SOIL SURVEY OF THE YAKIMA AREA, WASHINGTON.

By CHARLES A. JENSEN and B. A. OLSHAUSEN

INTRODUCTION.

Beginning April 15, 1901, two and one-half months were spent in making a soil survey of the Moxee and Atanum valleys and the Sunnyside district, in Yakima County, Wash. (See fig. 13.)

Four maps were made—one showing the classification of the soils according to texture, one the mean percentage of soluble salt in the first 6 feet of soil at water saturation, another the percentage of alkaline carbonates in the surface foot, and the fourth the depth to standing water, where this was within 10 feet of the surface.

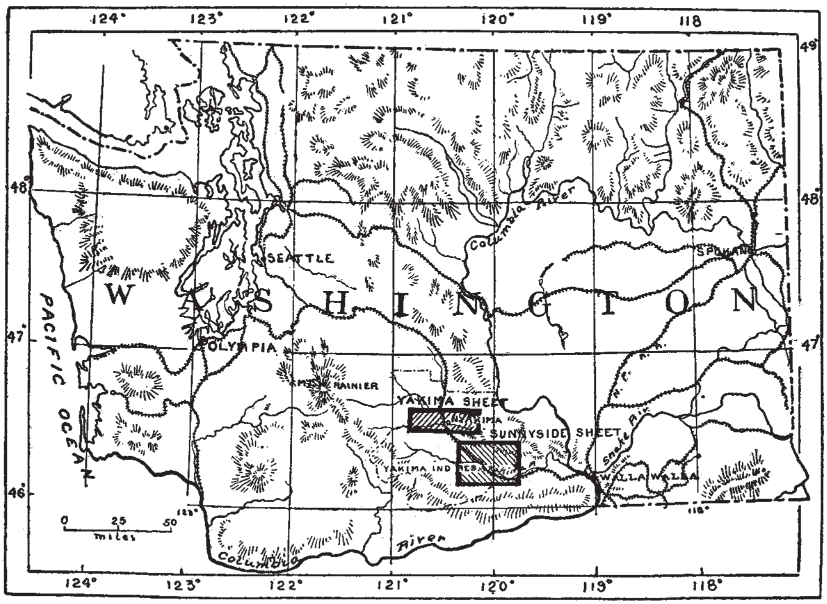


FIG. 13.—Sketch map showing areas surveyed in Washington.

The character of the subsoil water was carefully studied, especially where the accumulation of salt was going on, as was also that of the river, canal, and artesian waters. Samples of these waters and of the soils were sent in to the Bureau laboratory for more complete examination than could be made in the field.

As no good base maps of the area were to be had, the mapping was done by the party in the field. Maps of the Yakima River and of the canals, kindly furnished by the canal companies, were of considerable assistance in this work.

The writer wishes to acknowledge his indebtedness to Mr. H. B. Scudder, of North Yakima, president of the Yakima Land Company, for furnishing maps of the Sunnyside district and of the Fowler, Hubbard, and Moxee ditches, together with climatic data and much other general information concerning the districts surveyed; also to Mr. Albert S. Congdon, of North Yakima, president of the Yakima Valley Canal Company, for maps of that canal and of the Cowiche and Naches Canal, and agricultural data concerning the land under them; and to Mr. W. N. Granger, Zillah, general superintendent of the Sunnyside Canal, for data concerning that canal.

LOCATION AND BOUNDARIES OF THE AREA.

The area surveyed in the Moxee and Atanum valleys extends for a distance of about 24 miles east and west, with a base line approximately 2 miles south of the third standard parallel north, and with the extreme distance north and south through North Yakima of about 7 miles. The Yakima River runs north and south through the middle of the area. The area is bounded on the north by Selah Ridge and on the south by Yakima Ridge and Atanum Creek, and approximates 85 square miles.

The valley between the Yakima and Selah ridges, east of Yakima River, is known as the Moxee Valley, while that between Yakima and Cowiche ridges, west of Yakima River, is known as the Atanum Valley. The lower portion of the Atanum Valley is sometimes called Wide Hollow.

The area surveyed in the Sunnyside district extends for a distance of about 38 miles along the Yakima River, beginning about 4 miles below Union Gap. For the first 12 miles or so, beginning at its eastern end, the area varies in width from one-half mile to 2½ miles; thence westward the area gradually becomes wider, attaining a maximum width at Sunnyside of about 12 miles north and south, then gradually narrowing to about 2½ miles at Prosser. In the Sunnyside district the area under the present canal system is about 92 square miles, while under the proposed extension of the canal 20 square miles will be added to this. The total area mapped in the two districts is about 309 square miles.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The Atanum Valley and the region around Yakima are the oldest settled parts of the area surveyed. In these places agriculture by means of irrigation was carried on, though to a very limited extent, as long ago as 1860 or earlier. However, the advent of the Northern Pacific Railroad in 1883 really marks the beginning of the agricultural and horticultural importance of the valley. Yakima was at that time the most important settlement in the valley, but, owing to a disagreement with the railroad company over the selection of a depot site, the latter started the town at present known as North Yakima, which soon became the most important settlement of the region. It was not until after this that the principal canals were built and the country became well settled and took on an air of prosperity. Since then the development has been very rapid. The canals built within the last two or three years have attracted many new settlers to the valley.

PHYSIOGRAPHY.

The Selah and Yakima ridges, on the north and south sides, respectively, of Moxee Valley, were formed by the upheaval of the Columbia lava, and vary in height from 800 to 1,200 feet. The north slope of Yakima ridge is quite steep—8° to 20°—but it is covered over most of its extent with soil. The south slope of Selah Ridge is much steeper and for the most part rocky, the underlying basalt outcropping in many places. The whole valley has a gentle slope toward Yakima River, the eastern end of the valley being somewhat more inclined than the western.

The western portion of Atanum Valley is narrow and is bounded on the north by Cowiche Ridge and on the south by Yakima Ridge. The slope of the ridge on the north side of the valley is steep and rocky, but the valley itself is nearly level, with a gentle slope toward Yakima River. About 8 miles west of Yakima River the Atanum Valley becomes wider, the Cowiche Ridge turning northward and the valley being joined by the head of Wide Hollow. About 1 mile west of North Yakima there is a sudden rise in the level of the valley floor, which here forms a plateau, bounded on the north by Cowiche Ridge and on the south by Wide Hollow Slough, and gradually merging in the west in the head of Wide Hollow, toward which it slopes. This plateau is from 10 to 60 feet higher in elevation than the rest of the Atanum Valley.

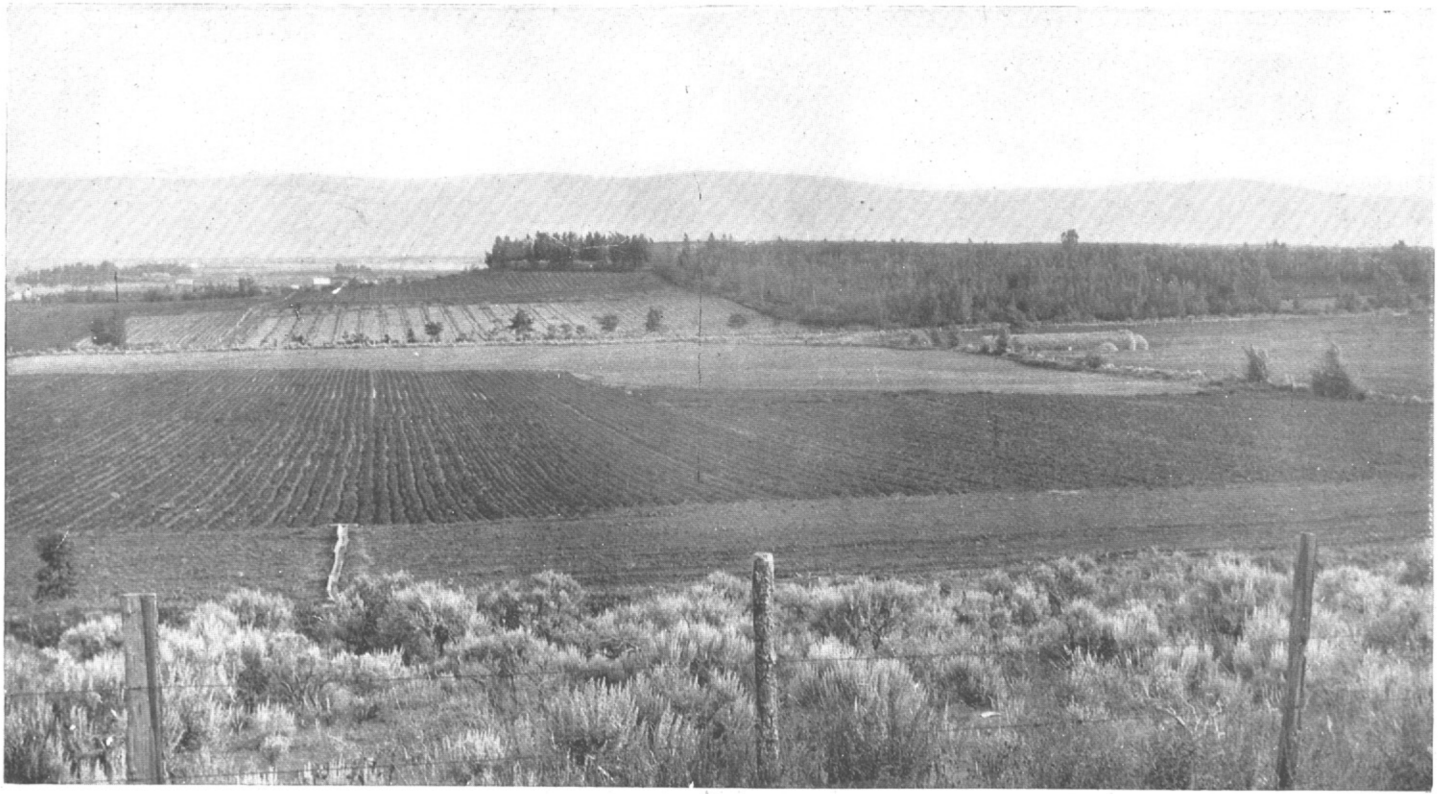
The areas in the Sunnyside district mapped as Meadow are level. The bluff indicated between the Yakima sandy loam and Meadow, in the western part of the district, is from 8 to 10 feet high in the western extremity and gradually becomes higher until a height of about 65 feet is reached at Zillah. This height continues to the western end of Snipes Mountain, from which place the bluff is from 6 to 10 feet high, owing to a lower level of the surrounding land. This bluff has been formed by the action of the river, which at present is washing away the bank at Zillah. Between this bluff and the Sunnyside Canal, in the western part of the district, the area is level. In and around Zillah, and extending southeast for 3 or 4 miles, the country is hilly, being intersected by draws from the foothills of Rattlesnake Mountain. The sides of some of these hills have a slope of 10° to 15°. They are, however, cultivated. The area between Snipes Mountain and the canal is nearly level, except for a few shallow draws along the canal, as is also the country in and around Sunnyside and between the Yakima River, Snipes Mountain, and Sunnyside, with the exception of a few sand hills and ridges that rise only 8 to 15 feet above the general level. The area from the Rocky Ford lateral east to the limit of the map is 50 to 100 feet higher than the country to the west of that lateral, and forms a plateau with a general slope toward the Yakima River, with an occasional outcropping of basalt. The area north of the constructed canal is in general more level than that portion immediately under the canal, there being but few draws deep enough to interfere with cultivation. The general slope toward the canal is gentle, and this would be very desirable land if it could be irrigated.

GEOLOGY.

In Middle Tertiary time the whole central portion of Washington, and probably much of Idaho and Oregon, was covered by the waters of a great lake, known as Lake John Day. Into this lake streams carried the sand and mud held in suspension in their waters, while volcanoes in times of violent eruption threw into it vast quantities of volcanic dust, ashes, and lapilli. The lake beds are hence composed of alternating strata of volcanic dust, gravel, sand, and finer soils, and are also interstratified with a widely spread sheet of basalt, as well as a number of more local sheets. This formation is known as the John Day system. The same formation is found on John Day River in Oregon, and was first studied there. (See figs. 14, 15.)

Since the deposition of the beds above mentioned the underlying Columbia lava, together with the superimposed John Day beds, has been raised and broken in various places, giving rise to the present relief of the area. Most of the soft beds have been removed from the tops of the ridges and hills by erosion, bringing into bold relief in many places the underlying basalt.

