrigation methods may materially improve the water duty, and furthermore the general rise of the ground water plane may tend to sub-irrigate some of the low lying lands.

(b) The increased length of discharge record may make a better showing for low and mean years than is indicated by the record now available and furthermore the lowest year now of record is 25% in excess of the minimum assumed in estimating possible maximum storage requirements.

(c) Maximum storage will not be required until the entire area is under irrigation, at which time the character of the crops grown and the exact irrigation requirements will be definitely known, when additional storage if needed can be more intelligently and economically provided.

CHIWAWA CREEK.

This creek has an excellent water shed of 164 square miles, extending westward to the summit of the Cascades, and it is one of the important feeders of Wenatchee River. Unfortunately it empties into the river below the dam site as now proposed, but to secure the great amount of storage required for this project, it must in some manner be included in the storage system. This can easily be accomplished by means of a feed canal not exceeding two miles in length extending from Chiwawa Creek to Fish Lake (see Plate II), thus making it in fact a part of the main reservoir. This canal could be unlined and would need to have a capacity of about 2,000 second-feet. There will also be required a low diverting dam on Chiwawa Creek, but the total cost of delivering this supply into the reservoir would be relatively small and should undoubtedly be done unless subsequent surveys prove that a storage reservior on Chiwawa Creek itself would be more economical, which however in my opinion is very doubtful.

OTHER SOURCES OF WATER SUPPLY.

Should the Wenatchee water supply prove insufficient for the area it is finally desired to irrigate, or in the event that it is desired to expand the project at some future date, other possible sources of water supply might be found in Entiat, Icicle and Peshastin creeks. They are at least worthy of consideration in this connection and continuous discharge records on these streams would be extremely valuable.

Some study has already been given to the Entiat possibility and the indications are that on account of the complicated water rights on this stream and the high cost of its diversion into the Wenatchee drainage basin its use would probably prove impracticable, but no such study has yet been given to the other two streams named.

POINT OF DIVERSION.

To irrigate an area of 435,000 acres there will be required a maximum canal capacity of nearly 5,000 second-feet. For a main canal length of 65 miles, and the gradients required for the varying types of conduit which will need to be employed, it is estimated that a total head of about 260 feet will be consumed. With a main canal elevation of 1,340 feet at Quincy this means that the canal must be diverted from the river at an elevation of 1,600 feet and it is found that this will be approximately where Fall Creek empties into Wenatchee River, about 12 miles below the proposed reservoir dam site. At this point a low overflow weir and head-works would need to be constructed to serve the purpose of diverting Wenatchee River into the main canal. It is proposed to release the water from Wenatchee Lake reservoir, as required, by means of an outlet tunnel which would drain the reservoir to contour elevation of 1,855 feet. This water would be turned directly into the natural channel of Wenatchee River, or it would be possible to utilize it for power purposes by carrying it in a power canal on low gradients to a point just above the proposed diversion dam site where a power house could be located. It is not known that such power development would prove economical or desirable and it is simply mentioned here as a possibility.

MAIN CANAL.

As has already been stated the capacity of the main canal will need to be about 5,000 second-feet at the intake and about 4,250 second-feet at its lower end for the acreage contemplated, and for the gradients now estimated it would have a length of 65 miles. It will be appreciated, of course, in dealing with canals of this magnitude that only the most careful surveys and most considerate study can determine the economic gradients and economic routes and, at least at the upper end of the canal, alternative routes are possible.

If the canal were diverted from Wenatchee River at the mouth of Fall Creek, instead of following Tumwater Canyon on the steep mountain side above the Great Northern Railway track, it

could leave the Wenatchee by means of a three-mile tunnel, thereby bringing it into Freund Creek Canyon. From this canyon it would follow Chumstick Valley to the north side of Wenatchee Valley which it would parallel for a distance of 31 miles, or to Columbia River. The water would be conveyed under Columbia River by means of a pressure tunnel, and the canal would continue in a southeasterly direction along a line approximately paralleling the Columbia River and distant from one to three miles therefrom, a length of 21 miles to Moses Coulee; thence easterly from Moses Coulee and away from the Columbia River a distance of 12 miles to the end of the main canal, this point being about one mile north of the town of Quincy.

The route of the main canal throughout the major portion of its length is over hilly and mountainous country, involving much rock work and heavy construction in general. On account of the rough topography and the several canyons and rivers to be crossed, all types of conduits will need to be employed, namely lined and unlined open canal, side hill flumes, inverted siphons, grade tunnels, and one pressure tunnel under Columbia River. Probably not to exceed 5 or 6 miles of unlined canal can be economically employed in its entire length and this at the extreme lower end of the canal.

