Geology and Ground Water Heart Mountain and Chapman Bench Divisions Shoshone Irrigation Project Wyoming

By FRANK A. SWENSON

With a section on

CHEMICAL QUALITY OF THE WATER

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By Frank A. Swenson

ABSTRACT

The Heart Mountain and Chapman Bench Divisions of the Shoshone irrigation project comprise about 100 square miles of land in northwestern Wyoming. The area is underlain by bedrock formations ranging in age from Permian to early Tertiary. The parts to be irrigated consist largely of stream terraces at three separate levels, underlain by Quaternary stream deposits of sand and gravel which in places are more than 100 feet thick. The average annual precipitation is low, ranging from about 6 to about 11 inches, and before irrigation the unconsolidated surficial material was dry except under the more extensive terraces. The consolidated rocks also crop out in an area of deficient rainfall and they also were dry or contained strongly mineralized water.

The water to be used for irrigation is derived from the Shoshone River and is of excellent chemical quality. After irrigation has been practiced for some time, a shallow body of ground water probably will form in the gravel deposits underlying the terraces, and this water can be utilized by constructing wells. Under the smaller terrace remnants the water table will decline during the winter and wells located in these areas probably will go dry each year. During the first few years after irrigation is begun, the water obtained from wells in some places will be rather highly mineralized.

INTRODUCTION

This report is based on field work done by the United States Geological Survey, principally during August and September 1946, under cooperative agreements with the United States Bureau of Reclamation. The principal objective of the studies was to obtain information on the domestic water supplies that may be available for families expected to settle on the Heart Mountain and Chapman Bench Divisions of the Shoshone irrigation project, Wyoming. As the initial study progressed it was found that it was necessary to study the geomorphology of the area in some detail in order that a more accurate prediction of the ground-water prospects could be made.

Initially the land under the Heart Mountain Division was partly subdivided by the United States Bureau of Reclamation into 83 numbered farm units. The farm-unit boundaries were established so as to make units of relatively equal size, irrigability, and productivity.

These farm-unit boundaries have no relation to township, tract, or lot boundaries. After the initial field work during 1946, a preliminary report was prepared for administrative use in assisting the settlers to obtain domestic water supplies on farm units 1–83. Later, farm units 84–221 were established, and, during April 1948, further field work was done to determine in detail the prospects of obtaining ground-water supplies on those units.

Since the original administrative report was written the land in the Heart Mountain Division has been settled and irrigated. Much of the area which was desert wasteland in 1946 now (1955) is cultivated, and more than 220 farms have been settled. Wells have been drilled on many of these farms, and data on 133 of those wells are given in the present report (table 4). Exploration for oil has resulted in the drilling of many seismograph shotholes, and partial logs of 57 of those holes were assembled. The inventory of the wells drilled on the homesteads since the original study was made was carried out during late 1950 and early 1951. Except for the records of the domestic wells and shotholes, and the results of minor collateral studies made in 1950 and 1951, the present report virtually is the same as the administrative report issued to interested agencies in June 1948. The major initial conclusions were not changed but, rather, were confirmed by the additional studies.

The present report was prepared under the direct supervision of Geo. H. Taylor, regional engineer in charge of ground-water investigations under the Missouri River basin development program.

A topographic map, scale 1:31,680, published by the U. S. Geological Survey in 1903 for the U. S. Reclamation Service, was used as a base for geologic mapping. After 1903, a resurvey of land lines was made which shifted the location of the section lines. The maps accompanying the present report show the section and property lines of the latest resurveys.

The section of this report dealing with the chemical quality of the water was prepared under the direct supervision of P. C. Benedict, regional engineer in charge of quality-of-water investigations in the Missouri River basin.

LOCATION OF AREA

The Heart Mountain Division (pl. 1), whose total area is about 83 square miles, is north of the Shoshone River and extends from about 3 miles west of Cody, Wyo., northeastward beyond Ralston, Wyo. It ranges from 1 to 9 miles in width, and has a maximum length of about 23 miles.

The Chapman Bench Division, whose total area is about 17 square miles, lies south of the Clarks Fork River, a tributary of the Yellowstone River, and between Pat O'Hara Creek and Little Sand Coulee. It is about 3 miles wide and 7 miles long, the south end being about

18 miles north of Cody. Early plans for development under the Missouri Basin program considered carrying water to the Chapman Bench Division from the northwest corner of the Heart Mountain Division, by means of a proposed Chapman Lateral. Later studies by the Bureau of Reclamation resulted in a decision to eliminate this area from further consideration, but it is again (1955) being reconsidered for development.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based principally upon the system of land subdivision of the Bureau of Land Management. (See fig. 1.) The first numeral of a well number denotes the township and the second numeral denotes the range. In the parts of

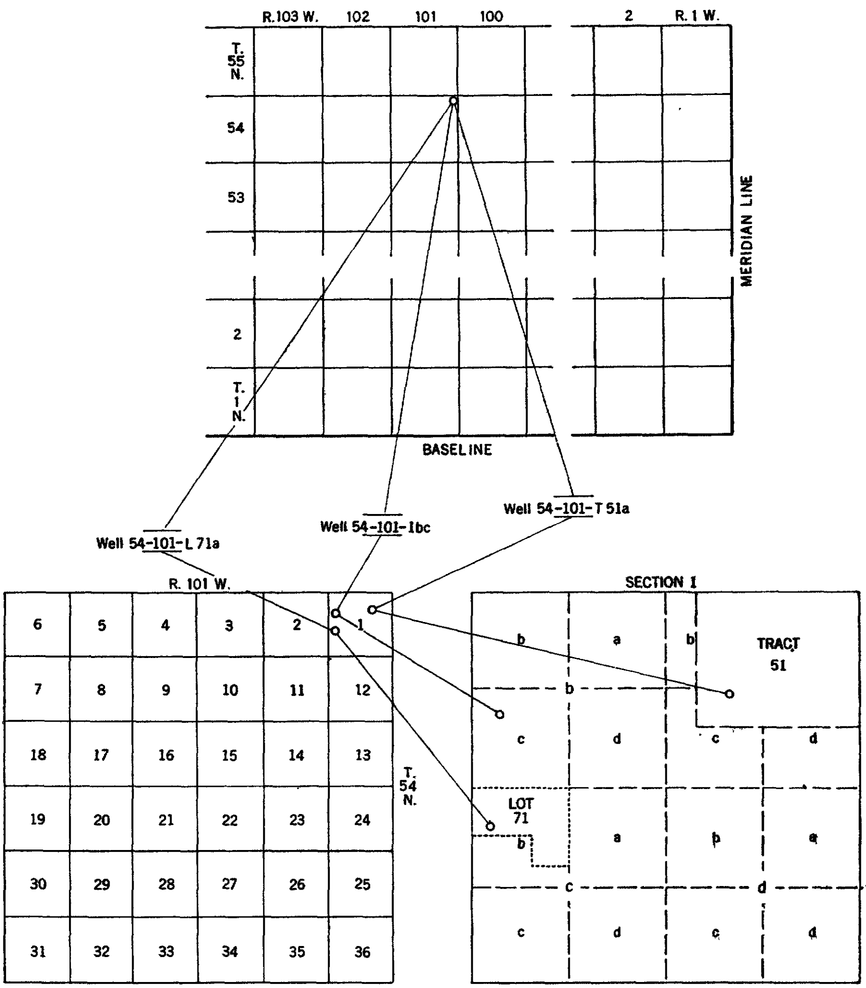

Figure 1.—Sketch showing system of well identification.

the area subdivided into sections, the third numeral of a well number denotes the section. Lowercased letters after the section number indicate, respectively, the quarter section and the quarter-quarter section. The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. When two or more wells are situated within the same 40-acre area, they are distinguished by numerals after the lowercased letters.

Some parts of the area are subdivided into tracts instead of sections. Here, the range number is followed by the capital letter T which is, in turn, followed by the number of the tract which is always greater than the number 36. When two or more wells are situated within the same tract, the tract number is followed by a lowercased letter, in consecutive order for individual wells.

Some other parts of the area are subdivided into lots instead of sections or tracts. Here the range number is followed by the capital letter L which, in turn, is followed by the number of the lot. Again, when two or more wells are situated within the same lot, the lot number is followed by a lowercased letter, in consecutive order for individual wells.

SUMMARY OF GEOGRAPHY AND GEOLOGY

The areas studied consist, to a large extent, of three separate stream terraces separated by ragged eroded escarpments. (See map of Heart Mountain division on pl. 2.) The elevation of the terraces gradually increases in a westerly direction and toward the mountains. Near the southern end of the Heart Mountain Division the highest and oldest terrace has been extensively eroded and few remnants remain. The terraces, in most places, have a sandy or gravelly loam soil underlain by Quaternary deposits of unconsolidated gravel resting upon the beveled bedrock surface. Before irrigation the area was virtually a desert, with a scanty cover of sage, cactus, and desert grasses.

The bedrock formations underlying the area range from the Embar formation of Permian and Triassic(?) age to the Wasatch formation of Eocene (Tertiary) age. Much of the area, except the extreme southwestern tip of the Heart Mountain Division, is underlain by the Wasatch formation (pl. 3). The older beds are exposed at the surface along the flanks of an anticlinal structure trending northwest at the mouth of Cottonwood Creek; they crop out also along the base of Rattlesnake Mountain just west of the area.

The average annual precipitation ranges from about 6 inches north of Ralston to about 9.3 inches near Cody. Precipitation at Clark, 3 miles north of Chapman Bench, averages about 11 inches a year. Because of the relatively low precipitation, there has been little groundwater recharge and in most places the unconsolidated surficial material was dry before irrigation except under the more extensive terraces. The consolidated rocks also crop out in areas of deficient rainfall; these rocks are dry or contain strongly mineralized water. Before the development of the area by irrigation, the only fresh-water body of any extent occurred under the Ralston Flat, which name is applied to about 30 square miles of sloping plain at the north end of the Heart Mountain Division. In 1946, when the study was begun, a water table had formed under about 2,000 acres of land put under irrigation about 1942 for use by the War Relocation Authority. These lands are principally in the northwest corner of T. 54 N., R. 100 W., and on the lower terrace along the Shoshone River, but some lie on the higher terraces south of Eaglenest Creek.

TOPOGRAPHY

RELIEF

The area studied ranges in elevation from 4,600 to 5,200 feet above sea level. The Shoshone River flows along the south and east edges of the Heart Mountain Division in a steep-walled gorge as much as 120 feet deep. This gorge is cut below a prominent terrace level which is, in places, as much as 1½ miles wide. This lowest or Cody terrace (Mackin, 1937) has a riverward slope of about 40 to 50 feet per mile, rising from the lip of the Shoshone River gorge to a somewhat ragged escarpment marking the boundary between the Cody and the intermediate or Powell terrace (Mackin, 1937). This riverward slope is largely the result of the presence of a wedge-shaped deposit of slope wash. The escarpment between the Cody and Powell terraces, more prominent in some places than others, is as much as 100 feet high. Erosion has broken down the escarpment in some places, and an arbitrary (dashed) boundary has been drawn (pl. 2) between the terrace levels at these locations.

The Powell terrace, best developed along the Shoshone River and in the flat north of lower Eaglenest Creek, has a slope of 65 to 80 feet per mile from the escarpment at its base to another escarpment marking the boundary of an upper terrace, here named the Ralston terrace. At the southern end of the Heart Mountain Division all remnants of the Ralston terrace have been destroyed by erosion and the upper edge of the Powell terrace is marked by broken, eroded country.

The Ralston terrace, the highest within the area studied, is well developed along Alkali Creek and south of upper Eaglenest Creek. Its upper limits form the divide between the Shoshone River and the Clarks Fork of the Yellowstone River. The badlands at the base of Polecat Bench are formed along an escarpment marking the boundary between the Ralston terrace and a still higher terrace, not present in the area of this report, which forms the flat surface of Polecat Bench.

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DRAINAGE

Seven intermittent streams and many small gullies head on Heart Mountain and cross the Heart Mountain Division. Cottonwood Creek might have a perennial flow if its waters were not diverted for irrigation. Springs at the Wyoming State Fish Hatchery, on Cottonwood Creek about 6 miles northwest of Cody, have a total flow of about 150 gpm (gallons per minute), all of which is utilized to irrigate land on the nearby valley bottom. Several of the other streams may have a perennial flow near their heads, but water in any quantity seldom flows as far as the Heart Mountain Canal. Trail Creek and Dry Creek, at the southwest tip of the Heart Mountain Division, head on Rattlesnake Mountain but neither has a perennial flow. Except for Alkali Creek, on Ralston Flat at the north end of the Heart Mountain Division, all the streams crossing the area flow in steep-walled gorges cut to depths ranging from 50 to more than 150 feet below the terrace levels. The bottoms of the valleys of Cottonwood, Trail, and Dry Creeks have a gentle slope, caused in part by lateral planation during the erosional cycle when the Cody terrace was formed. The lower course of Eaglenest Creek has been incised into the south edge of a broad flat developed during the erosional cycle when the Powell terrace was formed. Alkali Creek meanders across the broad Ralston Flat, into which it loses its water, and before irrigation in the area had been unable to cut an appreciable channel.

During construction of irrigation facilities, Alkali Creek was deepened and straightened below the Heart Mountain Canal to act as a drain and wasteway for surplus irrigation water. Plate 4*A* and *B* are photographs that show that the drain has been eroded considerably since it was constructed. The water in the drain shown by the photographs is ground-water drainage—the drain was carrying no surface-water drainage when these photographs were taken. In spite of the steep gradient, the stream is meandering and undercutting the banks. In the 4 years between the times that these photographs were taken, the stream widened its bottom from 10 feet to almost 100 feet in places. Considerable potential farmland has been destroyed, and several methods have been used to prevent additional widening.

Chapman Bench is bordered on the west by Pat O'Hara Creek, a spring-fed perennial stream. This creek flows in a relatively flat-floored valley which lies about 100 feet below the terrace level. Little Sand Coulee heads in the area of badlands topography south of Chapman Bench and after crossing the bench forms its east boundary. This stream flows only after heavy storms. Near the stream's confluence with the Clarks Fork River it is about 100 feet below the bench level.

A. SEPTEMBER 1946.

B. SEPTEMBER 1950.

ALKALI CREEK DRAIN NEAR EAST END OF RALSTON FLAT.

Flow in drain is ground-water pickup.

A. View upstream across wind gap leading from the Beartooth Mountains (in background) onto Ralston Flat.

B. View over divide in wind gap shown in *A*. Man stands approximately on contact between 45 feet of unconsolidated stream deposits and bedrock of the Wasatch formation.

GEOLOGY

PRE-QUATERNARY BEDROCK FORMATIONS

GEOLOGIC HISTORY

The Embar formation, the oldest rock formation exposed within the area, was deposited in a clear, shallow sea largely during Permian time. Deposition of the sediments ended in early Triassic time when a gradual rise of the land resulted in a recession of the sea from this region.

During much of the remainder of Triassic time the region stayed above sea level and the red beds of the Chugwater formation, totaling about 820 feet in thickness, were deposited. These sediments, with included gypsum beds, appear to have been deposited mainly under arid conditions.

Early in Late Jurassic time a sea again advanced across this region, and in Late Jurassic time the Sundance formation, the total thickness of which is about 480 feet, was deposited. The sea was shallow and most of the time was muddy, clearing up for short periods which are marked by thin beds of fossiliferous limestone. Possibly this same sea persisted into Morrison time, for some parts of the Morrison formation are marine, whereas other parts are continental.

At the beginning of Cretaceous time the sea-level fluctuations, which characterized Late Jurassic time, ended and the Cloverly formation, which totals more than 170 feet of sandstone and shale, was deposited. Conditions then remained stable for a long period, and the Thermopolis shale, about 650 feet thick, and the Mowry shale, about 380 feet thick, were deposited in the shallow muddy sea above the Cloverly. There was considerable volcanism to the west during this period of deposition, which gave rise to the bentonite beds of the Thermopolis and Mowry shales.

The deposition of the Mowry shale came to an end with the recession of the sea from this region. The Frontier formation, about 500 feet thick and consisting mostly of sandstone and shale, was then deposited largely under continental conditions, although there may have been short periods during which the sea again advanced and retreated, giving rise to lagoons in which the shales that alternate with the sandstone beds were deposited. In some other areas workable coal deposits were formed during this period, but conditions were not so favorable in the area of this study and only carbonaceous shales were deposited.

Frontier time ended with an advance of the sea, and the thick series of marine shales included in the Cody shale, totaling about 2,150 feet, was deposited. Sea-level fluctuations near the end of Cody time resulted in the deposition of the partly continental, partly marine sandstones found in the upper part of this formation.

The sea-level fluctuations persisted and the partly marine, partly brackish-water, and partly continental deposits of the Mesaverde formation, totaling about 1,100 feet in thickness, were formed. In some other areas fairly thick deposits of coal were formed during this period, but only carbonaceous shales are found in this region. The Meeteetse formation, including about 1,100 feet of clayey sandstone and shale, was then deposited in the fluctuating sea, which finally retreated from the region late in Meeteetse time. Several thin coal beds were formed late in this period of deposition.

