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GROUND-WATER HYDROLOGY OF OGDEN VALLEY AND SURROUNDING AREA, EASTERN WEBER COUNTY, UTAH, AND SIMULATION OF GROUND-WATER FLOW IN THE VALLEY-FILL AQUIFER SYSTEM

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	4,047	square meter
	0.004047	square kilometer
acre-foot	1,233	cubic meter
cubic foot per second	0.02832	cubic meter per second
	28.32	liter per second
foot	0.3048	meter
foot per day	0.3048	meter per day
foot squared per day	0.0929	meter squared per day
gallon	3.785	liter
gallon per minute	0.06308	liter per second
inch	25.4	millimeter
	2.54	centimeter
mile	1.609	kilometer
square mile	2.590	square kilometer

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{\circ}F = 1.8\ (^{\circ}C) + 32.$$

Air temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$^{\circ}C = (^{\circ}F - 32)/1.8.$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter expresses the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations stated in the inch-pound units of parts per million.

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ABSTRACT

The ground-water resources in Ogden Valley, eastern Weber County, Utah, were the subject of a study to provide a better understanding of the hydrologic system in the valley and to estimate the hydrologic effects of future ground-water development. The study area included the drainage basin of the Ogden River upstream from Pineview Reservoir dam and the drainage basin of Wheeler Creek. Ogden Valley and the surrounding area are underlain by rocks that range in age from Precambrian to Quaternary.

The consolidated rocks that transmit and yield the most water in the area surrounding Ogden Valley are the Paleozoic carbonate rocks and the Wasatch Formation of Tertiary age. Much of the recharge to the consolidated rocks is from snowmelt that infiltrates the Wasatch Formation, which underlies a large part of the study area. Discharge from the consolidated rocks is by streams, evapotranspiration, springs, subsurface outflow, and pumping from wells. Water in the consolidated rocks is a calcium bicarbonate type and has a dissolved-solids concentration of less than 250 milligrams per liter.

The unconsolidated valley-fill deposits, which constitute the valley-fill aquifer system, are more than 750 feet thick in parts of Ogden Valley. Water in the northern part of Ogden Valley and along the margins of the southern part of the valley is unconfined; water in the center of the southern part of the valley is confined in the lower, principal aquifer and unconfined in the overlying shallow water-table aquifer. Direct infiltration from snowmelt and seepage from stream channels are the major sources of recharge during spring runoff. During the remainder of the year, subsurface inflow from bedrock and infiltration of irrigation water probably are the major sources of recharge. Ground-water discharge occurs by seepage to streams, springs, drains, and Pineview Reservoir; by evapotranspiration; and by pumping from wells.

Ground-water flow in the principal aquifer is from the valley margins toward Pineview Reservoir in the southern part of Ogden Valley. Most ground-water flow near Pineview Reservoir is upward but downward leakage may occur near the Ogden well field.

In general, the dissolved-solids concentration of water in the valley-fill aquifer system does not exceed 350 milligrams per liter. Most of the water is a calcium bicarbonate type.

A three-dimensional finite-difference computer model of the valley-fill aquifer system was used to simulate ground-water flow. Transmissivity values for the principal aquifer estimated from the model ranged from 20 to 230,000 feet squared per day. Simulated recharge to the valley-fill aquifer system determined for the transient simulation ranged from 109 to 284 cubic feet per second, and simulated discharge ranged from 115 to 209 cubic feet per second. The model also was used to simulate the hydrologic effects of a hypothetical 1-year drought and increased discharge from wells.

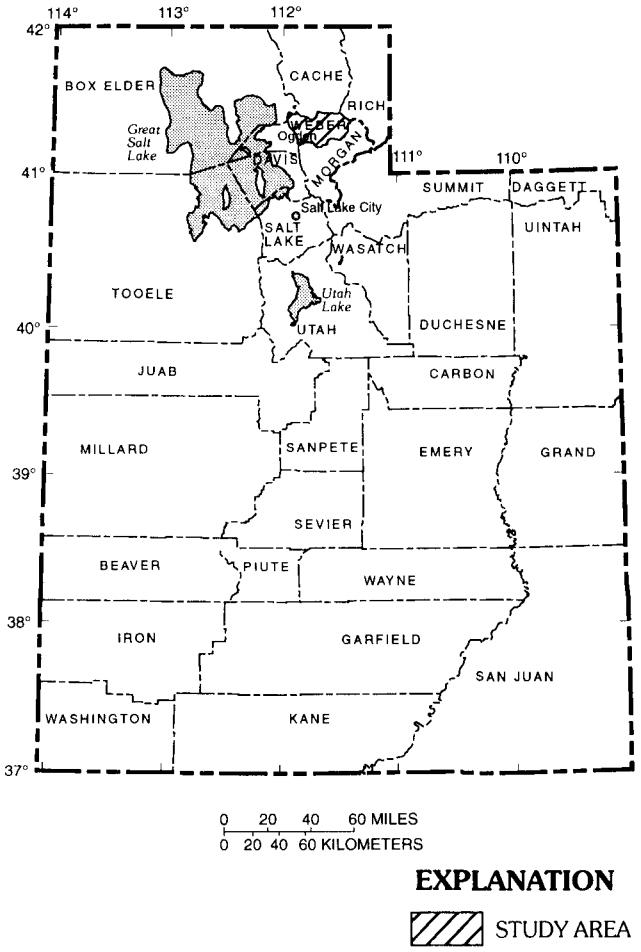


Figure 1. Location of the study area.

INTRODUCTION

Since about 1915, Ogden, Utah (fig. 1), which had a population of 64,907 in 1980 (Bureau of the Census, 1982), has obtained most of its municipal water supply from Ogden Valley in eastern Weber County, northern Utah (pl. 1). At present (1987), Ogden obtains most of its municipal water supply from ground water from a well field in Ogden Valley and from surface water from Pineview Reservoir and Wheeler Creek (pl. 2). Because the population of Ogden has decreased nearly 10 percent since 1960, additional municipal water supplies probably will not be needed in the near future. In contrast, the population in Ogden Valley has increased steadily, especially in the last few years, and probably will continue to increase. Thus, the need for additional municipal water supplies in the valley will increase.

Land use in Ogden Valley is changing from cropland and pasture that is irrigated almost entirely by surface-water sources and springs to subdivided housing tracts that primarily use individual or small community wells. Hydrologic changes that result from the changes in land use may affect the quantity and quality of ground water.

The increased use of ground water in Ogden Valley and the potential effects of land-use changes on water quantity and quality is of concern to local water users, developers, and the State of Utah. In addition, downstream users are concerned that increased ground-water withdrawals may reduce streamflow. To address these concerns, the U.S. Geological Survey, in cooperation with the Utah Department of Natural Resources, Division of Water Rights, studied the ground-water resources of Ogden Valley from July 1984 to June 1987. The purpose of the study was to provide a better understanding of the hydrologic system in Ogden Valley and to estimate the hydrologic effects of future ground-water development.

Most usable ground water in Ogden Valley comes from aquifers in the unconsolidated valley-fill deposits. The valley-fill deposits in Ogden Valley extend about 15 miles in length, 1 to 4 miles in width, and trend in a northwest-southeast direction. The series of aquifers and confining units of the unconsolidated valley-fill deposits are referred to as the valley-fill aquifer system in this report.

Ground water in Ogden Valley has been considered fully appropriated for many years. Additional water development in the area could be accomplished through a transfer based on an existing irrigation-water right or through an exchange of surface-water rights for water in Pineview Reservoir, which stores water for irrigation, municipal supply, hydroelectric-power generation, and flood control. Surface-water rights are leased from the Weber Basin Conservancy District. The majority of surface-water-right exchanges are for domestic use although some large users recently have filed exchange applications. Through the surface-water-right exchange application program, the quantity of water that will be pumped by the new well is released from Pineview Reservoir. The surface-water-right exchange application program assures an adequate supply of water for downstream users. Downstream demands on Ogden River water include irrigation, municipal supply, and hydroelectric-power generation.

Purpose and Scope

This report describes the results of the hydrologic study of Ogden Valley and the surrounding area. Hydrologic data collected during the study and selected data from previous studies were used to interpret the ground-water hydrology of the study area. These data were also used to develop a digital-computer model to simulate ground-water flow in the aquifer system of Ogden Valley.

The report describes hydrologic conditions in Ogden Valley in terms of ground-water recharge, movement, and discharge; surface-water and ground-water relations; ground-water storage; and general water quality. A water budget for 1985 was prepared from data collected during 1985 and from other information. Available data were evaluated in the context of understanding and analyzing changes to the hydrologic system.

Methods of Investigation

Most of the detailed hydrologic data for this study were collected from August 1984 to July 1986. Additional data from other sources also are included in this report. Electrical resistivity soundings were made throughout Ogden Valley to estimate the thickness of alluvial deposits. Major springs and wells in Ogden Valley and the surrounding area, including all public-supply and other large-yield wells, were inventoried. Water levels in 21 wells were measured monthly (except for biweekly measurements in April 1985) for a 2-year period. Also, water levels in a large number of wells were measured in February and June 1985 and in June 1986. A 4-day aquifer test was conducted on 7 observation wells in the city of Ogden well field. Single-well, 1-hour aquifer tests were conducted on 5 domestic wells.

Measurements were made of water discharging from the valley-fill deposits into Pineview Reservoir. Open-ended barrels that had a collection port on the closed end (seepage meters) were driven into the bottom of the reservoir, and the volumes of water collected over time were measured. Data obtained were used to calculate the estimated total discharge.

Surface-water and water-quality data also were collected. Streamflow measurements were made during February 1985 on major streams, except for the South Fork Ogden River. Streamflow measurements were made on the upper Middle Fork Ogden River during October 1984 and on Wheeler Creek during October 1985. Flow measurements were made on several irrigation ditches during the summer of 1985. Water samples from 23 wells, 5 springs, and 2 minor seeps were collected to analyze the quality of ground water.