The soil forming the surface of the area surveyed varies in thickness, so far as ascertained, from a few feet to 50 or 60 feet, although it is probably much thicker than this in places. Underneath this soil covering is a thick stratum of waterworn (principally basaltic) gravel and cobbles, varying in size from 2 to 12 inches in diameter. The gravel is remarkably well rounded and polished, showing that it has been subjected to an extended water action.



General View of Farming Lands in Moxee Valley.

The country is generally level, with but few slight ridges, as shown in the illustration.

On the invasion of the icebergs from the north, long after the John Day beds had been raised, the lake drained into the Pacific, and the present physiography established, another lake was formed in the central and eastern portion of Washington, known as Lake Lewis. This was not so extensive as the Tertiary lake and was probably not of long duration, as very little lake sediment accumulated during its exist-

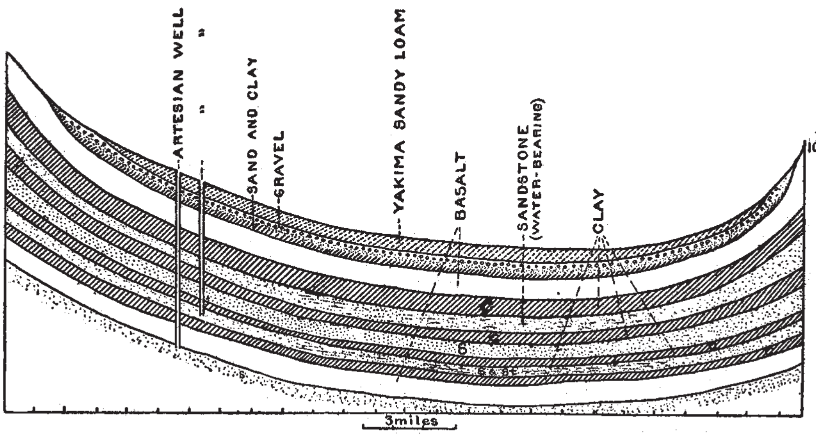


FIG. 14.—Section through Moxee Valley. *S*, sand; *S & St*, sand and sandstone; *c*, clay.

ence and the lake shores are not generally well marked, although one may be quite plainly seen on the ridge forming the north boundary of the Atanum Valley, near the western limit of the area.

There are a number of cuts and exposures showing the position of the successive strata of the John Day beds, but none better than the

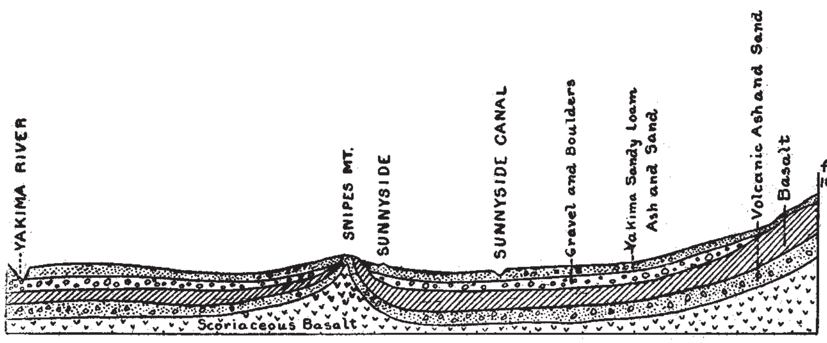


FIG. 15.—Section north and south through Sunnyside.

cut made during the spring of 1901 in building the Selah and Moxee Canal. Another interesting exposure occurs on Snipes Mountain. An examination of the fault exposed on the south side of that mountain showed successive layers of soil, volcanic ash, coarse sand, fine sand, big chert gravel, basalt, partially metamorphosed volcanic ash, loosely consolidated volcanic ash, and consolidated sand and volcanic ash mixed, the strata occurring in the order named, beginning at the top. (See fig. 16). The latter product is used to some extent for foundations of cellars, etc.

The volcanic dust and lapilli form a very considerable portion of the beds and are highly siliceous, differing widely from the basic basalt underneath. Russell gives it as his opinion that fully one-half of the John Day beds is volcanic dust.

A very noticeable feature in the Sunnyside district, and to some extent in the Moxee Valley, is the large quantity of schistose, basaltic, and granitic gravel and bowlders in many places found on the surface. These rocks and bowlders were dropped into Lake Lewis by the invading icebergs from the north, and furnish abundant evidence that that lake contributed little to the soil deposits, for otherwise this foreign material would in all likelihood have been covered up.

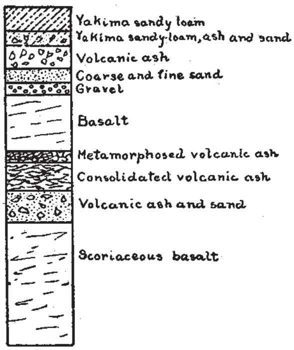


FIG. 16.—Section exposed in Snipes Mountain, Yakima area, Washington.

The only considerable break in the lake beds within the areas surveyed is Snipes Mountain, lying just west of Sunnyside town site. This mountain is a fault in the Columbia lava, protruded through the even and level valley floor surrounding it. The mountain is about 8 miles long and rises from 400 to 500 feet above the valley floor. There is a longitudinal valley in the western portion of it, caused by the eroding away of its crest, which presents a good view of the various strata to a depth of 200 or 300 feet.

CLIMATE.

Yakima County is decidedly an arid region, and agriculture without irrigation is not successful except in the lower areas, where the subsoil water comes sufficiently near the surface to supply the necessary moisture. The temperature during the summer months is sometimes high, but on account of the low relative humidity it is not oppressive. The winters are mild, though occasionally the mercury goes below zero, and the snowfall is not heavy in the valleys and soon disappears. The rivers and creeks are well supplied with water from the portion of the Cascade Mountains that drains through the county.

The Moxee Valley is visited by winds in the springtime, coming usually from the west and traversing the valley longitudinally. The Atanum Valley, being somewhat sheltered by the surrounding ridges, is not subject to severe winds. The Sunnyside district is more open and exposed to the wind, which is more frequent and stronger than in the Moxee Valley. In the spring of 1901 it caused some trouble in both the Moxee Valley and the Sunnyside district, but more in the latter place, by blowing away the surface of the newly broken and planted fields, necessitating the reseeding of much land. In some places also the young vegetation was covered up by the transported soil.

The following tables, prepared from the reports of the Washington section of the United States Weather Bureau, climate and crop service, show the normal monthly and annual precipitation and normal monthly and annual temperature for the Moxee Valley and Sunnyside district. The normal rainfall in the Moxee Valley is 9.33 inches, while that for the Sunnyside district is only 6.36 inches. With the exception of June, July, and August, the precipitaticn for the districts is quite evenly distributed. This amount of rain barely more than freshens vegetation, and of course does not decrease the necessity for irrigation

The mean annual temperature is higher by 1.6° F. in the Sunnyside district than in the Moxee Valley. The highest temperature recorded in the years 1898–1900 in the Moxee Valley was 105° F. on August 10, 1898; and the highest recorded for the same period in Sunnyside was 108° F. on the same date. A characteristic of the district is the comparatively low night temperature. No matter how warm it gets during the day, the nights are deliciously cool. The minimum temperature recorded in the Moxee Valley for the three years mentioned was −15° F. on January 4, 1899, and in Sunnyside −16° F. on the same date.

Normal monthly and annual temperature and precipitation in Moxee Valley and Sunnyside district.

Month.	Precipitation.		Temperature.	
	Moxee.	Sunny-side.	Moxee.	Sunny-side.
	Inches.	*Inches.*	°*F.*	°*F.*
January	2.30	1.37	29.7	31.3
February	.74	.36	34.4	35.3
March	.46	.10	43.6	44.5
April	.47	.16	50.1	51.9
May	.96	.57	57.0	58.3
June	.32	.21	64.6	66.5
July	.09	.12	71.7	75.0
August	.19	.32	67.5	68.8
September	.28	.43	61.1	62.6
October	1.22	.36	47.8	49.5
November	1.27	1.42	39.0	40.6
December	1.03	.94	32.4	33.9
Year	9.33	6.36	49.9	51.5

The following table shows the dates of the latest and earliest killing frosts in the spring and in the fall, respectively. As mentioned in the chapter on "Crops and Yields," fruit was injured in 1900 by a severe frost occurring after the trees had been forced into blossom by an early spring. In 1901 the season was three or four weeks later, and frosts injured only the earliest fruit, and then only in some parts of the area.

Generally speaking, the climate of the section is very good and quite favorable to orcharding, though the growers would find it advantageous to confine themselves mostly to late-blooming varieties of fruits. Though late spring frosts are not the general rule, they come often enough to make the growing of early blooming fruit somewhat risky.

Dates of killing frosts.

Year.	Last in spring.		First in fall.	
	Moxee.	Sunny-side.	Moxee.	Sunny-side.
1898	Apr. 2-4 June 28[a]	Apr. 2-4 June 28[a]	([b])	([b])
1899	May 13	May 12	Oct. 1	Oct. 10
1900	Apr. 27	Apr. 9	Sept. 26	Oct. 1
1901	June 7	Apr. —	Nov. 1	Nov. 1

[a] Reported by United States Weather Bureau as "Severe spring frosts occurred on April 2-4, and on June 28, in the eastern part of Washington," and "Beans and other tender plants were nipped by frost on June 28 in the eastern counties."

[b] No early autumn frost mentioned in report.

SOILS.

Five types of soil were recognized in the area surveyed. The following table shows the acreage of each type and its distribution between the two areas:

Areas of different soils.

Soil.	Yakima sheet.	Sunny-side. sheet.	Total.	Part of whole area surveyed.
	Acres.	*Acres.*	*Acres.*	*Per cent.*
Yakima sandy loam	34,450	115,130	149,580	75.7
Sunnyside sand	....	20,660	20,660	10.4
Meadow	9,960	5,100	15,060	7.6
Yakima stony loam	6,590	2,370	8,960	4.5
River wash	3,580	....	3,580	1.8
Total	54,580	143,260	197,840	....

YAKIMA SANDY LOAM.

This soil occupies all of the Moxee Valley proper, the Wide Hollow district, and the northern portion of the Atanum Valley. It also occupies the northern, eastern, and western portions of the Sunnyside district, excepting the meadow along the Yakima River. The soil is typically a fine gray sandy loam, light and friable, and varies in depth from a few inches to 60 feet or more. For the first 5 or 6 feet the soil is

CROPS OF ALFALFA ON THE YAKIMA SANDY LOAM IN THE YAKIMA VALLEY.

quite uniform, but below this depth it consists of alternating strata of sand and fine sandy loam, with occasional gravel, until the bed of waterworn gravel and cobbles that underlies the whole area is reached. In T. 9 N., R. 22 E. the sand forms the entire subsoil to some depth, in places being found from the sixth to the seventeenth foot, and probably reaching still deeper. Volcanic ash is often met with in this type; sometimes on the surface and sometimes at various depths below it. This deposit usually occurs in beds varying in thickness from a few inches to about 2 feet, but the individual beds found in the soil are not very extensive in area. The surface of the soil is often strewn with glacial gravel and bowlders, but there is not enough of such débris to affect materially its physical properties.

The soil is derived from the sediments of the pre-glacial Lake John Day. Since the deposition of these sediments, crustal movements have taken place, the underlying basalt having been broken and raised in ridges and plateaus. Erosion has gone on sufficiently to remove most of the lake sediments from the higher and steeper ridges and hills, but the slopes generally retain part of the original lake bedding, so that the Yakima sandy loam is found covering many of the hilltops and practically all the slopes and valley floors. The basalt exposed on some of the hills and ridges in the vicinity of this type has not undergone sufficient disintegration to form any appreciable part of the soil. Owing to the light texture and friable nature of this soil it is easily washed and intersected with gorges by the irrigation water. The stratification, as originally produced by the deposition of the sediments in the lake, is preserved below a depth of a few feet, the surface bedding having been destroyed by water and wind action.