Since the beginning of Lance time (uppermost Cretaceous) this region has received thousands of feet of continental deposits, but the sea has never again advanced over it. The Lance, Fort Union, and Wasatch formations, with a total thickness of more than 7,800 feet, were deposited by streams on flood plains or in swamps or shallow lakes. These streams were carrying fairly fine grained materials during much of Lance time, but the mountain building that marked the boundary between the Cretaceous and Tertiary periods led to steeper stream gradients and coarser sediments in Fort Union (Paleocene) time. The streams were overloaded with sediments and shifted channels often as they spread over the vast alluvial plain. Lenticular beds of coarse gravel were deposited in the channels themselves, but finer grained materials were spread over a great area. Another period of major deformation followed the deposition of the Fort Union formation, and, after a period of erosion, the sediments of the Wasatch formation were deposited during the Eocene epoch. These sediments were considerably finer grained than those of the Fort Union, but lenses of sandstone and conglomerate are not uncommon in the lower part of this thick shaly series. Much of the shale may have been deposited in extensive fresh-water lakes on the broad plains.

There is no way of knowing how thick the deposits of Tertiary age may have been before deposition ended and erosion and removal of these sediments began. As Mackin (1937) has pointed out, there are two lines of evidence which indicate that the Bighorn Basin was at least partly filled with sediments during Tertiary time. These are the superposition across structural barriers of all major streams that enter or leave the basin, and the presence of extensive deposits of stream gravels at elevations of 7,000 to 9,000 feet on the flanks of the Bighorn and other ranges that border the basin. The youngest known consolidated sediments in the basin are the lignitic shales which underlie the gravel capping of Tatman Mountain, which rises some 1,500 feet above the Greybull River about 25 miles west of Basin, Wyo. These shales were believed by Sinclair and Granger (1912, p. 62) to be of Eocene age, but there is a good possibility that even here erosion has removed a considerable thickness of younger overlying beds.

GEOMORPHOLOGY

Because of the gap in the sedimentary record, the later geologic history of the region must be interpreted from the geomorphic record. As indicated above, it is generally believed that the region had a low relief during middle or late Tertiary time. The flanks of the mountain ranges were buried by stream deposits, which partly filled the basin. The subsummit levels of the Beartooth and Bighorn Mountains, which levels are considered by Bevan (1925) and others to be of Pliocene age, were part of this great plain, which extended over the Owl Creek and Pryor Mountains and at least the southern end of Rattlesnake Mountain west of Cody.

A period of erosion started at an indeterminate time, probably late Miocene or early Pliocene, and has continued with minor interruptions to the present.

It is difficult to determine whether the start of this period of erosion was mainly the result of regional uplift or of an increase in precipitation; both factors probably were involved. All streams in the region were rejuvenated, and the exhuming of the mountain ranges and the development of the present topography were started by erosion. As erosion continued, all the major streams were superimposed across structures and the Wind River, Shoshone, and Bighorn Canyons were formed.

Mackin (1937) discussed the geomorphology of the entire Bighorn Basin, and this investigation has added some local detail to the history he so admirably worked out. As an introduction to these details, the following résumé of Mackin's work as it bears on this area is presented.

The oldest known stream-terrace gravels in the Bighorn Basin are those capping the youngest known consolidated rocks present on Tatman Mountain (pl. 1), 25 miles west of Basin, Wyo. These terrace gravels are about 1,500 feet (recent topographic mapping shows this elevation as compared with Mackin's 1,230 feet) above the valley of the Greybull River less than 7 miles to the north. The gravel capping of Tatman Mountain consists mainly of basic igneous rock types derived from the Absaroka Range to the west. The gravel is comparable in every way to materials carried today by the Greybull River, and to gravel found as other, lower, terrace deposits along that stream. The gradient, as determined by the present position of the gravel cap, was about 40 feet to the mile, approximately the same as that of the present Greybull River.

The next youngest stream-terrace gravel of any consequence in the Bighorn Basin caps Polecat Bench, which lies north and east of Ralston, Wyo., just outside the area of this report. Polecat Bench is a high-level mesa almost 20 miles long and 3 to 5 miles wide between the Shoshone and Clarks Fork Rivers. Where it is closest to (about 5 miles north of) the Shoshone River, it stands almost 800 feet above the river. Polecat Bench has been postulated to be a preserved remnant of the stream bed of the ancient Shoshone River because it lies in almost a direct line between the gap formed by the Shoshone Canyon, through which the Shoshone River enters the Bighorn Basin, and the wind gap cut through the Pryor Mountains to the northeast (Pryor Gap on pl. 1). If the gradient of Polecat Bench is projected through Pryor Gap, a good correlation with the gradient of a set of terraces along the broad valley now occupied by Pryor Creek is found. The gravel under Polecat Bench is similar in composition to the stream-terrace gravel along Pryor Creek, and Mackin (1937) concluded that the gravel deposits on Polecat Bench mark a former, considerably higher level, course of the Shoshone River.

On the basis of location and the general elevation of Polecat Bench, Alden (1932) tentatively correlated it with the upper, open valley of the Clarks Fork River. However, Mackin disagrees, although he recognizes the possibility that the Clarks Fork River once was a tributary of the Shoshone River. Mackin believes that the turns in the Clarks Fork River necessary to have caused it to flow over Polecat Bench as a tributary of the Shoshone River would have had to be too abrupt to be probable; however, the writer believes that the existing, abrupt turns in the Clarks Fork River are even sharper than any needed to have brought it across Polecat Bench. Mackin (1937, p. 840) cited the lack of gravel derived from plutonic igneous rocks in the deposits of Polecat Bench as confirmatory evidence that the Clarks Fork River was not a tributary of the Shoshone River when the gravels of Polecat Bench were deposited. However, later in his paper, Mackin (1937, p. 854–855) notes that perhaps this evidence is not so strong as it might be, as there is a good chance that the main stream of the Clarks Fork at that time had not cut down into the Precambrian rocks. Careful reading of Mackin's paper fails to indicate any other reason why he believes that the capture of the Clarks Fork River took place before the Polecat Bench course of the Shoshone River was abandoned.

Some data gathered during this study, to be discussed below, tend to indicate that the Clarks Fork River continued to be tributary to the Shoshone River after that river had been diverted from Polecat Bench. Certain anomalous relationships regarding the Clarks Fork River and Rock Creek, noted by Mackin (1937), can best be explained by assuming the capture of the upper part of the Clarks Fork River by a tributary of the Yellowstone River to have taken place after, rather than before, the Shoshone River had been diverted from its course across Polecat Bench.

During the present study the writer was early impressed by the broad, sloping physiographic feature known as Ralston Flat. The flat is a plain 3 to 4 miles wide and more than 10 miles long having a fairly uniform surface slope toward the east of about 65 feet to the mile. Alkali Creek, which drains much of the flat, is an intermittent stream that is virtually lost in the expanse of the plain, and it did appear possible that this insignificant stream could be responsible for having formed a flat of this size. When logs of seismograph shotholes and wells became available, it was found that Ralston Flat is underlain by a mantle of unconsolidated material which in places is more than 100 feet thick (pl. 6). Although the elevation of the land surface at the site of many of these holes has not been determined accurately, enough data are available to indicate that the bedrock surface under Ralston Flat has an eastward slope of about 55 feet to the mile, or about 10 feet less than the land-surface slope. It is apparent that a stream of the size of Alkali Creek, with its intermittent flow, could not have carved a valley as broad, and having as low a gradient, as the bedrock floor underlying Ralston Flat. It is conceivable that, after this broad valley was cut, given time enough Alkali Creek could have deposited a fill as thick as that now present, but it is doubtful that this stream ever had the volume of water required to transport the coarse cobbles which make up a considerable part of the fill.

The upper edges of Ralston Flat, on the north and west sides, form the divide between the Shoshone and Clarks Fork Rivers. Gentle slopes lead up from Ralston Flat to broad wind gaps (pls. 1 and 6) which must have been formed by streams flowing from the north and west. These wind gaps are cut into the bedrock and are floored with unconsolidated gravel deposits.

Plate 5*A* shows one of the wind gaps, three-eighths of a mile wide, looking upstream in sec. 7, T. 55 N., R. 102 W., across the divide to the Beartooth Mountain front. Its elevation is about 5,400 feet. Plate 5*B* shows a man standing approximately on the contact between the bedrock and unconsolidated material over the divide pictured in plate 5*A*. At this location the unconsolidated material is about 45 feet thick and is being removed by headward erosion of a "badland type" gully tributary to the Clarks Fork River, which is more than 800 feet lower and located about 6 miles to the northwest. It is obvious that a good-sized stream was required to cut the valley and to deposit the unconsolidated material present. A somewhat broader wind gap is in sec. 4, T. 55 N., R. 101 W. The gap is more than half a mile wide, and has an elevation of less than 5,100 feet. Near the head of the West Fork of Alkali Creek, sec. 5, T. 54 N., R. 102 W., there is another wind gap about half a mile wide. Directly in line with this gap and Alkali Creek is Skull Creek, a tributary of Pat O'Hara Creek. The upper couple of miles of Skull Creek has a low gradient, in marked contrast with the steep gradients in the next 2 miles. When the profile of Skull Creek's upper course is plotted across the wind gap to Alkali Creek there is close though not perfect agreement. The lack of perfect agreement may or may not be due to the glaciation that appears to have affected the headwaters of Skull Creek.

Mackin (1937) found many interesting and anomalous problems during his study of the Clarks Fork River and Rock Creek basins. They will be discussed in this report because of their importance to the present study. The Clarks Fork River heads near the northeast corner of Yellowstone National Park on the southwestern flank of the Beartooth Mountains and the northeastern flank of the Absaroka Range. The river flows more than 50 miles in a southeasterly direction in a canyon which approximately marks the boundary between the Absaroka Range, principally of volcanic origin, and the Beartooth Mountains, principally Precambrian granitic rock; the river turns abruptly at the mountain front and flows in a north-northeasterly direction to the Yellowstone River. Rock Creek heads on the northeastern flank of the Beartooth Mountains, and, after leaving the mountains about 5 miles south of Red Lodge, Mont., its course is parallel to the Clarks Fork River for almost 30 miles; Rock Creek then turns eastward and joins the Clarks Fork River near its confluence with the Yellowstone River.

The two parallel valleys exhibit marked contrasts. Relatively, Rock Creek valley is shallow, and has well-defined terraces from the mountain front to its junction with the Clarks Fork River. The Clarks Fork River valley is a broad, open lowland and differs from all other main streams in the area in that few main-stream terrace remnants are preserved except below the mouth of Rock Creek where they are nearly continuous. Mesa Bench, a stream terrace developed by the ancient Rock Creek, forms the divide between the parallel courses of Rock Creek and the Clarks Fork River. At its south end, Mesa Bench stands nearly 2,300 feet above the Clarks Fork River and 350 feet above Rock Creek. The eastern margin of Mesa Bench is an abrupt scarp; fresh landslides along the edge indicates the current, westward retreat of the scarp to be very rapid. If the works of man are disregarded, the future capture of Rock Creek by the Clarks Fork River can be predicted.

Two separate terrace surfaces are almost continuous for the first 30 miles after Rock Creek leaves the mountains. Those surfaces, designated by Mackin (1937), the Roberts and Red Lodge terraces (from higher to lower), indicate two pauses in the downcutting of Rock Creek. The gradient of the Red Lodge terrace is steeper than the gradient of the Mesa Bench, the Roberts terrace, or the present stream. This fact may have some significance, as will be mentioned later in this discussion.

The marked lack of adjustment between the Clarks Fork River and Rock Creek indicated to Mackin that some change had "recently occurred in the relative gradients of the two streams, such that, at any considerable distance from their accordant junctions, the elevation of the Clarks Fork River has been greatly decreased in relation to that of Rock Creek." As a working hypothesis, Mackin suggests that the Clarks Fork River formerly flowed to the Shoshone River and that it was captured by a headward-working tributary of the Yellowstone River. The introduction of the large, perennial Clarks Fork River into the valley of the much smaller pirate stream has resulted in vigorous downcutting and the marked lack of adjustment between the Clarks Fork River and Rock Creek.

Besides the lack of adjustment between the Clarks Fork River and Rock Creek, noted by Mackin, there is a very marked lack of adjustment of all streams flowing from the Beartooth Plateau to the Clarks Fork River. They have fairly gentle gradients to about the middle of their course; then there is a very sharp knickpoint where they drop steeply into deep canyons. Such a feature normally results from a very recent lowering of base level. Conceivably it could be the result of fairly recent piracy of Clarks Fork River and the rapid excavation of its course in easily eroded beds, or it could have resulted from a recent uplift of the Beartooth Mountains along the frontal fault north of the lower canyon of the Clarks Fork River. However, W. G. Pierce, of the Geological Survey, found no evidence of recent activity along this fault (1954, oral communication). The upper part of the Clarks Fork River appears to constitute a barbed drainage system leading into the pirate stream which diverted it northward. In the upper 50 miles of its course the river flows uniformly to the southeast until it approaches the mountain front, where it heads north and northeast parallel to the frontal fault. It again swings south and east, passing between the hogbacks of Paleozoic rocks which form the the mountain front, and then turns abruptly north and east at the mountain front, which appears to be the point of capture. Much of the upper course of the Clarks Fork River is along or near the contact of the Precambrian and Paleozoic rocks, but its deep box canyon ("The Box," pl. 1) is cut through the Paleozoic rocks and deep into the Precambrian. The broad, open upper canyon, above the box canyon, is in Paleozoic rocks. There is a prominent fault parallel to the southeasterly course of the river about a mile north of the box canyon, and the steep north wall of the open canyon is formed by the upthrown block of Precambrian granite (W. G. Pierce, 1954, oral communication).

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With these observed facts in mind, a review of the geomorphic history of the Clarks Fork River as outlined by Mackin seems advisable. If the piracy of the Clarks Fork River took place before Polecat Bench was abandoned by the Shoshone River, as Mackin states, it is questionable if Mesa Bench could have been formed, much less preserved, standing as it now does 2,300 feet above the Clarks Fork River. Mackin's hypothesis would necessitate assuming that Rock Creek, a stream which, though it starts at a high elevation, has only a small flow, had cut its valley down to at least the Mesa Bench level, an elevation of 4,800 feet 12 miles from the mountain front, while the larger Shoshone River was still flowing at 5,200 feet, more than 20 miles from the mountain front. Comparing the amount of cutting down by the streams of the area since the Mesa Bench and Polecat Bench surfaces were developed, one finds that Rock Creek is now flowing about 350 feet below the Mesa Bench and the Clarks Fork River about 2,300 feet below the Mesa Bench. The Shoshone River is now flowing about 800 feet lower than when it occupied a course over Polecat Bench. If the Clarks Fork River had been diverted at that time, it must have been by a stream flowing at the level of Mesa Bench. This would lead to the further assumption that Mesa and Polecat Benches are of equal age, for, with the emplacement of the large Clarks Fork River in the valley of the intermittent pirate, downcutting in the soft sediments would have been very rapid. As Mackin (1937, p. 848) says, the eastern margin of Mesa "bench is an abrupt scarp, varying from 500 to 1,500 feet in height, which descends to the Clarks Fork River lowland. Manifestly, such a feature could not have been present when Rock Creek was cutting laterally at the Mesa Bench level, for the stream would certainly have sooner or later spilled over the edge." The effect of this rapid downcutting of the master stream would be the lowering of base level for the tributary streams, and Rock Creek could not have formed both the Roberts and Red Lodge terraces (Mackin, 1937, pl. 10). The fact that the Red Lodge terrace has a steeper gradient than the higher terraces along Rock Creek may be significant as a clue to the time of diversion; it may be steeper because the local base level was lowered just before that terrace was formed.

The absence of main-stream terraces along the Clarks Fork River, above the mouth of Rock Creek, can easily be explained by recognizing a more recent piracy than that advocated by Mackin. The terraces that are relatively continuous along the Clarks Fork River below the mouth of Rock Creek may actually be terraces of Rock Creek. If the piracy were more recent, the Clarks Fork River would not be expected to have any terraces, as it has been at work developing a graded declivity since its has been in its present course. The lack of adjustment of all streams flowing from the Beartooth Mountains and to the Clarks Fork River also is indicative of a relatively recent piracy.

GEOLOGIC STRUCTURE

The Frontier formation and underlying rocks exposed northwest and west of Cody (pl. 3) dip northeastward along the flanks of Rattlesnake Mountain, which is a major faulted anticline forming a part of the western boundary of the Bighorn Basin. The Frontier formation crops out also in the crest of the anticlinal structure at the mouth of Cottonwood Creek. Formations between the top of the Cody shale and the base of the Wasatch formation crop out in relatively narrow belts northeast of this anticline. The belt formed by the Fort Union formation is about 1½ miles wide, but the other belts are less than half a mile wide each. The east limb of the anticline shows dips of as much as 59°, and the more resistant beds stand as hogbacks where erosion has destroyed the higher benches which formerly beveled the structure. For detailed information and structure sections the reader is referred to studies made by W. G. Pierce (1939).

