U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS—MILTON WHITNEY, Chief.

SOIL SURVEY OF THE PROVO AREA, UTAH,

BY

ALFRED M. SANCHEZ.

[Advance Sheets—Field Operations of the Bureau of Soils, 1903.]

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[PUBLIC RESOLUTION—No. 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized into the Bureau of Soils.]

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SOIL SURVEY OF THE PROVO AREA, UTAH.

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LOCATION AND BOUNDARIES OF THE AREA.

This survey was commenced April 1, 1903, at the town of Provo City, and continued until August 22, during which time about 370

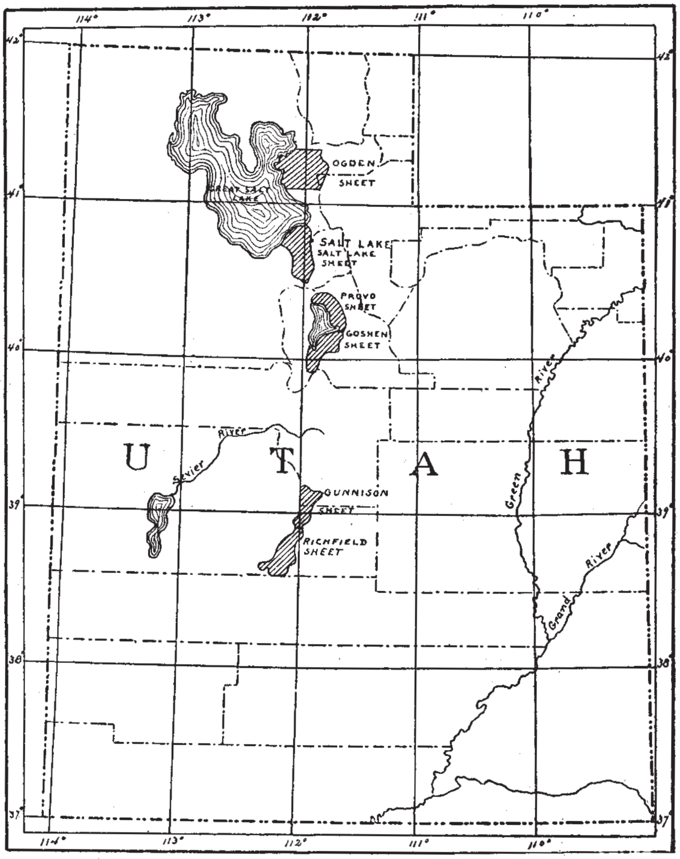


FIG. 1.—Sketch map showing position of the Provo area, Utah.

square miles of land were surveyed. The area mapped is entirely within Utah County, and, with the exception of a few and relatively unimportant areas, constitutes all the cultivated land in the county.

At the north of the area the Wasatch and the Oquirrh ranges of mountains come almost to a junction, with only a narrow strait between them, known as the Jordan Narrows, through which the Jordan River flows. To the east are the Wasatch Mountains, and these extend south for some distance below the area.

For the sake of facility in the publication of the maps the area was divided into two sheets: The Provo sheet, covering the northern, and the Goshen sheet, the southern part of the valley.

The Goshen sheet is approximately bisected by a line of mountains. The eastern half extends south to the county line; the western part is known as the Goshen Valley. The area surveyed in this valley is approximately 80 square miles, the greater proportion of which is not at present under cultivation. To the west and south of the Goshen Valley are the Tintic Mountains.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The first settlers of Utah Lake Valley came from Salt Lake City, where they had stopped over for a year on their journey from Illinois. The first company of settlers came over early in March, 1849. The company consisted of 30 families, and settled close to where the town of Provo City now stands. By the middle of March the settlers had built a fort consisting of log houses surrounded by a stockade 14 feet high. From the center, overlooking all, arose a long parapet upon which was mounted one or more cannon for protection against possible Indian attacks.

In the meantime the settlers had taken up land along Provo River, near the present town of Provo City, and had plowed, fenced, and planted with corn, wheat, and rye the greater part of a field consisting of 225 acres of land. Soon after 10 more families joined the settlers, and the field was divided into 40 lots and one lot given to each family.

The settlers, immediately upon planting their crops, began to use the water of the stream for irrigation. A number of farmers joined together and by their united labor constructed a canal that brought water to their farms. These were among the first steps toward irrigation in the West.

The first attempt at agriculture by the new settlers was not very successful, as Indian troubles during this time were frequent and the men could not give their crops the attention which they required. The second year was more successful, and good crops of wheat, corn, rye, and barley were obtained. In the years that followed more settlers came into the country, taking up land in different parts of the valley. For many years corn, wheat, barley, and potatoes were the principal products. The sugar-beet industry is comparatively new, while fruit growing is also a recent introduction.

CLIMATE.

The climate of Utah Lake Valley is characterized by low annual precipitation, moderate temperature, low relative humidity, and abundant sunshine. The highest temperature recorded at Provo City is 104° F., and the lowest 18° below zero.

The following table shows the normal monthly and annual temperature and precipitation for Heber and Mount Pleasant. These places, though not in the area surveyed, are believed to represent approximately the climatic conditions in Utah Lake Valley.

Normal monthly and annual temperature and precipitation.

Month.	Heber.		Mount Pleasant.		Month.	Heber.		Mount Pleasant.	
	Temperature.	Precipitation.	Temperature.	Precipitation.		Temperature.	Precipitation.	Temperature.	Precipitation.
	° F.	Inches.	° F.	Inches.		° F.	Inches.	° F.	Inches.
January	20.6	2.18	24.0	1.20	August	64.5	0.74	68.7	0.62
February	21.0	2.42	27.1	2.05	September	55.3	1.31	59.5	.94
March	32.2	2.31	34.5	1.57	October	44.3	1.49	48.0	.92
April	43.8	1.38	44.1	.70	November	35.6	1.63	36.4	.96
May	52.4	1.72	53.3	1.22	December	22.2	1.70	27.3	1.41
June	59.3	.44	61.2	.51	Year	43.1	18.36	46.2	12.88
July	66.2	1.04	70.0	.78					

PHYSIOGRAPHY AND GEOLOGY.

The area comprises two prominent physiographic features, first, an area of sloping land adjacent to the base of the mountains and usually above the present systems of irrigation, and, second, a larger and more level area farther removed from the mountains and generally under irrigation.

The first area consists chiefly of coarse material, sand, gravel, stones, and bowlders, and the surface is usually rough and uneven. A large part of this land is not at present under cultivation on account of insufficient water supply, although wherever irrigated it produces fair crops. The material constituting this feature is derived chiefly from the adjacent mountains, and has been brought into the valley by inflowing streams and rains.

The second feature is made up of the finer sediments deposited by ancient Lake Bonneville, which have, since its subsidence, been considerably modified by inflowing streams and by weathering. The entire area surveyed is within the bed of Lake Bonneville,[a] a water body of the Quaternary period, and all of the land here considered has been submerged by that ancient lake. During the Bonneville period the Utah Lake Valley was occupied by a landlocked bay, which was con-

[a] Some of the facts relating to the history of Lake Bonneville have been taken from G. K. Gilbert's report on this lake, published as Monograph I, U. S. Geological Survey, 1890.

nected with the main body of water by a narrow strait between the Oquirrh and the Wasatch ranges, now known as the Point of the Mountain.

The greatest expanse of Lake Bonneville is plainly marked on the Wasatch Mountains, where the lake waters carved a beach known as the Bonneville shore line. The altitude of this shore line is 5,200 feet above sea level, or about 718 feet above the present level of Utah Lake.

At the highest stage the lake waters overflowed the rim of the basin, the water escaping at the north end of Cache Valley into Snake River. A deep channel was eroded, forming what is now known as Red Rock Pass, and the lake water flowing out through this channel lowered the level of the lake 375 feet, at which point erosion ceased, and no further water escaped in this way. The lake waters must have maintained this new level for a considerable time, as is evinced by the magnitude of the phenomena recorded at this period. A prominent beach mark was carved during this time, designated by geologists as the Provo shore line. This shore line is a conspicuous feature of the Wasatch Mountains in the vicinity of Provo City, surpassing in strength all other shore lines below the Bonneville line.

While the lake water was at the Provo level or above, the inflowing streams formed great gravel accumulations at their mouths, and these accumulations, known as deltas, form a salient feature in the physiography of Utah Lake Valley. Large masses of gravel, intermingled with sand and some finer material, are found at the mouths of Provo River, American Fork Creek, and Spanish Fork River, as well as at the mouths of smaller streams in the area. Following the base of the Wasatch Range southward the first delta is that of Dry Creek. The gravel extends for some distance on each side of the creek and connects with the delta of American Fork Creek 2 miles farther south. Here the gravel spreads out fanwise with a radius of nearly 2 miles. It is bisected by the river which, after leaving the mountains, flows in a southwesterly direction for a distance of 2 miles and then turns abruptly south.

