Utah State Engineer

Technical Publication No. 13

GROUND-WATER RESOURCES OF SELECTED BASINS IN SOUTHWESTERN UTAH

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Prepared by the U. S. Geological Survey

in cooperation with

The Utah State Engineer

1966

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ABSTRACT

The purpose of this investigation was to correlate the results of past studies in parts of five developed basins in southwestern Utah and to give a unified concept of ground-water conditions in the entire area. The area of investigation comprises about 3,600 square miles in Washington, Iron, Beaver, and Millard Counties, including the five developed basins — Beaver, Cedar City, and Parowan Valleys and the Milford and Beryl-Enterprise districts in Escalante Valley. Annual precipitation in the area ranges from less than 8 inches in parts of the valleys to more than 30 inches in the mountains to the east, with most of the precipitation falling during the October-April period.

Virtually all recharge to the ground-water reservoir comes directly or indirectly from precipitation within the drainage basin. Streams issuing from the mountains are a major source of recharge to the aquifers, but the only stream with long-term flow records are Beaver River and Coal Creek. Water diverted for irrigation is another source of recharge, and about one-third of the water diverted from streams and applied to the land seeps to the ground-water reservoir.

Ground water occurs mainly in the alluvial fill in the valleys. Water-table conditions prevail along the valley edges, where the depth to water may exceed 200 feet. Artesian conditions occur in the central part of each basin, and each basin contains an area where wells flow at the surface.

Ground water moves toward the low lying central part of each of the basins and also between the basins primarily through valley fill in four gaps in the mountain masses which separate the valleys. Changes in water levels due to pumping have caused local changes in the direction of ground-water movement, the greatest changes being south of Milford and north of Enterprise.

Most ground water discharged in the area is pumped from wells for irrigation. Annual pumpage during the 1959-62 period ranged between 4,000 and 5,000 acre-feet from 15-20 wells in Beaver Valley. During 1962, 105,000 acre-feet was pumped from 307 wells in Escalante Valley, 19,000 acre-feet from 53 wells in Cedar City Valley, and 12,000 acre-feet from 56 wells in Paro-

wan Valley. Springs discharge significant amounts of water in Beaver, Parowan, and Cedar City Valleys; and phreatophytes, which grow in all valleys, consume large amounts of water. A small quantity of water leaves the area as underflow near Black Rock, and about 1,500 acre-feet per year leaves the area in the subsurface near Kanarraville.

During the period 1950-62, water levels have declined in the heavily pumped areas in all four valleys. The largest single decline measured was 58 feet in Parowan Valley. However, levels have remained essentially unchanged in areas of little pumping.

Most of the ground water is fresh and suitable for most uses, although some water near Milford is slightly saline, and water in a well near Kanarraville is moderately saline. No increase of salinity with depth has been observed down to 600 feet, the maximum depth sampled. Some water of poor quality exists at shallow depths in heavily pumped areas, particularly near Milford, because of the recirculation of water used for irrigation.

Intensive ground-water development has occurred in only about one-fourth of the area of the valley floors. Wells could be constructed and pumped in parts of the remaining area without significant effect on existing development. Such additional pumping would result in salvaging a considerable amount of water from present nonbeneficial losses. The best opportunities for such salvage are in parts of Beaver Valley; good conditions exist in Escalante and Parowan Valleys; and some additional development may be feasible in a small part of Cedar City Valley.

INTRODUCTION

Purpose, scope, and method of investigation

The investigation leading to this report was made as part of the cooperative program between the Utah State Engineer and the U. S. Geological Survey to study the water resources of Utah. The purpose of the investigation was to integrate the results of past ground-water investigations in five basins in southwestern Utah (fig. 1), to determine if the aquifers in the basins were hydraulically connected, and to present a unified concept of ground-water conditions in the entire area.

Water levels have been measured in observation wells in the different ground-water basins from time to time since 1908. During the current investigation additional observation wells were established between developed areas to determine the extent of hydraulic connection between them and to give more information about the effects of ground-water development in areas remote from the centers of pumping. Fieldwork consisted of a well inventory between the developed areas, a pumpage inventory in two of the basins (the State Engineer makes a pumage inventory in the other three basins), a determination of the specific conductance of the water from most of the pumped wells, the measurement of discharge and drawdown to determine the specific capacity of representative wells throughout the area, and the boring of test holes to determine the nature and thickness of alluvium in the areas connecting the basins. Office work consisted of tabulating and comparing past and present data, preparing hydrologic maps of the overall area and other illustrations, and writing a report. Basic data for this report were released separately (Sandberg, 1963), and that release should be consulted for information on specific wells referred to in this report.

Location

The area of investigation is in Washington, Iron, Beaver, and Millard Counties in southwestern Utah. (See fig. 1.) It comprises about 3,600 square miles, including the five developed basins (Beaver, Cedar City, and Parowan Valleys, and the Milford and Beryl-Enterprise districts in Escalante Valley), the undeveloped parts of the Escalante Valley (including the Black Rock and Lund districts), and mountainous areas between the valleys. (See fig. 4.) More than half the area is in the Escalante Valley.

Previous investigations

Previous ground-water investigations in southwestern Utah have been concerned mainly with the extent and effects of pumping of ground water in the five developed basins. A cooperative agreement for an investigation was made between the Geological Survey and the Utah State Engineer as early as 1908, and a continuing cooperative investigation of pumpage, water levels, and chemical quality began in 1935.

Lee (1908) made the first investigation, a reconnaissance of Beaver Valley and the northern part of Escalante Valley. Meinzer (1911) included Iron and Millard Counties as part of his investigation of western Utah. White (1932) described a method of estimating ground-water supplies based on discharge by plants and evaporation from soils as the result of his investigation in Escalante Valley. Thomas and Taylor (1946) made a detailed investigation of the geology and ground-water resources of Cedar City and Parowan Valleys. Other results of the cooperative ground-water program were reported by Fix and others (1950), Thomas and others (1952), Waite and others (1954), and Sandberg (1962). A report by Connor, Mitchell, and others (1958) includes data on chemical quality of water for both surface and ground waters in southwestern Utah. Bagley, Criddle, and Higginson (1958) described the water supplies and their uses for part of the project area. Criddle (1958) made an investigation of consumptive use and irrigation water requirements in the Milford area.

Topography and drainage

The valleys included within the area of investigation are in the Great Basin section of the Basin and Range physiographic province; however, the mountainous area along the eastern margin is in the High Plateaus of Utah section of the Colorado Plateaus physiographic province (fig. 1). The area in general consists of broad flat valleys separated by relatively low mountains. Altitudes range from more than 11,000 feet on the Markagunt Plateau to less than 4,900 feet in the Escalante Valley north of Milford. Long alluvial slopes generally form a transition from the mountains to the flat valley floors.

Most of the area, including Beaver, Escalante, and Cedar City Valleys, drains westward and northward toward Sevier Lake in Millard County. Parowan Valley drains westward to Little Salt Lake, a playa in the southwestern part of the valley, and the southern part of Cedar City Valley drains locally into Quichapa Lake (also called Shurtz Lake), a playa west of Cedar City. Several small playas collect water in Escalante Valley.

Surface streams which enter the area are fed largely from winter precipitation on the adjacent mountains. The Beaver River in Beaver Valley and Coal Creek in Cedar City Valley are the largest streams in the area and are the only two with long-term streamflow records (U. S. Geological Survey, 1963). Many smaller perennial streams enter the area from the surrounding

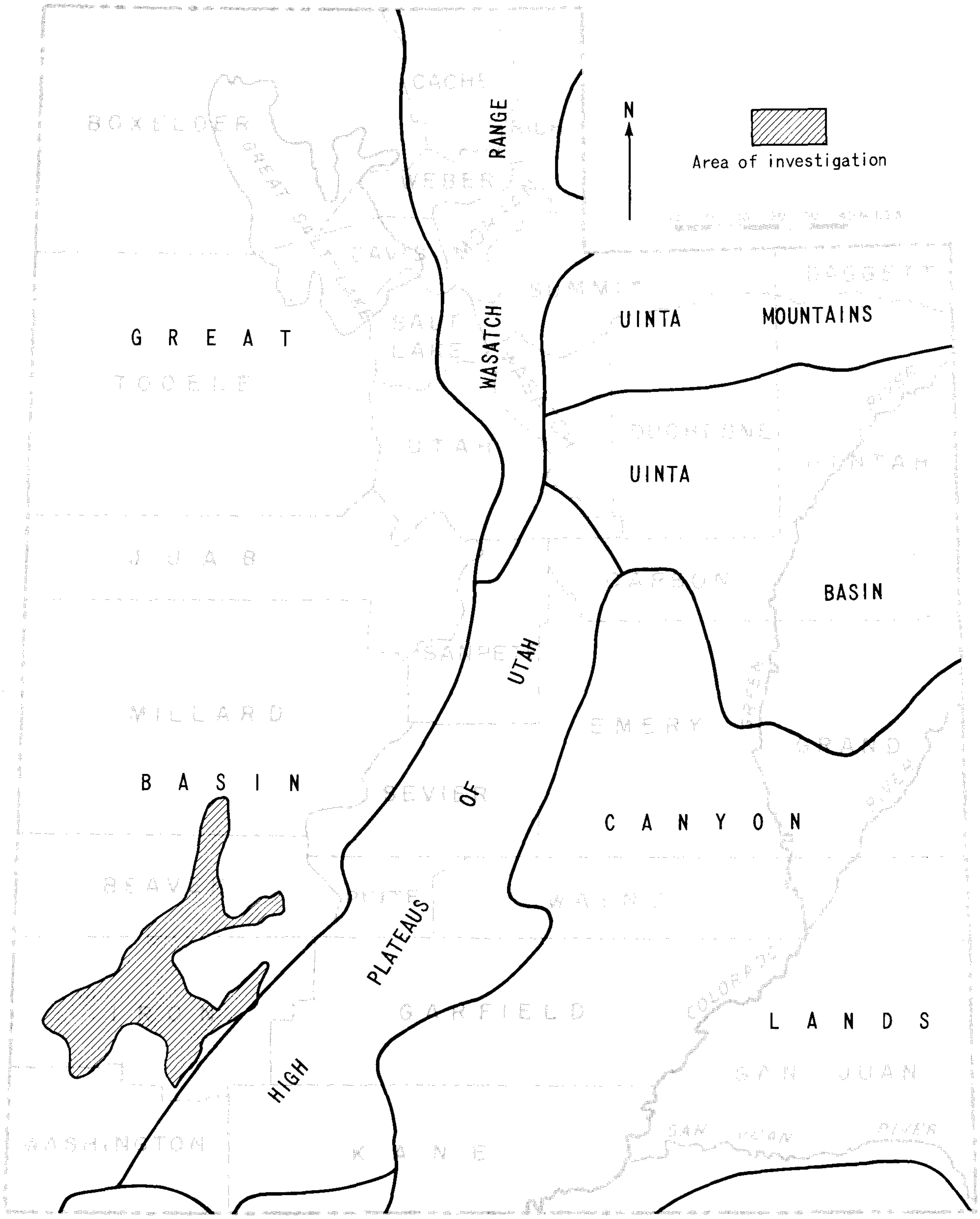

Figure 1.—Index map of Utah showing physiographic subdivisions and the area of investigation.

mountains, and additional water drains into the area in many intermittent and ephemeral streams fed by runoff of melting snow and intense summer storms.

Little surface water drains from valley to valley except between Beaver Valley and the northern part of Escalante Valley by way of the Beaver River. The Beaver River extends northward out of the Escalante Valley, but it is now regulated and seldom flows north of Minersville.

Surface water is stored mostly in four reservoirs in the area — Minersville Reservoir (also called Rockyford Reservoir) on the Beaver River east of Minersville, the Enterprise reservoirs on Shoal Creek southwest of Enterprise, and Newcastle Reservoir on Pinto Creek.

Geology

The mountains and valleys in the area are primarily the result of block faulting, the up-faulted blocks forming the mountains and the down-faulted blocks forming the valleys. During and following faulting, earth materials were eroded from the mountains and deposited in the valleys, forming the valley fill. The fill consists generally of unconsolidated beds of gravel, sand, silt, and clay. The total thickness of the fill is not known, but it is more than 3,000 feet in places and probably exceeds 5,000 feet in some of the valleys. The contact between the bedrock of the mountains and the valley fill is formed in places by faults which extend into the subsurface to unknown depths, whereas in other places the fill merely overlaps the bedrock. The valley fill is discussed in greater detail in the section on aquifers.

The mountains are composed mostly of sedimentary and extrusive igneous rocks, although some metamorphic and intrusive igneous rocks form part of the mountains in the western part of the area. The Markagunt Plateau to the east is composed of sedimentary rocks capped in places by volcanic rocks. The gaps between the principal valleys are mostly underlain by volcanic rocks.

Detailed information about the geology of southwestern Utah may be obtained from many of the references listed at the end of this report.

Climate

The climate of the area ranges from semiarid in the valleys to humid on the high plateaus. Annual precipitation ranges from less than 8 inches in parts of the valleys to more than 25 inches on the crest of the Mineral Mountains, and to more than 30 inches in other mountains in the area (U.S. Weather Bureau, 1963a). More precipitation falls near the mountain fronts along the eastern side of the area than in the western part of the area. Irrigation is necessary to mature crops because of insufficient precipitation in the valleys during the growing season.

Average May-September, October-April, and water-year precipitation for a 50-year, 33-year, and five 10-year periods preceding 1963 at five weather stations in the area are shown in table 1. The average October-April and water-year precipitation during the 1953-62 period was the lowest average for any of the 10-year periods.

Mean annual temperature at the five weather stations listed in table 1 range from 47° to 50°F, whereas extreme recorded temperatures range from 107° to –25°F.

Table 1 — **Average precipitation, in inches, for various periods between 1913 and 1962 at Beaver Powerhouse, Milford Airport, Modena, Cedar City Powerhouse, and Parowan**

Station	Period	1913-62	1930-62	1913-22	1923-32	1933-42	1943-52	1953-62
	May-September	[1]7.16	7.80	....	9.73	9.68	7.03	5.75
Beaver Powerhouse	October-April	[1]13.50	12.22	....	11.39	12.47	13.44	11.64
	Water year	[1]20.66	20.02	....	21.12	22.15	20.47	17.39
	May-September	3.09	3.09	3.40	3.25	3.33	2.87	2.57
Milford Airport	October-April	5.25	4.88	6.28	4.92	4.73	5.92	4.43
	Water year	8.34	7.97	9.68	8.17	8.06	8.79	7.00
	May-September	4.31	3.91	5.38	4.46	4.58	3.54	3.60
Modena	October-April	5.59	5.33	6.41	5.23	5.71	6.72	3.87
	Water year	9.90	9.24	11.79	9.69	10.29	10.26	7.47
	May-September	4.20	3.99	5.67	5.20	4.44	3.08	3.67
Cedar City Powerhouse	October-April	7.19	6.39	8.40	8.48	6.87	7.43	4.78
	Water year	11.39	10.38	14.01	13.68	11.31	10.51	8.45
	May-September	4.83	4.28	6.25	5.15	4.38	4.07	4.29
Parowan	October-April	7.41	7.12	8.49	6.80	7.10	8.13	6.54
	Water year	12.24	11.40	14.74	11.95	11.48	12.20	10.83

[1]Record began in 1918; average is for 1918-62.

Well-numbering system

The well numbers in this report indicate the well location by land subdivision according to a numbering system that was devised cooperatively by the Utah State Engineer and G. H. Taylor of the U. S. Geological Survey about 1935. The system is illustrated in figure 2. The complete well number comprises letters and numbers that designate 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 quarters of the section, of the quarter section, and of the quarter-quarter section. Thus, the number (C-29-8)9bad-1 designates well 1 in the NW¼NE¼SE¼ sec. 9, T. 29 S., R. 8 W., the letter C showing that the township is south of the Great Salt Lake Base Line and the range is west of the Salt Lake Meridian.

Acknowledgments

Well owners in the area willingly gave information about their wells and permitted water-level measurements and other data to be collected from their wells and pumping plants. Well drillers contributed logs of wells and supplied general information. Personnel of the State Engineer's Office; Wallace Sjoblem, Iron County Agricultural Agent; Grant Esplin, Beaver County Agricultural Agent; Leland Carlson, Unit Conservationist, Soil Conservation Service, Cedar City; and personnel of the California Pacific Utility and Telluride Power Cos. supplied engineering, agricultural, and electrical data.

GROUND WATER

Recharge

Virtually all recharge to the ground-water reservoir comes directly or indirectly from precipitation within the drainage basin. However, less than 6 inches of precipitation falls on most parts of the valleys during the growing season (U. S. Weather Bureau, 1963b), and practically all is transpired by vegetation, replenishes the soil moisture, or evaporates, leaving little to percolate down to the ground-water reservoir. Greater precipitation falls in the mountain areas surrounding the valleys, resulting in runoff from the mountains to the valleys. Recharge to the aquifers comes directly from the streams issuing from the mountains or from water diverted from the streams for irrigation.