WATER-BEARING PROPERTIES

The water-bearing properties of the pre-Quaternary rocks underlying the Heart Mountain and Chapman Bench Divisions have not been adequately tested by drilling. Table 1 shows a generalized geologic section of the rocks exposed in the area with interpretations of their probable water-bearing properties.

TABLE 1.—*Generalized section of bedrock formations exposed in Heart Mountain and Chapman Bench Divisions, Shoshone irrigation project*

[Section modified from W. G. Pierce (1939)]

Age	Formation	Thickness (feet)	Description	Probable water-bearing properties
Tertiary	Wasatch	1,000+	Red and drab clay; lenses of buff and white sandstone; some conglomerate lenses.	Fair to poor, depending on lenses of sandstone encountered by hole; water may be strongly mineralized, and recharge is slow.
	Fort Union	5,000	Thin-bedded buff to white sandstone; coarse conglomerate beds near top; drab to green and olive-brown shale; some red shale in upper part.	Fair to good yields of water available from conglomerate and sandstone if saturated; formation crops out in dry region and the water is somewhat mineralized.
Cretaceous	Lance	1,800	Thick-bedded white to buff sandstone; some conglomerate lenses; green to drab shale.	Fair to good yields of highly mineralized water obtainable where sandstone and conglomerate are saturated.
	Meeteetse	1,100	Gray to white soft clayey sand and sandstone; gray to pale-olive sandy clay; brown shale and bentonitic clay; thin beds of poor coal in upper part.	Generally not water bearing; meager supplies of highly mineralized water may be obtained from sandstone or coal beds; water is probably unfit for domestic use.
	Mesaverde	1,100	Massive light-buff to gray sandstone in lower part; thin-bedded sandstone with gray and brown shales above.	Small yields of water of fair quality probably available where sandstones are saturated.

TABLE 1.—*Generalized section of bedrock formations exposed in Heart Mountain and Chapman Bench Divisions, Shoshone irrigation project*—Continued

Age	Formation	Thickness (feet)	Description	Probable water-bearing properties
Cretaceous	Cody shale	2,150	Upper part thinly laminated buff sandstone and sandy shale; lower part dark-gray to black thinly laminated marine shale.	Not water bearing.
	Frontier	500	Two or more beds of thick lenticular gray to buff sandstone; gray, brown, and black (carbonaceous) shale and bentonite.	May yield small to moderate supplies of mineralized water, possibly unfit for domestic use.
	Mowry shale	380	Hard gray to brown shale, in part siliceous; breaks in thin rectangular fragments; several prominent bentonite beds.	Not water bearing.
	Thermopolis shale	650	Soft gray to black shale with numerous bentonite beds; one muddy sandstone about 50 feet thick near bottom.	Not water bearing.
	Cloverly	170+	Massive sandstone of variable thickness; gray and variegated shale.	Small to moderate yields of mineralized water. One well flows 35 gpm from this formation at depth of 1,320–1,485 feet on crest of structure northeast of Cody.
Jurassic	Morrison	450	Variegated sandy shale with lenticular conglomerate near middle; lilac-colored shale and chalcedony in upper part.	Not water bearing.
	Sundance	480	Green shale with greenish-gray shaly sandstone at top; thin beds of fossiliferous limestone; some red shale and gypsum in lower part.	Not water bearing.
Triassic	Chugwater	820	Red shale and sandstone; gypsum beds at the top.	Not water bearing.
Triassic (?) and Permian	Embar	130	Gray dolomitic limestone with nodular cherts; interbedded with gray shale and thin-bedded sandstone.	May yield usable supplies if water-filled caverns and fissures are encountered by well. De Maris Hot Springs, west of Cody, issue from upper part of this formation.

QUATERNARY UNCONSOLIDATED SEDIMENTS

DESCRIPTION

Underlying the three terraces shown on plate 2 are thick deposits of unconsolidated stream gravels. These gravel deposits are more than 100 feet thick in places and are exceptionally good potential ground-water reservoirs. In most places these gravels consist of well-rounded cobbles and but little fine material; however, in some places the cobbles are in a matrix of sand and in a few places the gravels are firmly cemented. The average annual precipitation is too scanty to have permitted formation of a permanent ground-water body, and the gravels before irrigation was begun were virtually dry except in places under the extensive Ralston Flat.

DEPOSITS UNDERLYING RALSTON TERRACE

Unconsolidated stream gravels underlie the Ralston terrace. The ancient stream crossing Ralston Flat appears to have been considerably larger than the existing Alkali Creek, and carried a heavy load of debris from the highlands farther west. The stream had a steep gradient, about 55 feet to the mile, and in times of flood carried coarse cobbles. The gravel underlying at shallow depth the west end of Ralston Flat is composed largely of subangular to well-rounded cobbles of limestone and dolomite derived from Paleozoic formations. Rounded cobbles of chert, quartzite, and crystalline rocks, comprising about 5 percent of the deposit, may have been derived in part from the destruction of a higher terrace deposit. The gravel deposit is unconsolidated, having only a lime-rich matrix of fine sand. The thickness of the deposit ranges from about 4 feet in the bed of Alkali Creek at the east edge of the Heart Mountain Division to more than 100 feet in the west-central part of Ralston Flat. The thickness appears to be greatest in an east-west belt across the middle of the flat and the deposit is fairly thin, or is missing, near the base of the shale hills that border the flat on the north and south (pl. 6). The sandy and gravelly loam soil that mantles this terrace appears to have been derived principally from the weathering and disintegration of the surficial part of the old stream deposits, but in part from erosion of the surrounding hills; some may be of eolian origin. The gravel that remains in the soil mantle consists mainly of chert and other silica-rich rocks which are resistant to chemical breakdown. The gravel south of Eaglenest Creek is not so coarse as that under the west end of Ralston Flat, and its thickness ranges from 4 to about 30 feet.

DEPOSITS UNDERLYING POWELL TERRACE

The Shoshone River, after downcutting and lateral planation in the cycle of erosion that formed the Powell terrace, became overloaded with debris and deposited a thick layer of gravel on its broad flood plain. This gravel deposit is more than 50 feet thick in some places near Cody. The deposit consists principally of rounded to subrounded cobbles of volcanic rocks from the Absaroka Range to the west. Mixed with these cobbles are others derived from the destruction of older terrace deposits consisting mainly of very well rounded quartzite and chert pebbles. Some large angular boulders of Paleozoic sedimentary rocks are present also.

The soils on the Powell terrace are sandy to gravelly loams. Some of the soil was derived from the breakdown of materials in the original stream deposits, but most of the soil material was derived from erosion of the older benches and the surrounding highlands. A considerable part may have been blown by wind from the Ralston terrace whose surface is like a cobblestone pavement near the edge of the escarpment marking the boundary between the Ralston and Powell terraces. There, the finer grained materials have been blown away and the exposed surfaces of the cobbles are wind polished and oxidized to a rich brownish color.

DEPOSITS UNDERLYING CODY TERRACE

Active stream erosion was resumed after the deposition of the sand and gravel underlying the Powell terrace. The Shoshone River appears to have reached grade after about 80 to 100 feet of downcutting, and lateral planation became the major factor of stream erosion. Eaglenest Creek became incised along the southern edge of the Powell terrace. Cottonwood, Dry, and Trail Creeks were incised into the piedmont slope which they had developed without regard to the underlying rock structure. As Cottonwood Creek cut deeper, it became superimposed across the structure and eroded deep notches across resistant rock formations, including the Frontier formation, which crops out at the mouth of the creek in the core of the anticline previously mentioned. The creek was able to develop a flood plain, in places almost half a mile wide, in the less resistant rocks upstream from the resistant rocks. Trail Creek and Dry Creek also were able to develop flood plains where they flowed over the less resistant beds. The Shoshone River formed a flood plain which is about 2 miles wide in most places. Part of this flood plain now lies south of the present gorge of the river, but parts as much as 1½ miles wide lie north of it in the Heart Mountain Division.

A layer of gravel was deposited on the flood plains that had been developed after active downcutting had ceased in the erosional cycle that formed the Cody terrace. This gravel layer, ranging from 2 to 15 feet in thickness, is not so thick as those developed on the higher benches. It is very firmly cemented at locations near Cody, but farther downstream no cementing material is present. The cementing material is calcareous, and at least some was derived from springs. The bench north of De Maris Hot Springs and west of Cody has a layer of calcareous tufa several feet thick above the firmly cemented gravel bed. Three large sinkholes (pl. 3) on this bench indicate that the rocks underlying the gravel bed at this location are cavernous.

The surficial material mantling the gravel deposit of the Cody terrace is a fine sand which is more than 20 feet thick in some places. A loamy soil is developed on the terrace. Part of the material is alluvial but some seems to be of eolian origin. Considerable settling and compaction occur when the land is irrigated and where the soil is especially thick. The land settled as much as 6 feet in some places during the first few years of irrigation, which resulted in a need for adding fill under the railroad and highway and for raising drops and other structures along the irrigation ditches. As soluble salts are not present in any considerable quantity, it is apparent that the settling is not the result of the leaching of salts. Therefore the settling must be the result of a rearrangement of soil particles under the wetting action of the water. In time the settling tends to reduce materially the permeability of the soil, and it may result in the formation of a tighter soil that will waterlog easily in spite of the excellent underdrainage provided by the gravel bed.

The Shoshone River has cut its present gorge to a depth of about 120 feet since the Cody terrace was formed. The stream still has a steep gradient and has only begun to form a flood plain on the slip-off slopes of the sharper bends. The deeply incised meandering course of the present river indicates that downcutting started suddenly, so that the old meanders from the erosional cycle that formed the Cody terrace were retained.

GROUND WATER

CONDITIONS BEFORE IRRIGATION

BEDROCK FORMATIONS

The Wasatch formation, which underlies the Chapman Bench and all but about 18 square miles of the Heart Mountain Division, is not very favorable for obtaining water from wells. The formation is composed largely of clay containing scattered lenses of sandstone and conglomerate. Wells penetrating only clay would yield little if any water, and those fortunate enough to penetrate sandstone or conglomerate probably would yield only small supplies of mineralized water.

Wells drilled in the belt, about 2 miles wide, underlain by the sandstones, conglomerates, and shales of the Fort Union and Lance formations (see pl. 3) probably would obtain at least small supplies of water. Water may be expected to be found at depths between 50 and 200 feet and to be somewhat mineralized; some may be unfit for domestic use.

The only water well (53–101–T85a) known to have been drilled in the Heart Mountain Division before the opening of new farm units during 1947 is on the V. F. Rotter farm. This well, drilled to a depth of about 100 feet in 1930, passed through unconsolidated material to a depth of 75 feet, where it entered a sandstone which continued to the bottom of the well. In 1946 the water stood at a depth of about 90 feet. The well was equipped with a cylinder pump powered by a windmill and an electric pump jack. The well is capable of yielding between 15 and 20 gpm of mineralized water (see section on "Chemical quality of the water"). The well is near the contact of the Wasatch and Fort Union formations, and probably draws water from the Fort Union formation.

The area extending from opposite Cody northeastward to the belt of the Fort Union and Lance formations is unfavorable for drilled water wells of moderate depth, because it is underlain by a thick section of tight shale. An exception might be formed by wells drilled into the sandstones of the Mesaverde formation. As those sandstones are limited in extent and are not well exposed, it would be difficult to locate favorable sites for wells. Gas and oil wells have been drilled to a maximum depth of 4,809 feet on the anticline near the mouth of Cottonwood Creek. Information concerning the water obtained is available for only one of those wells; well 53–101–21cc, owned by the Husky Oil Co., was drilled to a depth of 1,485 feet and flowed about 35 gpm from the Cloverly formation between 1,450 and 1,485 feet. The water is mineralized, containing more than 1,200 ppm (parts per million) of sodium bicarbonate. Some gas is in the water, and the pressure of the gas probably causes the water to flow from the well.

Wells drilled into the Frontier, Cloverly, and Embar formations west of Cody might obtain water. As these formations dip 16° to 22° to the northeast, wells to be of moderate depth must be located on the outcrop belt of a given formation or not far down the dip from it. The quantity of water from any of these formations will be limited and the water may be too highly mineralized for satisfactory domestic use.

UNCONSOLIDATED MATERIALS

The gravels under Ralston Flat provide an excellent ground-water reservoir. These gravels are unconsolidated, and, although they have a matrix of finer material, they are permeable and permit a ready movement of ground water. A permanent ground-water body existed before irrigation under the lower or eastern part of this flat, where the water table ranged between 4 and 35 feet below the land surface. The lower 2.7 miles of the Alkali Creek drainage ditch, constructed during 1946 essentially along the course of Alkali Creek, penetrated this water body, and a flow of about 250 gpm was developed (pl. 4*A*). Within 20 days after construction this drain caused the water table to decline 0.42 foot in well 55–100–L53a, situated about 350 feet south of the drain. The only other hole, 55–100–18bb, that penetrated the water body was an abandoned seismograph shothole. The ground-water level at that location was 34.9 feet below the land surface on September 20, 1946. It is probable that the water table at that location also was lowered by flow to the new drainage ditch, although no depth-to-water measurements are known to have been made at this point before construction of the ditch. The water table under the Ralston Flat apparently has a lower gradient than the land surface, and thus it is farther below the land surface under the higher parts than under the lower parts of the flat.

The water body in the gravel deposits under the highest parts of the flat probably was thin or absent and wells ending in these deposits would have been unsuccessful if constructed before irrigation of the flat. One such hole in the SE¼NE¼ sec. 22, T. 55 N., R. 101 W., was dug to a depth of 70 or 80 feet about 1926 and passed through the gravel bed and into the underlying shale of the Wasatch formation. The gravel deposit was dry at that time, but a small amount of strongly mineralized water was obtained from the shale. In 1946, the well was open to a depth of 58 feet, but it contained no water at that depth.

The small area of the Ralston terrace between the forks of Eaglenest Creek is underlain by a gravel deposit as much as 30 feet thick. Before irrigation, a permanent ground-water body had not developed in this deposit, as the only recharge was from precipitation on it. Even this small amount of water drained away rapidly, for the gravel bed is exposed in valley walls on all sides down the dip.

About 270 acres of land, chiefly on the Ralston terrace in sec. 1, T. 54 N., R. 101 W., was irrigated under the auspices of the War Relocation Authority for several years before 1946. The canal lateral carrying water to this land is on the Ralston terrace south of Eaglenest Creek. Leakage from that lateral and surplus water from irrigation developed a ground-water body in the gravel bed underlying the area. The gravel bed is as much as 30 feet thick and is quite permeable. Springs have appeared along the base of the layer of gravel where it is exposed in the banks of Eaglenest Creek and in the banks or bottoms of the small tributary coulees. A coulee about 30 feet deep and less than half a mile long had a flow, at a point in the SE¼ sec. 36, T. 55 N., R. 101 W., in 1947 of 50 to 75 gpm, all derived from seepage from the irrigated fields.

Gravel deposits under other small remnants of the Ralston terrace farther south had little recharge, and, as they are exposed along the edges of the terrace, no water body had formed under them. In places where the Heart Mountain Canal crosses the higher bench remnants the canal bottom has been sealed with bentonite to reduce or prevent leakage.

The Powell terrace north of lower Eaglenest Creek is several square miles in extent and is underlain by gravel which, in places, is about 20 feet thick. As the Garland Canal and Ralston Reservoir border this area on the east, a ground-water body probably had developed under at least this part of the bench. White alkali "bloom" on the land surface before irrigation of the Heart Mountain Division indicates that the water table already was high under the central part of secs. 28 and 29, T. 55 N., R. 100 W. The presence of ground water at slight depth may have resulted from ponding of the ground water by construction work downstream, but it may have been caused in part by seepage from the escarpment which borders the bench on the north. The soil in which waterlogging occurs is fairly tight as a result of surface wash from the shales of the Wasatch formation exposed in the escarpment. The southern and western parts of this bench are probably without a permanent ground-water body. The gravel bed is exposed along the valley of Eaglenest Creek, and water reaching it is drained away rapidly.

A permanent ground-water body was present under the Powell terrace in secs. 5, 6, and 7, T. 54 N., R. 100 W. This water body feeds the spring that issues at the base of the escarpment near the center of sec. 5, on the Sam Lanchbury ranch. The spring was reported (1946) not to have gone dry during the past 50 years. Since irrigation was started (1942) on the Ralston terrace, more than a mile to the west, the flow from this spring is reported to have increased during the winter and early spring months, and several other springs have appeared along the edge of the escarpment and in shallow coulees cut into its edge. These indicate that some of the irrigation water applied to the fields moves downward and then horizontally through the underlying gravels to the edge of the Ralston terrace, whence it again moves downward into the gravels underlying the Powell terrace and horizontally under this bench to the point of issue at the lower edge of the Powell terrace. The lag of about 6 months between the time when the water is applied to the fields and the time when springs appear or increase in flow gives a rough indication that the effect of irrigation moves through these gravels at a rate of about 1 mile in 6 months. There is a decrease in altitude of about 200 feet in this instance.

