Bulletin No. 193 - Cache County Water Conservation District No. 1

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WILLIAM PETERSON, G. D. CLYDE, D. S. JENNINGS, M. D. THOMAS, AND KARL HARRIS

Pumping Plant No. 1 showing discharge pipes (Bear River in background)

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LOGAN, UTAH
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L. M. WINSOR, B. S............................................................... Irrigation Engineer

*On leave of absence.
GENERAL CONSIDERATIONS

Location and Area.—Cache County Water Conservation District No. 1 lies on the west side of the valley about eight miles from and a little northwest of Logan, Cache County, Utah. Figure 1 shows the location of the project with respect to Salt Lake, Ogden, Brigham City, Logan, and Cache County. Cache County, with a population in 1920 of 27,000 people, is located in the north-central part of the state and occupies the greater
part of the fertile Cache Valley. Cache County Water Conservation District No. 1 includes 8490.78 acres (of which 7373.38 acres are allotted water) and extends from Bear River and its tributaries westward to the foothills and from Cache Junction on the north to an east-west line lying one-quarter of a mile south of the Logan-Petersboro road. Figure 2 shows the boundaries of the district. The land rises gently (except for a low bluff at the river’s edge) from an elevation of 4400 feet (that of the normal water surface in Bear River at the north end of the project) to an elevation of 4580 feet at the western extremity of the project.

Transportation.—The district is well provided with transportation facilities. It is served by the Oregon Short Line Railroad and the Utah-Idaho Central Railroad. The main line of the Oregon Short Line (which connects Utah, Idaho, and Oregon points) passes thru Cache Junction on the north end of the project. A branch line around the south end of Cache Valley connects Mendon, Wellsville, Hyrum, Millville, Providence, Logan, Smithfield, Richmond, and Lewiston with the main line at Cache Junction. In addition, a beet line crosses the district connecting Ballard Junction and Logan. The Utah-Idaho Central Railroad, an electric road furnishing excellent passenger and freight service, passes near the southern boundary of the district. Ten passenger trains daily operate over the electric road and two trains daily over the steam line to Cache Junction. The daily freight service is almost equal to express service.

Cache County is well equipped with first-class highways. The main graveled highway from Logan to Cache Junction traverses the district from south to north. Another graveled highway from Logan to Benson crosses the district at right angles to the former road. The highways to Box Elder County on the west and Mendon and Wellsville on the south are first-class graveled roads. Figure 2 shows the location of railroads and highways in the district. So excellent are the transportation facilities on this project that an average haul of one and one-half miles to a railroad loading-station is all that is required to put the farmers in touch with local or outside markets.

Community Development.—Cache Valley received its name from the early trappers who located their fur caches in it. The early history of the valley is typical of that of other valleys of the west. The valley was explored soon after the advent of the Mormons into Salt Lake City in 1847. The first white settlers in the valley were the trappers who gave the valley its name. A few years later a party of men sent out by Brigham
Fig. 1.—Map showing location of Cache County Water Conservation District No. 1
Young entered the valley for the purpose of colonization. The settlements in the valley are peculiar to Utah development in that the farming land is located outside and around the town. This type of development was followed primarily for protection against the Indians. Therefore, compact communities are found dotted throughout the valley with the bulk of the farming land surrounding the towns. There are in Cache County one city of the first-class, four cities of the second-class, seven cities of the third-class, and sixteen agricultural communities*.

The rural population of Cache County in 1920 was 17,553 and the urban population 9,439, giving a total population in Cache County of 26,992. The rural population live in communities containing from 110 to 1,948 people. These communities are in every case strictly farming or agricultural districts. Cache Junction, on the main line of the Oregon Short Line Railroad, lies in the north end of the project and has a population of about 300 people. Benson is situated across the river to the east of the project with a population of 316. Mendon, about three miles south of the district, has a population of 434, and Petersboro (located near the middle of the district and including most of the project) has a population of 320. These are all relatively young and thriving communities. Within a radius of about ten miles are located Logan, the county seat of Cache County and a city of the first-class; Richmond, the home of the Sego Milk; Smithfield, the home of the large pea and bean cannery; and Wellsville and Hyrum—all cities of the second-class.

Schools.—The Petersboro School (Fig. 3), which is housed in a fine brick building, is located in the south-central part of the district. The Cache Junction School on the north side of the district and the Benson School on the east side furnish ample facilities for public school education. Cache County supports three modern high schools—the Logan High School at Logan, the South Cache High School at Hyrum, and the North Cache High School at Richmond.

Within ten miles of the district is located the Utah Agricultural College which is the State College of Agriculture. This school is ideally located on the east side of the valley and ranks second to none in agriculture. In addition, Brigham Young College and Logan Academy, sectarian schools, are located in Logan. It will be noted in Figure 2 that the maximum distance to a public school is less than three miles, and ample provision for high-school and college education is provided within a radius of ten miles.

*U. S. Census Bureau, 1920
Fig. 2.—Map of Cache County Water Conservation District No. 1
(Scale, 1 in. = 1 mi.)
Industries.—Cache County is first and foremost an agricultural center. However, manufacturing and grazing occupy an important place in the industries of the county. Cache County boasts a total of fifty-three manufactures, employing an average of 910 wage earners. The average annual payroll amounts to $738,285; taxes and rent, $187,928; cost of raw material, $6,720,892; and value of products, $9,797,534. Of the fifty-three manufactures in Cache County there are six flour mills, five sugar factories, and four condensed milk factories. During May 1924 the milk factories were handling raw milk at the rate of 240,000 pounds daily. A pea-canning factory located at Smithfield is supplied with peas grown in the valley and shelled at the forty-eight wineries scattered through the section. The run during the 1923-season was over 200,000 cases, and since that time the factory has been considerably enlarged. The four sugar-beet factories in Cache County during 1924 paid to the farmers for beets $1,675,000 and paid out for help in handling the beets and manufacturing them into sugar $465,125. During the same year these factories refined 600,971 bags of sugar and produced 290,030 tons of beet pulp used in the county for fattening cattle and sheep. Alfalfa, grain, sugar-beet pulp, syrup, pea hay, and a mild winter climate furnish ample facilities for feeding thousands of cattle and sheep. A ready market, therefore, is available for practically all the farm products of the valley.

Electric power is available in abundant quantities. There are four power plants in Cache County with a combined capacity of 9060 horsepower. The transmission line from the Bear River system of plants passes just north of the project. In addition, the new Cutler plant, which the Utah Power & Light Company is building at an approximate cost of $5,000,000 in Bear River Canyon, is only about three miles distant. This plant alone will have a capacity of about 35,000 horsepower. Power from these plants is dependable. With Bear Lake storage the plants on Bear River could run continuously for two years if the natural flow from the Upper Bear River should fall to the lowest mark.

CLIMATE

The average annual rainfall at Logan (eight and a half miles from the project) over a 31-year period is 16.46 inches. This precipitation is divided as follows: March to June, inclusive, 6.67 inches; July to September, inclusive, 2.63 inches; and October to February, inclusive, 7.16 inches. Destructive storms either in winter or summer are very uncommon. The monthly distribution of the annual precipitation is clearly shown in Figure 4.
The amount of rainfall and its distribution are favorable for the production of dry-farm crops such as grain, alfalfa seed (in selected spots), and a few other crops of less importance. To extend the range of crops or to get a maximum yield irrigation must be resorted to, altho it is seldom necessary to irrigate in the spring to cause the seed to germinate or to bring the seeded crops up.

The climate of Cache County is invigorating and characteristic of the mountain region of Western United States. The mean temperatures for the spring and fall months are 45.7° F.
and 49.9° F., respectively. Comparatively high temperatures prevail in the afternoon during the summer months, but due to the elevation and low humidity the days are not oppressive and the nights are always cool. The average date of the last killing frost over a 26-year period in the spring is May 15th and the first killing frost in the fall over the same period is October 8th. The absolute latest frost in the spring and earliest frost in the fall during this 26-year period is June 17th and September 13, respectively. The average growing season is about 140 days and is sufficiently long to mature the staple crops (such as alfalfa, grain, sugar-beets, peas, truck, and small fruits) grown in the mountain states.

**TOPOGRAPHY**

In general, the surface slopes of the land within Cache County Water Conservation District No. 1 are uniform and slope gently downward to the east and north. On the north end of the project the elevation of the water surface in Bear River is about 4400 feet. From this point the ground surface rises abruptly about sixty feet and then flattens out into a relatively flat area with a few distinct knolls and hollows. Farther south the surface assumes a more gradual slope from the river to the main canal. Above the main canal the slope becomes greater, but in no case is it steep enough to interfere with irrigation.

The drainage from the west mountains is short and, therefore, has had little effect in modifying the topography. There is only one stream of any consequence which flows from the west mountains, and this is Three-Mile Creek near the south end of the district. Outside of the little stretch of irregular topography in the south end of the district the entire area west of the railroad is uniform in slope and in good shape for the application of irrigation water.

East of the railroad the surface drainage has had a more marked effect. The topography is characterized by narrow, natural drainage channels two to six feet deep, wide swales, wet marshy draws, and irregular depressions.