Recharge occurs from permeable stream channels in the valleys, especially near canyon mouths and high on alluvial fans, where the underlying rock materials usually consist of permeable gravel and sand that readily permit the downward percolation of water. The principal perennial streams which enter the area are the Beaver River in Beaver Valley and Coal Creek in Cedar City Valley. The average May-September, October-April, and water-year streamflow of Coal Creek and the Beaver River for the period 1923-62 and for 10-year periods since 1923 are shown in table 2. A considerable decrease in the average flows of both streams occurred during the period 1953-62. The May-September, October-April, and water-year flow in these streams

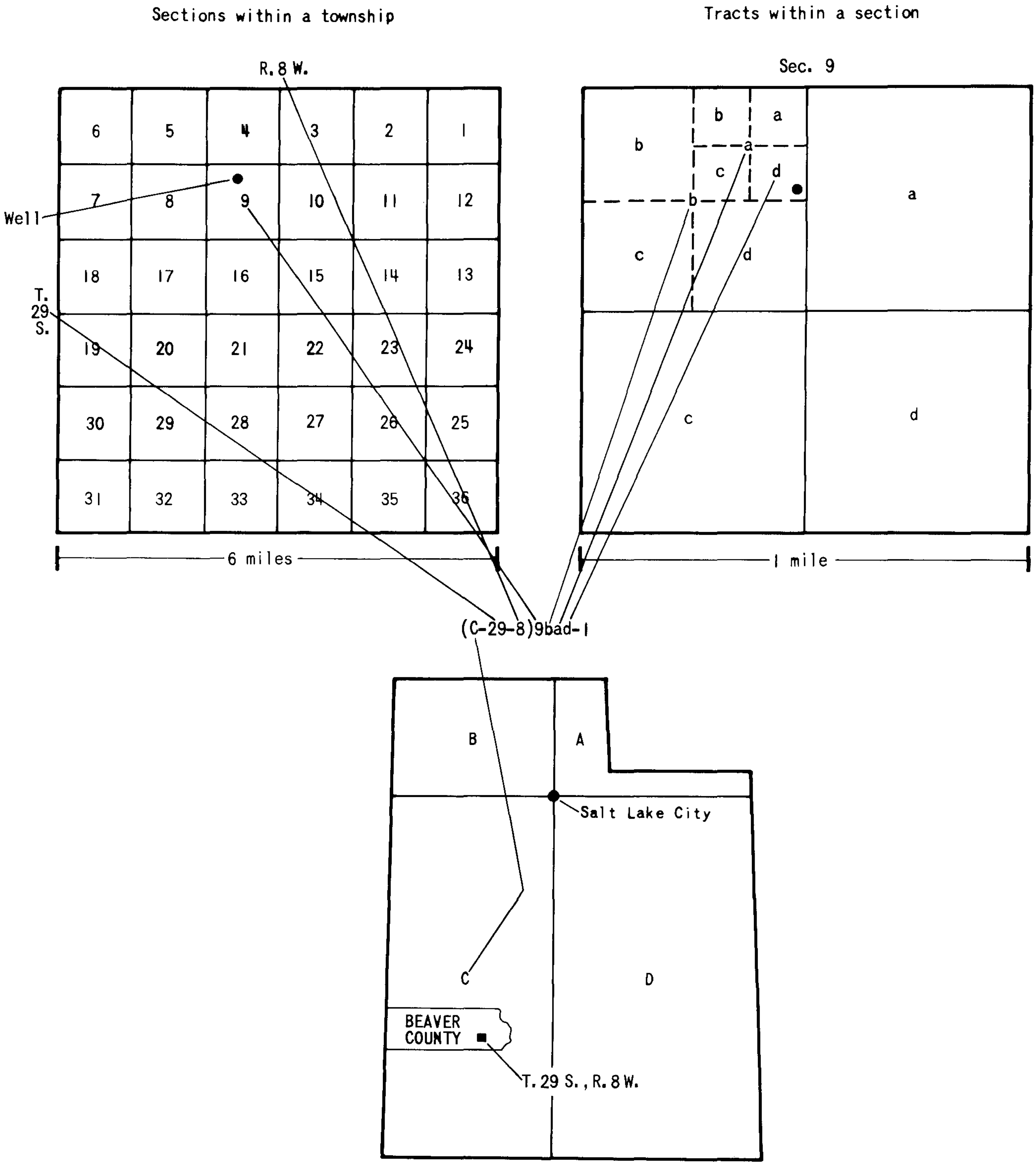

Figure 2.—Well-numbering system used in Utah.

Table 2 — **Average streamflow of the Beaver River and Coal Creek, in acre-feet, for various periods between 1923 and 1962**

Station	Number of years	Period	Average	1923–32	1933–42	1943–52	1953–62
Beaver River near Beaver	40	October-April	11,010	12,091	11,275	11,584	9,091
		May-September	25,839	25,686	29,359	28,883	19,428
		Water year	36,849	37,777	40,634	40,467	28,519
Coal Creek near Cedar City	27	October-April	7,704	....	....	7,672	6,542
		May-September	14,896	....	....	15,065	11,486
		Water year	22,600	....	....	22,737	18,028

for the period 1930-62 is shown in figure 3. The annual streamflow during this period has varied as much as 400 percent, resulting in large differences in the amount of water available for recharge in any one year. The variations of streamflow can be correlated directly with local variations of precipitation (fig. 3).

Other important perennial streams are Parowan Creek in Parowan Valley; North Creek in Beaver Valley; Shoal, Pinto, Pine, and Mountain Meadow Creeks in Escalante Valley; and Shurtz and Kanarra Creeks in Cedar City Valley. Many intermittent streams flow from deep canyons and discharge water to the valleys during most of the year, but these streams usually are dry in their lower reaches during late summer and fall. Many ephemeral streams flow to the valleys from shallow canyons in direct response to precipitation. Although individual ephemeral streams may seldom flow, the total water carried by all of them to the valleys is significant.

All the water in the perennial and intermittent streams entering the area, except some flood flow, is diverted for irrigation. When it is spread on the land it is exposed to a relatively large surface area where it can percolate into the ground, and it contributes significant amounts of water to the ground-water reservoir. The amount that reaches the ground-water reservoir depends on many factors, including (1) amount of water applied, (2) type of crop, (3) permeability of the soil and underlying materials, and (4) slope of the land surface. Water diverted from streams generally is used relatively near the mountain fronts where the valley fill contains considerable gravel and sand and consequently is quite permeable. It is estimated that about one-third of the surface water applied to the land in the area eventually reaches the ground-water reservoir.

Lands irrigated with water pumped from wells generally are further from the mountain fronts than lands irrigated with water from streams. Consequently, the texture of surface soils generally is finer and less water is lost by seepage. It is estimated that about one-fourth of the water pumped from wells returns to the ground-water reservoir.

Occurrence

Ground water in Beaver, Escalante, Cedar City, and Parowan Valleys occurs mainly in the valley fill. The aquifers are bodies of gravel and sand with the coarser materials generally near the edges or higher parts of the valleys and the finer materials near the central or lower parts of the valleys.

The main aquifers in Beaver, Parowan, and Cedar City Valleys are in alluvial fans which were formed by streams entering the valley and depositing rock materials eroded from the mountains. The fans extend into the valley toward the basin floor, and the coarse materials of the aquifers interfinger with finer materials deposited by ancient lakes. In the Escalante Valley, alluvial fans are around the edge of the valley, but most of the aquifers underlie the basin floor.

The thickness of the valley fill is not known, because wells have not completely penetrated the fill. Reported depths of some wells, however, indicate that the fill exceeds 1,000 feet in depth (Sandberg, 1963), and in Cedar City Valley, in sec. 9, T. 34 S., R. 11 W., an oil test bottomed in the fill at approximately 3,000 feet.

The water in the upper part of the alluvial fans is under water-table conditions. The maximum recorded depth to water is 215 feet in sec. 21, T. 37 S., R. 12 W., in Cedar City Valley. As the coarse materials in the fan interfinger with the finer materials found closest to the center of the valleys, the water may be confined under artesian conditions. Wells flow in the lowest

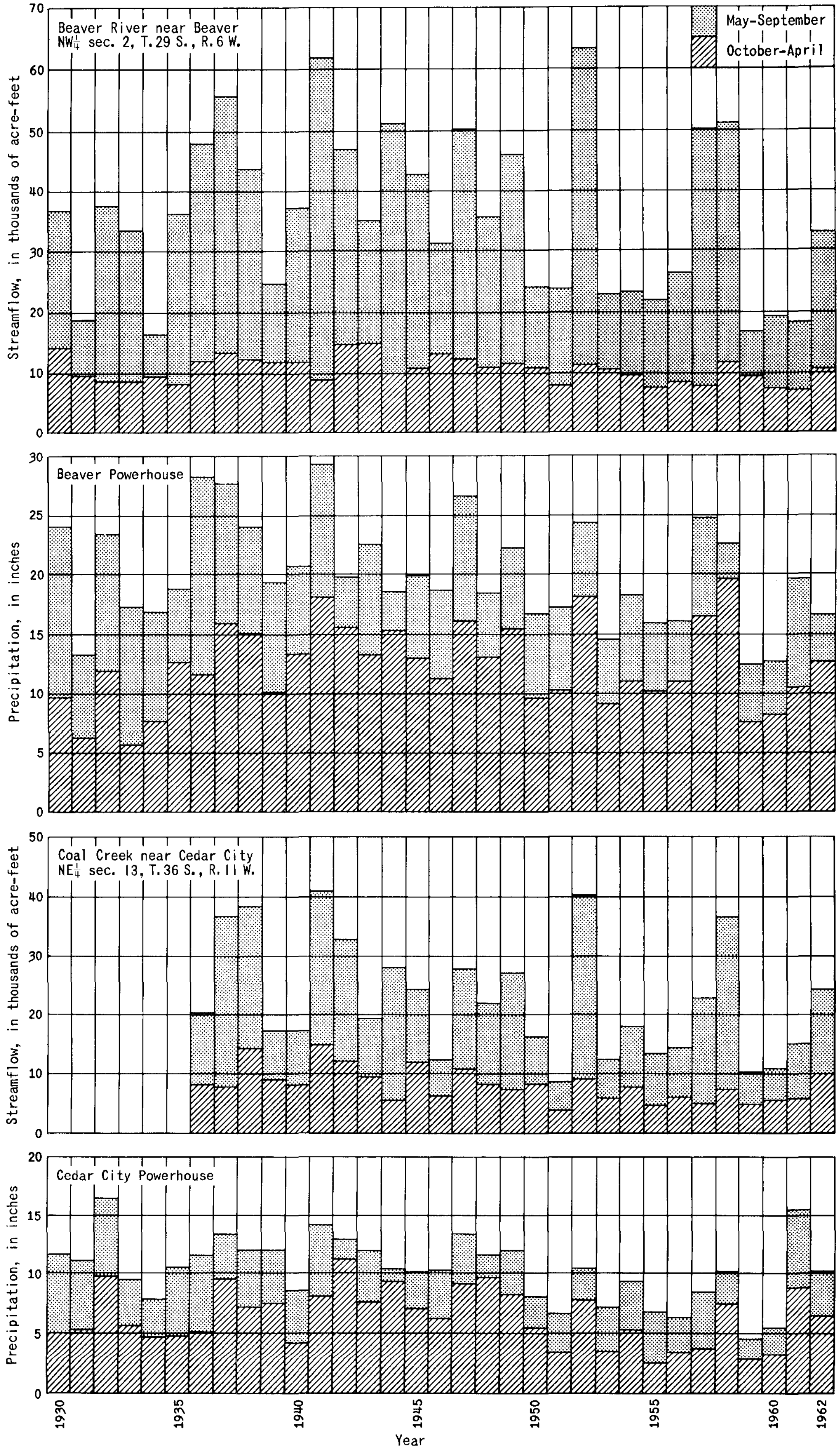

Figure 3.—Graphs of precipitation at Cedar City and Beaver Powerhouses and streamflow in Coal Creek and the Beaver River, 1930-62.

parts of some of the valleys, and a maximum head of 14 feet above the land surface has been recorded at well (C-33-8)19ccc-1 in Parowan Valley. If the water is only partly confined by the overlying fine deposits, the water will seep upward under pressure through the fine materials and may discharge at the surface in marshy areas.

The position of water levels in relation to the land surface in 1950 and 1962 for areas where data are available is shown in figures 4 and 5. In 1962, wells flowed in an area of approximately 48 square miles, including 6 in Beaver Valley, 3 in Escalante Valley, 4 in Cedar City Valley, and 35 in Parowan Valley. The area of flowing wells remained virtually unchanged from 1950 to 1962 except in Cedar City Valley where there was a significant decrease. In 1962, water levels were within 10 feet of the land surface in about 70 square miles (fig. 4). This area was somewhat larger in 1950 (fig. 5). In 1962, the depth to water in an area of approximately 650 square miles was from 10 to 100 feet. This area was about equally divided between depths to water of 10 to 40 feet and depths to water of 40 to 100 feet. In areas near the contact of the valley fill and the mountains, the depth to water generally exceeds 100 feet.

The capacity of a well to yield water depends in part on the water-yielding characteristics of the aquifer and in part on the construction and development of the well. The specific capacity of a well is defined as the number of gallons per minute it will yield for each foot of drawdown. The specific capacity was determined during 1962 at 54 irrigation wells and these data are summarized as follows:

Valley or district	No. of wells tested	Range in specific capacity (gpm per foot)	Average specific capacity (gpm per foot)	Median specific capacity (gpm per foot)
Cedar City	10	10-50	28	25
Parowan	9	5-25	13	10
Beaver	6	10-25	19	22
Milford	11	10-55	25	15
Beryl-Enterprise	18	10-140	60	45

Movement

General pattern of movement

Ground water moves through water-bearing materials under the force of gravity. The direction of movement is downgradient and is indicated by the slope of the water table or piezometric surface. The direction of movement in the four valleys is shown in figures 6 and 7, and profiles of the ground-water surface and land surface through each of the valleys or through adjoining valleys are shown in figure 8.

As indicated in figures 6 and 7, the ground water in Beaver, Parowan, and Cedar City Valleys moves in a generally westward direction away from the base of the Tushar Mountains and the Markagunt Plateau, the sources of most of the recharge. The water in Beaver Valley moves toward Beaver River canyon; the water in Parowan Valley moves toward the Little Salt Lake and Winn gap; and the water in Cedar City Valley moves toward Twentymile gap, Iron Springs gap, Quichapa Lake, and the gap near Kanarraville.

In the Escalante Valley, the ground water in the Beryl-Enterprise district moves from the edges of the valley into the center of the valley and then northwestward into the Lund district (figs. 6 and 7). Additional water enters the Lund district from the sides of the valley and from Cedar City Valley. The water then moves northeastward into the Milford district. Additional water enters the Milford district from the sides of the valley and from Beaver Valley, and the overall direction of movement is north toward Milford.

Movement between valleys

The movement of ground water between valleys generally is restricted by mountain masses. However, some water moves through the thin alluvial deposits in the gaps (canyons or narrow valleys) which connect the major valleys; and some moves through the rocks composing the mountain masses near several of the gaps. The four gaps through which ground water moves are Winn gap, between Parowan and Cedar City City Valleys; Iron Springs and Twentymile gaps, between Cedar City and Escalante Valleys; and Beaver River canyon between Beaver and Escalante Valleys.

Attempts were made to auger test holes to bedrock in the narrowest part of each of the gaps to obtain data for estimating the amount of underflow. The auger was effective only in penetrating fine-grained material, and at each hole it was not possible to determine whether bedrock was reached or boulders were encountered. The holes ranged from a few feet to about 60 feet deep, and materials encountered were mostly fine grained except near the bottom of each hole. The average coefficient of permeability of material obtained from each hole probably is less than 100.

Winn gap

The amount of underflow from Parowan Valley to Cedar City Valley through the alluviam in Winn gap is estimated to be approximately 1,000 acre-feet per year, or about 1.4 cfs (cubic feet per second). The hydraulic gradient through the gap is approximately 50 feet per mile (see fig. 8), the width at the surface is about three-fourths of a mile, and the average thickness of the water-bearing sediments through the gap is estimated to be from 100 to 150 feet.

The existence of springs and seeps at the western side of the hills in Tps. 34 and 35 S., Rs. 10 and 11 W., between Winn gap and Rush Lake indicates that ground water also moves through the bedrock from Parowan Valley to Cedar City Valley. The bedrock probably is volcanic rocks of Tertiary and Quaternary age. The discharge of the springs is about 3 cfs, hence at least this quantity is moving in the subsurface from Parowan Valley. Probably an unknown additional amount, moving through the bedrock, does not flow from the springs but recharges the valley fill in Cedar City Valley in the vicinity of the springs.

The estimate of combined underflow from Parowan Valley, approximately 3,000 acre-feet per year, or about 4 cfs, is about 60 percent of that estimated by Thomas and Taylor (1946, p. 169-170). Since their investigation, however, many springs in this area have become dry and the flow from others has diminished considerably.

Iron Springs gap

The amount of underflow from Cedar City Valley to Escalante Valley through Iron Springs gap probably is not more than 15 acre-feet per year. The hydraulic gradient through the gap is about 25 feet per mile, the width of the gap is about 1,600 feet, the average thickness of the water-bearing silt and clay in the sediments in the gap is about 25 feet, and the estimated permeability of the sediments is about 100.

It is estimated that nearly 500 acre-feet of water per year flows from springs and seeps in the gap. The total amount of water leaving the valley in the area of this gap, therefore, is about 500 acre-feet plus the 15 acre-feet that flows through the gap. This amount is about the same as estimated by Thomas and Taylor (1946, p. 103). Ground-water conditions in this area have been relatively stable; consequently, little change has occurred.

Twentymile gap

The amount of underflow from Cedar City Valley to Escalante Valley through Twentymile gap is about 100 acre-feet per year. The hydraulic gradient is about 50 feet per mile, the width of the gap is about 800 feet, and the average thickness of water-bearing sediments is about 125 feet. The water-bearing materials in the gap probably are silt and clay. This estimate of underflow is adapted from the estimate of Thomas and Taylor (1946, p. 104) because ground-water conditions have been stable in the area since their investigation.

Beaver River canyon

The amount of underflow from Beaver Valley to Escalante Valley through Beaver River canyon is estimated to be about 100 acre-feet per year. The hydraulic gradient is about 30 feet per mile through the canyon, the width is about one-half a mile, and the average thickness of the water-bearing sediments is about 75 feet. The water-bearing materials apparently are silt and fine sand. A few springs discharge in the canyon, but their total flow is small.

Change in pattern of movement

Seasonal changes

The withdrawal of large amounts of ground water in parts of the Escalante, Parowan, and Cedar City Valleys causes seasonal changes in the pattern of ground-water movement. Pumping causes water levels to decline in the heavily pumped areas, and this in turn causes ground water to be diverted toward these areas. A steepening of the water-level gradient and consequent increase in the rate of movement occurs upgradient from centers of pumping, whereas a flattening and consequent decrease in the rate of movement occurs downgradient from centers of pumping. A change in direction and general steepening also occurs laterally. The amount of water moving toward the centers of pumping thus increases from all sides. The effects of pumping are greatest during and immediately following the pumping season.

The largest seasonal changes of water levels were observed from 1 to 10 miles from the centers of the heavily pumped areas in the Beryl-Enterprise and Milford districts of Escalante Valley and in Cedar City and Parowan Valleys. The most significant of these changes was in the Beryl-Enterprise district in Tps. 34 and 35 S. (fig. 8, profile A-A′) where the ground-water gradient was reduced to approximately zero during the summer of 1962. This resulted in a virtual cessation of the movement of ground water out of this area.

In some areas water levels may not recover completely from the effects of a pumping season by the time the next pumping season starts. Repetition of this relationship during several successive years causes a permanent change in the contours of the water surface, and this in turn results in a long-term change in the pattern of ground-water movement.