A three-dimensional, finite-difference digital-computer model was used to simulate ground-water flow in the valley-fill aquifer system of Ogden Valley. The model was used to evaluate the adequacy of available data in simulating ground-water flow in Ogden Valley. Hydrologic effects of a hypothetical drought and of increased withdrawals from wells also were simulated.

Previous Studies

Fortier (1897) made discharge measurements of the Ogden River, its major tributaries, and irrigation use to resolve a water-rights dispute between irrigators in Ogden Valley and irrigators near Ogden. From July to September, increasingly more surface water flowed out of the valley than flowed into it; the discrepancy was attributed to seepage from irrigated lands that had been returned to surface water.

Browning (1925) analyzed a series of surface-water discharge measurements made on the Ogden River system during the summers of 1921 and 1925. Numerous gaining and losing reaches in the river system were detected and related to the hydraulic connection between river and aquifer. Browning (1925) indicated that withdrawals from the now-abandoned Ogden artesian well field may have had some effect on streamflow depletion.

The first comprehensive study of ground-water resources for Ogden Valley was conducted by Leggette and Taylor (1937). Leggette and Taylor (1937) investigated the ground-water hydrology near the Ogden artesian well field before the existence of Pineview Reservoir.

Thomas (1945, 1952, 1963) used water-level data to identify sources of recharge to the artesian aquifer in the valley-fill deposits that supplies the Ogden artesian well field. He also determined a tentative water budget for the aquifer (Thomas, 1963).

Lofgren (1955) described the valley-fill deposits in Ogden Valley. Some inferences were made as to the hydrologic characteristics of the various deposits.

The most recent hydrologic study in Ogden Valley was conducted by Doyuran (1972). Water-quality

sampling indicated coliform counts that locally exceeded standards and iron bacteria in water that discharged from artesian wells. Vegetation distribution was mapped, and vegetative evapotranspiration was estimated.

Hydrologic-Data Site Numbering System

The hydrologic-data site numbering system used in Utah is shown in figure 2. Surface-water gaging stations that have continuous discharge records available are identified by an eight-digit downstream-order number adopted by the U.S. Geological Survey. For example, the gaging station on the South Fork Ogden River near Huntsville, Utah, is designated 10137500.

Acknowledgments

The author gratefully acknowledges the cooperation given by Gary Clark and the Ogden City Water Utilities during the 4-day aquifer test. Thanks also are expressed to those persons who permitted access to their property and water wells in order to accomplish the necessary data collection.

DESCRIPTION OF STUDY AREA

The study area consists of the drainage basin of the Ogden River upstream from the dam at Pineview Reservoir, which was completed in 1936, and the drainage basin of Wheeler Creek, which flows into the Ogden River just downstream from the Pineview Reservoir dam. The drainage area of the Ogden River upstream from Pineview Reservoir dam is 310 square miles; the drainage area of Wheeler Creek is 11.1 square miles. Downstream from Pineview Reservoir dam, the Ogden River flows through Ogden Canyon to the Great Salt Lake, west of Ogden, Utah.

Physiography

The study area is in the Middle Rocky Mountains Physiographic Province (Fenneman, 1931), which is characterized mainly by anticlinal mountain ranges and intermontane basins. The Wasatch Range borders the west side of Ogden Valley, and the Bear River Range, a subdivision of the Wasatch Range, borders the northeast side of Ogden Valley. Ogden Valley is in the low western part of the study area. Pineview Reservoir is in the southern part of Ogden Valley and is a control for surface-water discharge from the valley. The three major tributaries of the Ogden River—the North Fork, Middle Fork, and South Fork—flow from the upland areas surrounding Ogden Valley into Pineview Reservoir (pl. 1).

High mountains border Ogden Valley except on the north and south where lower hills form divides between the Ogden River and adjacent drainages. The altitude of the southeastern part of the valley is about 4,900 feet. The altitude increases to about 5,000 feet at the North Fork Ogden River at Eden and to about 5,100 feet at the canyon mouths of Middle Fork Ogden River and South Fork Ogden River. The altitude of the northern part of the valley near Eden is about 5,100 feet. The altitude increases to about 5,600 feet in the upper North Fork Ogden River drainage, north of Liberty. The mountains surrounding Ogden Valley are more than 3,000 feet above the valley floor (fig. 3). About 15 percent of the study area is above 8,000 feet (Haws and others, 1970, fig. 4). Willard Peak, northwest of Ogden Valley, is the highest point in the study area and has an altitude of 9,764 feet.

Climate

Climatic records have been collected at the site of Pineview Reservoir dam since 1935. Average annual precipitation at the station for 1951-80 was 28.79 inches (U.S. National Oceanic and Atmospheric Administration, 1982). Annual precipitation for 1935-1986 ranged from 17.09 inches in 1966 to 53.45 inches in 1983. The climate at Pineview Reservoir dam is affected by orographic features of Ogden Canyon.

Two other stations recently have been established to record climatic data. One station is at Huntsville Monastery in the southeastern part of Ogden Valley, and the other is at Snow Basin in the mountains of the southwestern part of the study area. Sufficient record is not available to establish long-term climatic values at these stations; however, the average annual precipitation at Pineview Reservoir dam for 1977-85 was 11.9 inches greater than that at Huntsville Monastery.

The estimated distribution of normal (1931-60) annual precipitation ranges from about 20 inches near Huntsville and the low hills to the south to about 40 inches near the high mountains on the west side of the study area (U.S. Weather Bureau, 1963). The average annual precipitation in the Ogden River drainage above Pineview Reservoir dam is about 20.5 billion cubic feet based on the U.S. Weather Bureau (1963) precipitation distribution. The Wheeler Creek drainage receives an

Figure 3. Wasatch Range on west side of Ogden Valley near Liberty, Utah. Willard Peak is indicated by arrow in right background.

average annual precipitation of about 784 million cubic feet.

Precipitation for October to April occurs mainly in the form of snow and accounts for about 75 percent of the normal annual precipitation. Most of the snowmelt in Ogden Valley occurs from late March to early April. Snowmelt in the surrounding area usually occurs from April through May, although the snow on the south-and southwest-facing slopes usually melts slightly earlier because of increasing radiation from the sun during the latter part of the winter.

Potential evapotranspiration from a vegetative surface that has unlimited soil water can be estimated from the average annual evaporation from a free-water surface. Free-water surface evaporation for the study area ranges from slightly less than 35 inches per year to about 40 inches per year (Farnsworth and others, 1982, map 3).

Population, Land Use, and Water Supplies

The population of Ogden Valley in 1980 was 3,294 (Bureau of the Census, 1982). The population of the valley has more than doubled since 1960, while the population of Huntsville, the only census-designated incorporated town, has remained fairly stable.

The major land uses in Ogden Valley are cropland and pasture but land use is changing to subdivided housing tracts. The study area is a popular year-round recreational area. Three ski resorts are located in the mountains bordering the valley, game-hunting occurs in the surrounding foothills and mountains, and a popular boating and beach area exists at Pineview Reservoir (fig. 4).

The towns of Huntsville, Eden, and Liberty each have municipal water systems that are supplied by springs. Eden also has a well that provides supplemental water, generally during the summer. The Eden and Liberty water systems supply water to much of the population in the valley north of Pineview Reservoir.

Agriculture, in the form of stockraising, dairy operations, and crop farming (mostly irrigated), is the major form of employment although it is declining in importance. Of the 16 dairies that are active in Ogden Valley (Utah Department of Agriculture, written commun., 1984), 6 are supplied by municipal water systems, 5 are self-supplied by wells, and the remaining 5 are self-supplied primarily from springs. Few wells are used exclusively for stock water because surface water in ditches and canals provides water to most of the livestock. Although some small areas of cropland and pasture are irrigated by water from wells, most areas are irrigated by water diverted from surface-water sources and springs.

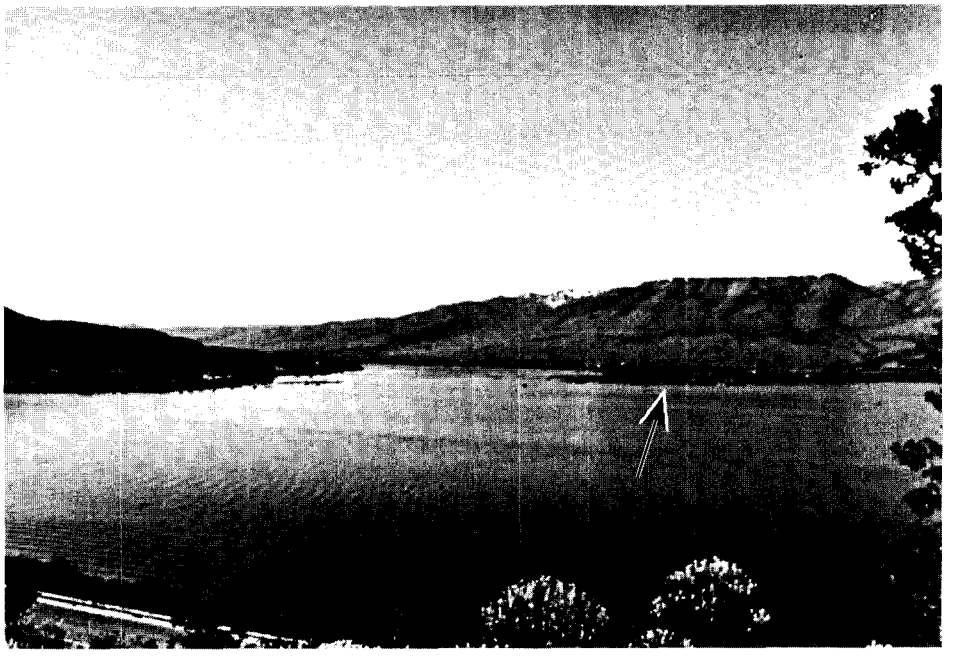


Figure 4. Pineview Reservoir (looking north along the North Fork Ogden River arm of the reservoir). Ogden well field is indicated by arrow on promontory on right side of photograph.