The areas of this soil, with a few exceptions, are generally well drained and free from excessive quantities of alkali. Some alkali is found in the subsoil, but unless the surface of standing water approaches sufficiently near the surface of the ground to permit it to reach the top by capillary movement the amount of alkali is not sufficient to prevent the growing of crops. When, however, by irrigation the level of standing water has been caused to rise to within a few feet of the surface, as has occurred over certain areas of this soil, the small percentage of alkali originally distributed uniformly throughout its depth accumulates on the surface and the soil is rendered sterile. The alkali conditions of this soil will be treated more at length in the chapter on "Alkali in Soils."

The Yakima sandy loam is the most important soil in the valley, both in point of extent (75.7 per cent of the area surveyed) and in the crops to which it is adapted. Its light, friable nature makes cultivation easy, and its great depth and natural fertility adapt it to the growing of any crop suited to the climate of Yakima Valley. The principal crops grown upon it are hops, alfalfa, clover, timothy, and fruit. The fruit consists chiefly of apples, pears, peaches, and prunes. Berries and truck are also raised to some extent. The soil is also well adapted to the cereals, but none of these are raised extensively. Sugar beets have been tried experimentally and seem to do well. This crop would have an advantage over hops in its greater stability of price, and over fruit in not being affected by the late frosts, which sometimes occur in this valley.

Hops do remarkably well, both in point of quantity and quality, and there is usually a good market for them. Considerable shipments of this crop are made to foreign countries. Fruit likewise flourishes, the soil being well adapted to it, and alfalfa grows luxuriantly, the soil being nearly ideal for this deep-rooted crop. Timothy and clover, usually mixed, are extensively raised, and there is a good market for all kinds of hay in the Sound cities and in Montana.

There are three phases of the Yakima sandy loam—the one without gravel, which has just been described, one in which gravel is prominent, and a loam phase, found in the Sunnyside district. The gravel phase forms but a small percentage of the area, and most of it is situated on the bench at the mouth of Wide Hollow, in and around Yakima, and in the northern portion of the Atanum Valley. These gravelly areas are indicated upon the soil map by symbols. This gravel consists of waterworn fragments of the same character as the gravel and bowlders making up the river bed, and ranges in size from very small gravel up to stones from 3 to 6 inches in diameter, though most of it has a diameter of between one-half and 1 inch only. The interstitial soil is typical Yakima sandy loam.

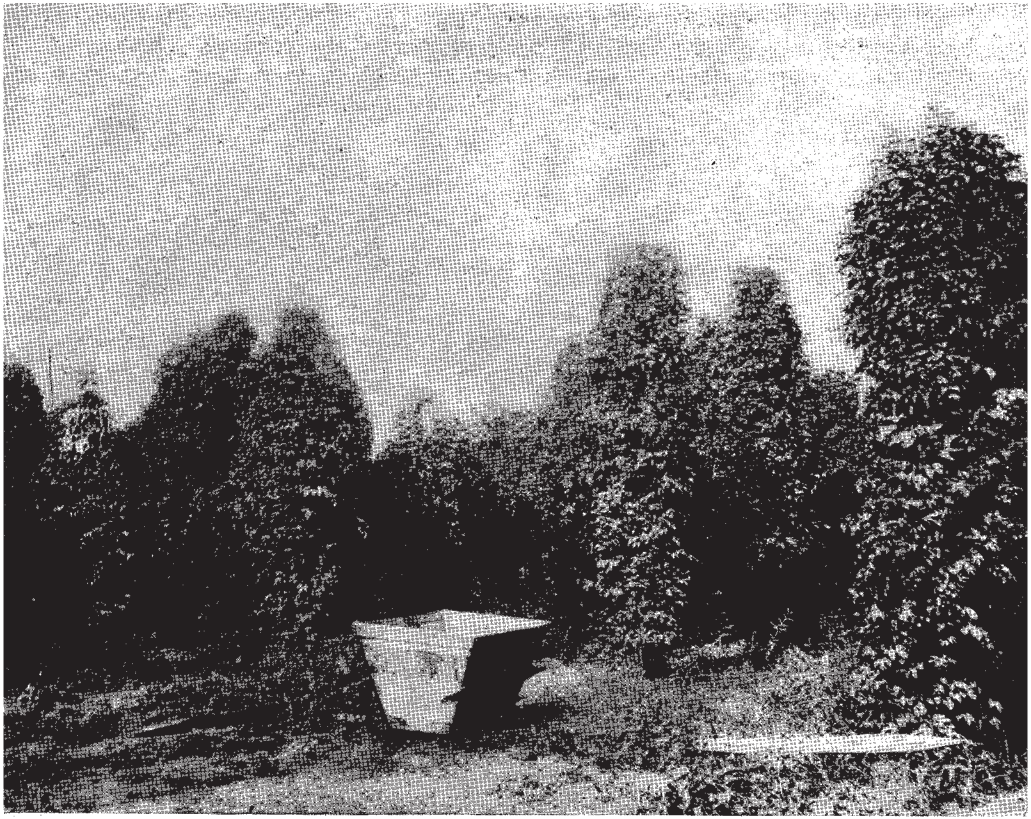
Fruits, alfalfa, and hops form the principal crops on this type, but neither crop does as well on this soil as on the nongravel phase. The gravel phase also requires more water than the other—an important consideration in an arid country.

The third phase of the Yakima sandy loam is found only in T. 9 N., R. 22 E. south of Sunnyside, and is not general, occurring at the surface in only small, local areas, very irregularly distributed. It varies in depth from 1 to 5 feet. In some other places in this township it is found at a depth of 1 or 2 feet below the surface, the surface soil being sandy loam and the immediate subsoil a sandy loam or sand. The loam usually contains small aggregations of clay that are difficult to separate and give the soil a gritty feel.

From a study of the nature and depth of the subsoil it seems probable that this loam is due to the filling up of former draws with fine transported material.

There is some alkali in this soil—a fact which will be considered further in another place.

This phase has not yet been cultivated, the whole area apparently being shunned on account of its supposed alkalinity. Rye planted in the autumn on this flat area does quite well without irrigation, but



HOPS, ONE OF THE PRINCIPAL CROPS OF THE MOXEE VALLEY.

where the loam reaches the surface crops would not be successful without first getting rid of the alkali.

The following table shows the mechanical analyses of samples of the typical soils and the gravelly phase of the Yakima sandy loam. Samples 5803 to 5805 show the mechanical conditions of the heavy subsoil in T. 9 N., R. 22 E., and also well illustrate the capacity of such soils to hold large amounts of salts. A somewhat noteworthy feature of this type is the large percentage of silt it contains as compared with the generally small amount of clay.

Mechanical analyses of Yakima sandy loam.

[Fine earth.]

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Surface soil, 0 to 12 inches in depth.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5796	Cen. sec. 12, T. 10 N., R. 21 E.	Sandy loam, virgin soil.	0.04	3.30	1.50	3.08	2.06	5.96	34.82	45.04	3.98
5802	W. cen. sec. 24, T. 9 N., R. 22 E.	Sandy loam, virgin soil.	.14	.88	......	.20	.82	7.78	6.06	78.68	4.30
5806	E. cen. sec. 25, T. 13 N., R. 18 E.	Sandy loam, 17 per cent coarse gravel.	.02	2.72	4.82	18.32	14.94	17.28	7.16	26.42	7.26
5364	Cen. sec. 36, T. 13 N., R. 18 E.	Sandy loam	.03	3.58	.94	3.21	7.11	22.16	22.14	31.97	8.89
5358	Cen. sec. 27, T. 13 N., R. 19 E.	Sandy loam	.02	4.40	Tr.	.60	1.27	5.03	10.94	60.75	16.45
		Subsoils 24 to 36 inches in depth.									
5797	Under 5796........	Sandy loam.......	.48	2.46	.24	.30	.42	2.84	41.26	47.80	4.06
5803	Under 5802........	Loam.............	.73	5.60	.12	.46	1.02	4.40	7.70	61.62	19.51
5365	Under 5364........	Sandy loam.......	.02	2.94	1.12	3.52	9.88	31.35	26.32	18.92	6.22
5359	Under 5358........	.....do	.09	4.06	.57	1.69	2.87	10.06	14.13	55.73	10.60
		Subsoils 48 to 60 inches in depth.									
5798	Under 5797........	Sandy loam.......	.24	2.08	.10	.16	.80	4.56	39.66	45.64	5.74
5804	Under 5803........	Clay loam	.08	6.96	1.20	2.10	.90	3.00	3.80	53.76	28.42
5366	Under 5365........	Light sandy loam.	.06	2.34	2.60	9.09	19.88	34.39	13.27	13.73	4.27
5360	Under 5359........	Sandy loam.......	.23	3.50	Tr.	1.60	3.94	18.21	22.50	41.14	8.40
5805	Under 5804........	Loam, 72 to 84 inches.	......	4.90	3.98	3.46	1.42	.56	2.12	61.26	22.62

SUNNYSIDE SAND.

This soil is typically a medium to fine sand, and is the lightest type found in the area surveyed. It is found only in the Sunnyside district, and there occurs at the western end and north of Snipes Mountain, in and around Sunnyside, and in an area extending for several miles southeast of that town. The soil varies in depth from a few inches to 7 or 8 feet, and the subsoil is the same as that of the Yakima sandy loam. Much, and probably most of it, is a wind deposit, which accounts for its irregular depth. There are many sand dunes and ridges in the area, some lying along the river being about 15 feet high.

This sand is still being slowly drifted by the wind, except where it is held by sagebrush or other native growth. Most of this type, and also of the Yakima sandy loam, was still in native vegetation when the survey was made, being covered generally with sagebrush and rabbit bush. Some portions of this type cleared during the fall and spring preceding the making of the survey, owing to its loose and incompact nature, and its being no longer shielded by vegetation, was affected sufficiently by the wind to require reseeding. This trouble, however, will cease when the ground becomes more generally covered by some permanent crop.

The Sunnyside sand is well adapted to truck, berries, alfalfa, clover, timothy, and fruit. It is usually well drained and free from alkali, but in respect to this is subject to the conditions that were described under the Yakima sandy loam.

Mechanical analyses of Sunnyside sand.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5793	⅛ mile N. of E. cen. sec. 8, T. 9 N., R. 23 E.	Virgin soil, 0 to 12 inches.	0.03	1.50	0.10	0.30	1.50	40.72	30.78	22.00	2.97
5790	SE. cor. sec. 31, T. 10 N., R. 23 E.	Virgin soil, 0 to 12 inches.	.01	2.18	.34	1.48	9.46	38.18	39.86	5.66	3.13
5794	Subsoil of 5793....	Sandy loam, 24 to 36 inches.	.04	1.42	Tr.	.18	.68	14.90	15.94	63.22	3.10
5791	Subsoil of 5790....	Light sandy loam, 24 to 36 inches.	.05	3.24	.14	.76	3.74	18.26	41.58	27.08	4.79
5795	Subsoil of 5794....	Light sand, 48 to 60 inches.	.05	2.00	......	Tr.	Tr.	19.96	58.30	16.00	3.77

MEADOW.

This name was given to the soils along the Naches and Yakima rivers and Atanum Creek. There are two phases of this type; the

FIELD OF CLOVER AND ORCHARD ON YAKIMA SANDY LOAM IN THE SUNNYSIDE DISTRICT.

This shows also the gently rolling character of the country. (Photograph furnished by W. N. Granger.)

first, the sandy or sandy loam soil, with occasional gravel, which occurs along the Naches River, Atanum Creek, and Yakima River in the Moxee Valley and in the Parker Bottoms, lying along the Yakima River in the western part of the Sunnyside district; and the second, the loam and clay loam phase, which occurs only in T. 9 N., R. 22 E., or just south of Sunnyside.

The first phase is usually a sandy loam, though sometimes the texture is that of sand, varying from a few inches to about 7 feet in depth. The surface is level and often somewhat low as seen by the water sketch map, but only a small area is subject to overflow. The soil is of river formation, and is underlain with waterworn gravel—the former river bed—which occasionally reaches the surface. It usually carries considerable organic matter, especially in the surface foot.

On some of the higher portions of this type hops and fruit are raised to a limited extent, and along the Atanum Creek some grain is produced, but, generally speaking, the type is preeminently a hay and grass soil, while the more brushy portions of it are used principally as pastures for dairy cattle. Considerable alfalfa is raised on the Parker Bottoms, where it does exceptionally well. Hops and fruit do not flourish on the meadows as they do on the uplands.

Very little irrigation is needed anywhere on this type, as the subsoil water is quite near the surface. This water, however, carries considerable salt, and that in the Parker Bottoms is no doubt getting more salty as the irrigation increases on the lands above the meadows.