Some lands were irrigated before 1946 along Buck Springs Creek where it crosses the Powell terrace near the abandoned campsite of the War Relocation Authority (sec. 12, T. 54 N., R. 101 W.), and the irrigation had resulted in the development of a ground-water body under a small area. Here, as of 1946, ground water was furnishing a flow of 50 to 75 gpm to a drainage ditch about 6 feet deep in the broad valley of Buck Springs Creek (sec. 13, T. 54 N., R. 101 W.).

No irrigating had been done, before 1946, on the Powell terrace between Buck Springs Creek and Cottonwood Creek. The terrace in this area is narrow and cut by steep-walled coulees. The only ground-water recharge was supplied by the scanty precipitation, and this water drained away quickly where the gravel is exposed at the edges of the escarpment or in the coulee walls. Therefore, no permanent water body had been formed under the area.

Parts of the Powell terrace north of Cottonwood Creek and between Cottonwood Creek and Trail Creek are crossed at their upper ends by the Heart Mountain Canal. A minor amount of water leaked from the canal and some small areas had been irrigated, so that a ground-water body of limited extent had developed before 1946. During 1946 water was seeping from the gravel bed that underlies the terrace at several places along the valley walls of the creeks. After some years of irrigation, the gypsum in the underlying bedrock south of Dry Creek may be partly dissolved and, thus, caverns may form, causing subsequent settling of surficial material and loss of large quantities of irrigation water.

No water-bearing gravels are in the ragged, eroded areas lying above the Powell terrace except where remnants of the Ralston terrace have been preserved. Some gravel bodies are present in the coulee bottoms, but generally they are the result of erosion and reworking of the bench gravels; also, they have a considerable admixture of finer grained materials derived from the erosion of shales and other rocks underlying the destroyed terraces. For this reason, wells constructed in the coulee bottoms are likely to have very small yields. Furthermore, there is considerable danger of waterlogging these lands if they are irrigated, unless adequate drains are constructed promptly. It may be advisable, in some places, to construct drains at the base of escarpments bounding irrigated tracts to capture seepage water and to prevent waterlogging of the bottom lands. The water could, of course, be re-used if it were of suitable quality.

Much of the Cody terrace north of the Shoshone River bridge (sec. 13, T. 53 N., R. 101 W.) has been irrigated since about 1942, and excellent ground-water bodies have been developed in the gravel under this terrace. Several good springs have appeared at the base of the gravel bed where it is exposed in the deep, narrow coulees or along the Shoshone River. During 1946, the springs maintained a flow of 75 to 100 gpm in the lower half mile of Buck Springs Creek. The mantle of fine-grained material on which the soil is developed is as much as 20 feet thick in places and is sufficiently permeable to allow water to reach the gravel bed, which is 2 to 16 feet thick. It is in the areas of the thickest soil mantle where the settling mentioned previously has taken place, and, in time, this may result in formation of a tight and easily waterlogged soil.

The narrow strips of the Cody terrace along the Shoshone River north of Cody had not been irrigated before 1947, and a ground-water body was not then present. The gravel bed underlying those strips of terrace is exposed in the walls of the Shoshone River gorge, and any moisture reaching the gravel rapidly drains away. The flat valley bottoms of Cottonwood, Trail, and Dry Creeks were underlain by permanent water bodies in 1946. The deposits in these bottoms are fairly tight, being derived mainly from erosion of fine-grained rocks bordering the streams; therefore, the yields of wells penetrating these deposits will be small.

The gravel underlying Chapman Bench is dry. In general, the soil mantle overlying the gravel bed is a fairly permeable gravelly loam, but the soil is tight along the forks of Little Sand Coulee where they cross the south end of the bench. After heavy rains, water from this coulee floods the bench, but little penetrates it to develop a permanent ground-water body. Along the west and north sides and much of the east side of the bench, the gravel bed is exposed in the banks of bordering streams and any water reaching it drains away rapidly.

PROBABLE FUTURE GROUND-WATER SITUATION

Except in a few places the soils on the terraces are permeable and water will move easily through them and into the underlying gravel. Thus, a ground-water body will begin to form when irrigation of the terraces underlain by gravel is started. Where a ground-water body existed before irrigation, the thickness of saturated materials will increase and the water table will rise. As the gravel lies on materials of low permability that impedes downward percolation, the water will be forced to move laterally and will form seeps and springs along the edges of the terraces where the gravel beds are exposed. As the gravel is permeable, the zone of saturation will be thin near the edge of each terrace, but wells constructed a few hundred feet from the edge of the terrace probably will find several feet of saturated gravel from which to draw water; farther back from the edge of the terrace thicker sections of saturated gravel will be found. Springs and small seeps will be numerous around the flanks of the terraces. Where these springs and seeps are sufficiently large, and if suitable sites underlain by impermeable materials also are present, small dams may be constructed to store water for stock use. Initially, the water from these springs and seeps likely will be too mineralized for re-use for irrigation.

The water obtained from wells will be considerably mineralized in some places during the first few years after irrigation is begun (see section on "Chemical quality of the water"). Several years may elapse before the water becomes fresh enough for domestic use in some areas relatively far from the edges of the more extensive terraces. The water from the wells always will be somewhat hard but otherwise will be of good quality after the more soluble salts have been leached out and carried away.

Irrigation ditches probably will carry water for about 6 months of each year. Leakage from them and seepage from the irrigated fields will result in an annual rise of the ground-water level. Water will continue to percolate downward through the soil mantle for a month or more, depending on the thickness and permeability of the soil, after seasonal irrigation is ended each year. Then the water table will decline; the decline will be most rapid under the smaller terrace remnants where the underlying gravel bed is exposed to the greatest degree.

Under terraces of this type, the water is expected to be drained away a few months after irrigation is ended, and wells will become essentially dry. The wells located on the lower slopes of such terraces probably will contain water longer than those higher on the terraces. Some small seeps and springs may continue to flow even though water cannot be obtained from wells. These seeps may be utilized for stock watering, but future farms located on terraces of this type likely will require cisterns or tanks to store domestic water for use in late winter and early spring.

The writer believes that a permanent ground-water body will be developed under each terrace remnant that is more than about 1 mile wide. Some wells on the higher slopes of such terraces probably will become dry early each spring, but those on the lower parts may be expected to continue to yield water throughout each year. The terrace surface approximately reflects the bedrock surface under the gravel bed, without the minor irregularities, and wells should be located with this fact in mind. Major springs and seeps around the edge of the terrace will indicate the important courses of ground-water flow and, roughly, the more favorable locations for wells.

Farms established on land other than on the terraces will be unfavorably situated to obtain adequate ground-water supplies. The lands that are not on the terraces are considerably more hilly and rolling that those on the terraces except for the lands in the broader stream valleys. Thus, farms established on other than the terraces probably will be located in the broader and more level stream valleys. The material in those stream valleys is fine grained and relatively impermeable and wells of large diameter will be required to obtain ample water. Water that moves slowly through the fine-grained material likely will be more highly mineralized than water obtained from the more permeable gravel beds.

Some downward percolation of water will occur when tracts underlain by the more permeable bedrock formations are irrigated, and in time these more permeable rocks will become saturated and a water table will be formed in them. Most of these rocks contain considerable amounts of soluble salts, and, until the salts are leached out, the water from them may be too mineralized for domestic use. If adequate drainage occurs, the water eventually may freshen, and dependable year-round supplies may become available by deeper drilling in the most favorable areas.

Much of the land proposed for development on this project is admirably suited for irrigation farming because of the underdrainage. It is expected, however, that serious waterlogging problems may develop in some places unless minimum quantities of water are used and artificial drains are constructed.

Those areas where the greatest danger of waterlogging appears to be are in the lower part of the Ralston Flat where the water table was close to the surface before irrigation was started. Underlying this large, continuous area is a great wedge of unconsolidated material of generally high permeability resting on the Wasatch formation which has relatively low permeability. This wedge decreases in thickness from more than 100 feet in secs. 21 and 22, T. 55 N., R. 101 W., to less than 4 feet near the Alkali Creek drain in secs. 15, 23, T. 55 N., R. 100 W., just above lateral A of the Powell Project. It is obvious that the thick section of unconsolidated material underlying the higher parts of the Ralston Flat can transmit much larger quantities of water than can the thin section underlying the lower part of Ralston Flat, even assuming the same permeability; moreover, the thicker section appears to be more permeable than the thinner. When water is delivered through the thick section of unconsolidated fill at a rate greater than the thinner section can transmit, the water table will be forced to the land surface. It is recommended that observation wells be drilled to the base of the gravel and that measurements of the water level be made periodically. In this way advance warning of waterlogging of the land may be had in time for drains to be correctly designed, located, and constructed. It is expected that, when irrigation is begun on the Ralston Flat, interception drains will be needed throughout the lower part of the flat.[1]

Some drainage problems probably will develop in the eastern part of the Powell terrace area north of Eaglenest Creek. The low area just west of the Garland Canal and the Ralston Reservoir had a shallow water table and alkali deposits before irrigation, and this condition will most likely spread westward. Other areas of potential waterlogging exist along the base of escarpments where springs may issue and in the flat, irrigated bottoms of small streams.

PRESETTLEMENT GROUND-WATER RECHARGE

The prospects for obtaining potable ground-water supplies for domestic and stock use will be improved if the main canal and some canal laterals constructed before settlement are utilized to begin the formation of a ground-water reservoir in the underlying gravel deposits. Water could be spread before settlement to aid in establishing and freshening the ground water so that supplies may be obtained as early after settlement as possible. Water percolating through the gravel deposits that underlie the terraces will remove objectionable soluble salts that have accumulated because of the arid climate. Water sample 54–100–5bc (see section on "Chemical quality of the water")

[1] Waterlogging occurred within 2 years after irrigation began.

indicates that, even after several years of leaching, the ground water still may be objectionably mineralized. As additional water is applied, the degree of mineralization will decrease and the water obtained from wells will become more usable for all purposes.

DETAILED SUGGESTIONS FOR OBTAINING GROUND-WATER SUPPLIES ON FARM UNITS

Water can be obtained on farm units 1–7 (pl. 7) by digging wells to the base of the gravel deposit that underlies those units. The depth of the wells probably will range from 20 to 40 feet and they should be carried to the dark-gray shale which underlies the gravel. Wells in units 1 and 2 should be located near the boundary between those units and should be as far down the slope from the Heart Mountain Canal as is practicable. A well in unit 5 should be near the west end of the unit to take advantage of water draining from under irrigated units 1 and 2. Wells in units 6 and 7 should be near the boundary between the units.

Units 8 and 9 are not favorably situated to obtain good ground-water supplies. The land is rough and only small areas are underlain by a good bed of gravel. The bottom of the valley of Cottonwood Creek, which flows between the units, is underlain by relatively impermeable fill. Large-diameter wells located on this valley bottom may provide ample supplies of water of fair to poor quality, and these wells are less likely to become dry than some wells on the bench above the valley bottom.

Units 10–12 are partly underlain by gravel but ground-water potentials are unfavorable. The hills to the west and north are composed of the Cody shale, and a considerable amount of fine-grained material from that formation is present in the soil. A well in unit 10 should be dug to the base of the gravel deposit near the south end of the unit to take advantage of the infiltration of water applied on this unit. The well probably will become dry in the spring, and cisterns or tanks should be provided for temporary storage of domestic water. Wells in units 11 and 12 should be located near the boundary between the units and should be dug to the base of the underlying layer of gravel.

Farm units 14–17 are rather rough and are not underlain by the gravel deposits found under the terraces. Units 13 and 14 are underlain by tight Cody shale and water probably cannot be obtained by drilling on those units. After several years of irrigation, dependable supplies of water might be obtained from wells drilled through the Mesaverde formation near the southeast end of unit 15 and near the southern end of the boundary between units 16 and 17. Obtaining a usable water supply by drilling on these tracts seems unlikely for at least several years after irrigation is begun. Some months after irrigation begins, small supplies of water of rather poor quality might be obtained from large-diameter wells dug in the lowest coulee bottoms on all five units.

Wells dug to the base of the gravel stratum in the eastern part of units 19 and 20 should produce water. Bedrock consisting of the Fort Union formation is near the surface in the western part of these units, and the water may sink to a depth too great to reach with a dug well. Wells drilled in these units and in the eastern part of unit 18 may obtain small to moderate supplies of somewhat mineralized water from the sandstones and conglomerates of the Fort Union formation.

Ample water supplies likely can be obtained from wells dug to the base of the gravel deposits under the terrace on which units 21 and 22 are located. However, a year-round supply of good water may not be available until a few years after irrigation is started and until the water has had an opportunity to become fresh. The water initially obtained will be mineralized and similar to the water in the V. F. Rotter well (53–101–T85a).

Units 23–31 and 33–36 have some land underlain by a layer of gravel which will yield adequate water to wells after irrigation is begun. Wells on these units should be located as far east as possible, except when this would place the well close to the edge of the bench. Wells on some of the higher units may not provide water in early spring, and cisterns or tanks should be provided to store domestic water for short periods.

Unit 32 is underlain by a thick soil and gravel deposit. A well dug through the gravel in the western half of the unit probably will provide an adequate supply of water.

The surface of farm units 37 and 38 is hilly and underlain by small remnants of the gravel of the Ralston terrace, but the deposits are not extensive enough to retain permanent bodies of ground water. The best opportunity to obtain ground water probably will be by digging large-diameter wells in the coulee bottoms, although the underlying materials are rather impermeable and the water supplies will be small. The quality of the water will be fair to poor.

Parts of units 39, 40, 41, 43, and 44 are underlain by gravel which will provide adequate water supplies to dug wells. A well in unit 39 should be dug as far east in the unit as practicable, but wells dug anywhere on the other units, except those located too close to the edge of the bench, should provide water. It should be possible to obtain water anywhere in unit 42.

Farm units 45–82 are at least partly located on one of the terraces underlain by gravel. Wells in units 45 and 46 should be as far east in the units as possible, and wells in all units should be located back from the edge of the bench. Units that are partly on one bench and partly on another will be insured a more permanent water supply if the wells are on the lower bench.

A well in unit 83 should be located on the bottom lands of Buck Springs Creek. The material underlying the bottom lands is not so permeable as the gravel under the benches, but an adequate supply can be expected in the southeastern part of the unit. This water probably will be of fair to poor quality, but it likely will be the best available.

Farm units 84–90 are on the lower or Cody terrace and are underlain by gravel. Wells on these units should be located as close as possible to the highway or western end of the units, because there will be ample recharge to the underlying gravel from irrigation on higher lands to the west and the water table will not be so effectively lowered by drainage to the gorge of the Shoshone River as in the eastern part of the units. Wells should be drilled to the base of the gravel deposit to insure a perennial water supply. Little information is available, but it seems doubtful that wells more than 80 feet deep will be required.

Farm units 91, 94, and 96–99 are on the Cody terrace near the base of the escarpment that rises to the higher Powell terrace. These units are underlain by gravel, and it will be possible to obtain a suitable domestic water supply by drilling to the base of the gravel. To obtain perennial water supplies, wells should be located as far as possible towards the eastern ends of these units. The depth of the wells will range from 40 to about 70 feet.

Farm units 92, 93, and 95 are on the Powell terrace and are underlain by gravel which will provide an ample domestic water supply. Wells should be drilled to the base of the gravel deposit. The well on unit 95 should be at the east end of the unit. The wells for units 92 and 93 should be located as far back from the edge of the escarpment as is practicable. Wells 50 to 75 feet deep will be required.

Farm unit 100 is on the Cody terrace and is underlain by gravel. The soil on the unit is fairly tight and contains considerable salt, but water obtained from gravel deposits underlying it should be acceptable for domestic and stock use. A well on unit 100 should be located toward the west end of the unit; it should be carried to the base of the gravel, and probably will need to be about 70 or 80 feet deep.

Farm unit 101 is on the Ralston terrace and is underlain by gravel. The gravel deposit is exposed in the valley walls of Eaglenest Creek, and water reaching it will drain rapidly towards the north from units 53 and 54. The well in unit 101 should be located as far as possible toward the southeastern part of the unit to take advantage of seepage into the gravels underlying the higher fields. The well will need to be about 50 feet deep.

Farm units 102–114 are on the Ralston terrace and are underlain by gravel which will provide ample supplies of domestic and stock water soon after irrigation is begun. The water may be expected to be hard and considerably mineralized. As irrigation is continued the quality of the water will improve but it always will be somewhat hard. To maintain a perennial water supply, wells on these units should be located as far as possible from the main canal supplying water to the units. Considerable leakage from the main ditch will occur and will provide recharge to the underlying gravel deposits which are virtually dry. Wells should be drilled to the base of the gravel. Their depths will range from about 35 feet on units 102–103 and 111–114 to about 80 or 90 feet on units 106 and 109.