About 9 miles from the American Fork Canyon southward along the mountains is Provo River. Here a broad mass of gravel spreads out from the canyon, having a radius of about 4½ miles and a height of nearly 70 feet. The river, which runs almost due south for 5 miles from the canyon, skirts its delta near the town of Springville. Hobble Creek has built up a well-marked delta, which extends for some distance from the canyon. The delta is divided by the creek and coalesces with that of Spanish Fork River 5 miles farther south. Near the town of Payson a small delta, formed by Payson Creek, is found; another delta occurs near Santaquin, and at the south end of Goshen Valley a high delta has been formed by Salt Creek.

To the east of Utah Lake Valley the Wasatch Mountains rise abruptly, attaining an elevation of from 6,000 to 7,000 feet above the general level of the valley. The range extends from the town of Nephi, near which it culminates in Mount Nebo, and runs in a general course a little west of north to the gate of the Bear River. Near the town of Santaquin a low spur of the Wasatch Mountains projects westward across the valley, and from this spur a line of hills springs out running northward to Utah Lake and separating the Goshen Valley from the main area. To the west of Goshen Valley are the Tintic Mountains, and these unite with the Wasatch spur and form the southern boundary of the area.

The surrounding mountains, with their great diversity of rocks, are the principal source of the material which constitutes the soils of this area. One very prominent feature of these mountains is the Archean rock, great masses of which outcrop at several plains along the range. Quartzites, carbonaceous and argillaceous shales, slates, and ferruginous rocks are commonly found. The Cambrian, Silurian, Devonian, and Cretaceous rocks are also represented. On the mountains east of Spanish Fork quite large masses of red sandstone are found and give rise to large accumulations of red sand found as large hills at the foot of the mountains. On the Tintic Mountains west of the Goshen Valley argillaceous limestones are found. These are the source of the large deposits of almost pure lime, a characteristic geologic feature of the valley.

To the west of the Provo area is Utah Lake, a body of fresh water fed chiefly by streams flowing into it from the Wasatch Mountains. It covers an area of about 90,000 acres, but is comparatively shallow, the average depth probably being about 7 feet. Jordan River is the outlet. Through it the lake water is carried to the Salt Lake Valley, where it is used for irrigation. The water furnished by Utah Lake is of fairly good quality.

The area surveyed varies in elevation from the present level of Utah Lake, about 4,482 feet above the ocean; to the Provo shore line, about 343 feet higher.

SOILS.

Eight types of soil were recognized and mapped in this area. All of these soils were correlated with types established by the Bureau prior to this survey. A survey of an area in Salt Lake Valley was made in 1899. Eight types of soil were recognized there, seven of which occur in the present survey. The soils of these two areas have had practically the same mode of formation, being derived from deposits of Lake Bonneville and from material brought down from the mountains and subsequently modified by wind and water.

Slight differences exist between certain soils found in the two areas, but in no case is the variation of sufficient importance to warrant a separation into two types. The Jordan clay is a case in point, differing slightly both in mode of formation and in physiographic position from the soil as found in the Salt Lake survey, but it is believed that the chief difference is principally due to the generally wet and swampy conditions in the latter area, and the existing opposite conditions in the former.

The Salt Lake sand is still forming on the shores of Great Salt Lake, while here the formation of this soil ceased long ago. The conditions along the shores of Utah Lake are not as favorable for the formation of this soil as along the Great Salt Lake.

The following table gives the extent of each of the soil types of the area.

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Jordan loam	99,648	41.8	Jordan clay	3,840	1.6
Maricopa gravelly loam	48,128	20.2	Salt Lake loam	3,456	1.4
Jordan sandy loam	38,400	16.0	Salt Lake sand	1,152	.5
Maricopa stony loam	33,728	14.1	Total	238,720	
Fresno sand	10,368	4.3			

MARICOPA STONY LOAM.

The Maricopa stony loam consists of a thin layer of sandy loam or loam containing a high percentage of rocks, bowlders, and conglomerate, underlain by coarser phases of the same materials. It is found in inclined areas at the base of the mountains and is made up of the coarser material washed from the steeper mountain slopes. The surface is usually rough. Owing to its position and character this soil is naturally well drained and free from alkali salts. All of this soil, however, lies above irrigation and is at present of no agricultural importance. Should water become available, however, the type would undoubtedly prove well adapted to fruit growing.

MARICOPA GRAVELLY LOAM.

The Maricopa gravelly loam is, in extent, the second of the various types of soil in the valley. It consists of sandy loam or loam from 3 to 6 feet or more in depth, intermingled with more or less gravel, which increases in size and quantity in the lower depths. In several cases little or no gravel is found in the first 2 or 3 feet of the soil, but it always occurs in the lower depths. This soil is the prevalent type of the bench lands of the valley and is at present undoubtedly the best agricultural soil in the district. The surface is usually sufficiently level to permit cultivation, though in a few localities it occurs in rather rough and steep hills. Owing to the character and relatively high position of this soil, it is naturally well drained and free from alkali salts.

In the central part of the valley most of this soil is irrigated, but in the northern and southern parts very little irrigation is possible.

The Maricopa gravelly loam was formed during the Bonneville and Provo periods from material brought in from the mountains by streams and deposited in the form of deltas at their mouths. The finer sediment of this soil was deposited from the material carried in suspension by the waters of the lake at the time of its recession. The areas of this type found on the lower lands were formed from the material of the benches, carried down by streams and rains.

The Maricopa gravelly loam is at present devoted chiefly to alfalfa, the grains, and fruit, and wherever supplied with sufficient moisture good yields of all these crops are obtained. In the central part of the valley, in the vicinity of Provo City, some of this soil is devoted to fruit growing, to which it is undoubtedly perfectly well adapted. Smaller areas of this soil are in orchards in other parts of the valley. In the northern and southern sections the greater part of this soil is dry farmed, with alfalfa and wheat as the principal crops. With normal rainfall fair yields are obtained in these cases, but on account of the unprecedented dry seasons during the last four years, the crops have been partial or total failures.

The following table gives mechanical analyses of samples of the fine earth of this soil type:

Mechanical analyses of Maricopa gravelly loam.

No.	Locality.	Description.	Organic matter.	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.*
9128	Near Mapleton Station, R. G. W. Ry.	Gravelly loam, 0 to 48 inches.	1.10	6.04	12.44	10.10	18.26	18.66	22.40	12.20
9127	NE. cor. of NW. ¼ sec. 2, T. 7 S., R. 2 E.	Sandy loam, 0 to 50 inches.	1.02	1.94	6.22	6.92	20.74	24.84	27.00	12.40

The following sample contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9128, 2.20 per cent.

FRESNO SAND.

Typically the Fresno sand is a loose white or gray sand, with little or no coherence. It is 6 feet or more in depth, though below the third foot the sand particles are usually slightly coarser.

This soil occurs in narrow strips along the east side of Utah Lake, and is also frequently found in small dunes below the bench lands, from which it is largely derived.

In the vicinity of Lehi City a considerable area of sand was mapped as belonging to the Fresno type, but using the gravel symbol. The soil in this locality is slightly coarser than the true type and contains considerable gravel, but this difference was not considered sufficient to justify its classification as a distinct soil type.

In a few places in the gravelly sand areas near Lehi City this soil lies in rather high and steep hills, the leveling of which for cultivation would prove too expensive. As a general rule, however, the surface of the soil is sufficiently level to permit cultivation.

With the exception of the areas in the immediate vicinity of Utah Lake, all of this soil is well drained and quite free from alkali salts. Close to the lake, however, the drainage is poor, and, as a consequence, soluble salts have accumulated to some extent.

The Fresno sand of this area is derived from material brought down from the mountains by streams flowing into the valley and there assorted by the action of water. It is possible that part of this soil may be direct sediment of Lake Bonneville, but more probable that all of it has been formed since the evaporation of the waters of that ancient lake.

Near Lehi City much of this soil is planted in alfalfa, and wherever irrigated good yields are secured. Wheat, barley, and fruits are also grown to a small extent. The soil seems to be particularly well adapted to fruit growing, though with a sufficient supply of moisture any crop suited to the region can be grown.

The following table gives mechanical analyses of samples of this soil type:

Mechanical analyses of Fresno sand.

No.	Locality.	Description.	Organic matter.	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.*
9113	Cen. sec. 24, T. 10 S., R. 1 W.	Sand, 0 to 50 inches.	0.81	0.60	6.78	13.90	52.90	16.62	3.10	5.90
9114	NE. cor. sec. 28, T. 6 S., R. 2 E.	Sand, 0 to 72 inches.	.61	1.96	10.30	20.88	44.98	10.52	4.84	6.52
9115	NE. cor. sec. 9, T. 5 S., R. 1 E.	Sand, 0 to 40 inches.	.67	5.70	19.50	15.30	29.80	13.12	8.16	8.44

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9113, 3.60 per cent; No. 9115, 0.60 per cent.

SALT LAKE SAND.

The Salt Lake sand consists of egg-shaped or spherical particles, largely calcareous. As it occurs in this area the soil is 6 feet or more in depth. It is known as oolitic sand on account of its resemblance to petrified eggs of fish.

