Ground-Water Conditions and Storage in the Central Sevier Valley, Utah

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By Richard A. Young and Carl H. Carpenter

ABSTRACT

The central Sevier Valley, in the central part of Utah, extends from the town of Kingston to the Yuba Dam and from the Tushar and Valley Mountains and the Pavant Range to the Sevier, Fishlake, Wasatch, and Gunnison Plateaus. A geologic and hydrologic investigation of the valley was made to determine the relation between surface water and ground water and to determine if ground water can be used for irrigation supplies without affecting existing water uses. During the investigation, data were collected for about 700 wells and 26 springs. Monthly water-level measurements were made at 93 observation wells, and automatic recording gages were maintained at 6 additional wells. Chemical analyses were made of water collected from 68 wells and springs. Test holes were drilled at 21 sites to determine the thickness and hydrologic properties of the water-bearing materials. Consumption of ground water by vegetation was estimated on the basis of area and applied rates of evapotranspiration.

The climate ranges from semiarid in the valley to humid in the surrounding high mountains, and the annual precipitation ranges from less than 10 inches to more than 30 inches according to altitude. The growing, or frost-free, season averages about 120 days in the valley. The average annual evaporation from open water at Piute Reservoir is about 55 inches.

The valley occupies a synclinal trough modified by a graben between the Sevier fault on the east and the Elsinore fault on the west. The mountains bordering the valley consist of sedimentary and igneous rocks, which range in age from Triassic to Tertiary. The valley fill, which is alluvium consisting of gravel, sand, silt, and clay, has a maximum known thickness of 800 feet.

Irrigation has been practiced in the central Sevier Valley since about 1850, and surface-water rights are fully appropriated. Water is diverted from the Sevier River and its tributaries into irrigation canals at many sites along the streams. The entire flow of the river is diverted at times during the irrigation season at the Annabella Canal diversion dam, the Vermillion Canal diversion dam, and the Rockyford Dam; but surface flow reappears below each of these dams. This flow is fed by ground water which has its source partly in return flow from irrigation. The total surface-water reservoir storage capacity in the area is about 312,000 acre-feet.

The valley is divided into five ground-water basins, which were formed by geologic forces and stream action. In downstream order, the basins are the Junction-Marysvale, Sevier-Sigurd, Aurora-Redmond, Redmond-Gunnison, and Gunnison–Sevier Bridge Reservoir basins. Ground water occurs under both artesian and water-table conditions in each of these basins. Artesian condi-

tions prevail in the central and downstream parts of the basins, where permeable beds of gravel and sand are confined by overlying beds of silt and clay. Water-table conditions usually prevail along the sides and at the upper ends of the basins. Water flows freely from most wells in the artesian areas.

Most of the available ground water is in the permeable beds of gravel and sand in the alluvium. Aquifer tests indicate that coefficients of transmissibility range from 4,000 to 900,000 gallons per day per foot and that coefficients of storage range from 0.0001 to 0.2. Probably about 1,500,000 acre-feet of ground water is stored in the gravel and sand deposits in the alluvium. About 30,000 acre-feet is stored in the Junction-Marysvale basin; about 800,000, in the Sevier-Sigurd basin; about 200,000, in the Aurora-Redmond basin; about 150,000, in the Redmond-Gunnison basin; and about 300,000, in the Gunnison-Sevier Bridge Reservoir basin. An additional large amount of water, although not readily available to wells, is stored in the beds of silt and clay.

The principal sources of recharge to the alluvium in the central Sevier Valley are the Sevier River and its tributaries, irrigation canals, and infiltration from irrigated fields. Some ground water also moves into the alluvium from bedrock sources surrounding the valley. Ground water is discharged mostly by evapotranspiration, wells, springs, and drains. A relatively small amount of the ground water leaves the area by subsurface outflow.

More than 1,300 wells, most of which are 4 inches or less in diameter and less than 150 feet in depth, have been constructed in the central Sevier Valley. Most of them flow, but the discharges are small. The specific capacities of six large-diameter wells range from 10 to 300 gallons per minute per foot of drawdown.

Approximately 200,000 acre-feet of ground water is discharged anually from the alluvium. Springs discharge about 60,000 acre-feet, and wells and drains combined discharge about 40,000 acre-feet; evapotranspiration from areas of phreatophytes is about 100,000 acre-feet. Most of the water discharged by springs, wells, and drains is used for irrigation.

Most of the ground water in the central Sevier Valley is of suitable chemical quality for irrigation, public supply, and domestic, stock, or industrial use. Of 72 samples of ground water analyzed, 69 percent were classified as fresh, 17 percent as slightly saline, and 14 percent as moderately saline. The concentration of dissolved constituents in the ground water generally increases downstream. The quality of water in the ground-water basins is as follows: Junction-Marysvale, excellent; Sevier-Sigurd, generally excellent; Aurora-Redmond, generally good except near the Arapien Shale; Redmond-Gunnison, good near Axtell and in the northwestern part but not suitable for domestic use in the remainder of the basin because of the influence of the Arapien Shale; Gunnison–Sevier Bridge Reservoir, good. In all basins, except where the alluvium is underlain by the Arapien Shale, wells more than 100 feet deep yield water of better chemical quality than that from wells less than 100 feet deep.

The surface-water and ground-water systems in the central Sevier Valley are interconnected, and the base flow of the Sevier River is affected by changes in ground-water levels. The absence of appreciable long-term changes in ground-water levels in the basins indicates that the total discharge of ground water is balanced by recharge to the aquifers each year. An inflow-outflow analysis of the Sevier-Sigurd basin shows that recharge of all water to the basin approximately equals discharge from the basin. The same principle applies to all the basins; consequently, increased pumpage of ground water would result in (a) an increase in the recharge from surface-water sources, (b) a decrease in the discharge from springs, flowing wells, and areas of phreatophytes, or (c) a combination of the above. A total, however, of about 35,000 acre-feet of water could probably be pumped from wells in the central Sevier Valley without greatly affecting the flow of the Sevier River and with only moderate effect on springs and existing wells.

The additional 35,000 acre-feet of ground water could be obtained by the construction and pumping of large wells. If such wells were properly located, the pumping would cause a lowering of water levels and, as a result, the drying up of existing wet areas which now support extensive growths of phreatophytes. About 100,000 acre-feet of ground water is now discharged annually by evapotranspiration in the central Sevier Valley. Salvage of about one-third of this loss by elimination of wet areas and phreatophytes would provide the 35,000 acre-feet of newly developed water.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The U.S. Geological Survey in cooperation with the Utah State Engineer made a geologic and hydrologic investigation of the central Sevier Valley, Utah, to determine the relation between surface water and ground water and to determine if ground water can be used for irrigation during periods of drought without affecting existing water uses.

This report of the investigation includes discussions on history and development of water resources; relation of geology to ground water; source, occurrence, recharge, and discharge of ground water; evapotranspiration; present ground-water development; fluctuations of water level; chemical quality of the water; relation of ground water and streamflow; analysis of inflow-outflow for a specific basin; and conclusions about potential development and its effect on the hydrologic conditions in the area.

LOCATION AND EXTENT OF AREA

The central Sevier Valley is in the central part of Utah (pl. 2). It includes the Sevier River valley between the town of Kingston on the south and the Yuba Dam on the north, a distance of about 90 miles, and extends from the Tushar and Valley Mountains and the Pavant Range on the west to the Sevier, Fishlake, Wasatch, and Gunnison Plateaus on the east. The area of detailed study was mostly limited to the valley floor, which includes about 300 square miles. Some study, however, was devoted to the entire drainage basin along the reach of the valley investigated, an area of about 2,800 square miles. In this report the term "central Sevier Valley" refers to the entire drainage basin between Kingston and the Yuba Dam.

PREVIOUS WORK

Two earlier water-supply studies were made in the central Sevier Valley by the U.S. Geological Survey: a reconnaissance of the ground-water resources in Sanpete and central Sevier Valleys (Richardson, 1907), and a study of the surface-water resources of the Sevier Lake basin (Woolley, 1947). Streamflow records have been collected in the valley since about 1900 by the Geological Survey, and they have been published in various water-supply papers. Records of diversions for irrigation are compiled by the Sevier River commissioners for most years.

Investigations of the geology of parts of the central Sevier Valley include those by Callaghan (1938, 1939), Callaghan and Parker (1961, 1962a, b), Willard and Callaghan (1962), Maxey (1946), Spieker (1946, 1949), and Kerr and others (1957).

Several geologic reports of parts of the area were prepared by graduate students at Ohio State University. They include those by Gilliland (1951), Hardy (1952), and McGookey (1960), and "Geology of the central part of the Pavant Range" by Herman Lautenschlager (written commun., 1952). All available reports were used in the compilation of the geologic map and as a guide to the geology of the area.

Information on water rights in the central Sevier Valley was compiled and presented in a court decree adjudicating the Sevier River system by the Honorable LeRoy H. Cox (1936), Judge of the Fifth Judicial District of the State of Utah.

A soil-survey report for the Richfield area (Wilson and others, 1958) was published by the Soil Conservation Service of the U.S. Department of Agriculture.

PERSONNEL AND METHODS OF INVESTIGATION

The project was started in July 1956 when R. E. Jackson, hydraulic engineer, and Kirk Bitter, geologic field assistant, began the fieldwork. Mr. Bitter left the project in September 1956, and in October 1956 R. A. Young, geologist, was assigned as project chief. C. H. Carpenter, hydraulic engineer, replaced Mr. Jackson in October 1957. R. D. Feltis helped with the supervision of the test-drilling program and assisted in examining the drilling samples in 1959 and 1960. L. J. Bjorklund contributed numerous ideas and much valuable assistance in the preparation of the manuscript. The project was under the general supervision of H. A. Waite, district geologist, from 1956 to 1960, and of H. D. Goode, acting district geologist, during part of 1960 and 1961.

The project began with the collection of basic data, including information on wells and springs, water-level measurements, streamflow records, geologic data, climatological data, water samples for chemical analysis, and well logs. Much of the basic data, including well and spring records, water-level measurements, well logs, and chemical-quality data were released as a separate report (Carpenter and Young, 1963) and are not included as basic data in this report.

Nearly 700 wells and 26 springs were visited, and, where possible, water levels, discharge measurements, and water samples for chemical analysis were obtained. Water levels were measured monthly in a network of 93 observation wells. Six additional wells were equipped with automatic water-level recording gages during various stages of the study. Water samples from 68 wells and springs were collected and analyzed to provide information on the suitability of the ground water for irrigation and other uses.

An areal geologic map was compiled in part from published and unpublished material, and in part by field and photogeologic studies of the area that had not been previously mapped. Hydrologic maps were prepared showing streams, areas of flowing wells and phreatophyte growth, canals, ground-water-level contours, recharge areas, location of wells and springs discussed in the report, and comparative diagrams of the quality of water.

A test-drilling program, financed through the State Engineer, in cooperation with the U.S. Geological Survey, by Garfield, Piute, Sanpete, Sevier, and Millard Counties and water users in the area, was undertaken in 1959–60 to provide information about the depth and composition of alluvial deposits in the valley fill. The selection of test-hole sites was made on the basis of convenience, geology, and maximum coverage. Single holes near the axis of the valley were deemed sufficient in most areas, but two sets of several test holes each—one set near Richfield and the other set near Venice—were drilled to provide information for cross sections of the valley.

Twenty test holes in the valley fill and one in bedrock were drilled by the rotary method. Cutting samples were obtained for each 10 feet of hole, and the holes were logged electrically to ascertain the depth and thickness of the various materials penetrated. The cuttings were inspected by microscope to determine their type, lithology, origin, fossil content, and amount of cementation. Water samples for chemical analysis were taken from the test holes where possible. Two of the test holes were cased and equipped with water-level recording gages to provide a record of fluctuations.

The data derived from the test drilling include drilling logs, drilling-time logs, electric logs, and sample logs. These data were compiled and analyzed to delineate the permeable zones in the valley fill and to obtain other pertinent information. Analyses of the data permitted an estimate of ground-water storage in the central Sevier Valley. An open-file report on the test drilling was released in mimeograph form (Young, 1960).

Records of streamflow and diversions of irrigation water within the area were studied and correlated with ground-water levels to determine the relation of ground water and streamflow in the valley. In addition, an inflow-outflow study was made in the Sevier-Sigurd basin.

The consumption of ground water by vegetation was estimated on the basis of area and applied rates of evapotranspiration. Areas and kinds of vegetation were mapped on aerial photographs and measured by planimeter. Estimates of water loss by evaporation from open-water surfaces were made by using available information on reservoir-surface areas and evaporation rates as determined by the U.S. Weather Bureau.

Estimates of ground-water discharge from wells, springs, and drains were based on periodic discharge measurements at selected locations. Aquifer tests were made at some wells to determine both the hydraulic properties of the water-bearing materials and the individual well performance.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of officials of Garfield, Piute, Sevier, Sanpete, and Millard Counties, and of the several irrigation companies in those counties for their cooperation in expediting the test-drilling program. Ben Gardner, Sharp Welding Co., Rodney Cowley, and Earl Ramey, well drillers, supplied cutting samples and well logs in the area, and the Hansen Engineering Co. made available well and well-performance data.

Advice concerning compilation of the geologic map was given by Drs. E. M. Spieker, Ohio State University, and J. H. Mackin, University of Washington.

Information on streamflow was given by the Sevier River Commissioners, K. B. Christensen and W. C. Cole. Personnel of the Soil Conservation Service and of the Forest Service, U.S. Department of Agriculture, provided information on native vegetation, watershed management, and irrigation practices. The authors also wish to thank the many individuals who have contributed information concerning their wells and who have allowed the use of their wells for observation.

WELL-NUMBERING SYSTEM

The well numbers used in this report indicate the well location by land subdivision according to a numbering system that was cooperatively devised by the Utah State Engineer and G. H. Taylor of the Geological Survey in about 1935. The system is illustrated in figure 1. The complete well number comprises letters and numbers that desig-

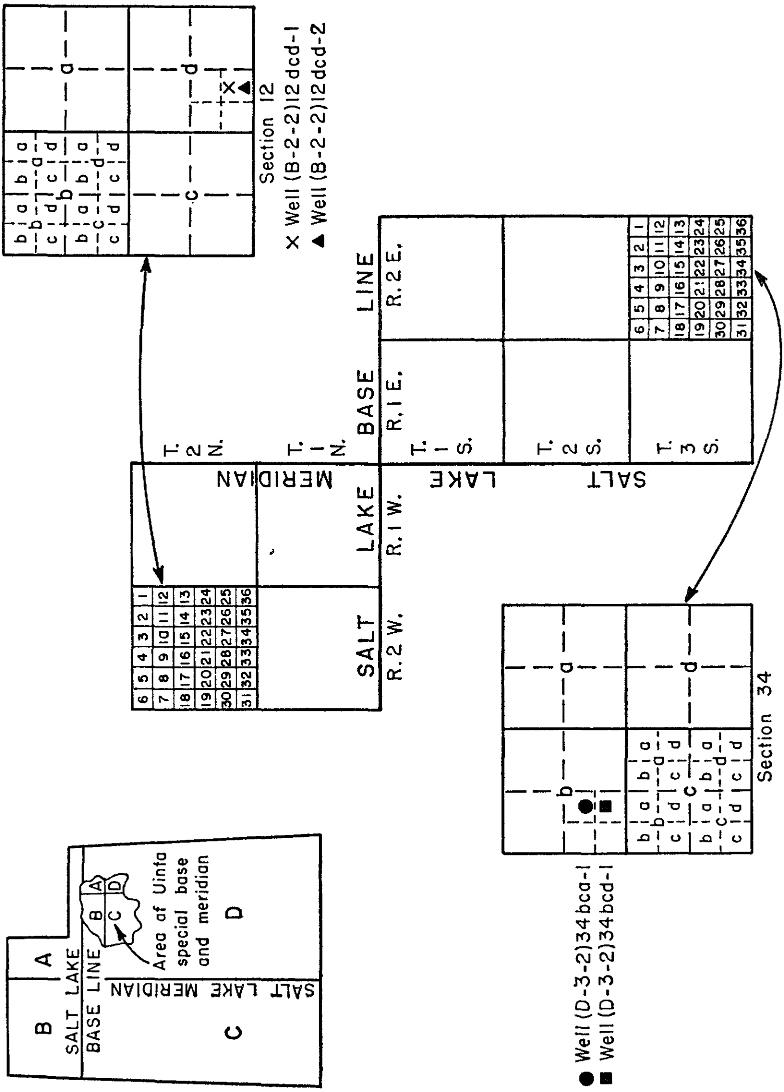

FIGURE 1.—Well-numbering system used in Utah.

nate consecutively the quadrant and township (shown together in parentheses by a capital letter designating the quadrant in relation to the base point of the Salt Lake Base and Meridian, and numbers designating the township and range); the number of the section; the quarter section (designated by a letter); the quarter of the quarter section; the quarter of the quarter-quarter section; and, finally the particular well within the 10-acre tract (designated by a number). By this system the letters A, B, C, and D designate respectively the northeast, northwest, southwest, and southeast quadrants of the standard base-and-meridian system of the Bureau of Land Management; and the letters, a, b, c, and d designate respectively the northeast, northwest, southwest, and southeast quarters of the section, of the quarter section, and of the quarter-quarter section. Thus, the number (B–2–2)12dcd–2 designates well 2 in the SE¼SW¼SE¼ sec. 12, T. 2 N., R. 2 W., the letter B showing that the township is north of the Salt Lake Base Line and that the range is west of the Salt Lake Meridian; the number (D–3–2) 34bca–1 designates well 1 in the NE¼SW¼NW¼ sec. 34, T. 3 S., R. 2 E.

GEOGRAPHY

PHYSIOGRAPHY AND DRAINAGE

The central Sevier Valley is defined as the part of the Sevier River valley between the town of Kingston on the south and the Yuba Dam on the north. The valley is in the High Plateaus section of the Colorado Plateau physiographic province (Fenneman, 1931, p. 295). It is mostly an alluvium-filled intermontane valley bordered on the east by the Sevier, Fishlake, Wasatch, and Gunnison Plateaus, and on the west by the Tushar and Valley Mountains and the Pavant Range (pl. 2). The Sevier, Fishlake, and Wasatch Plateaus reach altitudes of more than 11,000 feet, whereas the Tushar and Valley Mountains and the Pavant Range reach altitudes of more than 12,000, 8,000, and 10,000 feet, respectively. The Gunnison Plateau is more than 10,000 feet above sea level at its north end and slopes southward to merge with the valley floor near Gunnison at an altitude of 5,100 feet.

The central Sevier Valley is approximately 90 miles long and averages slightly more than 3 miles wide. The valley ranges in width from less than 300 feet in Marysvale Canyon to more than 8 miles near Gunnison. The altitude of the valley floor ranges from about 5,000 feet at the north end to about 6,000 feet at the south end. The average valley gradient ranges from about 4 feet per mile in the wide parts of the valley to about 40 feet per mile in the steeper, canyon sections.

The valley floor formed by the flood plain of the Sevier River is very flat laterally. Alluvial fans slope into the valley from the many canyons in the mountains that border the valley on each side, and in many places the fans overlap the flood plain.

The valley is divided by geologic conditions into five individual ground-water basins: Junction-Marysvale, Sevier-Sigurd, Aurora-Redmond, Redmond-Gunnison, and Gunnison-Sevier Bridge Reservoir. (See pl. 2.) A description of these basins is given in the section, "Structural features."

The Sevier River, which drains the valley, rises in the high plateaus of southern Utah above an altitude of 10,000 feet and flows northward through the trough of the Sevier Valley for about 175 miles before turning westward into the Sevier Desert. The river is fed along its course by numerous tributaries which drain into it from the surrounding mountains and plateaus.

CLIMATE

The climate in the central Sevier Valley, according to Köppen's classification (Trewartha, 1954, p. 382), ranges from semiarid on the valley floor to humid on the mountains and plateaus bordering the valley. In the valley, relative humidity generally is low, and sunshine is abundant, particularly during the summer months. Wind velocities are usually less than 2 miles per hour and rarely exceed 50 miles per hour.

Climatological stations are maintained by the U.S. Weather Bureau, and data are published in monthly reports. The principal stations are at Piute Dam, Richfield, and Salina.

Average annual precipitation ranges from less than 10 inches on the valley floor to 30 inches or more at the higher altitudes. Because of sparse precipitation on the valley floor, most crop production is dependent upon irrigation.

Winter storms are mainly of the cyclonic type. They originate in the North Pacific Ocean, are general over wide areas, are of moderate intensity, and last from one to several days. Winter precipitation usually is snow, particularly on the high mountains and plateaus where it may accumulate to depths of 10 feet or more and be equivalent to more than 20 inches of rain. During the spring and late autumn, precipitation generally falls over extensive areas as low-intensity rain.

During the summer and early autumn, precipitation commonly falls during high-intensity local thunderstorms of short duration. These summer storms usually originate from warm moist air moving northwestward from the Gulf of Mexico.

Comparison of long-term mean monthly precipitation data at Piute Dam, Richfield, and Salina shows that the south end of the project area receives more precipitation in the summer and early autumn, whereas the north end receives more during the winter and spring.

Although the monthly mean precipitation in the valley has only a small range—for example, mean precipitation at Salina ranges from 0.47 inch in September to 1.08 inches in March—there may be a much greater range in the precipitation during particular months. Monthly precipitation on the valley floor may range from 0 to 3½ inches, but in 1 day or within a few hours a thunderstorm may yield more than the mean monthly rainfall.

Precipitation in the central Sevier Valley was below the long-term mean in the great majority of the years during the period 1948–59. The effects of this prolonged precipitation deficiency on the cumulative departures from long-term mean annual precipitation, on cumulative departures from the average annual streamflow, and on year-end water levels in a key observation well are shown on graphs in figure 2. Periods of low precipitation, low streamflow, and low water level generally coincide. The sequence of dry years which resulted in lessened streamflow has caused irrigators to become increasingly interested in developing ground water in the central Sevier Valley to supplement surface-water supplies.

The growing season averages about 120 days in the central Sevier Valley. At Richfield, the number of frost-free days ranged from 45 in 1897 to 171 in 1934 and averaged 121 for the 44 years of record. The highest temperature in 33 years of record at Richfield was 104° F and the lowest was −28° F.

Mean-annual evaporation at Piute Reservoir is 55.2 inches. Mean monthly evaporation ranges from 0.65 inch in January to 11.0 inches in July (U.S. Weather Bur. written commun. 1958). These evaporation rates are regarded as being representative of the project area, although total evaporation probably is slightly greater at the north end of the area.

VEGETATION

Native vegetation in the central Sevier Valley includes desert to alpine species. The uncultivated lands of the valley floor support mainly saltgrass (*Distichlis stricta*), rabbitbrush (*Chrysothamnus nauseosus*), greasewood (*Sarcobatus vermiculatus*), willows (*Salix* sp.), and sagebrush (*Artemisia tridentata*). The alluvial fans and foothills up to an altitude of about 7,000 feet support mainly sagebrush, juniper (*Juniperus* sp.), scrub oak (*Quercus* sp.), mountain-mahogany (*Cercocarpus* sp.), and Pinyon pine (*Pinus edulis*). Above an altitude of 7,000 feet are mainly aspen (*Populus tremuloides aurea*), ponderosa pine (*Pinus ponderosa*), spruce (*Picea* sp.), and Douglas-

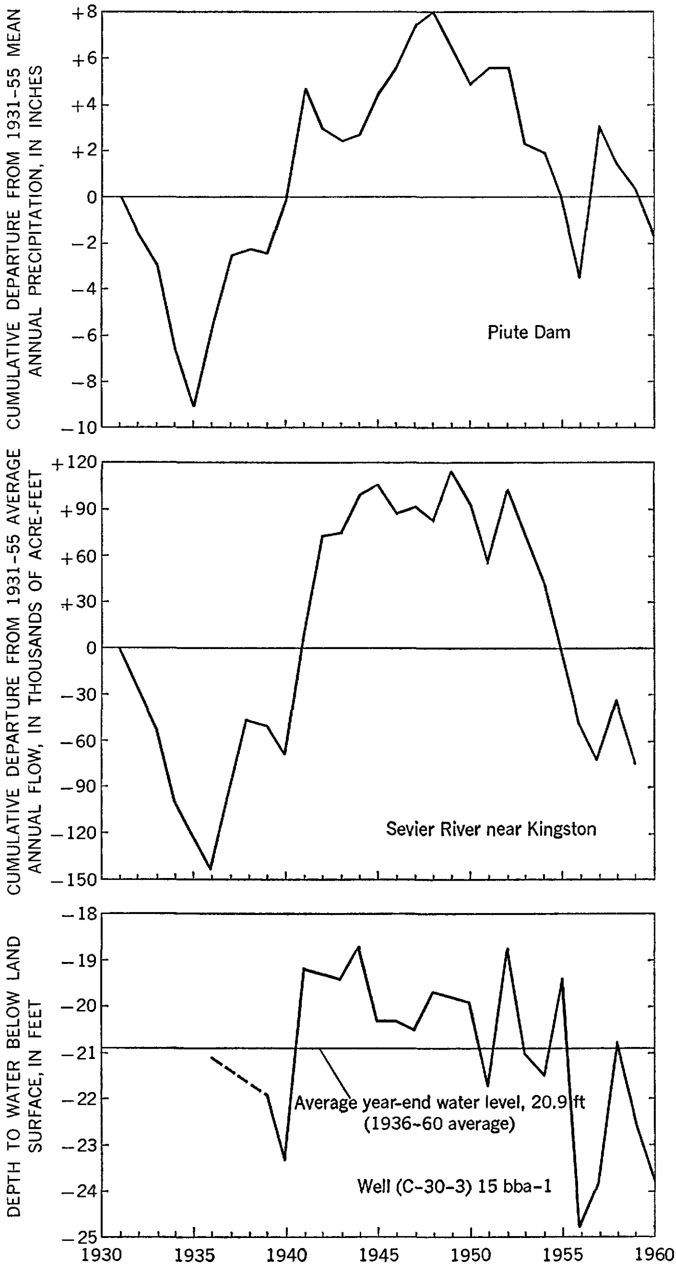

FIGURE 2.—Cumulative departure from long-term mean annual precipitation at Piute Dam; cumulative departure from average annual (calendar year) flow of the Sevier River near Kingston; and year-end water levels in well (C–30–3) 15bba–1.

fir (*Pseudotanga taxifolia*), all of which are particularly prolific on the mountain slopes having northern exposure. Along all stream channels in the valley, willows and cottonwood trees (*Populus* sp.) are the principal vegetation.

Saltcedar (*Tamarix* sp.), which is not native to the area, grows profusely on wet uncultivated lands and along stream and canal banks. It is of considerable interest in the central Sevier Valley because it is a rapidly spreading phreatophyte which consumes a relatively large amount of water.

POPULATION, AGRICULTURE, AND INDUSTRY

The largest community in the project area is Richfield, 165 miles south of Salt Lake City. The population of Richfield in 1950 was about 4,200, and in 1960 it was 4,400. The total population of the project area in 1950 was about 16,000, and in 1960, about 13,000. Most of the residents are engaged in agriculture and related activities, but they live in towns and villages rather than on farms. The principal crops grown on the cultivated and irrigated lands are sugar beets, alfalfa, small grains, corn, and potatoes. Sheep and cattle raising is also an important part of the agricultural economy of the area.