I thus purposely call attention to the magnitude of this main canal construction, not as a discouraging prospect, for I have abundant faith in the feasibility of the project, but because I desire not to minimize the actual difficulties which I know will be encountered and which must be solved.

Among the more important siphons required other than the Columbia River crossing, which is separately considered, may be mentioned the crossings of Chumstick Creek, Derby Canyon and Olalla Canyon westerly from Columbia River, and Rock Island Creek, Moses Coulee and Willow Springs Canyon easterly from Columbia River.

COLUMBIA RIVER CROSSING.

This proves to be one of the formidable features involved in utilizing the Wenatchee River water supply, for the bed of

Columbia River, at an elevation of about 600 feet above sea, is nearly 900 feet below the proposed hydraulic gradient of the canal line. It will therefore require the construction of a bridge to support an inverted siphon with a maximum head of about 800 feet, or a pressure tunnel under the river bed with a maximum head of about 1,000 feet. The proposed crossing is at a point about three miles north of Wenatchee, and its estimated length, including inclined approaches to the river crossing proper, is about 10,000 feet. It being necessary to conserve as much head as possible and because of the heavy friction losses involved in conducting the water in a series of small pipes, it is believed most economic to restrict the conduit to one, or at most two pipes. For a single pipe 22 feet is found to be the economic diameter, and for two pipes 16 feet each, and of these alternatives the single pipe is the less expensive and was therefore adopted in arriving at the preliminary estimates of the cost of the project.

To utilize a bridge for the support of a siphon at this crossing, it would be necessary to provide a clearance above high water sufficient to accommodate all present and prospective steamboat traffic. This would mean the construction of high piers at great cost, and the superstructure, with an imposed load at least five times that put upon our heaviest modern single track railroad bridge, would be unduly expensive, all of which would be in addition to the cost of the siphon proper.

A pressure tunnel below the river bed would not only be safer construction, but present estimates indicate that it would also be far more economic construction. I have assumed a depth of 100 feet below the river bed for this pressure tunnel, but its proper position can be determined only by careful surveys and extensive borings, which of course have not yet been made.

The type of construction contemplated is an outer shell of concrete not less than 18″ thick and properly reinforced to resist internal and external pressure, and an inner shell of steel 1″ thick to insure water tightness and also to resist internal pressure. The thickness of concrete used and the amount of rein-

forcement required will of course depend upon the character of rock formation encountered.

Such a pressure tunnel would not be an unusual type of construction, as is indicated by the Hudson River pressure tunnel forming a part of the New York Aqueduct which is now under construction. This tunnel will have an internal diameter of 14 feet and will be under a maximum head of 1,500 feet.

WASTEWAYS.

To properly regulate the canal and to afford protection, should rapid unwatering of the canal be required, probably not less than three wasteways will need to be provided; one just below the head works, one at Columbia River crossing, and one near the end of the main canal.

DISTRIBUTION SYSTEM.

This will consist of one main lateral extending south from Quincy and one extending as a continuation of the main canal from Quincy to a point north of and opposite Ephrata, with a final waste channel therefrom draining into Moses Lake. The land south of Frenchman Hills would be reached by extending one of the main laterals, in a tunnel through the low divide in the Frenchman Hills, or by an open canal around either end of the Hills as future surveys may prove to be most economical. In addition to the main laterals there will be required a sub-lateral system together with patrol houses and a telephone system for the proper operation of the canal.

Since the body of irrigable lands are generally located very favorably for irrigation, it is not believed the distribution system will prove unusually expensive. The cost should not exceed from $5 to $10 per acre, depending upon the area of farm unit to which the sub-laterals are constructed.

COST OF PROJECT.

In the absence of actual surveys for the major part of the work involved in this project one approaches the matter of final cost with some reluctance. Yet it is recognized that such pre-

liminary estimates are necessary as a basis for future studies and to point out the advisability of making more detailed investigations.