Two comparatively small areas of this soil occur in this district. These are found in the Goshen Valley, about 3 miles west of Utah Lake, and together comprise about 1,000 acres.

This soil is found as dunes, which sometimes reach 15 or 20 feet in height, and is naturally well drained. It is derived through the breaking up of lime hardpan, the peculiar shape of the particles resulting from the wearing and polishing action of wind and water. The sand, hardpan, and calcareous material are derived largely from the lake waters, and the type may be seen now forming along the shore of Great Salt Lake.

The Salt Lake sand found in the Goshen Valley was undoubtedly formed at a time when the waters of Lake Bonneville covered the valley, and was the result of a condition of saturation of the lake water as regards carbonate of lime. As a matter of fact the Salt Lake sand is underlain in this valley by deposits of lime carbonate, sometimes 8 or 10 feet in thickness. Agriculturally the Salt Lake sand is of no importance, not being at present under cultivation.

The following table gives the mechanical analysis of a sample of this soil type:

Mechanical analysis of Salt Lake sand.

No.	Locality.	Description.	Organic matter.	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.*
9129	Cen. sec. 32, T. 9 S., R. 1 W.	Sand, 0 to 72 inches.	0.10	2.10	26.78	16.38	38.50	10.44	1.82	4.16

The following sample contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9129, 4.40 per cent.

SALT LAKE LOAM.

The Salt Lake loam is a loam containing considerable proportions of fine and very fine sand, from 1 to 2 feet in depth, usually underlain by fine sand to a depth of 6 feet or more. It is found in the vicinity of Utah Lake, usually very close to the shore. Much of this land has, within the memory of the oldest inhabitants, been submerged by the waters of Utah Lake.

It is comparatively level and the drainage is very poor. In but few places does the water stand below 3 feet from the surface, and in the greater part of the areas of this type it is found within the first foot. The soil is derived from lake sediments considerably modified by stream and wind action. As a natural consequence of poor drainage most of the soil is alkaline, in many cases too strongly so for profitable cultivation. The nature of the soil is such, however, that with proper underdrainage and a few surface floodings it could be easily freed from injurious quantities of salt.

With the exception of a few acres west of Springville this soil is uncultivated and used chiefly for pastures. Under proper conditions of cultivation it would be well adapted to vegetables.

The following table gives mechanical analyses of samples of this soil type:

Mechanical analyses of Salt Lake loam.

No.	Locality.	Description.	Organic matter.	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.*
9132	Cen. sec. 24, T. 8 S., R. 1 E.	Sandy loam, 0 to 24 inches.	3.18	0.46	0.84	1.06	11.50	28.44	31.66	26.20
9130	Cen. sec. 12, T. 8 S., R. 1 E.	Sandy loam, 0 to 24 inches.	6.32	.68	1.32	1.10	12.52	26.08	28.70	29.30
9131	Subsoil of 9130......	Fine sand, 24 to 50 inches,	Tr.	.00	.12	.70	17.24	53.74	16.84	11.32
9133	Subsoil of 9132......	Fine sand, 24 to 50 inches.	.72	.00	.12	.60	18.04	49.44	18.80	13.40

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9130, 31.80 per cent; No. 9131, 18.40 per cent; No. 9132, 15 per cent; No. 9133, 19.60 per cent.

JORDAN SANDY LOAM.

The Jordan sandy loam is a sandy loam 1 to 2½ feet in depth, underlain by a loam to 4 feet, beneath which occurs a clay. Occasionally a layer of sand is found between the fourth and the fifth foot. It is found in small or large areas throughout the valley, and forms a considerable proportion of the cultivated soil. It usually occurs in the valley bottoms, though considerable areas are also found in the benches. The surface is generally sufficiently level to permit cultivation and irrigation.

In the vicinity of the lake much of this land is wet and swampy. Farther away from the shore the soil is better drained, while on the benches the drainage is naturally good. The soil is formed from lacustrine sediments and river deposits. In the bench lands it is probably chiefly derived from material washed from the mountains, though undoubtedly part of the soil there is sediment from Lake Bonneville. In poorly drained areas this soil is naturally alkaline, although generally the greater part of the salts is found in the upper few feet. Over large areas the alkali accumulations on the surface are very heavy, amounting to 3 or 4 per cent, and where these intense salty conditions prevail the land has generally been abandoned, or at least no effort toward its reclamation has been made. Where favored with good drainage the soil is free from alkali and makes very good farming land.

The Jordan sandy loam is the preferred soil for sugar beets in this valley, as under favorable conditions it gives the best results. Twenty and even 25 tons of beets per acre have been secured from this soil. Alfalfa, wheat, corn, and barley are successfully grown on this type, and fruits also do well.

The following table gives mechanical analyses of samples of this soil type:

Mechanical analyses of Jordan sandy loam.

No.	Locality.	Description.	Organic matter.	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.*
9126	NE. cor. sec. 23, T. 10 S., R. 1 E.	Sandy loam, 0 to 50 inches.	1.00	0.80	4.20	6.40	27.14	31.60	17.60	12.36
9124	Cen. sec. 23, T. 5 S., R. 1 E.	Sandy loam, 0 to 30 inches.	7.70	.62	2.58	2.66	9.18	19.46	41.00	24.40
9122	Cen. N. side sec. 3, T. 6 S., R. 2 E.	Sandy loam, 0 to 24 inches.	1.60	.44	.76	.78	5.48	16.44	40.44	35.32
9125	Subsoil of 9124......	Loam, 30 to 60 inches	.37	.24	.92	.74	5.63	19.48	44.00	28.70
9123	Subsoil of 9122......	Loam, 24 to 72 inches	1.24	.00	.40	.52	4.92	13.88	39.80	39.72

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9122, 3 per cent; No. 9123, 13 per cent; No. 9124, 39.60 per cent; No. 9125, 47.20 per cent; No. 9126, 14.60 per cent.

JORDAN LOAM.

The Jordan loam consists of a loamy soil 3 feet in depth, underlain by stiff, tenacious clay. In a few instances the soil was found underlain by sandy loam, but more generally by a yellowish clay.

This is the prevalent type of the area, and is found throughout the valley. One large area occurs in the vicinity of Spanish Fork and extending westward includes the towns of Lakeshore and Benjamin and reaches almost to the mountains. Northward, the area extends nearly to the shore of the lake. Another large area, comprising about 36 square miles, is found in the Goshen Valley. This extends from the town of Goshen northward to Utah Lake. Smaller areas are found throughout the district mapped. The soil generally occurs in the bottoms, but has been found also on the benches, where at a depth of 10 or 15 feet it is underlain by gravel.

The land is level, but being of a rather heavy character thorough cultivation is often very difficult. Close to the lake the drainage is poor, and over much of the land the ground water stands on the surface. Farther removed from the lake the depth to standing water is usually from 3 to 10 feet, while in the benches it is much deeper. The soil is derived chiefly from lacustrine sediments, modified by stream and wind action. In the bench lands material washed down from the mountains has contributed largely to the formation of this soil.

As a general rule the soil is more or less alkaline, though there are large areas that are entirely free from injurious quantities of salts. In the Goshen Valley the greater proportion of the type is intensely alkaline, especially in the vicinity of the lake, and as a consequence of the slow movement of water through this soil, due to its heavy character, alkali always tends to accumulate in it.

Sugar beets are grown successfully on the Jordan loam, but the lighter phases of the type usually give the best results. It is considered, next to the Jordan sandy loam, the best soil in the area for this crop. Alfalfa, wheat, and barley, with and without irrigation, are also grown on this type. When well drained and supplied with sufficient moisture for the growth of plants, the Jordan loam makes a most valuable agricultural soil, well adapted to any of the crops of the region.

The following table gives mechanical analyses of samples of this soil type:

Mechanical analyses of Jordan loam.

No.	Locality.	Description.	Organic matter.	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.*
9118	NE. cor. sec. 7, T. 5 S., R. 1 E.	Loam, 0 to 30 inches.	1.21	0.36	0.90	0.60	2.24	14.64	43.08	37.80
9120	Cen. sec. 22, T. 9 S., R. 1 W.	Heavy loam, 0 to 64 inches.	.85	.20	.40	.30	2.86	19.64	36.64	39.30
9119	Subsoil of 9118......	Clay, 30 to 72 inches.	.37	.30	.48	.40	2.60	10.32	19.92	66.90

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9118, 11.40 per cent; No. 9119, 26.20 per cent; No. 9120, 11 per cent.

JORDAN CLAY.

The Jordan clay consists of clay loam or clay 6 feet or more in depth. In the lower depths the soil is usually yellowish in color. In the wet lands around Great Salt Lake this type is decidedly blackish, owing to the presence of considerable quantities of organic matter.

This soil occurs in small areas in the northern part of the valley. North of the town of Pleasantgrove, along the mountains, two small areas are found. East of the town of Alpine another small area occurs, and along the mountains, to the north of Lehi City, a larger area of this soil is found. The surface is usually slightly sloping but not sufficiently so to prevent cultivation. Owing to its relatively high position the soil is well drained and free from alkali salts. In the Salt Lake Valley this soil is poorly drained and usually strongly alkaline.