The area south of Petersboro (both east and west of the track and north of Petersboro on the west side of the track) is more regular (See Fig. 5). The area is not cut up to any great extent by surface drainage, the soil is deeper, and the land is in good shape for irrigation without further leveling. The slope is uniform to the east so that wild-flooding or furrow methods of irrigation may be conveniently practiced. Of the entire irrigable area approximately 4200 acres come in this class and constitute by far the better lands of the project.
Fig. 5.—Map of Cache County Water Conservation District No. 1 showing surface contours and a paper location of a distribution system. (Scale, 1 in. = 1000 ft.)
The area north of Petersboro and east of the railroad, with the exception of a few isolated pieces, is characteristic of California “hog-wallow” land, being covered with knolls and hollows and underlain at a depth of six to ten inches with a compact heavy clay. Approximately 2500 acres of this area will require leveling which can be done with a box-level and a plow. Approximately 800 additional acres, including most of Section 5 and a portion of Section 8, are entirely too rough to level successfully because of irregular topography and the shallow depth of the surface soil which supports plant growth.

Figure 6 shows a typical area of the rough land. The area of the individual knolls and depressions is small, varying from three to four to as much as 500 square yards with the difference in elevation between the top of the knolls and the bottom of the depressions ranging from six inches to three feet. Figure 6 indicates that at least 18 inches of soil would have to be removed from the knolls to fill the depressions. This would require the use of scrapers and would remove all of the surface soil from the knolls.

DESCRIPTION OF SOILS

The productive capacity of soils varies from place to place. This fact is recognized by all who have studied soils. Serious attempts have been made, and are now being made, by soils students to find the reasons for these differences. The causes
of the variations are many and have been shown to be deep­seated and complex in the extreme. They involve studies that have to do with chemistry, physics, bacteriology, geology, and plant nutrition. It is recognized that the differences in the productive power of a soil are due, in part at least, to variation in the chemical and physical properties of the soil. A soil survey is an attempt to measure variations in these properties. It is an undertaking, the purpose of which is to group together soils that are all alike (or nearly alike) in these two properties and separate those that are different. It is, in fact, a classification of soils.

The soils of the Cache County Water Conservation District No. 1 have all been transported. They have accumulated slowly as the valley has developed. Cache Valley is a structural valley with mountains entirely surrounding it. The great structural depression has been filled in with sediments which began before the time of Lake Bonneville. The district was completely covered by the lake and the soil is partially made up from the fine sediments accumulated from the lake. These have been altered by river action, especially of Bear and Little Bear Rivers. Previous to the time of Lake Bonneville and during its earliest history the river flowed from Cache Valley to the west over the pass due west from the project where Beaver Dam Creek now flows. In the waters earlier than Lake Bonneville there were accumulated great masses of lime in the form of marl and oolite. During the same period there were deposited great quantities of volcanic ash interbedded with lake and river debris. In later periods the erosion has redistributed the ash and marl and it has become greatly intermingled with the land and river deposits. This has played an important part in forming the soils. The very fine clays, the granular ash, and the partially dissolved or leached marl have either been sorted or mixed with the river sediments to form the classes of the soils found in the district.

The fundamental physical property of soils used in classification is that of size of particles, or soil texture. Variations in texture are studied and the soils are grouped into clays, loams, and sands. These are known as soil classes. However, there are many different kinds of clays, sands, and loams, and to distinguish between them several other factors must be taken into account. These factors are as follows:

1. The kind of rock from which the soil material was derived.
2. The manner in which the soil material has originated.

That is, is the soil residual or transported? What has been the agent of transportation?
3. The soil profile, or the character of the soil and subsoil, the depth of the surface soil and the extent of variation in physical and chemical properties from surface soil to subsoil.
4. The location of the soil including the topography.
5. The color of the soil and the subsoil.

These factors taken together constitute a series, and the series plus the class constitute a soil type.

The soils of the area have been divided into two series: (1) Mendon and (2) Ballard. There have been recognized two types and two subtypes in the Mendon series and one type with one subtype in the Ballard series. It will be seen by reference to the soil map (See Fig. 7) that nearly all of the Mendon soils lie above the 4425-foot* contour and that the soil boundary between the series, in a general way at least, follows the contours. This is rather significant in view of the fact that the soil boundaries were drawn without knowledge of the contours. The Mendon soils are found on sloping topography. In this area the slope is mainly to the east.

The Mendon soils are dark-colored on the surface, while those of the Ballard are light. This color classification is a qualitative scheme of indicating the content of organic matter. Thus, in three representative samples of Mendon soils, the content of organic matter calculated from the organic-carbon dioxide in percentage was 3.76 with a range of 3.56 to 4.02, while six representative samples of Ballard soils gave an average of 2.01 (the minimum being 1.58 and the maximum 2.38). The Mendon soils are generally well supplied with organic matter, and the percentages indicated above are sufficient, provided other factors are favorable, to keep the soils in a good state of productivity. Soils from the Central Experiment Station at Greenville contain from 3.67 to 4.16 per cent organic matter. These soils are considered especially good and produce good crops.

The soils of the Ballard series are light-brown to light-gray on the surface. At a depth of usually eight inches (but varying from six to ten inches) there occurs a heavy tight subsoil of a light-reddish-brown color. This extends to about fifteen to eighteen inches in depth when a calcium-carbonate horizon is found. This horizon is very compact. At the top the calcium-carbonate horizon appears in the form of light specks, but at greater depths the specks enlarge into small white masses of calcium carbonate. Growth of these masses takes place largely

*Data used in the soil survey do not correspond exactly with the data used in the reservoir survey.
Fig. 7.—Soil Map of Cache County Water Conservation District No. 1
in a vertical plane. This would appear to be the result of a movement of the calcium carbonate with the water. At greater depths in this horizon the small masses of calcium carbonate increase in number until at about thirty-four to thirty-eight inches the total soil mass becomes light gray in color. This extends to about forty-six or forty-eight inches in depth, when the color of the subsoil again becomes brown with only specks of calcium carbonate occurring in it to about fifty or sixty inches. Below this the subsoil becomes a brownish-gray in color and less compact than it is from about eight inches to about fifty or sixty inches. It should be noticed in this connection that the surface soils of the Ballard series are generally low in calcium carbonate, as may be seen by the profile below.

A typical profile of Ballard clay with the field notes that were taken while the samples were being collected, together with the carbonate-carbon-dioxide of each horizon, is given below:

**Ballard Clay I.**—**Location:** southeast corner 10, No. 1, 40 No. 4, Section 5, Range 1 West, Township 12 North*:

<table>
<thead>
<tr>
<th>CARBONATE CO₂</th>
<th>CALCIUM CARBONATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–70—Light grayish-brown clay, granularity fair</td>
<td>0.09 %</td>
</tr>
<tr>
<td>10–22—Compact layer of heavy clay with white streaks, columnar structure</td>
<td>2.38</td>
</tr>
<tr>
<td>22–36—Compact light-brown clay with white streaks of calcium carbonate</td>
<td>11.75</td>
</tr>
<tr>
<td>36–48—Light-gray clay (white marks have become continuous)</td>
<td>14.50</td>
</tr>
<tr>
<td>48–60—Light grayish-brown compact clay (few white markings)</td>
<td>11.47</td>
</tr>
<tr>
<td>60–72—Light brown very compact clay</td>
<td>10.25</td>
</tr>
</tbody>
</table>

Within the area of the Ballard series variations from this typical profile occur, the most marked of which are shown on the soil map as Ballard Clay II. The manner in which this subtype

*For the sake of brevity in note-taking each 40-acre tract within the section has been numbered. The “40” in the upper right-hand corner of the section is No. 1. The numbers proceed from right to left for the upper tier of “40’s”, then from left to right for the second, and so on. The plan is similar to the numbering of the sections in a township. For more detailed work each “40” is divided into four 10-acre tracts, and these tracts are numbered in the same manner as those of the “40’s” in the section.

**Part of the carbonate-carbon-dioxide is present as magnesium carbonate, but it has been arbitrarily calculated as calcium carbonate.
differs in profile from the typical Ballard clay (Clay I) may be seen by the following:

**Ballard Clay II.**—**Location:** northwest corner 10 No. 2, 40 No. 1, Section 17, Range 1 West, Township 12 North:

0—10—Light brown clay  
10—20—Light grayish-brown compact clay  
20—32—Light compact clay with white streaks (calcium-carbonate markings)  
32—40—Light gray compact clay  
40—41—Very fine sand  
41—48—Pink clay, heavy and compact  
48—53—Very fine bluish-green sand  
53—56—Coarse yellow and green sand  
56—72—Structureless heavy compact clay

In the most typical sections the coarse sand is lacking, the fine sand resting directly upon compact clay. In many cases it appears that the sand is in thin strata alternating with thin layers of clay.

Visible concentrations of calcium carbonate do not extend below the sand layer in Ballard Clay II. In the most typical cases the sand layer occurs between thirty-six and forty-eight inches, but seldom occurs above thirty-six inches. It is entirely possible that the sand layer extends beneath the Ballard Clay I at a greater depth than six feet.