Hydrogeologic Setting

Ogden Valley and the surrounding area are underlain by rocks that range in age from Precambrian to Quaternary although Mesozoic rocks are not found in the area (table 1). The Precambrian rocks are mainly metasedimentary. Carbonate rocks predominate in the Paleozoic sequence, whereas deposits of Cenozoic age are predominately alluvial in origin. At its highest stage of about 5,090 feet, Pleistocene Lake Bonneville extended into Ogden Valley through Ogden Canyon. Unconsolidated lacustrine sediments undoubtedly were deposited in the valley, but stratigraphic correlation to other Lake Bonneville deposits was not attempted.

Stratigraphy and Hydrogeologic Units

Rocks in the stratigraphic section were grouped into six hydrogeologic units (table 1) based on relatively uniform lithology, similarity in values of primary permeability, and types and values of secondary permeability. The hydrogeologic units are the valley-fill deposits of Quaternary age (including fluvial, slopewash, and fanglomerate deposits), Norwood Tuff of Tertiary age, Wasatch Formation of Tertiary age, carbonate rocks of Paleozoic age, clastic rocks of lower Cambrian age, and metasedimentary rocks of Precambrian age.

On the basis of drillers' logs and a resistivity survey, the valley-fill deposits in Ogden Valley are estimated to be greater than 500 feet thick at Liberty and greater than 750 feet thick northeast of Huntsville, Utah (fig. 5). A gravity survey by Stewart (1958) indicates that the Wasatch Formation, Norwood Tuff, and valley-fill deposits in Ogden Valley may be as much as 5,000 feet thick.

Structure

Ogden Valley is a graben having west-and east-bounding faults oriented in a northwest-southeast direction. Along the faults, fairly permeable alluvium commonly is displaced against less permeable metasedimentary rocks or Norwood Tuff. Stewart (1958) determined that displacement on the western fault zone of Ogden Valley was 2,000 feet, and displacement on the eastern fault zone was 1,800 feet. A branch of the western fault zone may displace the near-surface sediments, now under Pineview Reservoir, by about 25 feet as shown on a cross section interpreted from well logs (Thomas, 1945, fig. 2). Stewart (1958) mapped another possible buried fault parallel to the western-bounding fault.

Table 1. Description of hydrogeologic units

Hydrogeologic units: The codes shown with unit names are used to identify hydrogeologic units, formations, or other deposits in plate 1 and in tables 6,7, 8, and 9.

General lithology and thickness: Descriptions modified from Lofgren (1955), Mullens (1969), Crittenden (1972), Sorensen and Crittenden (1979), Crittenden and Sorensen (1985a, 1985b), and Davis (1985).

Erathem	System	Series	Formation or deposit	General lithology and thickness	Water-bearing characteristics[1]	Hydro-geologic unit
CENOZOIC	Quaternary	Holocene and Pleistocene	Fluvial deposits (111ALVM)	Poorly sorted, unconsolidated silt, sand, gravel, and cobbles in flood plains and terraces as much as 160 feet above river level. Thickness as much as 20 feet.	Low to moderate permeability.	Valley-fill deposits (111ALVM)
			Slopewash and fanglomerate (111ALVM)	Quartzite cobbles, boulders, and gravel derived primarily from erosion of the Wasatch Formation. Thickness as much as 100 feet.	Low to moderate permeability.	
			Valley-fill deposits (111ALVM)	Brownish-tan, well-sorted, unconsolidated sand and silt; gravel and cobbles along the major stream channel. Thickness as much as 150 feet.	Moderate permeability.	
		Pleistocene	Valley-fill deposits (112ALVM)	Interbedded cobbles, gravel, sand, silt, and clay. A dark-blue and variegated, micaceous, silty clay layer (as much as 100 feet thick) exists throughout the lower valley. Probable thickness as much as 500 feet.	Moderate to high permeability. Major water-yielding unit in Ogden Valley. Well yields of more than 1,000 gallons per minute possible.	
		Plio-Pleistocene	Valley-fill deposits (112ALVM)	Interbedded gravel, sand, silt, and clay. This deposit likely occurs in deep parts of the structural trough. Probable thickness as much as 250 feet.	Moderate to high permeability.	
	Tertiary	Upper Eocene and lower Oligocene	Norwood Tuff (123NRWD)	White to tan-weathering, fine- to medium-bedded, friable tuff and sandy tuff. Maximum thickness may exceed 1,200 feet.	Very low to low permeability. Small-yield wells pump from this unit but drawdowns are large.	Norwood Tuff (123NRWD)
		Eocene, Paleocene, and (?) Upper Cretaceous	Wasatch Formation and Evanston (?) Formation (undivided) (124WSTC)	Light reddish-brown, poorly sorted, unconsolidated to poorly consolidated sandstone and pebble, cobble, and boulder conglomerate. Matrix is gravel, sand, and silt. Interbeds of sandy siltstone. Basal, brownish-gray, conglomeratic sandstone, conglomerate and gray siltstone. Thickness as much as 3,000 feet.	Low to moderate permeability. Major recharge medium for the upper drainage. Confined unit with low artesian pressure.	Wasatch Formation (124WSTC)

Table 1. Description of hydrogeologic units—Continued

Erathem	Series	Formation or deposit	General lithology and thickness	Water-bearing characteristics[1]	Hydro-geologic unit
PALEOZOIC	Permian	Park City Formation	Franson Member—Interbedded chert, limestone, sandstone, and sparse phosphate rock in upper part; light- to medium-gray, cherty limestone and dolomite in lower part. Thickness about 400 feet. Grandeur Member—Dark-gray, fetid limestone and dolomite; basal, light-gray limestone. Thickness 250 to 280 feet.	Probably low permeability resulting from bedding partings, fractures, and voids developed from solution of bicarbonate from the rock. Large springs in the eastern part of the study area originate from this unit.	Carbonate rocks (300CRSL)
		Phosphoria Formation	Meade Peak Member—Dark-gray, phosphatic limestone, dolomite, siltstone, and pelletal phosphorite. Thickness 230 feet.		
	Pennsylvanian	Wells Formation	Light-gray to grayish-orange sandstone. Minor light-gray limestone and dolomite in upper part. Thickness 400 feet. Medium- to light-gray, granular dolomite and medium-dark-gray limestone in lower part. Thickness 200 feet.		
		Round Valley Limestone	Gray, cherty limestone and pale-red siltstone. Thin beds of gray to green limestone in upper part; gray, cherty limestone in lower part. Thickness 250 to 300 feet.		
	Mississippian	Humbug Formation (331HMBG)	Tan and gray siltstone and fine-grained sandstone with interbedded dark- to medium-gray limestone and dolomite. Thickness about 1,600 feet.		
		Lodgepole Limestone (337LDGP)	Dark-gray limestone; medium-gray dolomite at top. Thickness 900 feet.		
		Deseret Limestone	Dark- to light-gray, medium- to thin-bedded limestone and dolomite with thin beds of dark gray to black chert. Thickness 200 to 250 feet.		
		Gardison Limestone	Medium- to dark-gray, thick-bedded to massive dolomite in upper part; dark-gray to black, thin- to medium-bedded dolomite in lower part. Thickness 295 to 850 feet.		
	Devonian	Beirdneau Sandstone	Tan-, orange-, and brown-weathering, fine- to medium-grained sandstone, dolomitic sandstone, and dolomite. Thickness 250 to 300 feet.		

Table 1. Description of hydrogeologic units—Continued

Erathem	Series	Formation or deposit	General lithology and thickness	Water-bearing characteristics[1]	Hydro-geologic unit
PALEOZOIC	Devonian	Hyrum Dolomite	Dark-gray to black, thin- to thick-bedded, fine-grained dolomite with lenses of intraformational dolomitic breccia. Thickness about 350 feet.		Carbonate rocks (300CRSL)
		Water Canyon Formation	Medium- to dark-gray dolomite in upper part; medium-gray dolomitic sandstone in lower part. Thickness about 80 feet.		
	Silurian and Upper Ordovician	Fish Haven Dolomite and Laketown Dolomite (undivided)	Dark- to brownish-gray, very fine to fine-grained dolomite; sparse beds of very light gray dolomite. Thickness 520 to 650 feet.		
	Ordovician	Garden City Formation	Light-gray, medium- to thick-bedded limestone, dolomite, and dolomitic limestone with interbedded siltstone or intraformational conglomerate. Thickness about 350 feet.		
	Upper Cambrian	St. Charles Limestone (371SCRL)	Dark-gray, white-weathering, thin- to thick-bedded dolomite with basal, gray-brown-weathering quartzite. Thickness 450 to 700 feet.		
		Nouman Dolomite	Light-gray, thin- to thick-bedded, finely crystalline dolomite with interbedded gray limestone in upper part. Thickness 450 to 650 feet.		
	Middle Cambrian	Bloomington Formation	Tan to drab-olive, thin-bedded shale. Interbedded, gray to orange-brown limestone in upper part. Thickness 165 feet. Light- to dark-gray limestone in middle part. Thickness 500 feet. Tan and olive shale with some interbedded gray limestone in lower part. Thickness 300 feet.		
		Maxfield Limestone	Medium to dark-gray, thin-bedded limestone with drab-olive to greenish-brown, micaceous shale interbedded with gray limestone in middle part. Thickness 850 feet.		