Mining contributes much to the economy of the central Sevier Valley. Two large wallboard plants utilize gypsum mined in the hills east of Sigurd. Mining of uranium and alunite is centered in and near the Tushar Mountains. Rock salt and bentonite are mined near Redmond, and bentonite is mined west of Aurora.

GEOLOGY

GENERALIZED STRATIGRAPHY

The consolidated rock formations exposed in the mountains surrounding the central Sevier Valley include most of the formations found in southern Utah from the Coconino Sandstone of Permian age to the Sevier River Formation of Pliocene or Pleistocene age. In the area shown on the geologic map (pl. 1), however, the oldest formation exposed is the Navajo Sandstone. Formations older than the Navajo have little or no effect on the ground-water potential in the central Sevier Valley.

The unconsolidated rocks that make up the fill in the central Sevier Valley flat are of Pleistocene and Recent age. They are the source of practically all the ground water obtained from wells in the central Sevier Valley.

The generalized geologic section in table 1 names and briefly describes the formations shown on plate 1, tells where they are exposed,

TABLE 1.—*Generalized geologic section in the central Sevier Valley*

System	Series	Geologic unit	Description and location	Thickness (feet)	Water supply
Quaternary	Pleistocene and Recent	Alluvium	Poorly to well-sorted clay, silt, sand, gravel, and boulders. Includes alluvial-fan material. Found on the valley floor in stream courses and in depressions on the plateaus.	0–800+	Poor to excellent. Yields large quantities of water to wells where clean sand or gravel is penetrated. Artesian conditions exist where near-surface clays confine water in underlying permeable deposits.
		Landslide deposits	Unsorted slide material derived from steep slopes. Found principally along the Sevier fault.	0–400+	Poor because of lack of sorting, but infiltration of surface water may be induced because of hummocky surfaces.
		Terrace gravel	Partly sorted sand and gravel deposits along present and former stream courses. Exist in Marysvale area, between Joseph and Monroe, and in Redmond Hills.	0–50	Generally well drained, but some of the larger bodies yield water to shallow wells and to springs.
	Pliocene or Pleistocene	Sevier River Formation	Fanglomerate deposit consisting of silt, sand, gravel, cobbles, and boulders derived from adjacent highlands by torrential runoff; very poorly sorted. Includes Axtell Formation of Spieker (1949, p. 38). Exposed along flanks of Sevier Valley and in basins on the plateaus.	0–800	Poor to moderate. Because of low permeability, functions as confining medium where it is underlain by permeable formations. A few wells derive small amounts of water from this formation.
	Miocene(?) and Pliocene(?)	Intrusive rocks	Quartz diorite, quartz monzonite, and monzonite intrusive into Bullion Canyon Volcanics. Exposed in Marysvale Canyon area and on Sevier Plateau.		Permeability relatively low. Does not yield ground water to wells.
		Volcanic rocks	Latitic, basaltic, and rhyolitic flows, tuffs, and agglomerates, including associated pyroclastic sedimentary rocks. Include Joe Lott Tuff, Mount Belknap Rhyolite, Dry Hollow Formation, Roger Park Basaltic Breccia, and Bullion Canyon Volcanics. Underlies much of southern two-thirds of project area.	7,000–13,000	Permeability mostly relatively low, but the Dry Hollow Formation and some undifferentiated basaltic flows are a source of water for many springs.
	Eocene	Dipping Vat Formation of McGookey (1960)	Evenly bedded tuffaceous sandstone containing pyroclastic fragments and sparse lenses of clay and silty limestone. Exposed along margins of Sevier Valley north of Richfield and in Redmond Hills.	200+	Good to poor. Contains beds of friable glassy sands which are extremely permeable. Wells are not known to penetrate this formation.

TABLE 1.—*Generalized geologic section in the central Sevier Valley*—Continued

System	Series	Geologic unit	Description and location	Thickness (feet)	Water supply
Tertiary	Eocene or Oligocene	Bald Knoll Formation of Gilliland (1951)	Pastel-colored clay, siltstone, sandstone, limestone, and pyroclastics that were deposited in lakes. Very poorly consolidated. Erodes to badlands by sheetwashing. Exposed on west edge of valley from Flat Canyon to Bald Knoll Canyon and in the east side in the Salina Canyon area.	600-1,000	Poor. Water was not found in a 920-ft section of this formation penetrated by well (C-21-1) 18daa-1. This formation may confine water in the underlying Crazy Hollow Formation in the Pavant Range.
	Eocene	Crazy Hollow Formation of Spieker (1949)	Red and orange sandstone, siltstone, and shale, light-gray sandstone, and salt-and-pepper sandstone. Diagnostic guide is occasional chert pebble in sandstone. Exposed on east and west margins of valley north of Richfield.	300-1,000	Good in sandstone, but formation is too deep beneath the floor of the valley for present development. Richfield Spring (C-23-3)26aca, issues from this formation.
		Green River Formation	Massive to thin-bedded white to yellowish-gray limestone and green to grayish-green shale. Exposed from Richfield north in Pavant Range, in Valley Mountains, and in Wasatch and Gunnison Plateaus.	400-1,200	May yield water where joints or solution cavities are developed in the limestone member.
		Colton Formation	Evenly bedded brownish-red shale and sandstone. Exposed from Salina north in Valley Mountains and in Wasatch and Gunnison Plateaus.	0-1,600	Permeability relatively low.
	Paleocene and Eocene(?)	Flagstaff Limestone	White to red massive to thin-bedded limestone, siltstone, and sandstone. Exposed from Richfield north in both sides of valley.	100-1,500	Wells are not known to penetrate this formation, although it yields about 1,900 gallons per minute to Fayette Spring, (D-18-1)19dab, from a solution cavity.
Tertiary / Cretaceous	Paleocene and Upper Cretaceous	North Horn Formation	Yellow-brown sandstone with minor gray and red shale and some conglomerate. Exposed in fault block east of Gunnison.	500-2,800	Yields water to wells adjacent to the project area where formation is fractured by faulting.
Cretaceous	Upper Cretaceous	Price River Formation	Buff sandstone to red boulder conglomerate. Exposed in Gunnison Plateau.	800-2,000	Wells are not known to penetrate this formation.
		Indianaola Group	Sandstone and coal-bearing shale. Exposed in fault block east of Gunnison.	7,000-15,000	Wells are not known to penetrate this group.

TABLE 1.—*Generalized geologic section in the central Sevier Valley*—Continued

System	Series	Geologic unit	Description and location	Thickness (feet)	Water supply
Jurassic	Upper Jurassic	Morrison(?) Formation	Red coarse sandstone and conglomerate. Exposed in fault block east of Gunnison.	1,800±	Wells are not known to penetrate this formation.
		Arapien Shale	Red and gray shale and red and gray fine-grained sandstone containing interbedded salt and gypsum. Exposed in east side of valley north of Glenwood, in Redmond Hills, in hills west of Gunnison, and in small outcrops southwest of Marysvale.	10,000±	Permeability low. This formation prevents ground water movement from the Wasatch and Fishlake Plateaus to the valley fill. It contributes large amounts of chloride and sulfate to water in the fill along the east side of the valley from Glenwood to Gunnison and in the vicinity of the Redmond Hills.
Triassic(?)		Navajo Sandstone	Red to white crossbedded sandstone. Caps the top of the upthrown block west of the Tushar fault.	Unknown	Generally permeable.

and gives an estimate of their water-yielding potential. In general, most of the consolidated formations lie too deep beneath the valley fill for present ground-water development.

STRUCTURAL FEATURES

FAULTING

The central Sevier Valley floor occupies a synclinal trough modified by a graben formed by the two largest faults in the area, the Sevier fault on the east and the Elsinore fault on the west. (See pl. 1.) The Sevier fault, a normal fault downdropped on the west, forms the west edge of the Sevier Plateau. The fault can be traced from northern Arizona to Glenwood in the central Sevier Valley of Utah, but it probably extends northward to the vicinity of Sigurd. Throw on this fault ranges from a few hundred feet near Glenwood to nearly 6,000 feet near Monroe. The Elsinore fault, a normal fault downdropped on the east, can be traced along the west side of the valley from Elsinore to the area west of Aurora. The throw of the fault ranges from about 500 to 1,000 feet, but at least half of the fault scarp is buried beneath the alluvium of the valley. Faults along the east side of the Valley Mountains may possibly be a northward continuation of the Elsinore fault.

The Tushar fault contributes to the formation of the graben in the southern part of the central Sevier Valley. (See pl. 1, cross section *A–A′*.) The fault trends northwestward across Piute Reservoir. The southwest side is uplifted at least 4,000 feet in its northern part, but the displacement decreases to the southeast.

Many smaller normal faults also are in the area. The Dry Wash fault extends northeastward from Dry Wash, a southern tributary of Clear Creek near Sevier, and forms the west edge of the low range of hills between Joseph and Monroe. Throw on the Dry Wash fault ranges from 400 to 500 feet, and the downdropped side is on the west. (See pl. 1, cross section *B–B′*.) The hills and plateaus surrounding the central Sevier Valley floor are cut by numerous normal faults, many of which are part of the larger north-trending fault zones; other faults trend approximately east and west across the major faults.

Thrust faulting is less common than normal faulting in the central Sevier Valley. Spieker (1949, p. 53) reported a series of strip thrusts in the area east of Redmond which involve the Arapien, Flagstaff, Colton, Green River, and Crazy Hollow Formations. (See pl. 1, cross section *D–D′*.)

VALLEY BASINS

Faulting, volcanism, intrusions, and stream action have shaped the valley floor and created several basins within the main central Sevier Valley graben. (See pl. 1, longitudinal section *E–E′*.) The Sevier River and its tributaries have deposited more than 800 feet of partly sorted alluvium in some of the basins, and this alluvium is the main source of ground water in the central Sevier Valley.

JUNCTION-MARYSVALE BASIN

The segment of the central Sevier Valley from the constriction of the valley at Kingston to the head of Marysvale Canyon is called the Junction-Marysvale basin. (See pl. 2.) The basin is divided into two subbasins by a bedrock constriction in the valley near Piute Dam (sec. 3, T. 29 S., R. 3 W.): one subbasin is in the vicinity of Junction and Kingston, and the other extends from Piute Dam to the head of Marysvale Canyon.

The subbasin above Piute Dam is a small alluvium-filled basin that has an area of about 3 square miles. Bedrock is at or close to the surface throughout this subbasin, and the alluvium has a maximum thickness of about 80 feet. Test hole 21, (C–30–3)16 bab,[1] penetrated 81 feet of alluvium overlying a tuff.

The subbasin between Piute Dam and the head of Marysvale Canyon is cut in volcanics, the Sevier River Formation, and terrace deposits on both sides of the valley. The subbasin is 12 miles long and ranges in width from 100 yards to 1 mile. The intrusive barrier formed by the Antelope Range at the north end of this subbasin slowed the flow

[1] See pl. 5 for location of wells, springs, and test holes referred to in this report.

of the Sevier River, thereby causing the deposition of sediments. The maximum thickness of the sediments, however, is not known.

Downstream from the Junction-Marysvale basin, the river flows through a steep-sided narrow gorge known as Marysvale Canyon. The canyon is approximately 8 miles long, and its floor ranges in width from about 300 feet in many places to more than 2,000 feet in a few places. All parts of the canyon are covered with alluvium, which is generally thin.

SEVIER-SIGURD BASIN

The segment of the central Sevier Valley from the mouth of Marysvale Canyon near the town of Sevier to a constriction in the valley at Rockyford Reservoir (sec. 30, T. 22 S., R. 1 W.) is called the Sevier-Sigurd basin. The constriction is formed by a lava body on the east and by an uplifted block, overlain by unsorted alluvial-fan material from North and South Cedar Ridge Canyons, on the west. The basin, which is formed in a graben, is 25 miles long and ranges in width from 2 to 5 miles. The alluvium has a maximum thickness of more than 800 feet at Venice. Along the axis of the basin, the alluvium increases in thickness from a feather edge at the mouth of Marysvale Canyon to more than 800 feet at Venice and then decreases in thickness to 280 feet west of Rockyford Reservoir.

AURORA-REDMOND BASIN

The segment of the central Sevier Valley from Rockyford Reservoir to the southernmost margin of the Redmond Hills anticline is called the Aurora-Redmond basin. It is 9 miles long and averages 3 miles in width. Across the basin the alluvium ranges in thickness from a feather edge on the valley margins to more than 660 feet east of Aurora. Along the axis of the basin, the alluvium increases in thickness from a feather edge at the Redmond Hills to 200 feet west of Salina and to a known maximum of 660 feet east of Aurora; it then decreases in thickness to 360 feet north of Rockyford Reservoir. The basin contains at least three layers of clay that appear to have been laid down by the Sevier River and its tributaries in lakes or ponds created by the obstruction formed by the Redmond Hills anticline.

REDMOND-GUNNISON BASIN

The Redmond-Gunnison basin is a Y-shaped depression; its northwest leg extends down the Sevier Valley to about 3 miles northwest from Gunnison, and its northeast leg extends about 7 miles up the San Pitch River northeastward from Gunnison to the Gunnison Reservoir. The basin is 12 miles long and ranges in width from 3 to 8 miles. The downstream boundaries are marked by the northernmost outcrops of the Arapien Shale in the project area. These outcrops are near the

Gunnison Reservoir dam and also about 2 miles west of Gunnison. (See pl. 1.) The outcrop of Arapien Shale west of Gunnison marks the probable northern limit of the Redmond Hills anticline which underlies the western part of the valley. Across the basin the alluvium ranges in thickness from a feather edge along the valley margins to 120 feet about 2 miles west of Centerfield and to 250 feet in the Willow Creek alluvial fan near Axtell. Along the valley bottom the alluvium ranges in thickness from a feather edge at the Redmond Hills and at the Gunnison Reservoir dam to 50 feet along the San Pitch River channel, to 120 feet west of Centerfield, and to a known maximum of 320 feet about 3 miles west of Gunnison.

GUNNISON-SEVIER BRIDGE RESERVOIR BASIN

The Gunnison–Sevier Bridge Reservoir basin extends from 3 miles northwest of Gunnison to the Yuba Dam (sec. 1, T. 17 S., R. 2 W.). The basin is about 18 miles long and averages about 3 miles in width. The basin consists of two subbasins, one above and one below the Sevier Bridge Reservoir narrows (sec. 27, T. 17 S., R. 1 W.). (See pl. 2.) Across the upper subbasin the alluvium ranges in thickness from a feather edge at the valley margins to 500 feet near Fayette. Along the axis of the subbasin, the alluvium increases in thickness from a feather edge at the Sevier Bridge Reservoir narrows to 500 feet near Fayette and then decreases to 320 feet 3 miles northwest of Gunnison. The alluvium in the upper subbasin appears to consist of fine-grained material which was deposited in a lake retained by a bedrock constriction across the valley at the Sevier Bridge Reservoir narrows. Little is known of the extent and thickness of the valley fill in the lower subbasin because this part of the valley is usually covered by water in the reservoir. The alluvium is probably thin, however, because bedrock is exposed at the extreme downstream end of the reservoir in the vicinity of the Yuba Dam.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PRE-QUATERNARY DEPOSITS

The pre-Quaternary deposits are exposed mainly in the mountains and plateaus bordering the central Sevier Valley floor (pl. 1). These deposits consist largely of consolidated sedimentary and igneous rocks which accept recharge but do not yield water readily to wells and springs. Most of the pre-Quaternary formations underlying the alluvial fill in the valley are too deep beneath land surface for consideration as sources of water. A few formations, however, do yield water to wells in the valley and to springs at the edges of the valley floor.

SEDIMENTARY ROCKS

The most permeable pre-Quaternary water-bearing sedimentary rocks in the project area are the Navajo Sandstone, the North Horn Formation, the Flagstaff Limestone, the Crazy Hollow Formation of Spieker (1949), the Dipping Vat Formation of McGookey (1960), and the Sevier River Formation. The formations that generally are least permeable are the Arapien Shale, the Morrison(?) Formation, the Indianola Group, the Price River Formation, the Colton Formation, the Green River Formation, and the Bald Knoll Formation of Gilliland (1951).

Navajo Sandstone.—The Navajo Sandstone, of Triassic(?) and Jurassic age, generally is very permeable, but it lies too deep beneath the floor of the central Sevier Valley to be of importance as a source of water. The only place in the project area where the Navajo is exposed at the surface is in the upthrown block west of the Tushar fault, southwest of Marysvale. (See pl. 1.)

North Horn Formation.—The North Horn Formation, of Late Cretaceous and Paleocene age, consists mainly of sandstone interbedded with some conglomerate and shale. It is exposed mainly in the Pavant Range and Valley Mountains and in the Wasatch and Gunnison Plateaus. Where it is fractured, the formation readily yields water to wells. Several wells have obtained large yields from this formation in areas adjacent to the project area. The North Horn lies too deep beneath the central Sevier Valley floor, however, for present consideration as a source of water.

Flagstaff Limestone.—The Flagstaff Limestone, of Late Paleocene and Early Eocene(?) age, consists of limestone, siltstone, and sandstone. It is exposed in the Pavant Range and Valley Mountains and in the Wasatch and Gunnison Plateaus. The Flagstaff is a good aquifer where it contains solution channels. No wells are known that penetrate the limestone, but many springs discharge from it in the Wasatch and Gunnison Plateaus. Fayette Spring, (D–18–1)19dab, has an average discharge of about 1,900 gpm (gallons per minute) from solution channels in the Flagstaff, and the flows from this spring and from others maintain the base flow of several streams that are tributary to the Sevier River.

Crazy Hollow Formation of Spieker (1949).—The Crazy Hollow Formation of Spieker (1949), of late Eocene age, consists mostly of sandstone, and it is exposed in isolated spots bordering the east and west sides of the valley north of Richfield. The formation is relatively permeable, but it lies too deep beneath the valley floor for present consideration as a source of water. Richfield Spring, (C–23–3)26aca, is reported to yield about 1,400 gpm from the Crazy Hollow where the eastward dipping formation is offset by the Elsinore fault.

Dipping Vat Formation of McGookey (1960).—The Dipping Vat Formation of McGookey (1960), of Eocene age, is an evenly bedded tuffaceous sandstone with spare lenses of clay and silty limestone and beds of friable glassy sand which are apparently very permeable. This formation is exposed along the margins of the valley north of Richfield and in the Redmond Hills. Although the Dipping Vat is not believed to be a significant water-bearing formation, it does accept recharge and transmit water to the valley fill.

Sevier River Formation.—The Sevier River Formation, of late Pliocene or early Pleistocene age, underlies the central Sevier Valley floor and is exposed nearly the whole length of the valley in places on both the east and west margins. It is generally a fanglomerate consisting of silt, sand, gravel, cobbles, and boulders which are very poorly sorted. Some permeable zones in the formation yield small to moderate amounts of water to domestic and stock wells. The formation yields water to many small springs and seeps along the bluffs on the west side of the valley between the mouth of Tenmile Creek and Marysvale at the contact between the Sevier River Formation and an underlying impermeable volcanic tuff. A narrow stand of willows, greasewood, and grass along the contact marks the seepage area. In other areas, where this contact is not exposed, water moving through the Sevier River Formation discharges directly into the alluvium; where the Sevier River Formation is underlain by more permeable formations, it acts as a confining medium.

IGNEOUS ROCKS

Igneous rocks of Miocene(?) and Pliocene(?) age underlie extensive tracts in the southern two-thirds of the project area in the Pavant and Antelope Ranges and Tushar Mountains and in the Sevier and Fishlake Plateaus. The igneous rocks are designated on the geologic map (pl. 1) as intrusive rocks and as volcanic rocks. The intrusives and most of the extrusives are very poor aquifers. Some extrusive volcanic rocks, however, yield water to springs. Only a few wells have been drilled into the Tertiary volcanic rocks because of rugged terrane, cost, and the uncertainty of penetrating water-yielding zones. The extrusive volcanic rocks that are most likely to yield water are the Dry Hollow Formation and some of the basalt flows.

Dry Hollow Formation.—The Dry Hollow Formation, of Pliocene(?) age, contains joints, cracks, and elongate vesicles which permit movement of water. Springs throughout the Pavant Range and Tushar Mountains and on the Sevier and Fishlake Plateaus discharge water from this formation and furnish water to maintain the base flow of many streams such as Clear Creek, Monroe Creek, and Lost Creek. The municipal supplies for Joseph, Elsinore, Monroe, and Salina come from springs issuing from the Dry Hollow Formation.

Basalt flows.—Some of the undifferentiated basalt flows in the project area consist of blocks of basalt separated by large openings through which water can readily move. Many contact springs issue from the basalt where the basalt overlies relatively impermeable formations. Glenwood Spring, (C-23-2)36cbd, Parcell Creek Spring, (C-23-2)25cca, and Indian Creek Spring, (C-23-2)25bdb, issue from the basalt at its contact with the underlying Arapien Shale.

QUATERNARY DEPOSITS

TERRACE GRAVEL

Terrace gravel covers benches from Piute Dam to the head of Marysvale Canyon between the base of the Tushar Mountains and the Sevier River, and it forms terraces on the north end of the hills between Monroe and Joseph and on the flanks of the Redmond Hills. The gravel was deposited by the ancestral Sevier River and its tributaries.

The gravel deposits on the benches south of Marysvale range from a featheredge to 50 feet in thickness, and they overlie the Sevier River Formation and a white tuffaceous clay of Tertiary age. The gravel contains materials ranging in size from fine sand to boulders 12 inches or more in diameter; and it consists mainly of volcanic fragments derived from the surrounding mountains, although it includes some quartzite, limestone, and shale pebbles. The particles of sedimentary origin are well rounded, and they were probably reworked from gravel that underlies the lavas in the central Sevier Valley area. The gravel derived from volcanic rocks is subangular to well rounded. Sorting is poor.

The terrace gravel south of Marysvale generally is well drained by springs issuing along the contact between gravel and the underlying formations, but it yields small amounts of water to a number of shallow stock and domestic wells on the bench.

The terrace gravel between Monroe and Joseph forms three terraces on the hills and blends into the alluvium down the slope. As in the Marysvale area, this gravel is derived mainly from volcanic rocks, and it is poorly sorted. It contains particles that range in size from fine sand to small cobbles. This gravel is not tapped by wells, and its water-yielding potential is unknown. Springs do not issue along the base of the gravel because water in the gravel is able to move downslope into the younger alluvium.

The terrace gravel on the Redmond Hills was raised to its present position by the uplift of underlying materials. It consists mainly of rocks of volcanic origin; but in the southern part of the Redmond Hills, the gravel contains a large percentage of black chert pebbles which are ¼–1½ inches in diameter. The gravel contains particles ranging in size from fine sand to cobbles which are 6–8 inches in diameter. Sand lenses alternate with sandy gravel lenses; some of the beds contain layers of clay and clay balls, ranging from ½ to 3 feet in thickness, derived from the clays exposed in the center of the Redmond Hills, and in places the beds are cemented by caliche. Water in the terrace gravel on the Redmond Hills drains directly into the alluvium; hence, the gravel has little potential as a ground-water reservoir in the areas of exposure.

LANDSLIDE DEPOSITS

Three large landslides are shown on the geologic map (pl. 1). They consist of boulders and blocks of lava which have broken from the scarp of the Sevier fault and moved down slope. The original soil mantle and weathered material from the clastic beds within the volcanics forms the finer parts of the slides and fills the spaces between the blocks. The surfaces of the slides are irregular and contain many small depressions which provide opportunity for infiltration of water. Springs along the toe of some of the slides indicate that the slides have some internal drainage, but because of poor sorting the slide material probably would not yield water readily to wells.

ALLUVIAL DEPOSITS OF PLEISTOCENE AND RECENT AGE

The alluvium of Pleistocene and Recent age overlies the consolidated rocks in the central Sevier Valley floor throughout an area of about 300 square miles. These deposits include poorly sorted silt, sand, and gravel laid down in alluvial fans and well-sorted gravel, sand, silt, and clay deposited in lakes and basins. The deposits, as determined by test drilling, differ in thickness from basin to basin.

The alluvium is derived from consolidated rock formations in the uplands that surround the valley. South of Richfield, on the west side of the valley floor, and south of Lost Creek, on the east side, most of the alluvium is derived from volcanic rocks. North of these two localities the deposits consist mainly of material derived from sedimentary rocks.

The alluvial fans extend into the valley from the mouths of side canyons. They contain material ranging in size from fine sand to boulders several feet in diameter; and, because of their high permeability, the fans constitute excellent areas for recharge.

The well-sorted stream deposits are the best aquifers in the central Sevier Valley. The basins containing the largest deposits of well-sorted alluvium are Sevier-Sigurd, Aurora-Redmond, and Gunnison–

Sevier Bridge Reservoir, whereas Junction-Marysvale and Redmond-Gunnison contain lesser amounts. All these basins contain layers of gravel, sand, silt, and clay of varying thickness.

The fill in the Sevier-Sigurd basin has a maximum known depth of more than 800 feet, in well (C–23–2)10dcc–1; and it consists of interbedded silt, sand, and gravel, with the coarser material predominant in the eastern half of the basin (pl. 3). The gravel ranges in texture from very fine to very coarse, and it yields water freely to wells. About 50 percent of the alluvium in this basin is highly permeable.

The valley fill in the Aurora-Redmond basin consists of lacustrine deposits containing gravel, sand, silt, and clay. These deposits are more than 660 feet thick east of Aurora; they are fairly continuous; and they yield water freely to wells. About 60 percent of the alluvium in this basin is highly permeable.

The alluvium in the Gunnison-Sevier Bridge Reservior basin has a maximum known thickness of about 500 feet, near Fayette. Particles in the fill range in size from clay to gravel 1 inch in diameter; beds are fairly continuous; and the coarser materials are highly permeable. Although some of the sediments were deposited in Pleistocene lakes and are fine grained, about 40 percent of the deposits in this basin are highly permeable and would yield large amounts of water to wells.

The Junction-Marysvale and Redmond-Gunnison basins contain lesser amounts of permeable alluvium. The alluvium in the Redmond-Gunnison basin consists mainly of poorly sorted gravel, sand, silt, and clay. A strip about 1 mile wide along the Sevier River and a small section along the lower San Pitch River channel also contain gravel, in which the pebbles have a maximum diameter of 1 inch. These gravels yield moderate amounts of water to wells. The alluvium averages about 200 feet in thickness throughout most of the Redmond-Gunnison basin, and about 30 percent of the fill is highly permeable.

Little is known about the thickness, sorting, character, and water-yielding properties of the alluvium in the Junction-Marysvale basin. Few well logs are available, and only one test hole was drilled. The similarity of the surface features of this basin to those of the other basins suggests that several hundred feet of sediments may be present. Such a thickness of sediments undoubtedly would have some water-yielding zones. The one test hole drilled in the Junction-Kingston vicinity penetrated 80 feet of alluvium, of which about 50 percent was fairly permeable.

WATER RESOURCES

HISTORY AND DEVELOPMENT

The first settlements in the central Sevier Valley were established about 1850, and most irrigation canals and ditches were constructed by 1865. Irrigation development reached a maximum about 1920. As early as 1878 it was recognized that streamflow in the river was highly variable and that reservoirs would have to be constructed to use the water resources to best advantage. Controversies ensued over water rights as early as 1886, and many court decrees defining the rights on the Sevier River have been recorded. The most comprehensive and most recent is the Cox Decree of 1936 (Cox, 1936), which included the water rights on the entire Sevier River system. This decree was based largely upon field surveys by the Utah State Engineer and upon records of streamflow and water use made by the Sevier River Water Commissioners in cooperation with the U.S. Geological Survey.