Chart A, Figure 8, gives the mechanical analysis of a typical profile of Ballard clay taken from the east center of 10 No. 4, 40 No. 4, Section 5, Range 2 West, Township 12 North. This is the location from which large samples of soil were collected for leaching experiments (see pages 23, 25). The sand was found at a depth of seventy-two inches. The mechanical-analysis data are given in graphs. The ordinates represent the percentage of material of smaller diameter than the value of the corresponding abscissa. The abscissae represent diameters in microns*. It will be seen from this chart that the soils are fine in texture. It is believed that the surface soil in this location is somewhat coarser than is generally the case for the Ballard soils. The profile below eleven inches, however, is quite typical. The curves show a marked concentration of fine particles in Sample 1171, the horizon from eleven to twenty-two inches in depth. Sample 1172 is coarser than 1171 but considerably finer than 1170 (zero to 11 inches). Below thirty-six inches the profile becomes coarser in texture, and this is accompanied by a less compact structure. The horizon in the Ballard soils between approxi-

*1000 microns = 1 millimeter; 25.4 millimeters = 1 inch
Fig. 8.—Chart showing Ballard and Mendon soil types.

approximately ten and forty inches is very compact and is penetrated with difficulty by water and roots. The compaction is due, in part at least, to the leaching downward of fine material from the surface soil. This movement of the fine particles thru the soil has been observed and some measurement made of it in the leaching experiments of the soil.

The percolate carrying the mineral from the soil is practically
clear in the early period of the leaching. However, when the alkali is reduced it gradually becomes cloudy. This cloudy appearance may be correlated with the change in reaction of the percolate noted later. The percolate from one of the tanks contained 1.6 gram of solid material per liter, all of which was below one micron in diameter, as determined by the Utah method of mechanical analysis. These data will appear later in a more detailed publication.

The soils of the Mendon Series vary in color from a reddish brown to a dark gray. There is no definite demarcation between soil and subsoil to about twenty-four inches in depth. From twenty-four to about sixty inches the soils generally have a more compact horizon. However, the compaction is much less definite in the Mendon than in the Ballard soils. From about thirty to thirty-six inches these soils have reddish-brown to light gray subsoils. The prevailing color of the soil within this horizon in the typical case is brown with gray specks of calcium carbonate occurring at the top. These specks increase in size and number to about sixty inches. Below this the soil structure is generally more open, and the gray coloring (due to calcium carbonate) is less pronounced. The Mendon soils also occur at higher elevations and in areas of more pronounced slope. Lack of demarcation between soil and subsoil and occurrence on more pronounced slopes and higher elevation account largely for the open structure of the Mendon soils.

Two Mendon silty clays are shown on the map as Mendon Silty Clay I and Mendon Silty Clay II. They are similar to the Mendon clays except that they are coarser in texture. Sample 1103 gives the mechanical analysis of the surface soil of this type and subtype. In this case the subtype has a much greater extent within the area than the type. Both the type and subtype are somewhat lighter in color than is the Mendon clay and its subtype of surface soil.

Below is given a typical profile of Mendon Clay I together with the carbonate-carbon-dioxide. The calcium-carbonate equivalent of the carbon dioxide is also given. This has been calculated from the determined carbon dioxide.

Mendon Clay I.—Location: northwest corner 10 No. 1, 40 No. 10, Section 29, Range 1 West, Township 12 North:

<table>
<thead>
<tr>
<th>Carbonate CO₂</th>
<th>Calcium Carbonate Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>0—12—Dark gray clay</td>
<td>2.27</td>
</tr>
<tr>
<td>12—24—Dark grayish brown clay</td>
<td>5.17</td>
</tr>
<tr>
<td>24—32—Light brown clay compact</td>
<td>2.27</td>
</tr>
<tr>
<td>32—52—Light brown clay compact mottled with calcium carbonate increasing at bottom</td>
<td>5.17</td>
</tr>
<tr>
<td>52—64—Light gray clay; calcium carbonate dominating the color</td>
<td>17.58</td>
</tr>
<tr>
<td>64—72—Brownish gray clay</td>
<td>19.19</td>
</tr>
</tbody>
</table>

Mendon Clay II is similar to Mendon Clay I except that it contains a layer of sand in its 6-foot column. The thickness of this layer varies from less than one inch to several inches and usually occurs below three feet in depth.

Mechanical analysis of a profile of Mendon Clay I is given in Chart B, Figure 8. It will be seen that there is little difference in the three horizons. Sample 1065, the top soil, is somewhat finer in texture than Sample 1067 which represents the profile from eighteen to forty inches, while the sample from ten to eighteen inches in depth is an exact duplicate of that from two to ten inches (Sample 1065). The Mendon soils within the area, as may be seen from the chart, are generally free or have low concentrations of soluble salts (alkali). The Mendon clay loam resembles the Mendon silty clay except that it is somewhat lighter in color and coarser in texture.

The fact that the Mendon soils are all fine-textured but with open structure to three feet or more in depth accounts partly for their recognized use in dry-farming. They are very retentive of water. Under irrigation the clay loams may be expected to yield well to these crops and to respond to a fair extent to trucking crops.

The Ballard soils, because of their heavy nature, are considerably restricted as to cropping systems. It is certain that a crop like sweet clover would grow on these soils and in addition would benefit the soils by growing on them. Such a crop should be grown that would extend the surface soil to a greater depth by penetrating the inert compact sub-surface. The series is often hummocky in topography, and leveling would be essential to successful irrigation. This would expose the inert sub-surface in many places. Under such conditions sweet clover is especially to be recommended.
Complete chemical analyses of typical profiles of the important soil types are not yet completed, but the total content of nitrogen, phosphorus, and calcium of a few surface samples typical of the two main soil types is given below:

**TABLE 1. — TOTAL NITROGEN, PHOSPHORUS, AND CALCIUM IN TYPICAL SURFACE SOILS**

<table>
<thead>
<tr>
<th>Soil No.</th>
<th>Soil Type</th>
<th>Nitrogen</th>
<th>Phosphoric Acid ($P_{2}O_5$)</th>
<th>Calcium Oxide (CaO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1079</td>
<td>Mendon Clay I</td>
<td>.14</td>
<td>..........</td>
<td>1.45</td>
</tr>
<tr>
<td>1095</td>
<td>Ballard Clay I</td>
<td>......</td>
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<td>.24</td>
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</table>

The soils (as are arid soils generally) are low in nitrogen and organic matter. From the data of this table and the fact that potassium in significant quantities was found in the drainage water from the soils, it is very unlikely that the soils will be found deficient in any plant-food element other than nitrogen and organic matter.

**ALKALI CONTENT**

The fact that the land in this project is nearly all of a heavy clay of great depth makes it important to consider carefully the possibility of the presence of excessive concentration of soluble salts in the soil. The survey shows that an alkali condition exists in places throughout the area, which is more prevalent in the hummocky land of the north half of the project. The highest concentrations are found in the swales and the enclosed depressions of the rolling typography. There are scarcely any swales which do not contain excessive quantities of soluble salt even when the surrounding land is comparatively free from alkali.

A large number of samples were taken in the fall of 1923, some of which were analyzed for the individual soluble salts while others were determined for total salts by the electric-bridge method. Since this time additional samples have been taken.

Some representative detailed analyses are given in Table 2. For the sake of simplicity the results have been arbitrarily calculated as sodium salts, tho calcium and magnesium were both present to the extent of about 0.01 per cent on the average, together with smaller amounts of potassium. The table shows that there is great variability, both qualitatively and quantitatively, in the salt content of samples taken very close together.
Fig. 9.—Map of Cache County Water Conservation District No. 1 showing surface contours, position of water-table, and distribution of alkali.
and that this variability is greater in the surface than in the lower depths. The analytical data also show that in the northern section of the project the salt mixture is composed for the most part of sodium chloride and sodium sulfate, with the latter generally predominating. Farther south the salt mixture contains more chloride than sulfate. This variability in composition and distribution is due to the fact that the salts move with the soil moisture and that the chlorides move more freely than the sulfates.

It is, therefore, evident that a few analyses cannot be definitely expected to characterize the alkali conditions in even a restricted area. To accomplish this it would be necessary to make many more analyses than have been attempted, and then only a temporary condition would be described. The analyses, indicated in Figure 9, must accordingly be regarded as suggestive only. Nevertheless, the presence of considerable amounts of salt in any locality is sufficient reason for undertaking the cultivation of that locality with caution and foresight because of the heavy and difficult permeable character of the soil. This is true even when the surface soil is fairly free from salt.

It is possible to judge the salt content of the surface layers of the soil with fair accuracy by observing the vegetation. The presence of nonhalophytic plants indicates the presence in general of less than 0.5 per cent of salt, and usually less than 0.2 per cent. Of the halophytes the small annual atriplex (Atriplex carnosa) is probably the most valuable indicator in the district. This plant prefers a salt concentration in the soil of 0.5 to 1 per cent and does not seem to thrive in any other environment. This range is the critical one in crop production, for while useful plants may not be entirely killed by it the profits of farming operations are fairly certain to be reduced to the vanishing point. Still higher concentration is shown by the samphire (Salicornia rubra) and inkweed (Suaeda sp.). The greasewood (Sarcobatus vermiculatus), while it usually indicates appreciable amounts of alkali, does not select any particular amount but seems to grow well in a very wide range of concentrations of salt. This is probably due to its perennial nature. The plant indicators give little or no information about the alkali in the lower depths of soil, a consideration which was of minor importance while the land was being dry-farmed but which must be fully taken into account under irrigation conditions.