Farm units 115–126 and 131–141 are on the Ralston terrace and are completely underlain by gravel which will provide ample water supplies within a year after irrigation is begun. Successful wells can be located anywhere within these units. The water will be rather highly mineralized during the first few years of irrigation but its quality will gradually improve. Wells should be drilled to the base of the gravel deposits, which are 20 to 70 feet thick. In general, the deepest wells will be required on units 119–122 and 136–139. As irrigation is continued, the water level will rise in the wells, and pump lifts of less than 50 feet can be expected after 1 or 2 years of irrigation, even in the deepest wells.

Farm units 127–130 and 142–146 are on the flanks of the Ralston terrace and are not underlain by gravel as thick or as continuous as in units previously discussed. However, ample water supplies likely can be obtained if wells are drilled to the base of the gravel deposits in locations as far as possible from the highest irrigation ditch serving these units. The depths of the wells will range from 15 to 25 feet, and some may become dry each spring before water is turned into the ditch.

Farm units 147–160 are on the Ralston terrace and are completely underlain by gravel which will provide ample water supplies within a year after irrigation is begun. Wells can be located anywhere within these units with a good chance for success. The water may be mineralized at first, but it can be expected to improve as irrigation is continued. Wells should be drilled to the base of the gravel deposits, and their depths will range from about 20 to about 60 feet. In general, the deepest holes will be required on units 150 and 154.

Units 161 and 162 are on the upper edge of the Ralston terrace, and the gravel under them is not so thick or so continuous as that under units to the north. Wells drilled to the base of the gravel, from 15 to 25 feet, can be expected to yield ample water supplies if they are located as far as possible toward the northeastern part of these units. The wells may become dry in late spring each year before water is turned into the irrigation ditch.

Farm units 163–178 are on the middle or Powell terrace and are in part underlain by gravel deposits which, although neither as thick nor as extensive as the gravel underlying the Ralston Flat, will provide an ample water supply in most places. Wells should be drilled to the base of the gravel, and their depths probably will range from 30 to 80 feet. They should not be drilled near the deep valley of Eaglenest Creek, as this valley has cut through the gravel and will drain the water away rapidly. The wells on units 163–166 and 168–170 should be located as far as possible toward the northern part of the units. Wells should not be placed close to the escarpment that rises to the higher terrace to the north, as fine-grained slope-wash material has been mixed with the gravel here, the aquifer is less permeable, and deeper drilling would be necessary. Uncontrolled ground-water seepage from the upper terrace should be given careful study, as that seepage will place several of the farm units toward the east in danger of waterlogging.

Farm units 179–186 are near the upper edge of the Ralston terrace and are not underlain by as thick or as extensive a gravel deposit as are units farther north. However, for most of the units this gravel deposit can provide an ample water supply if wells are drilled to the base of the deposit and as far as possible from the high ditch which irrigates the units. The only significant recharge to this gravel deposit will come from irrigation of the fields, and, as the bedrock beneath the area has a general slope toward the northeast, the wells on each unit should be located as far as possible in that direction. The depths of successful wells probably will range from 15 to 40 feet.

Farm units 188 and 189 are underlain by a relatively thin gravel deposit, but it can be expected to yield ample water supplies for domestic and farm use. The bed of gravel is practically absent near the Alkali Creek drain at the lower edge of unit 188, and for this reason a well on this unit should be constructed near its southwestern corner, where the gravel deposit can be expected to be about 25 feet thick.

Farm units 190 to 206 and 209 and 210 are underlain by a fairly thick layer of gravel which can be expected to provide ample water supplies for domestic and stock use. Wells should be drilled to the base of the gravel deposit, the depth of which will range from 20 to 40 feet. Wells can be drilled anywhere within these units with a good chance of success. Initially, the water will be somewhat mineralized, but it will improve in quality as irrigation is continued.

Farm units 207, 208, 211–213, 216, and 219–221 are on the flanks of the Ralston terrace and are not underlain by as thick or as extensive a gravel deposit as are the units to the west and south. In most areas ample ground-water supplies will be obtainable on each of these units soon after irrigation is begun, if the wells are drilled to the base of the gravel deposit and are properly located on the units. The wells should be drilled as far as possible below the high ditch, which provides water for the individual units. On unit 208 the best location would be in the southwestern corner, where the gravel deposit will furnish water that will percolate into it from irrigation on units 207 and 208. The well locations on the other units should be selected in a similar manner, remembering that the bedrock surface slopes to the south and west. The only water that will be available for effective recharge of the gravel deposit is that from seepage of irrigation water. This water will move down the slope of the bedrock, and wells should be located down the slope from the irrigated fields.

Farm units 209, 210, 214, 215, 217, and 218 are underlain by a layer of gravel which will provide ample domestic and stock-water supplies to wells drilled to bedrock. This gravel deposit is rather thin near the lower end of the Alkali Creek drain, but it can be expected to provide water to wells drilled anywhere within these units.

Whenever wells are drilled on the Heart Mountain Division, detailed drillers' logs should be filed with the U. S. Bureau of Reclamation; other pertinent information that also should be filed include the measured depth to water, date of measurement, statement on quality and quantity of water obtained, and other similar data. If possible, provision should be made in the pump installations to permit the periodic measurement of the depth to water in wells. This provision can consist of a hole drilled in the pump base and threaded for a ½-inch pipe plug, or a short length of pipe with screw cap imbedded in a concrete foundation, for insertion of a steel tape into the well. If the depth to water in wells is measured periodically, advance warning of waterlogging or other drainage problems, or of an impending lowering of the water table, will be available.

CHEMICAL QUALITY OF THE WATER

By Herbert A. Swenson

In 1946, before irrigation of land in the Heart Mountain Division, samples of water were collected from several sources to obtain general information as to its chemical character. These sources included wells, springs, and drains; samples were collected also from the Heart Mountain Canal and from a small spring-fed coulee. In 1950, ground-water samples were collected from representative wells that had been drilled since irrigation and settlement of the land. In addition, some sources sampled in 1946 were resampled in 1950 to observe any changes in quality of the water in the intervening period. Results of chemical analysis of all samples are shown in tables 2 and 3.

The data furnished a means of evaluating and predicting the quality of domestic water supplies available from wells and springs. In this region of deficient rainfall, ground water may contain soluble salts in objectionable concentrations. Water-quality criteria applicable to an urban supply would not be a practicable standard in determining the suitability of ground water in the Heart Mountain Division. For example, the U. S. Public Health Service (1946) recommends that total solids in drinking water should not exceed 1,000 ppm, and preferably not 500 ppm; however, of 11 ground-water samples analyzed, 9 contained more than 1,000 ppm of dissolved solids, and 5 contained more than 3,000 ppm. Although ground water in the project area is generally mineralized and hard, most supplies meet domestic needs and residents soon become accustomed to drinking concentrated water. After an extended period the chemical quality of the ground water should improve because of leaching of soluble salts from the water-bearing materials. The following discussion considers quality-of-water conditions in the Ralston, Powell, and Cody terraces and describes the chemical character of the irrigation water that is supplied to the project. The locations from which water samples were obtained are shown on plate 7.

Extremes in mineral content of ground water were observed in samples from six wells on the Ralston terrace. Well 55–101–16ca taps permeable gravel and yields water that contains 346 ppm of dissolved solids, the least mineralized ground water sampled in the area. The well is near the Heart Mountain Canal, and canal leakage probably recharges the underlying gravel. Water from this well is soft, contains excess iron, and is used for domestic purposes and stock watering. The water from well 54–101–2ad3, on the contrary, contains more than 6,000 ppm of dissolved solids and is extremely hard. This well, which is not used, draws water from saline deposits that are composed principally of sulfates of calcium, magnesium, and sodium. The well was drilled to 38 feet; however, at the time the well was measured and a water sample collected, the depth was 21.7 feet. Apparently the bottom of the hole was not cased, and gravel had slumped into the well. Well 55–100–L53a, a shallow well used for stock only, was sampled in 1946 and 1950. In the 4-year period the mineral content and hardness of the water increased by about 25 percent. Because of the increase in mineral content was due partly to higher concentrations of chloride and nitrate ions, it is thought that polluted surface inflow may be percolating into the aquifer. This well is located near large lambing sheds, and there have been large flocks of sheep in the area each spring. Well 54–101–3cb draws water from sandy gravel; the water is iron bearing, hard, and mineralized and serves domestic and stock uses. Water from well 55–100–

TABLE 2.—*Chemical analyses of ground and surface waters,*

[Analytical results in parts per

Location	Depth (feet)	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
53-101-1aa	101	Oct. 5, 1950	48	17	0.12	135	129	616	6.6
53-101-T85a	100	Sept. 20, 1946	-------	-------	.15	271	147	481	
53-101-T85a	100	Oct. 4, 1950	50	8.7	.35	325	160	408	9.6
54-100-5bc	Spring	Sept. 9, 1946	-------	-------	.10	49	44	462	
54-100-5bc	do	Oct. 5, 1950	50	7.0	.44	45	13	632	3.8
54-101-2ad3	38	do	-------	25	.38	350	676	452	8.4
54-101-3cb	34	do	-------	10	9.1	170	198	444	5.6
54-101-35da	96	Oct. 4, 1950	50	5.0	1.8	505	281	428	15
54-101-36ca	22.6	do	52	12	.37	240	130	212	5.0
55-100-18bb	77	Sept. 20, 1946	-------	-------	.05	32	18	108	
55-100-L53a	12.4	do	-------	-------	.02	41	59	250	
55-100-L53a	12.4	Oct. 5, 1950	-------	11	.16	56	74	281	15
55-101-12cb	147	do	49	22	.45	17	11	356	2.3
55-101-16ca	67	do	48	12	2.8	9	14	103	1.2
Heart Mountain Canal, center sec. 24, T. 53 N., R. 102 W.[1]	---------	Sept. 20, 1946	-------	-------	.05	16	5.5	6.5	
Buck Springs Creek drain, sec. 13, T. 54 N., R. 101 W.	---------	Sept. 9, 1946	-------	-------	.16	40	52	270	
Small spring-fed coulee, SE¼ sec. 36, T. 55 N., R. 101 W.	---------	do	-------	-------	.06	353	112	186	
Do	---------	Oct. 5, 1950	46	21	.10	90	66	314	2.4
Alkali Creek drain:									
Sta. 401 ±50, SW¼ lot 81, T. 55 N., R. 100 W.[2]	---------	Sept. 9, 1946	-------	-------	.10	34	35	78	
Farm unit 201, T. 55 N., R. 100 W.	---------	Oct. 5, 1950	48	12	.10	35	64	212	3.0
Sta. 485, NE corner lot 101, T. 55 N., R. 100 W.[3]	---------	Sept. 9, 1946	-------	-------	.10	55	54	312	
100 ft above lateral A of Powell project, south center lot 100, T. 55 N., R. 100 W.[4]	---------	do	-------	-------	.10	49	50	287	

[1] Sample originated 70 ft below surface of Shoshone Reservoir.
[2] Water level 11 ft below land surface.
[3] Water level 9 ft below land surface.
[4] Water level 7.7 ft below land surface.

18bb, which is an abandoned seismograph drill hole, is of good quality and is similar to water from well 55-101-16ca, except that it is harder and contains more sulfate and less iron. Well 55-101-12cb was drilled in 1950, and a sample of water collected in that year contained 1,150 ppm of dissolved solids, mostly sodium salts. The water is used for domestic and stock-watering purposes.

Springs in a small coulee south of Eaglenest Creek (SE¼ sec. 36, T. 55 N., R. 101 W.) result from infiltration of irrigation water. Water applied to fields and leaking from canals has developed a ground-water body in this area. Springs appear along exposures in banks of Eaglenest Creek and in small tributary coulees. Water from one coulee (SE¼ sec. 36, T. 55 N., R. 101 W.) was sampled in 1946 and again in 1950. The concentration of dissolved solids in

Heart Mountain Division, Shoshone irrigation project, Wyoming

million except as indicated]

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
248	0	1, 740	171	0. 9	10	0. 20	3, 120	2, 950	868	665	60	3, 720	7. 8
636	0	1, 530	89	. 9	107	-------	3, 250	--------	1, 280	759	45	--------	----
437	0	1, 700	59	1. 4	152	. 00	3, 350	3, 040	1, 470	1, 110	37	3, 560	7. 6
439	0	886	16	1. 0	. 0	-------	1, 630	--------	303	0	77	--------	----
100	0	1, 400	18	. 9	3. 3	. 20	2, 180	2, 170	142	60	91	2, 900	7. 4
196	0	4, 350	57	. 5	25	. 30	6, 360	6, 080	3, 660	3, 500	21	5, 830	7. 0
181	0	1, 890	81	1. 5	3. 8	. 30	3, 220	2, 900	1, 240	1, 090	44	3, 430	7. 3
40	0	2, 930	145	1. 3	32	. 30	4, 870	4, 360	2, 420	2, 390	28	4, 790	7. 2
167	0	1, 210	128	. 7	14	. 30	2, 020	2, 030	1, 140	1, 000	29	2, 530	7. 6
248	0	158	10	. 6	6. 7	-------	469	--------	154	0	60	--------	----
394	0	477	29	. 8	33	-------	1, 120	--------	345	22	61	--------	----
351	0	500	122	1. 0	119	. 00	1, 400	1, 220	442	154	57	1, 990	7. 3
252	0	478	104	1. 1	15	. 30	1, 150	1, 130	88	0	89	1, 700	7. 8
279	7	51	4. 0	1. 4	1. 6	. 20	346	--------	82	0	73	551	8. 3
62	0	23	1. 0	. 1	. 2	-------	113	--------	62	11	18	--------	----
140	9	712	20	. 7	1. 0	-------	1, 160	--------	314	184	65	--------	----
307	0	1, 220	158	. 5	1. 0	-------	2, 220	--------	1, 340	1, 090	23	--------	----
349	0	770	62	1. 2	11	. 30	1, 560	1, 510	496	210	58	2, 070	8. 0
132	4	260	8. 0	. 6	. 8	-------	494	--------	229	114	43	--------	----
296	11	490	38	1. 4	4. 6	. 10	1, 020	1. 020	350	89	57	1, 450	8. 2
364	7	671	18	. 7	3. 1	-------	1, 280	--------	359	49	65	--------	----
176	5	739	18	. 8	2. 8	-------	1, 220	--------	328	175	66	--------	----

1950 was about 30 percent less than the concentration in 1946, and the reduction in hardness was more than 60 percent. The change in concentration and properties in the 4-year period reflects the permeable character of the gravel bed and demonstrates effective, although slow, leaching as the water moves through the aquifer.

The Alkali Creek drain, roughly paralleling Alkali Creek which traverses the Ralston terrace, was sampled at 3 locations in 1946 and 1 location in 1950 [SW¼ lot 81 (Sta. 401±50); farm unit 201; NE corner lot 101 (Sta. 485); and south center lot 100; all in T. 55 N., R. 100 W.]. This drain, constructed in 1946, intercepts the water table, and the quality of the water approximates that in nearby wells. Well 55–100–L53a, for example, yields water that in 1946 contained 1,120 ppm of dissolved solids; in the same year drain water downstream (in lots 101 and 100, T. 55 N., R. 100 W.) contained 1,280 and 1,220 ppm, respectively.