Most of the data on water supply from the Sevier River have been collected since 1914, although there were many court decrees concerning water rights on the river before that time. During 1914 the U.S. Geological Survey and the Utah State Engineer agreed to install a stream-gaging network, part of which has been in operation since that time. All streamflow and reservoir records through 1960 have been summarized in two publications by the U.S. Geological Survey (1960, 1963).

Gaging stations maintained by the U.S. Geological Survey (U.S. Geol. Survey, 1958, p. 117–134) in 1960 in and near the central Sevier Valley are shown on plate 4 and are described as follows:

Station	*Location*
Sevier River near Kingston	NE¼NW¼ sec. 16, T. 30 S., R. 3 W.
East Fork Sevier River near Kingston	SW¼NW¼ sec. 13, T. 30 S., R. 3 W.
Sevier River below Piute Dam, near Marysvale	NW¼SE¼ sec. 34, T. 28 S., R. 3 W.
Clear Creek above diversions, near Sevier	NW¼SW¼ sec. 31, T. 25 S., R. 4 W.
Sevier River near Sigurd	SW¼ sec. 19, T. 22 S., R. 1 W.
Sevier River below San Pitch River, near Gunnison	NE¼ sec. 14, T. 19 S., R. 1 W.
Sevier River near Juab (below Sevier Bridge Reservoir)	SE¼ sec. 35, T. 16 S., R. 2 W.

The annual flow at the gaging stations on the Sevier River by water year since 1920 is shown in figure 3.

Annual reports on the distribution of the water of the river for most years have been prepared for the State Engineer by the Sevier River Water Commissioners and the U.S. Geological Survey. The records available since 1914 have been studied by engineers, lawyers, agriculturalists, and economists for planning the orderly use of water in the central Sevier Valley.

It became apparent soon after irrigation began in the central Sevier Valley that much of the water diverted and used for irrigation returned

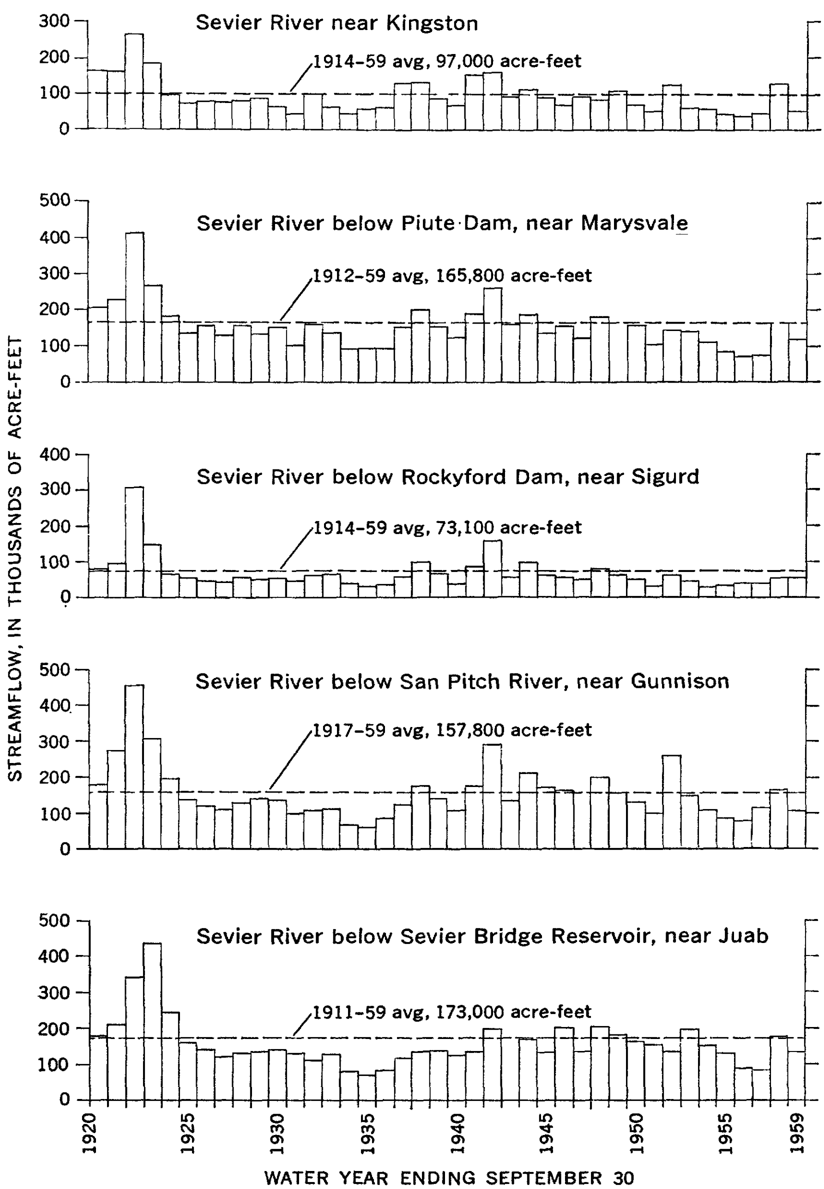

FIGURE 3.—Annual flow of the Sevier River at gaging stations in the central Sevier Valley.

to the river as discharge from springs and seeps, and made additional water available for diversion downstream. Return flow to the Sevier River is indicated by the increase in the flow of the river below the Annabella Canal diversion dam, Vermillion Canal diversion dam, and Rockyford Dam. These dams are shown on plate 5. The entire flow of the river is diverted at each of the dams at times during the irrigation season. In some reaches downstream from the dams, the increase in river flow during low-water periods is as much as was diverted at the dams.

The Cox Decree specified rights to ground water originating from springs, drains, and some wells. The well rights established in the decree are for irrigation wells only. Many other well-and-drainage water rights that include ground water for domestic, stock, industrial, and irrigation use are on file with the Utah State Engineer.

The Cox Decree made little mention of ground-water development from wells because it was assumed that unappropriated ground water did not exist in the central Sevier Valley. This assumption has persisted and has been a primary factor in the prevention of the large-scale development of ground water. Applications to the State Engineer for domestic and stock wells (limited to 6.75 gpm) have been approved, but requests for larger wells for irrigation have usually been refused.

SURFACE WATER

Surface water enters the central Sevier Valley from the Sevier River and two small canals near Kingston and from tributaries to the river within the valley. Surface water leaves the central Sevier Valley at Yuba Dam. Within the valley, surface water is stored principally in two reservoirs and is diverted from the river and from main tributaries by numerous canals. The complex system of diversions makes it difficult to consider fully any one part of the surface-water system without considering the rest; but each part will be discussed in turn, and then the effects of tributaries, main stem, and diversions on the regimen of the full surface-water system will be presented.

SEVIER RIVER

The Sevier River is fed chiefly from sources in the high plateaus south of the project area. Within the central Sevier Valley the river receives water from intermittent and perennial flow of tributary streams and from ground-water discharge, including return flow of water diverted from the river for irrigation. During 1914–59 the average annual inflow to the central Sevier Valley in the Sevier River near Kingston was 97,000 acre-feet, and the average annual outflow below Yuba Dam during 1911–59 was 173,000 acre-feet. The annual flow at these and other stations on the Sevier River is given in figure 3.

TRIBUTARIES

Runoff is intermittent in many of the tributaries of the Sevier River. The tributaries are fed almost entirely by precipitation on mountain watersheds, principally in the form of snow, and runoff is heaviest in late spring and early summer.

The perennial tributaries are sustained by precipitation, reservoir releases, and ground-water discharge. The drainage basins of the principal perennial tributaries range in area from 13 square miles for Deer Creek to 1,260 square miles for East Fork Sevier River, and the tributaries range in length from 6 miles for Water Canyon Creek to 75 miles for East Fork Sevier River. Table 2 lists the principal perennial streams entering the central Sevier Valley and gives information as to the approximate extent of the drainage areas, the water-storage facilities, the use and disposition of the water, and the discharge data.

Only during periods of spring runoff does any appreciable amount of streamflow reach the Sevier River from tributaries other than East Fork Sevier River, Clear Creek, Lost Creek, and Salina Creek. Many other tributaries contribute small quantities of water to the Sevier River, but the amount is not known. Much water in the tributaries does not reach the Sevier River because it is diverted and used for irrigation. Some of the diverted water, however, returns to the streams below diversion points as return flow from irrigation. (See table 2.)

The pattern of flow fluctuation above diversions in all perennial streams in the area is similar in that it increases owing to snowmelt usually early in spring, reaches a peak flow in late spring, and then recedes to base flow, which it usually reaches at midsummer. During the remainder of the year—late summer, fall, and winter—the streamflow depends mostly on ground-water discharge and is more consistent. Periods of excessive precipitation and drought increase and decrease both the snowmelt runoff and the base flow. The general pattern of flow fluctuation of perennial streams in the central Sevier Valley is illustrated in figure 4 by the hydrograph of Clear Creek.

RESERVOIRS

The total surface-water storage capacity within the project area is about 312,000 acre-feet. Piute Reservoir, constructed below the confluence of the East Fork Sevier River and the Sevier River in 1910, has a maximum capacity of about 74,000 acre-feet. Rockyford

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TABLE 2.—*Principal perennial streams entering the central Sevier Valley*

[See pl. 5 for location of streams]

Stream	Approximate drainage area (sq mi)	Approximate length (miles)	Direct contribution to the Sevier River	Remarks
Sevier River near Kingston.	1,110	50	Average annual flow near Kingston, 1914–59, 97,000 acre-feet.	
East Fork Sevier River near Kingston.	1,260	75	Average annual flow near Kingston, 1913–59, 60,670 acre-feet (85 cfs), most of which reaches the Sevier River.	Otter Creek Reservoir, capacity 52,500 acre-feet, and several smaller reservoirs store and regulate water. Many diversions for irrigation include one transmountain diversion.
City Creek	20	10	During the nonirrigation season and periods of high runoff, some flow reaches Piute Reservoir.	Entire flow used for irrigation in vicinity of Junction during irrigation season. Estimated average base flow above diversions, about 3,700 acre-feet (5 cfs).
Tenmile Creek	18	9	During the nonirrigation season and periods of high runoff, some flow reaches the Sevier River.	Entire flow used to irrigate approximately 120 acres during irrigation season. Estimated average base flow above diversions, about 1,500 acre-feet (2 cfs).
Manning Creek	30	11	do	Entire flow used to irrigate approximately 285 acres during irrigation season. Estimated average base flow above diversions, about 3,700 acre-feet (5 cfs).
Cottonwood Creek	20	10	do	Entire flow used to irrigate approximately 1,310 acres during irrigation season. Estimated average base flow above diversions, about 2,200 acre-feet (3 cfs).
Pine Creek (locally called Bullion Creek).	25	11	do	Entire flow used to irrigate approximately 1,575 acres during irrigation season. Estimated average base flow above diversions, about 3,700 acre-feet (5 cfs).
Beaver Creek	17	11	do	Entire flow used to irrigate approximately 525 acres during irrigation season. Estimated average base flow above diversions, about 2,900 acre-feet (4 cfs).
Deer Creek	13	8	do	Entire flow used to irrigate approximately 14 acres during irrigation season. Estimated average base flow above diversions, about 1,500 acre-feet (2 cfs).
Clear Creek	160	16	Average annual flow below diversions, 1912–17 and 1940–58, 22,440 acre-feet (31 cfs).	Several small reservoirs store and regulate water. Several diversions irrigate approximately 1,750 acres. Average base flow below diversions, about 4,400 acre-feet (6 cfs).
Monroe Creek	56	10	Seldom contributes flow directly to the Sevier River, even during peiods of high runoff.	Entire flow used to irrigate approximately 1,600 acres. Estimated average base flow above diversions, about 4,400 acre-feet (6 cfs).
Water Canyon Creek.	26	6	Seldom contributes flow directly to the Sevier River.	Entire flow used to irrigate approximately 37 acres. Estimated average base flow above diversions, about 700 acre-feet (1 cfs).
Lost Creek	110	18	During the nonirrigation season and periods of high runoff, some flow reaches the Sevier River. Gains about 1 cfs below diversions.	Several small reservoirs store and regulate water. Nearly all flow is diverted to irrigate approximately 2,100 acres. Estimated average base flow above diversions, about 4,400 acre-feet (6 cfs).

TABLE 2.—*Principal perennial streams entering the central Sevier Valley*—Con.

Stream	Approximate drainage area (sq mi)	Approximate length (miles)	Direct contribution to the Sevier River	Remarks
Salina Creek	300	32	Average annual flow below diversions, 1917–19 and 1943–55, 14,000 acre-feet (19.4 cfs).	Numerous small reservoirs and diversions store and regulate water. Nearly all flow is diverted to irrigate approximately 9,800 acres. Estimated average base flow above diversions, about 6,600 acre-feet (9 cfs).
Willow Creek	50	15	Seldom contributes flow directly to the Sevier River.	One small reservoir of approximately 580 acre-feet capacity stores and regulates water. Entire flow is diverted to irrigate approximately 1,250 acres. Estimated average base flow above diversions, about 1,500 acre-feet (2 cfs).
San Pitch River	890	60	During most years no flow reaches the Sevier River. During 1958, 28,760 acre-feet flowed into the Sevier River.	Many reservoirs and diversions are used to irrigate approximately 89,500 acres in the Sanpete Valley northeast of the project area and in the northeastern part of the central Sevier Valley. Estimated average annual flow into the central Sevier Valley through diversions, about 30,000 acre-feet (40 cfs). Estimates include Sixmile and Twelvemile Creeks.

Reservoir, near Sigurd, is a small regulating reservoir which has a maximum storage capacity of about 2,000 acre-feet. Sevier Bridge Reservoir, northwest of Fayette in the north end of the project area, is the largest reservoir on the Sevier River. It was constructed in 1904 and has a maximum capacity of about 236,000 acre-feet. The maximum and minimum quantities of water stored in Piute and Sevier Bridge Reservoirs for the 1956–60 water years [2] are as follows:

	Piute Reservoir		*Sevier Bridge Reservoir*	
Water year	*Maximum (acre-feet)*	*Minimum (acre-feet)*	*Maximum (acre-feet)*	*Minimum (acre-feet)*
1956	28, 760	150	74, 390	1, 810
1957	28, 320	196	70, 850	3, 540
1958	74, 010	<800	134, 400	25, 790
1959	55, 310	4, 640	108, 400	4, 620
1960	28, 910	0	70, 850	0

IRRIGATION CANALS AND DITCHES

Irrigation canals and ditches in the central Sevier Valley tap the Sevier River at intervals along its course and tap its tributaries near the mouths of their canyons. More than 60 irrigation companies

[2] The water year refers to the period between September 30 of the year stated and October 1 of the previous year.

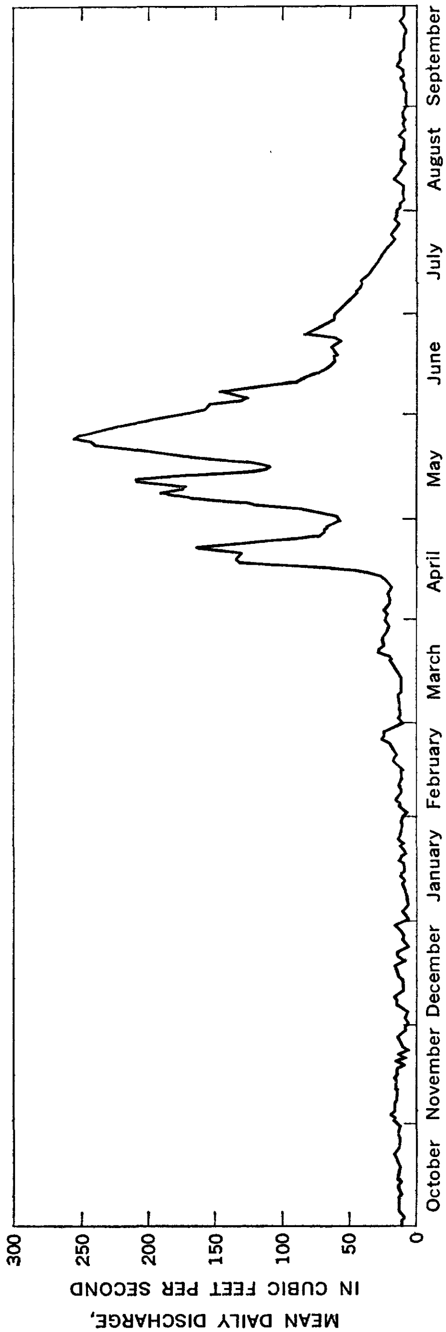

FIGURE 4.—Discharge of Clear Creek above diversions, near Sevier, for water year 1958.

TABLE 3.—*Gains and losses, in acre-feet, of the Sevier River between Kingston and Sevier Bridge Reservoir for the water years 1957–60*

[All information obtained from U.S. Geol. Survey Water-Supply Papers or from Sevier River Commissioners Annual Reports unless otherwise noted. For location of canal diversion points, see pl. 4]

Segment[1]	Water year ending September 30											
	1957			1958			1959			1960		
	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)
From Kingston to Piute Dam												
Sevier River near Kingston	45,970			127,000			53,500			36,810		
Junction Canal	4,300			4,050			4,220			4,430		
Junction Middle Ditch	2,060			1,540			1,750			1,800		
East Fork Sevier River near Kingston	33,370			67,410			42,870			39,900		
Allen Ditch		890			900			940			1,170	
Kingston Main Canal		5,300			4,840			5,510			5,670	
Nielson-Howes Ditch		1,500			930			1,380			1,560	
Sevier River below Piute Dam		76,530			166,300			120,300			85,040	
Change in storage in Piute Reservoir		+1,400			+23,880			−20,920			−4,610	
Total	85,700	85,620		200,000	196,850		102,340	107,210		82,940	88,830	
Gain results principally from Barnson Springs and City Creek. Loss probably due to an ungaged canal diversion from East Fork and to evapotranspiration			−80			−3,150			+4,870			+5,890
From Piute Dam to Sevier												
Sevier River below Piute Dam	76,530			166,300			120,300			85,040		
Sevier River near Sevier (estimated)[2]		84,630			196,300			123,900			92,640	
Total	76,530	84,630		166,300	196,300		120,300	132,900		85,040	92,640	
Gain results principally from tributaries and from ground water from Taylor Pond Springs			+8,100			+30,000			+12,600			+7,600

See footnotes at end of table.

Table 3.—*Gains and losses, in acre-feet, of the Sevier River between Kingston and Sevier Bridge Reservoir for the water years 1957–60*—Con.

Segment[1]	Water year ending September 30											
	1957			1958			1959			1960		
	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)	Inflow	Outflow	Gain (+) or loss (−)
From Sevier to Sigurd												
Sevier River near Sevier (estimated)[2]	84,630			196,300			132,900			92,640		
Clear Creek near Sevier (after diversions to the Clear Creek and Joseph-Cove Highline Canals)	33,180			25,320			5,440			10,030		
Monroe-South Bend Canal		15,020			18,210			15,510			12,970	
Sevier Valley-Piute Canal		33,130			75,200			48,750			32,710	
Joseph Canal		4,620			7,060			3,960			3,590	
Wells Canal		1,720			2,560			1,530			1,440	
Isaacson Ditch		410			370			270			250	
Monroe Canal		9,020			14,370			9,020			7,580	
Elsinore Canal		3,380			5,080			3,490			2,890	
Brooklyn Canal		6,190			9,690			5,150			4,630	
Richfield Canal		19,800			29,400			15,940			14,160	
Annabella Canal		5,640			7,510			4,510			4,140	
Vermillion Canal		9,920			15,470			7,090			7,430	
Rockyford-Willow Bend Canal		16,730			18,800			16,660			15,330	
Sevier River near Sigurd (below Rockyford Dam)		38,510			54,940			54,720			42,910	
Total	117,810	164,090		221,620	258,660		138,340	186,600		102,670	150,030	
Gain results almost entirely from ground water and return flow coming from artesian springs and drains in the area east of Richfield			+46,280			+37,040			+48,260			+47,360

From Sigurd to Gunnison												
Sevier River near Sigurd (below Rockyford Dam)	38, 510			54, 940			54, 720			42, 910		
Westview Canal		7, 660			7, 420			6, 220			6, 080	
Gunnison-Fayette Canal		10, 420			9, 290			7, 620			7, 860	
Dover Canal		3, 770			3, 390			2, 680			2, 680	
Sevier River below San Pitch River, near Gunnison		117, 700			166, 700			108, 700			84, 910	
Total	38, 510	139, 550		54, 940	186, 800		54, 720	125, 220		42, 910	101, 530	
Gain results from tributaries, ground water, and return flow. Tributaries are Lost Creek, Salina Creek, and the San Pitch River. Ground water and return flow comes from Redmond Lake, flowing wells, and numerous drains			+101, 040			+131, 860			+70, 500			+58, 620
From Gunnison to Juab (below Yuba Dam)												
Sevier River below San Pitch River, near Gunnison	117, 700			166, 700			108, 700			84, 910		
Sevier River near Juab (below Yuba Dam)		86, 610			175, 600			134, 400			96, 930	
Change in storage in Sevier Bridge Reservoir		+36, 300			−8, 960			−24, 010			−4, 540	
Total	117, 700	122, 910		166, 700	166, 640		108, 700	110, 390		84, 910	92, 390	
Gains or losses are net results of gains from ground water and return flow (principally from flowing wells and sloughs) and losses from evapotranspiration (principally from Sevier Bridge Reservoir)			+5, 210			−60			+1, 690			+7, 480

[1] The actual boundaries of the segments were at gaging-station sites; but for convenience in description, prominent nearby geographic points were used.

[2] Estimated by correlation of past records of gain between Piute Dam and Sevier with inflow to Piute Reservoir.

maintain about 300 miles of canals in the central Sevier Valley. Individual canals range in length from less than 2 miles to more than 50 miles. Most of the canals are excavated in and constructed of natural earth materials, but some are lined with concrete in places to prevent loss of water by seepage. The principal canals that divert from the Sevier River and its tributaries between Kingston and Sevier Bridge Reservoir are shown on plate 4.

GAINS AND LOSSES TO THE SEVIER RIVER

The river gains and loses water in many places along its course through the central Sevier Valley. Water gain is from tributaries, drains, springs, seeps, and, to a slight extent, from direct precipitation. Water loss is by diversion into canals for irrigation, by evaporation along the river's course and in reservoirs, and by transpiration where vegetation grows along the banks. In places the stream loses water by seepage into its channel and banks.

The gains and losses between Kingston and Sevier Bridge Reservoir are summarized in table 3 for water years 1957–60. The only tributaries included in table 3 that have gaging stations are Clear Creek and East Fork Sevier River. The flow from unmeasured tributaries, however, is included in the measured flow of the river at many stations along its course. Table 3 includes data for quantities of water diverted from the river into 16 canals. This water is a loss to the stream at the point of diversion; but part of it, probably less than 30 percent, seeps to the ground-water reservoir and eventually returns to the river downstream from the point of diversion. Losses by evapotranspiration, as such, are not included in table 3. Much of the water diverted into canals, however, is eventually consumed by evapotranspiration.

Table 3 shows the gains and losses of the Sevier River as indicated by measured inflow, flow at intervals along the stream, measured diversions, and changes in surface-water storage, all listed in downstream order. The table gives gains and losses to and from the river within five segments of the central Sevier Valley. These segments of the valley are similar to but not identical with the respective valley basins described above in the section on structure.

A slight overall loss of water in the Sevier River from Kingston to Piute Dam is indicated in table 3 for the years 1957 and 1958 when Piute Reservoir was gaining storage, and a gain is indicated for the years 1959 and 1960 when the reservoir was losing storage. The loss was primarily due to bank storage, evapotranspiration, and a small unmeasured diversion from East Fork Sevier River. The gain was largely due to release from bank storage and to ungaged flow from

City Creek and Barnson Springs, (C–29–3)16ccb. The flow from Barnson Springs decreases when Piute Reservoir is nearly full because the springs are then inundated under several feet of water, and the pressure of this water reduces the hydraulic head which causes water to flow from the springs.

A consistent gain of water in the reach from Piute Dam to Sevier is indicated in table 3. This gain is derived principally from the various tributaries to the river and from Taylor Pond Springs, (C–27–3)17dcb. The contribution of water from tributaries varies considerably from year to year, depending upon the amount of precipitation in the drainage area of the tributary.

A consistent gain in the Sevier River is indicated for the reach from Sevier to Sigurd, and the data in table 3 indicate that during some years more water is diverted for irrigation within the reach than enters at the upstream end. This gain is mainly due to accretion of ground water, including return flow from irrigation. Actually the diversion to the Vermillion and Rockyford-Willow Bend Canals is almost entirely return flow from water diverted upstream.[3] A more detailed study of this segment of the valley is given below in the section, "Inflow-outflow analysis of the Sevier-Sigurd basin."

A consistent gain each year is also shown in the reach from Sigurd to Gunnison, and it is partly due to inflow from tributaries and partly due to the discharge of ground water that is caused largely by return flow from irrigation. The quantity of water contributed by tributaries varies widely from year to year because of changes in the amount of precipitation, whereas the ground-water discharge, which locally includes considerable return flow, is more consistent. The diversions to the Westview, Gunnison-Fayette, and Dover Canals consists largely of return flow.[3] The large gains in 1957 and 1958 are attributed mainly to the larger than usual flows in Salina Creek and the San Pitch River.

A small gain is indicated in table 3 during each year except 1958 in the reach of the river from Gunnison to Juab. The gains are largely attributed to springs and flowing wells in the upper end of the Sevier Bridge Reservoir. The quantity of water discharged from these springs and wells is decreased when they are inundated by the reservoir; and this accounts in part for the loss and small gain in 1958

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[3] Much of this water has been used for irrigation upstream. Consequently, it has a greater dissolved mineral content and is less desirable for irrigation than water that has not been used—such as water derived directly from snowmelt and springs in the mountains. The rights to the water derived from return flow, however, are considered among the best in the valley because the supply is dependable late in the irrigation season when most streamflow is usually low and reservoirs may be nearly empty.

and 1959, respectively, as compared to the comparatively large gains in 1957 and 1960, when the reservoir contained less water. The loss indicated in 1958 may also be attributed in part to evapotranspiration and to changes in bank storage.

GROUND WATER

PRINCIPLES OF GROUND-WATER OCCURRENCE

Water that fills the openings in consolidated and unconsolidated rocks in zones of saturation of the earth is called ground water. In consolidated rocks the most common openings are fractures, although some granular rocks contain water in pore spaces between grains, and other rocks have solution cavities that contain water. In unconsolidated deposits the openings are between rock particles. Rock formations that yield water readily to wells are called aquifers.

Water in an aquifer may occur under either confined (artesian) or unconfined (water-table) conditions. Artesian conditions occur where a permeable bed, such as gravel, is overlain and underlain by less permeable (confining) beds, such as clay. Because it is confined, the water in the permeable bed is under pressure. If the hydrostatic pressure is sufficient to cause the water to flow at the ground surface from a well penetrating such a bed, the well is a flowing artesian well. If the hydrostatic pressure is not sufficient to cause the water to flow at the surface, the well is a nonflowing artesian well. The height to which the pressure can raise the water is called the pressure head, or simply, the head. The imaginary surface formed by pressure heads is called the piezometric surface.