The possibility of removing the excess salt by the installation of a drainage system is being carefully studied. This work is not yet completed, but the method of attack and some of the
### Table 2.—Composition of Soluble Salts in District

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<tr>
<th>Soil No.</th>
<th>Location</th>
<th>Depth</th>
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*Samples a, b and c above were taken within six feet of each other

**Samples a and b were taken two feet apart
outstanding results thus far obtained may be briefly summarized at this time.

Soil samples were taken near the east center of 10 No. 4, 40 No. 4, Section 5, in a place which was considered to be representative of a large area in that district. The salt content of the soil is given in Table 2 (Samples 2, 3, 4) and the mechanical analysis is shown graphically in Figure 8. The soil samples were taken in heavy galvanized iron cylinders one foot in diameter and one, two, or six feet long. Each container was forced into the soil without disturbing the soil column, the process being aided by digging around the vessel and cutting away the soil column for a distance of about an inch below the bottom of the metal until it was only slightly larger than the cylinder. In this way columns of soil one, two, and six feet in length were obtained with the natural field structure unimpaired. A cap with an outlet was placed over the bottom of the vessel which was then brought to the laboratory for the leaching experiments. It has been found that the rate of leaching with distilled water (which at first represents a depth of about two inches daily) falls rapidly as the salt is removed, accompanied by a change in the reaction of percolate from a neutral solution to a decidedly alkaline solution, until the rate of leaching is less than one inch in four months. At this stage freezing the soil causes an increase in the rate of percolation, but this falls off again on continued leaching. This impermeable condition would greatly retard any direct attempt at drainage. To prevent this puddled condition in the soil, some samples have been leached with a saturated solution of gypsum, and it has been found that while the rate of leaching fell off decidedly at first (one inch in 20 to 40 days), the rate increased after the removal of the sodium salts until it was about one inch daily. It should be noted that Bear River contains appreciable amounts of the salts of sodium calcium and magnesium which might be expected to prevent the extreme impermeability noted with distilled water*. It seems likely that other salts would give better results than gypsum, and the subject is being investigated further. In any case, success in leaching and draining this land will be dependent on the use of some chemical treatment to counteract the puddling effect of the alkalinity developed when the sodium salt is removed. Finally, it may be said that the presence of the sand layer in the profile of a considerable portion of the project is a hopeful feature which may contribute materially to the success of any drainage operation.

HISTORY

The greater portion of the land which comprises this district was settled in the early eighties. But as the average annual precipitation over the area is only about 15 inches and no water was available for irrigation, only hay and grain crops were grown under dry-farming conditions on the better soils. Little attempt was made to farm the heavier clay soils found in the eastern and northern part of the district. These heavier clay soils were used for pasture.

About 1917 the Ballard brothers, who owned considerable land on the north end of the project, constructed a pumping plant on Bear River and supplied water to what is now called the Ballard Ditch. This ditch has a capacity of 12 second-feet, and the water is used to irrigate the area west of the Logan branch of the Oregon Short Line Railroad and north of Rocky Point. Some very good crops of grain and alfalfa have been raised on this area. Sugar-beets have been added to the cropping system since the application of irrigation water.

Cache Junction (a division point on the Oregon Short Line Railroad to Idaho and the junction of the branch line to Logan) is the largest town in the project. Most of the people live on the farms scattered over the district.

Up to 1919 the settlement of the project was very slow due to the lack of water and to the fact that to make a success of dry-farming it was necessary to have large holdings.

Cache County Water Conservation District No. 1 is strictly an agricultural area, there being no other industries developed in this section at the present time. The crops grown consist chiefly of grain, alfalfa, sugar-beets, potatoes, and a few truck crops. The crop map, shown as Figure 10, indicates approximately 1050 acres of alfalfa, 2080 acres of grain, 62 acres of potatoes, 375 acres of sugar-beets, 1187 acres of fallow, and 1780 acres of uncultivated land, in addition to 800 acres of uncultivated pasture land. As indicated, most of the crops are grown on the south end of the project and west of the railroad. Table 3 gives the estimated acreage, the average yield, and the value of the crops grown during 1923.

At the present time some alfalfa seed is being grown successfully. Peas and beans for canning and seed purposes are adapted to this area, and it is expected that they will become important cash crops of the area, supplying seed companies and local canning factories.
Fig. 10.—Map of Cache County Water Conservation District No. 1 showing crops grown during 1923
At the peak of the prosperous times following the war (1919) Messrs. Skeen & Skeen, a private corporation, investigated the section to develop an irrigation enterprise which would reclaim and bring under cultivation the lands included in the present project.

Skeen & Skeen planned to construct a pumping plant on Bear River north of Cache Junction to lift the water some 63 feet to the head of the main canal. At a point near Ballard Junction a secondary pumping plant was planned to consist of two units, the first to lift water 67.5 feet to Canal No. 2 and the second to lift water 125 feet to Canal No. 3. These plans also included the construction of the three main canals but left the

1The following has been summarized from Engineer T. H. Humphreys' report to Messrs. Skeen & Skeen.

The general plan of the Skeen & Skeen project for supplying water to irrigate the lands within Cache County Water Conservation District No. 1 consisted of a main pumping plant on the west bank of Bear River (a half mile north of Cache Junction), a secondary pumping plant located on the west bank of the main canal near Ballard Junction, a main canal to carry the water from the main pumping plant southward toward Mendon, and two main laterals running southward from the secondary pumping plant.

Main Pumping Plant.—The main pumping plant called Pumping Plant No. 1 (see cover cut) is housed in a fine brick structure 54.5 feet by 26 feet resting on a substructure of heavily reinforced concrete which in turn rests on piles three feet on centers. The pumping installation consists of four pump units each having a capacity of 25 second-feet. Each pump unit is an 18-inch double suction split case, centrifugal pump with a bottom suction and a horizontal discharge. A flexible coupling attaches each pump to a 250-horsepower induction motor, both being set on a common bedplate. These motors are 3-phase, 60-cycle, of the squirrel-cage type using current at 440 volts. Each motor is controlled from its own switchboard panel. The capacity of each pump is 11,250 gallons per minute when operating under a 68-foot head. When running at a speed of 690 R.P.M. each unit has a guaranteed efficiency of 80 per cent.

The discharge pipe line from Plant No. 1 consists of a circular pipe
distribution system to be constructed by the farmers (See Fig. 5).

The original plan was to organize a development company to develop the water and sell it to the land owners. Later the land-holders pooled their interests and attempted to float a $200,000-bond issue with this land as security. They attempted to sell these bonds on the Pacific Coast but found no market for such class of bonds. The bond buyers advised the organization of an irrigation district under the laws of Utah. Therefore, in 1921 the land owners proposed the organization of an irrigation district to take over the then-partially-completed project.

Under the laws of Utah the organization of an irrigation district must be initiated by the Governor of the State of Utah, or fifty or a majority of owners of land or holders of title or evidence of title to land requiring water in any district. This petition shall be made to the county commissioners of the county in which the district is located and shall request that a water survey and an allotment of water for the lands within the proposed district be made, that the land to be included

manifold 52 feet long, leading from the pumps, made from quarter-inch riveted steel plate, 90 feet of quarter-inch steel-plate pipe (5 feet in diameter), and 532 feet of reinforced concrete pipe (5 feet in diameter). The pipe line is protected with relief valves. A reinforced concrete outlet and 200 feet of lined canal section have been built at the end of the discharge line leading into the main canal. The equipment was manufactured by Allis-Chalmers Manufacturing Company and installed by the Western Engineering & Construction Company.

Main Canal.—The main canal from the discharge to Ballard Junction has a bottom width of twelve feet, side slopes of one and a half to one, a depth of water of three feet, a free board of two feet, a bank width of six feet, a slope of two feet per mile, a mean velocity of two feet per second, and a carrying capacity of 100 second-feet.

Below Ballard Junction the main canal is first reduced in carrying capacity to 50 second-feet and then to 25 second-feet, and is now completed to the Logan-Petersboro Road. All subsidiary canal structure, such as headgates, bulkheads, and turnouts, are of reinforced concrete and steel. Private bridges are of wood.

Pumping Plant No. 2.—This pumping plant is located on the west bank of the main canal at a point near Ballard Junction. Here three 14-inch horizontal centrifugal pumps are installed to lift 40 second-feet of water from the main canal thru 1200 feet of three-sixteenths-inch riveted steel pipe (3 feet in diameter) into Canal No. 2 which is 67.5 feet above the main canal. Each pump is directly connected to a 150-horsepower electric motor. Canal No. 2 has a capacity of 40 second-feet at its head and decreases in size as it approaches the south end of the district.