TABLE 3.—*Chemical analyses, in equivalents per million, of ground and surface waters, Heart Mountain Division, Shoshone irrigation project, Wyoming*

Location	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)
53-101-1aa	Oct. 5, 1950	6.74	10.62	26.79	0.17	4.06	0.00	36.23	4.82	0.05	0.16
53-101-T85a	Sept. 20, 1946	13.52	12.09	20.91		10.42	.00	31.81	2.51	.05	1.73
53-101-T85a	Oct. 4, 1950	16.22	13.18	17.74	.25	7.16	.00	35.39	1.66	.07	2.45
54-100-5bc	Sept. 9, 1946	2.44	3.62	20.08		7.19	.00	18.45	.45	.05	.00
54-100-5bc	Oct. 5, 1950	2.25	.59	27.48	.10	1.64	.00	29.15	.51	.05	.05
54-101-2ad3	do	17.47	55.63	19.65	.21	3.21	.00	90.56	1.61	.03	.41
54-101-3cb	do	8.48	16.32	19.30	.14	2.97	.00	39.35	2.28	.08	.06
54-101-35da	Oct. 4, 1950	25.20	23.10	18.61	.38	.66	.00	61.00	4.09	.07	.52
54-101-36ca	do	11.98	10.72	9.22	.13	2.74	.00	25.19	3.61	.04	.23
55-100-18bb	Sept. 20, 1946	1.60	1.48	4.70		4.07	.00	3.29	.28	.03	.11
55-100-L53a	do	2.05	4.85	10.88		6.46	.00	9.93	.82	.04	.53
55-100-L53a	Oct. 5, 1950	2.79	6.05	12.22	.38	5.75	.00	10.41	3.44	.05	1.92
55-101-12cb	do	.85	.91	15.48	.06	4.13	.00	9.95	2.93	.06	.24
55-101-16ca	do	.45	1.19	4.49	.03	4.57	.23	1.06	.11	.07	.03
Heart Mountain Canal, center sec. 24, T. 53 N., R. 102 W	Sept. 20, 1946	.80	.45	.28		1.02	.00	.48	.03	.00	.00
Buck Springs Creek drain, sec. 13, T. 54 N., R. 101 W	Sept. 9, 1946	2.00	4.28	11.76		2.29	.30	14.83	.56	.04	.02
Small spring-fed coulee, SE¼ sec. 36, T. 55 N., R. 101 W	do	17.62	9.21	8.08		5.03	.00	25.38	4.46	.03	.01
Do	Oct. 5, 1950	4.49	5.43	13.65	.06	5.72	.00	16.03	1.75	.06	.19
Alkali Creek drain:											
Sta. 401±50, SW¼ lot 81, T. 55 N., R. 100 W	Sept. 9, 1946	1.70	2.88	3.40		2.16	.13	5.42	.23	.03	.01
Farm unit 201, T. 55 N., R. 100 W	Oct. 5, 1950	1.75	5.25	9.22	.08	4.85	.37	10.20	1.07	.07	.08
Sta. 485, NE corner lot 101, T. 55 N., R. 100 W	Sept. 9, 1946	2.75	4.44	13.57		5.96	.23	13.97	.51	.04	.05
100 ft above lateral A of Powell project, south center lot 100, T. 55 N., R. 100 W	do	2.45	4.11	12.47		2.88	.16	15.39	.51	.04	.05

Eaglenest ranch spring (54–100–5bc), issuing at the base of the escarpment near the center of sec. 5, T. 54 N., R. 100 W., on the Powell terrace, was sampled in 1946 and again in 1950. In 1950 the concentration of dissolved solids had increased by about one-third. The flow of this spring has increased since the beginning of irrigation, and the higher concentration in 1950 may have been the result of salt-laden drainage from irrigated land. The spring has been a source of domestic supply for many years. Well 54–101–35da, drilled in 1947, yields a very hard, saline water of the sulfate type that contains troublesome concentrations of iron. The water is used for domestic and stock-watering purposes. Buck Springs Creek drain (sec. 13, T. 54 N., R. 101 W.) was sampled in 1946, and the water contained 1,160 ppm of dissolved solids. The flow into this drain is the result of irrigation of lands along Buck Springs Creek.

Well 53–101–1aa on the Cody terrace yields a hard, mineralized water that serves as a domestic and stock supply. The well ends in 26 feet of blue shale, and movement of water through this material is limited. Well 54–101–36ca, tapping sand and gravel, yields a less concentrated water which also serves as a domestic and stock supply.

Well 53–101–T85a, located about 5 miles northeast of Cody near the contact of the Wasatch and Fort Union formations, yields a hard, mineralized water. The water was sampled in 1946 and again in 1950, and the mineral content in 1950 (3,350 ppm) was about 3 percent higher than that in 1946. The well probably draws water from the Fort Union formation. In 1950 the water contained 152 ppm of nitrate, a concentration considered to be excessive in water used for domestic purposes. The well is located in a barnyard, which is a likely source of the nitrate.

Irrigation water transported in the Heart Mountain Canal and applied to project lands is of excellent quality. A sample collected near the center of sec. 24, T. 53 N., R. 102 W., representing water drawn from 70 feet below the surface of the Shoshone (Buffalo Bill) Reservoir, contained 113 ppm of dissolved solids and had a hardness of 62 ppm. This water has about one-third the mineral content of the least concentrated ground water that was sampled in the area.

Examination of the chemical analyses in table 2 makes clear that an increase in dissolved solids is associated primarily with increases in calcium, magnesium, and sulfate concentrations. Figure 2 also shows that an increase in total concentration of water from wells and springs is accompanied by a proportionate increase in sulfate, calcium, and magnesium ions. Concentrations of sodium and potassium, on the other hand, show little relationship to increase in total concentration.

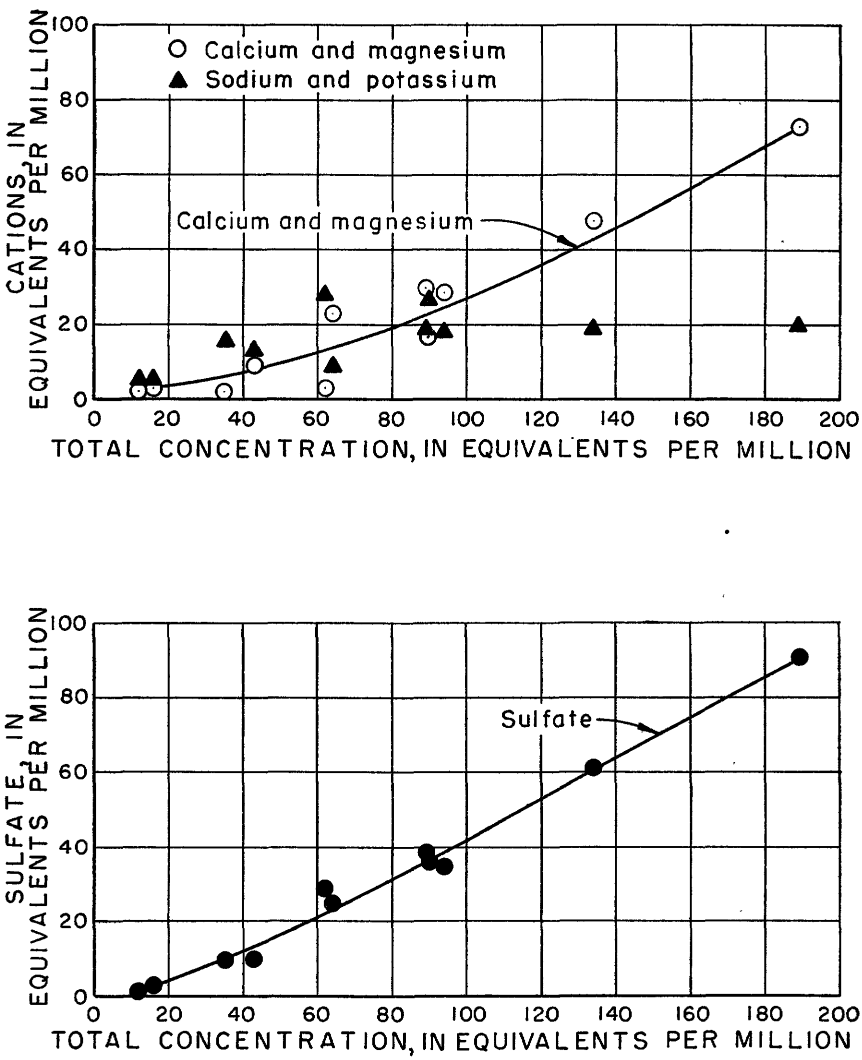

FIGURE 2.—Relation of principal constituents of ground water to total concentration, Heart Mountain Division, Shoshone irrigation project, Wyoming.

Ground-water supplies available in the Heart Mountain Division are, with few exceptions, hard and strongly mineralized. Some supplies contain iron or nitrate in objectionable amounts. It is reasonable to assume that the ground water in favorably located wells in gravel will improve in chemical quality in less time than will supplies pumped from fine-grained shale or clay deposits. Over a period of years, the water-bearing materials will have been leached of much of their soluble solids, and water available for pumping should become less concentrated.

SUMMARY

Much of the land to be irrigated in the Heart Mountain Division of the Shoshone irrigation project is underlain by sand and gravel terrace deposits. Three prominent terrace levels are recognized and have been mapped. The geomorphic history of the area has been worked out as it has a definite bearing on the ground-water hydrology of the area.

The water that is to be used for irrigation is diverted from the Shoshone River and it is of excellent quality. Before irrigation began the unconsolidated surficial deposits were dry except under the more extensive terraces. Bedrock aquifers contained limited amounts of strongly mineralized water.

After irrigation is practiced for some time a shallow ground-water reservoir will form in the sand and gravel terrace deposits. This water may be utilized by the ranchers, who are expected to settle on the irrigation units, for domestic and stock needs. During the first few years after irrigation is begun, the water obtained from wells constructed in the terrace deposits may be rather highly mineralized. Where there is good circulation of the ground water, the chemical quality of the water will improve most rapidly.

INVENTORY OF WELLS DRILLED AFTER IRRIGATION WAS BEGUN

To obtain supplemental data and to check previous estimates, a field inventory of the water wells that had been drilled by the settlers on the Heart Mountain Division was made during the fall of 1950 and spring of 1951. During the course of this field work, 133 water wells were located (table 4) and all available pertinent data about them, including drillers' logs for 97 wells (p. 42), were recorded. Before then, many shotholes had been drilled in the area during geophysical prospecting by oil-development companies. The logs of many of the shotholes were made available for study. These supplemental data proved to be mainly confirmatory of the estimates and conclusions initially made in the preliminary report.

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BASIC DATA

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming

53-101-1aa. Art Winther, farm unit 88

	Thickness (feet)	Depth (feet)
Clay	2	2
Gravel	33	35
Cement rock	5	40
Sand and gravel	11	51
Shale, blue	2	53
Sandstone	21	74
Shale, blue	26	100

53-101-1ac. Beldon Reynolds, farm unit 87

	Thickness (feet)	Depth (feet)
Soil	2	2
Gravel	38	40
Sand	8	48
Clay	7	55
Shale	20	75
Sandstone, gray	25	100

53-101-2bd. Philip R. Bare, farm unit 26

	Thickness (feet)	Depth (feet)
Soil	45	45
Gravel, loose, and cobbles	2	47
Cement rock	2	49
Sand and fine gravel	16	65

53-101-9ca. H. N. Talbott, farm unit 17

	Thickness (feet)	Depth (feet)
Topsoil	10	10
Gravel and sand	38	48

53-101-11ba. E. F. Zenoniani, farm unit 23

	Thickness (feet)	Depth (feet)
Clay and gravel	50	50
Gravel, cemented	7	57
Clay and shells	18	75
Sandstone	5	80
Sand, gray (water)	25	105

53-101-12ab. Wm. A. Cannon, farm unit 84

	Thickness (feet)	Depth (feet)
Topsoil	5	5
Sand and gravel	48	53
Sandstone	10	63

53-101-12cd. Cyrus Robertson, farm unit 22

	Thickness (feet)	Depth (feet)
Gravel and sandy soil	5	5
Gravel	55	60
Gravel, cemented	3	63
Gravel	12	75
Clay	5	80
Shale	50	130

53-101-19ca. Kenneth E. Stapp, farm unit 5

	Thickness (feet)	Depth (feet)
Soil and rocks	20	20
Gravel, cemented	3	23
Gravel, coarse	6	29
Gravel, fine, and sand	16	45
Shale	1	46

53-101-19cd. Wayne L. Smith, farm unit 6

	Thickness (feet)	Depth (feet)
Soil	30	30
Cement rock	3	33
Gravel and sand	13	46
Shale	1	47

53-101-21ac. Wm. Ross, farm unit 11

	Thickness (feet)	Depth (feet)
Soil	18	18
Gravel, cemented	24	42
Shale, blue	18	60
Shale, brown	5	65
Shale, blue	20	85

53-101-21cc. Husky Oil Co.

	Thickness (feet)	Depth (feet)
Frontier formation	440	440
Mowry formation	360	800
Thermopolis shale	330	1, 130
Muddy sand	60	1, 190
Skull Creek shale	130	1, 320
Dakota sandstone	165	1, 485

53-101-21db. C. A. Long, farm unit 12

	Thickness (feet)	Depth (feet)
Topsoil, gravel, cemented gravel	51	51
Shale	6	57

53-101-3bd. Clarence C. Schoonover, farm unit 224

	Thickness (feet)	Depth (feet)
Soil and gravel	26	26
Clay, blue	42	68

53-101-T54a. Ray R. Rivinoja, farm unit 85

	Thickness (feet)	Depth (feet)
Clay soil	5	5
Gravel	33	38
Cement rock	10	45
Gravel	13	58
Clay	7	65
Sand and fine gravel	20	85

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

	Thickness (feet)	Depth (feet)
53-101-T54b. Mearl Pearte, farm unit 86		
Soil	8	8
Gravel	27	35
Gray clay	10	45
Gray sandstone	20	65
Sand, salt-and-pepper	20	85
53-101-T61b. Wm. N. Wibel, farm unit 222		
Soil and gravel	15	15
Cody shale	112	127
(Sandy stringers at 45 and 113 feet)		
53-101-T85a. V. F. Rotter		
Soil, sandy, and pebbles	29	29
Gravel	21	50
Pebbles, cemented	2	52
Sand and gravel	23	75
Sandstone	25	100
53-102-13da. J. W. Walters, farm unit 3		
Soil and gravel	20	20
Shale	105	125
53-102-24da. Alex Brug, farm unit 2		
Soil and gravel	35	35
Gravel, cemented	3	38
Gravel, fine, and sand	12	50
53-102-24dc. Herbert Grund, farm unit 1		
Soil	25	25
Gravel, cemented	2	27
Gravel, coarse	10	37
Gravel, fine, and sand	14	51
54-100-6ca1. Orville C. Mocabee, farm unit 65		
Sandy loam	4	4
Gravel	43	47
Clay, brown	6	53
Clay, blue	20	73
Gravel	7	80
Sand, fine, and gravel	15	95
54-100-6ca2. Chas. C. Robinson, farm unit 67		
Soil and sand	40	40
Gravel	5	45
Clay, gray	20	65
Gravel, fine, and sand	30	95
54-100-6cb. Alvin Huggins, farm unit 62		
Sand and gravel	75	75
Gravel	7	82
54-100-7bb. Howard Wade, farm unit 61		
Sand and gravel	45	45
Sandstone	7	52
Sand and gravel	23	75
54-100-19bb. W. Thompson, farm unit 77		
Gravel and sand	68	68
54-100-19bc. Arthur Oster, farm unit 76		
Soil	25	25
Sand	3	28
Gravel	47	75
Sand	9	84
Gravel	46	130
Shale	1	131
54-100-19bd. Kenneth H. Calver, farm unit 74		
Sand and gravel	55	55
Boulders	15	70
Sandstone	15	85
54-100-31bb. H. E. Rauchfuss, farm unit 90		
Sand, dirty	12	12
Gravel and sand	26	38
Clay	5	43
Shale, blue	15	58
Shale, cinnamon	6	64
Shale, blue	14	78
Sandstone	5	83
Shale	7	90

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

54-100-L46a. L. H. Brand, farm unit 68

	Thickness (feet)	Depth (feet)
Sandy soil and gravel	40	40
Gravel	5	45
Clay, blue	10	55
Sandstone	10	65
Sandstone, salt-and-pepper	18	83

54-100-L46b. James L. White, farm unit 69

	Thickness (feet)	Depth (feet)
Sand and gravel	51	51
Sandstone	23	74
Shale, cinnamon	15	89
Shale, blue	13	102
Sandstone	2	104
Shale, blue	20	124
Shale, sandy	11	135

54-100-L55a. Lymen Hopkins, farm unit 66

	Thickness (feet)	Depth (feet)
Soil, sandy	35	35
Clay, yellow	5	40
Sand and gravel	5	45

54-101-1ac1. C. A. Rogers, farm unit 58

	Thickness (feet)	Depth (feet)
Sand and gravel	10	10
Clay, yellow; sand and gravel	26	36

54-101-1ac2. R. A. Griswald, farm unit 63

	Thickness (feet)	Depth (feet)
Lime, sand, and conglomerate	26	26
Sand, loose	1	27

54-101-1bc. Milton L. Patterson, farm unit 59

	Thickness (feet)	Depth (feet)
Gravel and sand	15	15
Clay, brown	50	65
Clay, gray	30	95
Sand, gray	15	110
Sand, fine, gray	25	135

54-101-2ad1. Chas. L. Bovee, farm unit 55

	Thickness (feet)	Depth (feet)
Loam, sandy	25	25
Clay	10	35
Gravel	5	40
Sand	9	49

54-101-2ad2. Wesley Hedrick, farm unit 54

	Thickness (feet)	Depth (feet)
Lime and soil	10	10
Sand and sandy shells	45	55
Sand (water)	7	62
Clay, yellow	1	63

54-101-2ad3. Wesley Hedrick, farm unit 54

	Thickness (feet)	Depth (feet)
Lime and gravel	38	38

54-101-2bc. Chester A. Blackburn, farm unit 50

	Thickness (feet)	Depth (feet)
Sand and gravel	32	32
Sandstone	43	75

54-101-2bd. Jack H. Butcher, farm unit 53

	Thickness (feet)	Depth (feet)
Sand	8	8
Conglomerate, limy	23	31
Sand	9	40

54-101-3cb. Paul Scheuneman, farm unit 48

	Thickness (feet)	Depth (feet)
Gravel, sandy	34	34

54-101-13db. M. F. Lewis, farm unit 79

	Thickness (feet)	Depth (feet)
Soil	10	10
Gravel	40	50
Cement rock	10	60
Sand, black	15	75

54-101-22dc1. D. Botts, farm unit 38

	Thickness (feet)	Depth (feet)
Soil	4	4
Sand and gravel	17	21
Clay, sandy	8	29
Sandstone	53	82
Shale, blue	2	84