Table 1. Description of hydrogeologic units—Continued

Erathem	Series	Formation or deposit	General lithology and thickness	Water-bearing characteristics[1]	Hydro-geologic unit
PALEOZOIC	Middle Cambrian	Blacksmith Limestone	Gray- to blue-gray, thin- to medium-bedded limestone and dolomite. Thickness about 1,200(?) feet.		Carbonate rocks (300CRSL)
		Ute Limestone	Light- to dark-gray, medium- to thin-bedded silty limestone with interbedded gray sandstone and greenish shale. Thickness 700(?) feet.		
		Langston Dolomite	Brown-weathering, thin-bedded, massive dolomite. Thickness 170 feet.		
		Ophir Formation	Light blue-gray limestone and shaly limestone. Drab-olive shale in upper part, blue-gray limestone and tan to orange-brown limestone in middle part; light-brown to drab-olive, micaceous shale and brown-weathering sandstone and dolomite in lower part. Thickness 450 to 600 feet.		
	Lower Cambrian	Tintic Quartzite (374TNTC)	White, pink, buff, and tan, medium- to thick-bedded, medium- to coarse-grained quartzite; interbeds of quartz-pebble conglomerate. Thickness 1,100 to 1,400 feet.	Probably very low permeability. Most water movement is through fractures.	Clastic rocks (374TNTC)
		Bingham Group: Geertsen Canyon Quartzite	White, gray, pink, and light-green, medium- to coarse-grained quartzite in upper part; tan, white, maroon, and green quartzite in lower part. Thickness 4,000 to 4,400 feet.		
PRECAMBRIAN		Bingham Group: Browns Hole Formation	White to terra cotta, well-sorted, medium- to fine-grained quartzite with gray-weathering, dense basalt and reworked volcanic conglomerate in lower part. Thickness about 400 feet.	Probably very low permeability. Most water movement is through fractures. One well in the Mutual Formation flows at a high rate.	Metasedimentary rocks (400PCMB)
		Bingham Group: Mutual Formation (400MUTL)	Grayish-red, pink, maroon, and pale-purplish, medium- to coarse-grained quartzite. Thickness 435 to 1,200 feet.		
		Bingham Group: Inkom Formation	Purple and drab-olive-green, thin-bedded siltstone, sandstone, argillite, and quartzite with gray-weathering, basal tuff. Thickness 360 to 450 feet.		

Table 1. Description of hydrogeologic units—Continued

Erathem	Formation or deposit	General lithology and thickness	Water-bearing characteristics[1]	Hydro-geologic unit
PRECAMBRIAN	Caddy Canyon Quartzite	White, tan, gray, green, and purple, medium-grained quartzite. Thickness 1,500 to 2,500 feet.		Metasedimentary rocks (400PCMB)
	Kelley Canyon Formation	Dark-gray to black argillite. Locally, drab-olive siltstone and thin quartzite at top, pinkish-gray limestone in middle, and gray-weathering dolomite at base. Thickness 2,000 feet.		
	Maple Canyon Formation	Light-green to greenish-gray, arkosic quartzite and sandstone. Conglomeratic quartzite and drab-olive argillite in upper part, drab-olive argillite in lower part, and, locally, basal gray limestone. Thickness about 1,500 feet.		
	Formation of Perry Canyon	Upper member—Medium- to dark-gray, medium- to fine-grained, graywacke and gray to dark-green, micaceous siltstone. Thickness about 1,400 feet. Lower member—Gray to black diamictite consisting of pebble- to boulder-sized, quartzitic and granitic clasts in black, medium- to fine-grained, sandy matrix. Thickness as much as 350 feet.		
	Formation of Facer Creek	Green, purple, and black slate and phyllite. Thickness unknown.		

[1] The ranges of permeability are defined in terms of hydraulic conductivity as follows:

Range	Hydraulic conductivity, in feet per day
Very low	Less than 0.5
Low	0.5 to 5
Moderate	5 to 50
High	50 to 500
Very high	Greater than 500

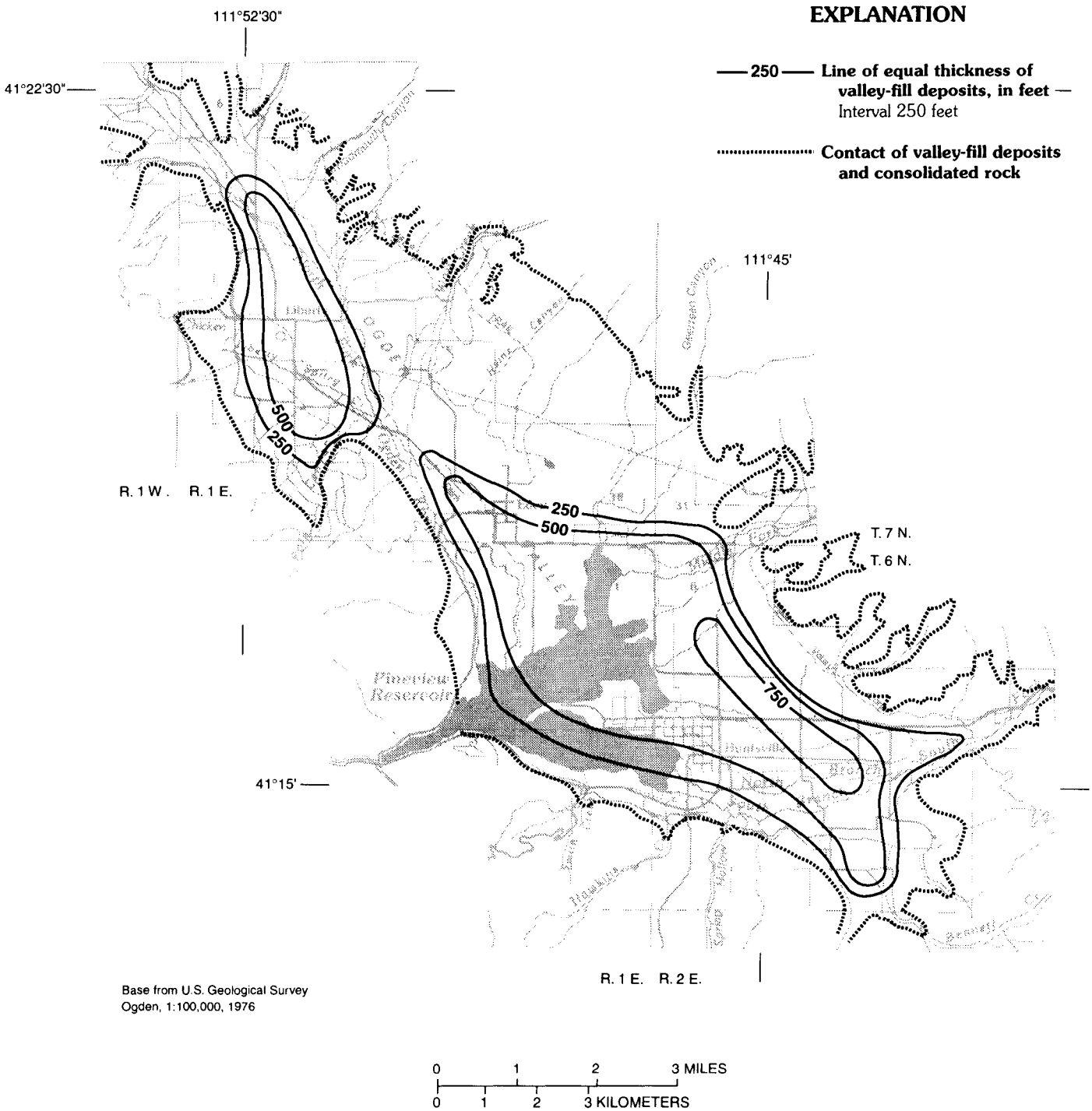


Figure 5. Thickness of valley-fill deposits.

A previously unmapped fault in the valley-fill deposits was determined from results of an aquifer test conducted at the Ogden well field. The fault was projected across the southwest side of Ogden Valley, under Pineview Reservoir, and across the narrow promontories jutting into the reservoir (pl. 1).

A large syncline extends into Ogden Valley from south of the study area. The syncline probably is the area within which the Tertiary sediments were deposited in Ogden Valley (Eardley, 1944, p. 856). The syncline predates the normal faulting that formed Ogden Valley.

A series of stacked overthrust plates, including the Willard thrust sheet, is exposed in the western part of the study area (Davis, 1985). The structure of the overthrust plate is very complex and is not fully understood. Precambrian rocks generally have been thrust over Paleozoic rocks. The overthrusting is considered to predate the deposition of the Wasatch Formation.

The structure in the remainder of the study area is exposed through erosional windows in the relatively flat-lying Wasatch Formation and consists of folds and minor fault features. The Wasatch Formation blankets much of the study area east and south of Ogden Valley.

SURFACE-WATER HYDROLOGY

Surface water and ground water are hydraulically connected in Ogden Valley. Surface-water data and field observations were used in the analysis of ground-water flow in the valley-fill aquifer system.

Streams

The major streams in the study area are the North Fork Ogden River, Middle Fork Ogden River, and South Fork Ogden River. Their juncture to form the Ogden River is in the area now inundated by Pineview Reservoir. Other streams that originate in the surrounding mountains and that have substantial discharge are Wolf Creek, Geertsen Canyon creek, and Bennett Creek (pl. 1). The remaining streams have smaller watersheds and are ephemeral; flow from these streams into Ogden Valley generally occurs only from February through June.

Locations of selected active (1986) and discontinued gaging stations in the study area are shown on plate 2. Station 10137500 (pl. 2), which is on the South Fork Ogden River just upstream from Ogden Valley and a major irrigation diversion, is the only active gaging station that measures discharge into Ogden Valley. Wheeler Creek (pl. 1), which also has an active (1986) gaging station, discharges to the Ogden River below Pineview Reservoir dam; thus, it is not part of the inflow to Ogden Valley.