The only place where this soil itself carries so much salt as to be detrimental to plant growth is in the lower portion of the Atanum Valley, which will be referred to in another place.

The second phase of this type, which occurs in T. 9 N., R. 22 E., along the river south of Sunnyside, is of but small extent. It is a loam or clay loam soil, carrying a high percentage of organic matter and varying in depth from about 4 to 7 or 8 feet. It is always free from gravel. Excepting an occasional small tule swamp this area is not subject to overflow from the river and is used mostly as pasturage. No cultivation of the meadows has been attempted, though some hay is cut from them. This soil, also, is of river formation, but it is heavier than the other phase on account of the rather sluggish movement of the river at this place, which has afforded the transported clay particles an opportunity to subside. There is very little alkali in this type.

The following table of analyses shows the sandy loam phase to be practically the same mechanically as the Yakima sandy loam, excepting the organic content, which is greater in the Meadow. Nos. 5807 and 5808 show the loam phase of Meadow south of Sunnyside to be considerably heavier than the other phase of this type.

2889—02——26

Mechanical analyses of Meadow.

[Fine earth.]

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Surface soils, 0 to 12 inches in depth.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5369	¼ mile W. of cen. sec. 28, T. 13 N., R. 19 E.	Truck soil	0.05	3.90	0.30	3.24	6.60	33.66	27.64	19.90	4.17
5367	¼ mile S. of cen. sec. 3, T. 12 N., R. 18 E.	Wheat and hay land.	.0	8.17	Tr.	.39	1.11	7.48	8.76	65.26	8.46
5809	Cen. SE. ¼ sec. 17, T. 11 N., R. 20 E.	Hay land	1.70	6.28	......	1.02	1.94	11.12	5.64	57.70	11.76
5807	Cen. NE. ¼ sec. 26, T. 9 N., R. 22 E.	.....do	.06	7.76	.04	.52	.86	3.84	4.56	66.22	15.22
5368	Under No. 5367	Coarse gravel 37 per cent, 12 to 18 inches.	.02	6.52	.87	3.48	5.18	14.20	10.80	48.48	8.57
		Subsoil 24 to 36 inches in depth.									
5810	Under No. 5809	Sandy loam	.67	3.84	.14	1.32	2.36	25.96	23.10	34.62	9.05
5808	Under No. 5807	Loam	.07	4.94	......	.16	.26	2.50	8.88	65.02	18.13

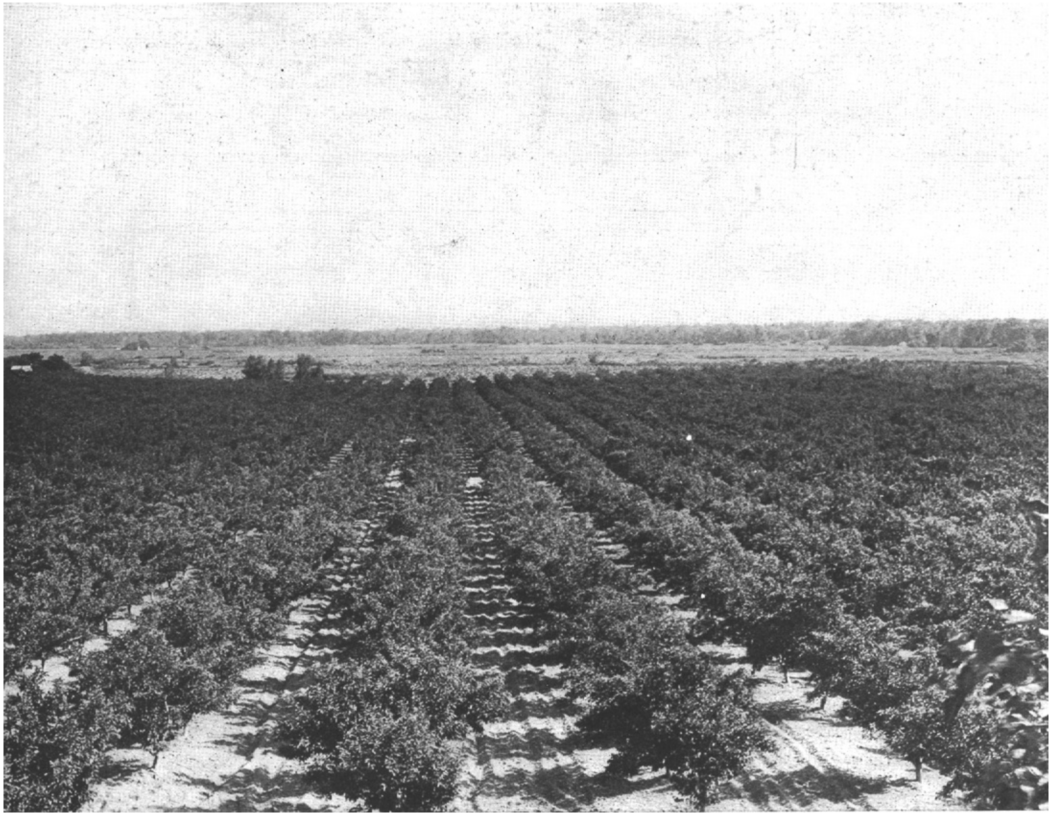
YAKIMA STONY LOAM.

This soil occurs at the eastern end and northern side of Moxee Valley and again north of Prosser in the Sunnyside district. It consists of an intermixture of basaltic gravel and bowlders with the Yakima sandy loam, and is marked here and there by outcrops of basaltic ledges. This type has been derived by the removal of the soft John Day beds by erosion, as is evidenced by the exposure in many places of the underlying basalt. The area in the Moxee Valley is not of much value for cultivated crops, being better adapted to grazing. In the Sunnyside district, as noted on the soil map, the type does not form a continuous area, but contains many small areas of good soil. Very often the largest bowlders are picked off and the land cultivated.

No mechanical analysis is given of this type, as the interstitial soil is Yakima sandy loam. The rocks and bowlders are too large to enable their percentage to be determined in small samples.

RIVER WASH.

This type, which forms about 7 per cent of the North Yakima area, is a coarse river wash, consisting of a large admixture of waterworn



An Orchard on the Meadow Land in Parker Bottom in the Sunnyside District.

gravel and many large bowlders 6 to 10 inches in diameter, and having the interstices between this coarser material filled with sand or sandy loam. In some places the bowlders constitute the greater part of the soil. The type is the result of river action, being the former bed of the Naches River, which carried most of the finer soil farther down the valley. It occupies a narrow strip extending from the mouth of the Naches Canyon down through North Yakima to about 1½ to 2 miles north of that town. The width of the area varies from one-half to about 1 mile.

On account of the small amount of soil and the large amount of gravel and cobbles it contains this type is generally unproductive, though there is an occasional area of good soil that is used to produce truck. Where the soil is a few feet deep, cherries and peaches do well on it. These productive areas, being irregular and small, are not indicated on the soil map. This type is not now subject to overflow, usually lying from 8 to 20 feet above the river bottom.

The fertile spots being Yakima sandy loam, no mechanical analysis is given of this type.

HARDPAN.

Some sodium carbonate hardpan was found in a few places in Wide Hollow, but the formation was not sufficiently general to warrant mapping. Traces of such a formation were also found in sec. 35, T. 13 N., R. 18 E., and some in sec. 1, T. 12 N., R. 18 E. It was not, however, a typical hardpan, and was only from one-fourth to one-half an inch thick and easily bored through.

A little lime hardpan lying about 3 feet below the surface is found in the Sunnyside district, but it usually occurs on the sides of cuts, and is not sufficiently consolidated over the area in general to be noticed in boring. It is, however, plainly visible in some places along the canal banks and in cuts, where it forms more readily than in the soil itself.

ALKALI IN SOILS.

The salt content in the first 6 feet of soil, as shown by the alkali map (Pl. LVIII) of the Moxee and Atanum valleys, is the mathematical mean percentage of salt as determined in foot sections of soil at water saturation by means of the electrolytic bridge. The map (Pl. LIX) showing the percentage of water-soluble alkaline carbonates, or black alkali, represents the surface foot, and the percentage was determined directly in the field by titrating with potassium acid sulphate ($KHSO_4$) with phenolphthalein as the indicator. In this titration the soil was used in the proportion of 11.80 cc. saturated soil to 250 cc. water.

In the Moxee Valley practically the only places containing injurious amounts of alkali in the first 6 feet of soil are in the eastern and southwestern portions of the valley. East of the area mapped, however, there are quantities of alkali in the soil and some coatings on the surface, but fortunately there is practically no water in that section, and the salts are not likely to be carried down to the cultivated areas in sufficient quantity to become dangerous.

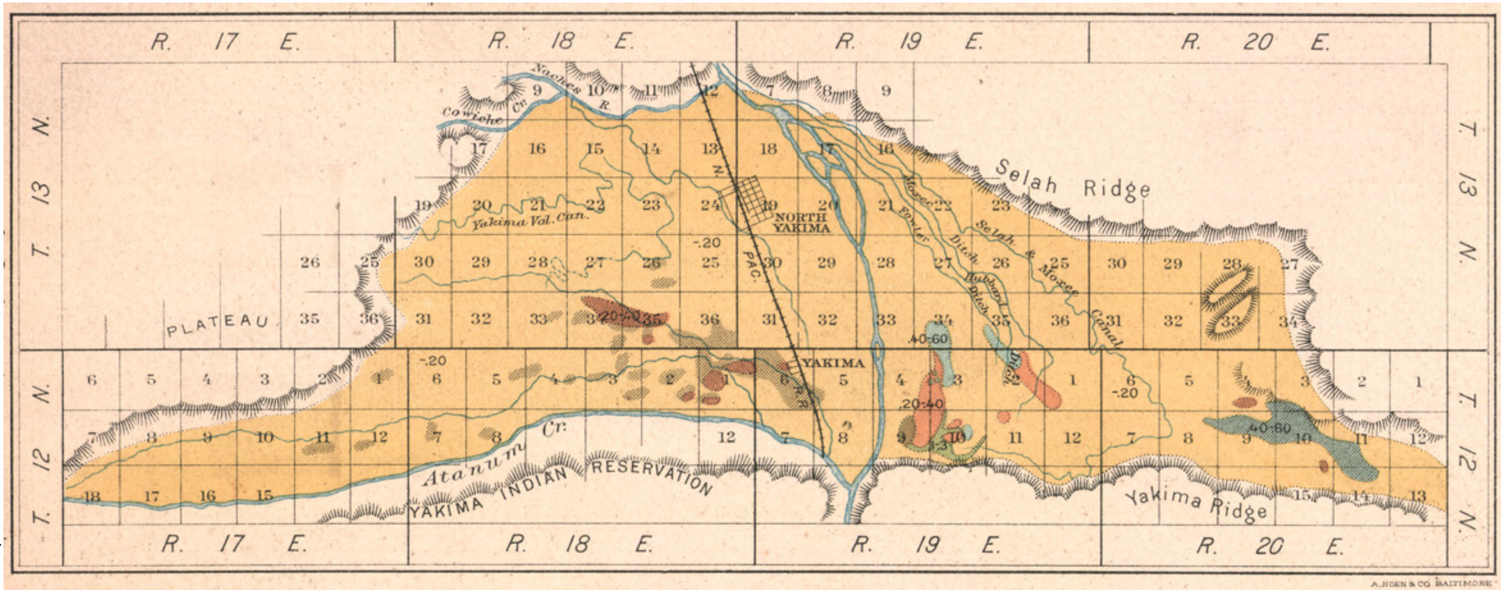
The alkali found in the southwestern portion of the valley is of a different character from that in the eastern portion, containing more chloride and less normal carbonate. This alkali seems to come from the foothills, as coatings of salt occur on the slopes. Most of sec. 6, T. 12 N., R. 20 E., and the immediately surrounding land is level. It is covered with a growth of greasewood, which has given rise to the general idea that it contains injurious amounts of alkali, and seems to have been avoided for this reason. A number of determinations, however, showed that there was no alkali in the first 6 feet, i. e., less than two-tenths of 1 per cent of total salt, or not enough to injure crops.