Though undoubtedly a considerable proportion of the material constituting this soil was originally lacustrine deposits, laid down from the fine sediments carried in suspension by the waters of Lake Bonneville, it is believed that the greater part of the type has been formed from the fine material washed from the mountains since the desiccation of the ancient lake.

Little or none of this soil is at present under irrigation, but most of it is dry farmed, principally to alfalfa and wheat. It appears to be a little too heavy for the best results with alfalfa, but if supplied with sufficient moisture it would probably prove well adapted to wheat.

The following table gives mechanical analyses of samples of this soil type:

Mechanical analyses of Jordan clay.

No.	Locality.	Description.	Organic matter.	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.*
9117	Cen. sec. 27, T. 4 S., R. 1 E.	Clay, 0 to 72 inches..	1.07	0.10	0.36	0.34	2.34	12.76	33.10	50.20
9116	NE. cor. sec. 20, T. 5 S., R. 2 E.	Clay, 0 to 72 inches..	.11	.12	.24	.08	.22	2.92	23.04	73.20

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9116, 16.60 per cent; No. 9117, 29.20 per cent.

WATER SUPPLY.

The principal streams used for irrigation in this valley originate in the Wasatch Mountains. Their water is of good quality, though generally the amount is insufficient for the irrigation of all the cultivated lands. The central part of the valley is fairly well supplied with irrigation water. Here there are many springs and flowing artesian wells, many of which are large enough to irrigate considerable land. In the northern and southern parts of the valley, however, irrigation water is more scarce, and large areas of cultivated land that are never irrigated may be found. Around Payson and Santaquin, and in the Goshen Valley the greater part of the land is not irrigated.

The principal streams supplying irrigation water in the valley will be considered in the order in which they occur from north to south.

The first is Dry Creek, which enters the valley near the town of Alpine, runs in a southwesterly direction toward Lehi City, and empties into Utah Lake. No measurements of the amount of water in this stream have been made. While considerable land is irrigated along its course, the water supply falls very far short of being sufficient for the irrigation of all the agricultural lands in this locality. The water of Dry Creek is of excellent quality, as may be seen from the table of analyses made in the Bureau laboratory, given on a succeeding page.

Three miles south of Dry Creek, along the mountains, American Fork Creek enters the valley. Two measurements taken by the county engineer, one at high water (May 18, 1903) and the other at low water (April 6, 1903), show a discharge of 128 and 24 second-feet, respectively. As seen from the above figures, the volume of the stream was increased over four times within about a month and a half of the time of the first measurement. This is accounted for by the snows that begin to melt in the mountains about May 1. From this date high water continues until about July 1, when the volume begins to decrease.

All of the water of American Fork Creek is used for irrigation. It is taken out at the mouth of the stream by canals, which irrigate part of the bench and valley soils around the towns of American Fork and Pleasantgrove. The water supply is inadequate to irrigate all of the lands in these localities.

Considerable land west of Pleasantgrove and around American Fork is irrigated by flowing wells. In all cases where tested the water from these wells was found to be of good quality.

East of the town of Pleasantgrove a small stream enters the valley. Its supply of water is used in irrigating a few farms in the vicinity of the town. About 10 miles from the mouth of American Fork Creek, south along the mountains, is the entrance of Provo River. This stream for about 5 miles from its mouth runs in a direction almost due south, then turns abruptly west toward Utah Lake. Provo River is the largest stream in the area, and although in the latter part of the irrigating season its supply of water becomes very much reduced, the country in this vicinity is better supplied than any other portion of the valley.

The following measurements, taken by the county engineer, show the conditions of the stream at the dates on which it was measured:

Measurements of Provo River.

Date.	Mean velocity per second.	Discharge per second.
	Feet.	*Cubic feet.*
May 27, 1903	3.24	393
June 5, 1903	3.13	1,197
July 9, 1903	2.23	220

Of the above amounts of water in Provo River, the following were taken out by canals and used for irrigation at approximately the respective times of the above measurements.

Amount of water in second-feet withdrawn from Provo River.

Name of canal.	May 5, 1903.	June 17, 1903.	July 6, 1903.
	Second-feet.	*Second-feet.*	*Second-feet.*
Little Dry Creek	3.33	14.53	5.05
Provo City	79.20	168.30	67.30
Upper East Union	23.16	37.18	17.95
River Bottoms	17.50	25.00	22.25
Timpanogos	18.70	22.54	9.93
West Union	60.58	61.66	35.97
Provo Bench	98.40	115.05	47.27
Fausset Field	3.33	5.00	1.66
Lake Bottoms	....	25.00	12.54
Total	304.20	474.26	219.92

By comparing the total amounts of water in the river at the dates of measurements given above with the amounts found in the canals at approximately the same dates, respectively, it may be seen that on May 5, 1903, there passed in Provo River about 393 second-feet of water, of which the irrigating canals carried 304.2 second-feet, leaving about 90 second-feet of water to enter Utah Lake. On June 5 the total water in the river measured 1,197 second-feet and twelve days later the irrigating canals were carrying 474.26 second-feet of water, leaving about 723 feet in the river to find its way to Utah Lake. On July 9 the river was discharging 220 second-feet of water, and at this time all of the water was being taken by the canals.

Most of the irrigation water of this stream is taken out at its mouth by canals, which branch considerably in traversing the country. The canals are owned and operated by the farmers, each having certain shares of stock in the canal or canals under which he has land under irrigation. During the high-water stages of Provo River no division of the waters according to rights among the several canals is necessary, for the supply is sufficient to fill all the canals and each is entitled to enough to supply its reasonable necessities without regulation or control. However, when the water of the river is not sufficient to fill all the canals to their full carrying capacity, some distribution of the waters becomes imperative. By a court decree it has been decided that when the waters of Provo River become reduced to a volume not sufficient to fill the canals to their full carrying capacities, as they are now constructed, the several canals are entitled to different proportions depending on the actual supply.

The lands around the town of Springville, 6 miles south of Provo City, are irrigated mainly by Hobble and Spring creeks; though several springs and artesian wells also irrigate considerable land. Two measurements of the water of Hobble Creek have been taken by the county engineer. One on April 7, 1903, showed a discharge of 22.3 second-feet, and another on August 14, 1903, a discharge of 14.3 second-feet.

The next stream south of Hobble Creek is Spanish Fork River. This stream ranks next to Provo River in the quantity of water carried. The following measurements of the river have been made:

Water carried by Spanish Fork River.

Date.	Discharge.
1903.	*Sec. feet.*
March 6	124
April 27	172
May 28	268
June 20	145
July 29	72

Spanish Fork River irrigates considerable land around the towns of Mapleton, Spanish Fork, Lakeshore, Palmyra, and Benjamin, but at no time is the water in the stream adequate to irrigate all the cultivated lands in these localities. Large areas of dry-farmed land, principally in alfalfa and wheat, occur, and during seasons of little rainfall crops in these lands prove partial or total failures. A scheme, which if carried through will put much of this at present almost worthless land under irrigation and prove of great benefit to the country, is now under investigation. It is proposed to construct an earthen dam about 45 feet high and 600 feet long across the main fork of Strawberry Creek to form a reservoir in which to store the surplus water of the creek. The reservoir will have a capacity of about 25,000 acre-feet. The stored water will be brought in a tunnel about 3½ miles long through the ridge between Bryans Fork of Strawberry Creek and the middle branch of Diamond Creek, which stream is a tributary of Spanish Fork River, and the supply in the latter will be greatly augmented. The scheme appears thoroughly practicable, and it is hoped will be successfully carried through.

Near the town of Salem a pond or small lake fed by springs is used in irrigating considerable land in the vicinity. Near the town of Payson a small stream enters the area and is used in irrigating a small part of the lands of that locality. During the winter the water of the creek is stored in small reservoirs located in several parts of the canyon, and used during the irrigating season. The water supply is utterly inadequate and irrigates a very small part of the cultivated lands of this locality. Measurements of Payson Creek have been made by the county engineer, and show a discharge on May 2, 1903, of 34.5 second-feet and on August 14, 1903, of 6.37 second-feet.

In case the plan of storing the waters of Strawberry Creek, already mentioned, is carried through, much of the land around Payson will be put under irrigation, to the great benefit of this community.

Three miles south of Payson a small lake fed by springs is used to irrigate land in the vicinity of the town of Spring Lake. The next source of irrigation water is Santaquin Creek, which irrigates land around the town of the same name. The creek is small, and like all other streams of the valley is inadequate to irrigate the lands of its locality. Two measurements of the stream, taken by the county engineer, show a discharge of 26.5 second-feet and 4.23 second-feet on May 2 and August 13, 1903, respectively.

In the Goshen Valley Current Creek furnishes the greater part of the irrigation water. The creek is fed principally by springs, and derives little or no direct supply from snows and rains in the mountains. Its volume of water is very uniform throughout the year. No official measurements of the stream have been made, but the area of land under irrigation from this creek is very small, probably not exceeding 4 square miles. During the winter months the water of Current Creek is stored in a reservoir west of the town of York, Juab County, and is used in the irrigating season on lands around the Mount Nebo settlement. About 1,000 acres of land around Mount Nebo are partially irrigated by this stored water.