Streamflow characteristics at selected gaging stations are shown in table 2. The South Fork Ogden River has the largest drainage area and discharge of all of the streams in the study area. Mean monthly and mean annual discharge for the period of record, excluding water years 1982-86, for selected gaging stations is shown in table 3. Water years 1982-86 were excluded because runoff in those years was greater than the mean flow.

The streams and the valley-fill aquifer system are hydraulically connected and exchange water. Many of the streams lose water and recharge the valley-fill aquifer system where the streams flow into Ogden Valley. The North Fork Ogden River, Middle Fork Ogden River, and South Fork Ogden River gain flow from the valley-fill aquifer system before entering Pineview Reservoir.

Water that discharges to Spring Creek, which drains much of the area in the valley north and east of Huntsville (fig. 6), originates in the mountains northeast of Huntsville. Flow at the mouth of Spring Creek is perennial (fig. 7) because the creek gains water that discharges from the valley-fill deposits east of Huntsville. Discharge at seven sites (fig. 6) in the Spring Creek drainage was measured monthly during November 1984 through June 1986 and plotted in a composite hydrograph (fig. 8).

Discharge at the South Fork Ogden River and at Wheeler Creek during 1984-86 is shown in figure 9. The South Fork Ogden River is regulated partly by Causey Reservoir. Flow in Wheeler Creek generally is characteristic of flow from a small unregulated stream.

Reservoirs

Two major reservoirs store surface water in the study area. Pineview Reservoir on the Ogden River in the southwestern part of Ogden Valley provides irrigation and municipal water to the Ogden area, powers a small hydroelectric-power-generation plant downstream, and provides a recreational area in Ogden Valley. Filling of the reservoir began in November 1936, and maximum storage capacity was reached in June 1938. The altitude of the full reservoir pool was 4,871 feet. The reservoir had a storage capacity of about

Table 2. Streamflow characteristics at selected gaging stations

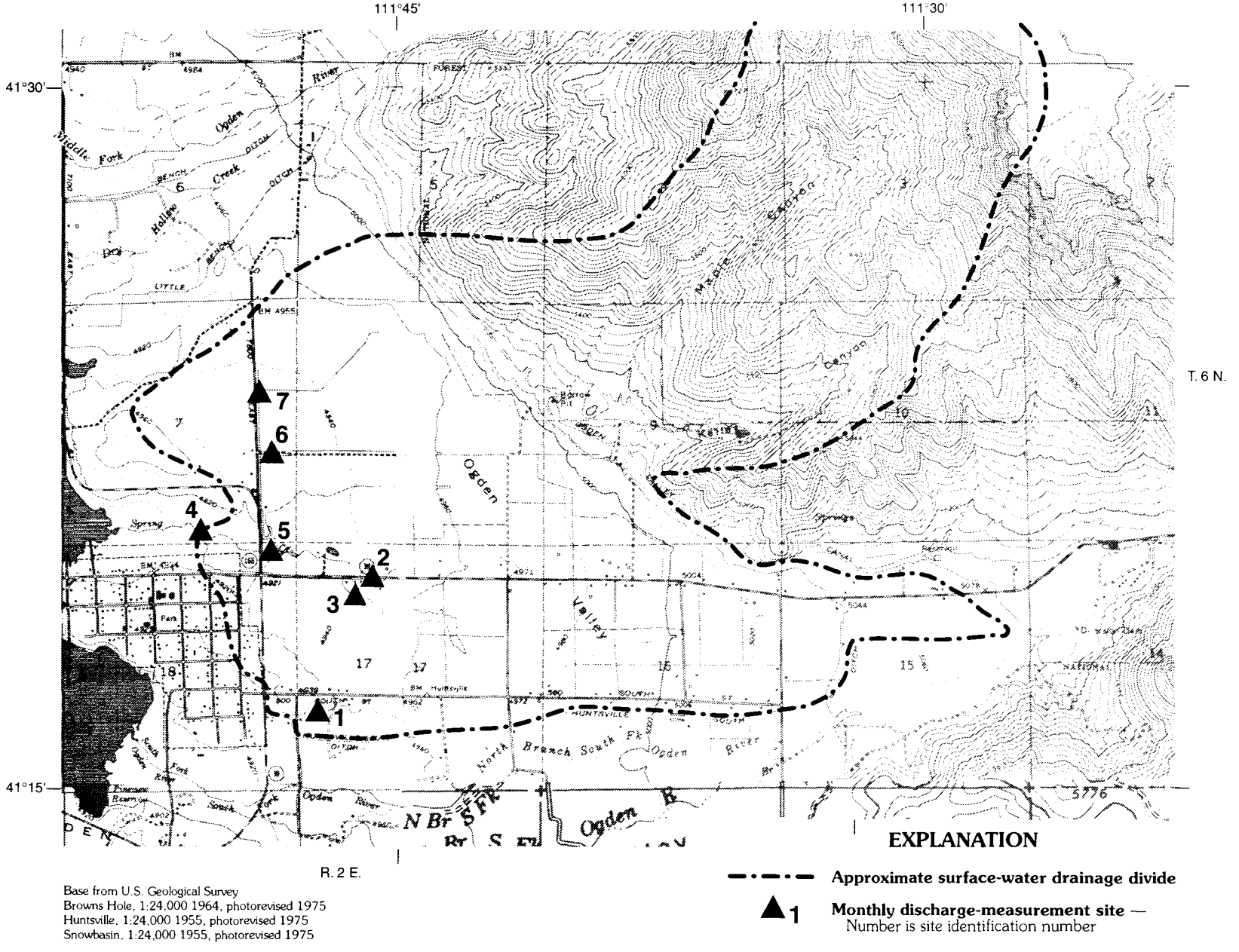
Station name and number	Period of record (water years)	Drainage area (square miles)	Discharge (cubic feet per second)		
			Maximum	Minimum	Average
South Fork Ogden River near Huntsville, Utah (10137500)	1921-86	148.0	1,890	9	118
South Fork Ogden River at Huntsville, Utah (10137600)	1960-65	170.0	1,090	3.2	77.8
North Fork Ogden River near Eden, Utah (10137680)	1964-74	6.0	156	.8	12.1
North Fork Ogden River near Huntsville, Utah (10137700)	1960-65	61.4	693	0	35.3
Middle Fork Ogden River above irrigation diversions near Huntsville, Utah (10137780)	1964-74	31.3	744	.4	31.8
Middle Fork Ogden River at Huntsville, Utah (10137800)	1958-65	32.0	623	0	20.1
Spring Creek at Huntsville, Utah (10137900)	1958-65 and 1986	7.2	210	2.6	10.4
Wheeler Creek near Huntsville, Utah (10139300)	1959-86	11.1	[1]600	0	[2]11.2

[1]Estimated.

[2] Streamflow records since 1977 do not include diversions by the city of Ogden.

Table 3. Mean monthly and mean annual discharge for selected gaging stations

Station number	Water years	Mean monthly discharge (in cubic feet per second)												Mean annual discharge
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
10137500	1922-65	40.2	40.8	42.3	41.3	47.3	79.7	287	428	144	56.6	42.3	39.1	107
10137500	1966-81	45.3	40.1	39.9	44.4	50.5	97.6	257	446	185	92.2	84.8	60.0	120
10137600	1960-65	7.45	10.8	26.2	26.7	52.8	61.5	259	362	89.5	19.0	10.4	7.66	77.8
10137680	1964-74	3.88	4.59	4.35	5.53	4.90	11.0	28.7	43.1	22.8	7.87	4.39	3.60	12.1
10137700	1960-65	.03	.03	6.64	16.2	25.2	28.4	149	151	49.5	5.08	1.27	1.83	36.2
10137780	1964-74	2.89	4.14	5.82	8.50	9.90	31.9	100	173	35.9	4.78	1.67	1.78	31.7
10137800	1958-65	.20	.28	2.37	1.83	7.50	11.2	97.3	115	14.3	1.08	.17	.50	21.0
10137900	1958-65	6.15	7.21	7.89	6.96	9.40	10.9	13.0	14.6	16.2	9.26	6.81	6.94	9.62
10139300	1959-81	1.34	1.38	1.78	2.65	2.30	7.39	23.6	34.2	26.6	7.10	2.71	1.72	9.40



Base from U.S. Geological Survey
Browns Hole, 1:24,000 1964, photorevised 1975
Huntsville, 1:24,000 1955, photorevised 1975
Snowbasin, 1:24,000 1955, photorevised 1975

Figure 6. Location of sites in Spring Creek drainage where discharge was measured monthly.