In unconfined conditions the upper surface of the zone of saturation is defined as the water table. The water level in wells penetrating deposits that are under water-table conditions indicates the position of the water table below land surface. The water table is not a plane surface. It is usually an irregular sloping surface, and ground water moves in the aquifer in the direction of the slope of the water table. If the pressure head in an artesian aquifer declines to a point below the overlying confining bed, water-table conditions will result.

Most of the available ground water in the central Sevier Valley is in the coarse sand and gravel of the unconsolidated deposits in the various ground-water basins. The ground water occurs under both artesian and water-table conditions. The consolidated bedrock formations do contain some ground water in places, but the rocks are generally ground-water barriers, retarding underflow from basin to basin.

SOURCE OF GROUND WATER

The source of almost all the water in the central Sevier Valley is precipitation within the drainage basin.[4] Water that reaches the land surface as precipitation either (a) evaporates into the atmosphere; (b) is transpired by plants into the atmosphere; (c) seeps into the ground, where some is retained as soil moisture; (d) percolates downward to the zone of saturation and becomes part of the ground-water reservoir; (e) leaves the area as streamflow; or (f) leaves the area as subsurface flow.

AQUIFER CHARACTERISTICS

The amount of ground water that can be developed from an aquifer and the effects of development in a basin depend upon the hydraulic characteristics of the aquifer as well as its extent and saturated thickness. The principal hydraulic properties of an aquifer are its ability to store water, expressed by a coefficient of storage, and its ability to transmit water, expressed by a coefficient of permeability.

The coefficient of storage of an aquifer is defined as the volume of water that the aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. In a saturated rock the ratio of the volume of the rock to the volume of water that the rock will yield by gravity is called specific yield. Under water-table conditions, for all practical purposes, the coefficient of storage is equivalent to the specific yield.

The field coefficient of permeability is expressed as the number of gallons per day, at the prevailing temperature, that is transmitted through a cross section 1 foot high and 1 mile wide under a hydraulic gradient of 1 foot per mile. The field coefficient of transmissibility is the product of the field coefficient of permeability and the thickness of the aquifer, in feet, and it is expressed in gallons per day per foot. Knowledge of the coefficients of storage and transmissibility will help in determining, among other things, the magnitude, rate, extent, and significance of the lowering of water levels in an aquifer caused by a discharging well.

The methods used to determine the hydraulic characteristics of the aquifers during this study were the discharging-well methods described by Wenzel (1942, p. 95–97), the flowing-well method of Jacob and Lohman (1952), and a method based on the cyclic fluctuations of water levels described by Ferris (1952). The results of aquifer tests are summarized in table 4.

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[4] During the period 1950–58, an average of 10,300 acre-feet was diverted annually by diversion ditches or tunnels from the Colorado Basin to the headwaters of the San Pitch River. By contrast, an average annual rainfall of 10 inches would yield approximately 2.6 million acre-feet annually in the Sevier Basin above the Yuba Dam.

TABLE 4.—*Results of aquifer tests in the central Sevier Valley*

Basin	Well	Field coefficient of transmissibility (gpd per ft)	Coefficient of storage	Reference to method used
Junction-Marysvale	(C-30-3)15bba-1	150,000	0.20	Ferris (1952).
Sevier-Sigurd	(C-23-2)29bbc-1	300,000	.0001	Wenzel (1942, p. 95-97).
	(C-23-2)31dcb-3	900,000	.001	Do.
	(C-23-2)34aba-1	15,000		Jacob and Lohman (1952).
	(C-23-3)25bab-1	20,000		Wenzel (1942, p. 95-97).
	(C-24-3)12bda-1	900,000	.001	Do.
	(C-25-4)32aba-2	4,000	.20	Ferris (1952).
Aurora-Redmond	(C-21-1)13abd-1	20,000		Jacob and Lohman (1952).

A wide range of values for the aquifer properties is shown in table 4. This is common in areas filled with alluvium having varying degrees of sorting. The wide range in the coefficients of storage indicates that water occurs under artesian, partial artesian, and water-table conditions. Under artesian conditions, the coefficient of storage ranges from about 0.00005 to 0.005, and under water-table conditions it ranges from about 0.05 to 0.30. Thus the well in the Junction-Marysvale basin and one well in the Sevier-Sigurd basin, (C–25–4)32aba–2, are both water-table wells; one well in the Sevier-Sigurd basin, (C–23–2)29bbc–1, is an artesian well; and the two other wells for which storage coefficients were determined in the Sevier-Sigurd basin topped water under partial artesian pressure.

ESTIMATE OF GROUND-WATER STORAGE

The storage capacity of a ground-water reservoir can be determined if the areal extent, the saturated thickness, and the average storage coefficient of the aquifer are known.

The areal extent and thickness of the aquifers in the central Sevier Valley were delineated by test drilling. The estimated average storage coefficients assigned to the sand and gravel composing the principal aquifers of the area range from 0.15 to 0.20. The area underlain by the aquifer, multiplied by the saturated thickness of permeable materials, multiplied by the assigned average storage coefficient, gives an estimate of the amount of ground water that can be released by gravity from storage in the sand and gravel deposits of the alluvium. Table 5 summarizes the estimated storage of ground water in the sand and gravel deposits of the alluvium in the various ground-water basins. The total of 1,500,000 acre-feet estimated for the sand and gravel deposits probably represents only about half of the total quantity of ground water stored in the valley fill. The other half is in silt and clay which will not readily yield water to wells.

TABLE 5.—*Estimated storage of ground water in the sand and gravel deposits of the alluvium in the central Sevier Valley*

Basin	Thickness of saturated aquifer (feet)	Assigned average storage coefficient	Area underlain by aqnifer (acres)	Estimated recoverable storage (acre-feet)
Junction-Marysvale	100	0.20	1,600	30,000
Sevier-Sigurd	340	.20	12,000	800,000
Aurora-Redmond	400	.20	3,200	200,000
Redmond-Gunnison	50	.15	20,000	150,000
Gunnison-Sevier Bridge Reservoir	200	.15	11,500	300,000
Total (rounded)				1,500,000

FLUCTUATIONS OF WATER LEVEL

Ground-water levels do not remain stationary; they fluctuate in response to withdrawals or additions of water. Water-level fluctuations vary in duration from minutes to years. If the period is less than 1 month, the fluctuations may be called short term; if the period is from 1 month to 1 year, the fluctuations may be called seasonal; if the period exceeds 1 year, the fluctuations may be called long term.

SHORT-TERM FLUCTUATIONS

Short-term fluctuations in the central Sevier Valley are caused by changes in atmospheric pressure, changes in surface flow, use of ground water by phreatophytes, and discharge from wells.

The records from a water-level recording gage on well (C–24–3) 35bdd–1 show the effects of changes in atmospheric pressure on water levels (fig. 5). The water surface in the well is depressed as the atmospheric pressure increases, and, conversely, the water surface rises as atmospheric pressure drops. The ratio of the change in water level to the change in atmospheric pressure, expressed in equivalent units, is termed the "barometric efficiency of the aquifer" (Ferris and others, 1962, p. 85). The water level in this well rose 0.12 foot in 28 hours on December 25–26, 1957. During this time the atmospheric pressure, recorded by a barograph at the well, decreased 1.50 inches of mercury, the equivalent of 1.7 feet of water. The ratio $\frac{0.12}{1.7}$ indicates that the barometric efficiency of the aquifer is 7 percent.

The records of the water-level recording gages on wells (C–30–3) 15bba–1 and (C–25–4)32aba–2 indicate the effects of changes in nearby surface flow. Well (C–30–3)15bba–1 is 30 feet deep, and it taps water under water-table conditions in alluvium. The diversions of irrigation water to Kingston Main Canal about 0.4 mile away are reflected by water-level fluctuations at this well with a time lag of from 2 to 8 days. (See fig. 6.) Similarly, fluctuations of the water

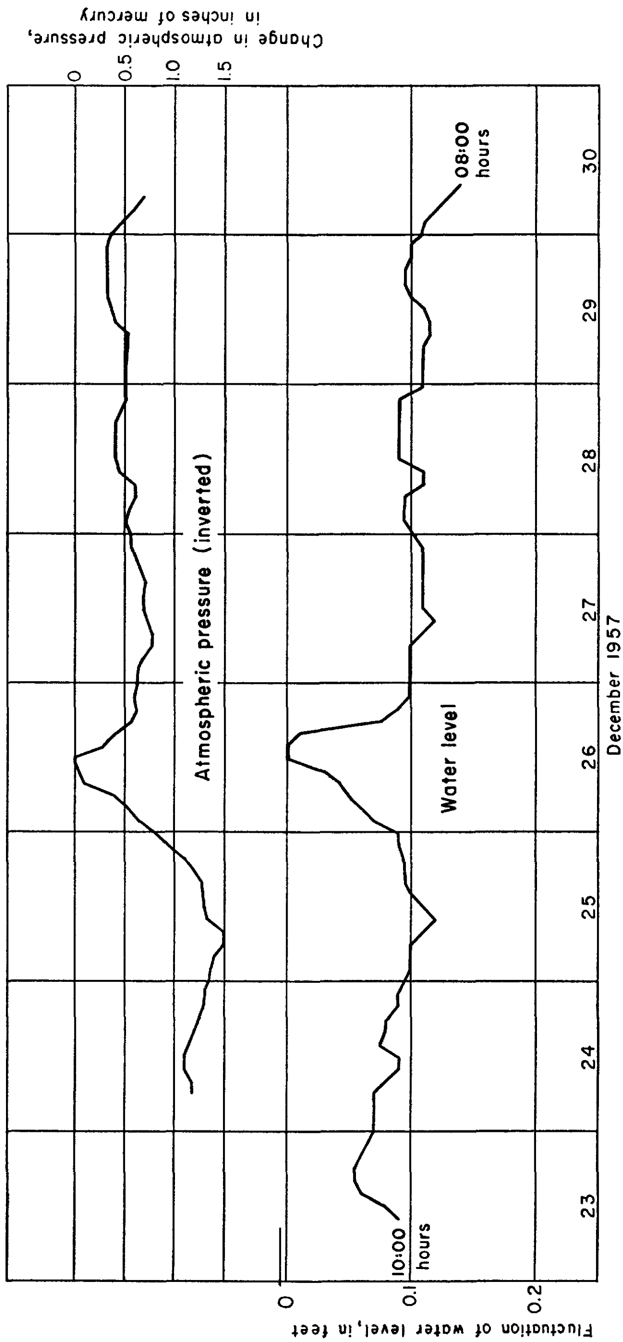

FIGURE 5.—Fluctuation of water level in well (C-24-3)35bdd-1 caused by change in atmospheric pressure, December 23–30, 1957.

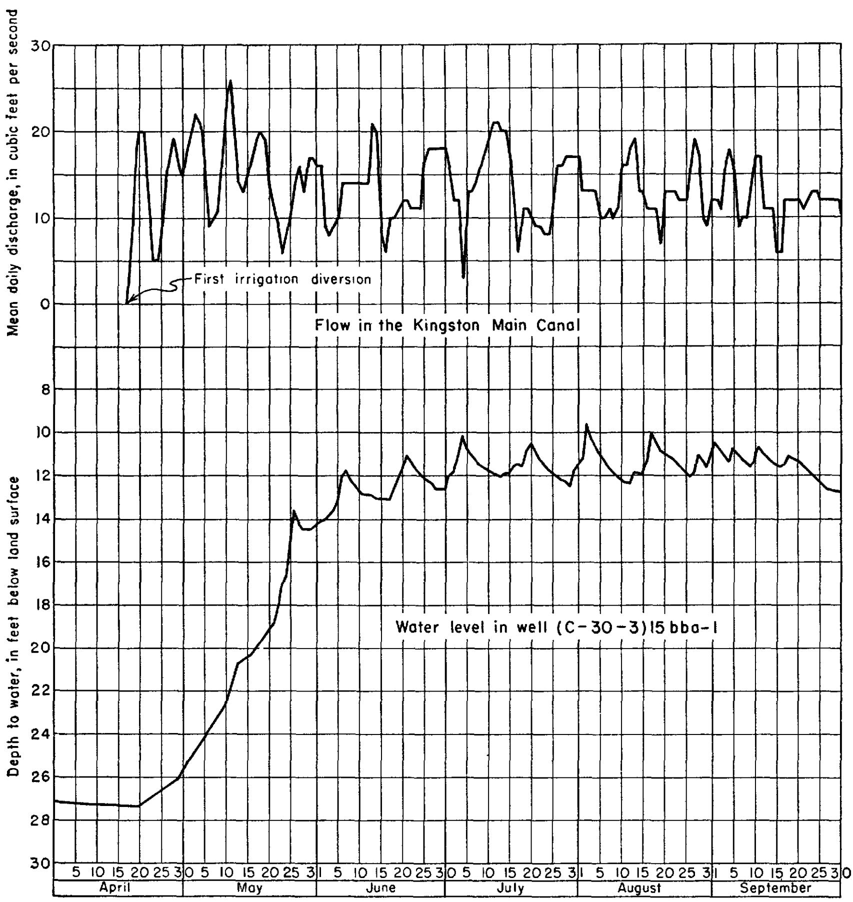

FIGURE 6.—Correlation of fluctuation of water level in well (C–30–3)15bba–1 with change of discharge in the Kingston Main Canal, 1958.

level in well (C–25–4)32aba–2 can be correlated with the discharge of Clear Creek about 0.25 mile away. This well is 64 feet deep, and it taps unconfined ground water in the alluvium.

Daily fluctuations of water levels may be caused by vegetation in areas where the water table is near land surface. (See pl. 5.) In these areas the water levels decline in the daytime and recover during the night.

Short-term fluctuations of water levels may be caused by discharge from wells for short periods. The influence of discharging wells on water levels is discussed in greater detail in the next section, "Seasonal fluctuations."

SEASONAL FLUCTUATIONS

Water levels fluctuate seasonally in most wells in the central Sevier Valley. Seasonal rises of the water table are caused mostly by seepage of water from streams and by diversions of water from streams for irrigation. Seasonal fluctuations in artesian pressure, particularly in the Sevier-Sigurd basin, are caused mostly by capping and uncapping flowing wells. Little fluctuation occurs in artesian wells which are more than 200 feet deep.

The pattern of fluctuation of water levels in wells that tap ground water under water-table conditions is similar in each ground-water basin in the central Sevier Valley. Water levels usually begin to rise in May in response to increased streamflow due to spring runoff and early-season applications of irrigation water diverted from the river. The levels continue to rise throughout the irrigation season and are usually highest in July, August, or September, near the end of the irrigation season. When the irrigation season ends, water levels decline slowly until the following spring. The hydrograph of well (C–25–4) 11cac–1 illustrates this fluctuation pattern. (See fig. 7.)

The artesian pressure in the wells penetrating the shallow artesian aquifers in the Sevier-Sigurd basin shows fluctuations caused mainly by the capping and uncapping of flowing wells. Pressures usually are highest in November or December, when most of the flowing wells are capped and the flow is stopped or retarded, and they remain fairly high until March or April. Pressures are usually low from May until about July or August when most of the flowing wells are uncapped and flow freely. The hydrograph of well (C–23–2) 15dcb–4 illustrates this fluctuation pattern. (See fig. 7.)

In the ground-water basins other than the Sevier-Sigurd basin, the water pressure in most wells penetrating shallow artesian aquifers has seasonal fluctuations which are much smaller than the fluctuations in the Sevier-Sigurd basin. This condition is probably due to three reasons: (1) there are fewer flowing wells, (2) the flowing wells are generally spaced farther apart, (3) a much smaller proportion of the flowing wells are capped during the nonirrigation season. The fluctuations of artesian pressure are small in a few wells penetrating the shallow artesian aquifers in these basins, and they seem to be independent of any seasonal influences.

Little seasonal fluctuation of water levels has been observed in artesian wells which are more than 200 feet deep. In most of these wells the total fluctuation of the piezometric surface does not exceed 3 feet during a period of several years. The hydrograph of well (C–23–2) 31dcb–2, which is 225 feet deep, is typical for deep artesian wells in the basins in the central Sevier Valley. (See fig. 7.)

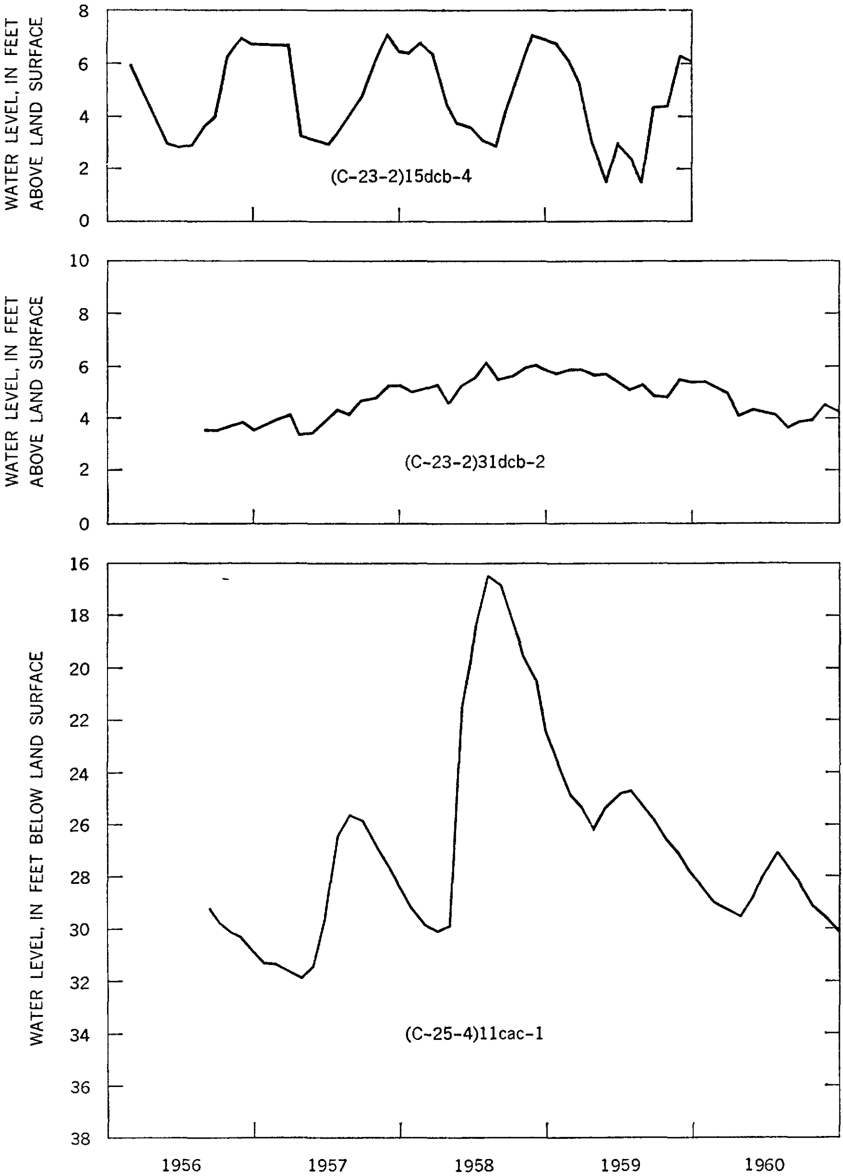

FIGURE 7.—Water levels in wells (C-23-2)15dcb-4, (C-23-2)31dcb-2, and (C-25-4)11cac-1.

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LONG-TERM TRENDS

Fluctuations of water levels in wells in the various ground-water basins of the central Sevier Valley have shown similar long-term trends during past years of record. As an example, the hydrograph of well (C-21-1)27aad-1 (fig. 8) shows that water levels were relatively low in 1935, rose from 1935 to 1941, and remained fairly steady through 1947. From 1948 to 1960, with the exception of 1952 and 1958, which were years of high precipitation, there was a fairly consistent decline in water level. The water-level trend correlates with records of precipitation and streamflow in the Sevier River basin. High ground-water levels are usually associated with periods of high precipitation and increased streamflow, and the converse is also true. Hence the years of deficient precipitation and streamflow from 1948 to 1960 are reflected by the low ground-water levels during the same period. (See fig. 2.)

RECHARGE

The principal sources of recharge to the alluvium in the central Sevier Valley are the Sevier River and its tributaries, irrigation canals, and infiltration from irrigated fields. The principal areas of recharge in the valley are shown on plate 6. Recharge from the Sevier River and its tributaries occurs where the streams flow across coarse alluvial deposits consisting of gravel and sand. Such areas of recharge, in general, exist where streams enter the various ground-water basins and where ground water is under water-table conditions. Recharge from canals takes place where the canal has been constructed in coarse alluvial-fan material near the mouths of canyons and along the borders of the valley near the mountains. Infiltration from irrigated fields occurs mainly in the upper parts of the various ground-water basins where water-table conditions prevail and the soils are coarse grained.

In addition to the principal sources of recharge, some ground water moves into the alluvium from the bedrock in the mountains surrounding the valley, the bedrock is recharged by direct precipitation and surface runoff. The rocks generally dip toward the valley, and ground water probably moves into the Sevier Valley in bedrock aquifers almost everywhere along the valley sides. An exception is that part of the east side of the valley that extends from Glenwood to Gunnison Reservoir dam; there the thickness and low permeability of the Arapien Shale retard the movement of ground water from the east.

DISCHARGE

Ground water is discharged from the valley floor in the central Sevier Valley mostly by evapotranspiration, wells, springs, seeps, and

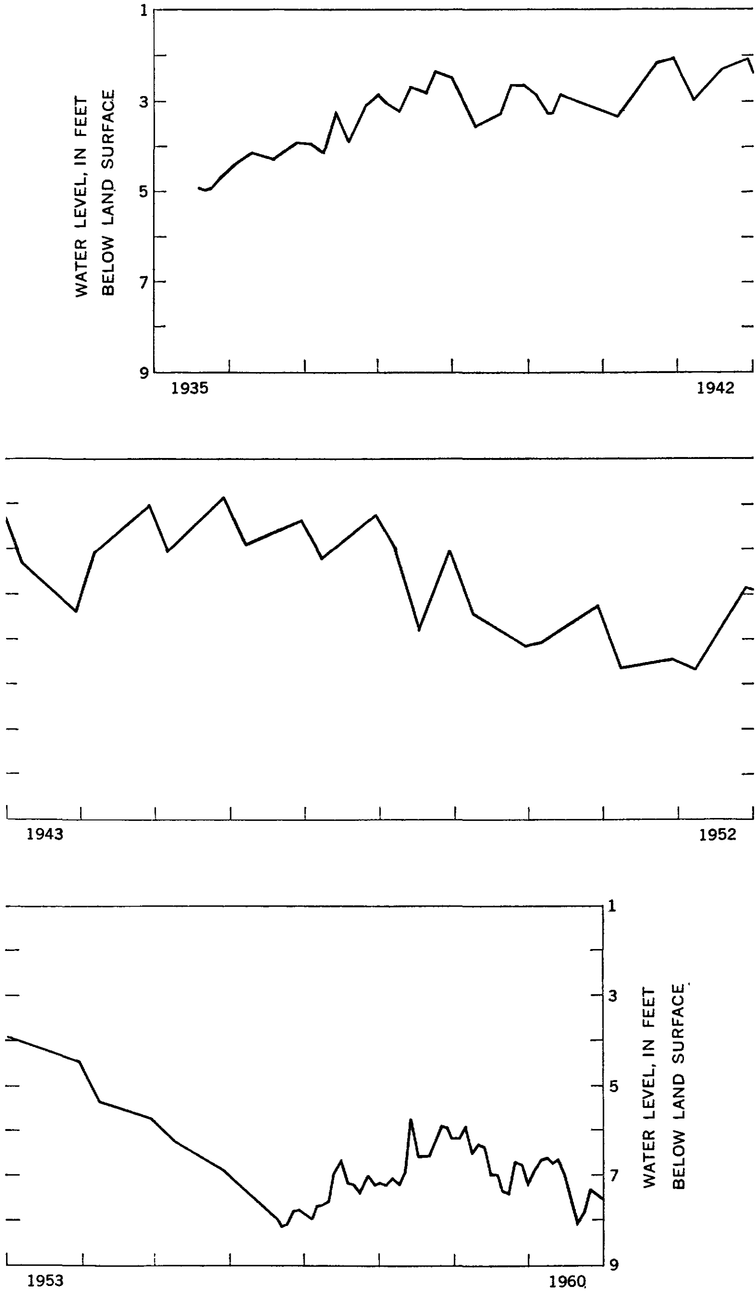

FIGURE 8.—Water levels in well (C–21–1)27aad–1.

drains; in specific basins, some ground water is discharged by subsurface movement into the valley fill of the next basin downstream. Essentially all the discharge is from water in the fill, but some of the discharge from springs along the margins of the valley has its source in the bedrock of the surrounding mountains.

EVAPOTRANSPIRATION

Evapotranspiration is that part of the precipitation which is returned to the air through transpiration by vegetation or through direct evaporation. Water can evaporate directly from open-water surfaces, from the ground-water table when it is at or near the land surface, from the soil zone, and from any exposed surface on which precipitation falls. It is estimated that about 100,000 acre-feet of water, most of which is derived from the ground-water table, is discharged annually by evapotranspiration from about 33,500 acres of wet bottom land in the central Sevier Valley. In addition, about 26,000 acre-feet of surface water is evaporated from the three main reservoirs in the area.

Evaporation from open-water surfaces.—The average annual evaporation from open-water bodies in the central Sevier Valley is more than six times the long-term mean annual precipitation. Evaporation data have been collected with a standard U.S. Weather Bureau land pan at Piute Dam for the period May through November since 1918. The dam is 6,000 feet above sea level, and the average annual rate of evaporation is 55 inches (U.S. Weather Bur., Salt Lake City, Utah, written commun., 1958).

The annual evaporation from the three largest surface-water reservoirs in the central Sevier Valley is about 26,000 acre-feet, and it is summarized below:

Reservoir	*Estimated average water-surface area (acres [1])*	*Annual evaporation (acre-feet [2])*
Piute	1,200	4,800
Rockyford	300	1,200
Sevier Bridge	5,000	20,000
Total	6,500	26,000

[1] Areas based on data in Woolley (1947, p. 125–128).
[2] Based on an evaporation rate of 48 inches per year.

Evaporation of ground water.—The amount of ground water discharged by evaporation depends primarily upon the depth to the water table and the soil type. Where the water table intersects the land surface, evaporation takes place directly from the ground-water body. Where the water table is a few feet below land surface and the soil is fine grained, the capillary fringe [5] overlying the water table may reach the land surface, and evaporation takes place directly from the ground-water body.

When ground water evaporates, the minerals that had been in solution are precipitated in the soil zone. An excessive accumulation of certain minerals may destroy the usefulness of the soil for agricultural purposes.

Transpiration.—Transpiration is defined as the process by which plants discharge water vapor to the atmosphere. If the water table is within reach of the roots of plants, ground water will be taken directly from the zone of saturation and discharged by transpiration. The rate of transpiration depends upon climatic conditions, plant type and size, depth to the water table, and quality of the ground water. The quantity of water transpired by plants which have some recognized benefit to mankind is called consumptive use (Thomas, 1951, p. 217). Water that returns to the atmosphere without benefiting man is consumptive waste; thus, the water transpired by nonbeneficial vegetation is part of consumptive waste.