About 2 miles east of the town of Goshen is the head of Warm Creek. This stream is fed by three or four large springs and a few other smaller ones, all of which combined furnish water for the partial irrigation of about 500 acres of land.

Kimball Creek at the south end of the valley is very small and unimportant for irrigation.

Altogether only about 3,000 acres of land or about one-sixteenth of the area surveyed in this valley are at present under irrigation. The rest of the land is either dry farmed or is uncultivated, most of it being in the latter condition. There is little or no prospect at present for the increase of the supply of water for irrigation in this valley.

The table following shows the character of the several more important waters used for irrigation in the Provo area.

Analyses of river waters used in irrigation in the Provo area.

[In parts per 100,000.]

Constituent.	Provo River at canyon.	Spanish Fork River at canyon.	American Fork Creek at canyon.	Dry Creek at canyon.	Payson Creek at canyon.	Santaquin Creek at canyon.	Current Creek at canyon.	Warm Creek.
Ions:								
Calcium (Ca)	5.1	6.8	4.5	1.7	1.2	1.2	4.7	11.4
Magnesium (Mg)	2.9	3.6	2.4	2.7	1.7	3.1	5.4	4.8
Sodium (Na)	2.8	4.6	.4	1.5	2.2	3.1	8.9	38.1
Potassium (K)	2.2	1.7	1.0	1.4	.3	.5	4.4	9.2
Sulphuric acid (SO_4)	4.4	6.4	4.2	3.4	3.2	3.3	11.5	11.4
Chlorine (Cl)	2.8	2.8	Tr.	1.4	......	......	21.1	70.3
Bicarbonic acid (HCO_3)	20.5	27.7	14.5	12.1	12.1	21.2	18.1	33.3
Carbonic acid (CO_2)	......	......	......	......	1.4	1.4	1.5	2.8
Conventional combinations:								
Calcium bicarbonate ($Ca(HCO_3)_2$)	9.1	11.3	7.7	0.9	......	......	......	27.1
Magnesium sulphate ($MgSO_4$)	......	......	......	......	0.5	0.7	0.4	......
Potassium chloride (KCl)	4.2	3.2	......	2.7	......	......	8.4	17.5
Sodium chloride (NaCl)	1.3	2.1	......	.2	......	......	2.6	79.2
Sodium bicarbonate ($NaHCO_3$)	8.5	13.8	1.5	5.1	4.2	7.9	24.9	17.7
Sodium carbonate ($NaCO_3$)	......	......	......	......	2.4	2.4	2.6	4.9
Magnesium bicarbonate ($Mg(HCO_3)_2$)	11.4	14.1	9.4	10.5	10.2	17.5	......	......
Calcium sulphate ($CaSO_4$)	6.2	9.1	5.9	4.8	4.0	4.0	15.9	16.1
Potassium bicarbonate ($KHCO_3$)	......	......	2.5	......	.8	1.3	......	......
Magnesium chloride ($MgCl$)	......	......	......	......	......	......	20.8	18.8
Total solids	40.7	53.6	27.0	24.2	22.1	33.8	75.6	181.3

UNDERGROUND AND SEEPAGE WATERS.

The underground-water map accompanying this report shows the depth to standing water at the time the survey was made. Three classes of lands are shown by color on the map—where the ground water level is within 3 feet of the surface, where it is from 3 to 10 feet, and where it is below 10 feet from the surface.

The level at which ground water stands over these areas is very changeable, depending on the character of the season. In periods of heavy rainfall the water table rises, while at times of drought it naturally lowers. This fact is particularly noticeable in the land in the immediate vicinity of Utah Lake, where at times of heavy rains water stands on the surface of much of the land, while during periods of little rainfall it falls to 3 or 4 feet below the surface or deeper.

Within the area where the ground water is within 3 feet of the surface of the soil none but the shallow-rooted crops, such as sugar beets and potatoes, can be grown with any chance of success, and then there is constant danger of injury from harmful accumulations of alkali. Attempts to grow deeper-rooted crops, such as alfalfa, on these lands have proved failures. For the alfalfa the ground water should never be closer than 5 or 6 feet from the surface, and even with the water at this depth there is danger of the plant roots, after a certain period of growth, entering the level of the water. For fruit growing the water table should be even lower in order to secure the best results.

The principal cause of the high water table in much of this land is the seepage from irrigation on the higher lands. The wet lands to the east and southeast of Provo City, to the north of Spanish Fork, and to the northeast of Payson, as well as in many other places throughout the valley, have been caused by seepage from the irrigating canals in the coarse and porous soils of the bench lands. It is obvious that great care should be exercised in the construction and use of canals, especially those on porous soils, and the unavoidable waste from the canals should not be allowed to accumulate in low places. Much of the wet land also is caused by springs and flowing wells, which are more or less numerous throughout the bottom lands. These wells keep the land in the vicinity saturated with water, making it swampy and unfit for cultivation, and while the water is usually free from injurious amounts of soluble salts, yet by continuous evaporation considerable alkali accumulates on the surface of the soil in these localities. A few ditches to conduct the water away from these wells to other parts of the fields, instead of allowing it to soak into the adjacent land, would prove very beneficial to lands already affected and prevent the spread of the alkali. The only way in which land in this condition can be made fit for cultivation is by draining it. This should be done wherever the land is too wet to grow crops, and money employed in this way would bring sure and lasting returns, provided the drainage system is properly installed.

There are at present over 2,000 acres of this wet land in the vicinity of Utah Lake, used chiefly for pasture and practically worthless otherwise, which if properly drained would have a greatly enhanced value. The soil in this locality is naturally rich and under proper conditions for cultivation would produce excellent crops.

As the country is becoming more thickly populated and the value of land is rising the necessity for draining this wet land is becoming more apparent. It is to the interest of the whole community, from a sanitary as well as from a commercial standpoint, thoroughly to drain these swampy places.

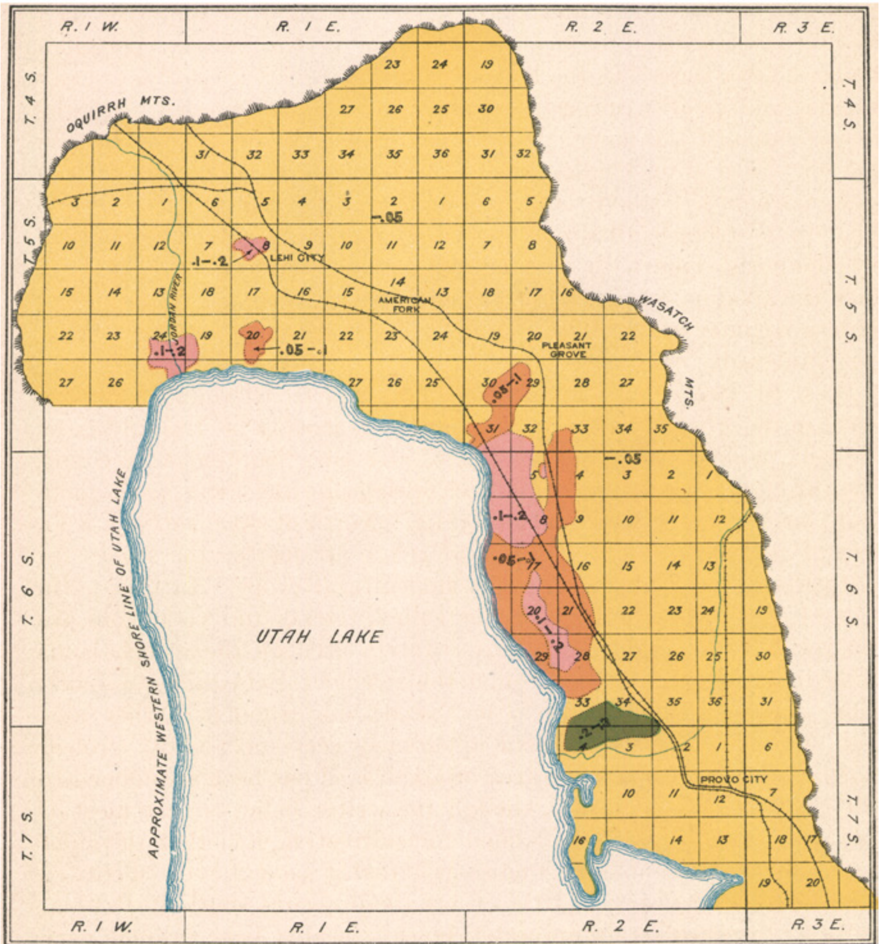
On a small scale, a certain amount of drainage is being done around Provo City, and in all these cases fair success has been attained. In case it is impossible to agree on some public plan to drain the whole of the land around the lake, drainage should be undertaken privately by everyone owning this kind of land.

ALKALI IN SOILS.