The alkali conditions in Wide Hollow and the Atanum Valley are more serious. Many places that were formerly among the best in the area have been abandoned to salt-grass and greasewood. The mean salt content in the first 5 or 6 feet is not great, however, being in no place more than four-tenths of 1 per cent, with the maximum salt content in the surface foot. Very often, however, the salt in the first foot is from one-half to three-fourths black alkali, and an accumulation on the surface is very common. There is a surprisingly small amount of chloride in this area. In the upper part of the Atanum Valley there is not much alkali, as it has been washed down by the water, either in irrigation or in the movement of the subsoil water, which is generally near the surface.

A comparison of the black alkali map (Pl. LIX) with the underground water map (Pl. LX) shows that the most salt occurs where the water is nearest the surface—3 feet to 6 feet—and in sections 23 and 24 in T. 12 N., R. 18 E., where the alkali conditions are worst, the water is much nearer 3 feet than 6 feet, and therein lies the trouble. The seepage water from irrigation in the upper part of the valley and from the bench lands to the north follows the subsoil strata down to these low places, and there by capillarity is brought to the surface to evaporate.

The upper part of the valley is not likely ever to become sufficiently alkaline to cause trouble, as the gravel is near the surface and has sufficient slope to make the natural underdrainage good.

It is well known that the black alkali is much more injurious than the white, the same percentage considered. A good illustration of this was found on a small spot in an orchard situated in the upper portion of the Atanum Valley. A few trees on the salty area were either dead or dying, and an examination made within a few inches of the trunk of a dead tree showed in the first foot, which carried the



ALKALI MAP, YAKIMA SHEET

maximum, only 0.15 per cent of salt, while the mean of the first 3 feet was less than 0.10 per cent. An equal amount of white alkali would have had no injurious effect whatever, but the percentage of sodium carbonate carried in the surface foot is sufficient to account for the condition of the trees.

Another interesting case was found in the lower portion of the valley, where fruit trees were growing in soil containing 0.21 per cent of sodium carbonate in the surface foot, with a heavy coating of the same salt all over the surface. The ground around the trunks of the trees, however, had received a liberal coating of stable manure, which had been applied some time before. The trees did not have a healthy appearance, being yellowish in color and later in season than the trees on better soil, and some were either dead or dying. This condition, however, was probably due in part to the fact that the subsoil water was within 3½ feet of the surface, which is too close to allow a healthy condition of fruit trees. An examination of the soil without the manure showed the presence of 0.21 per cent of sodium carbonate, 0.17 per cent of sodium hydrogen carbonate, and 0.04 per cent of chloride in the surface foot. The surface foot under the manure showed sodium carbonate 0.10 per cent, hydrogen carbonate 0.17 per cent, and chloride 0.06 per cent. The surface foot unaffected by manure carried 0.80 per cent of soluble salt, while the surface foot under the manure carried 0.50 per cent. This observation would seem to indicate that the application of manure decreases somewhat the percentage of alkaline carbonates, probably by acting as a mulch and decreasing evaporation. The data obtained, however, are not sufficient to warrant the drawing of a definite conclusion.

The only alkali accumulation in the soils of the Sunnyside district was found in T. 9 N., R. 22 E., in secs. 15, 16, 21, 22, 23, 24, and 25, and a little in sec. 14. Altogether the alkali area is not more than 2 square miles in extent. The percentage of salt in these places varies from 0.40 per cent to 3 per cent in the first 6 feet, but in about one-half the areas the content ranges from 1 per cent to 3 per cent of salt. All of this area contains black alkali in the surface foot in amounts varying from 0.05 per cent to 0.30 per cent, but much the greater portion of it carries only from 0.05 per cent to 0.10 per cent. The greasewood, which is popularly supposed to indicate alkali soils is distributed quite independently of either the total salt content or the black alkali, though it was always found where a large amount of salt occurred. By a large number of determinations it was found that the township is not nearly as alkaline as it has been thought to be. It is universally the case that the highest percentage of salt content occurred in the heavy phases of sandy loam. Usually the maximum salt content was in the fourth or fifth foot.

There were alkaline carbonates in all the determinations made, and sulphates were always present. The chlorides varied somewhat in relative quantity, but were never high, and the amount of bicarbonates was also moderate. Neither the percentage of total salt nor of black alkali was high where the soil was light and underlain with sand.

On the north slope of Snipes Mountain, at its eastern end, considerable salt occurs, but, excepting a small area at the foot of the mountain, the salt is 5 or 6 feet below the surface, and is practically all sulphate.

In the Parker Bottoms in section 21 a little alkali was found which was supposed to be black alkali. The ground was colored dark brown and black in places, resembling black alkali, but the salt was bicarbonate and sulphate. It is known that bicarbonates and sulphates have the power of charring organic matter to a slight extent, but the black color found here may also have been due to the presence earlier in the season of alkaline carbonate which had been converted into the bicarbonate later by aeration. A 12-foot boring made near the center of the southwest forty of sec. 6, T. 11 N., R. 20 E., on the bench land just north of the road showed a maximum of 0.15 per cent in the eleventh and twelfth feet. A 13-foot boring was made above the Sunnyside Canal, about one-fourth north of the northeast corner of sec. 36, T. 11 N., R. 20 E. The maximum was found in the sixth foot, with about 0.12 per cent. The twelfth foot contained a heavy trace of carbonate.

The writer visited the same place about five weeks afterwards, and it was found that the constant irrigation and seepage from the canal had caused a coating of salt to be deposited on the banks of the canal and on the sides of a waste ditch near by. This accumulation was sulphate.

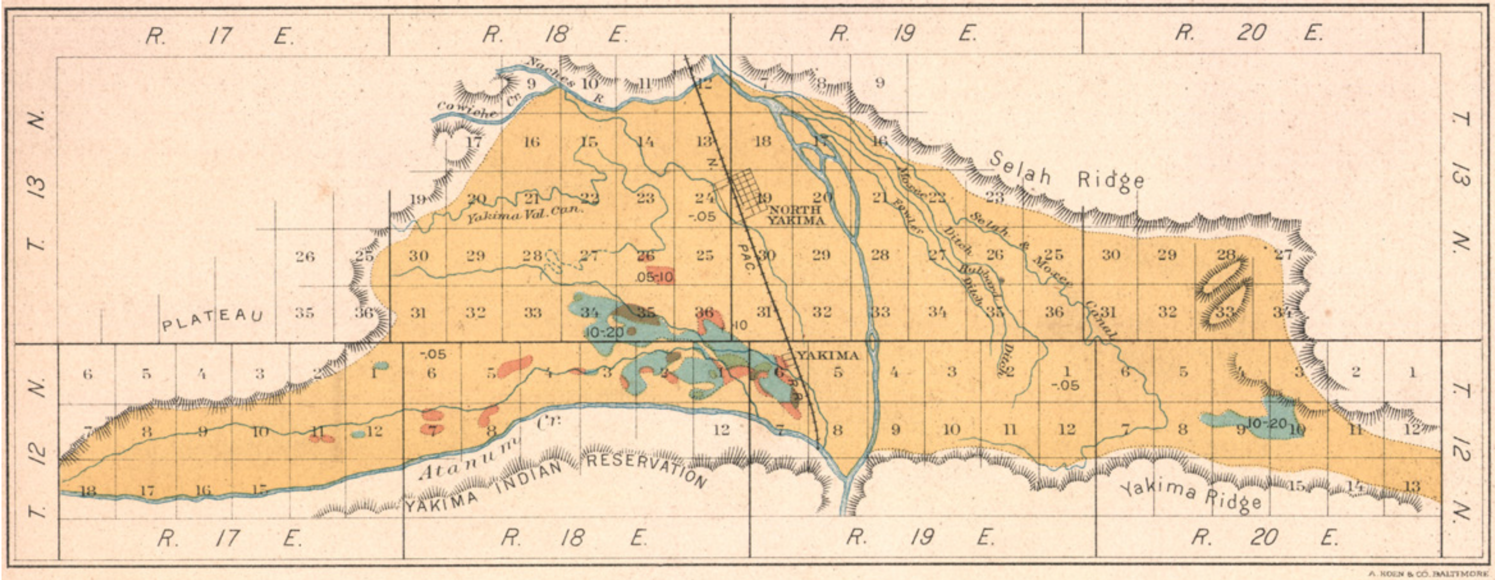
An 18-foot boring was made near the center of sec. 21, T. 12 N., R. 22 E., where the maximum salt content was found to be in the eleventh foot, which contained about 0.05 per cent total salt.

An 8-foot boring at one-fourth east of northwest corner sec. 32, T. 10 N., R. 23 E., showed the maximum salt content in the eighth foot, with 0.06 per cent total salt, and water at about 9 feet. A well about one-eighth of a mile from this boring was examined and found to contain about 300 parts of salt in 100,000 parts of water. This shows what the continued leaching of water through the soil will do if it is allowed to accumulate as subsoil water even where the soil itself carries only a small amount of salt.

The above determinations show that the soils in the Sunnyside district do not contain any large amount of alkali, but, though there is not yet any surface accumulation of salt, except in T. 9 N., R. 22 E., and at the bottoms of a few draws under the canal and on the canal banks, it will be shown in the chapter on "Seepage waters" that even in this district great care must be exercised in the use of irrigation water or trouble will ensue.

Report of Bureau of Soils, U. S. Dept. Agr. 1901.

Plate LIX



BLACK ALKALI MAP, YAKIMA SHEET

-.05	.05-.10	.10-.20	.20-.30	+.30
Less than .05 per cent	From .05 to .10 per cent	From .10 to .20 per cent	From .20 to .30 per cent	Over .30 per cent.

The following tables contain the results of chemical analyses of alkali in soils:

Chemical analyses of salts in alkali soils.

Constituent.	5815. Meadow near NW. cor. sec. 1, T. 12 N., R. 18 E., soil 0 to 12 inches.	5811. Meadow near NW. cor. sec. 1, T. 12 N., R. 18 E., soil 0 to 12 inches.	5816. Under No. 5815, sandy loam, 12 to 24 inches.	5812. Under No. 5811, sandy loam, 12 to 24 inches.	5813. Under No. 5812, sandy loam, 24 to 36 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	0.88	3.42	6.28	4.49	4.93
Magnesium (Mg)	.88	3.42	2.09	2.62	2.05
Sodium (Na)	30.69	28.52	19.46	16.11	14.00
Potassium (K)	5.07	4.94	4.79	8.61	9.05
Sulphuric acid (SO_4)	12.80	6.46	.59	1.49	4.52
Chlorine (Cl)	4.63	11.03	4.19	2.62	3.70
Carbonic acid (CO_3)	26.50	42.21	17.37	11.99	8.64
Bicarbonic acid (HCO_3)	18.55		45.23	52.07	53.11
Phosphoric acid (PO_4)				Tr.	
Nitric acid (NO_3)					
Conventional combinations:					
Calcium sulphate ($CaSO_4$)	2.86	9.12	.89	1.87	6.17
Magnesium sulphate ($MgSO_4$)	4.19				
Potassium chloride (KCl)	9.71		8.98	5.61	7.82
Sodium chloride (NaCl)					
Sodium bicarbonate ($NaHCO_3$)	25.40		22.46	36.72	45.28
Sodium carbonate (Na_2CO_3)	46.80	66.94	30.85	13.86	6.58
Sodium sulphate (Na_2SO_4)	11.04				
Calcium chloride ($CaCl_2$)		1.90			
Magnesium chloride ($MgCl_2$)		13.30			
Potassium carbonate (K_2CO_3)		8.74		9.73	8.64
Calcium bicarbonate ($Ca(HCO_3)_2$)			24.25	16.48	13.17
Magnesium bicarbonate ($Mg(HCO_3)_2$)			12.57	15.73	12.34
Per cent soluble	.92	.52	.67	.53	.48

Chemical analyses of salts in alkali soils—Continued.