Long-term changes

The general pattern of ground-water movement in the area during the period 1950-62 has remained virtually unchanged except in and adjacent to areas of heavy pumping in the Escalante Valley. The dated profiles of figure 8 and comparison of the contours in figures 6 and 7 indicate that significant changes in the direction of movement have taken place in Escalante Valley in the area from 1 to 8 miles south of Milford and from 1 to 10 miles north of Enterprise.

Comparison of contours in the Milford district for March 1962 and March 1950 indicates that some ground water was moving eastward and westward toward the middle of the valley in 1962, whereas it was moving generally northward in 1950. Profiles A-A′ and D-D′ of figure 8 show that the gradient changed significantly between March 1950 and March 1962, but that it is not near the point of reversal, as it is in parts of the Beryl-Enterprise district.

In the southern part of the Beryl-Enterprise district, the configuration of the contours indicates that most of the water was moving east and west toward the center of the valley in 1962, whereas it was moving generally northeastward along the axis of the valley in 1950. This is evident by comparing the 5,120-foot contours in figures 6 and 7. The reduction in gradient in the Beryl-Enterprise district for the 12-year period is shown on profile A-A′ in figure 8. If this gradient continues to be reduced at the same rate as that of the past 12 years, the direction of movement probably will be reversed by 1965. Following reversal, the gradient will increase toward the southwest, and the area affected will enlarge.

A profile of water levels through the Ecalante Valley in 1927 is shown in figure 8 (profiles A-A′ and D-D′). Comparison with profiles for 1950 and 1962 indicates a significant reduction of the northward gradient in the general vicinity of Enterprise and smaller reductions of gradient south of Milford. Little or no changes occurred in the unirrigated areas which constitute about three-fourths of the total area of Escalante Valley.

The direction of movement of the ground water in Beaver, Cedar City, and Parowan Valleys did not change significantly between 1950 and 1962 (figs. 6 and 7). In Cedar City and Parowan Valleys, however, the gradients were flattened slightly in the heavily pumped areas.

Discharge

Water is discharged from the ground-water reservoirs in the four valleys by natural processes and by wells. Natural processes include discharge from springs and seeps, evaporation and transpiration, and subsurface outflow from the area. Discharge from wells includes both pumped and flowing wells.

Natural discharge

Springs and seeps

Springs and seeps discharge significant amounts of water from the valley fill in Beaver, Parowan, and Cedar City Valleys, mostly within the area where the piezometric surface is above the land surface. (See fig. 4.) The discharge from springs and seeps in Escalante Valley is relatively small.

Discharge from springs and seeps in Beaver Valley is mostly along or near the Beaver River, between Beaver and Minersville Reservoir. Water from the springs and seeps is channeled into irrigation ditches or flows into the Beaver River. Part of the water supply for the Minersville Reservoir originates as discharge from the springs and seeps. A few springs discharge in other parts of the valley at or near the mountain-valley contacts; however, these usually dry up or diminish greatly in flow during the late summer months.

Most of the springs and seeps in Parowan Valley are in the lower part of the valley north of T. 34 S. Water from these springs and seeps is consumed mostly by nonbeneficial vegetation or by evaporation. Some of it, however, is collected in ponds and used for irrigation. A few springs discharge at or near the mountain-valley contacts, mainly on the east side of the valley.

Numerous springs and seeps in Cedar City Valley discharge mainly from three areas, (1) the Enoch-Rush Lake vicinity near the mountain-valley contact, (2) west of Rush Lake, and (3) near Quichapa Lake. A few other springs and seeps discharge along the eastern edge of the valley. Some of the water discharged by springs and seeps in the valley is used for irrigation and livestock, but most is consumed by nonbeneficial vegetation.

Only a few springs and seeps discharge in Escalante Valley, mostly near the mountain-valley contacts. Other seep areas are in the lowlands along the Beaver River north of Milford and hot springs discharge in the Mineral Mountains between Milford and Black Rock and in sec. 28, T. 30 S., R. 12 W. The latter spring discharges between 2 and 4 cfs of highly mineralized water which has a temperature of about 175°F. This water is not used. Water from most of the other springs and seeps in the valley is used mainly for stock.

Evaporation and transpiration

Most evaporation of ground water is in lowlands near seeps and springs where the water table is near or at the land surface. The largest of such areas in the four valleys are Little Salt Lake in Parowan Valley and Quichapa Lake in Cedar City Valley. Thomas and Taylor (1946, p. 105, 171) estimated that the amount of ground water lost annually by evaporation was about 500 acre-feet from Quichapa Lake and about 5,800 acre-feet from Little Salt Lake.

A large amount of ground water is discharged in the four valleys by transpiration or phreatophytes. White (1932, p. 90-92) estimated that phreatophytes annually discharge approximately 16,000 acre-feet of water near Milford and approximately 5,000 acre-feet from an area of 60,000 acres near Beryl. White stated that comparatively little ground water could be salvaged from the vegetation in the vicinity of Beryl unless water levels were lowered at least 20-30 feet. It is estimated that about the same amount of water was transpired in 1962 near Beryl because water levels in the area are relatively unchanged. Probably a smaller amount of water was lost to phreatophytes in 1962 in the Milford area because water levels have declined in most of the areas where phreatophytes formerly grew.

Additional areas of phreatophyte growth (mostly greasewood) in the Escalante Valley are near Lund and in the area along the Beaver River stream channel between Milford and Black Rock. In Beaver Valley phreatophytes (mostly meadow grass, rabbitbrush, and greasewood) grow mainly in the lowlands between Beaver and Minersville Reservoir. In Parowan Valley water is lost from phreatophytes(mostly grass, rabbitbrush, and greasewood) which grow in the lowlands north of T. 34 S. In Cedar City Valley losses from phreatophytes (mainly grass, rabbitbrush, and greasewood) are mostly in the Enoch-Rush Lake vicinity.

Subsurface outflow

Ground water leaves the four-valley area by subsurface outflow in only two places: (1) in the Escalante Valley near Black Rock and (2) in Cedar City Valley near Kanarraville. At each of these places water levels slope toward areas outside of the valleys. (See figs. 6 and 7.)

The amount of water moving out of the Escalante Valley near Black Rock probably is small because the valley is locally constricted, and the transmissibility of the water-bearing materials probably is low. Some water may move through the bedrock that forms the constriction, but the amount, if any, probably is small.

About 2 cfs, or 1,500 acre-feet of water per year, moves southward from Cedar City Valley through the water-bearing materials in a 2-mile wide gap near Kanarraville at the south end of the valley. The gradient is about 50 feet per mile and the transmissibility, as determined from a pumping test north of Kanarraville, is about 20,000 gallons per day per foot.

Discharge from wells

Flowing wells

About 3,000 acre-feet of water is discharged annually from flowing wells within the four valleys. About 2,000 acre-feet flows from wells in Parowan Valley, and about 1,000 acre-feet is discharged in Beaver Valley. A few small flowing wells exist in both Cedar City Valley and Escalante Valley, but the quantity of water discharged is not significant. The areas where wells flowed in 1962 and 1950 are shown in figures 4 and 5. The area of flowing wells in Parowan Valley is about three times as large as the combined areas of flowing wells of the other valleys.

The flowing wells in all of the valleys are drilled and cased. Most are 2 to 4 inches in diameter, but some are as large as 14 inches in diameter. All the larger flowing wells are in Parowan and Beaver Valleys. Some wells are as much as 1,000 feet deep, but most are less than 500 feet. Most of the flowing wells are used for stock watering, although some are used for irrigation. Flows from individual wells range from less than 1 gpm (gallon per minute) to more than 100 gpm.

About 200 wells were flowing during at least part of 1962 in Parowan Valley, 100 flowed in Beaver Valley, 10 in Cedar City Valley, and 5 in Escalante Valley. The number of flowing wells in Parowan and Cedar City Valleys has decreased since 1939 and 1940 when there were about 300 and 50 flowing wells, respectively (Thomas and Taylor, 1946, p. 127, 176). The numbers of flowing wells in Beaver and Escalante Valleys in 1962 probably were about the same as in 1940; however, there are no records for comparison.

The piezometric heads at flowing wells in the four valleys range from less than 1 inch to about 15 feet, with the highest heads being in the lower parts of Parowan Valley. Selected measured heads are shown in figures 4 and 5.

Pumped wells

Most of the ground water discharged in the four valleys is pumped from wells, and most of the water pumped is used for irrigation. Small amounts also are pumped for stock, domestic, and public supply. Records of all the irrigation wells and selected stock, domestic, and public-supply wells in service in 1962 are shown in table 1 of Sandberg (1963).

Stock wells

Wells used for livestock are mostly 8 inches or less in diameter and are pumped by windmills at rates ranging from about 1 to 10 gpm. Most of the wells are in uncultivated areas used mainly for grazing. It is estimated that about 1,000 acre-feet of water is pumped annually for livestock from about 100 wells within the four valleys.

Domestic wells

Domestic wells in the four valleys are used mainly on farms and ranches. Pumps on domestic wells usually are of the jet type and are driven by electric motors. It is estimated that about 500 acre-feet of water is used annually in the four valleys for domestic purposes.

Public-supply wells

It is estimated that about 100 acre-feet of water is pumped annually for public supply in Beaver Valley, 200 acre-feet in the Milford district and 100 acre-feet in the Beryl-Enterprise district of the Escalante Valley, 500 acre-feet in Cedar City Valley, and 100 acre-feet in Parowan Valley. Milford gets all of its water from municipally-owned wells; Cedar City gets much of its water from wells; and Parowan, Beaver, Minersville, and Enterprise get part of their water supply from wells.

Irrigation wells

The annual pumpage from irrigation wells in the four valleys was computed for those years since 1930 for which data were available. Most irrigation wells in each valley are concentrated fairly close together (see fig. 9), and the annual discharges in the heavily pumped areas are shown in figure 10. Pumpage from most individual wells in the Milford and Beryl-Enterprise districts of Escalante Valley and in Cedar City and Parowan Valleys have been reported through 1960 by Fix and others (1950), Thomas and others (1952), Waite and others (1954), and Sandberg (1962).

The wells are equipped with turbine pumps, most of which are driven by electric motors, ranging from 5 to 125 horsepower. A few pumps are driven by diesel, gasoline, and butane engines. Depths of irrigation wells range from less than 100 to nearly 1,000 feet, although most are between 200 and 500 feet deep. Some of the wells were drilled in the early 1920's, but the majority have been drilled since 1945. The wells were drilled generally by either cable-tool or rotary methods, but a few were drilled by the reverse-rotary method.

Beaver Valley—Only a small part of the water used for irrigation in Beaver Valley is pumped from wells; most of the water is diverted from the Beaver River and its tributaries. Between 15 and 20 wells were pumped for irrigation during the 1959-62 period, and the annual pumpage was between 4,000 and 5,000 acre-feet. The period of record is too short for a long-term comparison, but the pumpage in Beaver Valley has probably remained about the same since 1945.

Escalante Valley — Pumped wells supply nearly all the water used for irrigation in the Milford district. The amount of water pumped for irrigation increased slightly during the period 1954-62, following a marked increase during the period 1944-53. (See fig. 10.) Approximately 43,000 acre-feet of water was pumped from 137 irrigation wells in 1962 within an area of about 35 square miles south of Milford (fig. 9). Cultivated land west of Minersville is irrigated mostly with water from the Beaver River diverted from the Minersville Reservoir, but this supply is supplemented on one farm by water pumped from an irrigation well.

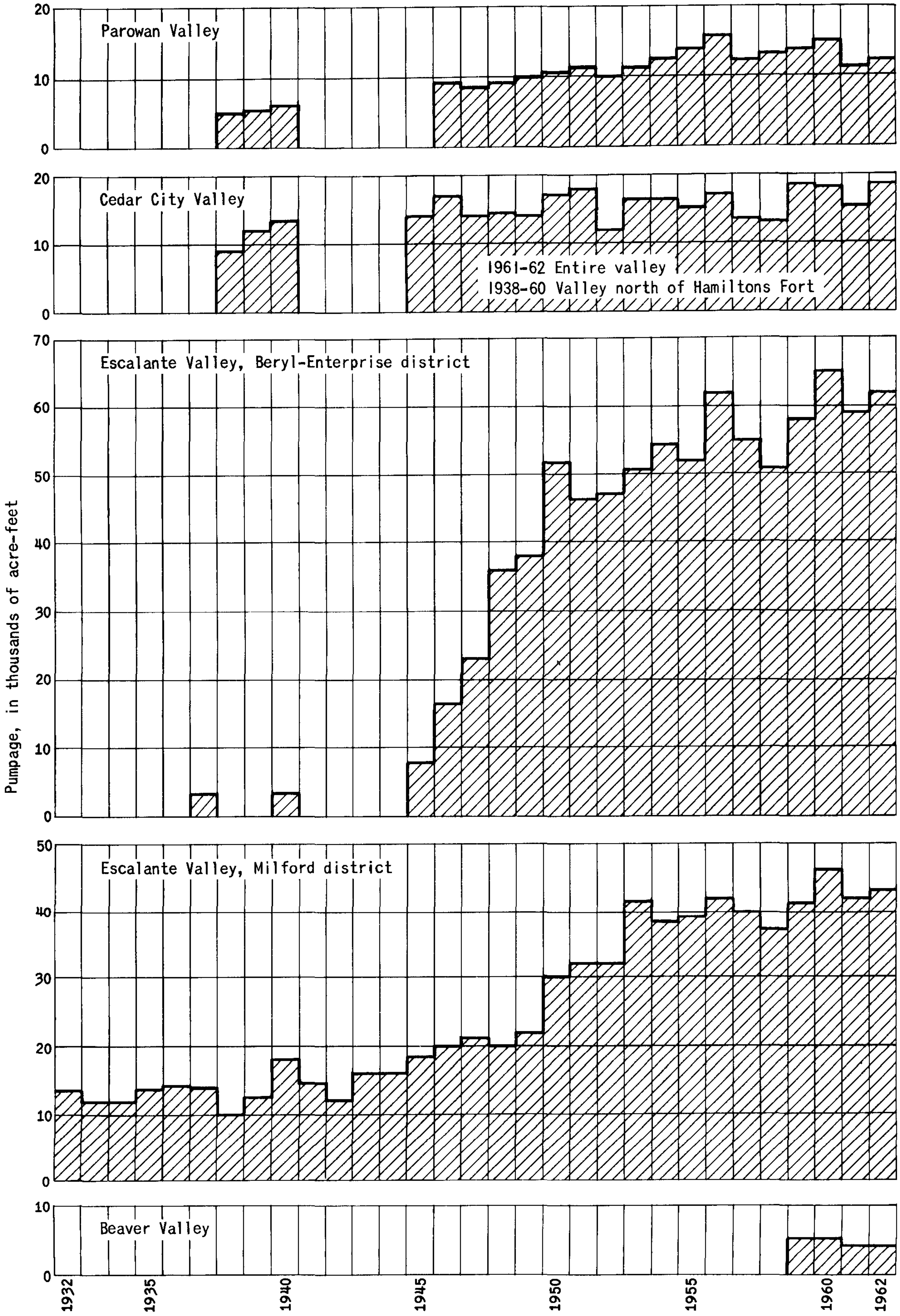

Figure 10.— Graph showing annual pumpage for irrigation in Beaver, Cedar City, and Parowan Valleys, and in the Beryl-Enterprise and Milford districts of Escalante Valley.

All water used for irrigation in the Beryl-Enterprise district, except for a small surface-water supply from the four creeks south of Enterprise and Newcastle is obtained from pumped wells. The amount of water pumped for irrigation increased markedly in the 1940's and then increased gradually from 1950 to 1962 (fig. 10). Approximately 62,000 acre-feet of water was pumped from 170 wells during 1962 in an area of about 75 square miles north of Enterprise (see fig. 9).

Cedar City Valley — The amount of water pumped from wells in Cedar City Valley for irrigation is about equal to the water diverted from streams. During wet years more surface water is available and used for irrigation, but during dry years more ground water is used. More ground water than surface water was used during the 1950-62 period, but more surface water than ground water was used prior to 1950. Essentially all the flow in Coal Creek was diverted for irrigation. (Compare figs. 3 and 10.) The flow of Coal Creek was used in this comparison as it represents most of the surface water entering Cedar City Valley. Approximately 19,000 acre-feet of water was pumped from 53 wells during 1962 in an area of about 25 square miles in the valley west of Cedar City (see fig. 9).

Parowan Valley — Most of the water used for irrigation in Parowan Valley is obtained from pumped wells, some is diverted from streams, and a small amount is obtained from flowing wells. The amount of water pumped fluctuated only slightly between 1953 and 1962 (fig. 10). Approximately 12,000 acre-feet of water was pumped from 56 wells during 1962 in an area of about 22 square miles north and west of Parowan (see fig. 9).

Water-level fluctuations

Water levels rise and fall in response to recharge to and discharge from the ground-water reservoir. The fluctuations may be daily, seasonal, or long term; and the magnitude of the fluctuations varies considerably within valleys and between valleys. Representative hydrographs for nine wells in the four valleys are shown in figure 11, and additional hydrographs and water-level data are given by Sandberg (1963).

Fluctuations in relation to recharge

The sources of recharge to the ground-water reservoir are precipitation directly on the valleys, streams issuing from the mountains, and water diverted from the streams for irrigation. (See section on recharge, p. 11.) Precipitation that falls on the valley floors usually adds little to ground-water storage and causes very little direct rise of water levels. However, it may indirectly result in small rises of water levels owing to a decrease of discharge. This occurs with a reduction or cessation of pumping for short periods after precipitation in the heavily pumped areas and by a temporary reduction in the use of ground water by phreatophytes in areas where the water table is close to the land surface.