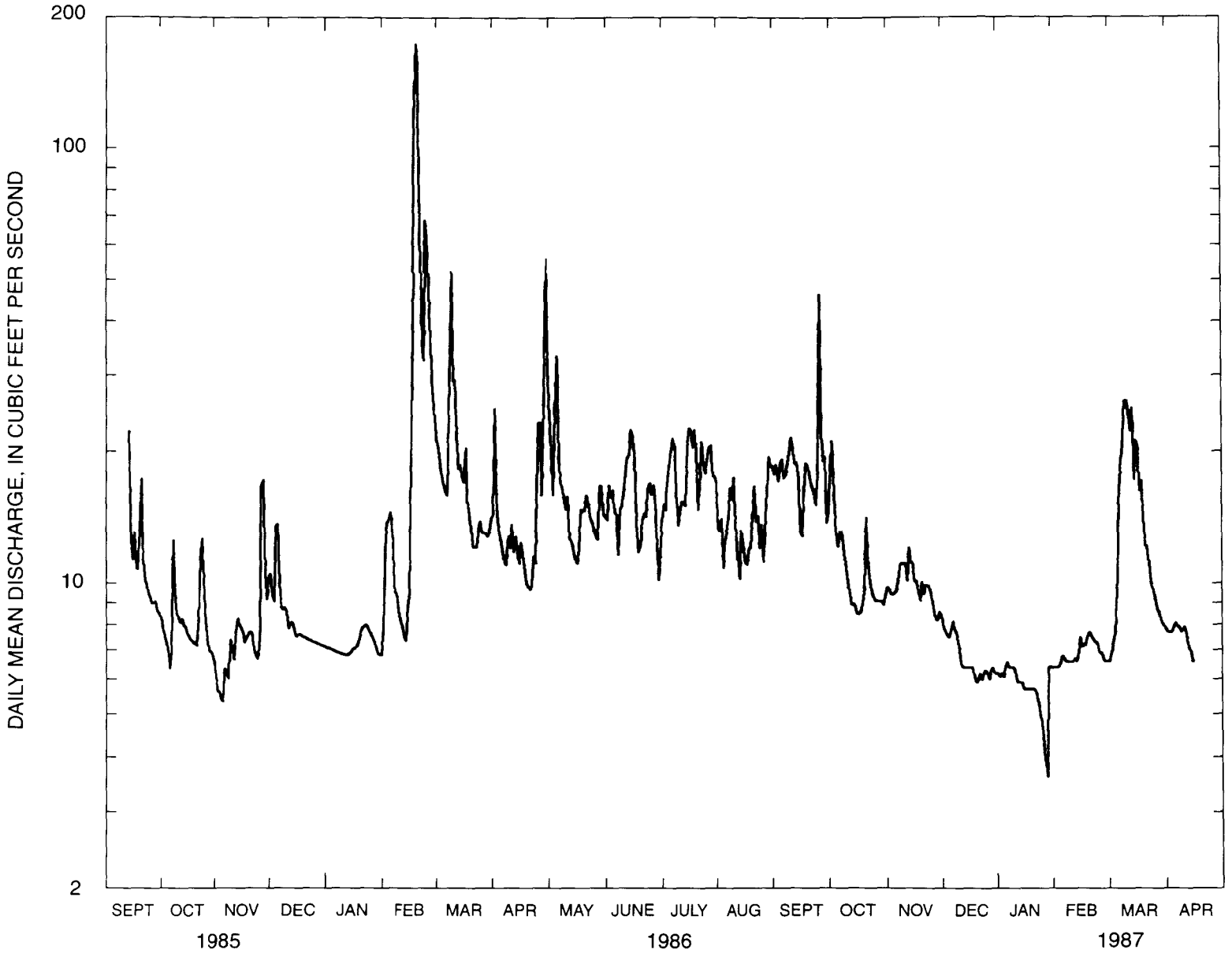


Figure 7. Daily mean discharge at Spring Creek at Huntsville (station 10137900), September 1985 through April 1987.

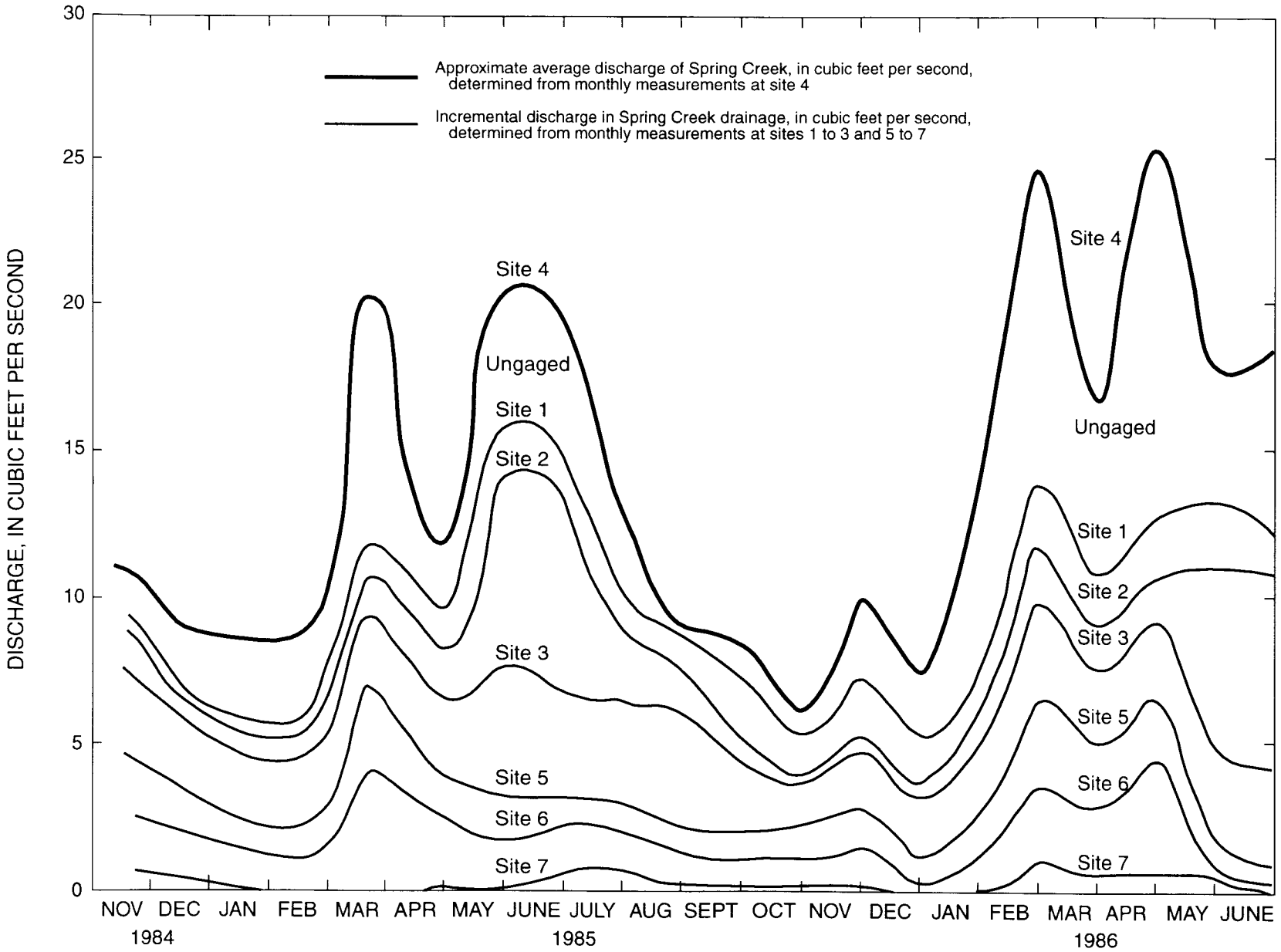


Figure 8. Discharge determined from monthly measurements at seven sites in the Spring Creek drainage, November 1984 through June 1986.

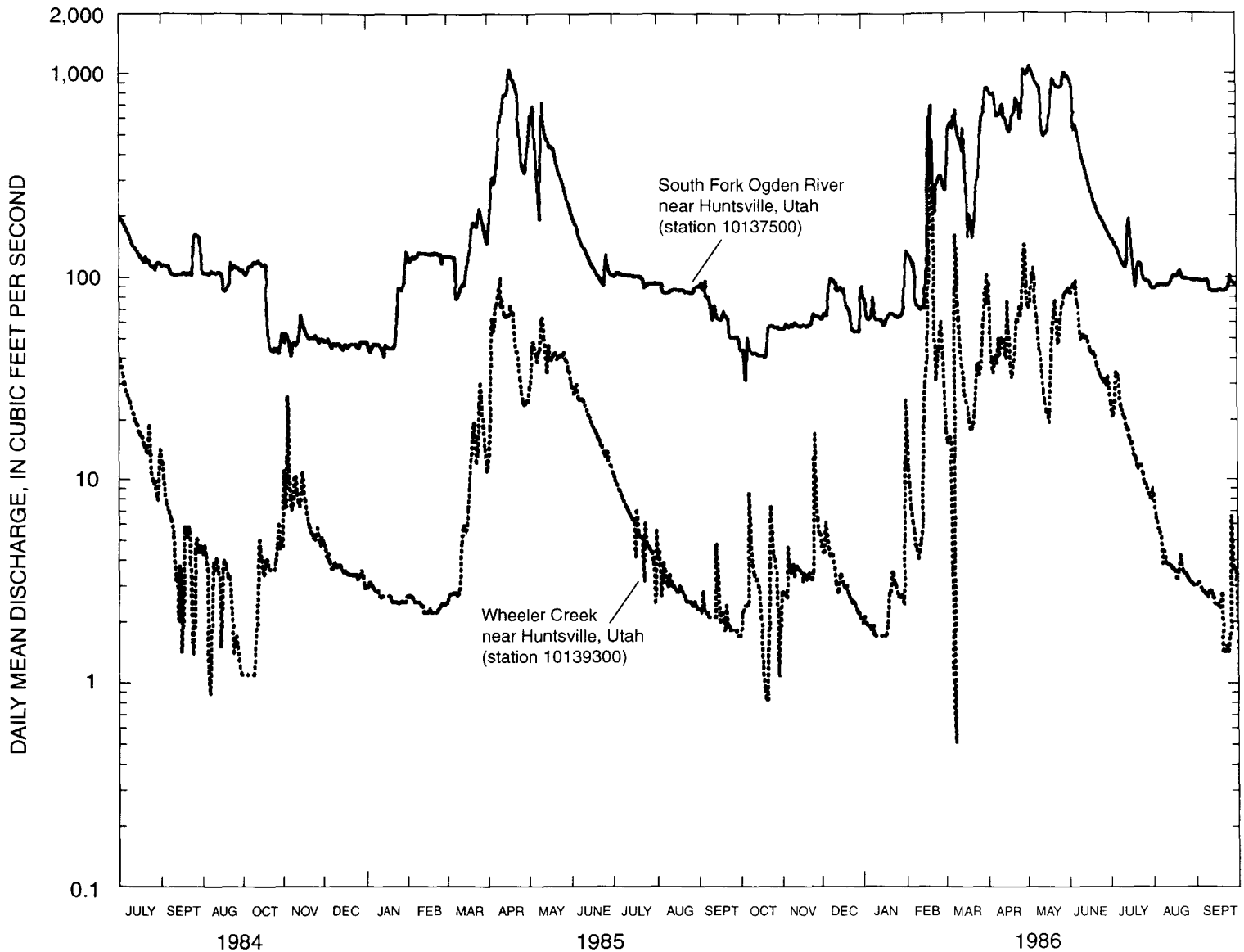


Figure 9. Daily mean discharge at the South Fork Ogden River near Huntsville (station 10137500) and at Wheeler Creek near Huntsville (station 10139300), July 1984 through September 1986 (discharge adjusted for diversions by city of Ogden).