As in all other irrigated countries, more or less alkali is found in this valley. As a general rule, the alkaline areas here are found in lands of the lower levels, though in a few cases slight accumulations of salts are found in some of the bench lands. The reason for the absence of injurious quantities of alkali in the bench lands is that the soils are usually loose and porous, and, situated as they are in a higher level with reference to the lands in the valleys, permit a thorough drainage. In the bottom lands, however, the soil is usually heavier and poorly drained, and these conditions, together with the low position of the lands, always tend to accumulate soluble salts in the soil. For 2 or 3 miles from the lake, and all along the eastern side, more or less alkali land is found. To the northeast of Provo City quite strongly alkaline areas occur, and these extend northward all along the lake with varying degrees of saltiness. About Lehi City the alkaline belt is narrower and is mostly confined to the immediate proximity of the lake. In the vicinity of the Utah Sugar Factory quite salty conditions prevail.

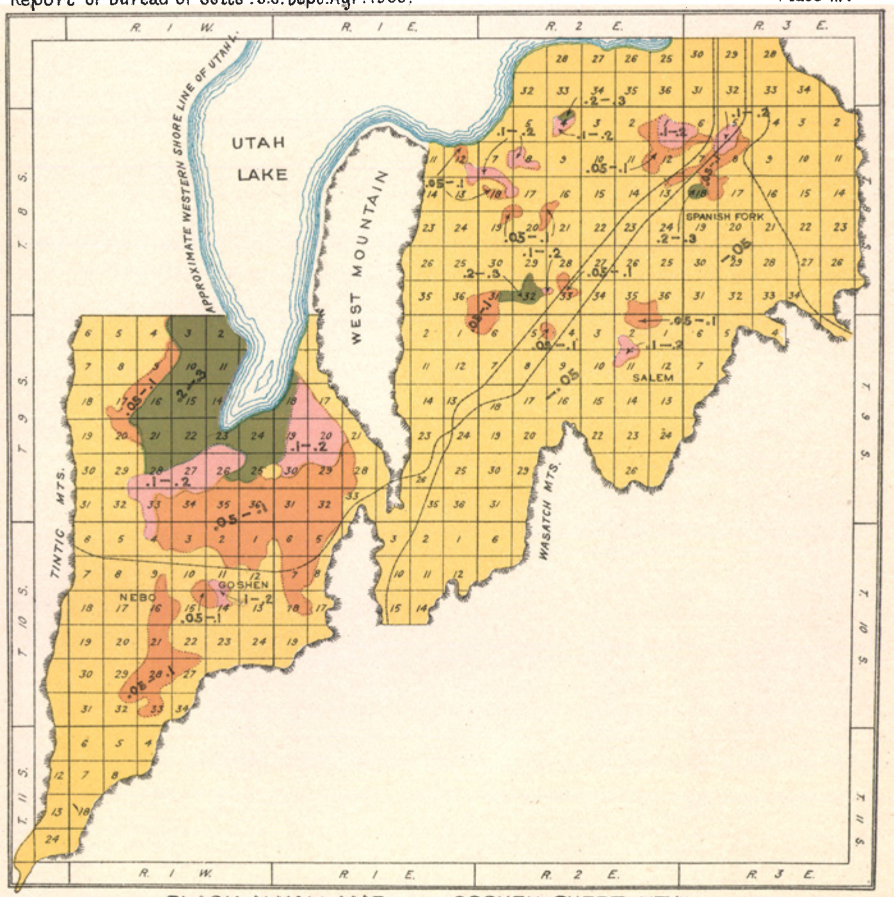
West of Provo City little or no alkali is to be found. This is because the ground water in this locality is usually on the surface of the land, which is kept well washed of any salts that tend to accumulate through evaporation. West of Springville and close to the lake quite large areas of alkaline land occur. North of Spanish Fork is an area of badly alkaline land, most of it too strong for the successful cultivation of any of the common agricultural crops. In this, as in several other cases throughout the valley, the alkaline conditions are the result of seepage of irrigation waters used on the trench lands immediately to the east. Around the towns of Benjamin and Lakeshore considerable alkali is to be found; but in much of this salty land sugar beets are at present apparently very successfully grown. Northeast of Payson a large area of alkali land has been abandoned to salt grass and alkali bushes, though the writer believes that most of this land could be easily reclaimed for cultivation, and that the chief reason for its present salty conditions is that it has not been cultivated for a number of years. Little or no alkali occurs south of Payson, probably because irrigation water in this locality is at present very scarce. For this reason the accumulation of alkali through excessive irrigation is not likely to occur here for some time.

The principal source of the alkali found in the Provo sheet and the eastern part of Goshen sheet is in the evaporation of Utah Lake and seepage waters. While it is entirely possible that some of the salts may be the result of the evaporation of the waters of Lake Bonneville, which once covered this country, it is not probable that much of the salts now found in the soil are directly derived from this



BLACK ALKALI MAP. PROVO SHEET. UTAH.

- -.05: LESS THAN .05 PER CENT
- .05-.1: FROM .05 PER CENT TO .1 PER CENT
- .1-.2: FROM .1 PER CENT TO .2 PER CENT.
- .2-.3: FROM .2 PER CENT TO .3 PER CENT.



BLACK ALKALI MAP. GOSHEN SHEET. UTAH.

-.05	.05-.1	.1-.2	.2-.3
LESS THAN .05 PER CENT	FROM .05 PER CENT TO .1 PER CENT.	FROM .1 PER CENT TO .2 PER CENT.	FROM .2 PER CENT TO .3 PER CENT.

source. Over most of the alkali areas found in the valley the surface of the soil is within capillary reach of the ground water, and consequently rapid evaporation at the surface is continually going on, with the result that salts are concentrated at this point.

As a general rule, the greater part of the alkali found in the soils of this valley is in the first 3 feet of soil, little or no alkali being found below this depth. In some places of heavy soils underlain by clay, however, the alkali is quite uniformly distributed throughout the 6 feet, which is the depth to which the alkali determinations are usually made.

A comparatively thin layer of alkali is often all that is necessary materially to injure plant growth. For instance, in several cases alfalfa was found suffering from alkali where nearly all of the salts found in the soils occurred within 6 inches of the surface. In one particular case alfalfa was found suffering from alkali in a sandy loam soil with 0.65 per cent of salts in the first foot, 0.25 per cent in the second, and an average of about 0.20 per cent for the 6 feet. Many tests were made in the field with a view of ascertaining, if possible, the maximum limit of alkalinity that sugar beets will withstand. In most cases beets were found growing successfully in soils containing 0.60 per cent of alkali or less, but quite often fields were encountered where the same plants were growing apparently well in soil containing as high as 1.40 per cent of soluble salts as the average of 6 feet. A very interesting observation was made in connection with these tests. It was noticed repeatedly that the amount of alkali that sugar beets will stand is in a great measure dependent on the character of the soil. Many tests were made in sugar-beet fields where it was evident from surface conditions that the plants were suffering from alkali. In all such cases it was found that where the soil was loam or heavier the amount of alkali required to injure the crops was higher than where the soil was of a lighter class. Several cases were observed where sugar beets in a sandy soil were suffering with 0.65 per cent of alkali in the first foot of soil, 0.62 per cent and 0.55 per cent in the second and third feet, respectively, with the amount of salt diminishing greatly in the lower depth. On the other hand, beets were found growing apparently well in a heavy loam soil with 1.40 per cent of alkali in the first foot, 1.50 per cent in the second, 1.55 per cent in the third, and an average of 1.50 per cent for the 6 feet. Similar observations on sorghum and alfalfa in this and other alkali areas appear to confirm the above conclusions. Whether the same relation between the texture of the soil and the limit of endurance to alkali conditions exists as regards other plants remains to be investigated.

The following analyses of crust give the chemical composition of the alkali in this area:

Chemical analyses of salts in alkali crusts.

Constituent.	NE. cor. sec. 19, T. 9 S., R. 1 E.	NE. cor. sec. 28, T. 9 S., R. 1 W.	SW.4–40, sec. 10, T. 7 S., R. 2 E.	NE. cor. 6–40, sec. 3, T. 7 S., R. 2 E.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	2.96	0.34	1.48	0.52
Magnesium (Mg)	.97	.30	2.70	.72
Sodium (Na)	32.44	36.26	24.98	33.52
Potassium (K)	2.71	1.25	3.16	2.52
Sulphuric acid (SO_4)	1.18	3.55	45.91	12.22
Chlorine (Cl)	59.25	21.70	6.51	9.23
Bicarbonic acid (HCO_3)	.44	15.16	10.98	16.68
Carbonic acid (CO_3)	.05	21.44	4.28	24.59
Conventional combinations:				
Calcium sulphate ($CaSO_4$)	1.67	1.17	5.02	1.77
Calcium chloride ($CaCl_2$)	6.82	1.52	13.31	3.57
Potassium chloride (KCl)	5.14	2.37	6.05	4.82
Magnesium chloride ($MgCl_2$)	3.81	2.23	46.95	11.99
Sodium chloride (NaCl)	81.85	33.97	5.95	11.43
Sodium bicarbonate ($NaHCO_3$)	.61	20.88	15.18	22.95
Sodium carbonate (Na_2CO_3)	.10	37.86	7.54	43.47

Peculiar conditions exist in the Goshen Valley which is, as a whole, very strongly alkaline. With the exceptions of the bench lands immediately adjoining the mountains and a few other smaller areas in the bottoms, sufficient salts occur in all of the soils materially to injure the crops, or entirely to prevent profitable cultivation. As may be seen from the alkali map for the valley, very large areas of land containing from 1 to 3 per cent of alkali are found here. In this class of soils it is doubtful if any of the common agricultural crops will grow with any degree of success.