Water levels in parts of all the valleys fluctuate seasonally in response to changes in streamflow and diversion of water for irrigation. Water levels in Beaver Valley generally fluctuate in this manner more than do water levels in the other valleys. The levels in Beaver Valley generally are highest in July and August, near the end of the irrigation season, and lowest in January and February, when streamflow is low. The effects of streamflow and the spreading of water for irrigation is shown in figure 11 by the hydrograph for well (C-29-7)21baa-1, located within the city of Beaver. Water levels in this well have been as much as 25 feet higher in

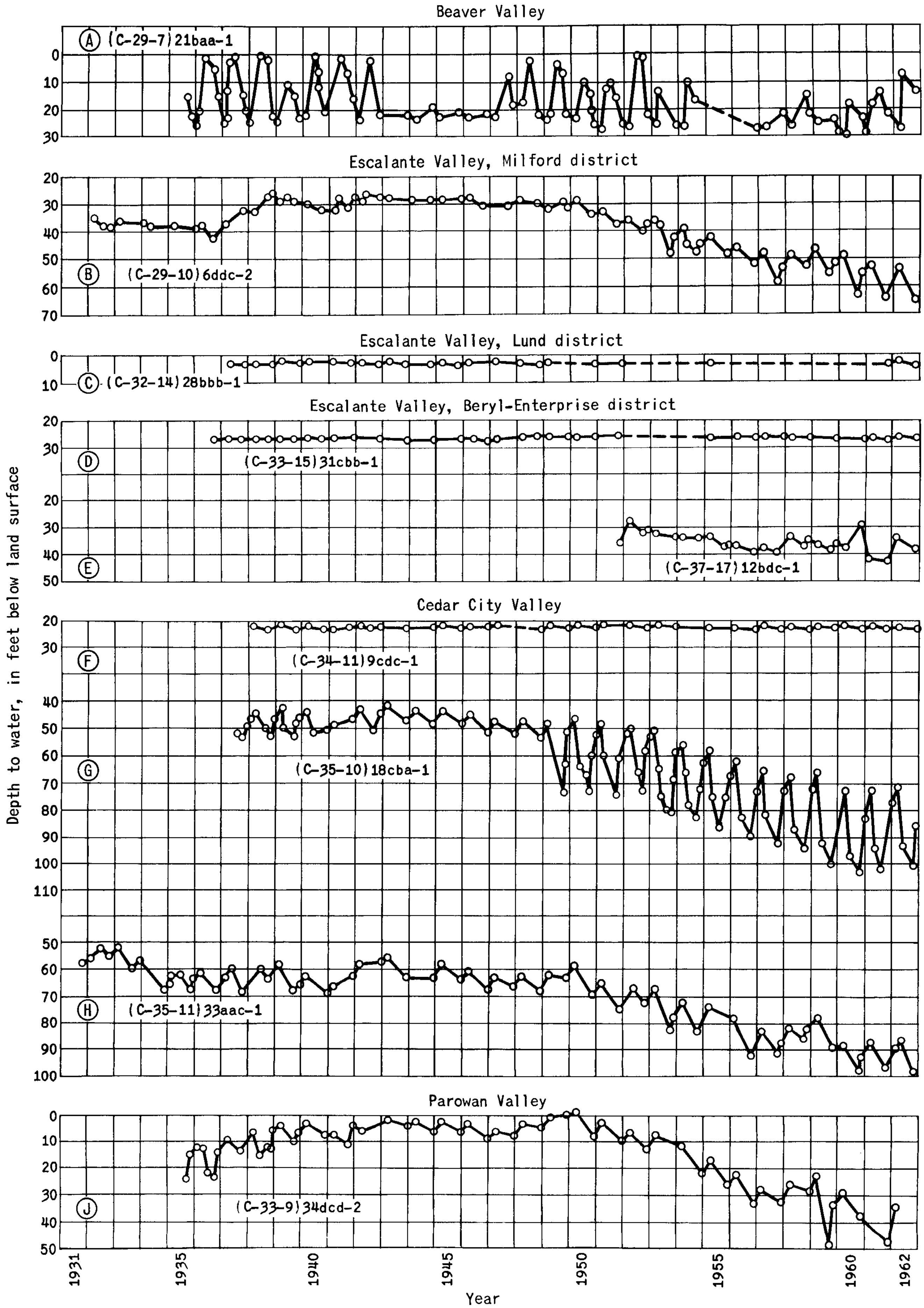

Figure 11.—Hydrographs of water levels in nine selected wells in Beaver, Cedar City, and Parowan Valleys, and in the Milford, Lund, and Beryl-Enterprise districts of Escalante Valley.

the summer than in the winter. A similar pattern of water-level fluctuations in Beaver Valley was reported by Lee (1908, p. 51-52):

"The conditions brought about by the behavior of the underground water in Beaver basin have become serious and are apparently growing worse year after year. According to report, the swampy areas caused by the midsummer rise of the water are increasing in size, and during the summer of 1906 roads and city streets that had never before been affected were rendered impassable, and dwellings that heretofore had been regarded as safe became uninhabitable."

The condition described in the foregoing quotation has since been alleviated locally by drains, but in much of the valley the water table still rises to or near the land surface during the summer months.

Streamflow and surface water diverted for irrigation in Escalante Valley affect water levels only locally. Near Enterprise, water levels fluctuate in response to changes of flow in Shoal Creek (well (C-37-17)12bdc-1 in fig. 11). Water levels in wells south of Milford rise when water flows in the Beaver River or in the Low Line Canal between Minersville and Milford. This occurs only during years when above-average precipitation in the Tushar Mountains results in above-average streamflow. Since 1950, this has happened particularly during 1952, 1957, and 1958. The effects of increased streamflow are shown by the hydrograph for well (C-29-10)6ddc-2 in figure 11. Some carryover effects occur following years of high streamflow as is indicated by relatively high water levels in 1953 and 1959 (compare hydrograph (C-29-10)6ddc-2 with fig. 3).

The fluctuation of water levels in some wells in Cedar City Valley correlates directly with the flow in Coal Creek, as is indicated by the hydrograph for well (C-35-11)33aac-1 in figure 11 and changes in streamflow shown in figure 3. The years of greater-than-average flow in Coal Creek, such as 1952, 1957, 1958, and 1962, correspond to years when water levels rose or declined less than during other years. A residual effect on the water levels is also noticeable during the year following each of the wet years.

Streams and water diverted for irrigation in Parowan Valley undoubtedly affect water levels in the valley. Water levels rose during 1957, 1958, and 1961 when above-average precipitation (fig. 3) resulted in greater streamflow and consequently greater recharge. The rise in water levels is indicated in the hydrograph for well (C-33-9)34dcd-2 in figure 11.

Fluctuations in relation to discharge

Water is discharged from the ground-water reservoir by springs and seeps, by evapotranspiration, by subsurface flow, and by wells. (See section on discharge, p. 19.) Although daily water-level fluctuations can be caused by evapotranspiration (White, 1932, p. 23-24), the largest and most significant short- and long-term water-level fluctuations in the four valleys are caused by pumping of wells for irrigation. During the pumping season, which is from about March 15 to about November 1, water levels decline as much as 30 feet in the pumped areas. Water levels may recover to prepumping season levels before the next pumping season or there may be a net annual decline. Typical annual cycles for the 1949-62 period in Cedar City Valley are shown by the hydrograph for well (C-35-10) 18cba-1 in figure 11. This hydrograph illustrates the general pattern of drawdown and recovery in all the pumped areas.

If the effects of pumping cause a net annual decline of water levels, and the same pattern is repeated during successive years, the result will be a long-term downward trend of water levels.

The decline of water levels is increased where pumped wells are relatively close together. The cone of depression in the water table or piezometric surface around a pumped well increases in width and depth as pumping continues, and it may merge with the cone of depression around another pumped well. This results in an increased drawdown in each of the pumped wells, a condition called mutual interference of wells.

Water levels declined 24 feet in the Milord district during 1950-62 in sec. 31, T. 28 S., R. 10 W., where there are 13 irrigation wells (fig. 9). In like manner, levels declined 21 feet in sec. 36, T. 28 S., R. 11 W., where there are 11 irrigation wells. Similar conditions exist in the Beryl-Enterprise district (particularly in secs. 5 and 31, T. 36 S., R. 16 W.; secs. 16, 21, and 29, T. 35 S., R. 16 W.; and secs. 1 and 12, T. 35 S., R. 17 W.) and in Cedar City Valley (secs. 27 and 33, T. 35 S., R. 11 W.; and secs. 5 and 8, T. 36 S., R. 11 W.).

Long-term fluctuations of water levels

If recharge to the ground-water reservoir exceeds discharge, water levels will rise; conversely, if discharge exceeds recharge, water levels will decline. Between 1950 and 1962 the precipitation in southwestern Utah was below average (fig. 3), and this, directly and indirectly, resulted in a decline of water levels in parts of Escalante, Cedar City, and Parowan Valleys.

The greatest declines of water levels were in those areas where ground water is pumped for irrigation. In those areas the below-average precipitation had a twofold effect: It resulted in a decrease in the amount of surface water available for recharge and an increase in the amount pumped from wells. Hydrographs for selected wells in the heavily pumped areas of Escalante, Cedar City, and Parowan Valleys are shown in figure 11 (hydrographs B, E, G, H, and J). The downward trend of water levels during the period 1950-62 in the Milford district of the Escalante Valley (hydrograph B), and in Cedar City (hydrographs G and H), and Parowan Valleys (hydrograph J) were due directly to pumping and indirectly to below-average precipitation. The downward trend in the Beryl-Enterprise district of the Escalante Valley (hydrograph E) was due to pumping. The largest declines measured for the period 1950-62 were 25 feet in the Milford district, 32 feet in Cedar City Valley, 58 feet in Parowan Valley, and 32 feet in the Beryl-Enterprise district (fig. 9).

Water levels have remained essentially unchanged outside of the heavily pumped areas, except for small changes caused by variations in precipitation. This is illustrated in figure 11 by hydrographs for selected wells in Beaver Valley (hydrograph A), the Lund district (hydrograph C) and an area of little pumpage in the Beryl-Enterprise district (hydrograph D) of Escalante Valley, and an area of little pumpage in Cedar City Valley (hydrograph F).

QUALITY OF WATER

General statement

Chemical analyses of water from 71 selected wells and springs in the four valleys are shown in table 3. Other analyses, mostly for samples collected prior to 1951, were reported by Connor, Mitchell, and others (1958), Thomas and Taylor (1946), White (1932), and Lee (1908).

Table 3 — Chemical analyses of water from selected wells and springs in the Beaver, Escalante, Cedar City, and Parowan Valleys

(Analyses by U.S. Geological Survey)

Well number	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Na + K: Sodium (Na)	Na + K: Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids1/	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Specific conductance (micromhos/cm at 25°C)	pH
			Parts per million																		
Beaver Valley																					
(C-28-7)21daa-1	6-27-62	53	31	0.01	48	6.8	16		134	25	30	0.5	3.7	-	227	148	38	19	0.6	361	7.4
(C-29-7)19bcd-1	9-11-61	56	50	2/.38	44	7.3	49		184	60	22	-	2.8	-	325	140	0	43	1.8	445	7.5
21cad3/	7- 8-61	56	31	.01	38	6.3	10	2.5	142	16	6.0	.3	7.5	0.02	194	120	4	15	.4	283	7.3
21cda-1	7- 8-61	54	31	.00	59	8.8	14	2.5	180	27	28	.4	1.9	.04	266	184	36	14	.4	414	7.4
21cdb4/	7- 8-61	57	32	.01	36	7.3	12	2.9	144	15	7.5	.4	6.9	.03	190	120	2	17	.5	289	7.4
(C-29-8)9bad-1	8- 9-62	64	44	.11	248	30	63		253	250	292	.7	.7	-	1,050	745	538	16	1.0	1,700	7.3
25cac-2	9-11-61	68	69	2/.05	32	5.4	29		128	48	7.0	-	.7	-	254	103	0	38	1.2	298	7.9
31add-1	8-10-60	53	49	.01	82	18	97	5.3	397	89	54	.4	1.8	.18	592	277	0	43	2.5	886	7.8
(C-29-9)36dcc5/	9-15-61	70	69	.01	107	39	84		498	93	75	-	.6	-	713	428	20	30	1.8	1,090	7.9
Escalante Valley, Black Rock district																					
(C-27-10)6ddb-1	6-27-62	56	22	2/.00	25	15	202		250	20	236	1.2	.7	2.0	647	124	0	78	7.9	1,190	8.2
Escalante Valley, Milford district																					
(C-28-10)7adb-1	12- 2-55	78	35	-	13	5.8	62	2.8	160	40	16	.6	.5	-	255	56	0	69	3.6	390	8.2
17ccc-1	5-18-62	58	45	.02	389	117	202	9.7	169	777	685	.1	1.8	.32	2,310	1,450	1,310	23	2.3	3,560	7.6
21ccd-1	5- 2-59	58	53	.01	160	95	68		146	346	320	-	9.9	-	1,120	790	670	16	1.1	1,810	8.1
30bdd-2	9- 6-61	58	45	2/.10	281	47	99		254	551	228	-	9.9	-	1,390	895	687	19	1.4	1,920	7.5
(C-28-11)25dcd-1	5-18-62	67	36	.12	71	16	36	4.0	144	121	60	.3	.4	.08	416	244	126	24	1.0	668	7.7
(C-29-10)5cdd-3	9- 6-61	56	37	2/.06	173	27	47		270	165	159	-	34	-	775	542	321	16	.9	1,190	7.4
18add-2	5-18-62	56	33	.01	51	11	16	3.0	141	41	38	.2	1.6	.04	264	172	56	17	.5	434	7.2
(C-29-11)4baa-1	6-27-62	60	17	2/.01	120	81	356		169	712	372	1.4	3.2	.63	1,750	635	496	55	6.2	2,710	7.4
11cdd-2	5-18-62	58	38	.06	71	25	39	4.5	140	74	108	.4	28	.09	457	279	164	23	1.0	797	7.2
12ddd-1	5- 2-59	58	37	.01	78	16	22		130	49	104	-	4.9	-	375	261	154	15	.6	644	8.2
28add-2	5-18-62	57	43	.02	131	23	81	6.2	189	160	195	.2	6.0	.15	739	422	267	29	1.7	1,220	7.2
(C-30-9)7acc-1	6-27-62	92	32	2/0.00	111	23	190		230	477	65	3.3	0.5	0.42	1,020	372	183	53	4.3	1,460	7.7
(C-30-10)10baa-1	6- 6-60	56	34	.05	122	26	32		217	113	124	-	13	-	571	412	234	14	.7	942	8.0
19abd-1	9- 6-61	70	60	2/.03	40	8.5	43		147	54	34	-	5.2	-	317	135	14	41	1.6	438	7.7
(C-30-12)286/	10-17-54	(7/)	112	2/.78	82	11	370	51	384	458	212	6.0	.6	-	1,490	250	0	72	10	2,160	7.1
(C-30-13)22ccc-1	6-27-62	59	34	4.2	89	23	54		167	107	130	.6	1.5	-	521	318	181	27	1.3	886	7.6
Escalante Valley, Lund district																					
(C-33-13)3caa-1	6-27-62	57	40	.05	184	57	97		195	441	200	.5	3.5	-	1,120	694	534	23	1.6	1,640	7.5
(C-34-13)16ccc-1	8- 9-62	64	30	.12	108	22	32		199	212	31	.2	6.4	-	540	362	199	16	.7	790	7.8
Escalante Valley, Beryl-Enterprise district																					
(C-35-15)3dcc-2	5- 1-62	56	61	2/.05	347	50	214	8.0	198	736	428	.2	5.3	.49	1,950	1,070	908	30	2.8	2,750	7.5
3ddc-1	5- 1-62	56	63	2/.02	347	56	478	8.4	343	1,270	412	.4	7.1	1.5	2,810	1,100	814	48	6.3	3,850	7.1
(C-35-16)9add-1	5-23-62	55	52	2/.02	65	7.3	16	3.9	196	23	32	.2	2.7	.03	298	191	30	15	.5	450	7.3
(C-36-15)7dba-1	7- 7-59	87	76	.01	53	3.4	267		91	492	93	-	12	-	1,040	146	71	80	9.6	1,580	7.7
7dcc-1	5- 5-59	65	81	.00	71	10	315		96	624	118	-	11	-	1,280	219	140	76	9.2	1,740	7.5
9dbc-1	4- 6-59	55	34	.03	143	28	34		8/170	134	125	-	114	-	698	474	335	13	.7	1,190	8.5
(C-36-16)5a-9	5-23-62	57	40	2/.02	199	14	26	7.0	250	92	208	.3	20	.03	729	554	349	9	.5	1,220	7.5
6c-3	5-29-59	58	60	.00	53	8.0	22		188	12	31	-	2.7	-	281	164	10	23	.8	407	8.2
31ccc-1	9- 7-61	51	35	2/.09	65	10	28		242	25	24	-	7.8	-	314	204	6	23	.9	473	7.5
(C-36-17)2d9/	5- 5-59	64	104	.00	150	27	28		238	71	187	-	17	-	701	486	291	11	.5	1,100	7.5
2d-2	10-20-61	63	46	2/.00	49	4.6	26		168	16	29	-	3.3	-	257	141	3	29	1.0	381	7.5
(C-37-17)12bdc-1	8- 3-60	55	59	.00	75	13	29	4.3	278	24	29	.1	23	.02	393	240	125	20	.8	572	7.6
14bac-1	8- 3-60	55	65	.00	69	14	33	5.7	292	23	30	.2	5.6	.04	390	227	0	23	1.0	567	7.8

Table 3 — (Continued)