Constituent.	5802. W. cen. sec. 24, T. 9 N., R. 22 E., sandy loam, 0 to 12 inches.	5803. Under No. 5802, sandy loam, 24 to 36 inches.	5804. Under No. 5802, loam, 48 to 60 inches.	5787. SE. cor. sec. 23, T. 9 N., R. 22 E., loam, 0 to 12 inches.	5788. Under No. 5787, loam 24 to 36 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	2.12	1.38	0.91	Tr.	1.86
Magnesium (Mg)	2.66	1.58	.91	0.38	1.70
Sodium (Na)	20.74	26.55	29.10	25.25	26.82
Potassium (K)	7.45	5.94	3.67	10.48	4.80
Sulphuric acid (SO_4)	13.83	23.37	22.68	32.04	27.92
Chlorine (Cl)	7.98	1.98	3.21	18.06	21.72
Carbonic acid (CO_3)	7.98	13.86	12.41	.98	5.42
Bicarbonic acid (HCO_3)	37.24	22.77	24.05	12.81	9.76
Phosphoric acid (PO_4)	....	2.57	3.06	Tr.	....
Conventional combinations:					
Calcium sulphate ($CaSO_4$)	6.91	4.75	3.06	Tr.	6.35
Magnesium sulphate ($MgSO_4$)	12.23	7.72	3.67	1.74	8.37
Calcium chloride (KCl)	14.36	4.15	6.89	20.00	9.14
Sodium chloride (NaCl)	1.59	....	....	13.98	28.50
Sodium bicarbonate ($NaHCO_3$)	51.08	31.50	33.08	17.67	13.33
Sodium carbonate (Na_2CO_3)	13.83	24.57	21.90	1.74	9.61
Sodium sulphate (Na_2SO_4)	....	14.65	26.19	44.87	24.70
Potassium sulphate (K_2SO_4)	....	8.31	....	....	....
Sodium phosphate (Na_3PO_4)	....	4.35	5.21	....	....
Per cent soluble	.38	1.01	1.30	1.03	1.29

The analyses given in the first part of the above table show the effect of stable manure on sodium carbonate in the soil.

Samples 5815 to 5817 represent the salt as unaffected by the fertilizer, and Nos. 5811 and 5813 show the character of the salt after the application of manure during the preceding winter. It is seen that in the first 2 feet there is a diminution of total soluble salt and also a decrease in the absolute amount of carbonate, though the percentage of carbonate in the first foot is greater where the manure was applied. It is interesting that there are no nitrates in the soil manured. As nitrates are very soluble, they had probably leached out of the soil.

Samples 5802 to 5804 show the distribution of salt downward in a salty area south of Sunnyside, in a sandy loam soil, and samples 5787 and 5788, the same in a loam soil not far from the other boring. It will be seen that the heavier soils carry more salt than the lighter ones, the increase being principally in sulphates and chlorides.

UNDERGROUND AND SEEPAGE WATERS.

The underground and seepage waters show the character of the soluble salt in the soil, and are to a certain extent indicators of the amount of salt the soil carries. Allowance must be made in the latter case, however, for the movement of the underground water, the concentration being, of course, less if the water has comparatively good circulation.

Chemical analyses of typical samples of subsoil water.

No. of sample.	Location.	Depth in feet.	Parts of salt per 100,000.			
			Total salt content.	Bicarbonates.	Chlorides.	Sulphates.
	MOXEE AND ATANUM VALLEYS.					
36	Wide Hollow slough, near W. cen. SW. ¼ sec. 36, T. 13 N., R. 18 E.	......	40	32	3	
41	Natural slough, cen. SW. ¼ sec. 35, T. 13 N., R. 18 E.	......	24	23	1	
53	Small spring, seepage, ⅛ SW. of cen. sec. 11, T. 12 N., R. 17 E.	......	30	28	Tr.	
16	Well, ⅛ W. of. E. cen. sec. 10, T. 12 N., R. 19 E.	14	353	121	183	Not tested.
21	Artesian well, about cen. sec. 9, T. 12 N., R. 20 E.	903	22	17.4	.5	
	SUNNYSIDE DISTRICT.					
94	Well, ¼ E. of SW. cor. sec. 18, T. 10 N., R. 22 E.	50	44	36	2	
102	Well, near E. cen. sec. 30, T. 10 N., R. 23 E.	15	44	33	Tr.	Slight.
109	Well, ⅛ N. of cen. sec. 35, T. 10 N., R. 22 E.	45	85	44	2	Heavy.
139	Well, ⅛ S. of NW. cor. sec. 29, T. 9 N., R. 23 E.	18	80	74	5	
140	Well, ⅛ E. of NW. cor. sec. 32, T. 10 N., R. 23 E.	7	431	64	24	Do.

The above table shows that practically the only salt found in the subsoil and drainage waters in the Atanum Valley is the bicarbonate. Sample 53 is a typical sample of the seepage water in this area, coming as it does directly out of the ground where the seepage water has come near enough the surface to make the ground quite wet; as seen, it carries only bicarbonates, except for a trace of chloride. Samples 36 and 41 represent quite well the seepage water which is being carried away continuously by the natural drainage channels. While the percentage of salt in these samples may not be considered high, it must be remembered that the water in these sloughs flows all the time, and that in the aggregate the amount of salt carried away is considerable. Sample 16 shows the character of the salt in the southwestern part of the Moxee Valley. It differs from the salt in the Atanum Valley in the considerable quantity of chloride present.

In the same table is shown the character of a few typical samples of the subsoil water in the Sunnyside district. It is seen that most of the wells are characterized by a rather high percentage of salt, the greater part of which is composed of sulphate and bicarbonate, with chloride present in smaller quantities. The seepage and subsoil water in the Parker Bottoms is of the same character as that farther down the district, but as a rule the salts in the water are not as concentrated. This is due to the fact that the subsoil water in the bottoms has a much freer circulation, and the salt is consequently being slowly carried away.

Sample 140 is the only one taken in the district where the subsoil water was within 10 feet of the surface when the survey was made, a condition existing over so small an area that no provision for it was made in the water map.

The sketch map (Pl. LXI) showing the character of the underground water was prepared from analyses of the well waters made during the survey. It will be noticed that the condition of the subsoil water in T. 9 N., R. 22 E., is better than in most other parts of the area, notwithstanding the fact that this is the only place where there was an excess of salt in the soil. The reason is that the subsoil here is a coarse sand which offers very little resistance to the movement of the underground water, and consequently the salt in the water does not reach a state of high concentration.

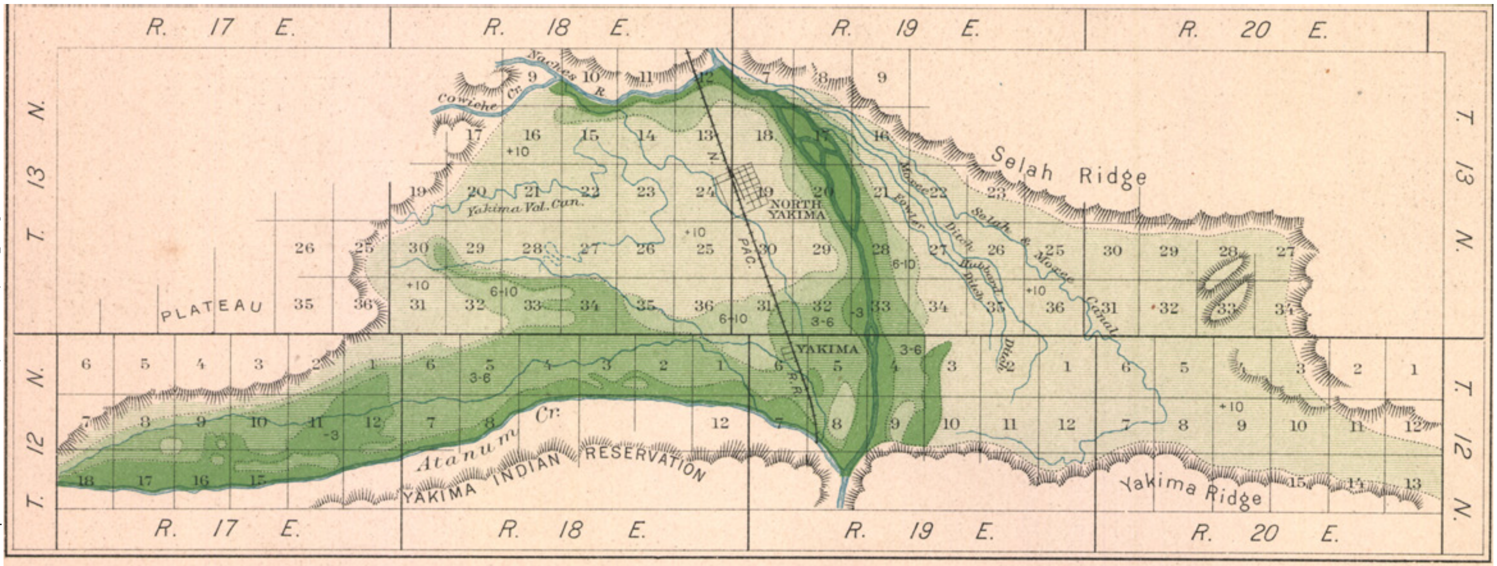
DRAINAGE AND RECLAMATION OF ALKALI LANDS.

The best way to reclaim alkaline lands that were originally good and the best way to prevent good land from becoming alkaline is to keep the subsoil and seepage waters that carry dissolved salts sufficiently far below the surface to prevent an accumulation of salt through evaporation. If the soil is originally alkaline, there is but one sure and permanent cure for the trouble, that is, to dissolve out the excess of soluble salt by moderate but frequent applications of good water, at the same time draining the water out of the subsoil; the process to be continued until the excess of salt has been removed.

More especially is this true in case of the areas that have become damaged by alkali by allowing the subsoil water to come near enough to the surface to form an accumulation of salt by evaporation, in which class are the damaged lands in Wide Hollow and the Atanum Valley. The salts accumulated in these places are alkaline carbonates or black alkali, and an examination of the seepage water shows that it carries in all cases more than a normal amount of bicarbonate, but no normal carbonate. Examination also shows that the seepage or subsoil water is sufficiently near the surface to be brought up by the capillarity of the soil grains to the surface, there to be evaporated. There can be but one consequence—the comparatively harmless bicarbonate will lose through evaporation some of its carbon dioxide and be converted into

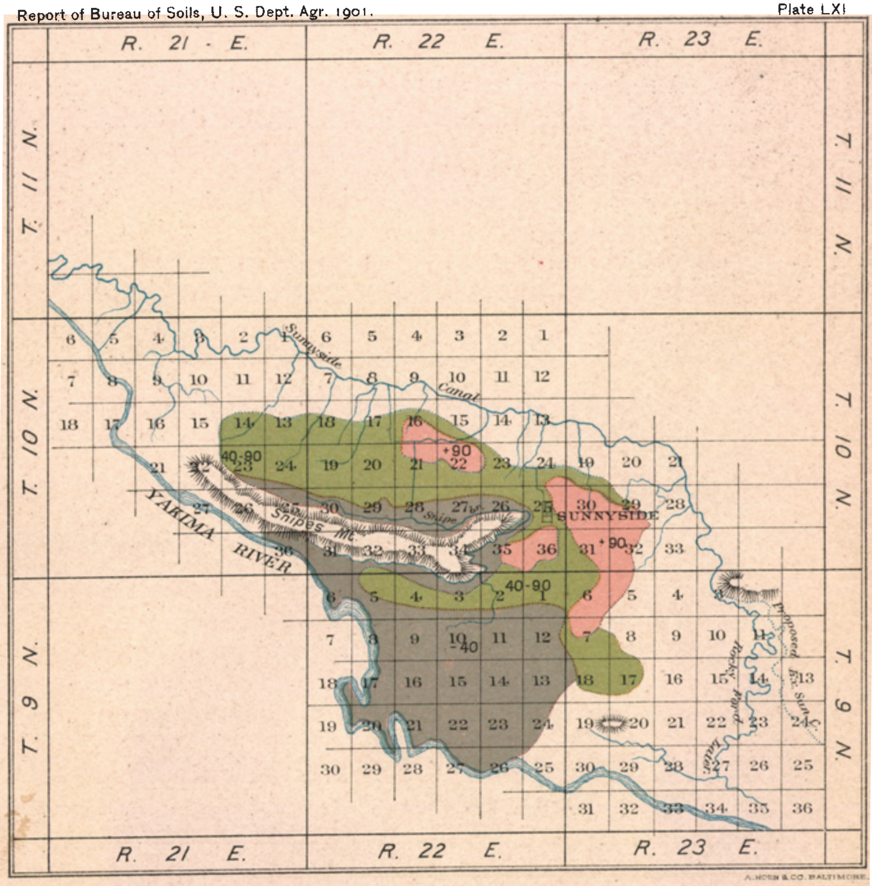
Plate LX

Report of Bureau of Soils, U. S. Dept. Agr. 1901.