Pumping Plant No. 3.—Pumping Plant No. 3 is housed in the same building as Plant No. 2. Provision has been made for three 14-inch horizontal centrifugal pumps each to be directly connected to a 250-horsepower motor to lift the water thru 125 feet of head to Canal No. 3. At the present time a single temporary pump has been installed to supply water to Canal No. 3. Canal No. 3 has been completed and water is available to the higher lands in the district.
within the district be determined, listed with water allotment, and platted, and further that the question of final organization be submitted to the land owners of the proposed district for final vote. A majority of the votes\(^2\) cast is necessary to organize the district. In compliance with the state law a petition was presented to the Board of County Commissioners of Cache County and the water allotment made to each parcel of land by the State Engineer. Of the 8490.78 acres included in the district, 7373.38 acres are allotted water, the balance being classed as non-irrigable. The total allotment amounts to 14,623.96 acre-feet, varying from 0.8 acre-foot to 3 acre-feet per acre. Figure 11 shows the ownership and water allotment in the district.

Upon the completion of the water allotment by the State Engineer an election was called for the purpose of voting the district. Originally the district extended south almost to Mendon but later was revised to its present position. With the revised boundary, as shown in Figure 11, the majority of the owners voted for the organization of the district. The outstanding object in the organization of the district was to enable the financing of the project from the sale of bonds. A bond election, therefore, followed the organization of the district, and a bond issue of $375,000 was authorized.

The purpose of this bond issue was to purchase the existing system (then in course of construction by Skeen & Skeen) and to carry the project to completion. The bonds were 6-per-cent Serial Gold Bonds maturing as follows:

\[
\begin{align*}
\$10,000 & \text{ due December 1, 1929} \\
\$10,000 & \text{ due December 1, 1930} \\
\$10,000 & \text{ due December 1, 1931} \\
\$10,000 & \text{ due December 1, 1932} \\
\$10,000 & \text{ due December 1, 1933} \\
\$12,000 & \text{ due December 1, 1934} \\
\$12,000 & \text{ due December 1, 1935} \\
\$12,000 & \text{ due December 1, 1936} \\
\$12,000 & \text{ due December 1, 1937} \\
\$12,000 & \text{ due December 1, 1938} \\
\$16,000 & \text{ due December 1, 1939} \\
\$16,000 & \text{ due December 1, 1940} \\
\$16,000 & \text{ due December 1, 1941} \\
\$16,000 & \text{ due December 1, 1942} \\
\$16,000 & \text{ due December 1, 1943} \\
\$30,000 & \text{ due December 1, 1944} \\
\$30,000 & \text{ due December 1, 1945} \\
\$30,000 & \text{ due December 1, 1946} \\
\$30,000 & \text{ due December 1, 1947} \\
\$30,000 & \text{ due December 1, 1948} \\
\end{align*}
\]

Of the $375,000-bond issue authorized, bonds amounting to but $340,000 were sold. Skeen & Skeen were paid $275,000 for the project canals, pumping plants, and water-right; $15,000 constituted organization expenses.

Under the Utah State Law an irrigation district is given the power to tax. This power to tax, therefore, becomes a lien upon the lands in the district to the extent of the assessments against it. Considerable question has arisen as to whether the tax necessary to pay interest and sinking funds on bonds be-

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\(^2\)One vote allowed for each acre-foot of water allotted.
Fig. 11.—Map showing ownership and water allotment (1923), Cache County Water Conservation District No. 1.
comes a lien upon the district as a whole or upon each parcel individually. If it becomes a lien upon the district as a whole, then the individual who pays his assessments regularly is also compelled to assist in paying the assessments of his delinquent neighbors. This was the question at issue in the case of Nelson vs. Bonneville Irrigation District in the Supreme Court of Utah. In the language of the court the question is briefly stated as follows:

“The question at issue in this proceeding is whether or not, under the Irrigation District act of the State of Utah (Chap. 68, Laws Utah 1919, as amended by Chap. 73, Laws Utah 1921) a budget can be certified by the directors of an irrigation district and a tax levied by a board of county commissioners in one year to include the delinquencies of the previous year. In other words, whether a cumulative levy can be made so that the property of one land owner can be made liable for its proportion of delinquencies arising from refusal of others to pay assessments on their lands.”

Further:

“It will be controlling of this case to determine whether the bonded indebtedness of an irrigation district partakes of the nature of a general municipal indebtedness or severable and partakes of the nature of an indebtedness for local improvements.”

Section 19 of the Utah Irrigation District Law reads: “All taxes levied under this act are special taxes.” In other words, they are special assessments fixed to pay for special benefits received, and for that reason one cannot and should not be required to pay for the delinquencies of his neighbors in excess of 15 per cent provided for by law.

Under the above decision, land on which assessments have been paid is thereby relieved of the lien for that assessment and may not be reassessed for more than its proportionate share because of the failure of other land owners to pay. The bond holders in this case cannot look to the liability of the district as a whole, but in case of default are limited to the purchase of tax-sale certificates on delinquent land. This decision should clear up in the minds of many the question of the security of their lands after they pay their own assessments.

Thru an invitation from the local bankers, the Utah Experiment Station became interested in this project early in the spring of 1924. The object of the first visit was to answer some questions regarding soil value, soil structure, and the relation to drainage water. The problem was found to be too complicated
to solve in the field, and it was finally decided to give all the aid possible by making a soil survey of the district in more detail than had been made heretofore and to carry the soil work into chemical and physical analysis. Study was also given to the water supply, cost of completing distribution system, preparing land for irrigation, and the feasibility of drainage.

It is hoped that if similar projects are to be launched in the future, the Experiment Station may be privileged to do detailed study in advance and guide the enterprise rather than only to help in solving the problems developed in the process.

**WATER-SUPPLY**

Cache Valley is well supplied with water. On the north, Bear River enters the valley with an estimated annual flow at Preston, Idaho, of 676,300 acre-feet. The local streams entering the valley are the Logan River (average annual flow 246,000 acre-feet), Blacksmith Fork River (estimated average annual flow 103,000 acre-feet), and Little Bear River (estimated annual flow 61,000 acre-feet). The average annual outflow of the valley, as measured at Collinston, Utah, is estimated at 1,300,000 acre-feet.

**Main Irrigation Supply.**—The old Ballard Ditch has an appropriation from Bear River to the extent of 12 second-feet. Another filing (amounting to 100 second-feet) was made according to legal requirements with the State Engineer of Utah in August 1919. This appropriation which has been completed gives a total of 112 second-feet of water for the entire project. Of this area, approximately 7450 acres are irrigable. Considering an irrigation season of 100 days, one second-foot will supply 200 acre-feet and 112 second feet will supply 22,400 acre-feet. This supply is equivalent to approximately 3 acre-feet per acre spread over 7450 acres.

According to the Utah State Law, before the organization of an irrigation district is permitted the State Engineer must make a water allotment. This water allotment has been made by the State Engineer and varies from 0.8 acre-foot per acre on a very small portion of the area to 3-acre-feet on some of the higher land. Figure 11 shows the larger portion of the area to have an allotment of 2 acre-feet per acre, with the area under the upper canals receiving the highest allotment.

Not once in the twenty-five years of stream-flow records on Bear River has the stream failed to supply the district appropriation. The certainty of supply has been still further increased recently with the Bear Lake storage development of the
Utah Power & Light Company. Bear Lake has a storage capacity of over 500,000 acre-feet, or sufficient water to run the plants of the Utah Power & Light Company on Bear River for two years without drawing on the natural flow. This ideal storage, situated on Bear River, improves materially the water rights on that stream. During the low-water season water is turned out of the lake to maintain the power plants along the river. Much of this increased flow is available for irrigation on the lower reaches of the streams. The water-supply for irrigation purposes, therefore, is ample; in fact, it approaches the maximum quantity allowed per acre by the state law, and it is available at the time when it is most needed.

Local Water Supply.—There are no streams in the district which flow the year around. Three-Mile Creek is the only stream of any consequence. It flows out of the foothills west of the south end of the project and has been utilized since the area was settled to irrigate small areas along its course.

Springs.—There are several springs coming from West Cache Valley Fault (which runs in a general north-south direction west of the district). Two of these, the Peterson and Mitchell Springs, flow approximately one-half second-foot. On the Peterson Ranch this water is reservoired and used to irrigate the land below. The rest of the water coming from this fault consists of small seeps and springs flowing from ten to fifty gallons per minute. These springs occur consistently from Cache Junction on the north to the extreme southern boundary of the district. They are located at a higher elevation than the project, and the aggregate flow is sufficient to furnish domestic water for a family on every 40-acre tract on the project. The water is pure, cold, and has a desirable taste, making it an ideal water for domestic use.