Based therefore upon the reconnaissance work that has already been done and upon the important data thus far assembled, I would say that I have arrived at a preliminary estimate of approximately $100 per acre for a project of 435,000 acres, which estimate I regard as conservatively high. The gross figures entering into this estimate are as follows:

Chiwawa Diversion	$85,000
Storage (960,000 acre-feet)	2,370,000
Main diversion dam and headworks	150,000
Main canal, exclusive of Columbiar River crossing (63 miles)	24,948,000
Wasteways	200,000
Columbia River Crossing	5,500,000
Distribution System	3,263,000
Rights of Way other than reservoir	50,000
	$36,416,000
Engineering and contingencies, 20%	7,283,000
Total	$43,699,000

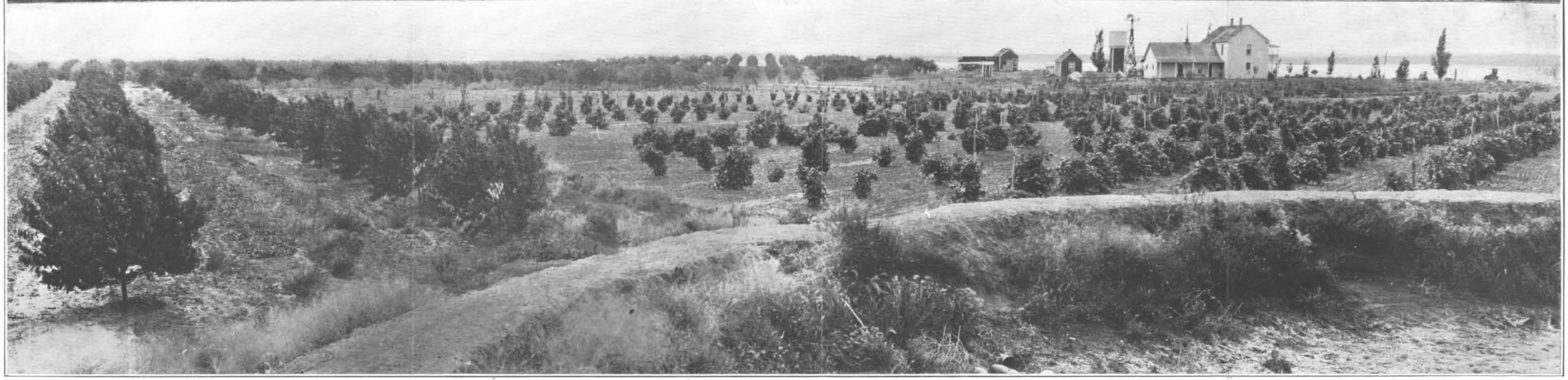
FUTURE WORK.

There is yet much work to be done before a final estimate of the cost of this project can be determined. Among other things there will be required an actual survey of the canal line, a land classification of the irrigable area, a detailed study of the distribution system, surveys and borings of the Columbia River crossing and additional dam surveys in Wenatchee Canyon.

LAND VALUES.

Granting that the project is physically feasible, as I fully believe it is, there yet remains the important consideration as to whether the final values attainable by the lands to be irrigated will justify the expense of bringing the water to them.

The probable range of land values that will obtain on this project are best illustrated by the actual land values at the present time in the Yakima and Wenatchee districts. The sale of developed orchards in these districts at $2,000 per acre is so



frequent as to no longer excite comment and I would hesitate to place the average price at which such orchards could be purchased at less than $1,000 per acre. By a developed orchard is meant one having healthy trees of approved varieties, eight years old or more, and having of course an ample water right. For good lands under a canal with ample water right, but as yet unplanted to orchard, it is difficult to find a desirable tract for less than $300 per acre.

The above should be a fair criterion of what the Quincy Valley lands will bring. With an assured water supply and considering the exceptionally favorable features of the project, namely, its climate, the fertility of its soil and its excellent transportation facilities, I believe it conservative to assume that these lands unimproved but with a water right will be worth $300 per acre, and this value would of course more than justify the estimated cost of irrigation.

CONCLUSION.

Before closing I would call attention to the great need of opening up new agricultural areas on this western coast to meet the land demand that is certain to ensue upon the completion of the Panama Canal. The consummation of that enterprise, it is conceded by every thoughtful writer on the subject, is bound to bring the Pacific Coast an unprecedented immigration from European countries and efforts should be made to prepare for that situation.

There are a number of large irrigation projects awaiting development, not only in Washington, but in other states as well, projects which will ultimately cost from $15,000,000 to $50,000,000 each and if this western country is to achieve its full development it must find some means of undertaking these larger schemes when engineering investigations prove them to be feasible and practical. If they prove too large or for other reasons fail to attract private enterprise, then it is my confident belief that at some early day a definite effort must and will be made to secure such legislation as will make possible their construction through the guarantee of state or federal aid, or perhaps by means of both these agencies.

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