The alkali of this valley comes from two principal sources: First, from the continuous evaporation of the ground water, where this is within capillary reach of the surface of the soil, and, second, from the evaporation of the water of Lake Bonneville, which once covered the country. The soils in the bottom of the valley are particularly heavy to a considerable depth, and at the time of the evaporation of the waters of the ancient lake, were left thoroughly impregnated with salts, and they have not, to the present time, been washed of the alkali left by the desiccation of the lake waters. The chief reasons why these old deposits of salts have not been removed are probably, first, because the drainage of these soils is very poor, and, second, because the water for irrigation in this locality is utterly insufficient for a thorough flooding of the soil. Conditions here are different in this respect from those in the Provo sheet, for there streams are more common and the drainage facilities more favorable.

As would naturally be expected from the conditions of its deposition, alkali is found to considerable depths in the soils of this valley, and it is only in the immediate vicinity of the lake, where the ground water is close to the surface, that less salts are found below the third foot than in the upper 3 feet of the soil.

Black alkali or sodium carbonate is found in more or less injurious quantities in some parts of the valley. It is seldom found, however, in amounts exceeding 0.10 per cent outside the Goshen Valley, without the presence also of an excess of white salts. This form of alkali is very much more injurious to plants than the white form, and 0.10 per cent of this salt is considered fatal to crops. Wherever this salt occurs in considerable quantities, and where gypsum may be obtained at a cost not too great, it is advisable to apply powdered gypsum to the soil, and mix it in well by cultivation and irrigation. With the application of gypsum to soils containing black alkali a chemical reaction takes place by which the corrosive sodium carbonate is changed into sodium sulphate—a much less injurious salt. This chemical action is illustrated in the land immediately adjoining Utah Lake and within reach of the lake water. The water of the lake contains gypsum in solution, and coming in contact with any black alkali that may be formed in the soil immediately changes it into the white alkali. It is doubtful whether the application of gypsum to the soil of this valley would be practicable, and it is believed that more lasting results, as regards both the black and the white alkali, may be obtained by drainage, as will be explained in a subsequent chapter.

In the Goshen Valley black alkali is found in considerable quantities, and over quite large areas. As may be seen from the black alkali map of this sheet the areas of 0.10 to 0.20 per cent and 0.20 to 0.30 per cent of sodium carbonate are quite large. None of this land is at present under cultivation, and it is evident from surface conditions that no agricultural plant would grow in the soil.

Black alkali is not as readily drained from the land as are the less injurious salts. Its presence tends to puddle the soil and it appears to cling more tenaciously to the soil grains. In the Goshen Valley black alkali is always found associated with more or less of the other salts, and it is seldom found in amounts exceeding 0.10 per cent without the presence also of an excess of white salts. It is evident from these observations that since the application of gypsum to the soil would be of no immediate benefit to the land, as far as the growing of crops is concerned, on account of the presence of an excess of white salts, drainage is the only practicable remedy. Proper drainage would remove the white salts, and gradually the sodium carbonate would also be washed out of the soil.

RECLAMATION OF ALKALI LANDS.

It is well known that alkali accumulates in fertile soils, and that once the injurious quantities of salts are removed these lands produce most excellent crops. There is no doubt that the alkali soils of this valley, most of which are at present practically worthless, would, if freed from alkali and supplied with sufficient moisture, grow successfully any crop adapted to the region. There are at present in this valley 49,408 acres of land containing more than 0.40 per cent of alkali as an average for 6 feet. Over most of this land soluble salts occur in sufficient quantities to be either injurious to crops or entirely to prevent successful cultivation.

The value of most of this land is nominal, varying from $5 to $15 an acre. If properly reclaimed, it would be worth, under irrigation, at least $80 an acre. Thus it is evident that if some method could be found by which this land could be brought into a state of fertility it would add greatly to the wealth of the community.

Mr. Thomas H. Means, of this Bureau, found the method of flooding with open drains successfully used in Egypt, where the soils are of a heavy character and stand well in bank, but it is doubtful if the method would prove practicable in the light soils of this valley, where much difficulty would be experienced in keeping small ditches open, and it will be best to use tile drains. This requires the same land preparation as where open ditches are used, the essential difference between the two being that since tiles are used in this case, the trenches may be filled with soil, thus requiring no room and leaving all the land available for cultivation. This method is considered the most rapid and effective way of reclaiming alkali land. Tile drains, if properly laid, require no repairing and are efficient for many years. Three or 4 inch tiles may be used, buried at a depth of 3 feet and about 150 feet apart. The expense, including the cost of the tiles, digging the ditches, and laying and covering the tiles, will not exceed $20 an acre.[a]

In an experiment conducted by this Bureau in a tract of 40 acres of land, 3 miles west of Salt Like City, very satisfactory results have been obtained. The soil here contained, before the tiles were laid, an average of nearly 6 per cent of alkali in 6 feet. The land was subjected to a single flooding at the end of the past season and up to May, 1903, when the writer visited the tract, the drains had been running steadily as the result of this flooding and subsequent rains and snows, carrying off water containing between 2 and 3 per cent of salt. The tile drains, in this experiment, are laid 150 feet apart. This seems to be a good average distance at which to place tiles, though in some of

[a] For particulars of alkali land reclamation in Egypt see Bul. 21 Bureau of Soils, U. S. Dept. of Agr.

the lighter soils of Utah Lake Valley a distance of 200 feet apart would probably not be too great.

The following table shows the extent of the several grades of alkali land in the area:

Areas of alkali lands.

Grade.	Acres.	Per cent.
Less than 0.20 per cent	159,488	69.9
From 0.20 to 0.40 per cent	29,824	11.6
From 0.40 to 0.60 per cent	15,680	5.7
From 0.60 to 1 per cent	10,368	3.9
From 1 to 3 per cent	23,360	8.9
Total	238,720	....

AGRICULTURAL METHODS.

The methods of agriculture in use in Utah Lake Valley will be best considered in connection with the principal crops grown.

By far the most important crop in the valley is the sugar beet. The cultivation of this crop is done chiefly under the direction of a local company, the agents of which superintend the preparing of the soil and the planting, cultivating, irrigating, and harvesting of the crop. The plowing for beets is usually done in the fall or early in the winter, the ground being plowed 10 or 12 inches deep. In the spring as soon as the weather permits, generally early in April, the ground is gone over with a disk harrow cutting 3 or 4 inches into the soil. After harrowing, a masher, consisting of 3 or 4 planks lapped together, is dragged over the field. This implement leaves the ground very smooth. When in this condition the land is usually irrigated and again prepared in the same manner as before. The ground is then ready for the planting.

The seeds are planted from three-fourths inch to 1¼ inches deep, in rows 18 to 20 inches apart. From 15 to 20 pounds of seed are used for an acre. As soon as the plants have four leaves thinning commences. The beets are first blocked out with a hoe, leaving from 1 to 3 plants in a hill or bunch. Small boys follow, pulling out the smaller and weaker plants and leaving the stronger ones from 7 to 10 inches apart in the rows. Where the soil is known to be rich the plants are left closer together than where it is poor, the object being in the first case to check the excessive growth of the beet, for beets weighing over 3½ pounds each are rejected by the sugar company.

As soon as thinned the beets are usually irrigated, though in certain parts of the valley where the ground water is close to the surface little or no irrigation is practiced. The usual method of irrigating is by making furrows between the rows down which the water is run.

In some cases, however, the whole field is flooded. Harvesting commences about September 5 and ends about December 5. The knife used in topping consists of a thin blade 14 to 16 inches long and 1½ to 2½ inches wide, with a hook at one end with which to pick up the beet.

One of the instructions of the company to the growers is never to plant beets in alfalfa land that has not been planted to other crops for at least two preceding seasons. The direction is based on the fact that newly plowed alfalfa land is very rich in nitrogen, in fact too rich for sugar beets, making them grow larger at the expense of the sugar content. For this reason the alfalfa land is usually first planted in wheat or barley, followed by corn the second year, after which it may be planted to beets.

No fertilizer other than stable manure is used on these soils. The manure is usually plowed under in the fall, thus giving it time to decompose by the spring when the beets are planted. Some damage has been done to land where farmers have attempted to grow beets continuously on the same soil. However, the company now has competent land superintendents who plan such systems of rotation as will not impair the natural fertility of the soil.