Surface Wells.—Surface wells at a depth of from fifteen to fifty feet are obtainable on most of the area west of the Oregon Short Line Railroad. The water from these wells is very cold and is satisfactory for culinary use. However, the wells should be properly located with respect to barns and other outbuildings as the surface drainage will reach these wells. These surface wells are directly affected by the application of irrigation water. As soon as the water is turned into the canals the water surface rises in the wells. The temperature of the water in these wells varies from 60 to 68°F. The total mineral content, as determined by the Wheatstone Bridge, averages 482 parts per million, which is very low.
Table 4.—Temperature, Capacity, and Total Salts in Springs and Wells on Cache County Water Conservation District No. 1

<table>
<thead>
<tr>
<th>Name of Owner of Well or Spring</th>
<th>Temperature (°F.)</th>
<th>Total Salts (p.p.m.)*</th>
<th>Capacity</th>
<th>Kind</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Henry Kidman</td>
<td>55</td>
<td>592</td>
<td></td>
<td>Deep pump well</td>
</tr>
<tr>
<td>2 Henry Kidman</td>
<td>60</td>
<td>489</td>
<td></td>
<td>Dug well</td>
</tr>
<tr>
<td>3 Henry Kidman</td>
<td>66</td>
<td>400</td>
<td>½ g.p.m.</td>
<td>Spring</td>
</tr>
<tr>
<td>4 Orson Kidman</td>
<td>70</td>
<td>500</td>
<td></td>
<td>Drain</td>
</tr>
<tr>
<td>5 Cunningham</td>
<td>67</td>
<td>475</td>
<td></td>
<td>Dug well</td>
</tr>
<tr>
<td>6 Cunningham</td>
<td></td>
<td></td>
<td></td>
<td>Pump well</td>
</tr>
<tr>
<td>7 Hans Anderson</td>
<td>55</td>
<td>487</td>
<td></td>
<td>Pump well</td>
</tr>
<tr>
<td>8 Schoolhouse</td>
<td>63</td>
<td>470</td>
<td></td>
<td>Pump well</td>
</tr>
<tr>
<td>9 Peterson Spring</td>
<td>57</td>
<td>390</td>
<td>½ c.f.s</td>
<td>Spring</td>
</tr>
<tr>
<td>10 Farrell Spring</td>
<td>57</td>
<td>449</td>
<td>¼ c.f.s</td>
<td>Spring</td>
</tr>
<tr>
<td>11 Peterson Ranch</td>
<td>60</td>
<td>305</td>
<td></td>
<td>Drain</td>
</tr>
<tr>
<td>12 Peterson Ranch</td>
<td>56</td>
<td>400</td>
<td></td>
<td>Flowing well</td>
</tr>
<tr>
<td>13 Peterson Ranch</td>
<td>60</td>
<td>490</td>
<td>2 g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>14 Salisbury Ranch</td>
<td>66</td>
<td>525</td>
<td></td>
<td>Spring</td>
</tr>
<tr>
<td>15 Intermountain Sugar Co.</td>
<td>59</td>
<td>437</td>
<td>½ g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>16 Intermountain Sugar Co.</td>
<td>60</td>
<td>430</td>
<td></td>
<td>Flowing well</td>
</tr>
<tr>
<td>17 Partington Spring</td>
<td>60</td>
<td>531</td>
<td></td>
<td>Spring</td>
</tr>
<tr>
<td>18 Ed Edwards</td>
<td>55</td>
<td>477</td>
<td>4 g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>19 Jones</td>
<td>55</td>
<td>524</td>
<td>4 g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>20 Frank Nye</td>
<td>58</td>
<td>577</td>
<td>4 g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>21 Ed Edwards’ North Well</td>
<td>58</td>
<td>577</td>
<td>1 g.p.m.</td>
<td>Flowing well</td>
</tr>
<tr>
<td>22 J. O. Maughan</td>
<td>57</td>
<td>510</td>
<td>½ g.p.m.</td>
<td>Flowing well</td>
</tr>
</tbody>
</table>

*parts per million

**Artesian Wells.**—There are several flowing wells in the district (See Fig. 5). These wells are from 100 to 400 feet deep and are usually two inches in diameter. The common practice in drilling wells in this area is to case only the upper twenty or thirty feet and leave the balance of the hole open as it is in clay which stands fairly well for a few years. However, after several years these open holes fill up and the flow diminishes. Several of the wells in the district are in this condition, and the water is barely oozing over the top of the casing. The more important of the flowing wells have been kept open and are now flowing from one-half to four gallons per minute. These wells are coming from deep sources so there is little danger of pollution. The total mineral content of these wells, as determined by the Wheatstone Bridge, varies from 430 to 477 parts per million, an amount quite common in culinary water.

Table 4 shows the total mineral content in solution as determined by the Wheatstone Bridge in several springs, surface wells, and flowing wells on the project.
DISTRIBUTION SYSTEM

Canal Systems.—In the construction of irrigation projects throughout the west it is common practice to construct only the main canals and laterals and to leave the construction of the distributaries to the water users. Such practice has been followed on this project. In working out the design of a distribution system for this project, only preliminary field investigations have been made; therefore, these figures should not be used in a construction program without a further field work.

Main Canal.—The main canal is designed for a capacity of 100 second-feet from Plant No. 1 to Plant No. 2. Below Ballard Junction the canal is reduced in carrying capacity first to 50 second-feet and then to 25 second-feet. At the present time the canal is constructed to a point just south of the Logan-Petersboro Road. The area south of and including the Peterson Ranch (which lies east of the main canal) is served from the main canal at the present time (1925), and no further construction of the distribution system is necessary for this portion of the district.

With the exception of the Roundy piece little has been done toward constructing a distribution system to supply water to the large area north of the Peterson Ranch and east of the Oregon Short Line Railroad. The crop map of 1923 indicates that the portion of this area which has been cropped has been handled under dry-farm methods.

A paper location of a distribution system for this area has been made to form the basis of an estimate of the cost of bringing the water to the corner of each 40-acre tract. This system has been laid down on a map with 5-foot-contour intervals and is, therefore, necessarily very approximate.

The topography of the area is of such a nature that the methods of irrigation adaptable to this area are confined to two (with a possible third) in some localities. These methods are: wild-flooding, furrow, and border-check. Using the wild-flooding and furrow methods, the heavy compact soil and the steep slopes make it necessary to use small heads to secure an economical irrigation. A head of about 3 second-feet is all that one man can handle so that the surface runoff will not be excessive. Ditches of from 3 to 9 second-feet capacity can be constructed with a plow and a V-ditcher except in a few places where flumes or low fills will have to be constructed: Iron turnouts will be provided at the heads of laterals, and wooden check gates will be used to check the water from the distrib-
utary to the farm ditch. These check gates will be supplied so that each 40-acre tract may be served from the laterals.

**Canal No. 2.**—The total area served under Canal No. 2 is 1325 acres. With few exceptions all farms under this ditch are in good condition to use irrigation water; the land is fairly uniform with a well-defined slope to the east. Ditches and structures have been built so that the entire area may now be served. More structures (particularly drops, checks, and turnouts) are necessary to adequately control the water. It is estimated that five turnouts (three combination-turnouts and checks and two by-passes to take care of the surface runoff) are necessary for the adequate control and distribution of the water in Canal No. 2.

**Canal No. 3.**—Under Canal No. 3 it is planned to irrigate some 575 acres lying in a long, narrow strip parallel to the canal and varying in width from a quarter to a half mile. The slope of this area is very high, ranging from 40 to 70 feet per mile. This steep slope alone limits the method of irrigation to wild-flooding for non-cultivated crops such as alfalfa and grain and to the furrow method for the cultivated crops, such as sugarbeets, corn, peas, beans, and potatoes. This tract being narrow, the distribution system will consist of five short distributaries having a total length of about one and a quarter miles, the necessary checks, turnouts, measuring devices, and drops to control the water. It is estimated that eleven combination-checks and turnouts will be required to get the water out of the canal. In addition, one turnout on each of the five distributaries will be necessary. The canal is exposed to the surface drainage from the area above the canal, and some form of protection against the filling of the canal with silt must be provided. This surface drainage can be taken care of by overhead or underflow by-passes. At least four such by-passes are absolutely necessary for the safety of the canal.

**Measurement of Water.**—The contract with Skeen & Skeen, under which the original project was purchased, calls for only as much of the 112 cubic feet per second appropriated from Bear River as is necessary to irrigate the area in the project. As already stated, the State Engineer allotted so much water to the district, the total being 14,623.96 acre-feet. The right held by Skeen & Skeen of 112 second-feet amounts to 22,400 acre-feet per season of 100 days. Therefore, there is a margin of 7716 acre-feet over and above the amount allotted by the State Engineer which is available should it be necessary for the pro-
duction of crops. The executing of this contract, however, makes necessary the installation of measuring devices to determine just how much water is necessary to produce crops on the project. The water should be measured into the main canal and at the head of each lateral. There is sufficient fall to the laterals to install at the head of each a standard rectangular weir, and a current-meter-rating-station can be readily established at the head of each canal. The complete checking of the water used to comply with the terms of the contract will require three current meter stations and about twenty-five weirs.

**Operation.**—The electric energy used in pumping the water for the project is supplied by the Utah Power & Light Company, and the charge is based upon the maximum monthly demand for power. It is desirable, therefore, to keep the maximum monthly demand as low as possible. The minimum monthly demand can be obtained by making the demand for water as nearly uniform as possible throughout the season. The irrigating season is about 100 days in length. The pumps are usually started late in May and run until early September. The following monthly distribution of the water on this project is desirable:

<table>
<thead>
<tr>
<th>Month</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>2 per cent</td>
</tr>
<tr>
<td>June</td>
<td>30 per cent</td>
</tr>
<tr>
<td>July</td>
<td>35 per cent</td>
</tr>
<tr>
<td>August</td>
<td>30 per cent</td>
</tr>
<tr>
<td>September</td>
<td>3 per cent</td>
</tr>
</tbody>
</table>

The above schedule gives the maximum demand during the month of July, during which month a total of 5118 acre-feet will be supplied. To supply this quantity of water on a 2-week-rotation schedule will require laterals with a minimum capacity of 3 second-feet. Some of the longer laterals will have a minimum capacity of 6 second-feet so as to carry two streams. Rotation will be practiced between farms on each lateral, the water being in the laterals continuously throughout the irrigation season. Figure 5 shows the proposed distribution system for the area considered. The various structures are indicated in their approximate locations.