UNDERGROUND WATER MAP, YAKIMA SHEET

-3	3-6	6-10	+10
Water less than 3 feet deep	Water from 3 to 6 ft. deep	Water from 6 to 10 ft. deep	Water more than 10 ft. deep



UNDERGROUND WATER MAP, SUNNYSIDE SHEET

-40	40-90	+90
Less than 40 parts	From 40 to 90 parts	More than 90 parts

the normal carbonate. As the soil is light in texture in this area this capillary action goes on quite rapidly; but on the other hand there is this advantage—the water can be removed from it correspondingly easier.

The alkali in the Wide Hollow and Atanum areas has originated from the seepage water brought down from the lands above. It will be quite useless here to try to effect a permanent cure by attempting to change the character of the salt by application of some other salt—as calcium sulphate, for instance—for while this will change some of the black alkali to white alkali it only adds more salt to a surface foot, already containing an excess, without in the least decreasing the tendency to form black alkali, which will continue to accumulate as long as the subsoil waters containing bicarbonate are near enough the surface to be evaporated.

In some areas in Wide Hollow the dangerous practice obtains of allowing the seepage water from above to subirrigate the land. This is a very good method of increasing the salt content of the soil, and the nearer the water approaches the surface and the longer the practice is continued, the more salt there will be accumulated.

The Wide Hollow waste slough forms an excellent natural drainage channel for the lower portion of Wide Hollow, from sec. 36, T. 13 N., R. 18 E., and below. This goes through much of the salty area, and is from 5 to 10 feet below the surface of the soil. The soil is light in texture, readily permitting the water to percolate through it, and frequent applications of water, with a few drains about 4½ to 5 feet deep, would accomplish much toward reclaiming the land. Another good natural drainage channel is the northern branch of Atanum Creek. It does not drain as large an area of the alkaline lands as the waste slough, neither is it as deep, but much of the land in the eastern part of T. 12 N., R. 18 E., could be reclaimed by draining into it. Atanum Creek itself would take care of the area between it and the branch just mentioned. A drain 4½ to 5 feet deep, containing rocks covered with willows, and this in turn covered over with soil would effect this, but tiles will be found more economical. Even open drains, where they would not interfere seriously with cultivation, would serve very well.

The good results of draining can already be noticed on a small area—a hop field—in sec. 31, T. 13 N., R. 19 E., which has but one open drain cut through it at a depth of about 5 feet. When visited in the latter part of June this drain carried a continual flow of seepage water, which would otherwise have remained in the soil and caused damage. Another example of the good effects of drainage can be seen on sec. 36, T. 13 N., R. 18 E. If a little of this kind of work had been undertaken when the conditions first began to be bad, much of this otherwise valuable land would have been saved. Even as it is now the cost of reclaiming would undoubtedly be less than the increase in the value of the reclaimed land.

A supposed method of reclamation of alkaline land which deserves notice here is practiced locally in the lower portion of the Atanum Valley. It consists of building a dike around the piece of land to be "reclaimed" and running sufficient water into the inclosed area to have free standing water all over the surface. This is left standing for a time, to dissolve part of the salt, when the dike is cut and the water run out. The idea is to dissolve the surface coating of salt and flood it off. This is an excellent method for filling up the soil completely with alkaline water and for the accumulation of more alkali by evaporation. Not only is the subsoil water under the particular area itself raised, but also under other lands lying below it. This is the very way in which the alkali in this area originated, and no better method could be devised for making the general conditions of the area worse than they already are. A series of such dikes and the surrounding soil seen in June resembled snowdrifts, the white material being heavy accumulations of alkaline carbonates.

The area in the central portion of the Moxee Valley, sec. 6, T. 12 N., R. 20 E., and the immediately surrounding land, which is low and flat compared with the adjacent areas, while at present in very good condition, will be likely to become alkaline when the lands east of it are irrigated. The subsoil is light and sandy, but it would be well to prevent an accumulation of salt by cutting a few drains east and west and conducting them either toward the river or the draw which traverses secs. 2, 11, and 12 in T. 12 N., R. 19 E.

Township 9 N., R. 22 E., is the only place where any accumulation of alkali is found in the Sunnyside district, except in a few places on the banks of the canal and at the bottom of some draws near the canal. The alkali problem will be more difficult to handle in this area, not only on account of the heavy soil in which the alkali is found, but also because of the fact that in many places the maximum salt content is from 4 to 5 feet below the surface, instead of being in the surface foot as in the Wide Hollow area. As there are no natural drainage channels in this place, the seepage water would have to be conducted toward the river by artificial means. As long as the subsoil water does not come nearer than within 6 or 7 feet of the surface (it is now 16 to 20 feet below) all that will be necessary is to dig drains through the heavy soil to a depth of 5 feet or, in some places, 6 feet, conducting them to the light soil having the thick underlying stratum of coarse sand. This stratum would carry away the water without injuring the soil above, provided the subsoil water is kept below the limits stated. The light-textured soil would not be likely to become alkaline or need drainage, as the substratum of sand would amply take care of both the water used in its irrigation and that led to it by the proposed drains.

In portions of secs. 29, 31, and 32, T. 10 N., R. 23 E., the subsoil water, which was 30 to 35 feet below the surface two years before the survey was made, was within 7 to 10 feet of the surface in the spring of 1901, with nearly 300 parts of salt in 100,000 parts of water. There is no doubt whatever that the water in this low place will continue to rise until trouble with alkali ensues, unless the water is kept down by means of a drain, cut through the lowest place and conducted to the swale that runs from this place into T. 9 N., R. 22 E. One good drain through this low section of land would undoubtedly be enough, if it were put in in time, to prevent an accumulation of salt near the surface. This land is some of the best in the area, and it would be well worth while to take this precaution in time.

In connection with the foregoing statements an examination of the sketch map, showing the condition of the subsoil water in the Sunnyside district, will be instructive.

WATER SUPPLY AND METHODS OF CULTIVATION AND IRRIGATION.

The usual method of bringing new land under cultivation, especially the lighter type of soils, is to clear it of native vegetation and seed it to grass or clover, or sometimes to grain. When a sod has thus been formed the soil becomes more compact and easier to handle, with a surface much better adapted to the setting of orchards. Land can be seeded at practically any time of the year excepting winter; autumn is the best time, however, for seeding to hay crops, both on account of the winter start and because of the spring winds, which give trouble where the lighter types of soil have but recently been stirred.

In raising hops two principal systems of caring for the vines obtain. The trellis system consists of putting large, strong poles, 8 to 12 feet long, firmly in the ground 10 to 15 feet apart and connecting the tops with stout wire. The vines are placed about 3 feet apart, and at each a short stake is driven into the ground, a stout twine being fastened to it and tied to the overhead wires. The vines climb up these and upon reaching the wire are trained along it in each direction. When the hops are being gathered these strings can be cut, which facilitates the work of picking. Another method largely used is to drive a stout stake 7 to 10 feet long, in the ground, at each vine, connecting the tops with twine. The poles can then be pulled at picking, if necessary. The trellis system is more elaborate, as well as the more expensive, but is generally thought to be the better system.

Owing to the topography of these districts, almost any kind of a slope can be obtained. As fruit is sometimes injured by early spring frosts, it might be expected that north or northwest slopes would be better for orchards than south slopes, as in the colder exposures the blossoms are not likely to be forced out so soon in an early spring and are therefore less likely to be damaged.

As winds are somewhat frequent in the more open areas, it would be found that wind-breaks planted around the orchards would not only protect young trees just planted, but would also prevent the waste of fruit which is now very often prematurely blown from the trees.

Some of the fruit growers try to get double value from the land by raising alfalfa and other crops between the trees, but the practice is of doubtful economy. It not only renders it inconvenient to care for the trees properly, but, what is much more serious, it also removes from the soil much plant food and water, especially where the deep-rooted alfalfa is grown, which the trees might otherwise make use of. It is a general fact, and one has but to observe these orchards closely after a few years of such practice to notice it, that they do not give as large and well-developed fruit as the orchards that are properly cultivated and kept free of all vegetation. Fruit trees need cultivation and attention as well as any other crop, and even the deep and fertile soil found in these districts must become partly exhausted by the practice of intermediate cropping. Besides this, much more water is needed for irrigation, as the field can not be cultivated and the moisture preserved in that way. In a clean, well-kept orchard, cultivation takes the place of irrigation to a large extent. On the other hand, an occasional clover crop between the trees for the purpose of fertilizing by plowing under is a good plan.

Usually it is necessary to irrigate the newly seeded soil to insure a good start, especially when planting is done in the summer. Irrigation is everywhere practiced, except where the subsoil water comes sufficiently near the surface to supply the roots with the necessary amount of moisture. The furrow method of irrigation is universally used. It requires less water, and owing to the light texture of the soil it is the safer method, especially on the steeper slopes, where the water could not be well controlled in flooding.

The practice of running the furrows straight down the hills is wrong, both because of the danger of washing the land itself and also because it is wasteful of water and tends to accumulate salt in lower lands. It is much better to run the furrows around the hills, with just slope enough to keep the water flowing gently. This allows the soil to absorb sufficient water without turning a large surplus onto lands below which get the benefit of the waste water carrying salts in solution.

The area surveyed is well supplied with water. Most of the water used comes either from the Naches or the Yakima River. The Atanum Creek also furnishes water for much of the irrigated soil in the Atanum Valley, but, owing to the subsoil water, irrigation is not so necessary there as on the higher lands. The principal canals and ditches on the west side of Yakima River are the Yakima Valley Canal, the Naches and Cowiche Canal, and the Union and Schanno ditches.

The Yakima Valley Canal covers most of the plateau and the area between Wide Hollow Slough and Cowiche Ridge. Its capacity is 37 second-feet, with a loss by evaporation and seepage of 30 to 33 per cent on the hottest days, by actual determination. It is 15 miles long and covers 3,000 acres. The capital stock consists of 3,000 shares, one for each acre irrigated, which are attached to and can not be dealt in apart from the land; hence ownership is vested in the farmers and the proposition is cooperative. This canal, which was built in 1894, receives its water supply from the Naches River.

The Cowiche and Naches Canal is about 6 miles long, with a somewhat smaller capacity than the Yakima Valley Canal, and covers about 2,000 acres. It is supplied with water by Cowiche Creek until that dries up, after which it takes its supply from the Naches River. It is one of the oldest canals, having been built in 1882. The stock is divided into 240 shares, which, not being attached to the land, can be bought and sold like any other personal property. Accordingly, shares are often rented to farmers, the rent ranging from $8 to $10 per share. The amount of land one share will irrigate depends upon the type of soil to be watered, whether it be of the gravel or non-gravel phase, the variation being from 4 to 20 acres. The ditch is favorably located and easily and cheaply operated. The Union and Schanno ditches, which are both small, cover the land northwest of North Yakima and in and below the town.

The Fowler, Hubbard, and Moxee ditches, each carrying from 25 to 30 second-feet, and lying on the east side of the Yakima River, are among the oldest ditches of the country. These ditches were the only ones on that side of the river until the spring of 1901, when the Selah and Moxee Canal was built. This canal covers practically all the land above the Moxee ditch, east to about the north and south center lines of secs. 5 and 8, T. 12 N., R. 20 E., and all the land of agricultural value along the Yakima and Selah ridges. It is about 26 miles long, including the flume work on the side of Selah ridge, has a capacity of about 75 second-feet, and covers about 5,000 acres. It was built by contract and will finally become the property of the farmers, the shares in the canal being attached permanently to the land. Water rights can be bought by the farmers for cash, or half the land for water right to the other half. The canal gets its water supply from the Yakima River above its junction with the Naches River.

In the eastern part of Moxee Valley, just east of the Selah and Moxee Canal, is a flourishing agricultural community that gets its water for irrigation from artesian wells. There are many successful wells now used, and many more were being drilled when the survey was made. The depth at which good flows of water are found varies from 600 to

1,100 feet, depending largely upon the elevation. The wells run from 0.15 to 2 second-feet for 3½ to 4 inch bottom casings. The temperature of the water is comparatively high, varying from 67° F. to 80° F.

Fig. 14 (p. 393.), representing a geological section through the artesian basin in Moxee Valley, was constructed from records of some of the wells in the district. As local variations in the strata are frequent, this section is only very general.