Well number	Date of collection	Temperature (°F)	Parts per million															Percent sodium	Sodium adsorption ratio (SAR)	Specific conductance (micromhos/cm at 25°C)	pH
							Na + K														
			Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids 1/	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$				
Cedar City Valley																					
(C-33-10)29adc-1	6-27-62	58	31	.19	63	21	73		166	70	74	.3	109	-	523	244	108	39	2.0	886	7.5
(C-33-12)11aaa-1	6-28-62	57	38	.46	108	33	88		210	291	83	.7	1.3	-	746	404	232	32	1.9	1,090	7.5
(C-34-11)36cdd-2	8- 5-60	67	37	.01	46	28	26	5.1	234	67	20	.4	1.8	.11	346	230	38	19	.7	522	7.9
(C-35-11)13dda-1	5- 4-59	57	53	.00	64	35	26		260	79	34	-	20	-	439	303	90	16	.6	675	8.1
33aac-1	8- 5-60	53	23	.01	212	91	28	3.7	298	666	20	.1	.5	.08	1,190	904	660	6	.4	1,520	7.5
(C-35-12)34dcd-1	5-26-59	54	30	.00	72	42	34		183	239	18	-	2.9	-	528	352	202	18	.8	777	7.9
(C-36-11)18ada-1	5-23-62	57	35	2/.05	243	96	53	2.9	246	779	68	.1	27	.16	1,430	1,000	800	10	.7	1,820	7.8
18bdc-1	2- 3-58	56	28	-	113	62	31		171	367	55	-	6.0	-	746	538	398	11	.6	1,080	7.7
(C-36-12)12dba-1	9- 5-61	56	22	2/.09	86	40	17		177	231	17	-	7.8	-	508	380	235	9	.4	712	7.6
20acc-1	11- 9-61	59	34	2/.01	76	17	25		162	36	100	-	2.4	-	370	260	127	17	.7	624	7.4
33dbc-1	5-26-59	53	124	.00	36	7.3	15		146	8.8	17	-	.8	-	281	120	0	22	.6	286	7.7
(C-37-12)11aab-1	7-13-59	70	54	.02	47	28	34		178	137	12	-	3.0	-	403	234	88	24	1.0	586	7.7
23acb-1	8-16-60	57	16	.01	51	22	33	2.0	162	135	18	.0	1.0	.14	358	218	85	25	1.0	538	7.7
23bbd-1	4-22-59	54	28	.01	473	243	463		166	1,010	1,380	-	66	-	3,750	2,180	2,040	32	4.3	5,690	8.2
34abb-1	9- 5-61	53	16	2/.07	88	33	26		268	154	13	-	15	-	477	353	133	14	.6	689	7.8
Parowan Valley																					
(C-32-8)22bbb-1	4- 4-59	58	62	.00	19	5.6	27		125	6.4	15	-	.6	-	197	71	0	46	1.4	257	8.1
35bcb-1	4- 4-59	51	7.2	.03	12	2.7	19		48	1.5	28	-	.4	-	106	40	1	50	1.3	175	7.9
(C-33-8)21dcc-1	9- 4-57	52	19	.05	64	22	20		315	13	14	-	7.1	-	314	252	0	15	.6	527	7.4
31ccc-2	9-26-61	48	28	2/.06	59	20	30		250	31	38	-	5.0	-	334	230	25	22	.9	540	7.8
(C-33-9)24aba-1	4- 4-62	50	4.6	2/.11	10	2.9	58	1.2	107	19	41	.4	.1	.04	190	38	0	76	4.1	345	7.9
32cdd-4	5- 4-59	55	36	.00	30	18	13		10/183	17	6.0	-	.7	-	211	148	0	16	.5	321	8.4
33aad-1	8- 5-60	51	32	.01	32	19	12	2.2	196	20	8.0	.2	3.0	.01	224	158	0	14	.4	346	8.0
33abd-1	4- 4-59	58	30	.01	27	17	17		11/178	17	7.0	-	1.8	-	205	139	0	21	.6	310	8.4
34cbd-1	10-16-57	54	34	.01	46	18	18		210	21	23	-	4.5	-	268	190	18	17	.6	430	8.0
34dcd-2	5- 4-59	54	28	.00	51	27	13		281	19	9.5	-	6.3	-	292	241	11	10	.4	479	7.8
35acd-2	9-26-61	55	26	2/.02	57	21	18		252	28	18	-	8.6	-	301	228	21	15	.5	481	7.6
(C-34-8)31ddb-1	9-10-57	49	20	.05	72	26	8.5		302	41	10	-	.4	-	327	286	38	6	.2	515	7.4
(C-34-9)3bcd-1	8- 5-60	54	34	.00	50	26	10	2.5	274	22	8.0	.1	6.3	.00	294	232	7	9	.3	454	7.8
16cdd-2	10-31-61	52	31	2/.00	63	23	15		298	21	8.5	-	5.8	-	314	250	6	12	.4	493	7.4
(C-34-10)13cbd-1	9-11-61	54	40	2/.02	46	22	22		244	32	12	-	2.9	-	297	205	5	19	.7	436	7.8

1/ Dissolved solids calculated from determined constituents.
2/ In solution at time of collection.
3/ Spring north of Beaver Fish Hatchery. Approximate location.
4/ Spring east of Beaver Fish Hatchery. Approximate location.
5/ Spring in bottom of Minersville Reservoir. Approximate location.
6/ Thermo Hot Springs. Approximate location. Covers several acres.
7/ Temperature on August 9, 1962, was 167°F.
8/ Includes equivalent of 9 ppm carbonate (CO_3).
9/ Mine shaft. Sample taken from water pumped from shaft. Approximately 300 yards south of well 2d-1.
10/ Includes equivalent of 5 ppm carbonate (CO_3).
11/ Includes equivalent of 6 ppm carbonate (CO_3).

Water may be classified by its concentration of dissolved solids, expressed as ppm (parts per million), or by its specific conductance, expressed in micromhos per centimeter at 25°C. A convenient classification, used by Robinove, Langford, and Brookhart (1958, p. 3), is as follows:

Class	Dissolved solids (ppm)	Specific conductance (micromhos/cm at 25°C)
Fresh	Less than 1,000	Less than 1,400
Slightly saline	1,000 to 3,000	1,400 to 4,000
Moderately saline	3,000 to 10,000	4,000 to 14,000
Very saline	10,000 to 35,000	14,000 to 50,000
Briny	More than 35,000	More than 50,000

The relation between dissolved solids and specific conductance in the four valleys was determined for the 71 analyses in table 3. The average dissolved solids (in ppm) is 68 percent of the specific conductance (in micromhos per centimeter) in Beaver Valley, 64 percent in Parowan Valley, 68 percent in Cedar City Valley, and 67 percent and 64 percent in the Beryl-Enterprise and Milford districts of the Escalante Valley. For the entire area, the dissolved solids range from 54 to 85 percent of the specific conductance and average 66 percent. Thus, a reasonable estimate of dissolved solids of ground water in the four valleys can be made by multiplying the specific conductance by 0.66.

The specific conductance of ground water in the four valleys is shown in figure 12. The determinations of specific conductance were made from samples collected at random during the summer of 1962 from pumped wells without consideration of well depths, aquifers penetrated, or depths at which the well casings were perforated. The data shown in figure 12, interpreted according to the classification of water presented above, indicate that most ground water in the four valleys is fresh. Some ground water in Escalante, Cedar City, and Beaver Valleys is slightly saline, and water in a well near Kanarraville is moderately saline. Because of insufficient control wells, the contours in most of the Black Rock and Lund districts should be considered as approximate.

Some of the valleys in the Great Basin in Utah, which are similar in structure to the four valleys discussed in this report, contain highly mineralized ground water which underlies fresher water. An increase in the concentration of chemical constituents in ground water with depth has not been observed in any of the four valleys. However, the deepest well sampled in the area is only 600 feet deep. Although the water yielded by this well is fresh (see analysis for well (C-36-12)12dba-1 in table 3), more saline water may be at greater depths. The most significant change noted in chemical quality of water with depth is in the heavily pumped area of the Milford district of Escalante Valley. There the shallow ground water is more highly mineralized than the deeper water because of the return flow of water used for irrigation. This is discussed in greater detail in the section "Quality of water by valleys," which follows:

Quality of water by valleys

Beaver Valley

Virtually all the ground water in Beaver Valley is fresh and suitable for all types of use. Analyses of water from six wells and three springs are shown in table 3. Only one of the samples analyzed exceeded the recommended maximum concentrations for public supply (U. S. Public Health Service, 1962, p. 34) of dissolved solids (500 ppm) and chloride and sulfate ions (250 ppm each).

All the boron concentrations shown in table 3 are less than the suggested maximum tolerable concentration for crops sensitive to boron (Wilcox, 1955, p. 11-12).

The analyses in table 3, however, indicate a low-sodium hazard and a medium to high-salinity hazard for irrigation when classified in figure 13 according to the method of the U. S. Salinity Laboratory Staff (1954, p. 80). The waters which show the high-salinity hazard were obtained in the lower part of the valley from two wells near Adamsville, (C-29-8)9bad-1 and (C-29-8)31add-1, and a spring in the bottom of the Minersville Reservoir (C-29-9)36dcc. An increase of salinity toward the lower parts of the valley is also indicated in figure 12. The higher salinities in the lower areas are due partly to return flow from irrigation and partly to the concentration of salts by direct evapotranspiration of ground water in waterlogged areas and sloughs where the water table is at or close to the surface.

Escalante Valley

Milford district

The ground water in the Milford district is either fresh or slightly saline, and the water of poorest quality is in the central part of the heavily pumped area, 1 to 3 miles south of Milford (fig. 12). Analyses of water from 15 wells in the district (table 3) include 6 in which the chloride or sulfate content exceeds the maximum concentration recommended (250 ppm) by the U. S. Public Health Service (1962, p. 34) for public supply and 10 in which the dissolved solids exceeds the recommended maximum (500 ppm). Well (C-30-9)7acc-1, which supplies part of the public supply for Minersville, yields water that contains 3.3 ppm of fluoride. This exceeds the maximum concentration recommended by the U. S. Public Health Service (1962, p. 8) for public supply. The only other source of water in the district with an excessively high fluoride content is the hot-spring area in sec. 28, T. 30 S., R. 12 W., south of Thermo. Ground water is used for domestic purposes, including drinking, throughout the district.

The temperature of most ground water in the district ranges from 56° to 78°F. At well (C-30-9)7acc-1 the temperature was 92° F, however, and at the hot-spring area south of Thermo, temperatures of 167° and 175°F have been recorded.

All except two of the boron concentrations shown in table 3 are less than the suggested maximum tolerable concentration for crops sensitive to boron (Wilcox, 1955, p. 11). The boron concentrations in water from wells (C-29-11)4baa-1 and (C-30-9)7acc-1 may be toxic to certain plants, such as fruit trees, which are extremely sensitive to boron concentration (Wilcox, 1955, p. 12).

Most of the water in the Milford district for which analyses are available has a low-sodium hazard and a medium to high-salinity hazard for irrigation. (See fig. 14.) The exceptions are

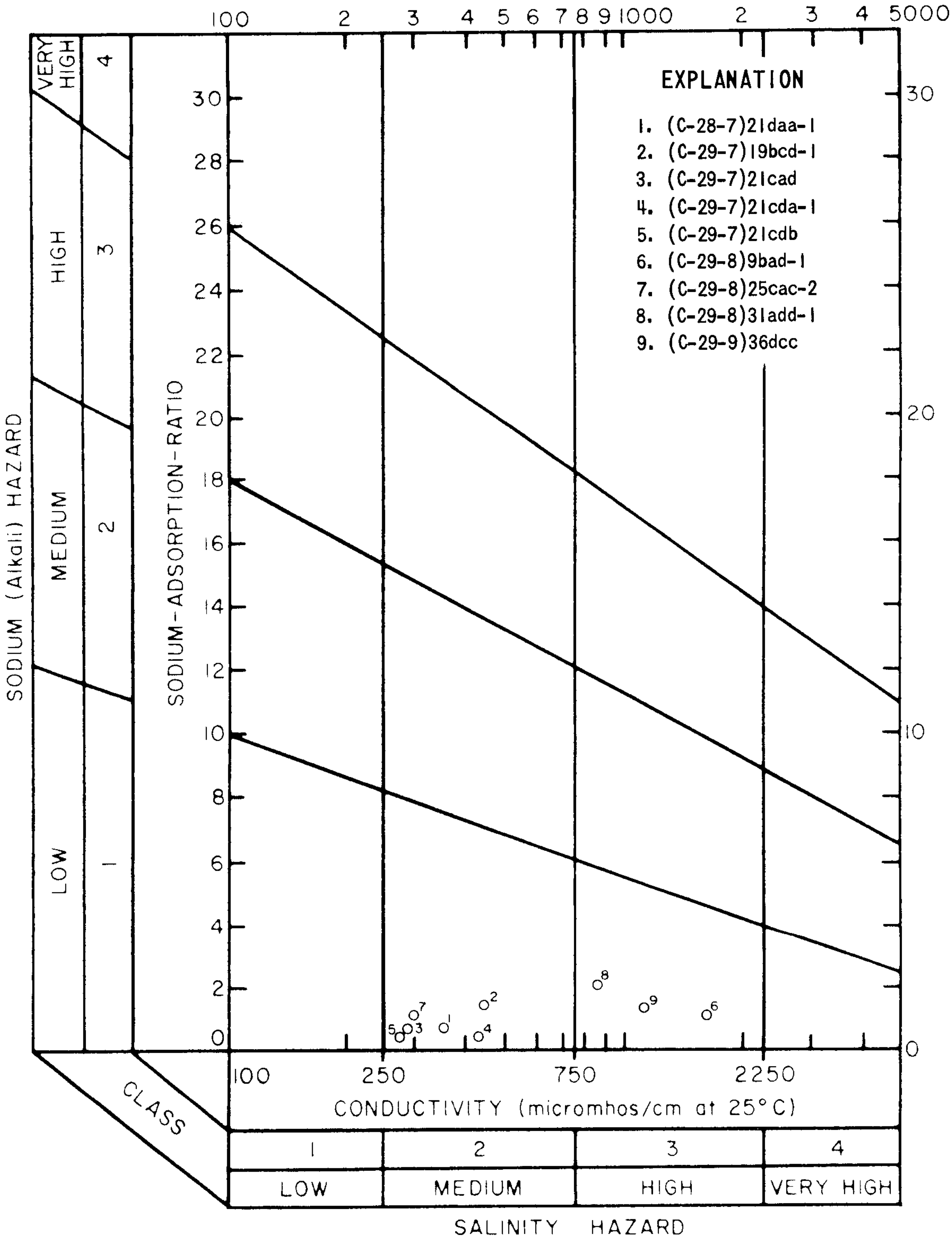

Figure 13.—Classification of ground water for irrigation in Beaver Valley.

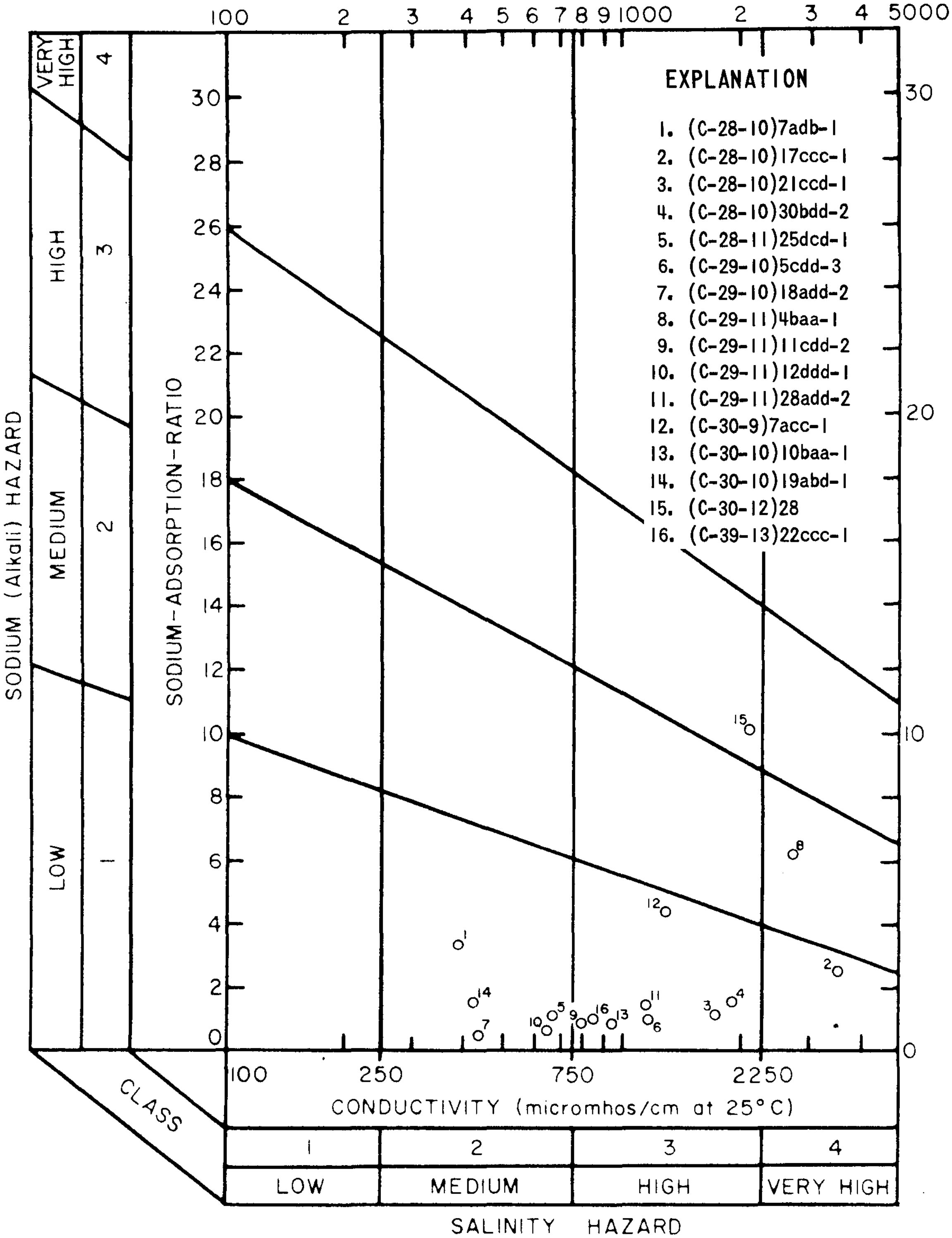

Figure 14.— Classification of ground water for irrigation in the Milford district, Escalante Valley.

the water from two wells, (C-28-10)17ccc-1 and (C-29-11)4baa-1, with a very high salinity hazard, the water from well (C-29-11)4baa-1 with a medium-sodium hazard, and the water from spring (C-30-12)28 with a high-sodium hazard. The highest salinities are found in the heavily pumped area south of Milford (fig. 12). Much of the mineral concentration is due to recirculation of excess water previously applied for irrigation. The area is one in which the water table is close to the surface (fig. 5), however, and part of the mineral concentration is caused by direct evapotranspiration of ground water.

The increase of salinity due to recirculation and evapotranspiration has been greatest in the shallow aquifers. This is illustrated by a comparison of analyses of water sampled from sets of wells in three parts of the district. Well (C-28-10)7adb-1, in Milford, is 533 feet deep and yields water with 255 ppm of dissolved solids; whereas well (C-28-10)17ccc-1, about 1 mile south of Milford, is 92 feet deep and yields water with 2,310 ppm of dissolved solids. Well (C-28-11)25dcd-1, 4 miles south of Milford, is 431 feet deep and yields water with 416 ppm of dissolved solids; whereas nearby well (C-28-10)30bdd-2 is 148 feet deep and yields water with 1,390 ppm of dissolved solids. Well (C-29-10)18add-1, 7 miles south of Milford, is 168 feet deep and yields water with a specific conductance of 816 micromhos per centimeter; whereas a replacement well about 100 yards away, (C-29-10)18add-2, is 450 feet deep and yields water with a specific conductance of 434 micromhos per centimeter.