44,000 acre-feet and covered about 1,800 acres when filled. In 1957, the dam at Pineview Reservoir was raised 30 feet, and storage capacity in the reservoir increased to 110,200 acre-feet. Pineview Reservoir covered about 2,900 acres when filled. The additional storage capacity was allocated for flood control, and the Weber Basin Conservancy District gained surface-water rights to water in that storage (Blaine Johnson, Ogden River Commissioner, oral commun., 1986). Actual storage in the modified reservoir did not reach the maximum until June 1962. Normal operating fluctuation of the reservoir pool for 1963-81 was about 25 feet. The low stage usually occurs in late February or early March, and the high stage usually occurs in June.

Causey Reservoir is located in a narrow canyon east of Ogden Valley on the South Fork Ogden River above Beaver Creek. The reservoir provides water for irrigation and for exchange rights for water wells in Ogden Valley (Blaine Johnson, Ogden River Commissioner, oral commun., 1986). Filling of the reservoir began in January 1966, and maximum storage capacity was reached in April 1966. Causey Reservoir has a storage capacity of 6,870 acre-feet and covers 195 acres when filled.

Irrigation and Other Diversions

In 1925, about 11,150 acres were irrigated in Ogden Valley (Browning, 1925). A court decree in 1948 indicated that about 10,550 acres were irrigated (Judge John A. Hendricks, Second Judicial District of the State of Utah, no. 7487, 1948). In the mid-1960's, 12,050 irrigated acres were mapped (Haws and others, 1970, p. 109). In 1981, the irrigated acreage was about 7,050 acres as determined for this study from aerial photography. This latest value probably represents a permanent decrease in irrigated acreage.

Water in the North Fork Ogden River is diverted at several places. The first major diversion from the North Fork Ogden River flows into a storage pond that feeds the Liberty Pipeline, which supplies water under pressure to sprinkler irrigation systems in much of the northern part of Ogden Valley. The West Ditch (pl. 2) diverts water from the Liberty Pipeline storage pond and delivers water to irrigated land along the northwestern side of the valley. The Eden Canal (pl. 2) diverts water from the North Fork Ogden River, between Liberty and Eden, to irrigated land north of Pineview Reservoir.

The Middle Fork Ogden River (stations 10137800 and 10137780; table 3) has relatively little flow during the irrigation season. The low flow is diverted through a few ditches to the area northeast of Pineview Reservoir.

Water is diverted from the South Fork Ogden River through canals and is used to irrigate much of the southern part of Ogden Valley. Water from the South Fork Ogden River is diverted at three places. The largest diversion, about 85 cubic feet per second, is about 0.5 mile downstream from the point where the South Fork Ogden River flows into Ogden Valley. About 80 cubic feet per second of water is diverted by canal to the north side of Ogden Valley, and about 5 cubic feet per second of water is diverted by pipeline to the south side of Ogden Valley (N.W. Plummer, Regional Director, U.S. Bureau of Reclamation, written commun., 1981).

The canals that divert water to the north side of Ogden Valley deliver water to much of the area east and north of Huntsville. The largest canal from this diversion, the Mountain Valley (or Ogden Valley) Canal, carries water along the northeast boundary of the valley and delivers water to the Middle Fork Ogden River drainage and to the area east and south of Eden.

The pipeline that diverts water to the south side of Ogden Valley supplies the Roman Catholic Monastery southeast of Huntsville with irrigation water for alfalfa and small-grain fields. Water from Monastery Spring [(A-6-2)27dcc-S1] in upper Bennett Creek also is used for irrigation of these fields. Excess water and return water from the fields flows into the Huntsville South Bench Canal (pl. 2), which supplies irrigation water to the area south of the South Fork Ogden River and Pineview Reservoir.

The other two diversions from the South Fork Ogden River are minor. About 1 cubic foot per second of water is diverted from above the gaging station (10137500; pl. 2) on the South Fork Ogden River, and about 1 cubic foot per second of water is diverted between the gaging station and the large diversion 0.5 mile downstream from where the South Fork Ogden River flows into Ogden Valley.

Water from Wolf Creek is diverted at two places. Water from the upstream diversion is delivered to Wolf Creek Resort north of Eden for irrigation of the golf course and for culinary use. Water from the downstream diversion is used to irrigate fields north and northwest of Eden.

Diversions from smaller watersheds and springs, including Chicken Creek, Sheep Creek, Pole Canyon creek, Hawkins Creek, and Bennett Creek, also are used for irrigation. Ditches and canals that encircle the valley also capture some of the water that runs off the valley slopes.

Two pipelines divert water from Pineview Reservoir and Wheeler Creek. The first pipeline delivers water from Pineview Reservoir for hydroelectric-power generation and irrigation. The hydroelectric-power-generation plant has surface-water rights to all of the yearly natural flow in Ogden Valley, but the delivery rate of water is limited to 260 cubic feet per second by the capacity of the pipeline. Between late April and early October, water in this pipeline also is distributed for irrigation outside of Ogden Valley (Blaine Johnson, Ogden River Commissioner, oral commun., 1986). The second pipeline delivers 15 to 20 cubic feet per second of water (the working capacity of the Ogden City Water Utilities filtration plant) from Pineview Reservoir and Wheeler Creek to Ogden between May and October (Gary Clark, Ogden City Water Utilities, oral commun., 1986).

Water Quality

Surface-water samples were collected at 10 locations throughout Ogden Valley and the surrounding area by Thompson (1983). Streams were sampled early and late in the irrigation season. The dissolved-solids concentration for all samples, except those from Spring Creek, was less than 200 milligrams per liter during the springtime high flows. Spring Creek derives much of its flow from ground-water discharge. In August, the dissolved-solids concentrations more than doubled because of irrigation losses as the water was reused. All water was a calcium bicarbonate type.

Specific conductance and water temperature for many of the streams in Ogden Valley and the surrounding area were measured during base-flow periods (tables 4 and 5). The specific conductance of all samples was less than 400 microsiemens per centimeter, which relates to a dissolved-solids concentration of less than about 250 milligrams per liter. Data from the lower North Fork Ogden River Basin (sites N11 and N13) and from Liberty Spring Creek (table 4) show warmer water temperatures that may result from ground-water seepage. Water in Wheeler Creek (table 5) has relatively large specific-conductance values, possibly because Wheeler Creek flows through an area of the predominantly carbonate terrain.

GROUND-WATER HYDROLOGY OF CONSOLIDATED ROCKS SURROUNDING OGDEN VALLEY

The lithology and water-bearing characteristics of the consolidated rocks surrounding Ogden Valley are shown in table 1. The consolidated rocks generally are divided into five characteristic hydrogeologic units—the Norwood Tuff, Wasatch Formation, carbonate rocks, clastic rocks, and metasedimentary rocks.

The consolidated rocks surrounding Ogden Valley that transmit and yield substantial quantities of water are the Wasatch Formation and carbonate rocks. The Wasatch Formation crops out over much of the area east of Ogden Valley (pl. 1) and is at depth south of and beneath parts of Ogden Valley. The carbonate rocks crop out over a large area in the upper South Fork Ogden River drainage above Causey Reservoir and in smaller areas west of Liberty; south and northeast of James Peak; and west, southwest, and southeast of Pineview Reservoir (pl. 1). The dissolved-solids concentration of water in the consolidated rocks is less than 250 milligrams per liter and the water is a calcium bicarbonate type.

Recharge

Much of the recharge to consolidated rocks in the uplands surrounding Ogden Valley probably originates from snowmelt that infiltrates the Wasatch Formation. The 1931-60 average annual precipitation in the South Fork Ogden River drainage is about 7.54 billion cubic feet; the average annual precipitation in the Wheeler Creek drainage is about 784 million cubic feet.

Few data are available on recharge from losing streams or subsurface inflow from adjacent areas. A seepage run made October 17, 1985, indicated that Wheeler Creek was losing about 0.4 cubic feet per second between the lower part of Snow Basin and the Ogden River. Relatively little recharge to the consolidated rocks occurs by subsurface inflow from adjacent ground-water systems because much of the area surrounding Ogden Valley is topographically higher than the adjacent areas.