Consumptive waste of ground water in the central Sevier Valley is attributed mainly to phreatophytes and to evaporation. Phreatophytes are plants that depend for their water supply on ground water that lies within reach of their roots (Robinson, 1958, p. 1). The principal phreatophytes in the central Sevier Valley are saltgrass, saltcedar, willow, cottonwood, greasewood, and rabbitbrush. Numerous studies and experiments conducted in the Western United States under a wide variety of conditions which include climate, density of plant growth, depth to water table, quality of ground water, and soil types, indicate that a fully developed growth of saltcedar or cottonwood uses from 5 to 7 acre-feet of water per acre annually, and that saltgrass, willow, greasewood, and rabbitbrush use approximately 2–3 acre-feet (Robinson, 1958, p. 49–75).

Areas that contain small bodies of surface water fed by springs and areas in which the water table is close to the land surface are also generally areas of extensive phreatophyte growth. In such areas the rate of evapotranspiration is great. A value of 3 acre-feet per acre per year was considered a conservative average rate of evapotranspiration from these areas, and this figure was used in preparing a tabulation of the estimated evapotranspiration for

[5] According to Meinzer (1923, p. 26), "The capillary fringe is a belt that overlies the zone of saturation and contains capillary interstices some or all of which are filled with water that is continuous with the water in the zone of saturation but is held above that zone by capillarity acting against gravity."

each basin in the central Sevier Valley. (See table 6.) Areas of principal phreatophyte growth are shown on plate 5.

No estimate was made of the evapotranspiration from the banks of tributary-stream channels or from irrigation canals.

WELLS

The estimated average annual discharge of ground water from wells in the central Sevier Valley is about 16,000 acre-feet. Of this total, approximately 10,000 acre-feet was used for irrigation, 300 acre-feet for public supply, 300 acre-feet for industry, and the remainder for domestic and stock purposes. The amount discharged by different kinds of wells in the five basins is listed in table 7. The figures were estimated by compiling information on the type and period of use of the well, periodic measurements of discharge of selected wells, discharge measurements made during well inventory, and yields reported by well owners and drillers. Discharge from wells is relatively small compared to discharge by other means in the central Sevier Valley. The discharge of flowing wells is greatest when artesian pressure is high, usually during years of high precipitation and high streamflow. Discharge from pumped wells is usually greatest when precipitation and streamflow are low.

SPRINGS

Ground water is discharged in the central Sevier Valley by springs issuing from the alluvium and from bedrock. Listed below is the estimated annual flow of springs discharging from the alluvium in the five ground-water basins of the central Sevier Valley. Almost all the water is used for irrigation.

Basin	*Discharge (acre-feet)*
Junction-Marysvale [1]	11,000
Sevier-Sigurd	20,000
Aurora-Redmond [2]	11,000
Redmond-Gunnison	4,000
Gunnison–Sevier Bridge Reservoir	12,000
Total	58,000

[1] Discharge mostly from Barnson Springs, (C–29–3) 16ccb, and Taylor Pond Spring, (C–27–3)17dcb.

[2] Discharge mostly from Redmond Lake Springs, (C–21–1)11a.

The discharge of springs from the alluvium is directly proportional to the yield and pressure of flowing wells in the central Sevier Valley. This is shown by the correlation of the water level in well (C–23–2) 27bda–1 with the discharge of springs from the alluvium in sec. 4, T. 24 S., R. 2 W. (See fig. 9.)

TABLE 6.—*Evapotranspiration in ground-water basins of the central Sevier Valley*

Basin	*Area of phreatophyte growth where the water table is close to land surface* (acres)	*Estimated annual evapotranspiration of ground water (based on a rate of 3 acre-feet per acre)* (acre-feet)
Junction-Marysvale	3, 500	10, 500
Sevier-Sigurd	10, 000	30, 000
Aurora-Redmond	3, 000	9, 000
Redmond-Gunnison	7, 000	21, 000
Gunnison–Sevier Bridge Reservoir	10, 000	30, 000
Total (rounded)	33, 500	100, 000

Discharge of ground water from springs in bedrock near the floor of the central Sevier Valley is estimated to be about 15,000 acre-feet annually. Although some of the water is used for public supply, most of it is used for fish culture or for irrigation. The principal springs that discharge from bedrock near the valley floor are Fayette Spring, (D–18–1)19dab, which discharges 1,900 gpm from the Flagstaff Limestone; Glenwood Spring, (C–23–2)36cbd, which discharges 4,500 gpm from volcanic rocks of Teritary age; and Richfield Spring, (C–23–3)26aca, which discharges 1,400 gpm from the Crazy Hollow Formation of Spieker (1949). A much greater amount of water is discharged from many bedrock springs in the more remote parts of the mountains surrounding the central Sevier Valley. The water dis-

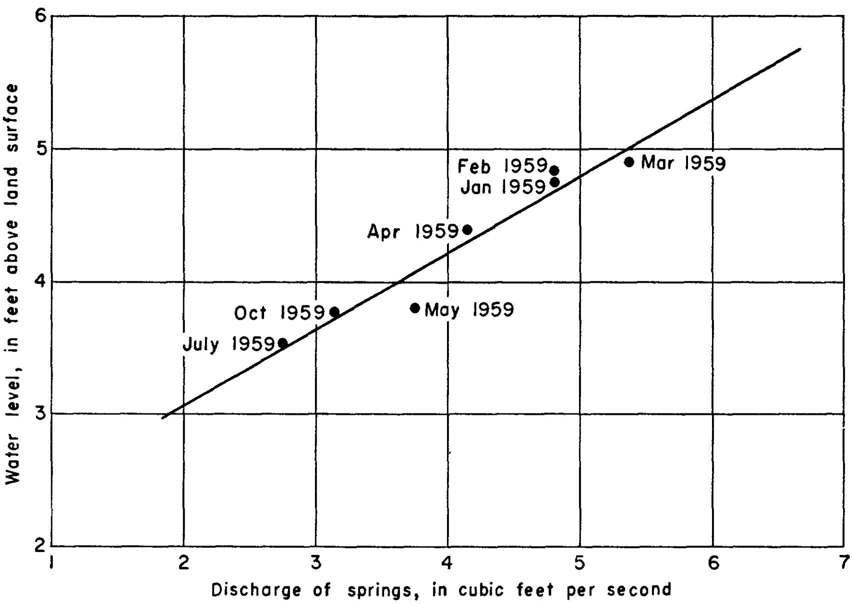

FIGURE 9.—Relation of water level in an artesian well, (C–23–2)27bda–1, to discharge of springs from alluvium in sec. 4, T. 24 S., R. 2 W.

TABLE 7.—*Estimated annual discharge of ground water from wells in ground-water basins of the central Sevier Valley*

Basin	Discharge from wells										Total estimated discharge
	Mainly for irrigation					For stock, domestic, municipal, and industrial use					
	Number of wells		Estimated discharge (acre-feet)			Number of wells		Estimated discharge (acre-feet)			
	Pumped	Flowing	Pumped	Flowing	Total	Pumped	Flowing	Pumped	Flowing	Total	
Junction-Marysvale	0	0	0	0	0	28	0	(2)	0	0	0
Sevier-Sigurd	3	247	500	2,000	2,500	158	258	700	4,000	4,700	7,200
Aurora-Redmond	0	0	0	0	0	68	13	200	200	400	400
Redmond-Gunnison [1]	3	200	700	3,500	4,200	153	0	300	0	300	4,500
Gunnison-Sevier Bridge Reservoir [1]	0	205	0	3,500	3,500	18	24	(2)	400	400	3,900
Total, all basins	6	652	1,200	9,000	10,200	425	295	1,200	4,600	5,800	16,000

[1] Flowing wells in these areas flow during the entire year.
[2] Estimated discharge is negligible.

charged from these remote springs is accounted for in the base flow of the perennial streams that enter the valley. Most of these springs flow from volcanic rocks of Tertiary age.

DRAINS

Discharge of ground water from drains is estimated to be about 22,000 acre-feet annually in the central Sevier Valley. Almost all the water is used for irrigation. The estimated annual discharge of drains in each basin is:

Basin	*Discharge (acre-feet)*
Junction-Marysvale	1,000
Sevier-Sigurd	10,000
Aurora-Redmond	1,000
Redmond-Gunnison	8,000
Gunnison–Sevier Bridge Reservoir	2,000
Total	22,000

The seasonal discharge of water from drains in the central Sevier Valley usually fluctuates directly with the amount of irrigation water applied to the land.

SUBSURFACE OUTFLOW

Some ground water leaves each ground-water basin in the central Sevier Valley by subsurface outflow. The amount lost is considered to be negligible in the Junction-Marysvale and the Aurora-Redmond basins owing to the subsurface geologic barriers at the downstream end of the basins. Gravel and sand beds, however, at the downstream end of both the Sevier-Sigurd basin and the Redmond-Gunnison basin annually transmit about 2,000 and 4,000 acre-feet of water, respectively, to the basins downstream. The quantity of water moving downstream from the project area by subsurface outflow at the Yuba Dam is believed to be small owing to a subsurface geologic barrier at the damsite.

DEVELOPMENT

WELLS

More than 1,300 wells have been constructed in the central Sevier Valley by digging, jetting, cable-tool drilling, or rotary drilling.[6] Many domestic and stock wells were dug by hand before the other methods were introduced into the area. These dug wells, many of which are still in use, ranged in depth from 12 to 72 feet and were lined and supported by rock or concrete.

[6] A description of well-construction methods was given by Todd (1959, p. 115–149).

Most of the newer wells less than 6 inches in diameter were jetted, whereas most wells 6 inches in diameter or larger were drilled by the cable-tool method. Twenty-seven wells were drilled in the project area by the rotary method. Of these, 21 were test holes drilled by the Geological Survey to evaluate the water-bearing materials underlying the valley, 5 were drilled as oil or gas tests, and 1 was drilled by the city of Richfield in exploration for water. Numerous seismic holes, mostly 2–4 inches in diameter, have been drilled by the rotary method for oil and gas exploration.

Most of the wells in the alluvium of the central Sevier Valley are less than 150 feet deep. The majority of the wells are drilled just deep enough to produce a moderate amount of water; and usually only a small part of the aquifer is penetrated, especially in areas of artesian flow. Most wells are 4 inches or less in diameter, and only 19 wells are larger than 8 inches in diameter.

Standard screw-joint or butt-welded casing is used in most wells that are 6 inches or larger in diameter. Standard black iron pipe is usually used for wells smaller than 6 inches in diameter. Most of the wells produce water through the open bottom of unperforated casing, but a few casings have been perforated in the lower part, usually with a Mills knife or similar device. Wells intended for large discharge are usually equipped with perforated casing and are developed by surging and pumping at excessive rates to remove silt and fine sand which impede the movement of ground water to the well.

The small domestic and stock wells are pumped mostly by gasoline-driven or electrically driven centrifugal or piston pumps. Jet pumps supply water to many rural homes. Most of the irrigation wells are equipped with deep-well turbine pumps driven by electric motors or by gasoline or diesel engines.

Specific capacity of wells.—Specific capacity is a term used to indicate the efficiency of a well. It depends on many conditions, including the hydraulic properties of the aquifer, the construction of the well, and the development of the well. Specific capacity is expressed in gallons per minute (gpm) per foot of drawdown, and it is calculated by dividing the discharge of a well by the drawdown of the water surface in the well after pumping at a constant rate. The specific capacity of a given well varies somewhat depending upon the rate of pumping and the length of time pumped. Observed specific capacities of wells in the central Sevier Valley range from 10 to 300 gpm per foot of drawdown. Specific capacities for selected wells in the valley, most of which were reported by the owner or by the well driller, are given in table 8.

The rather wide range in specific capacities of wells in the valley is attributed mainly to differences in well construction and differences

TABLE 8.—*Specific capacities and related data for selected wells in the central Sevier Valley*

Well	*Depth (feet)*	*Diameter (inches)*	*Discharge (gpm)*	*Specific capacity (gpm per foot of drawdown)*
(C-19-1)23bcc-1	193. 5	12	1, 800	300
(C-19-1)23cac-1	78	8	600	18
(C-22-1)5bac-1	490	8	200	10
(C-23-2)14cdd-1	103	10	125	63
(C-24-3)12bda-1	375	12	1, 350	108
(C-24-3)23bad-1	115	8	100	100

in the permeability of the saturated materials penetrated. For example, well (C-24-3)12bda-1, a well of high yield, has a specific capacity of 108 gpm per foot of drawdown. The well is 375 feet deep; it penetrates 149 feet of gravel and 38 feet of sand; and it is supported with 12-inch steel casing of which 95 feet is perforated. By contrast, well (C-22-1)5bac-1, a well of moderate yield, has a specific capacity of 10. The well is 490 feet deep; it penetrates 40 feet of saturated gravel and 30 feet of saturated sand; and it is supported with 8-inch casing of which 35 feet is perforated.

Interference of wells.—Interference occurs when the yield of a discharging well is decreased because of the discharge of a well nearby. It can be caused by either flowing or pumped wells, although the effects from pumped wells are usually greater and more significant. When a well is discharging, the water table or piezometric surface of the aquifer surrounding the well is depressed and assumes the form of an inverted cone, the apex of which is the well. The extent and depth of this cone, called the cone of depression, depend on the hydraulic properties of the aquifer, the rate of discharge, and the duration of discharge. The cone of depression develops much faster under artesian conditions, where it is formed largely by the release of hydrostatic pressure, than it does under water-table conditions, where its development depends largely on the quantity of water removed from the aquifer. Interference takes place when the spreading cone of depression reaches the cone of depression of another discharging well and adds to the drawdown at the other well, thus decreasing its specific capacity or efficiency.

The rate of development of the cone of depression around a pumped irrigation well near Richfield, (C-24-3)12bda-1, was observed in an observation well, (C-23-2)31dcb-3, equipped with an automatic water-level recording gage. The observation well was 1¾ miles northeast of the pumped well. Thirty minutes after pumping at 1,350 gpm began, the water level in the observation well began to decline. It declined 0.4 foot during the first 24 hours of pumping, after which it remained steady until the pumping stopped. Thirty minutes after the pump was stopped, the water level in the observation well began to rise, and it rose steadily for about 24 hours to approximately the original water level. Drawdown effects over relatively large distances in short periods of time, such as in this example, are characteristic of artesian conditions.

Mutual interference of closely spaced artesian wells has been observed in the vicinity of Venice where seasonal decline of water level is caused by uncapping many artesian wells in the springtime and allowing them to flow freely during the irrigation season. (See well (C-23-2)15dcb-4 in fig. 7.) This decline can be attributed to the mutual interference of many discharging artesian wells.

Advantages of ground-water development by wells.—The advantages of developing ground water by means of wells for any use stem from reservoir characteristics and physical-chemical characteristics of the water. The ground water is in transient storage in huge subterranean reservoirs which can be tapped by wells to provide water when and where it is needed. An irrigation supply based on surface-water rights can be deficient or glutted depending upon seasonal precipitation. Deficiency leads to crop failure; glut leads to waste of water and to waterlogging of agricultural land. Wells can be pumped to provide irrigation water only when needed by the crops, thus eliminating waste and insuring harvest.

Water stored in surface reservoirs and conducted to the irrigated land through surface canals is subject to large losses by evapotranspiration. These losses are essentially eliminated when water is stored in a subterranean reservoir. The canal losses, and even the need to construct or maintain lengthy canals, are eliminated by pumping wells constructed at the site where the water is needed.

Water pumped from wells is relatively free of silt, weed seeds, and organic contamination, and the water maintains relatively constant temperature and chemical characteristics throughout the year. These features are of considerable significance when considering water for municipal or industrial use.

A particular advantage of the full development of ground water in the central Sevier Valley is that such development could result in the salvage of water from present nonbeneficial and low-beneficial use. If ground-water levels could be lowered a few feet, many of the sloughs and excessively wet areas, where large quantities of water are now wasted by evapotranspiration, would disappear. The lowering of ground-water levels could be accomplished by pumping from wells penetrating the principal aquifers in the various ground-water basins. The areas that are the most promising for such development are the Sevier-Sigurd basin and the Gunnison-Sevier Bridge Reservoir basin. Such a development program, however, would have to proceed carefully to allow for compensation for the expected reduction in flow in some flowing wells and springs. As the discharge of the flowing wells and springs decreases, it would be necesary to use some of the water pumped from wells to satisfy the water rights contingent on the flowing wells and springs. Eradication of phreatophytes and improvement of drainage systems would make the ground-water development program still more effective.

SPRINGS

Almost two-thirds of the ground water used in the central Sevier Valley comes from springs. Springs furnish the public water supply for every community within the valley with the exception of Venice and Axtell. Most of the springs discharge from bedrock in the mountains adjacent to the valley. Development ordinarily consists of a collecting chamber at the site of the spring and a gravity conveyance and distribution system. Some municipal springs such as Richfield Spring, (C–23–3)26aca, and several springs, (C–21–1)11a, used by the town of Redmond are equipped with pumps that lift the water into enclosed reservoirs, thus providing adequate head for distribution.

Many springs in the valley and many bedrock springs in the surrounding mountains are major sources of irrigation water. Much of the water discharged from these springs flows into the Sevier River and its tributaries and is stored in surface-water reservoirs for future irrigation use.

Some springs in the central Sevier Valley are used for commercial purposes. The waters of Glenwood Spring, (C–23–2)36cbd, the Three Lakes Springs, (C–24–2)4cbd, and springs (C–23–2)27ccd, (C–23–2)28dad, and (C–23–2)28ddd are used for fish culture. Glenwood Spring issues from volcanic rocks of Tertiary age, whereas the other springs discharge from the alluvium.

DRAINS

Drainage has been attempted in nearly all areas underlain by artesian aquifers in the central Sevier Valley. However, the resulting drainage systems have become more important as a source of return-flow irrigation water for the irrigation of pastures and for use downstream rather than as a means of lowering water levels. Most of the existing drains are open channels, although some tile drains have been constructed in the Richfield and Centerfield areas.

West of Centerfield, in T. 19 S., R. 1 W., the tile drains discharge into open drains, which in turn discharge into the river. At intervals along the bottom of the open drains, 2-inch wells have been jetted down 20–50 feet into the alluvium; each well flows about 5–25 gpm. This combined system of wells, tile drains, and open drains is a very effective drainage system.

Several canals have been constructed to collect water from slough and spring areas and to deliver it to irrigated lands. In a sense these canals can also be called drains. However, the intended result was not drainage but recovery of water for irrigation use. As these drains were not designed to dewater the waterlogged land, no effective lowering of water level has resulted.

Drains in artesian areas, such as the downstream parts of the five ground-water basins in the central Sevier Valley, are not effective unless they tap the more permeable water-bearing beds in the valley fill. The sand and gravel deposits, in artesian areas, are generally overlain by at least 20 feet of relatively impermeable silt and clay (pl. 3) which will yield water to drains slowly but not in sufficient quantity to be effective. The underlying permeable deposits of gravel and sand can be tapped by deeper drains, by flowing wells in the bottom of drains, or by drains extending into spring areas where the springs already tap the underlying permeable deposits.

According to Utah State law, a quasi-public corporation known as a drainage district can be organized to undertake drainage on a large scale. As early as 1920, drainage districts, each controlling 1,000–4,000 acres, were organized in Sevier and Sanpete Counties. These drainage districts were not successful because (a) the areas included in the districts were too large, (b) ultimate drainage construction costs exceeded estimates, (c) the drains were not adequately designed, and (d) the drains were not properly maintained.

RELATION OF GROUND WATER AND STREAMFLOW

The base flow of the Sevier River in most of the valley is dependent on ground-water levels. The river loses water at the upstream end of most of the basins, where water levels are appreciably below the stream channel, and gains water in the downstream parts, where water levels are above the stream level. The water that enters the ground-water reservoirs from the river moves downstream, but it moves through the aquifers more slowly than the surface water moves downstream. The quantity of water moving through the aquifers, however, is probably large, because the aquifers have a high average permeability, a large cross-sectional area, and a hydraulic gradient of several feet per mile.

The ground-water reservoir is similar to a surface-water reservoir in that it temporarily stores water. At several places in the central Sevier Valley, geologic barriers impede the downstream movement of ground water, causing water levels to rise and the reservoir to become full and overflow. In these areas the ground water leaves the reservoir by springs, seeps, and evapotranspiration. Much of the discharge from the springs and seeps returns to the river. The river thus becomes a gaining stream, and the flow continues downstream to the next basin, where the cycle is repeated. The rate of ground-water discharge into a stream depends largely on ground-water levels and on the permeability of the materials underlying the stream bed.

Figure 10, which illustrates overall conditions in the Sevier-Sigurd basin, shows that the decrease in ground-water storage coincides closely with the period of each year when outflow from the basin exceeds inflow. The gain in streamflow during this period is from ground-water discharge. The increase in ground-water storage coincides with the period when inflow to the basin exceeds outflow. The loss in streamflow during this period is due to evapotranspiration and to recharge to the ground-water reservoir. Only the actual measured surface-water flows entering and leaving the Sevier-Sigurd basin are considered in figure 10. Additional water enters the basin from small unmeasured perennial streams, ephemeral streams, and subsurface inflow from bedrock sources. A more complete inflow-outflow analysis is presented in the following section.

In addition to natural discharge to the streams, withdrawals of ground water by wells and drains impose an additional draft on the ground-water reservoir. If enough water is withdrawn, the natural overflow will decrease significantly or may stop. The surface-water and ground-water systems in the central Sevier Valley are in equilibrium, and the removal of water from the ground-water reservoir would (a) increase recharge from surface water, (b) decrease discharge from springs, flowing wells, and evapotranspiration, or (c) both.

INFLOW-OUTFLOW ANALYSIS FOR THE SEVIER-SIGURD BASIN

THE ANALYSIS

In any segment of a valley, the quantity of water entering by surface-water inflow, ground-water inflow, and precipitation is equal to the quantity of water leaving the area by surface-water outflow, ground-water outflow, and evaportranspiration plus or minus the quantity gained or lost in surface-water and ground-water storage. An attempt was made to analyze each of the ground-water basins in the central Sevier Valley on this basis to allocate quantities of water to each category. The major difficulties encountered in the analyses were the complexity of the transmission and distribution systems for irrigation water, and the lack of data on both the amount of tributary inflow from both perennial and ephemeral streams and the amount of ground water entering each basin by side inflow from bedrock sources. Because of these difficulties, some estimates and assumptions were necessary.

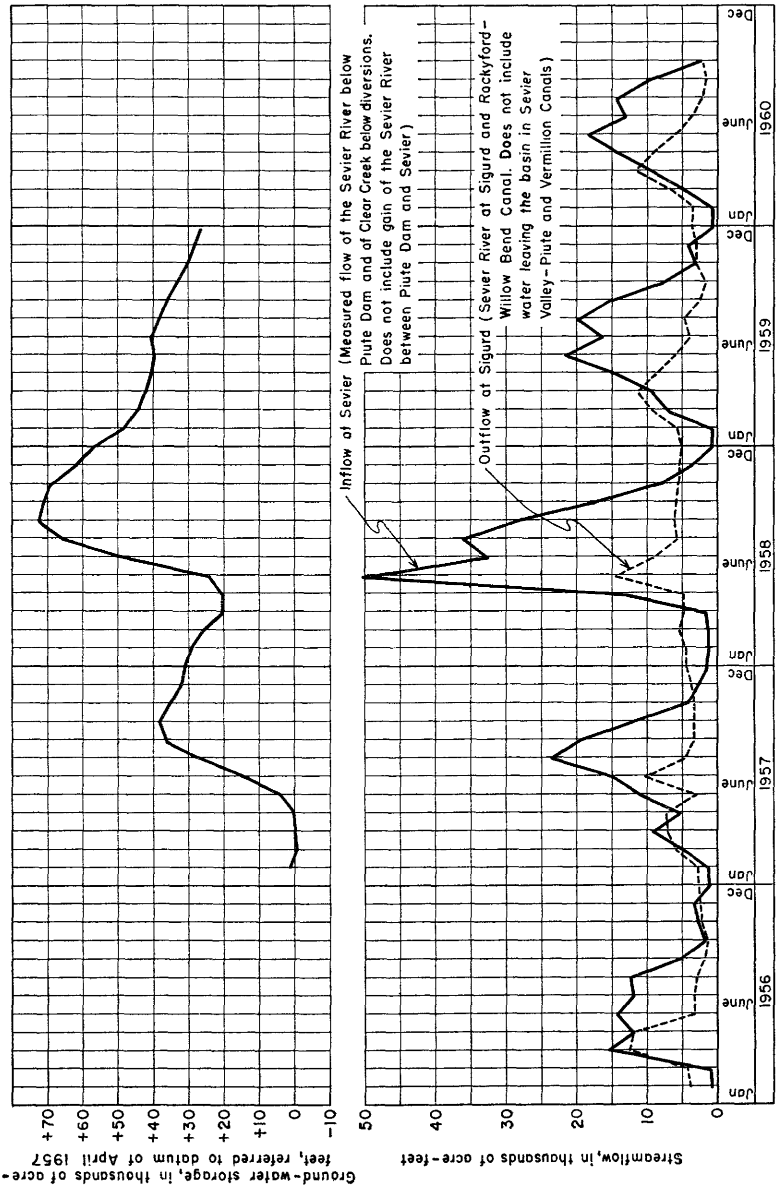

FIGURE 10.—Change in ground-water storage, and surface-water inflow to and outflow from the Sevier-Sigurd basin.

TABLE 9.—*Inflow and outflow of water and change in storage, by calendar year, Sevier-Sigurd ground-water basin*

	1957	1958	1959
	(1,000 acre-feet)		
Surface-water inflow	132	234	139
Ground-water inflow at upper end	neg.	neg.	neg.
Precipitation on ground-water basin	57	24	37
Inflow from other sources	50	25	14
Total water entering the basin	239	283	190
Surface-water outflow	80	138	103
Ground-water outflow	2	2	2
Evapotranspiration from cultivated areas	80	79	74
Evapotranspiration from noncultivated wet areas	30	30	30
Evapotranspiration from noncultivated brushland	17	7	11
Evaporation from open surface-water reservoirs	1	1	1
Total water leaving the basin	210	257	221
Change in surface-water storage	neg.	neg.	neg.
Change in ground-water storage	+29	+26	−31
Total water entering the basin	239	283	190

The best conditions for an inflow-outflow analysis were found in the Sevier-Sigurd basin, and the analysis for the 1957–59 calendar years is presented in table 9.

The inflow-outflow analysis of the Sevier-Sigurd basin indicates that more than 200,000 acre-feet of water enters and leaves the basin during most years. Of this amount, about half flows out of the basin in the river, in canals, and through the ground-water aquifer to be available for use downstream; the other half is consumed in the basin. Of the water consumed in the basin, an average of 64 percent is used in cultivated and irrigated areas, 25 percent is used in wet noncultivated areas, 10 percent is used in noncultivated brushlands, and 1 percent is evaporated from one reservoir.

The amount of water flowing into the basin from different sources varies widely from year to year because of changes in the precipitation pattern in the drainage basin and because of changes in storage in surface-water reservoirs upstream. In dry years, reservoirs may be drained to supply the irrigation-water demand, whereas in wet years some water may be held in storage for use during the following years. During 1957–59 the measured streams supplied an average of 71 percent of the total inflow, whereas 17 percent came from precipitation on the ground-water basin, and 12 percent was inflow from other sources. Most of the inflow was from various unmeasured streams, but some was from ground-water movement into the basin from the mountains on both sides of the valley.