Beryl-Enterprise district

The ground water in the Beryl-Enterprise district is either fresh or slightly saline, and the water of best quality is in the southern part of the district (fig. 12). Analyses of water from 12 wells and a mine shaft in the district (table 3) include 4 in which the chloride or sulfate content exceeds the maximum concentration recommended (250 ppm) by the U. S. Public Health Service (1962, p. 34) for public supply and 7 in which the dissolved solids exceeds the recommended maximum (500 ppm). However, ground water is used for domestic purposes, including drinking, throughout the district.

The temperature of most ground water in the district ranges from 55° to 65°F. However, at well (C-36-15)7dba-1 the temperature was 87°F. This well is just northwest of Newcastle, in an area where local residents report that the ground water is hot.

The boron concentrations in water from wells (C-35-15)3dcc-2 and (C-35-15)3ddc-1 (table 3) may be toxic to certain plants which are sensitive to boron concentration (Wilcox, 1955, p. 11). The analyses in table 3, however, indicate that boron concentrations throughout the remainder of the district are less than the suggested maximum tolerable concentration for crops sensitive to boron (Wilcox, 1955, p. 11).

Most of the water in the Beryl-Enterprise district for which analyses are available has a low to medium-sodium hazard and a medium to high-salinity hazard for irrigation. (See fig. 15.) The exceptions are the water from wells (C-35-15)3dcc-2 and (C-35-15)3ddc-1 which have a very high salinity hazard. It is not known why the water from these wells is so saline or has such a high boron content as is noted above.

Black Rock and Lund districts

Insufficient analyses are available to justify many generalizations about the chemical quality of water in the Black Rock and Lund districts.

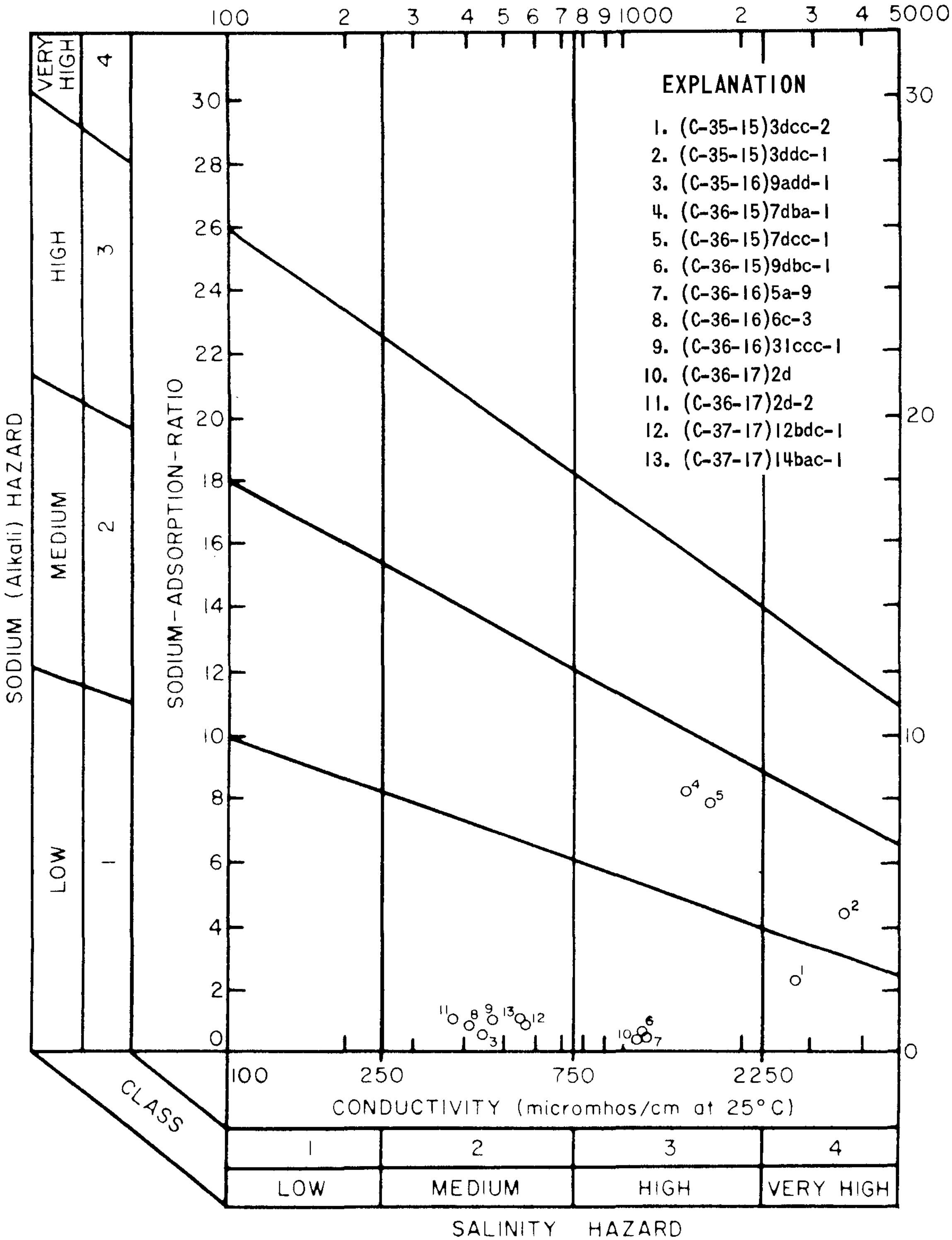

Figure 15.—Classification of ground water for irrigation in the Beryl-Enterprise district, Escalante Valley.

The water in the Black Rock district is either fresh or slightly saline, according to the measurements of specific conductance contoured in figure 12. In the one complete analysis available for the Black Rock district (table 3), the dissolved-solids content slightly exceeds the maximum concentration recommended by the U.S. Public Health Service (1962, p. 34); but in other respects the water is suitable for public supply. The boron concentration in the water is 2.0 ppm, the greatest concentration recorded in the entire four-valley area, and the water may be toxic to many types of crops (Wilcox, 1955, p. 11). The water has a medium-sodium and a high-salinity hazard for irrigation.

Most of the water in the Lund district is slightly saline. (See fig. 12.) The dissolved-solids content, in both of the complete analyses available for the district (table 3), exceeds the maximum concentration of 500 ppm recommended by the U. S. Public Health Service (1962, p. 34). The water from well (C-34-13)16ccc-1 contains only 540 ppm of dissolved solids, however, and in other respects it is suitable for public supply. The water from both wells has a low-sodium and high-salinity hazard for irrigation.

Cedar City Valley

The ground water in Cedar Valley is either fresh or slightly saline, and the water of poorest quality is in the sediments of the Coal Creek fan near Cedar City (fig. 12). Analyses of water from 15 wells in the valley (table 3) include 5 in which the chloride or sulfate content exceeds the maximum concentration recommended (250 ppm) by the U. S. Public Health Service (1962, p. 34) for public supply and 8 in which the dissolved solids exceeds the recommended maximum (500 ppm). Ground water is used for domestic purposes, including drinking, throughout the valley.

The temperature of the water at 13 of the 15 wells sampled was between 53° and 59°F (table 3). The temperatures at the other two wells were 67° and 70°F.

Practically all the ground water in the valley is suitable for irrigation. Boron concentrations were determined for water from five wells in the valley, and they are all less than the suggested maximum tolerable concentration for crops sensitive to boron (Wilcox, 1955, p. 11).

All the analyses in table 3 except one indicate a low-sodium hazard and a medium to high-salinity hazard for irrigation. (See fig. 16.) Water from well (C-37-12)23bbd-1, which is used for stock, contains 3,750 ppm of dissolved solids; and it probably is too saline to be used for irrigation. An abandoned irrigation well near well (C-37-12)23bbd-1 was reported to yield water which was harmful to crops because of high salinity.

Parowan Valley

The ground water in Parowan Valley is fresh (fig. 12). Water in Little Salt Lake is heavily mineralized, however, and shallow ground water near the lake probably also is of poor chemical quality. The temperature of the water at 15 wells ranged between 48° and 58°F (table 3).

As indicated by the analyses in table 3, the water in the valley is all suitable for irrigation. Boron concentrations determined for water from three wells were all less than the suggested maximum tolerable concentration for crops sensitive to boron (Wilcox, 1955, p. 11). Most of the water in the valley has a low-sodium hazard and a medium-salinity hazard for irrigation. (See fig. 17.) The water from well (C-32-8)35bcb-1, however, has a low-sodium hazard and a low-salinity hazard.

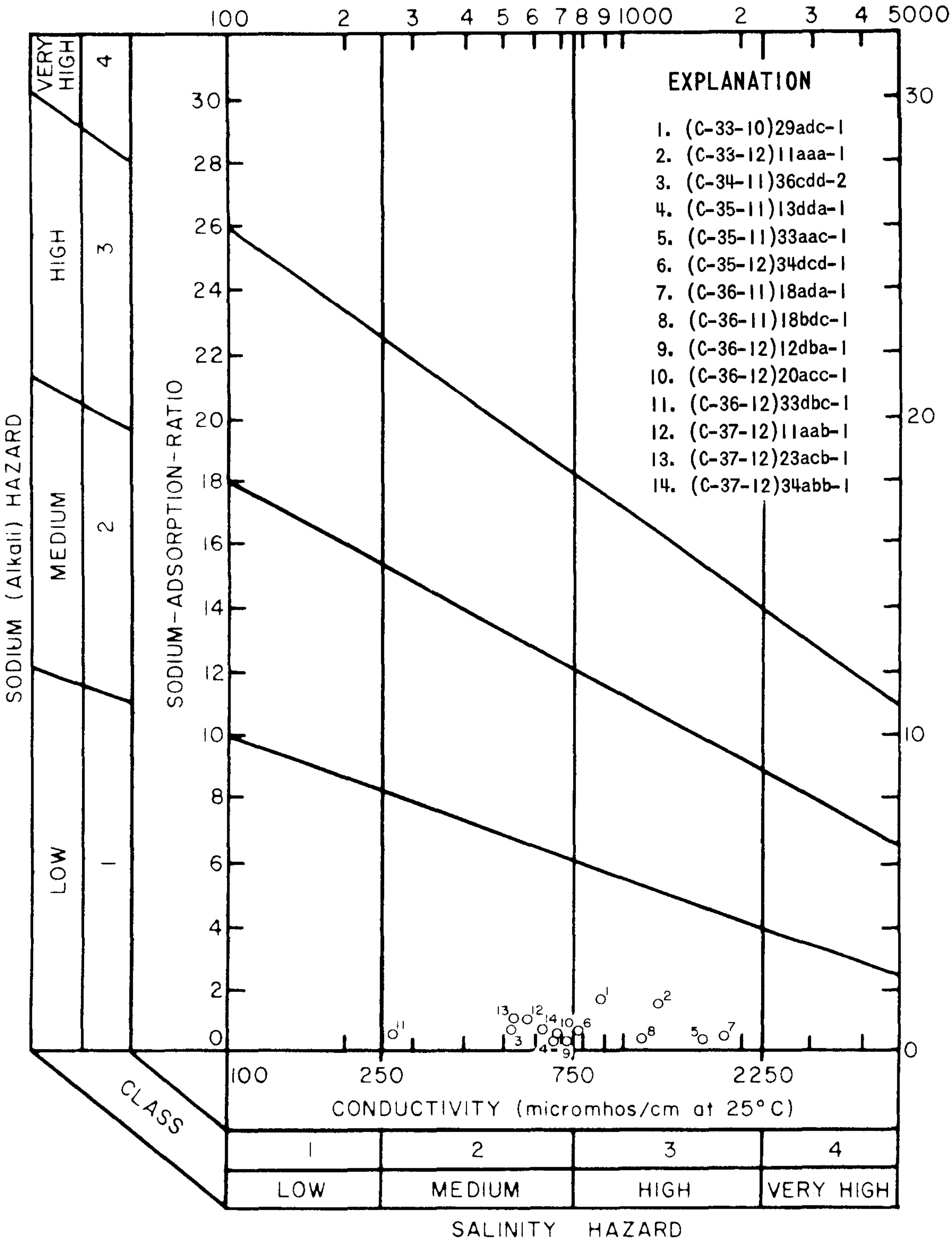

Figure 16.—Classification of ground water for irrigation in Cedar City Valley.

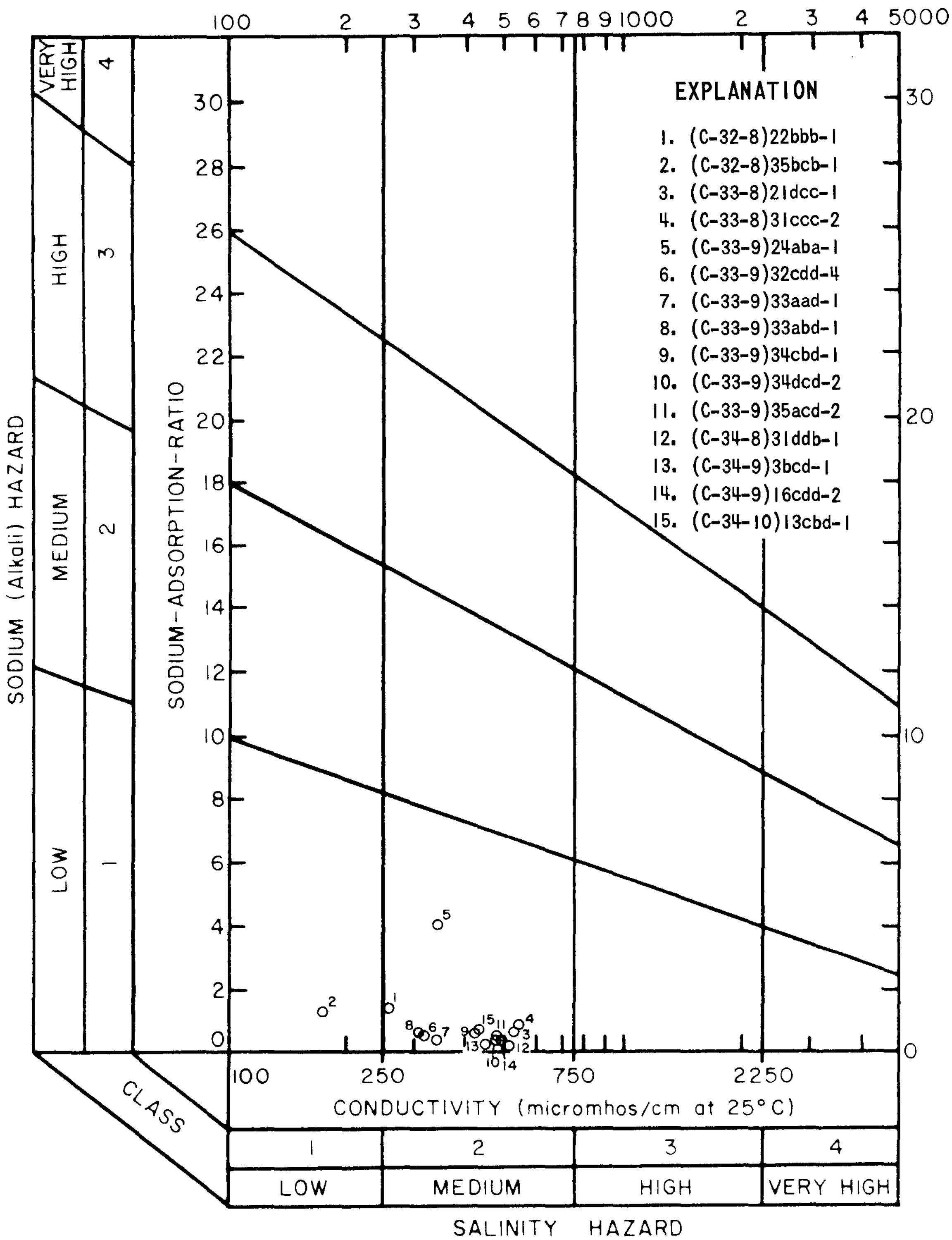

Figure 17.—Classification of ground water for irrigation in Parowan Valley.

FUTURE DEVELOPMENT

Maximum development of the ground-water resources in the four valleys involves efficient economic use of the resource. This includes the elimination, as far as possible, of wasteful losses.

Intensive development of ground water with consequent lowering of water levels has taken place in only about one-fourth of the area in the four valleys (fig. 9). Parts of the remaining area are underlain with permeable water-bearing materials and new wells could be constructed and pumped without significantly affecting existing wells.

The amount of ground water available for development in the large areas where water is used mainly for livestock has remained virtually unchanged since water-level records were first compiled in 1930. The hydrographs of wells in these areas show that net water-level changes since the 1930's have been very small. (See fig. 11, hydrographs A, C, D, and F.)

A considerable amount of ground water could be salvaged from nonbeneficial losses where water levels are relatively near or at the land surface and where the water is used by phreatophytes or is evaporated. The areas where water could be salvaged correspond, in general, to the areas in figure 4 where the water table is shown as less than 10 feet below the land surface. The uncultivated parts of these areas comprise about 5 percent (70,000 acres) of the total uncultivated land surface in the four valleys.

Beaver Valley

The opportunities for salvage of ground water by additional development is more favorable in Beaver Valley than in any of the other valleys. The water table in Beaver Valley rises during the summer months (see fig. 11, hydrograph A) and causes waterlogging and waste of water by evapotranspiration. Pumping would tend to lower the water table and prevent this waste of water. The pumpage of between 4,000 and 5,000 acre-feet annually during the period 1959-62 (see fig. 10) has had little effect on the long-term pattern of water-level fluctuations. A considerably larger amount undoubtedly would be pumped, and the consequent decline in water levels would result in considerable savings of water which is presently lost by evaporation and transpiration.

Escalante Valley

Estimates by Fix and others (1950, p. 177) and Waite and others (1954, p. 48) indicated that there was probably several million acre-feet of water in storage in the sediments in the Beryl-Enterprise district in the southern part of Escalante Valley. Marsell (1962, p. 49) estimated that the amount of water underlying the entire Escalante Valley was about 25 million acre-feet, or more than enough to fill Lake Mead. Water for irrigation presently is pumped from depths as great as 170 feet, but much of the water in storage in the valley is probably too deep for present economical development.