It will be noted that on lateral “C” there is an island of high ground. This area (approximately 80 acres in extent) will not warrant the necessary expense to get the water to it. It should, therefore, be excluded from the district.

**Cost of Operation and Maintenance.**—In spite of the fact that Cache County Water Conservation District No. 1 is a pumping project, the annual operation and maintenance charges in-
cluding the power costs are less than on many gravity systems. The annual charges for 1924 were higher than for any previous year. These charges are given below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Acre-foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest on bonded indebtedness</td>
<td>$1.44</td>
</tr>
<tr>
<td>Power</td>
<td>$.84</td>
</tr>
<tr>
<td>Operation and Maintenance</td>
<td>$.32</td>
</tr>
<tr>
<td><strong>Total Annual Cost per Acre-foot</strong></td>
<td><strong>$2.60</strong></td>
</tr>
</tbody>
</table>

Cost of Completing Distribution System.—The total estimated cost of completing the distribution system so that water may be delivered to the corner of each 40-acre tract is as follows:

- **Main Canal** ........................................... $3676
- **Canal No. 2** ........................................ 1215
- **Canal No. 3** ........................................ 455
- **Measuring Devices** ................................. 250

**Total Cost** ........................................ $5596

This represents an acre-cost of seventy-five cents distributed over the district.

Preparation of the Land.—The artificial application of water to land by the usual methods of irrigation requires that the land be prepared to permit the uniform distribution of water. Land properly prepared for irrigation has a smooth slope and is free from irregular depressions where water can collect and form knolls which cannot be uniformly wetted.

The steps involved in the preparation of land for irrigation are as follows:

1. Clearing the surface of native vegetation
2. Smoothing and leveling the surface
3. Construction of the farm-distribution system based on method of irrigation

Since there is no native vegetation outside of the grass family on this project only the last two steps are of particular interest. The problem of preparing the land for irrigation on this project, therefore, may be divided into two parts: (1) Leveling the land and (2) construction of a farm-distribution system.

**Leveling the Land.**—The object of leveling is to permit the uniform application of water to the land. The amount of leveling necessary will depend upon the method of irrigation to be used; therefore, the method of irrigation should be decided upon before the land is leveled.
Practically the entire area south of and including the Peterson Ranch is being supplied with water. In general, the land has been well prepared and the water can be economically applied.

The area north of the Peterson Ranch and east of the railroad (including Sections 4, 5, 8, 9, 16, and 17 of Township 12 North, Range 2 West, and Sections 31, 32, and 33 of Township 13 North, Range 2 West) is too uneven to permit the application of water (See Fig. 5). This area must be leveled. To properly do this most of the land will require from two to four leveling with a box-level after deep plowings. Most of Section 5 and a portion of Sections 4 and 8 are entirely too rough to level with such equipment and will require scrapers in addition to the plow and box-level. Excluding most of Section 5 and a part of Sections 4 and 8, this area can be leveled at an estimated cost of $5 an acre. Most of Section 5 and part of Sections 4 and 8 are so very rough and the surface soil so shallow that it is neither practical nor economically feasible to level this area. These parcels of land, therefore, should be removed from the district.

The balance of the land under the main canal and west of the railroad (including that area under the Ballard Ditch) is being served with water, and no further work need be done.

The total estimated cost of leveling the uneven land under the main canal is $15,000. Table 5 is a summary of cost data pertaining to reclaimed farms in Utah up to 1922.

Almost the entire area under the second lift is being irrigated at the present time and is in fair shape for the economical application of irrigation water.

With the exception of about 80 acres belonging to the Peterson Ranch, the entire area under the third lift will have to be leveled before the furrow method of irrigation can be practiced. The necessary leveling, however, may be done with an ordinary box-level after plowing at an estimated cost of $3 an acre. The total estimated cost of leveling land under Canal No. 3 is $1485.

Construction of Farm-distribution System.—Table 5 indicates an average cost of farm-distribution systems in Utah to be $1.30 an acre. The lands in Cache County Water Conservation District No. 1 are typical of the lands indicated in Table 5, and it is, therefore, assumed that a farm-distribution system can be constructed on these farms for an average of $1.30 an acre. The total area on which the construction of a farm-dis-
Table 5.—Summary of Cost Data Pertaining to Reclaimed Utah Farms (1922)

<table>
<thead>
<tr>
<th>Location</th>
<th>Land Reclaimed from</th>
<th>Acre-Cost</th>
<th>Clearing</th>
<th>Leveling</th>
<th>Distribution System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>$5.00</td>
<td>$10.00</td>
<td>$1.00</td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>15.00</td>
<td>10.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>8.00</td>
<td>7.50</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>7.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>10.00</td>
<td>12.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>2.00</td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milford</td>
<td>Sagebrush</td>
<td>10.00</td>
<td>5.00</td>
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<td></td>
</tr>
<tr>
<td>Clearfield</td>
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<td></td>
<td></td>
<td>10.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Farmington</td>
<td>Partially Improved</td>
<td>20.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fillmore</td>
<td>Sagebrush</td>
<td>7.00</td>
<td>3.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pahvant</td>
<td>Desert</td>
<td>10.00</td>
<td>4.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genola</td>
<td>Sagebrush</td>
<td>6.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Genola</td>
<td>Sagebrush</td>
<td>6.00</td>
<td>1.25</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Genola</td>
<td>Sagebrush</td>
<td>2.00</td>
<td>2.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Santequaun</td>
<td>Dry-farm</td>
<td></td>
<td>3.00</td>
<td></td>
<td>2.00</td>
</tr>
<tr>
<td>Dry Gulch</td>
<td>Virgin</td>
<td>2.50</td>
<td>4.50</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>Dry Gulch</td>
<td>Virgin</td>
<td>10.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Dry Gulch</td>
<td>Virgin</td>
<td>1.00</td>
<td>3.00</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Cedar City</td>
<td>Brush</td>
<td>10.00</td>
<td>5.00</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Cedar City</td>
<td>Brush</td>
<td>9.00</td>
<td>3.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Cedar City</td>
<td>Brush</td>
<td>5.00</td>
<td>2.00</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Cedar City</td>
<td>Brush</td>
<td>4.00</td>
<td>4.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Cedar City</td>
<td>Brush</td>
<td>7.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utah Lake (west side)</td>
<td>Desert</td>
<td>7.00</td>
<td>7.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lehi</td>
<td>Greasewood</td>
<td>3.00</td>
<td>3.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Honeyville</td>
<td>Partially Improved</td>
<td></td>
<td>3.40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The distribution system is necessary is about 5000 acres, making a total of $6500.

Summary of Estimated Costs Necessary to Complete Project.
—The cost estimates given here are based upon only very preliminary investigations and they must be accepted as approximate costs. From a comparison with the cost of projects already constructed, it is thought that these estimates are fairly conservative.

Cost of completing distribution system: $5,596
Cost of leveling land in district: $16,485
Cost of farm-distribution system: $6,500

Total: $28,581.00
Estimated construction acre-cost to complete project: $3.86
SUMMARY

(1) Cache County Water Conservation District No. 1 is located on the west side of Cache Valley in northern Utah, just south of Cache Junction, and contains 7373.38 acres of land to which water is allotted.

(2) The district is well-supplied with transportation facilities. An average haul of one and one-half miles to a railroad loading station is all that is required to put the farmers in touch with the local or outside markets.

(3) Within ten miles of the district are located one city of the first-class and four cities of the second-class.

(4) The district is so situated that the maximum distance to a public school is less than three miles, and ample provisions for high school and college education are provided within a radius of ten miles.

(5) Local industries (such as sugar-beet factories, canning factories, milk condensing factories, dairies, and flour mills) furnish a ready market for practically all the farm products of the valley.

(6) The climate and growing season of Cache County Water Conservation District No. 1 are well suited to the growing of such crops as alfalfa, grain, sugar-beets, corn, potatoes, beans, peas, and some truck crops.

(7) The land surface within the district slopes to the east and north and (with the exception of about 800 acres in the north-central part) has good surface drainage.

(8) Approximately 4200 acres covering the area west of the railroad and east of the railroad but north of Petersboro have a uniform surface, deep rich soil, good drainage, and can be irrigated with very little additional expense.

(9) About 2500 acres of land east of the railroad and north of Petersboro will require leveling before irrigation water can be economically applied.

(10) Cache County Water Conservation District No. 1 was organized at the peak of agricultural prosperity, and as a result some lands (approximately 800 acres) were included in the project which will be difficult to reclaim.