ELEMENTS OF THE ANALYSIS

Surface-water inflow and outflow.—In the analysis shown in table 9, surface-water inflow was based on measurements of the river below

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Piute Dam, estimates of gain in flow between Piute Dam and Sevier, measurements of Clear Creek near Sevier below diversions, and reported measurements of Richfield and Glenwood Springs. The amount of water entering the basin from several other ungaged streams is included in the item, "Inflow from other sources." Surface-water outflow from the Sevier-Sigurd basin was based on measurements of flow in the Sevier River below Rockyford Dam and in the Rockyford–Willow Bend Canal and on estimates of flows in the Sevier Valley–Piute and Vermillion Canals.

The streamflow in 1958 was greater than that in 1957 and 1959 because of above-average precipitation during the period from October 1957 to April 1958. (See fig. 2.) Although precipitation from April 1958 through December 1959 was below average, streamflow remained fairly high because of hold over storage in Piute Reservoir. The surface-water inflow to the Sevier-Sigurd basin was consistently greater than the outflow during the period of analysis. This is undoubtedly an annual occurrence, and it is attributed to the consumption of water in the basin by evapotranspiration.

Ground-water inflow and outflow.—Ground-water inflow to and outflow from the Sevier-Sigurd basin were estimated on the basis of knowledge of the local geology and of the thickness and permeability of the water-bearing materials in the constricted parts of the valley at the upper and lower ends of the basin. Sufficient information was not available to make a direct estimate of the amount of ground water moving into the basin from the sides. An indirect estimate of this movement, however, is included in the item, "Inflow from other sources."

The ground-water inflow at the upper end of the Sevier-Sigurd basin was regarded as negligible, because the alluvium at the bottoms of Marysvale and Clear Creek Canyons is too thin to permit the flow of significant quantities of water. The ground-water outflow at the lower end of the basin was estimated on the assumptions that the permeable beds of gravel and sand in the vicinity of Rockyford Dam were 1 mile wide and that they were somewhat thinner than indicated at test hole 14, (C–22–1)19bad–1, about 1 mile downstream. A geologic constriction of the valley plus a local steepening of the ground-water piezometric surface suggests a local decrease in transmissibility.

Precipitation on ground-water basin.—The annual precipitation at Richfield, near the center of the Sevier-Sigurd basin, was 11.15, 4.69, and 7.14 inches in 1957, 1958, and 1959, respectively, according to the U.S. Weather Bureau. This precipitation was applied to the 62,000 acres that constitutes the Sevier-Sigurd ground-water basin. The amount of water added directly to the area by precipitation was thus computed to be about 57,000 acre-feet in 1957, 24,000 acre-feet in 1958, and 37,000 acre-feet in 1959.

Evapotranspiration from cultivated areas.—The average annual quantity of water consumed by cultivated crops in the Sevier-Sigurd basin was estimated by a method described by Roskelly and Criddle (1952). About 34,000 acres of cultivated land was divided into crop types, including alfalfa, corn, small grains, potatoes, sugar beets, wild hay, and pasture, and into idle land; but the acreage for each crop type varied from year to year depending upon the available water supply. Gross water-use requirements for each type (Roskelly and Criddle, 1952, table 5, Richfield-Salina area) were multiplied by the acreage of each type to determine the annual amount of water consumed. It was assumed that all precipitation on the area of cultivated crops was consumed by evapotranspiration.

Evapotranspiration from noncultivated wet areas.—The average annual quantity of water consumed on about 10,000 acres of wet noncultivated land in the Sevier-Sigurd basin was estimated to be about 30,000 acre-feet. This amount is listed for each of the 3 years in table 9 because the wet area was about the same for each year, and the amount of water consumed probably did not vary much. Evapotranspiration from wet areas includes evaporation from waterlogged land and transpiration from phreatophytes and other vegetation. Ponds and sloughs are regarded as being part of the wet areas.

Evapotranspiration from noncultivated brushland.—About 18,000 acres of the 62,000 acres that constitutes the Sevier-Sigurd ground-water basin is not cultivated, but it is covered with native brush and other vegetation that depend entirely on soil moisture derived directly from precipitation. It was assumed that all the precipitation was evaporated or consumed by the brush and other vegetation and that none reached the ground-water reservoir. The annual precipitation at Richfield was 11.15, 4.69, and 7.14 inches in 1957, 1958, and 1959, respectively. Applying this precipitation to 18,000 acres results in figures for evapotranspiration from noncultivated brushland of approximately 17,000, 7,000, and 11,000 acre-feet during the 3-year period.

Evaporation from surface-water reservoirs.—Rockyford Reservoir, which has an average water area of about 300 acres, is the only large body of open water in the Sevier-Sigurd basin. The average evaporation from open water at Piute Reservoir, 40 miles to the south, from April through October, when there usually is water in Rockyford Reservoir, is about 49 inches (U.S. Weather Bur., written commun., 1958). Applying this rate of evaporation to the open-water acreage at Rockyford Reservoir results in a figure for evaporation of about 1,000 acre-feet.

Change in surface-water storage.—Changes in water storage in Rockyford Reservoir are not recorded, although the water going through the reservoir is measured at the gaging station on the river below the dam and on the Rockyford-Willow Bend Canal. Rockyford is a regulating reservoir which remains nearly full from about April 1 until about October 15 of each year; it is usually empty during the rest of the year. Inasmuch as the inflow-outflow study is based on calendar years and Rockyford Reservoir is normally empty on January 1 of every year, the changes in storage during the study years are regarded as negligible.

Change in ground-water storage.—The changes in ground-water storage in the Sevier-Sigurd basin were determined as follows: A Thiessen polygon (Linsley, Kohler, and Paulhus, 1949, p. 78) was constructed around each observation well in the part of the basin where water-table conditions prevail. (See fig. 11.) The water level in 13 observation wells on April 1, 1957, was selected as a reference datum. For each well, the monthly water-level change (with reference to the datum water level of April 1) was multiplied by the area of the Thiessen polygon surrounding the well and by 0.2, the estimated average specific yield of the water-bearing material. The totals for each well were then added to give the monthly change in ground-water storage within the basin, in acre-feet. The monthly status of ground-water storage referred to the datum of April 1, 1957, and annual changes by months are listed in table 10.

The data in table 10 indicate that the ground-water storage increased by 29,000 acre-feet and 26,000 acre-feet during 1957 and 1958, respectively, and decreased by 31,000 acre-feet during 1959. The increases during 1957 and 1958 were mostly due to above-normal precipi-

TABLE 10.—*Monthly status of ground-water storage in the Sevier-Sigurd basin, in acre-feet, referred to the datum of April 1, 1957, and annual changes by months for the period December 1956–December 1959*

Month	Monthly status 1956	Change 1956–57	Monthly status 1957	Change 1957–58	Monthly status 1958	Change 1958–59	Monthly status 1959
January			+1,000	+28,000	+29,000	+19,000	+48,000
February			−700	+26,700	+26,000	+18,000	+44,000
March			−400	+20,400	+20,000	+22,000	+42,000
April			0	+20,000	+20,000	+20,000	+40,000
May			+3,900	+20,100	+24,000	+15,000	+39,000
June			+14,000	+33,000	+47,000	−7,000	+40,000
July			+27,000	+38,000	+65,000	−27,000	+38,000
August			+36,000	+36,000	+72,000	−36,000	+36,000
September			+38,000	+33,000	+71,000	−38,000	+33,000
October			+35,000	+34,000	+69,000	−39,000	+30,000
November			+32,000	+30,000	+62,000	−34,000	+28,000
December	+2,000	+29,000	+31,000	+26,000	+57,000	−31,000	+26,000

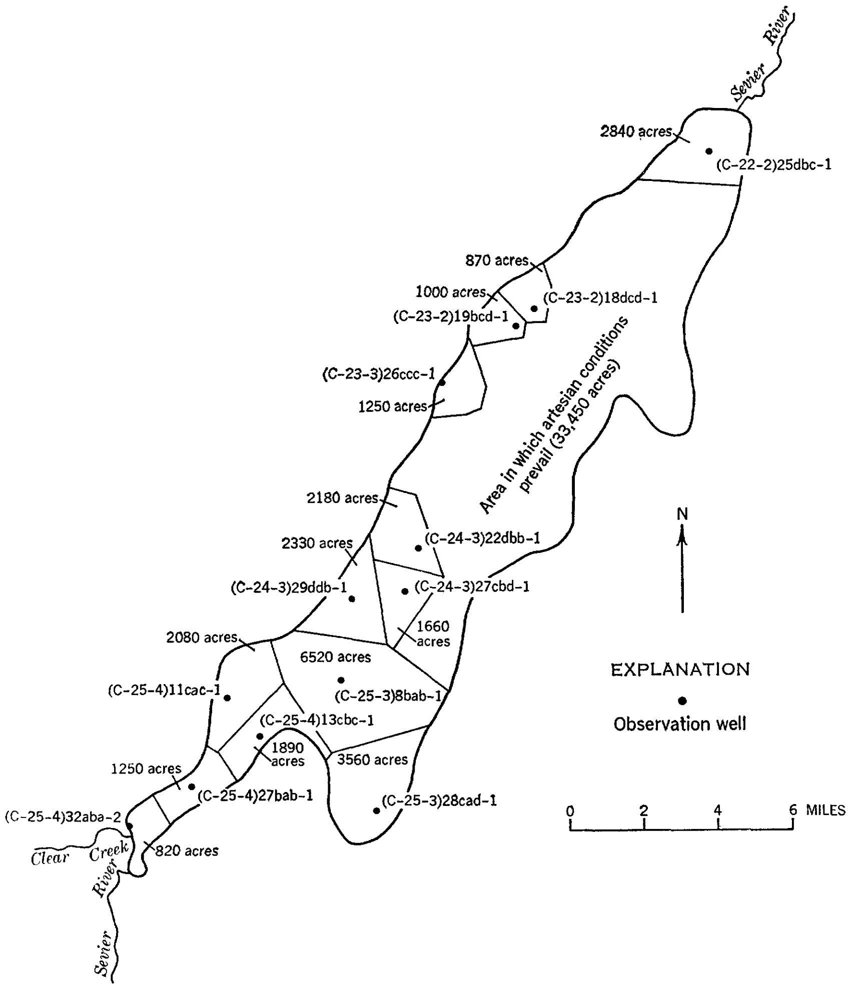

Figure 11.—Valley floor in the Sevier-Sigurd ground-water basin showing Thiessen polygons drawn around observation wells in water-table areas.

tation in the drainage basin during 1957 and to an increase in 1958 in the amount of water available for irrigation in the areas of recharge. The decrease during 1959 was due to a decrease in the amount of irrigation on the recharge areas and to subnormal precipitation in the drainage basin during 1958 and 1959.

A change in ground-water storage of about 5,600 acre-feet in the Sevier-Sigurd basin would cause a change in ground-water level of 1 foot. This is calculated on the basis that the areas in the basin that are under water-table conditions comprise 28,250 acres (fig. 11) and that the average specific yield of the water-bearing materials in these areas is 0.2. Small changes in water level result in very little change in storage in the areas under artesian conditions because the coefficients of storage are small. Aquifer tests at three artesian wells in the basin indicated coefficients of 0.0001, 0.001, and 0.001. (See table 4.) Thus, a decline of ground-water level of 1 foot in the 33,450 acres that constitutes the artestian areas would result in a change of storage of only about 33 acre-feet.

Inflow from other sources.—The item "Inflow from other sources" in table 9 was the last to be determined in the inflow-outflow analysis of the Sevier-Sigurd basin. It represents inflow not previously accounted for in the analysis, and it includes perennial flow in Monroe, Water Canyon, and Cottonwood Creeks, inflow from intermittent and ephemeral streams flowing into the valley, and side inflow of ground water. This item was computed by taking the difference between the known inflow and the total of the known outflow plus or minus changes in storage.

Most of the inflow from other sources is from Water Canyon, Cottonwood, Thompson, Monroe, and Dry Canyon Creeks, which flow from the Sevier Plateau on the east, and from North Cedar Ridge, South Cedar Ridge, Willow, and Cottonwood Creeks, which flow from the Pavant Range on the west. Of this group, Monroe Creek is by far the largest. It is perennial, and it probably discharges more than 10,000 acre-feet of water into the valley during most years. Very little of this water, however, reaches the Sevier River directly. Most of it seeps into the alluvial fan at the mouth of Monroe Creek Canyon or is diverted during the irrigation season to irrigate about 1,600 acres of cultivated land. Water Canyon and Cottonwood Creeks have small perennial flows from the east. The other creeks, fed by snowmelt, flow only in the spring and early summer, but they contribute considerable water to the basin. Water from each creek is used to irrigate some land—probably less than 100 acres for any individual stream.

Most of the ground-water inflow probably seeps into the earth near the mountain front from the creeks listed in the paragraph above. During periods of snowmelt and following summer rainstorms, a moderate amount of water flows down the mountainsides, seeps into alluvial fans at the mouths of the many canyons on both sides of the valley, and eventually moves into the ground-water basin. Some water seeps into landslide deposits and other accumulations of unconsolidated earth materials along the mountainsides and eventually finds its way to the main ground-water reservoir. Some water enters bedrock formations in the mountains, moves toward the basin through the bedrock, and eventually flows into the alluvium of the ground-water basin.

Total water entering and leaving the basin.—During any time interval, the total amount of water entering a basin is equal to the amount leaving the basin plus or minus any change in storage. This total for the Sevier-Sigurd basin was 239,000 acre-feet in 1957, 283,000 acre-feet in 1958, and 190,000 acre-feet in 1959.

GROUND-WATER CONDITIONS BY BASINS

Large quantities of ground water are stored under both artesian and water-table conditions in the valley fill of each of the five ground-water basins in the central Sevier Valley. The greatest amounts are stored in the permeable gravel and sand of the Sevier-Sigurd basin (about 800,000 acre-feet) and the Gunnison-Sevier Bridge Reservoir basin (about 300,000 acre-feet). The other basins contain lesser, yet substantial, amounts. Most of the ground water currently used is developed from springs in four of the five basins and from drains in the Redmond-Gunnison basin. The Sevier-Sigurd basin and the Gunnision-Sevier Bridge Reservoir basin could probably each yield an additional 15,000 acre-feet of ground water to wells without greatly affecting streamflow. Most of this water would be salvaged from nonbeneficial use. This and other information is presented in greater detail in the following discussion of each ground-water basin.

JUNCTION-MARYSVALE BASIN

Availability and storage of ground water.—Ground water is available in the Junction-Marysvale basin in the alluvium which fills the valley from Piute Dam to the head of Marysvale Canyon. Additional ground water is available both in the terrace deposits on the benches downstream from Piute Dam on both sides of the valley and in the alluvium near Junction.

No wells have been constructed in the alluvium on the valley floor between Piute Dam and Marysvale Canyon, and it is not known if the ground water is under artesian or water-table conditions. Wet meadows and marshes indicate that the alluvium in the lower part of the valley is completely saturated with water. Ground water occurs under water-table conditions in the terrace deposits and in the alluvium near Junction. The known depth to the water table in the Junction-Marysvale basin ranges from 15 feet in well (C–30–3)15bba–1 to 50 feet in well (C–28–3)22bbc–1.

Although there is little information concerning the thickness and character of the deposits in the Junction-Marysvale basin, probably about 30,000 acre-feet of ground water is stored in the sand and gravel deposits between Piute Dam and Marysvale Canyon. (See table 5.)

Existing development.—Most of the ground water used in the Junction-Marysvale basin is from springs which discharge from the alluvium and the terrace deposits. The two biggest springs, Barnson Springs, (C-29-3)16ccb, and Taylor Pond Spring, (C-27-3)17dcb, both discharge from the alluvium; and they yield about 11,000 acre-feet of water annually for use in irrigation. The public supplies for both Marysvale and Junction come from bedrock springs in the mountains adjacent to the project area.

Very little ground water has been developed by wells in the Junction-Marysvale basin. Records were obtained for 28 wells, and these records indicate that all the wells provide water for domestic and stock purposes. Most of the wells are on the terrace on the west side of the valley; 24 wells obtain water from the terrace deposits, whereas the remaining 4 produce from bedrock. Twenty-one of the wells are drilled, and 7 are hand dug. Well (C-28-3)34ccd-1, at Piute Dam, was drilled 237 feet deep in volcanic agglomerate and produced about one-half gallon per minute from joints in the rock at a depth of 204 feet. The other three bedrock wells are probably in the Sevier River Formation. Wells (C-27-3)29aaa-1 and (C-28-3)8ddb-1 yield 60 and 5 gpm respectively, whereas the yield of well (C-28-3)22bbc-1 is not known.

Open drains have been excavated in the wet bottom land between Piute Dam and Marysvale. In secs. 28 and 33, T. 27 S., R. 3 W., about 2 miles of drain discharges about 1,000 acre-feet of water annually into the Sevier River. The water is used for irrigation downstream.

Potential development.—About 5,000 acre-feet of water could probably be developed annually from the gravel and sand deposits underlying the Junction-Marysvale basin with little effect on streamflow. About 10,000 acre-feet of water is consumed in the basin each year by saltgrass, willows, and other phreatophytes. This loss occurs on 3,500 acres of wet lowlands between Piute Dam and the head of Marysvale Canyon. Probably about half of this 10,000 acre-feet of water could be salvaged from nonbeneficial use by pumping from wells. In doing so, the natural discharge from Taylor Pond Spring near the head of Marysvale Canyon would probably be affected to some extent. The discharge from Barnson Springs and from the many small springs issuing from the terrace deposits west of the lowlands would not be affected.

SEVIER-SIGURD BASIN

Availability and storage of ground water.—Ground water under both artesian and water-table conditions is available in the alluvium throughout the Sevier-Sigurd basin. Artesian conditions prevail from Central to Sigurd, generally east of U.S. Highway 89, and in a small area on the southwest side of the Dry Wash fault, northeast of Joseph. (See pl. 6.) Water-table conditions prevail mainly in the areas from

Sevier to Joseph, Monroe to Central, and along the west side of the valley extending from Elsinore to Sigurd. Ground water in small to moderate amounts generally sufficient only for stock and domestic purposes is also available under water-table conditions in the Sevier River Formation near Joseph.

Artesian conditions in the alluvium in the Central-Sigurd area are caused by 60–80 feet of silty clay of low permeability which overlies the permeable gravels in most of the area. The piezometric surface of the water ranges from about 40 feet below land surface in well (C–23–2)17cdd–1 to 20 feet above land surface in well (C–23–2) 19dab–1. The hydraulic head generally increases with the depth of the well; this increase suggests upward leakage from the deeper artesian aquifers into the shallower artesian aquifers.

Artesian conditions in a small basin northeast of Joseph are due in part to the Dry Wash fault. Ground-water rises along the barrier formed by the fault into a series of gravel beds and is there confined under pressure by an overlying layer of silt of low permeability.

Recharge for the artesian basin takes place upstream where the ground water occurs under water-table conditions. (See pl. 6.) The observed water table in the recharge area ranges in depth below land surface from 125 feet in well (C–25–3)28cad–1 to 33 feet in well (C–24–3)27cbd–1.

The Sevier-Sigurd basin has the largest ground-water storage capacity of any of the basins within the central Sevier Valley. Probably about 800,000 acre-feet of ground water is in storage in the sand and gravel deposits of the basin. (See table 5.) Most of this water is in the artesian area extending from Central to Sigurd. There the principal water-bearing zones are lenses of sand and gravel which are at various depths below the land surface. (See pl. 3.) The beds of sand and gravel are separated by water-bearing silt and clay which are too fine grained to yield water readily to wells.

Existing development.—Most of the ground water now used in the Sevier-Sigurd basin is discharged by springs from both alluvium and bedrock. The major springs discharging from the alluvium are in the Three Lakes area, sec. 4, T. 24 S., R. 2 W; at Herrins Hole, (C–23–2) 23bdb; in the springs areas in secs. 27, 28, and 33, T. 23 S., R. 2 W.; and at Black Knoll Spring, (C–23–2)12bbc. Discharge from these springs and seepage along the west side of Rockyford Reservoir have a combined total annual discharge of about 18,000 acre-feet. The water is used for irrigation and for fish culture.

The major springs discharging from bedrock are Glenwood Spring, (C–23–2)36cbd; Parcell Creek Spring, (C–23–2)25cca; Indian Creek Spring, (C–23–2)25bdb; Richfield Spring (C–23–3)26aca; Monroe

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Hot Springs, (C-25-3)10dda; and Joseph Hot Springs (C-25-4) 23aac. These springs have a combined annual discharge of about 10,000 acre-feet, most of which is used for irrigation. Richfield and Glenwood Springs are the municipal supply for Richfield and Glenwood, and Glenwood Spring is used also for fish culture. The communities of Sevier, Joseph, Monroe, Elsinore, Austin, Annabella, Central, Sigurd, and Vermillion all obtain water for public supply from bedrock springs in the mountains adjacent to the project area.

Wells produce about 7,000 acre-feet of ground water annually in the Sevier-Sigurd basin. About 6,000 acre-feet flows freely from wells, and the other 1,000 acre-feet is pumped. Although more wells have been constructed in the Sevier-Sigurd basin than in any other part of the central Sevier Valley, most of them are small-diameter wells ranging from 50 to 180 feet in depth. They are used mostly for stock and domestic purposes, and their yields are small.

Records were obtained for more than 300 flowing wells between Central and Sigurd. Most of these wells are used for stock watering and for irrigation of pastures; but in the vicinity of Venice, wells provide water for irrigation and for domestic use. They are mostly 2–4 inches in diameter, and they yield water through the open bottom of casings without benefit of well screens or casing perforations. Records were obtained in the Sevier-Sigurd basin for only 12 wells that are 8 inches or more in diameter. All these wells yield water through screens or perforated casings. Six of the wells are used for irrigation, 3 for municipal supply, and 3 for industrial use. Four of the wells, flow, whereas the other eight are pumped. Three of the flowing wells—(C-24-2)5bcc-5, (C-24-2)6abc-1, and (C-24-2)6bbd-1—are used for irrigation, as are three of the pumped wells—(C-24-3)23bad-1, (C-24-3)12bda-1, and (C-23-2)14cdd-1. The municipal wells are (C-23-1)20adc-1, (C-23-3)25bab-1, and (C-24-3)29ddb-1. The three industrial wells are (C-23-2)1aab-3 and (C-23-2)1aac-6, used by a gypsum processing plant, and (C-24-3)27cbd-1, used for washing sugar beets.

About 10,000 acre-feet of ground water is drained annually from an estimated 20 miles of both open and buried tile drain in the Sevier-Sigurd basin. About 4,000 acres of land is drained, and the water is used to irrigate both cultivated fields and pasturelands downstream.

Potential development.—An additional 15,000 acre-feet of water could probably be pumped annually from wells penetrating the gravel and sand deposits of the Sevier-Sigurd basin without greatly affecting the flow in the Sevier River. About 10,000 acres of wet meadowland containing growths of saltgrass, willows, and other phreatophytes annually discharge about 30,000 acre-feet of water into the air. It is believed that about half of this water could be salvaged.

New production wells would have the least effect on the river if they were constructed in the area between Central and Sigurd, where artesian conditions prevail. In this part of the basin, the cones of depression surrounding pumped wells would spread to relatively large areas, but they would have little effect on the flow in the river because the 60–80 feet of silt and clay overlying the permeable gravel and sand deposits in most of the area would prevent appreciable leakage from the river. The amount of water entering the river through springs, seeps, sloughs, flowing wells, and drains, however, would be slightly reduced. Springs issuing from bedrock in adjacent areas, such as Richfield Spring, (C–23–3)26aca, and Glenwood Spring, (C–23–2)36cbd, would not be affected.

AURORA-REDMOND BASIN

Availability and storage of ground water.—Ground water is available in the alluvium throughout the Aurora-Redmond basin under either artesian or water-table conditions. Artesian conditions exist from the area east of Aurora to the Redmond Hills. Water-table conditions exist from immediately below Rockyford Reservoir to Aurora and on both the east and west sides of the valley bordering the artesian area. The piezometric surface in the artesian area ranges from 10 feet below land surface in well (C–21–1)27aad–1 to 10 feet above land surface in well (C–21–1)13abd–1. The depth to water in the area where water-table conditions prevail ranges from 10 feet below land surface in well (D–21–1)19bbc–2 to 180 feet in well (C–21–1)16dbc–1.

Ground water is available in the Sevier River Formation on the west side of the valley. The formation yields from 1 to 18 gpm to existing stock wells in the area, but the potential yield of the aquifer to wells is not known.

The amount of ground water stored in the sand and gravel deposits of the Aurora-Redmond basin is about 200,000 acre-feet. (See table 5.) Most of this storage is in the artesian area in beds of sand and gravel which range from depths of about 20 to 585 feet below the land surface. The beds of sand and gravel are separated by water-bearing silts and clays which are too fine grained to yield water readily to wells.

Existing development.—The largest development of ground water in the Aurora-Redmond basin is from springs. The most concentrated area of springs is in secs. 11 and 12, T. 21 S., R. 1 W., and these springs feed Redmond Lake. The springs are fed by the upward movement of water from the artesian aquifers along the south side of the Redmond Hills, and they discharge about 11,000 acre-feet of water annually. The water is used for irrigation near Redmond during the growing season and is discharged into the Sevier River during the winter. Bedrock springs in the mountains adjacent to the valley supply water for municipal use at Salina and Aurora.

Very little ground water has been developed by wells in the Aurora-Redmond basin. The wells tap either the alluvium or the Sevier River Formation, and most of the wells are less than 6 inches in diameter and supply water for domestic and stock use only. Several 6-inch wells drilled on the south side of the Redmond Hills produce water from gravel in the alluvium 65 feet below land surface, and they supply water for the town of Redmond. The town of Aurora uses an 8-inch well, (C–22–1)5bac–1, to supplement the supply from spring (C–21–1)20bcc, which is the principal municipal source of water.

With the exception of wells in the Sevier River Formation, only one well in the basin derives water from bedrock. Well (C–21–1)26bdb–1, a flowing well, was originally drilled as an oil test, and it taps water from Tertiary volcanic rock at 620 feet.

Little development by drains has been attempted in the Aurora-Redmond basin. A few open and a few buried tile drains have been constructed near the lower parts of fields bordering the Sevier River to convey excess irrigation water off the land.

Potential development.—Any development to salvage water from nonbeneficial use in the Aurora-Redmond basin should be in the artesian area in the vicinity of Redmond Lake. Development elsewhere would tap the flow of the Sevier River. Wells should be constructed along the west margin of the basin, where the water is fresh. The ground water along the east margin of the basin is slightly to moderately saline because of the proximity of deposits of Arapien Shale. Although about 3,000 acre-feet of water might be developed from the artesian area, probably not more than 500–1,000 acre-feet of water could be pumped annually without greatly affecting springs that feed Redmond Lake. Such development should proceed with caution, however, because Redmond Lake furnishes about 11,000 acre-feet of water each year to irrigators in the vicinity of Redmond. Although about 9,000 acre-feet of water is used annually by vegetation of low economic value on about 3,000 acres of waterlogged land in the Aurora-Redmond basin, a substantial part of this water probably could not be salvaged by pumping from wells without affecting the discharge from the springs flowing into Redmond Lake.