The annual discharge of ground water from areas of the Escalante Valley exceeds the recharge to those areas. Hence part of the water pumped is taken from storage, and water levels, particularly in parts of the Milford and Beryl-Enterprise districts, have declined considerably (see fig. 9). The areas of significant decline, however, comprise less than one-fourth of the valley. Future development by means of salvage of ground water probably is feasible in several parts of the Escalante Valley including (1) an area south of the Milford district and west of Minersville, (2) the Lund district, and (3) the northeast, north, and west parts of the Beryl-Enterprise district. Development in the Black Rock district probably is not feasible because the valley fill has low permeability and would yield only small supplies of water to wells. Test drilling in the district, however, may discover permeable gravel and sand beds which would yield larger quantities of water to wells.

Cedar City Valley

Thomas and Taylor (1946, p. 141) felt that by 1940 Cedar City Valley was "approaching the maximum practicable development of ground water." The discharge of ground water in the valley has remained fairly uniform since then (fig. 10); and it would not be practicable to withdraw additional water from the central part of the valley where there is a concentration of irrigation wells (fig. 9).

Some additional development may be feasible in T. 34 S., R. 11 W., an area presently devoted largely to grazing. The water table within most of the area is less than 40 feet below the land surface, and near Rush Lake it is less than 10 feet below the land surface (fig. 4). According to Thomas and Taylor (1946, p. 141), however, this area may contain soils of relatively low quality and aquifers of relatively low yield.

Parowan Valley

Most of the ground-water development in Parowan Valley has been south of the middle of T. 33 S., and future development probably is feasible only in the northern part of the valley. Only a few stock wells are in this area, and much of it is underlain by leaky artesian aquifers from which much water seeps to the land surface where it is wasted by evaporation and transpiration. Thomas and Taylor (1946, p. 198) estimated that about 10,700 acre-feet of water is discharged annually by evaporation, transpiration, and from numerous small springs in Parowan Valley; and most of the area of high evapotranspiration is in the northern part of the valley. Losses in the magnitude of those reported by Thomas and Taylor probably still occur, because water levels, well development, and other factors have not greatly changed since their investigation. Considerable water could be pumped from the northern part of the valley, and the consequent decline in water levels would result in considerable savings of water which is presently lost by evaporation and transpiration.

SUMMARY AND CONCLUSIONS

Virtually all recharge to the ground-water reservoirs comes directly or indirectly from precipitation within the drainage basin. Recharge occurs mostly along stream channels at the marginal parts of the valleys where water seeps into permeable sand and gravel beds in the valley fill. Excess water diverted for irrigation also is an important source of recharge.

Large quantities of ground water of acceptable quality for most uses are in storage in the unconsolidated deposits of the valleys.

The hydraulic gradients and the direction of ground-water movement have changed locally due to pumping from wells. The direction of movement generally is westward through Beaver, Parowan, and Cedar City Valleys, thence northward through Escalante Valley toward Sevier Lake. Small to moderate amounts of water move from valley to valley through the fill in several connecting gaps, and a small quantity of water moves through bedrock from Parowan Valley to Cedar City Valley. Small quantities of ground water leave the area northward at Black Rock, and about 1,500 acre-feet per year leaves the area in the subsurface near Kanarraville.

In 1962, about 3,000 acre-feet of water was discharged from flowing wells in the four valleys. About 140,000 acre-feet was pumped from wells for irrigation, 1,000 acre-feet for livestock, 1,000 acre-feet for public supply, and 500 acre-feet for domestic use.

Water levels declined as much as 58 feet in the area during the period 1950-52. Although the declines are attributed to the combined effects of pumping and drought, they have been negligible in areas of little pumping.

Some deterioration in the quality of ground water at shallow depths has occurred in the heavily pumped areas due to recirculation of the water for irrigation. This is most apparent in the area south of Milford.

Most of the existing ground-water development has been in about one-fourth of the area of the valley floors. Additional wells could be constructed and pumped in parts of the remaining area without significant effect on existing development. Such additional pumping would result in salvaging a considerable amount of water from present nonbeneficial loss. The best opportunities for such salvage are in parts of Beaver Valley; good conditions exist in part of Escalante Valley and in the northern half of Parowan Valley; and some additional development may be feasible in Cedar City Valley near Rush Lake.

The collection of hydrologic data should continue in the area so that water management can be based on facts. The measurement of water levels and the collection of pumpage data should continue in order to provide a continuous record of ground-water conditions in the four valleys. The collection of ground-water samples for analysis should continue in order to watch for possible changes of chemical quality due to pumping, recirculation of water for irrigation, or the use of fertilizers.

The collection of isolated basic data, however, will not answer such questions as: What is the total recharge to the ground-water aquifers? What is the total quantity of ground water in storage? What is the maximum amount of water of suitable quality that can be withdrawn from the area on a continuous basis? Answers to such questions will require a comprehensive investigation of the entire hydrologic system in the four valleys. Such an investigation would involve deep test drilling in all the valleys; thorough testing of the valley fill to determine transmissibility and storage capacity; determination of precipitation and evapotranspiration over the entire drainage basin; accurate measurement of the discharge of all surface streams, springs, and wells; and determination of the chemical quality of all sources of water in the area.

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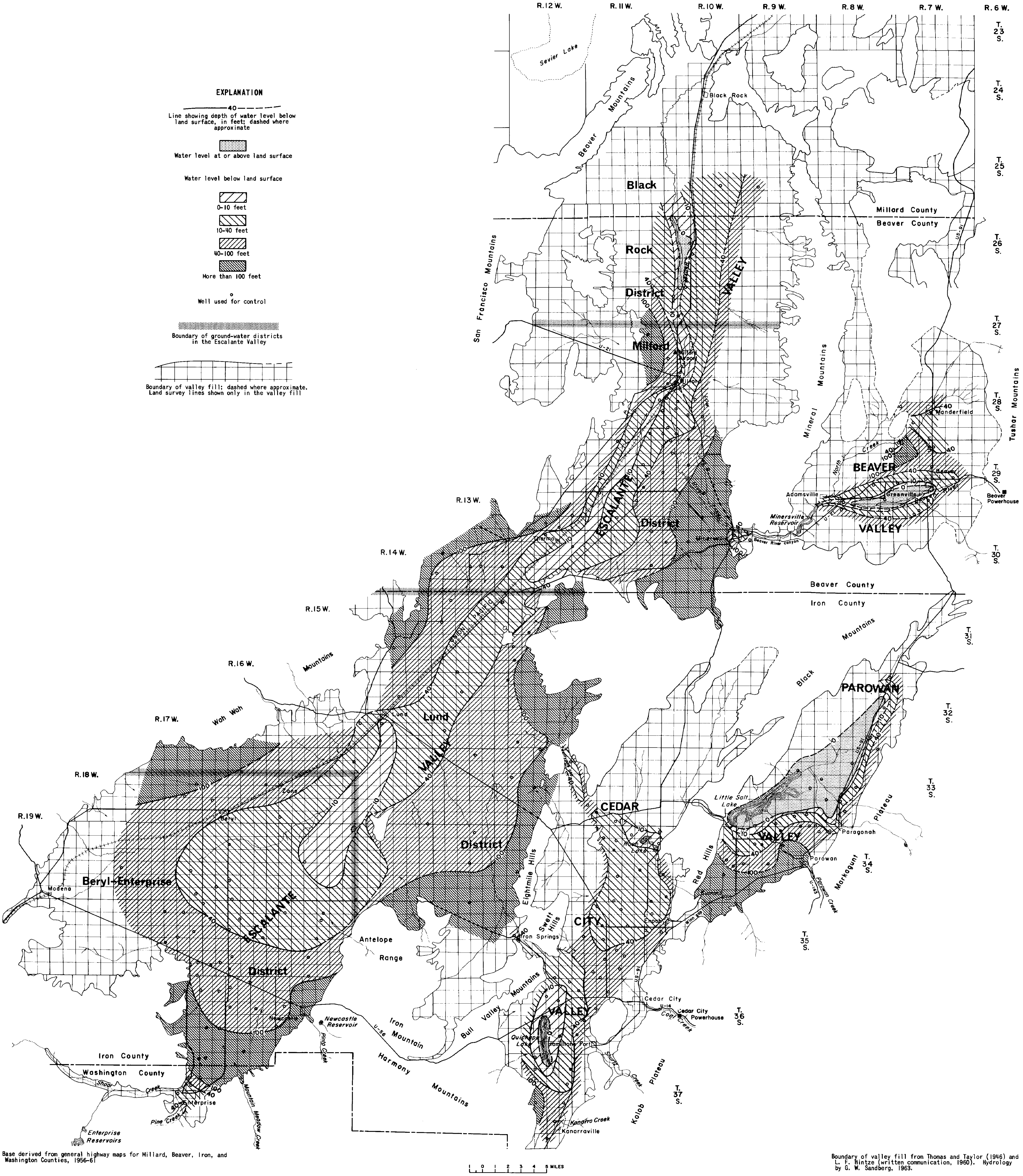

Base derived from general highway maps for Millard, Beaver, Iron, and Washington Counties, 1956-61

Boundary of valley fill from Thomas and Taylor (1946) and L. F. Hintze (written communication, 1960). Hydrology by G. W. Sandberg, 1963.

MAP SHOWING THE RELATION OF WATER LEVEL TO LAND SURFACE IN SELECTED VALLEYS OF SOUTHWESTERN UTAH, MARCH 1962

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FIGURE 5 1966

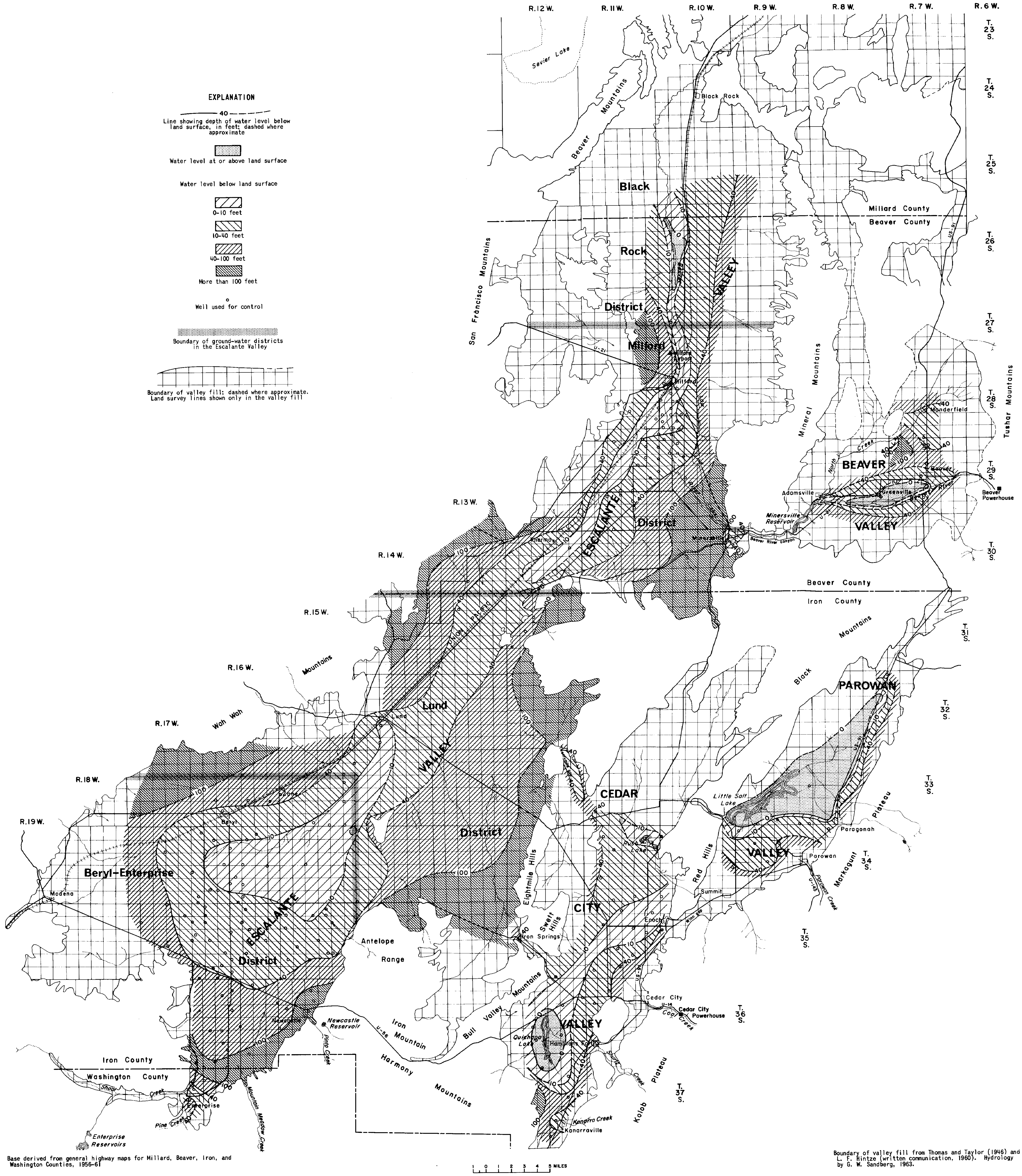

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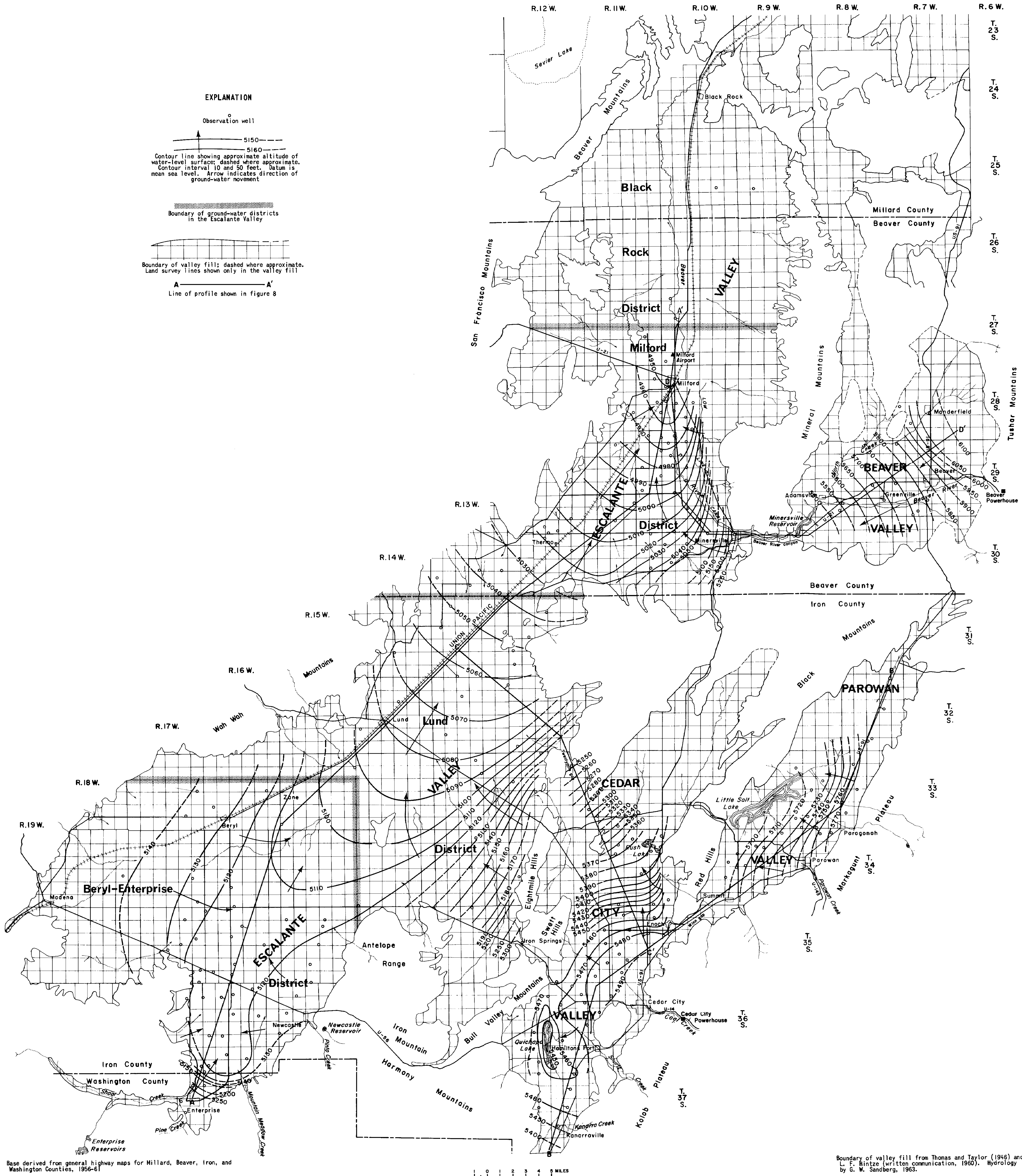
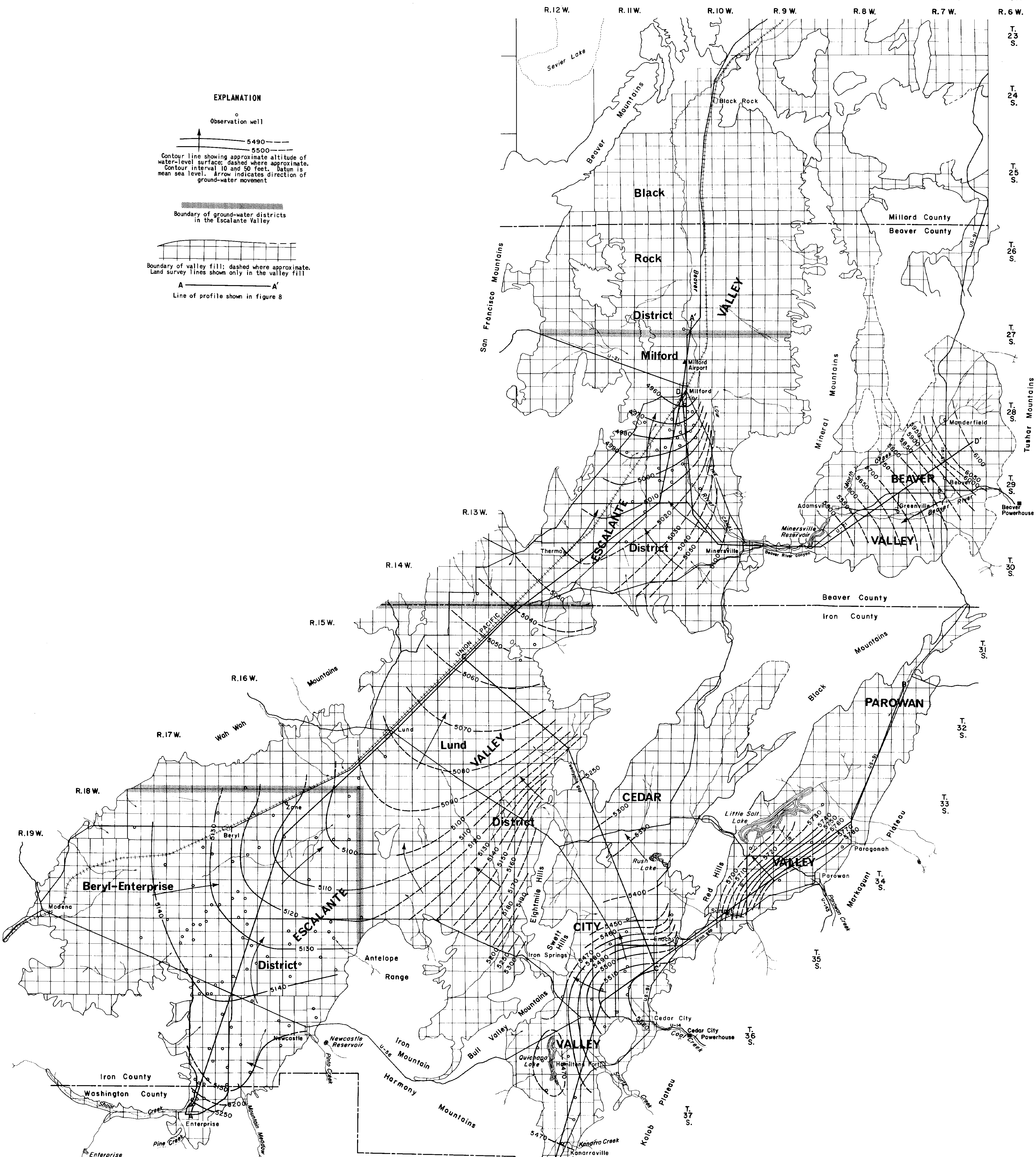
FIGURE 6 1966