54-101-23ca. R. W. Jolovich, farm unit 39

	Thickness (feet)	Depth (feet)
Soil	10	10
Soil and gravel	40	50
Clay, sandy, yellow	25	75
Clay, yellow	20	95
Clay, blue	15	110
Sandstone, gray	5	115
Sand, salt-and-pepper	16	131

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

54-101-24ab. Fred N. Giles, farm unit 81

	Thickness (feet)	Depth (feet)
Gravel and sand	80	80
Sandstone	12	92
Sandstone, gray, soft	26	118
Shale, gray	1	119

54-101-24bc. T. J. Shipley, farm unit 44

	Thickness (feet)	Depth (feet)
Gravel, sandy	35	35
Gravel	7	42
Clay, sandy	33	75
Clay	20	95
Cement rock	10	105
Sand, gray (water)	30	135

54-101-25bb. Ray Bjornestad, farm unit 35

	Thickness (feet)	Depth (feet)
Soil	2	2
Gravel	113	115
Gravel, fine	6	121

54-101-35ad. Dean R. Baker, farm unit 29

	Thickness (feet)	Depth (feet)
Soil, sandy	45	45
Gravel, river	15	60
Cement rock	15	75
Sand and fine gravel	20	95
Clay, gray, and shale	5	100

54-101-35da. Dale R. Good, farm unit 27

	Thickness (feet)	Depth (feet)
Soil and fine gravel	30	30
Gravel	15	45
Gravel, cemented	20	65
Gravel	29	94
Shale	2	96

54-101-35dd. Ralph Calvert, farm unit 95

	Thickness (feet)	Depth (feet)
Soil	20	20
Gravel	7	27
Gravel, cemented	12	39
Gravel	6	45
Gravel, fine	10	55
Sand	20	75

54-101-36bb. Clarence R. Buchholtz, farm unit 93

	Thickness (feet)	Depth (feet)
Soil	25	25
Gravel	25	50
Clay, gray	25	75
Sandstone	5	80
Sandstone, gray	37	117

54-101-36ca. Lee B. O'Gorman, farm unit 91

	Thickness (feet)	Depth (feet)
Soil, sand, and gravel	25	25

54-101-36dd. Forrest R. Allen, farm unit 89

	Thickness (feet)	Depth (feet)
Soil, sand, and gravel	38	38
Clay	4	42
Sandstone	24	66
Shale, blue	9	75

55-100-7ba. Daro E. Larson, farm unit 211

	Thickness (feet)	Depth (feet)
Gravel and yellow clay	8	8
Gravel	22	30
Shale, red, green, brown	35	65
Sandstone, gray	68	133

55-100-8ba. D. L. Holcroft, farm unit 212

	Thickness (feet)	Depth (feet)
Soil	3	3
Gravel and soil	4	7
Sandrock, soft	8	15
Clay	24	39
Sandstone	47	86

55-100-8bb. D. L. Holcroft, farm unit 212

	Thickness (feet)	Depth (feet)
Soil	2	2
Soil and gravel	8	10
Clay, sandy, yellow	20	30
Clay, yellow	35	65
Clay, blue	10	75
Sandstone, gray	5	80
Sand, salt-and-pepper	15	95

55-100-16ca. Harry T. Cullen, farm unit 214

	Thickness (feet)	Depth (feet)
Soil	3	3
Gravel and sand (water)	18	21
Clay, yellow	25	46
Sandstone, gray (water)	23	69
Shale, blue	1	70

55-100-L37a. Wm. M. Brown, farm unit 166

	Thickness (feet)	Depth (feet)
Sand and gravel	22	22
Clay	21	43
Sandstone, yellow	23	66
Sandstone, gray	8	74
Shale, blue	4	78

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

	Thickness (feet)	Depth (feet)
55-100-L37c. A. L. Howard, farm unit 176		
Sand and gravel	26	26
Shale, red and pink	34	60
Sandstone, gray	10	70
Sand (water)	23	93
55-100-L38b. J. H. Bodle, farm unit 174		
Soil and gravel	14	14
Clay	25	39
Shale, sandy	23	62
Sandstone	9	71
Shale, sandy	15	86
Sandstone, gray	19	105
55-100-L42a. Joseph A. Koch, farm unit 184		
Soil and gravel	24	24
Clay	15	39
Sandstone	48	87
Shale, blue	2	89
Sandstone	7	96
55-100-L43a. William O. White, farm unit 186		
Soil	2	2
Gravel	10	12
Sand	6	18
Clay	18	36
Shale, sandy, gray	36	78
Clay, red	35	113
Shale, gray	23	136
Shale, brown	2	138
Shale, gray	6	144
Shale, sandy	8	152
Shale, blue	1	153
55-100-L44a		
Rock and sand	25	25
Clay	25	50
Shale	75	125
Sandstone	25	150
55-100-L53d. Albert Kamm, farm unit 192		
Soil and gravel	12	12
Sandstone, soft	15	27
Sandstone, brown	43	70
Sandstone, gray	18	88
Shale, blue	3	91
55-100-L53e. Harvey J. Adams, farm unit 197		
Soil	15	15
Gravel, fine (water)	10	25
Clay	5	30
Gravel (water)	5	35
Clay	15	50
Gravel (water)	5	55
Shale, blue	15	70
Clay, yellow	15	85
Clay, red	10	95
Sandstone	5	100
Shale, blue	30	130
55-100-L71a. C. S. Randolph, farm unit 198		
Soil, sandy	20	20
Gravel, fine	10	30
Clay, yellow	5	35
Clay, blue	5	40
Sandstone, gray	23	63
Clay, blue	7	70
55-100-L81a. Buskart		
Soil	3	3
Gravel	34	37
Sandstone, soft	9	46
Shale, blue	23	69
Sandstone, gray	13	82
Shale, blue	16	98
55-100-L81b. Buskart		
Soil	3	3
Gravel	15	18
Sandstone	14	32
Clay	9	41
55-100-L82a. H. H. Robinson, farm unit 207		
Soil and gravel	21	21
Clay	37	58
Clay, yellow and red	3	61
Shale, cinnamon	7	68
Shale, blue	21	89
Shale, sandy	45	134
Sandrock, gray	10	144
Shale, blue	11	155
55-100-L82b. Carl C. Hill, farm unit 208		
Soil and gravel	21	21
Sandstone, soft	26	47
Shale, blue	42	89
Shale, sandy	5	94
Shale, blue	14	108

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

	Thickness (feet)	Depth (feet)
55-100-L84a. M. O. Fielding, farm unit 210		
Soil, sandy, yellow	40	40
Sand shells	10	50
Shale, brown, blue, gray	68	118
Sandstone	17	135
55-100-L94a. L. H. Snider, farm unit 196		
Soil, gravel, and sand	20	20
Clay, yellow	25	45
Clay, gray	10	55
Sandstone	20	75
55-101-9bd. Homer A. Winn, farm unit 111		
Sand and gravel	25	25
Clay	10	35
Sand (water)	15	50
Shale	130	180
Sandstone	6	186
55-101-9cd. Loran G. Otto, farm unit 108		
Soil	2	2
Soil and gravel	13	15
Gravel, coarse	2	17
Clay	30	47
Clay and sand	13	60
Sandstone	26	86
Sand	10	96
55-101-9dc. Robt. F. Van Dyke, farm unit 109		
Soil	2	2
Soil, limy	13	15
Gravel, fine	5	20
Clay	27	47
Sand and clay	13	60
Sand, hard (water)	20	80
Shale	15	95
55-101-10cc. L. F. Fulton, farm unit 116		
Soil	5	5
Gravel	21	26
Sand and clay	32	58
Sandstone	7	65
Clay, yellow	5	70
55-101-13cc. Robt. J. Jirsa, farm unit 152		
Soil	2	2
Gravel and soil	38	40
Clay, yellow, and gravel	20	60
Sand, yellow, and fine gravel	50	110
55-101-13dc. Harold F. McHose, farm unit 154		
Soil	2	2
Soil and gravel	38	40
Gravel, fine	50	90
Gravel, brown, and fine sand	10	100
Sandstone, gray	30	130
Sand, shale, and clay	85	215
55-101-14cb. O. C. Anderson, farm unit 138		
Soil	2	2
Gravel and soil	43	45
Gravel and sand	30	75
Sand, fine	5	80
Clay, yellow	10	90
Sandstone	5	95
Sand, gray	15	110
55-101-14da. Lyle Baker, farm unit 139		
Gravel and soil	40	40
Gravel and clay	35	75
Sandstone	16	91
55-101-14dc. C. C. Musser, farm unit 136		
Soil and gravel	40	40
Clay, yellow	30	70
Clay, sandy, yellow	15	85
Sandstone, yellow	10	95
Sand, yellow	25	120
55-101-15cc. H. Beslanowitch, farm unit 121		
Soil and gravel	40	40
Clay, yellow	40	80
Clay, gray	10	90
(Not reported)	5	95
Sandstone, salt-and-pepper	8	103
Sandstone	24	127

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

	Thickness (feet)	Depth (feet)
55-101-15dc. E. L. Thawley, farm unit 122		
Soil	2	2
Gravel and soil	38	40
Gravel and clay	35	75
Clay, yellow	35	110
Sandstone	10	120
Sand, salt-and-pepper	10	130
55-101-16ca. R. A. Ransier, farm unit 107		
Gravel	60	60
Cobbles, limestone	3	63
Sand and gravel	4	67
55-101-21aa. Lawrence L. French, farm unit 104		
Soil	2	2
Gravel and soil	43	45
Clay, yellow, and gravel	35	80
Sand, brown, and fine gravel	20	100
Sandstone, yellow	33	133
Sand, yellow, and fine gravel	7	140
55-101-21da. V. W. Olson, farm unit 103		
Gravel, limestone	40	40
Gravel	25	65
Clay	5	70
Sandstone	15	85
55-101-22ad2. Ben F. Krause, farm unit 126		
Soil	2	2
Soil and gravel	38	40
Clay, yellow	30	70
Clay, blue	25	95
Clay, sandy	7	102
Sandstone, gray	18	120
Sand, salt-and-pepper	30	150
55-101-22cc. Geo. A. Long, farm unit 102		
Soil	2	2
Gravel, limestone	33	35
Clay	10	45
Gravel	10	55
Sandstone, yellow	45	100
55-101-22dc. Jay L. Kirby, farm unit 127		
Sand and gravel	91	91
Clay	30	121
Shale	44	165
Shale, brown	12	177
55-101-23aa. Earl B. Wilson, farm unit 135		
Soil and gravel	40	40
Clay and gravel	30	70
Clay, blue	10	80
Clay, red	5	85
Clay, blue	10	95
Sandstone	20	115
Sand, salt-and-pepper	25	140
55-101-24cb. H. L. Bright, farm unit 157		
Soil	2	2
Soil and gravel	28	30
Clay, yellow	43	73
Sandstone, gray	20	93
Sand, salt-and-pepper	15	108
55-101-24cd. Paul H. Ethridge, farm unit 159		
Soil, sandy, gray	10	10
Clay	6	16
Sandstone	39	55
Clay	25	80
Shale, sandy	8	88
Shale, blue	70	158
Shale, cinnamon	15	173
Shale, sandy	12	185
Sandrock (water)	25	210
55-101-25ba. Wm. H. Cook, farm unit 161		
Soil, sandy, gray	24	24
Clay	11	35
Sandstone, soft	15	50
Sandstone, hard	16	66
Shale, sandy	20	86
Sandstone	20	106
Sandstone, brown	13	119
Shale, sandy	7	126
Shale, blue	20	146
Sandstone, gray (water)	9	155
Shale, blue	9	164

Drillers' logs of water wells, Heart Mountain Division, Shoshone irrigation project, Wyoming—Continued

	Thickness (feet)	Depth (feet)
55-101-25da. Vincent J. Spiering, farm unit 162		
Soil and gravel	40	40
Clay, sandy	40	80
Clay, gray	15	95
Shale	8	103
Sandstone, gray	7	110
Sandstone	25	135
Clay, blue	10	145
Sandstone	10	155
Sand, salt-and-pepper	20	175
55-101-26aa. Albert F. Gay, farm unit 130		
Soil and gravel	22	22
Clay	5	27
Sandstone	41	68
Shale, blue	3	71
Sand, gray	17	88
Shale	14	102
Sandstone	3	105
Shale, blue	3	108
Sandstone	4	112
Shale, blue	3	115
Sandstone, hard, gray (water)	77	192
55-101-26da. L. P. Allshouse, farm unit 129		
Sand, fine, and gravel	35	35
Sandrock	165	200
Shale, gray	50	250
Sand (water)	30	280
55-101-36cc2. Sterling P. Johnson, farm unit 56		
Conglomerate, limy, and soil	9	9
Sand and gravel	41	50
Clay, yellow	1	51
55-101-36dd. W. J. Slusser, farm unit 64		
Soil	1	1
Gravel and soil	34	35
Clay, yellow	30	65
Quicksand	25	90
Clay, blue	7	97

Table 4.—*Record of wells in the Heart Mountain Division, Shoshone irrigation project, Wyoming*

Well no.: See text description of well-numbering system, p. 3.
Farm unit no.: The number assigned to individual farm units where the area was subdivided into homesteads by the U. S. Bureau of Reclamation.
Type of well: Dr, drilled; B, bored; D, dug.
Depth of well: Measured depths in feet and tenths; reported depths in feet.
Type of casing: P, steel pipe; T, tile; G, galvanized iron; W, wooden; N, none.
Method of lift: Cy, cylinder pump; J, jet pump; H, hand operated; E, electrically operated; F, natural flow, reported gallons a minute; W, windmill; G, gasoline engine; N, none; P, pitcher pump; S, submerged pump.
Use of water: D, domestic, In, industrial; S, stock; N, none.
Measuring point description: Tca, top of casing, a minus sign indicates below land surface; Ls, land surface; Bp, base of pump; Hc, hole in casing; Tp, top of platform.
Depth to water below measuring point: Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

Well no.	Owner or tenant	Farm unit no.	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Elevation above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement
53-101- 1aa	Art Winther	88	1947	Dr	101	8	P	Cy, H	D, S	Tca	0.6	4,722.8	22.45	Sept. 20, 1950
1ac	Beldon Reynolds	87	1950	Dr	100	6	P	Cy, H	D, S	Ls			50	Oct. 3, 1950
1cc	V. S. Morrison	98	1948	Dr	85	6	P	Cy, H	D, S	Tca	0	4,766.2	31.39	Sept. 19, 1950
2bd	Phillip R. Bare	26	1948	Dr	65	6	P	Cy, H	D, S	Tca	.4	4,934.3	42	1948
													12.90	Sept. 19, 1950
9ca	H. N. Talbott	17	1949	Dr	48	6	P	Cy, H	D, S	Tca	1.0		11.39	Sept. 17, 1950
11ba	E. F. Zenoniani	23	1949	Dr	105	6	P	J, E	D, S	Ls		4,900.7	45	Sept. 19, 1950
12ab	Wm. A. Cannon	84	1950	Dr	63	6	P	Cy, H	D, S	Ls		4,766.8	48	Sept. 16, 1950
12cb	Robert R. Skaggs	21		Dr	65	6	P	J, E	D, S	Ls		4,815.4		
12cd	Cyrus Robertson	22	1948	Dr	130	6	P	J, E	D, S	Ls		4,799.4	65	Sept. 20, 1950
19ca	Kenneth E. Stapp	5	1947	Dr	46	6	P	Cy, H	D, S	Tca	.5		24.32	Nov. 27, 1947
													24.26	Sept. 13, 1950
21ac	William Ross	11	1948	Dr	85	6	P	J, E	D, S	Ls			45	Nov. 1948
21cc	Husky Oil Co		1945	Dr	1,485	7	P	F-35	D, In					
21db	C. A. Long	12	1949	Dr	57	6	P	J, E	D, S				45	Nov. 1949
30bd	Clarence C. Schoonover	224	1949	Dr	68	6	P	J, E	D, S				34	Dec. 1949
T54a	Ray R. Rivinoja	85	1950	Dr	85	6	P	Cy, H	D, S	Bp	.3	4,760.3	39.70	Sept. 20 1950
T54b	Mearl Pearte	86	1950	Dr	85	8	P	Cy, H	D, S	Tca	.5	4,754.7	36.75	Do.
T61a	Wayne L. Smith	6	1947	Dr	47	6	P	J, E	D, S	Tca	1.2		20	1949
T61b	Wm. N. Wibel	222	1950	Dr	[1] 127	6	P	N	N	Ls			6.00	Sept. 13, 1950
T85a	V. F. Rotter		1908	Dr	100	6	P	Cy, W, E	D, S	Tca	1.4	4,815.2	30.34	Oct. 4, 1950
T89a	S. A. Hodges	96	1947	Dr	90	6	P	Cy, H	D, S	Ls		4,785.6	40	Nov. 1947
T89b	Theo. Thompson	97	1948	Dr	87	6	P	J, E	D, S	Tca	−1.8	4,785.6	43.94	Sept. 17, 1950
102- 13da	J. W. Walters	3	1948	Dr	[2] 125	6	P	N	N	Ls			25	Sept. 26, 1950
24da	Alexander Brug	2	1947	Dr	50	6	P	J, E	D, S	Hc	−5.0		29.50	Sept. 13, 1950
24dc	Herbert Grund	1	1947	Dr	51	6	P	N	N	Tca	.6		35.51	Do.
T62a	Cecil Stauffer		(old)	B	21.3	3	T	Cy, H	D, S	Bp	.2		8.65	Do.