As regards grain and alfalfa, the methods of cultivation and irrigation in this valley differ but little from those in general use. It might be said, however, that cultivation is often too shallow to secure the best results. In the central part of the valley, where irrigation water is more plentiful than in the northern and southern portions, wheat and alfalfa are usually irrigated. The common method of irrigation is by flooding, though where water is scarce the furrow method is practiced. Large areas of alfalfa and wheat in the southern portion of the valley are not irrigated at all, on account of insufficient water supply. It is not very often that more than one crop of alfalfa per year is secured in these cases, and for the last four years the crops have been almost total failures. In the case of fruit growing the cultivation is quite thorough. Deep plowing is usually practiced and the land is harrowed frequently. In this way the orchards are kept free from weeds and the soil is always in fine tilth. Frequent surface cultivation is beneficial not only in removing obnoxious weeds but also in forming a mulch that conserves the moisture in the soil.

AGRICULTURAL CONDITIONS.

The unprecedented dry seasons experienced during the last few years have greatly affected the agricultural conditions in Utah Lake Valley. This is particularly true of the northern and southern portions of the district, where less irrigation water is usually available than in the central part. For the four years preceding the season 1902–3 the crops of the northern and southern parts of the valley have been partial or total failures. In the central part the effects of the drought during these years have been a little less severe. During the season 1902–3, however, winter snows on the Wasatch Mountains were more plentiful and rains in the valley were much more frequent. As a result, crops of all kinds have produced abundantly, farmers have taken new courage, and business enterprises have resumed normal activity.

Agriculture in Utah Lake Valley is at present in a very progressive state. The farming class is, as a whole, energetic, enterprising, and thrifty. The majority of the farmers own their own lands, and there are but few mortgages on the farms. There are over 2,600 farms in Utah County, and the average size of the farms is 47 acres. Intelligent farm laborers may be secured for $30 a month and board.

Utah Lake Valley is, in many respects, the most important agricultural district in the State of Utah. This is particularly true as regards the growing of sugar beets, potatoes, and a few other special crops. About 5,160 acres of land are annually planted to sugar beets, yielding an annual product of about 71,000 tons, or an average of 13.7 tons per acre. Yields of 20 and even 25 tons per acre are common in the best soils throughout the valley. The cultivation of the sugar beets, as already stated, is done chiefly under the direction of a local company. This company operates a sugar factory near Lehi City and buys the sugar-beet product of Utah County. The company employs a corps of able agriculturists under whose direction the beets are usually very successfully grown. At the time of planting the beets a contract is entered into by the grower and the company. By this contract the company agrees to buy the beet product of the grower at certain prices and subject to certain conditions. The company will furnish the seed and plant the land, for which expense the grower agrees to pay the company $2.75 per acre planted. The beets are delivered at the nearest delivery station of the company at the expense of the grower and for the following prices per ton, on a basis of 80 per cent purity: Sugar content 12 per cent, $4.25; 13 per cent, $4.50; 14 per cent, $4.75.

The cultivation of sugar beets is at present mostly restricted to the lands on the lower levels or in the vicinity of Utah Lake. This is due to the facts that in the higher lands irrigation is usually more difficult and uncertain and that the soil is loose and porous, thus requiring very frequent applications of water. The soil usually preferred for sugar beets, and from which the best results are obtained, is the Jordan sandy loam. This soil is of a medium light texture and is easily worked, thus permitting rapid and thorough cultivation. Next to the Jordan sandy loam, the Jordan loam is considered best, though the lighter phases of this type are usually preferred. Wherever irrigation water is obtainable beets are grown successfully in the loamy or gravelly soils of the bench lands.

For several reasons much of the land in the vicinity of Utah Lake is well adapted to the cultivation of sugar beets. The soil is naturally rich in plant food and little or no fertilization is required, and, owing to the position and character of the soil, comparatively little irrigation water is necessary for the complete development of the crop. Moreover, sugar beets, being a shallow-rooted crop, are well suited to conditions where the standing water is close to the surface of the ground, as is usually the case in the vicinity of the lake. Besides this, lands in this locality are usually alkaline, and the cultivation of other than alkali-resistant crops would, in most cases, prove a failure, unless it was preceded by thorough drainage of the soil.

Next to the sugar-beet industry alfalfa growing is probably the most important branch of farming in Utah Lake Valley. About 26,500 acres of land, yielding on the average 2 tons of hay to the acre, are planted to this crop. Alfalfa is grown more or less in all soils and throughout all parts of the valley, but more commonly in the bench lands, where, when supplied with sufficient moisture, particularly good crops are obtained. It is an exceptionally deep-rooted crop and will not grow in land where the water table is so close to the surface as to permit the plant roots to enter the water. This fact has been clearly demonstrated in the vicinity of Utah Lake. Lands near the lake, where the depth to standing water is 3 or 4 feet, and at periods of heavy rains much less, have been sown in alfalfa. The plants do remarkably well for the first two or three years, but die as soon as the roots enter the level at which water stands. In some of the bench lands considerable areas are devoted to growing alfalfa without irrigation. In the majority of these cases one crop only is obtained in a season, though during seasons of unusual rainfall two crops a year have been secured. The average yield for this crop where dry farmed is from one-half ton to 1½ tons of hay per acre. Most of the alfalfa grown in the valley is consumed within the county, but large quantities are also shipped out, principally to neighboring mining points. The prices vary from $4 to $15 a ton, depending on the kind and quality of the hay and the season of buying.

Upon the lighter soils of the lower levels growing potatoes is a quite prominent industry. The crop is usually irrigated, though in several cases where the ground water is close to the surface little or no irrigation is practiced. The average yield per acre is about 160 bushels, and over 32,800 bushels of potatoes are annually grown in the county. The potatoes are of fine quality.

Corn is an important product and is grown more or less in all soils throughout the valley. About 30,000 bushels of corn were grown in 1902, with an average yield of about 20 bushels per acre. A considerable acreage of barley is grown around Spanish Fork and in other parts of the valley. Oats and sorghum are also quite extensively grown; wheat and rye to a small extent.

Fruit growing is a comparatively new industry in Utah Lake Valley. The climate is such as to permit the successful cultivation of fruits able to withstand a certain amount of frost. The tendency for the last few years has been to increase the acreage in orchards. Considerable fruit is grown in some of the bench lands to the north of Provo City. Apples, pears, plums, peaches, and a few of the small fruits have been successfully produced, and the area in this vicinity devoted to fruit growing is increasing every year. In the bench lands around the town of Mount Nebo, in the Goshen Valley, an orchard of peaches, pears, plums, and apples is giving fair returns under rather unfavorable conditions as regards irrigation.

Sheep raising is the oldest industry in the State of Utah. In Utah County this industry is quite prominent. According to records collected by the State statistician, there were in the year 1901, 130,327 head of sheep in the county, giving an annual wool product of 814,965 pounds. Most of the wool is shipped to eastern points, but a considerable quantity is made into fabrics of various kinds at the mills in Provo City.

The system of roads in this valley is very incomplete. The roads are few and often very rough, apparently little judgment being exercised in their construction. In a district like this, where the transportation of the products of the country by wagon is of such importance, more attention should be paid to the construction and proper care of roads. The railroad transportation facilities are very good. The San Pedro, Los Angeles and Salt Lake Railroad and the Rio Grande Western Railway traverse the main areas from north to south and offer ample facilities for transportation. The Goshen Valley is crossed from east to west by a branch of the Rio Grande Western Railway. As a whole, agriculture in this valley is in a very prosperous state. With increasing knowledge and practice of scientific methods of agriculture, and with the proposed more adequate system of irrigation, Utah Lake Valley promises to become the most important agricultural district in the State.

NOTE.—Interesting in connection with the drainage and irrigating systems about Utah Lake is the change in the composition of the lake water itself. Prof. F. W. Clarke, of the United States Geological Survey, called our attention to the great discrepancy existing between the analysis of Utah Lake water made by the Bureau in 1903 and that made by him twenty years earlier (U. S. Geol. Survey Bul. No. 9, p. 29, 1884). A second sample was procured by the Bureau in 1904 and the analysis of this sample confirms fully the analysis of 1903.

The results of these analyses are given below, together with Professor Clarke's earlier analysis:

Analyses of Utah Lake water.

[Parts per million.]

	Clarke.	Bureau of Soils.	
	1883.	1903.	1904.
Ca	55.8	80.0	67.0
Mg	18.6	92.0	86.0
Na	17.7	247.0	230.0
K	(?)	30.0	22.0
SO_4	130.6	365.0	378.0
Cl	12.4	336.0	337.0
HCO_3	....	266.0	194.0
CO_3	60.8	....	11.0
SiO_2	10.0	....	28.0
	306.0	1,416.0	1,353.0

An examination of the figures shows that the total salt content has increased very markedly since 1883. The greatest increase is in the sodium and the chlorine, and is no doubt due to the predominance of sodium chloride in the seepage waters from the irrigated lands adjoining the lake. The causes of the increased total salt content of the lake water are obviously: the influence of seepage water from the surrounding irrigated lands which have been brought under cultivation since the analysis of Clarke was made; the diversion of fresh streams for irrigation purposes, which streams formerly flowed directly into the lake; and the relatively large differences produced by evaporation in so shallow a body of water.

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