REDMOND-GUNNISON BASIN

Availability and storage of ground water.—Ground water is available under either water-table or artesian conditions almost everywhere in the alluvium of the Redmond-Gunnison basin of the central Sevier Valley and in the Sevier River Formation on the west side of the valley. Water-table conditions prevail from Redmond north to Gunnison on both the east and the west sides of the valley. The depth to the water table below land surface ranges from 10 feet in well (D–19–1) 22dca–1 to 160 feet in well (C–19–1)35cdd–1.

Artesian conditions exist in a narrow strip of alluvium extending from Redmond northward to west of Axtell along the center of the valley. From the area west of Axtell northward, the artesian area increases in width as the confining silty clay cover extends from the river both eastward and westward. The silty clay cap ranges in thickness from 20 to 80 feet and continues northward into the next basin. The piezometric surface in the artesian areas ranges from 24 feet below land surface in well (C–19–1)23cba–1 to 4 feet above land surface in well (C–19–1)25cdd–5.

About 150,000 acre-feet of ground water is in storage in the sand and gravel deposits of the Redmond-Gunnison basin. (See table 5.) The most permeable of these deposits underlie the artesian area at depths of from about 20 to 180 feet below land surface.

Existing development.—Ground-water development in the Redmond-Gunnison basin has mostly been from flowing wells in the bottom of open drains. About 5 miles of such drains, containing approximately 200 flowing wells, each 2 inches in diameter, exist in the area adjacent to the Sevier River, generally west of Centerfield. About 8,000 acre-feet of water from these drains is used annually for irrigation downstream.

Wells 6 inches or less in diameter supply water for domestic and stock use on individual farms throughout the basin, the greatest concentration being in and around Axtell. Most domestic and stock wells are in the alluvium, but many on the west side of the valley are in the Sevier River Formation.

Three large-diameter pumped wells—(C–19–1)10dcb–1, (C–19–1) 23bcc–1, and (C–19–1)23cac–1—produce about 700 acre-feet of water annually for irrigation. These wells derive water from gravel zones in the alluvium between 35 and 180 feet below land surface.

Springs discharge about 4,000 acre-feet of water annually from the alluvium along the valley floor west of Centerfield. It is not known if the springs are natural or if they are concealed old open drains. Water from the springs flows into the river and is diverted for irrigation downstream.

No springs are known to discharge from bedrock within the Redmond-Gunnison ground-water basin. Numerous springs discharge from bedrock in the hills east of the valley, however, and two of them (D–19–2)4daa and (D–19–2)20ddd, furnish water for the municipal supply at Gunnison and Centerfield, respectively. Bedrock springs also supply irrigation water for areas east of Gunnison and Axtell. The source of water for the bedrock springs is precipitation on the Wasatch Plateau to the east. Part of the precipitation sinks into the earth and percolates down through the bedrock. When it meets the underlying relatively impermeable Arapien Shale, the water is forced to the surface, and springs result.

Potential development.—The development of ground water as a means of salvaging water is not recommended in most parts of the Redmond-Gunnison basin, although about 21,000 acre-feet of water is wasted annually on about 7,000 acres of wetland in the basin. Ground water in the gravel and sand beds underlying most of the basin is slightly to moderately saline because the Arapien Shale, which contains salt and gypsum deposits, underlies most of the valley at depth of less than 200 feet. Pumping large quantities of this water for irrigation would result in return flow of water of very poor quality, thus a lower general quality of water downstream in the Sevier River system.

If the salvage of water is attempted, the results would be more fruitful in the northwestern part of the basin west of the Sevier River in secs. 11, 14, and 23, T. 19 S., R. 1 W., where the valley fill is more than 300 feet thick and the ground water contains less dissolved minerals. In this part of the basin, a layer of silty clay that is about 20–80 feet thick separates the river from the underlying sand and gravel aquifer. The water in the aquifer, therefore, is under artesian conditions, and pumping from wells would have little effect on flow in the river. There might be a decrease in flow, however, from sloughs, drains, and flowing wells which drain into the river. Because the area that might be developed is comparatively small, pumping large quantities of water may induce the inflow of slightly to moderately saline ground water into the aquifer from adjacent areas. The amount of water that could be developed annually during a long period of time would probably be less than 1,000 acre-feet.

GUNNISON-SEVIER BRIDGE RESERVOIR BASIN

Availability and storage of ground water.—Ground water in the Gunnison-Sevier Bridge Reservoir basin is available in large quantities under artesian conditions in the alluvium in the center of the valley floor and in lesser amounts under water-table conditions in the alluvium and in the Sevier River Formation at the sides of the valley floor. The observed water table ranges in depth from 30 feet below land surface in well (C–19–1)12dcc–1 to 90 feet below land surface in well (C–19–1)3bbc–1. Much of the artesian area is overlain by the Sevier Bridge Reservoir. The confining material in the artesian area is a silty clay which ranges in thickness from about 20 to 80 feet and is a continuation of the same confining material that overlies the artesian area in the Redmond-Gunnison basin. The observed piezometric surface in the artesian area ranges from 5 feet below land surface in well (C–19–1)12cac–1 to 7 feet above land surface in well (C–18–1)3ccd–1.

About 300,000 acre-feet of ground water is stored in the sand and gravel deposits in the Gunnison-Sevier Bridge Reservoir basin. (See table 5.) The best aquifers are the beds of sand and gravel between depths of 40 and 425 feet below land surface.

Existing development.—Ground water from wells in the Gunnison-Sevier Bridge Reservoir basin is used mostly for stock and for irrigation. Records were obtained for more than 200 flowing wells, each 2–3 inches in diameter and 20–80 feet deep, in the center of the valley. These wells discharge about 3,900 acre-feet of water annually. Domestic and stock wells that are 6 inches or less in diameter derive water from alluvium and from the Sevier River Formation and are used on individual farms throughout the basin. Only one well, (C–18–1)12abb–1, that exceeds 6 inches in diameter has been drilled in this basin.

Springs and seepage areas, particularly in secs. 2, 11, and 13, T. 18 S., R. 1 W., annually discharge about 12,000 acre-feet of water which is used for irrigation. Springs discharge water from the alluvium where there are leaks in the confining silty clay. Some of the "springs" may have originated as flowing wells whose casings have since rusted away.

The drains in the Gunnison–Sevier Bridge Reservoir basin consist mostly of a few channels that have been excavated to convey water from spring areas to the Sevier River. Also, some waste ditches at the lower ends of irrigated fields convey excess irrigation water to the river. The combined annual discharge of drains and springs in the basin is about 14,000 acre-feet.

Fayette Spring, (D–18–1)19dab, is the only large bedrock spring in the Gunnison-Sevier Bridge Reservoir basin. The source of the spring is precipitation on the Gunnison Plateau, and it issues from solution channels in the Flagstaff Limestone. The spring discharges about 1,900 gpm, or about 3,000 acre-feet annually, and it is the source of municipal supply for Fayette as well as an irrigation supply for lands in the near vicinity.

Potential development.—About 15,000 acre-feet of water could be pumped annually from gravel and sand artesian aquifers in the valley fill in the Gunnison-Sevier Bridge Reservoir basin without greatly affecting the flow in the Sevier River. Much of this water would be salvaged from the estimated 30,000 acre-feet of water which is discharged from about 10,000 acres of wetland supporting growths of saltcedar, willow, and other phreatophytes. Because the river is separated from the aquifer by about 20–80 feet of silty clay, pumping from wells would not directly affect the streamflow. The pumping, however, probably would decrease the side inflow into the stream from sloughs, springs, drains, and flowing wells. The flow from Fayette Spring would not be affected by pumping from aquifers in the valley fill.

EFFECTS OF DEVELOPING ADDITIONAL GROUND WATER IN THE CENTRAL SEVIER VALLEY

Pumping additional water from wells in any of the ground-water basins in the central Sevier Valley would eventually lower ground-water levels and reduce artesian pressures. The amount of lowering would be proportional to the net amount of water removed. The net removal of about 5,600 acre-feet of water from the Sevier-Sigurd ground-water basin would probably lower water levels in the basin 1 foot. Similar or smaller amounts of water removed from the other ground-water basins also would probably lower water levels in those basins a like amount.

If water is pumped from wells penetrating artesian aquifers, a reduction of artesian pressure would spread rapidly to rather large areas and would eventually affect water-table areas. If, on the other hand, the water is pumped from wells penetrating water-table aquifers, the lowering of water levels would spread slowly and would be limited largely to the vicinity of the pumped wells. If the pumping from the water-table areas were continued long enough, the effects of pumping would eventually extend to the artesian areas and cause a reduction of artesian pressure.

The greatest benefits of pumping would result from reducing artesian pressures. The reduction of artesian pressure would reduce or stop the discharge of ground water at the land surface in large areas and would eventually cause many sloughs and waterlogged areas to become dry. This would make available for beneficial use much water now being wasted by nonbeneficial evapotranspiration. Much waterlogged land, now impregnated with residue salts left by evaporation of ground water, would eventually become fertile if irrigation water were applied at intervals from above rather than seepage water applied constantly from below. With more efficient overall use of water, more water would be available to satisfy local and downstream water rights.

The flow of water in the Sevier River would not be greatly affected by reduced artesian pressures, because the river is separated from the artesian aquifers by 20–80 feet of relatively impermeable silty clay which would prevent seepage directly from the river. The amount of water flowing into the river from springs and seeps in the alluvium, however, would be reduced by a reduction in artesian pressure. A general lowering of areal ground-water levels would result in a slight increase of seepage from the river to the ground-water body in those areas where the water table slopes away from the river.

The greatest detriment of reducing artesian pressures would be the reduction or cessation of flows from wells and springs which tap the alluvium. Losses resulting from these reduced flows could be replaced by part of the water pumped from new production wells or by water diverted from the river upstream.

A program of developing the ground-water resources of the central Sevier Valley probably should proceed slowly. Production wells at first might be several miles apart. A network of observation wells around the production wells could be measured periodically to determine the amount and extent of the lowering of water levels or the reduction of artesian pressures. Production wells could be constructed almost anywhere in the artesian areas without directly tapping the river. In the water-table areas, however, production wells might be at least one-half mile from the river to prevent the spread of the cone of depression to the river, which would greatly increase the natural seepage from the river to the ground-water reservoir. The discharge from springs and flowing wells in the vicinity of the production wells could be measured periodically to determine any reduction in flow.

To be most effective, a program of ground-water development could be coordinated with a program improving surface-water diversion and distribution systems and a program of phreatophyte control. Probably about 35,000 additional acre-feet of water could eventually be pumped annually from the ground-water reservoirs in the central Sevier Valley without disadvantages that could not be managed or corrected. Most of this 35,000 acre-feet of water would be salvaged from nonbeneficial use.

QUALITY OF WATER

MINERAL CONSTITUENTS OF WATER

The major chemical constituents of water in the central Sevier Valley are silica, calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate. Constituents commonly present in small amounts are iron, fluoride, manganese, and boron. Other properties and characteristics that affect the quality of water are temperature, specific conductance, pH, and hardness. Table 11 gives the chemical analyses of water from selected wells, test holes, and springs in the area. The chemical quality of surface waters was given by Connor and others (1958, p. 272–275).

QUALITY IN RELATION TO USE

IRRIGATION

The characteristics of a water that appear to be most important in determining its suitability for use in irrigation are "(1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium" (U.S. Salinity Laboratory Staff, 1954, p. 69).

The concentration of soluble salts, or salinity, may be expressed in units of dissolved solids or of specific conductance. In this report, the classification of water is that used by Robinove, Langford, and Brookhart (1958) and is as follows:

Class	*Dissolved solids (ppm)*	*Specific conductance (micromhos at 25° C)*
Fresh	<1,000	<1,400
Slightly saline	1,000–3,000	1,400–4,000
Moderately saline	3,000–10,000	4,000–14,000
Very saline	10,000–35,000	14,000–50,000
Brine	>35,000	>50,000

Fresh water is suitable for irrigation, and slightly to moderately saline water can be used with proper land drainage. Of the 72 samples of ground water from the central Sevier Valley for which analyses are given in table 11, 69 percent were fresh, 17 percent were slightly saline, and 14 percent were moderately saline. The quality-of-water diagrams in plate 5 indicate that the ground water becomes generally more saline in a downstream direction.

The relative proportion of sodium to other cations and the probable extent to which a soil will absorb sodium from the water (thereby becoming less permeable), may be expressed in terms of sodium-adsorption-ratio (SAR), where $SAR=\frac{Na^{+}}{\sqrt{\frac{Ca^{+2}+Mg^{+2}}{2}}}$. The SAR value is an index of sodium hazard. The concentrations of sodium, calcium, and magnesium in the formula are expressed as equivalents per million.

TABLE 11.—*Chemical analyses of water from selected wells, test holes, and springs in parts of Sanpete, Sevier, and Piute Counties*

[All analyses by U.S. Geol. Survey]

Well or spring [1]	Date of Collection	Geologic source [2]	Temperature (° F)	Silica (SiO2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Na+K: Sodium (Na)	Na+K: Potassium (K)	Lithium (Li)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Dissolved solids [3]	Hardness as CaCO3	Noncarbonate hardness as CaCO3	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos per centimeter at 25° C)	pH
Sanpete County																						
(C-17-1)																						
34cdb-1	9-3-57	Qal	54	34	0.46	0.00	51	44	143	8.7	0.6	227	48	282	0.5	2.5	731	308	122	3.6	1,440	8.1
(C-18-1)																						
12abb-1	8-27-57	Qal	55	17	.09	.00	38	39	59	2.3	.2	245	25	114	.2	1.4	417	256	54	1.6	775	7.8
25ddc-1 (TH 20)	10-21-59	Qal	54	17	----	----	78	72	198		----	260	95	432	----	1.8	1,020	492	279	3.9	1,580	7.4
(C-19-1)																						
11bdd-1 [4]	10-8-56	Qal	51	22	.25	----	214	173	748	5.4	----	442	833	1,160	.1	89	3,460	1,240	883	9.2	5,440	7.2
	8-27-57	Qal	50	25	.23	.00	225	153	765	17	----	476	822	1,130	.1	64	3,370	1,190	800	9.7	5,360	7.4
23cac-1	9-3-57	Qal	53	34	.11	.00	116	101	438	6.2	1.6	605	518	399	.5	93	2,010	705	209	7.2	3,280	7.6
25cdd-5	7-2-58	Qal	52	34	.04	----	202	174	391		----	514	996	402	----	57	2,510	1,220	799	4.9	3,500	7.4
25dcc-1 (TH 17)	11-5-59	TKs	----	15	----	----	359	60	1,700		----	20	705	2,860	----	57	5,770	1,140	1,120	22	9,230	7.9
(D-18-1)																						
19dab (S)	8-27-57	Tf	64	13	.00	.00	49	43	99	1.9	.3	305	43	152	.3	1.2	553	300	50	2.5	1,020	7.6
(D-19-2)																						
4daa (S)	do	Fz, Tg	67	13	.05	.02	38	19	94	3.8	.4	[5] 310	71	34	1.1	.1	429	173	0	3.0	711	8.3
20ddd (S)	8-28-57	Tg	55	19	.09	.00	74	66	49	1.7	.2	450	107	37	.3	23	598	456	87	1.0	978	7.5
(D-20-1)																						
4abc-1	9-3-57	Qal	54	22	1.0	.03	192	143	271	9.5	1.5	458	902	228	.6	48	2,040	1,067	692	3.6	2,960	7.5
25aad (S)	12-8-59	Qal	53	25	----	----	45	45	118		----	396	65	108	----	11	612	298	0	3.0	1,030	7.7
Sevier County																						
(C-21-1)																						
11ada-1	8-27-57	Qal	70	40	0.03	0.00	34	19	144	6.5	0.6	158	95	181	0.5	0.7	599	163	34	4.9	1,040	8.0
13abd-a	8-20-58	Qal	66	51	----	----	35	15	104		----	147	94	112	----	.7	484	151	30	3.7	758	7.9
20bcc (S)	8-26-57	Qal	57	14	.02	.00	42	41	15	1.9	.2	325	15	20	.2	2.9	312	274	7	.4	571	7.7
25bba-1 (TH 12)	11-25-59	Qal	----	27	----	----	22	14	171		----	337	70	95	----	.4	565	112	0	7.0	824	8.1
26bdb-1	7-2-58	Tv	60	35	.03	----	34	18	86		----	134	92	98	----	1.2	430	158	48	3.0	715	7.6

See footnotes at end of table.

TABLE 11.—*Chemical analyses of water from selected wells, test holes, and springs in parts of Sanpete, Sevier, and Piute Counties*—Con.

Well or spring [1]	Date of Collection	Geologic source [2]	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Na+K: Sodium (Na)	Na+K: Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids [3]	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos per centimeter at 25°C)	pH
				Parts per million																		
Sevier County—Continued																						
(C-22-1)																						
5bac-1	8-26-57	Qal	60	34	0.34	0.00	37	33	37	6.1	0.4	223	63	51	0.3	2.9	375	228	46	1.1	631	7.9
9add-2	6-29-59	Qal	57	30	----	----	561	326	709		----	240	2,180	1,280	----	13	5,220	2,740	2,540	5.9	7,070	7.6
20acc-1	8-30-57	Qal	59	52	1.7	.00	311	147	110	8.6	1.2	208	596	555	.3	80	1,960	1,380	1,210	1.3	3,100	7.5
(C-22-2)																						
35dcd-1	do	Qal	56	24	.40	.00	96	82	24	5.1	.4	526	112	48	.2	32	682	576	146	.4	1,180	7.6
(C-23-1)																						
20adc-1	9- 3-57	Qal	58	66	.19	.00	50	17	38	9.6	.7	228	16	61	.3	3.8	374	195	8	1.2	599	7.9
(C-23-2)																						
9abc-1	8- 6-59	Qal	58	29	----	----	37	38	27		----	262	36	39	----	.5	336	248	33	.8	563	7.9
10dcc-1 (TH 5)	4-18-60	Qal	53	22	----	----	89	67	88		----	529	154	62	----	11	753	500	66	1.7	1,170	7.7
14cbc-1 (TH 4)	4-19-60	Qal	52	38	----	----	79	31	34		----	188	112	90	----	0	476	324	170	.8	768	7.5
15cad-13	4-25-58	Qal	52	15	----	----	220	145	211		----	492	523	465	----	1.9	1,820	1,140	742	2.7	2,830	7.5
15cca-1	do	Qal	53	25	----	----	178	192	359		----	448	699	650	----	5.0	2,330	1,240	868	4.4	3,580	7.4
15cdb-3	do	Qal	53	27	----	----	164	119	256		----	431	482	420	----	8.3	1,690	898	545	3.7	2,660	7.4
15dbb-1	do	Qal	52	30	----	----	109	30	17		----	160	200	63	----	5.9	534	396	265	.4	818	7.9
15dbc-8	do	Qal	53	33	----	----	165	97	176		----	471	361	298	----	17	1,380	812	426	2.7	2,170	7.5
15dcb-4	7-15-57	Qal	52	35	.03	.00	69	34	2.1	4.1	.3	318	51	29	.2	4.3	404	312	52	.5	650	7.7
19dab-1	do	Qal	62	18	.00	.00	51	33	15	3.2	.4	294	26	21	.0	1.3	315	262	22	.4	545	7.8
20abd-1	4-25-58	Qal	52	19	----	----	293	381	564		----	540	1,350	1,180	----	10	4,060	2,300	1,850	5.1	5,820	7.3
27bcc-2 [6]	9-21-56	Qal	55	----	----	----	----	----	30	----	----	172	44	34	----	----	----	180	39	.9	490	8.0
27ccd (S)	8-21-56	Qal, Fz	56	----	----	----	----	----	30	----	----	192	76	42	----	----	----	224	67	.9	560	7.8
	7-15-57	----	56	36	.00	.00	52	20	25	4.1	.7	184	68	39	.2	2.9	338	212	60	.8	552	7.9
28bdd-8	do	Qal	51	37	.01	.04	726	184	45	7.5	1.6	578	2,020	76	.0	20	3,400	2,570	2,090	.4	3,560	7.0
28dad [7] (S)	9-21-56	Qal, Fz	57	----	----	----	----	----	36	----	----	250	324	46	----	----	----	532	327	.7	1,060	7.4
28ddd (S)	do	Qal, Fz	55	----	----	----	----	----	32	----	----	190	76	36	----	----	----	212	56	1.0	544	7.7
31dcb-3	5- 5-60	Qal	54	32	----	----	65	13	10		----	156	53	36	----	4.9	291	216	88	.3	459	7.4
(TH 1)			53	----	----	----	----	----	56	----	----	398	42	70	----	----	----	356	30	1.3	871	7.3
34aba-1	9-21-56	Qal																				
36cbd (S)	7-15-57	Con; Tv-Ja	59	41	.00	.00	26	6.4	10	1.9	.3	114	3.2	13	.1	.7	159	91	0	.5	232	8.0
(C-23-3)																						
25bab-1	7- 6-60	Qal	61	12	----	----	52	35	27		----	313	37	29	----	.4	341	271	14	.7	576	7.7
26aca (S)	7-30-57	Fz, Tch	68	14	.04	.01	45	38	12	4.0	.5	298	27	20	.2	.8	310	269	25	.3	548	7.9
36abd-1	7- 9-59	Qal	53	6.6	----	----	60	47	29		----	349	54	46	----	.0	415	343	57	.7	752	8.0

(C-24-2)																					
6abc-1	9-24-56	Qal	51	----	----	----	----	----	40	----	----	292	214	33	----	----	----	424	185	.8	902	7.4
	7-15-57	----	52	32	.02	.03	123	37	40	4.0	.4	298	247	32	.0	5.2	668	459	215	.8	1,000	7.6
(C-24-3)																					
2ddd-1	7-23-57	Qal	51	35	.05	.03	568	241	414	18	1.6	702	2,490	74	.1	32	4,220	2,410	1,830	3.7	4,670	7.1
12bda-1	8-13-59	Qal	52	41	----	----	71	28	16		----	270	52	31	----	8.7	381	292	71	.4	618	7.9
24cca (S)	7-29-57	Qal	55	46	.03	.00	46	11	40	1.6	.4	258	16	14	.5	2.2	306	160	0	1.4	482	8.2
29ddb-1	7-30-57	Qal	55	32	.19	.00	49	46	39	6.9	.8	274	59	83	.2	5.4	457	312	87	1.0	705	8.0
33add-2	7-23-57	Qal	55	36	.05	.27	109	26	64	5.0	.5	434	77	49	.0	20	600	379	24	1.4	968	7.4
(C-24-4)																					
32bbb (S)	7-30-57	Tv	52	40	.04	.01	48	9.6	10	5.8	.6	178	9.2	19	.2	3.2	235	159	13	.3	371	7.9
(C-25-3)																					
5dcd-2	7-31-57	Qal	58	33	.16	.03	82	34	23	7.1	.8	388	52	19	.2	16	461	344	26	.5	744	8.1
10dda (S)	7-23-57	Fz, Tv	169	54	.07	.02	282	34	562	63	4.8	354	898	630	2.6	.0	2,700	844	554	8.4	4,100	7.6
10dda [8] (S)	9-10-57	Fz, Tv	169	54	.38	.1	288	33	555	67	1.1	416	833	660	3.0	.0	2,860	----	----	8.2	4,020	6.4
25dca (S)	7-23-57	Tv	47	26	.05	.13	23	4.6	4.9	1.1	.2	78	17	3.5	.1	.2	119	76	12	.2	178	7.5
28cad-1	7-30-57	Qal	63	22	.02	.00	44	41	20	3.4	----	[9] 277	60	8.0	.8	6.8	343	278	23	.5	595	8.7
34ccd (S)	4-10-57	Qal	64	33	----	----	56	15	17		----	168	84	10	----	.3	298	202	64	.5	475	7.6
(C-25-4)																					
12abd-1	7-31-57	Qal	60	51	.02	.00	120	50	65	3.9	.5	[10] 465	118	57	1.1	55	763	505	104	1.3	1,160	8.4
23aac (S)	7-23-57	Fz, Tv	130	85	.56	.16	282	36	1,440	68	8.0	426	1,270	1,750	2.7	.0	5,150	852	502	22	7,790	6.9
23aac [11] (S)	9-11-57	----	147	84	----	----	264	44	1,380	45	1.5	412	1,250	1,690	6.0	.0	4,970	----	----	21	7,520	6.6
29ddc-1	7-30-57	QTsr	59	56	.01	.00	61	10	34	8.0	.6	226	31	42	.5	2.2	358	193	8	1.1	557	8.0
(C-26-4)																					
29bba-1	7-22-57	Tv?	53	23	20	6.5	327	112	30	5.8	1.0	36	1,240	17	3.9	.1	1,790	1,280	1,250	.4	2,050	5.7
(D-22-2)																					
15aac-1 [12]	8-27-57	TKs	66	11	.28	.00	26	10	47	5.1	.4	196	43	6.0	.4	.1	245	106	0	2.0	409	8.0
(D-24-1)																					
18bcd [12] (S)	8-26-57	Tv	53	44	.04	.00	21	3.8	9.0	3.0	.2	91	3	9.3	.2	1.2	140	68	0	.5	184	7.8
Piute County																					
(C-27-4½)																					
36cca [12] (S)	7-22-57	Tv	61	12	0.03	0.00	111	13	4.1	2.1	1.8	144	206	3.4	4.6	0.1	429	331	199	0.1	638	7.8
(C-29-3)																					
16ccb (S)	10-22-59	Qal	58	33	----	----	45	13	27		----	188	42	16	----	2.9	271	165	11	.9	423	7.6
(C-29-4)																					
21acc [12] (S)	7-29-57	Tv	55	39	.02	.00	23	4.5	5.0	2.8	.4	107	1.8	2.0	.1	.7	134	76	0	.3	176	7.7
(C-30-3)																					
16bbb-1	7-22-57	Qal? or QTsr	55	52	.10	.16	42	8.5	28	4.4	2.0	106	103	14	3.1	.5	306	138	53	1.0	434	8.0

[1] S, spring; TH, test hole.
[2] Con, contact; Fz, fault zone; Ja, Arapien Shale; Qal, Recent alluvium; QTsr, Sevier River Formation; Tch, Crazy Hollow Formation of Spieker (1949); Tf, Flagstaff Limestone; Tg, Green River Formation; TKs, Tertiary and Cretaceous sedimentary rocks (undifferentiated); Tv, volcanic rocks.
[3] Dissolved solids calculated from determined constituents.
[4] Contains 1.0 ppm boron (B).
[5] Includes equivalent of 2 ppm carbonate (CO_3)
[6] Contains 0.14 ppm boron (B).
[7] Contains 0.2 ppm boron (B).
[8] Contains 3.9 ppm boron (B).
[9] Includes equivalent of 17 ppm carbonate (CO_3).
[10] Includes equivalent of 13 ppm carbonate (CO_3).
[11] Contains 4.8 ppm boron (B).
[12] Bordering project area.