(11) The soils of the area have been classified into two series: (1) Mendon and (2) Ballard.
(12) The following types and subtypes of these series of soils are used in this classification:

<table>
<thead>
<tr>
<th>Types</th>
<th>Subtypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendon Clay I</td>
<td>Mendon Clay II</td>
</tr>
<tr>
<td>Mendon Silty Clay I</td>
<td>Mendon Silty Clay II</td>
</tr>
<tr>
<td>Mendon Clay Loam</td>
<td>Ballard Clay II</td>
</tr>
<tr>
<td>Ballard Clay I</td>
<td>Ballard Clay II</td>
</tr>
</tbody>
</table>

(13) Each subtype has a layer of sandy material within its 6-foot column.

(14) The darker-colored soils of the area have been placed in the Mendon series, while the lighter-colored soils are classed in the Ballard series. There are also differences in profile which correspond to the color differentiation.

(15) The Mendon series are usually low in alkali and the soils are generally productive.

(16) The soils of the Ballard series are in lower elevations and carry significant quantities of alkali.

(17) The Ballard series have a well-compacted horizon beginning at about eight to ten inches below the surface and extending to approximately forty inches. The compaction is so marked that water and plant roots penetrate the horizon with difficulty. Methods of modifying this horizon are being studied as a phase of the drainage experiment now being conducted at this station.

(18) A considerable portion of the north half of the project is impregnated with soluble salts, consisting of a mixture of sodium chloride and sodium sulfate.

(19) The highest concentrations of salt are found in the swales and depressions.

(20) Certain native plants growing in the district are an index to the presence of salt.

(21) Leaching experiments looking to the reclamation of alkali land are described. The drainage possibilities are discussed, and it is emphasized that this work must be preceded by a complete investigation of the problem on account of the heavy nature of the soil.

(22) The water-supply for the district is ample. A continuous flow of 112 cubic feet per second during the irrigation season is available if needed.

(23) Wells for culinary purposes can be obtained on almost any part of the district.

(24) The average per-acre-bond issue is $47.
(25) The estimated additional first cost per acre to complete the entire system is $3.86.

(26) Good land in the district is worth (with water) from $150 to $200 an acre.

(27) The operation and maintenance cost for 1924 was $1.16 an acre-foot including the power charges.

(28) Under the present interpretation of the Utah Supreme Court the bonds do not constitute a blanket lien on the entire project.
LIST OF AVAILABLE PUBLICATIONS

BULLETINS

121—Soil of Southern Experiment Farm.
122—Nature of Dry-farm Soils of Utah.
124—Fruit Variety Tests on Southern Experiment Farm.
125—Chemical Milling and Baking Value of Utah Wheats.
122—Minor Dry-land Crops at Nephi Experiment Farm.
133—Irrigation and Manuring Studies, I.
134—Nitric Nitrogen Content of Country Rock.
137—Quality of Home-grown Wheat vs. Imported Wheat.
138—How to Control Grasshoppers (1915).
139—Movement of Soluble Salts with Soil Moisture.
140—Summer Pruning of a Young Bearing Apple Orchard.
141—Variation in Minimum Temperatures due to Topography of a Mountain Valley in Relation to Fruit Growing.
142—Irrigation of Peaches.
143—Fruit Tree Root Systems.
144—Water Table Variations.
145—Soil Alkali Studies.
146—Irrigation of Wheat.
147—Alkali Content of Irrigation Waters.
150—Further Studies on Nitric Nitrogen Content of Country Rock.
151—Freezing of Fruit Trees.
152—Effect of Soil Moisture on Certain Factors in Wheat Production.
153—Selecting Dairy Bulls by Performance.
155—The Beet Leaf Hopper.
156—Irrigation of Sugar-beets.
157—Irrigation of Potatoes.
158—Soil Moisture Studies under Dry-farming.
159—Soil Moisture Studies under Irrigation.
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161—Orchard Heating.
163—Composition of Irrigation Waters of Utah.
164—Factors Affecting Depth of Sowing Certain Crops.
165—Labor Costs and Seasonal Distribution of Labor in Irrigated Crops.
166—Climate of Utah.
167—Irrigation of Oats.
169—Use of Alkali Water for Irrigation.
178—Irrigation of Barley.
181—Duty-of-Water Investigations on Coal Creek, Utah.
182—Net Duty of Water in Sevier Valley.
183—Water-holding Capacity of Irrigated Soils.
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185—Influence of Nitrogen in Soil on Azofication (Technical).
186—Irrigation Experiments in Sugar-beets.
187—Irrigation Experiments in Potatoes.
188—Maintaining the Productivity of Soil.
189—Ridding the Land of Wild Morning Glory.
190—Corn Silage in the Dairy Ration.
191—Oedipodinae of Utah (Technical).
192—Biennial Report of Director, 1923 and 1924.
193—Cache County Water Conservation District No. 1.
CIRCULARS

8—Varieties of Fruit Recommended in Utah.
9—Pruning the Apple Orchard.
12—Thinning Apples.
13—Fruit for Exhibition.
16—Better Seed.
17—Number and Distribution of Licensed Stallions and Jacks, 1913.
18—Better Horses for Utah.
19—Licensed Stallions in Utah, 1915.
21—Dry-farming in Utah.
22—Some Sources of Potassium.
23—Seed Situation in Utah.
24—Licensed Stallions in Utah, 1917.
26—Storing Vegetables for Winter.
27—Licensed Stallions in Utah, 1917.
28—Contagious Abortion in Mares and Cows.
29—Control of Rodent Pests.
30—Codling Moth.
31—Alfalfa Weevil.
32—Feeding Farm Animals.
34—Sugar-beet Production in Utah.
35—Licensed Stallions in Utah during Season of 1918.
36—Practical Information on Measurement of Irrigation Water.
37—Field Beans.
39—A Day at the Utah Agricultural Experiment Station.
   (Contains complete list of publications issued by Station from 1890
   to 1918, inclusive).
41—Soil Alkali.
43—Feeding Work Horses.
44—The Agriculture of Utah.
45—Alfalfa Production under Irrigation.
48—Rural Credits in Utah.
49—This Public Domain of Ours.
50—Feeding and Brooding Chicks.
51—Foot-and-Mouth Disease.
52—Rules and Regulations for Intermountain Egg-laying Contest.
53—Summary of Publications, 1923 and 1924.
54—The More Important Insects Injurious to the Sugar-beet in Utah.

MISCELLANEOUS U. S. D. A. PUBLICATIONS

Department Bulletin 1173—Experiments in Wheat Production on Dry Lands
of Western United States.
Farmers’ Bulletin 883—Grains for the Utah Dry Lands.
Soil Survey of Ashley Valley, Utah.
Soil Survey of Delta Area, Utah.

MIMEOGRAPHED SHEETS

1—Peach Insects and Their Control.
2—Fruit-tree Leaf-roller.
3—Apple Spray Schedule for Utah.
4—How to Poison Grasshoppers in Utah.
5—Alfalfa Seed Production.
6—Feeding for Egg Production.
7—Onion Culture in Utah.
8—The Use of Oil as a Dormant Spray for the Fruit-tree Leaf-roller on
   Apple.
9—Mixtures of Seed for Sowing Pastures.
REPRINTS FROM SCIENTIFIC ARTICLES

4—Origin of Alkali.
8—Production and Movement of Nitric Nitrogen in the Soil.
11—Corn under Irrigation.
13—Alkali Content of Certain Utah Soils.
15—Influence of Salts on the Nitric Nitrogen Accumulation in the Soil.
25—Capillary Moisture-holding Capacity.
26—Effect of Certain Colloidal Substance on Growth of Wheat Seedlings.
27—Determination of Normal Temperatures by Means of the Equation of the Seasonal Temperature Variation and a Modified Thermograph Record.
28—A New Soil Elutriator.
30—A Capillary Transmission Constant and Methods of Determining it Experimentally.
34—Pathogenicity of Corticium vagum on the Potato as Affected by Soil Temperature.
40—Influence of Salts on Bacterial Activities of the Soil.
41—Role of Osmotic Pressure in Toxicity of Soluble Salts.
42—The Soil Solution.
48—Influence of Salts on Azofication of Soil.
53—Effectiveness of Mulches in Preserving Soil Moisture.
54—Sugar-beet Root Maggot.
58—Further Studies on Pathogenicity of C. vagum on Potato as Affected by Soil Temperature.
63—Soil Temperature as a Factor Affecting Pathogenicity of C. vagum on Pea and Bean.
62—Test for Determining Character of Curd from Cows' Milk and Its Application to Study of Curd Variance as an Aid to Food Value of Milk for Infants.
63—Leaching of Alkali Soil.
66—Aqueous Vapor Pressure of Soils II. Studies in Dry Soils.
67—Influence of Sodium Arsenite on Microflora of Soil.
68—Statistical Study of Distribution of Soil Material in U. S. According to Size of Its Particles.
69—Studies in Eradication of Wild Morning Glory.
70—Effect of Dry Heat on Alfalfa Seed and Its Adulterants.
71—Influence of Manure and Irrigation Water on Carbon, Phosphorus, Calcium, and Magnesium of Soil.
72—A Land Policy for the Public Domain.

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Logan, Utah, U. S. A.