MAP SHOWING LOCATION OF OBSERVATION WELLS, LINES OF PROFILES, WATER-LEVEL CONTOURS, AND DIRECTION OF GROUND-WATER MOVEMENT IN SELECTED VALLEYS OF SOUTHWESTERN UTAH, MARCH 1962



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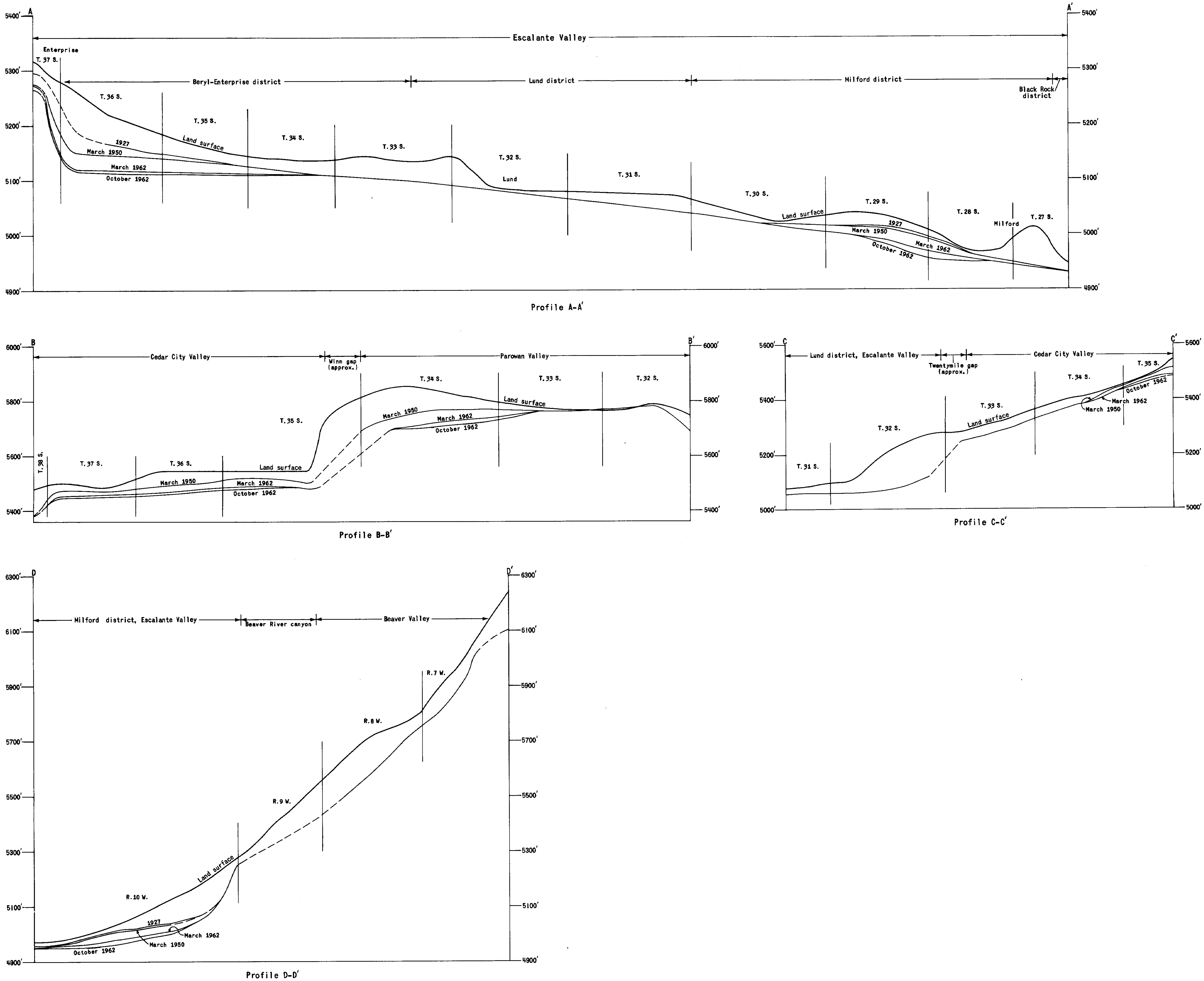
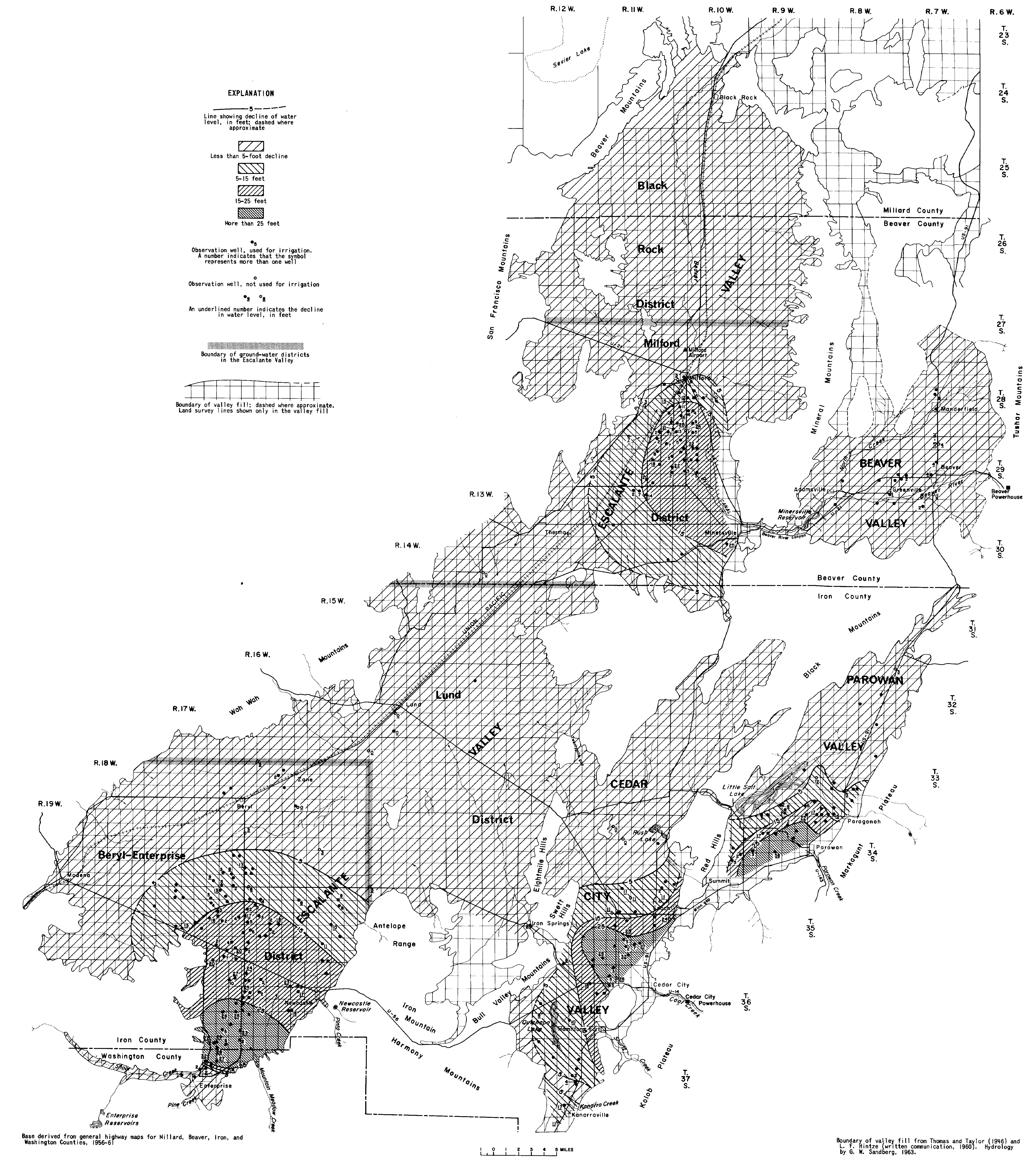


0 1 2 3 4 5 MILES
Horizontal scale
Datum is mean sea level
Vertical scale exaggerated
Trace of profiles shown in figures 6 and 7

Topographic profile from field data and U.S. Geological Survey topographic maps.

Profiles for 1927 adapted from White (1932)

PROFILES SHOWING RELATION OF GROUND-WATER LEVELS TO LAND SURFACE IN SELECTED VALLEYS OF SOUTHWESTERN UTAH



MAP SHOWING LOCATION OF IRRIGATION AND SELECTED OBSERVATION WELLS IN 1962, AND CHANGES IN GROUND-WATER LEVELS, MARCH 1950 TO MARCH 1962 IN SELECTED VALLEYS OF SOUTHWESTERN UTAH

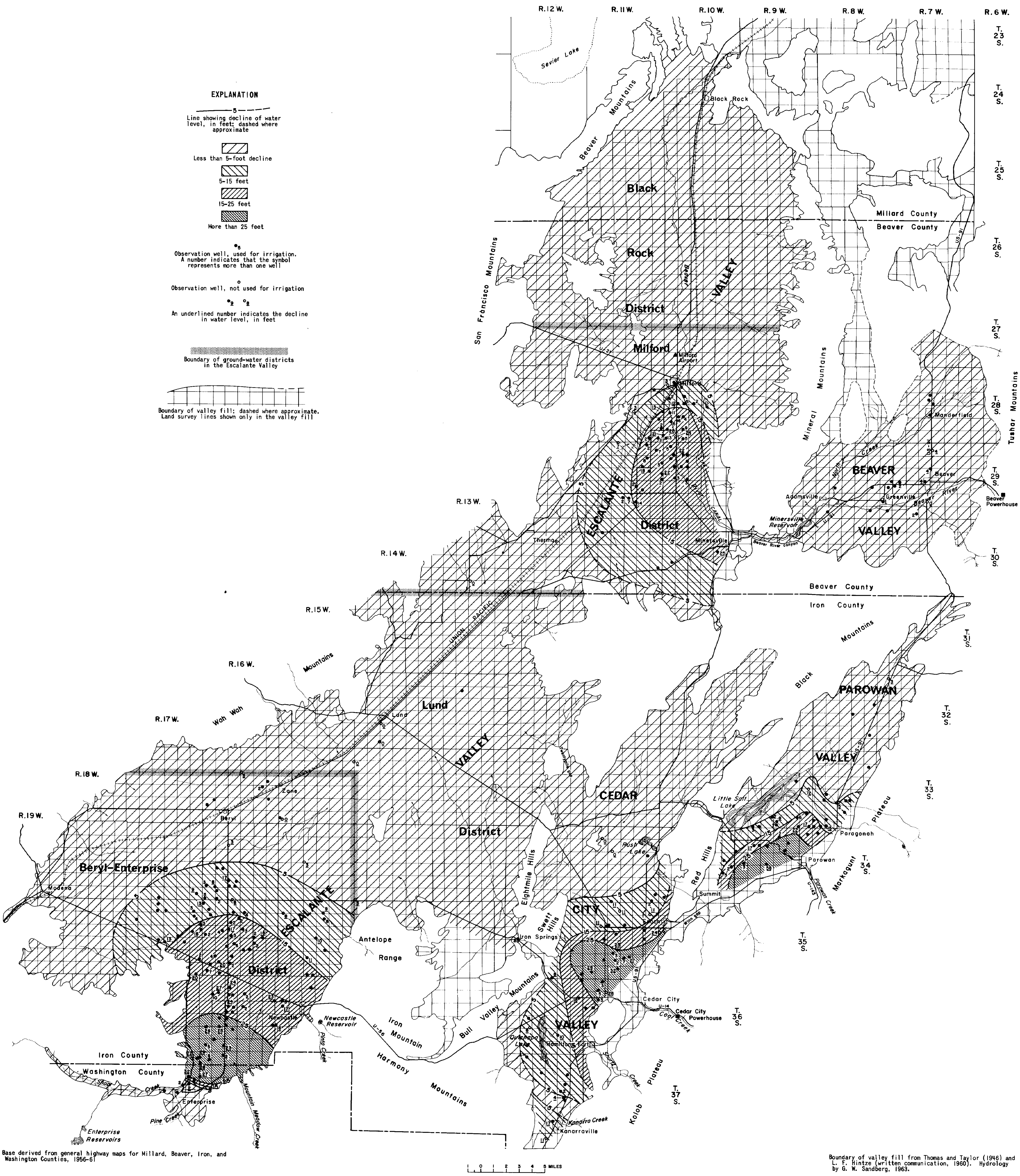


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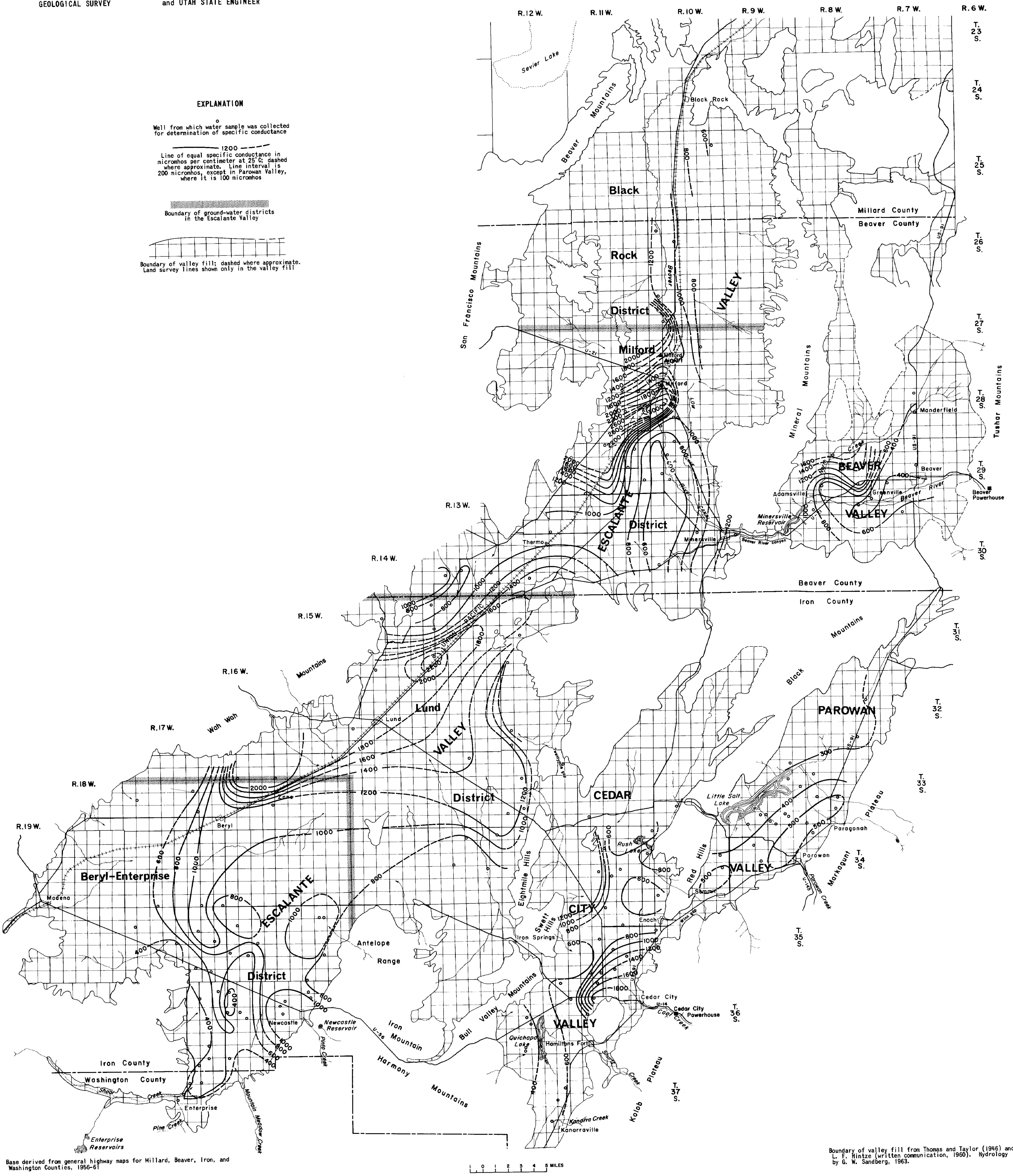
FIGURE 12 1966



MAP SHOWING SPECIFIC CONDUCTANCE OF GROUND WATER, FROM SAMPLES COLLECTED DURING THE SUMMER OF 1962 IN SELECTED VALLEYS OF SOUTHWESTERN UTAH