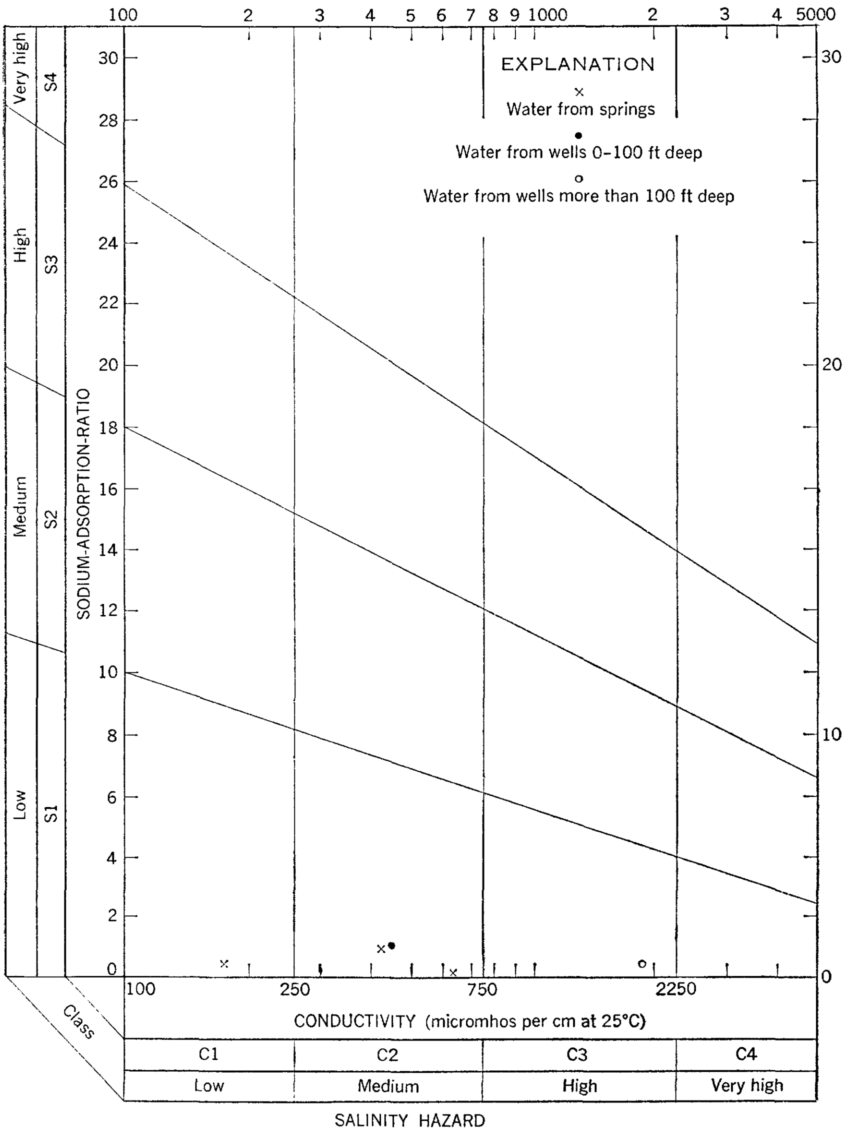

FIGURE 12.—Sodium-adsorption-ratio and salinity hazard of water in the Junction-Marysvale basin.

Water from selected wells and springs in the central Sevier Valley has been classified in figures 12–15 by using the indices of salinity and sodium hazard according to a diagram developed by the U.S. Salinity Laboratory Staff (1954, p. 80). The data plotted in figures 12–15 indicate that in general the water of best quality for irrigation is from

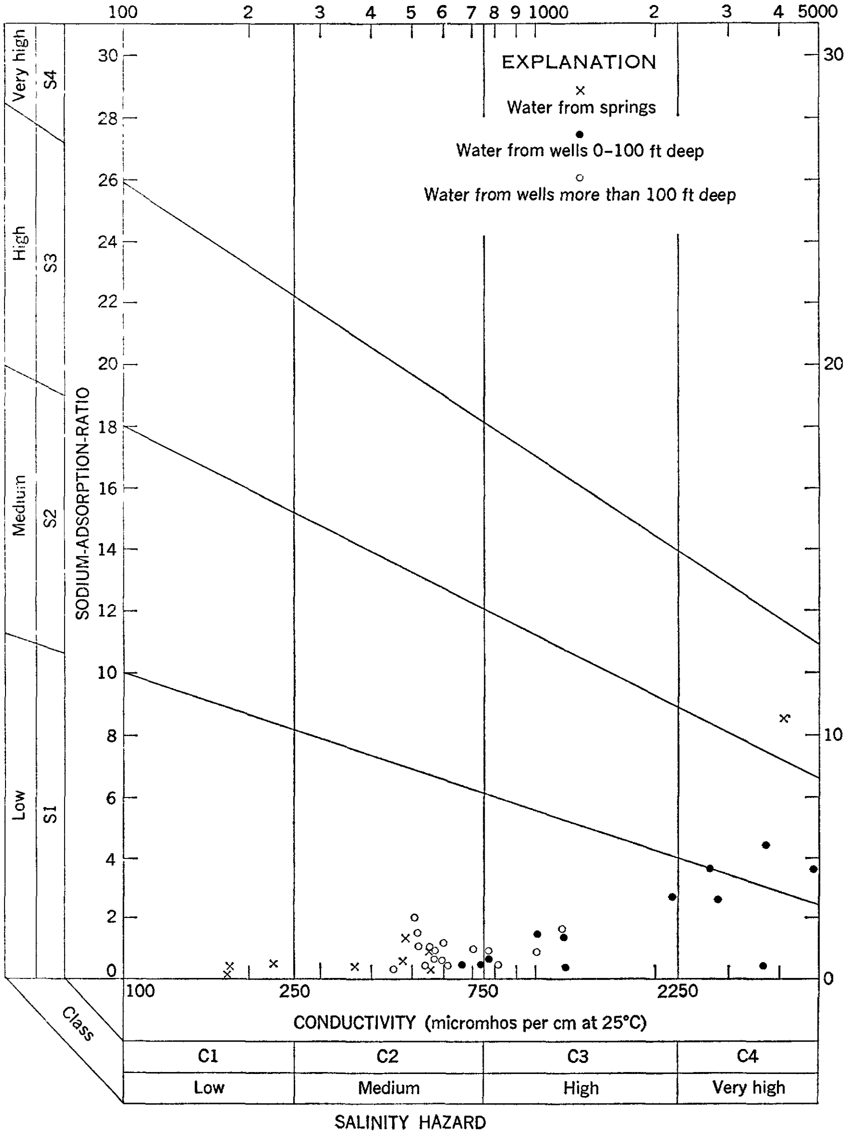

FIGURE 13.—Sodium-adsorption-ratio and salinity hazard of water in the Sevier-Siguard basin.

springs; that, in any given basin, wells more than 100 feet deep yield water of better quality for irrigation than do wells less than 100 feet deep; and that in general the quality of water for irrigation deteriorates in a downstream direction. (See quality-of-water diagrams on pl. 5.)

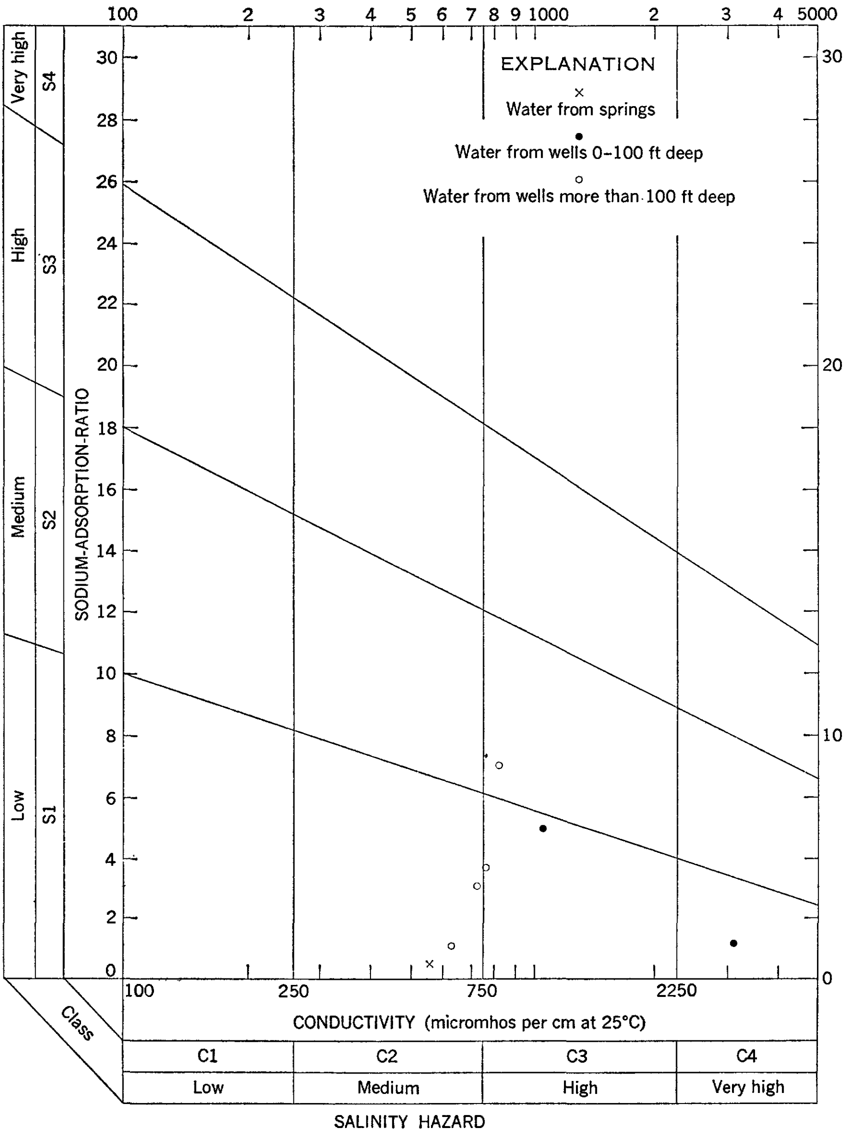

Figure 14.—Sodium-adsorption-ratio and salinity hazard of water in the Aurora-Redmond basin.

A small quantity of boron is essential to the normal growth of all plants, but excessive concentrations of boron are toxic to plants. Toxicity varies according to the tolerance of individual species. (See tables 9 and 14 in U.S. Salinity Laboratory Staff, 1954.) In general, water containing less than 0.33 ppm (parts per million) of boron is not

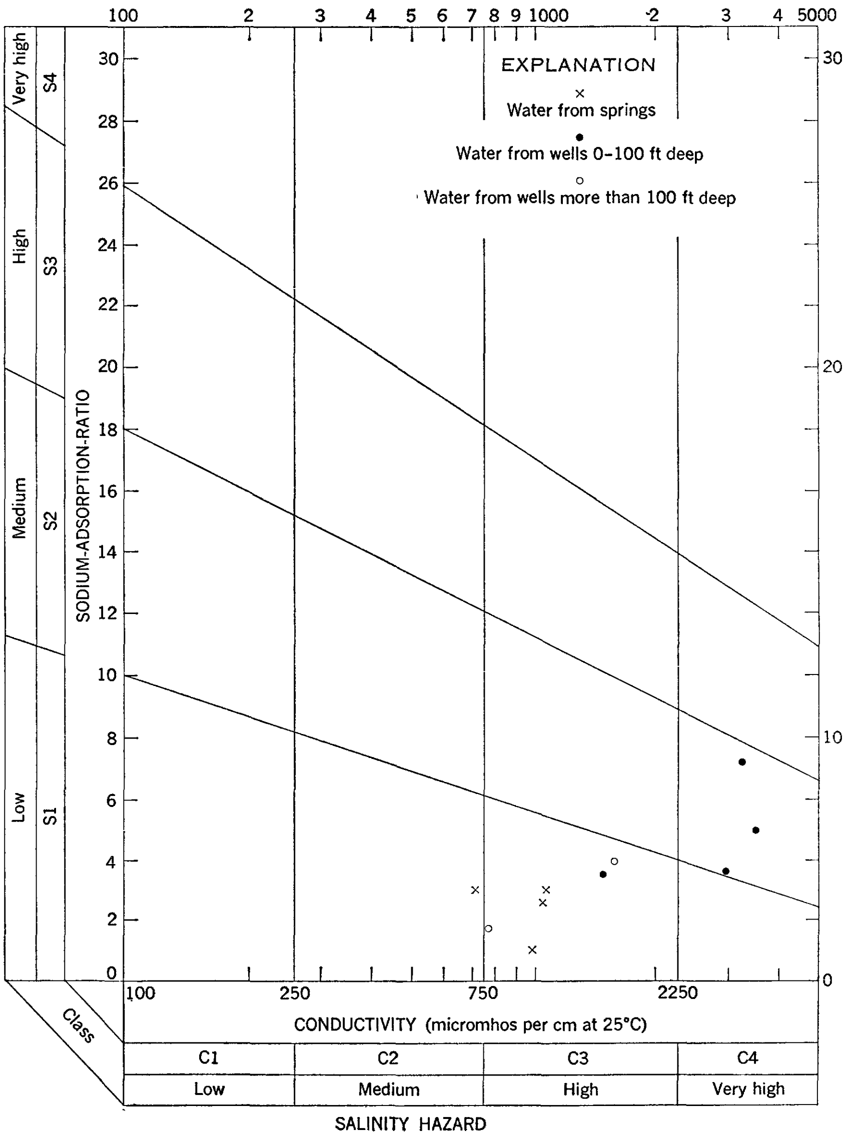

FIGURE 15.—Sodium-adsorption-ratio and salinity hazard of water in the Redmond-Gunnison-Sevier Bridge Reservoir basin.

harmful to any plant, whereas water containing more than 3.75 ppm may be toxic to all crops if used undiluted. Five samples from the central Sevier Valley were analyzed for boron. (See table 11.) Two of the samples, from well (C–23–2)27bcc–2 and spring (C–23–2)28-dad, contain less than 0.33 ppm of boron; thus, water from these

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sources is suitable for irrigation of all types of plants. One sample, from well (C–19–1)11bdd–1, contains 1 ppm of boron; water from this source might not be suitable for irrigation of certain plants, such as fruit trees, which are particularly sensitive to boron. Water from two hot springs, (C–25–3)10dda and (C–25–4)23aac, contains 3.9 and 4.8 ppm, respectively; if this water were used undiluted for irrigation, damage to plants would result.

The relation of the bicarbonate concentration to the concentration of calcium plus magnesium may be expressed as residual sodium carbonate (RSC), where $RSC = (CO_3^{-1} + HCO_3^{-1}) - (Ca^{+2} + Mg^{+2})$.[8] The U.S. Salinity Laboratory (1954, p. 81) stated, "Waters with more than 2.5 meq. per 1. (millequivalents per liter) 'residual sodium carbonate' are not suitable for irrigation purposes." Of the samples analyzed, only water from test hole 12, (C–21–1)25bba–1, has RSC that exceeds 2.5 meq per 1.[9]

DOMESTIC AND PUBLIC SUPPLY

The U.S. Public Health Service (1962) has recommended drinking water standards for domestic and municipal use. The recommended maximum concentration for some of the more common chemical substances are

Substance	*Parts per million (ppm)*
Chloride	250
Fluoride	(1)
Iron	.3
Manganese	.05
Nitrate	45
Sulfate	250
Dissolved solids	500

1 The recommended maximum fluoride concentration is variable, depending on air temperature. For temperatures similar to that at Richfield, the maximum recommended fluoride concentration is 1.2 ppm. (See U.S. Public Health Service, 1962, p. 8.)

According to the analyses listed in table 11, the recommended maximum concentrations were exceeded as follows: Chloride in 18 samples, fluoride in 7 samples, iron in 8 samples, manganese in 6 samples, nitrate in 8 samples, sulfate in 21 samples, and dissolved solids in 33 samples. About 50 percent of the samples do not exceed any of the recommended maximum concentrations of the Public Health Service.

The hardness of water is an important consideration in both domestic and public supplies. Soap consumption for cleansing, washing, and laundering operations increases as the hardness increases. Water

8 The concentrations are expressed in equivalents per million.

9 The sample was collected soon after test hole 12 was completed. before the well was bailed or pumped. Thus, the sample may have been contaminated with drilling mud.

hardness is also related to incrustations (boiler scale) formed in pipes, coils, and boilers. Calcium and magnesium are the principal constitutents that cause hardness. Hardness equivalent to the carbonate and bicarbonate is called carbonate hardness; the remainder of the hardness is called noncarbonate hardness.

The classification used by the U.S. Geological Survey to describe water with reference to hardness is as follows: Less than 60 ppm, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and more than 181 ppm, very hard. Water having a hardness of more than 200 ppm needs to be softened for most purposes. Of the 70 samples for which hardness was determined, all exceeded 60 ppm and 55 exceeded 181 ppm. The Tertiary volcanic rocks, where unfaulted, yielded water softer than that from any other formation.

LIVESTOCK

Although animals are able to tolerate water with higher dissolved-solids concentrations than is man, prolonged periods of drinking highly mineralized water may result in physiological disturbances, such as wasting, gastrointestinal disturbances, disease, and eventual death of the animal. Other effects are reduction in lactation and rate of reproduction. The Department of Agriculture of Western Australia (1950) listed the following threshold salinity (dissolved solids) concentrations, in parts per million, for:

Poultry	2,860
Swine	4,290
Horses	6,440
Cattle, dairy	7,150
Beef	10,000
Sheep, adult, dry	12,900

The State of Montana (W. F. Storey, oral commun., 1962) rates water containing less than 2,500 ppm of dissolved solids as good for use by livestock, 2,500–3,500 ppm as fair, 3,500–4,500 ppm as poor, and more than 4,500 ppm as unfit. Most of the ground water in the central Sevier Valley is suitable for livestock, although the stock will not drink some of the highly mineralized water if better water is available.

INDUSTRY

Industries use water extensively for processing, cooling, and steam generation. The requirements as to quality of the water for industrial use vary according to the particular use involved and the product being manufactured. Very saline water can be used for cooling if fresher water is not available, but industry generally requires fresh water for processing and for steam generation.

Hardness and silica content are two of the major considerations in industrial supplies. Hardness has been discussed above in the section, "Domestic and public supply." Silica forms a hard adherent scale in boilers, and Moore (1940, p. 263) suggested the following allowable concentration of silica in water for boilers operating at various pressures: less than 150 psi (pounds per square inch), 40 ppm; 150–250 psi, 20 ppm; 250–400 psi, 5 ppm; and more than 400 psi, 1 ppm. Of the 66 samples analyzed for silica (listed in table 11), all exceeded 5 ppm, 50 exceeded 20 ppm, and 14 exceeded 40 ppm. The volcanic rocks of Tertiary age, on the average, contained water that had a higher silica content than did water from the other formations.

Temperature is a major factor in considering water to be used in cooling systems. Temperature measurements of the water from 436 wells ranged from 43° to 68°F. Almost 90 percent of the temperatures measured, however, were between 51° and 59°F. A temperature of 150°F was reported for water from well (C–22–1)32da, which was drilled to a depth of 9,638 feet as an oil test. Temperature measurements of water issuing from 24 springs ranged from 47° to 68°F, and 75 percent of these were between 51° and 59°F. Monroe Hot Springs, (C–25–3)10dda, and Joseph Hot Springs, (C–25–4)23aac, both of which issue along fault lines, were measured at 169° and 147°F, respectively.

QUALITY OF GROUND WATER, BY BASIN

Water of good to excellent quality for irrigation and stock use and for domestic, industrial, and public supply is available in aquifers throughout most of all the ground-water basins in the central Sevier Valley except the Redmond-Gunnison basin. In the latter basin, most of the ground water is slightly to moderately saline, and it generally is not satisfactory for irrigation unless disluted with fresh water.

Ground water in the Junction-Marysvale basin generally is suitable for all types of use. Some waters, however, contain fluoride in excess of the amount recomemnded for domestic and public supply by the U.S. Public Health Service (1962, p. 8). Well (C–30–3)16bbb–1 contains 3.1 ppm of fluoride, and well (C–26–4)29bba–1 contains 3.9 ppm. Spring (C–27–4½)36cca, which flows from Tertiary volcanic rocks about 3 miles southwest of Marysvale and furnishes the public supply for Marysvale, yields water containing 4.6 ppm of fluoride. Well (C–26–4)29bba–1, which is believed to tap Tertiary volcanic rocks, yields water that contains 20.0 ppm of iron and 6.5 ppm of manganese and has a pH of 5.7. Such water would be unsuitable for domestic, industrial, or public supply unless treated.

Ground water in the Sevier-Sigurd basin generally is suitable for all types of use. Monroe Hot Springs, (C–25–3)10dda, and Joseph

Hot Springs, (C–25–4)23aac, however, yield highly mineralized water. The two springs rise along faults, and their waters are not representative of the ground water generally found in the central Sevier Valley. The water from both springs is mixed with surface water and used for irrigation.

The quality of the ground water in the Aurora-Redmond basin is generally suitable for all types of use. Water obtained from wells in and near the Arapien Shale, along the east side of the basin, however, is generally of poor quality. This water is not recommended for irrigation unless diluted with fresher water and used on well-drained land.

In the Redmond-Gunnison basin, water in the alluvium near Axtell and in the northwestern part of the basin is generally of acceptable quality for most uses. In most of the remainder of the basin, however, the water is not suitable for public supply or for domestic use because of excessive concentration of mineral constituents dissolved from the Arapien Shale. This slightly to moderately saline water can nevertheless be used for irrigation if sufficiently diluted with fresher water and used on well-drained land. An unidentified sandstone underlying the Sevier River Formation in the center of the valley also contains water of poor quality.

The ground water in the alluvium in the Gunnison-Sevier Bridge Reservoir basin is generally of suitable chemical quality for irrigation and other uses. The water from deep wells is of better chemical quality than is water from shallow wells.

SUMMARY AND CONCLUSIONS

The central Sevier Valley contains five distinct ground-water basins which were formed by geologic forces and stream action. The basins, in downstream order, are the Junction-Marysvale, Sevier-Sigurd, Aurora-Redmond, Redmond-Gunnison, and Gunnison-Sevier Bridge Reservoir basins. Ground water is available for development in each of the basins.

Ground water occurs under both water-table and artesian conditions in all ground-water basins in the central Sevier Valley. In the upper four basins, water-table conditions exist along the sides and at the upstream end of each basin, and artesian conditions exist in the middle and at the downstream end of each basin. In the Gunnison-Sevier Bridge Reservoir basin, water-table conditions exist along the sides and artesian conditions exist along the middle for the entire length of the basin. Water levels in wells in the valley range from at land surface to about 220 feet below, and artesian heads reach a maximum of about 20 feet above land surface. Many wells flow in the artesian areas.

Alluvial fill in the central Sevier Valley consists of gravel, sand, silt, and clay. About 50 percent of the alluvium is permeable gravel and sand which yields water readily to wells and springs. The approximate percentages of gravel and sand in the various ground-water basins are as follows: 50 percent in Junction-Marysvale, 50 percent in Sevier-Sigurd, 60 percent in Aurora-Redmond, 30 percent in Redmond-Gunnison, and 40 percent in Gunnison-Sevier Bridge Reservoir.

About 1,500,000 acre-feet of ground water which can readily be developed by wells is stored in the gravel and sand deposits in the various basins as follows: Junction-Marysvale, 30,000 acre-feet; Sevier-Sigurd, 800,000 acre-feet; Aurora-Redmond, 200,000 acre-feet; Redmond-Gunnison, 150,000 acre-feet; and Gunnison-Sevier Bridge Reservoir, 300,000 acre-feet. Similar quantities of water probably are stored in the silt and clay deposits in each basin, but little of this water is readily available to wells.

The ground-water reservoirs are recharged mostly from the Sevier River and its tributaries by direct infiltration and by seepage from irrigation systems and irrigated lands. A secondary source of recharge is inflow from bedrock aquifers surrounding the valley. The source of all the water for recharge is precipitation which falls within the Sevier River drainage basin.

Water discharges from the ground-water reservoirs by springs, evapotranspiration, flowing and pumped wells, drains, and subsurface movement. The annual discharge of springs issuing from the alluvium is about 60,000 acre-feet; evapotranspiration from areas of phreatophytes is about 100,000 acre-feet; and discharge from wells and drains is about 40,000 acre-feet. The total discharge amounts to about 13 percent of the 1,500,000 acre-feet of ground water stored in the gravel and sand beds of the alluvial fill. The absence of appreciable long-term changes in water levels in the basins indicates that the total discharge of ground water is balanced by recharge to the aquifers.

The surface-water and ground-water systems in the central Sevier Valley are interconnected, and discharge from either system affects the quantity of water available to the other system. About 100,000 acre-feet of ground water is discharged from springs, drains, and wells in the central Sevier Valley, and an additional 35,000 acre-feet could probably be developed without greatly affecting the flow of the Sevier River. About 5,000 acre-feet of ground water could be supplied by wells in the Junction-Marysvale basin with little influence on existing wells, springs, or surface drainage. The Sevier-Sigurd basin could supply about 15,000 acre-feet to wells with moderate effect on existing wells, springs, and surface drainage. It is doubtful if any considerable amount of ground water could be pumped in the

Aurora-Redmond basin without affecting the discharge from Redmond Lake. In the Redmond-Gunnison basin, the permeable aquifers contain water of poor chemical quality; therefore, no large-scale development by wells should be attempted. About 15,000 acre-feet of ground water could be pumped in the Gunnison–Sevier Bridge Reservoir basin with only a moderate effect on existing wells, springs, and surface drainage.

The additional 35,000 acre-feet of ground water could be obtained by the construction and pumping of large wells. Proper location of the wells would result in minimum damage and maximum benefits when surrounding water levels declined as the wells were pumped. Part of the 35,000 acre-feet of additional water could be developed by the construction of drains in any of the ground-water basins. The drains would lower water levels and convey excess water developed by wells to the river channel.

The immediate effects of pumping large wells and constructing additional drains would be a lowering of water levels. The result would be the drying up of wet areas and the elimination of some of the large quantities of phreatophytes which now cover extensive areas where the water table is at or close to land surface. It is estimated that about 100,000 acre-feet of ground water is discharged annually by evapotranspiration in the central Sevier Valley. Salvage of about one-third of the ground water discharged by evapotranspiration would provide the 35,000 acre-feet of newly developed water. If the development took place under careful control and management, it might be possible to develop even more ground water than the 35,000 acre-feet indicated. In the distant future, if the need for additional water justifies considerable more expense than does the present economy, most of the 100,000 acre-feet of annual evapotranspiration could be salvaged by complete development of the ground-water basins. Such development would require the installation of many wells and the expense of pumping a large part of the total water supply.

The ground water in the central Sevier Valley is generally of suitable chemical quality for irrigation, stock, domestic, industrial, and public supply. The mineral content in solution in both ground and surface waters increases in a downstream direction, owing mostly to repeated use of the water for irrigation. Ground water of poor chemical quality occurs mainly in the Redmond-Gunnison basin and along the east side of the Aurora-Redmond basin, in or near deposits of the Arapien Shale. The discharge of ground water from areas underlain near the surface by the Arapien Shale adds dissolved minerals to the surface water.

In each of the ground-water basins in the central Sevier Valley, shallow wells yield water containing more dissolved solids than does water from deeper wells, and alkali has locally accumulated on the land surface. Increased withdrawals of ground water, accompanied by a lowering of water levels, would stop the accumulation of alkali and eventually result in an improvement of soil fertility. The chemical quality of the ground water at shallow to moderate depths probably also would improve in places.

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