54-100- 6ca1	Orville C. Mocabee	65	1948	Dr	95	6	G	Cy, E	D, S	Ls	----------	4,706.5	----------	----------
6ca2	Chas. C. Robinson	67	1948	Dr	95	6	P	Cy, E	D, S	Ls	----------	4,707.3	40	1948
6cb	Alvin Huggins	62	1947	Dr	82	6	P	Cy, H	D, S	Ls	----------	4,718.4	72	1947
7bb	Howard Wade	61	------	Dr	75	6	P	Cy, H	D, S	Tca	.4	4,688.9	28.30	Sept. 28, 1950
18cc	Glen V. Mangus	78	1947	Dr	80.0	6	P	Cy, H	D, S	Tca	1.0	4,676.2	58.36	Apr. 7, 1948
19bb	Wallace Thompson	77	1947	Dr	68	6	P	Cy, H	D, S	Tca	0	4,679.1	40.10	Sept. 25, 1950
19bc	Arthur Oster	76	1950	Dr	130	6	P	Cy, H	D, S	Bp	.8	4,714.0	47.70	Sept. 28, 1950
19bd	Kenneth H. Calver	74	1947	Dr	85	6	P	Cy, E	D, S	Tca	.3	4,682.8	49.10	Sept. 20, 1950
31bb	H. E. Ranchfuss	90	1949	Dr	90	8	P	Cy, E	D, S	Tca	1.0	4,696.6	12.80	Do.
L46a	L. H. Brand	68	1947	Dr	83	6	P	N	N	Tca	.8	4,667.3	31.83	Sept. 28, 1950
L46b	James L. White	69	1949	Dr	135	6	P	Cy, E	D, S	Tca	0	4,624.1	34.46	Sept. 19, 1950
L55a	Lyman W. Hopkins	66	1947	Dr	45	6	P	Cy, H	D, S	Tca	.6	4,686.6	37.20	Sept. 28, 1950
101- 1ac1	C. A. Rogers	58	1950	Dr	36	6	P	N	N	Tca	.3	4,847.5	5.25	Sept. 22, 1950
1ac2	R. A. Griswold	63	1947	Dr	27	6	P	Cy, H	D, S	Tca	.5	4,847.5	11.80	Do.
1bc	Milton L. Patterson	59	1947	Dr	135	6	P	Cy, H	N	Tca	.6	4,890.5	105	May 6, 1949
1db	Gerald DeMill	60	1947	Dr	[3] 80	6	P	N	N	Tca	.6	4,839.7	18.56	Sept. 22, 1950
2ad1	Chas. L. Bovee	55	1948	Dr	49	6	P	Cy, H	D, S	Tca	.6	4,927.7	7.93	Do.
2ad2	Wesley Hedrick	54	1947	Dr	63	6	P	N	N	Tp	.2	4,900.7	5.10	Do.
2ad3	do	54	1950	Dr	38	6	P	Cy, H	N	Tca	.5	4,894.5	5.60	Sept. 22, 1951
2bc	Chester A. Blackburn	50	1947	Dr	75	6	P	Cy, H	D, S	Tca	.8	4,991.9	15.30	Sept. 22, 1950
2bd	Jack H. Butcher	53	1947	Dr	40	6	P	Cy, E, H	D, S	Tca	.6	4,950.0	7.10	Sept. 25, 1950
3cb	Paul Scheuneman	48	1947	Dr	34	6	P	Cy, H	D, S	Tca	.5	5,096.2	10.78	Aug. 11, 1947
13cd	Donald B. Stewart	80	1948	Dr	98	6	P	N	N	Tca	−5.0	4,779.6	58.50	Sept. 22, 1950
13db	M. F. Lewis	79	1947	Dr	75	6	P	Cy, H	D	Tca	.4	4,739.0	27.20	Sept. 25, 1950
22dc1	D. Botts	38	1951	Dr	84	6	P	Cy, H	S	Tca	.6	5,045.7	Dry	Apr. 18, 1951
22dc2	Harry D. Reintsma	37	1950	Dr	150	6	P	J, E	D, S	Tca	2.6	5,044.1	46.45	Sept. 25, 1950
23ca	R. W. Jolovich	39	1951	Dr	131	6	P	Cy, G, H	D, S	Ls	----------	4,951.6	55	Jan. 1951
24ab	Fred N. Giles	81	1950	Dr	119	6	P	Cy, E	D, S	Tca	−5.0	4,757.2	75	Sept. 22, 1950
24bc	T. J. Shipley	44	1948	Dr	135	6	P	Cy, E	D, S	Ls	----------	4,818.3	75	Apr. 1948
24cc	Donald Knapp	40	1951	Dr	74	6	P	Cy, H	D, S	Ls	----------	4,809.6	----------	
25bb	Ray N. Bjornestad	35	1948	Dr	121	6	P	Cy, E	D, S	Tca	1.0	4,841.3	30.55	Sept. 25, 1950
35aa	Daniel LeBlane	30	1949	Dr	------	6	P	J, E	S	Ls	----------	4,828.7	50	May 7, 1948
35ad	Dean R. Baker	29	1948	Dr	100	6	P	Cy, E	D, S	Ls	----------	4,844.4	63	June 28, 1948
35da	Dale R. Good	27	1947	Dr	96	6	P	Cy, E	D, S	Tca	.5	4,849.0	48.10	Sept. 14, 1950
35dd	Ralph Calvert	95	1949	Dr	75	6	P	Cy, H	D, S	Tca	.5	4,846.9	39.90	Sept. 18, 1950
36bb	Clarence R. Buchholz	93	1948	Dr	117	6	P	J, E	D, S	Ls	----------	4,823.9	37	1948
36ca	Lee B. O'Gorman	91	1949	D	22.6	10	T	Cy, H	D, S	Tp	.2	4,722.1	12.67	Oct. 7, 1950
36cd	Owen McFarland	94	------	D	30.2	10	W	Cy, H	N	Tca	−5.0	4,735.9	12.70	Sept. 20, 1950
36dd	Forrest R. Allen	89	1949	Dr	75	6	P	Cy, H	D, S	Tca	.4	4,720.0	22.90	Do.
55-100- 7ba	Daro E. Larson	211	1950	Dr	133	6	P	Cy, E	D, S	Ls	----------	4,796.7	----------	----------
7cb	Elmon B. Tolar	146	1951	Dr	80	6	P	N	N	Tca	2.5	4,838.4	32.01	Apr. 16, 1951
8ba	D. L. Hollcroft	212	1950	Dr	86	------	N	N	N	----------		----------	Dry hole	----------
8bb	do	212	1951	Dr	95	6	P	N	N	Tca	1.5	4,756.8	29.46	Apr. 16, 1951
16ca	Harry T. Cullen	214	1950	Dr	74	6	P	Cy, H	D, S	Tca	.2	4,703.5	7.81	Apr. 18, 1915
18bb	----------	------	1946	Dr	77	6.5	P	N	N	Tca	.3	----------	34.40	Aug. 12, 1946
													34.62	Sept. 6, 1946
													34.92	Sept. 20, 1946
													34.79	Apr. 18, 1947
19cc	Ed. H. Schaefer	194	1951	Dr	140	6	P	N	N	Tca	.9	4,887.4	33.96	Apr. 12, 1951
22bb	L. L. Trudean	215	1950	Dr	70	6	P	N	N	Tca	.3	4,640.6	6.73	Sept. 20, 1950

See footnotes at end of table.

TABLE 4.—*Record of wells in the Heart Mountain Division, Shoshone irrigation project, Wyoming*—Continued

Well no.	Owner or tenant	Farm unit no.	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Method of lift	Use of water	Measuring point: Description	Measuring point: Distance above land surface (feet)	Measuring point: Elevation above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement
55-100- 31bc	W. M. Jackson	164	1951	Dr	108	6	P	Cy, E		Ls		4,785.0		
L37a	Wm. M. Brown	166	1950	Dr	77	7	P	J, E	D, S	Ls		4,723.6		
L37b	Jack C. Hirst	167	1950	Dr	63	6	P	N	N	Tca	0	4,713.5	10.10	Sept. 21, 1950
													11.62	Apr. 11, 1951
L37c	A. L. Howard	176	1950	Dr	93	6	P	Cy, H	D, S	Tca	.4	4,730.6	43.60	Sept. 22, 1951
L38a	Phillip A. Ell	168	1950	Dr	85	6	P	N	N	Tca	−4.0	4,696.8	7.40	Sept. 21, 1950
L38b	J. H. Bodle	174	1950	Dr	105	6	P	Cy, E	D, S	Ls		4,692.6	31	Do.
L42a	Joseph A. Koch	184	1951	Dr	96	6	P	Cy, H	D, S	Tca	.4	4,762.1	24.36	Apr. 16, 1951
L43a	Wm. O. White	186	1950	Dr	153	6	P	Cy, H	D, S	Tca	1.1	4,659.9	5.74	Sept. 15, 1950
L44a			1946	Dr	150		N	N	N					
L53a	Taggert Construction Co.			D	12.4	72	W	H, P	S	Tp	.5	4,695.9	6.65	Aug. 8, 1946
													7.07	Aug. 28, 1946
													7.41	Sept. 18, 1946
													7.57	Apr. 18, 1947
													8.64	Sept. 13, 1947
													6.02	Oct. 5, 1950
L53b	do.			B	16	12	P	Cy, H	D, S	Tca	2.0	4,688.8	13.01	Aug. 8, 1946
L53c	John H. Kranter	191	1950	Dr	107	6	P	J, E	D, S	Tca	−3.5	4,729.3	15.60	Sept. 22, 1950
L53d	Albert G. Kamm	192	1950	Dr	92	6	G	Cy, H	D, S	Tca	.5	4,790.0	22.10	Sept. 21, 1950
L53e	Harvey J. Adams	197	1949	Dr	130	8	P	Cy, H	D	Ls		4,772.0		
L70a	Robert E. Darling	177	1950	Dr	90	6	P	Cy, H	D, S	Ls		4,755.9		
L71a	C. I. Randolph	198	1951	Dr	70	6	P			Ls			19	
L81a	Buskart		1950	Dr	98	6	P	N	N	Ls		4,715.0		
L81b	do.		1950	Dr	40	6	P	Cy, E	S	Tca	2.5	4,710.3	7.90	Sept. 29, 1950
L81c	Lyle Cassell		1951	Dr				S, E	D	Ls		4,741.7		
L82a	H. H. Robinson	207	1950	Dr	155	6	P	Cy, H	D, S	Tca	1.2	4,770.2	25.60	Sept. 16, 1950
L82b	Carl C. Hill	208	1950	Dr	108	6	P	Cy, H	D, S	Ls		4,748.5	32	Aug. 11, 1950
L84a	M. O. Fielding	210	1950	Dr	135	8	P	Cy, E	D, S	Ls		4,834.5	67	Sept. 29, 1950
L94a	L. H. Snyder	196	1950	Dr	75	5	P	Cy, H	D, S	Ls		4,778.2	35	Mar. 1950
101- 9bd	Homer A. Winn	111	1949	Dr	186	6	P	Cy, H	N	Ls		5,119.4	77	Jan. 1949
9cd	Loran G. Otto	108	1948	Dr	96	6	P	Cy, H	D, S	Bp	.8	5,104.2	11.10	Sept. 28, 1950
9dc	Robt. F. Van Dyke	109	1948	Dr	95	6	P	Cy, H	D, S	Tca	.2	5,048.3	37.50	May 6, 1949
													22.13	Sept. 25, 1950
10cc	L. F. Fulton	116	1950	Dr	70	6	P	Cy, H	D, S	Tca	2.0	5,064.8	17.40	Sept. 26, 1950
11cc	Marion Aimone	115	1949	Dr	87	6	P	Cy, H	D, S	Tca	.8	4,992.7	19.95	Sept. 15, 1950
12cb	F. B. Meins	143	1950	Dr	147	6	G	Cy, H	D, S	Tca	.9	4,918.7	66.06	Oct. 5, 1950

12cd	O. J. Tirrell	147	1951	Dr	107	6	P	N	N	Tca	3.5	4,899.4	27.24	Apr. 18, 1951
13cc	R. J. Jirsa	152	1951	Dr	110	6	P	Cy, H	D, S	Ls		4,934.2	45	Feb. 1951
13cd	Elmer J. Collar	153	1951	Dr						Ls		4,911.5		
13dc	Harold F. McHose	154	1951	Dr	215	6	P	Cy, H	D, S					
14ab	G. W. Hutchinson	140	1951	Dr	87	6	P	Cy, H	D, S	Ls		4,943.7		
14cb	O. C. Anderson	138	1951	Dr	110	6	P	Cy, H	D, S	Ls		5,010.0	65	Oct. 1950
14cc	Wm. P. Stone	137	1951	Dr	135	6	P	Cy, H	D, S	Ls		5,020.9		
14da	Lyle Baker	139	1950	Dr	91	6	P	Cy, H	D, S	Ls		4,932.0	35	Oct. 1950
14dc	C. C. Musser	136	1950	Dr	120	6	P	Cy, H	D, S	Ls		4,979.7	62	May 1950
15ab	Chas. A. Nunley	118	1950	Dr	140	6	P	Cy, E	D, S	Ls		5,030.4		
15cc	H. Beslanowitch	121	1950	Dr	127	6	P	Cy, H	D, S	Ls		5,098.7	67	Aug. 1950
15dc	E. L. Thawley	122	1950	Dr	130	6	P	Cy, H	D, S	Ls		5,064.7	70	Nov. 1950
16ca	R. A. Ransier	107	1950	Dr	67	8	P	Cy, E	D, S	Tca	.8	5,144.4	39.20	Sept. 25, 1950
21aa	Lawrence L. French	140	1951	Dr	140	6	P	Cy, H	D, S	Ls			75	Nov. 1951
21da	V. W. Olson	103	1950	Dr	85	6	G	Cy, H	D, S	Ls		5,127.1	44	Feb. 1950
22ab	C. T. Denton	123	1947	Dr	130	6	P	Cy, H	D, S	Ls		5,066.9		
22ad1	Unknown		1926	D	58	48	W	N	N	Ls			Dry	Aug. 10, 1946
22ad2	Ben F. Krause	126	1951	Dr	150	6	P	Cy, H	D, S	Ls			80	1951
22cc	Geo. A. Long	102	1948	Dr	100	6	P	Cy, H	S	Tca	.5	5,118.8	23.27	Sept. 28, 1950
22dc	J. L. Kirby	127	1951	Dr	177	6	P	Cy, H	D, S	Tca	.6	5,080.7	67.42	Apr. 19, 1951
23aa	Earl B. Wilson	135	1950	Dr	140	6	P	Cy, H	D, S	Ls		4,941.7	85	Mar. 1950
23bb	Chas. W. Roland	134	1951	Dr	131	6	P	Cy, H	D, S	Ls		5,024.2		
24cb	H. L. Bright	157	1951	Dr	108	6	P	N	N	Tca	1.1		22.79	Apr. 11, 1952
24cd	Paul H. Ethridge	159	1951	Dr	210	6	P	S, E	D, S					
24da	J. L. Lanik	155	1950	Dr	150	6	P	Cy, H	D, S	Tca	.4	4,889.7	60.30	Oct. 3, 1950
25ba	Wm. H. Cook	161	1951	Dr	164	6	P							
25da	Vincent J. Spiering	162	1950	Dr	175	6	P	Cy, E	D, S	Ls		4,936.4	115	Aug. 1950
25dd	Joseph B. Storm	163	1950	Dr		6	P	Cy, H	D, S	Ls		4,841.9		
26aa	Albert F. Gay	130	1950	Dr	192	6	P	J, E	D, S	Ls		4,969.8	100±	Sept. 26, 1950
26da	L. P. Allshouse	129	1950	Dr	280	6	P	N	N	Ls		5,013.6		
36cc1	L. B. Solberg	101	1948	Dr	120	6	P	J, E	D, S	Ls		4,874.9	20	Aug. 1948
36cc2	Sterling P. Johnson	56	1947	Dr	51	6	P	Cy, E	D, S	Bp	.8	4,865.6	14.30	Sept. 22, 1950
36dd	W. J. Slusser	64	1951	Dr	95	6	P	Cy, H	D, S	Ls		4,812.3	40	Jan. 1951

[1] Measured depth, 8.4 ft, Sept. 13, 1950.
[2] Measured depth, 12.0 ft, Sept. 26, 1950.
[3] Measured depth, 66.2 ft, Sept. 22, 1950.

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