The water contains sulphuretted hydrogen, and one of the wells examined carried 0.03 per cent of sodium hydrogen carbonate. This amount is not in itself very injurious, but when the water evaporates to any extent on the surface this salt is converted into the normal carbonate, or black alkali. White crusts of this salt were found along the roads and ditch banks, and it would be wisdom to use this water sparingly.

An enactment of the legislature of Washington which became the law on March 16, 1901, provides that, except for domestic use, the water of artesian wells shall not be permitted to flow in any year between October 1 and April 1. This law, if enforced, will undoubtedly prove of much value to this community. It will not only conserve the water supply of the basin, but it will prevent in some measure the accumulation of injurious amounts of alkali, and in this way will be of incalculable value to the owners of the lower lands.

There are a few ditches in these districts not mentioned, but they are small, and it was found inexpedient to map them.

A canal which will draw its supply from the head of Tieton Creek has been in course of construction, but at the time of the survey no work was being done on it. This canal will be between 35 and 40 miles long and will cover the territory north of the Atanum Valley and, in addition, much of the country west of the limits of the map.

In the Sunnyside district there is but one canal, the Sunnyside Canal, built by the Washington Irrigation Company, and taking water from Yakima River a short distance below Union Gap. It was begun in 1891 and practically finished as far as constructed at present in 1893. Its present length is about 42 miles, and when the proposed extension is finished it will be about 58 miles long. Its capacity is 750 second-feet, and the area covered by the present system is estimated by the company to be 45,000 acres, to which an additional 20,000 acres will be added when the proposed extension is completed. Permanent water right for land under it can be purchased at $20 per acre, or one-half land for water to the other half, with an assessment of $1 per acre annually. The water service is at the rate of 1 second-foot to 160 acres. Shares can not be purchased without land.

There is always a good supply of water for irrigation in the Yakima and Naches rivers, but some of the smaller creeks to the east of the area surveyed dry up during the summer. The subjoined table gives the discharge of Yakima River at Union Gap after all the canals in

THE SUNNYSIDE CANAL.

the Moxee, Atanum, Naches, and Selah valleys have been supplied. Certainly no fear need be entertained for the present as to water supply. There is nearly as much danger in an oversupply of water as in a shortage, especially in such deep, loose soil as the Yakima sandy loam. This soil absorbs a large quantity of water, and the tendency is to saturate it, thereby raising the subsoil water dangerously near the surface. The small amount of salt uniformly distributed throughout this soil is sufficient, when dissolved by the underground water and brought to the surface, to give trouble. The farmer who puts an excess of water on his land not only injures himself, but also injures even to greater degree those below him. A smaller amount of water more often repeated is better for the crops and less damaging to the land. It would be a wise measure, though it would no doubt be considered an injustice by the people, if the canal companies would restrict the amount of water supplied to the quantity actually needed on the portion of the farms cultivated instead of giving the farmer enough water for the whole farm to be applied to only a portion of it.

Mean discharge in second-feet and mean total acre-feet of Yakima River at Union Gap' Yakima County, Wash., for April, May, June, July, August, and September. (Drainage area, 3,300 square miles.)

[From Water-supply Paper No. 55 of the United States Geological Survey—Smith.]

Year.	Mean discharge for six months, April to September, inclusive.		Year.	Mean discharge for six months, April to September, inclusive.	
	Second-feet.	Acre-feet.		Second-feet.	Acre-feet.
1897	7,179	435,340	1900	3,707	223,748
1898	5,750	347,866	1901	[a] 6,303	....
1899	6,636	401,573			

[a] For five months.

The minimum discharge of the river at the above station recorded since 1896 is 685 second-feet in the months of September and October, 1898.

All the irrigation water in the area surveyed is of excellent quality, the total solids being from 6 to 8 parts of soluble matter per 100,000 parts of water.

CROPS GROWN AND YIELDS.

The principal crops grown in the area surveyed are hops, alfalfa, clover, timothy, potatoes, and fruit. The fruit includes apples, pears, peaches, apricots, plums of various kinds, and some cherries and berries. The growing of these crops is almost uniformly successful, though occasionally late frosts injure the fruit.

Hops receive much attention, except around Outlook and Sunnyside and in the upper Atanum Valley, and many large, well-kept fields are to be seen. The yield in 1900 averaged about 1,700 to 1,800 pounds of dried hops per acre, and the price obtained was from 11 to 13 cents per pound. This has been the average price for the last three or four years. The average cost of raising hops is from 7 to 8 cents per pound, and their production pays well when prices maintain the recent level, but prices of this product fluctuate widely and have been so low sometimes that it did not pay to harvest the crop. It is called a "make or break" crop, a "gambling" crop, etc., and certainly it is a risky crop to handle, requiring as it does the investment of considerable capital. The nongravel phase of the Yakima sandy loam is the best soil type for the production of hops.

Another principal crop is fruit, and when the orchards are properly cultivated its production is very profitable. Net returns from the product of 1 acre ranging from $50 to $70 are quite common, and much larger returns are obtained in exceptional cases. Probably from $50 to $60 would be a conservative estimate of the average value of the product of 1 acre.

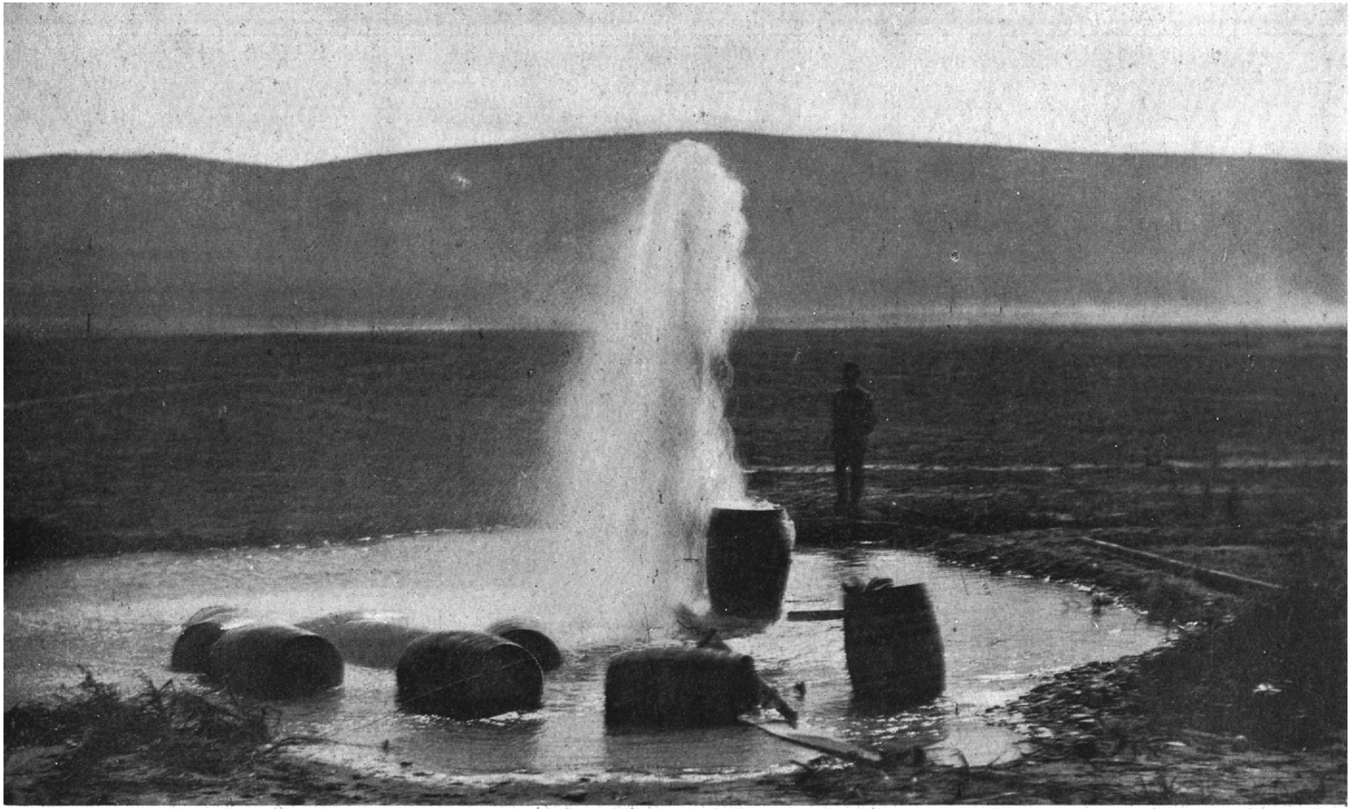
Alfalfa, clover, and timothy do well. From 6 to 7 tons of hay per acre in three cuttings of alfalfa are common, and as much as 9 tons have been grown on a single acre. An interesting example of what clover and timothy will do is shown by a piece of ground of 16 acres near Sunnyside, upon which, in 1901, 54 head of cattle were being pastured. When seen by the writer, in the middle of June, the cattle were unable to keep the crop down; on the contrary, it was in full bloom. The soil of this particular field was of the Sunnyside sand type—the same type which when first cultivated is so loose and light that the wind frequently blows the seed out of the ground. The price of hay depends upon the severity of the winter and the method of disposing of it. In 1900 alfalfa brought from $3.50 to $4.25 per ton in the stack, from $7 to $8 delivered in town, loose, and from $6.50 to $7.50 baled f. o. b.

Potatoes do well on the sandy loam soils and on the river-bottom soils. Eight tons per acre is a common yield, and, of course, heavier crops are obtained sometimes. It is difficult to determine the average price obtained for potatoes, as prices vary widely. Ten dollars a ton is a common price at harvest time. At the time the survey was made potatoes were bringing $33 per ton.

Grain is not much grown in the area surveyed, as the farms are usually small and the other crops mentioned bring better returns under the more intensive methods of culture usually practiced.

AGRICULTURAL CONDITIONS.

Most of the Sunnyside district and the Moxee Valley east of the Moxee ditch are practically new, the portion of the Moxee Valley mentioned being entirely untried at the time the survey was made. The Sunnyside district had been settled only about three years. The building of the Selah and Moxee Canal, which was finished in May, 1901, together with the artesian wells just east of this canal, makes



ARTESIAN WELL IN THE MOXEE VALLEY.

These wells are used for irrigation purposes.

practically all of the Moxee Valley available for cultivation. Judging by the portion of the valley that has been cultivated for a number of years, the new area just opened will be a very productive one. Some of the best hop and alfalfa fields found in the district surveyed are located under the Moxee and Hubbard ditches, where in a number of instances a yield of 2,000 pounds of dried hops per acre has been produced. All the conditions in the newer portion of the valley are the same as here.

The artesian-water district in the eastern part of the Moxee Valley is a very successful farming and fruit area, and proves conclusively the feasibility of irrigating by this means.

Favorable conditions exist also in the Wide Hollow district, exception being taken, of course, to the alkali areas in the lower portion of it. The district known as Nob Hill, one of the most beautiful locations in the valley, is devoted to the production of hops, tree fruits, and grapes; all doing well. In the upper portion of the Atanum Valley, while hops and fruit are raised to a limited extent, hay forms the most important crop. The brushy creek bottoms furnish excellent grazing for dairy cattle, and the only creamery in the North Yakima district is situated there.

While most of the Sunnyside district was either just being put under cultivation or in the native state of vegetation, enough had been done on a number of isolated farms to show the great fertility of the area and to warrant the prediction that the district will have a most successful future. The area around Parker Bottoms and Zillah is the oldest in the district, and there hops, fruit, and hay are successfully grown. Hay forms the most important crop in the Parker Bottoms, the lands being not so well adapted to fruit and hops as the higher lands to the north. The areas around Outlook and Sunnyside were as yet hardly settled, but they have all the requisites of a successful farming and fruit country. Clover and alfalfa give immense yields, and the hardier fruits can not help but prove profitable. Here, as at North Yakima, it would be advisable to go more extensively into the later blooming varieties of fruits.

Small farms are the rule in the districts surveyed. Eliminating the few large ranches owned by land companies, the average size of farms is between 15 and 20 acres.

The area surveyed has a promising future, and with a judicious use of water in the lower areas it should become the center of prosperous fruit, hop, and hay industries. The surrounding hills and mountains furnish good grazing, and these ranges are available most of the year, the winters not being severe.

Shipping facilities are good, the Northern Pacific Railroad traversing the whole Yakima Valley, with stations convenient to all parts of it. There are good markets on the coast and in the surrounding States for all the produce of this region.

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