Table 4. Miscellaneous measurements of streamflow, specific conductance, and water temperature during base flow in Ogden Valley, February 23 to March 1, 1985

[N1, miscellaneous measurement site on North Fork Ogden River; M1, miscellaneous measurement site on Middle Fork Ogden River; S1, miscellaneous measurement site on South Fork Ogden River; —, no data]

Site number (pl. 2)	Drainage basin and location of measurement site	Streamflow (cubic feet per second)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	Water temperature (degrees Celsius)
	North Fork Ogden River drainage			
N1	North Fork Ogden River, 200 feet above diversion gate, sec. 1, T. 7 N., R. 1 W	10.4	115	1.5
N2	Cobble Creek, below road culvert, sec. 7, T. 7 N., R. 1 E	.4	91	2.0
N3	North Fork Ogden River, 200 feet above County Highway 162 bridge, sec. 7, T. 7 N., R. 1 E	8.0	115	0
N4	Spring flow, measured alongside County Highway 162 under powerlines, sec. 20, T. 7 N., R. 1 E	1.4	330	5.0
N5	Diversion ditch from Liberty Spring Creek (north of main channel), east of road culvert, sec. 19, T. 7 N., R. 1 E	1.4	315	9.0
N6	Liberty Spring Creek (main channel), upstream of road culvert, sec. 19, T. 7 N., R. 1 E	3.5	290	8.5
N7	Liberty Spring Creek (south channel, flow in winter primarily from bedrock springs to the south), 400 feet downstream from road culvert, sec. 19, T. 7 N., R. 1 E	.6	350	3.5
N8	Pine Creek, above County Highway 162 culvert, sec. 28, T. 7 N., R. 1 E	.2	265	2.0
N9	Pole Canyon creek, below County Highway 162 culvert, sec. 28, T. 7 N., R. 1 E	.5	205	.5
N10	Liberty Spring Creek, above confluence with North Fork Ogden River, sec. 28, T. 7 N., R. 1 E	13.0	325	8.0
N11	North Fork Ogden River above confluence with Liberty Spring Creek, sec. 28, T. 7 N., R. 1 E	7.3	145	7.5
N12	Wolf Creek, below County Highway 162 culvert, sec. 28, T. 7 N., R. 1 E	3.6	275	3.0
N13	North Fork Ogden River, 100 feet above County Highway 162 bridge, sec. 34, T. 7 N., R. 1 E	18.0	260	6.0
	Middle Fork Ogden River drainage			
M1	Middle Fork Ogden River, 200 feet above road bridge, sec. 5, T. 6 N., R. 2 E	8.5	155	0
M2	Middle Fork Ogden River, at discontinued gaging station 10137800, below County Highway 166 bridge, sec. 1, T. 6 N., R. 1 E	4.2	170	2.0

Table 4. Miscellaneous measurements of streamflow, specific conductance, and water temperature during base flow in Ogden Valley, February 23 to March 1, 1985—Continued

Site number (pl. 2)	Drainage basin and location of measurement site	Streamflow (cubic feet per second)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	Water temperature (degrees Celsius)
	Middle Fork Ogden River drainage—Continued			
M3	Small channel north of main Middle Fork Ogden River channel, below County Highway 166 culvert, sec. 1, T. 6 N., R. 1 E	0.2	—	—
M4	Geertsen Canyon creek, above County Highway 166 bridge, sec. 36, T. 7 N., R. 1 E	2.8	100	3.0
M5	Small channel west of Geertsen Canyon creek, above County Highway 166 culvert, sec. 36,T. 7 N., R. 1 E	2.9	245	0
M6	Second small channel west of Geertsen Canyon creek, in County Highway 166 culvert, sec. 2, T. 6 N., R. 1 E	.1	—	—
M7	South branch Dry Hollow Creek, above County Highway 166 bridge, sec. 6, T. 6 N., R. 2 E	.3	—	—
M8	North branch Dry Hollow Creek, 300 feet below County Highway 166 bridge, sec. 1, T. 6 N., R. 1 E	.7	230	2.5
M9	Small channel south of Dry Hollow Creek, above County Highway 166 bridge, sec. 7, T. 6 N., R. 2 E	.4	—	—
M10	Kelley Canyon creek, 30 feet above road culvert, sec. 9, T. 6 N., R. 2 E	.2	335	1.5
M11	Maple Canyon creek, above road culvert, sec. 9, T. 6 N., R. 2 E	.5	130	1.5
	South Fork Ogden River drainage			
S1	Spring flow in channel, above County Highway 39 culvert, sec. 11, T. 6 N., R. 2 E	.9	64	3.5
S2	Quarry Hollow creek, above road culvert south of Monastery, sec. 22, T. 6 N., R. 2 E	1.4	265	.5
S3	Bennett Creek, 300 feet below bridge, sec. 21, T. 6 N., R. 2 E	2.4	270	0
S4	Huntsville South Bench Canal (Bennett Creek), above diversion structure at Bally Watts Creek confluence, sec. 21, T. 6 N., R. 2 E	8.9	375	3.5

Table 5. Miscellaneous measurements of streamflow, specific conductance, and water temperature during base flow, upper Middle Fork Ogden River, October 1984, and Wheeler Creek, October 1985

[—, no data]

Drainage basin and location of measurement site	Streamflow (cubic feet per second)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)	Water temperature (degrees Celsius)
Upper Middle Fork Ogden River drainage			
Right Fork, Middle Fork Ogden River, upstream of confluence with springflow, sec. 30, T. 8 N., R. 3 E	1.4	365	6.0
Springflow (originating in sec. 25, T. 8 N., R. 2 E.), sec. 30, T. 8 N., R. 3 E	.1	365	7.0
Right Fork, Middle Fork Ogden River, upstream of confluence with springflow, sec. 6, T. 7 N., R. 3 E	1.7	345	8.5
Springflow (originating in sec. 31, T. 8 N., R. 3 E.), sec. 6, T. 7 N., R. 3 E	.4	340	7.5
Right Fork above confluence with Left Fork, Middle Fork Ogden River, sec. 14, T. 7 N., R. 2 E	2.1	285	10.0
Left Fork above confluence with Right Fork, Middle Fork Ogden River, sec. 14, T. 7 N., R. 2 E	.5	130	9.5
Springflow (originating in sec. 4, T. 7 N. R. 2 E.), sec. 14, T. 7 N., R. 2 E	.4	134	10.0
Middle Fork Ogden River at trail crossing, sec. 27, T. 7 N., R. 2 E	3.5	240	11.0
Middle Fork Ogden River above first diversion structure, sec. 33, T. 7 N., R. 2 E	4.2	255	12.0
Wheeler Creek drainage			
Wheeler Creek, below marshy area, sec. 29, T. 6 N., R. 1 E	1.0	375	4.0
Middle Fork Wheeler Creek, at road crossing, sec. 28, T. 6 N., R. 1 E	.1	—	—
Wheeler Creek above East Fork Wheeler Creek confluence, sec. 22, T. 6 N., R. 1 E	1.0	395	4.0
East Fork Wheeler Creek above road crossing, sec. 27, T. 6 N., R. 1 E	.2	810	4.5
East Fork Wheeler Creek above Wheeler Creek, sec. 22, T. 6 N., R. 1 E	.1	—	—
Wheeler Creek at gaging station 10139300, sec. 16, T. 6 N., R. 1 E	.9	440	9.0

Discharge

Discharge from the consolidated rocks is by streams, evapotranspiration, springs, subsurface outflow, and wells. Discharge from the consolidated rocks to streams was estimated by analysis of streamflow records of low-flow conditions in the late fall and winter. Presumably, most of the flows recorded during low-flow conditions represent ground-water discharge. In addition, a seepage run was made on the Middle Fork Ogden River.

The average monthly flow in the upper North Fork Ogden River drainage, upstream from station 10137680, determined for the base-flow period November through February for water years 1964-74, was about 5 cubic feet per second. Ground-water discharge to the stream, as indicated by the average daily minimum flow, increased from 3.2 to 4.1 cubic feet per second from November to February.

Average monthly flow and daily minimum flow for upper North Fork Ogden River drainage (upstream from station 10137680)

Month	Average monthly flow (cubic feet per second)	Average daily minimum flow (cubic feet per second)
November	4.6	3.2
December	4.4	3.3
January	5.5	3.5
February	5.0	4.1

The average monthly flow in the upper Middle Fork Ogden River drainage, upstream from station 10137780, determined for the base-flow period November through February for water years 1964-74, increased from 4.1 to 9.9 cubic feet per second. Ground-water discharge to the stream, as indicated by the average daily minimum flow, increased from 2.8 to 7.4 cubic feet per second.

A seepage run made October 11, 1984, on the upper Middle Fork Ogden River indicated a gain of about 1.4 cubic feet per second between the upstream reaches of the river and Ogden Valley.

Average monthly flow and daily minimum flow for upper Middle Fork Ogden River drainage (upstream from station 10137780)

Month	Average monthly flow (cubic feet per second)	Average daily minimum flow (cubic feet per second)
November	4.1	2.8
December	5.8	3.8
January	8.5	4.9
February	9.9	7.4

The average monthly flow in the South Fork Ogden River drainage, upstream from station 10137500 (generally the South Fork Ogden River watershed upstream from Ogden Valley), determined for the base-flow period November through February for water years 1922-65 (before Causey Reservoir dam was constructed), was about 43 cubic feet per second. Discharge of Causey Spring accounts for about 21 cubic feet per second or nearly 50 percent of the base flow in the South Fork Ogden River drainage. The base flow in Beaver Creek, which enters the South Fork Ogden River downstream from Causey Reservoir, has never been recorded but probably is about 2 cubic feet per second. Therefore, the maximum possible discharge of ground water to the South Fork Ogden River, upstream from station 10137500, is about 20 cubic feet per second.

The average monthly gain in flow to the South Fork Ogden River between Causey Reservoir dam and station 10137500 was determined from the flow records collected at stations 10137300 and 10137500 from November through February for water year 1967. Beaver Creek, which is the only substantial source of surface-water inflow to the South Fork Ogden River in this reach, is assumed to consist of only base flow from November through February. The gain in flow to the South Fork Ogden River and the base flow of Beaver Creek are the estimated ground-water inflow to the South Fork Ogden River drainage upstream from Ogden Valley for water year 1967. The estimated inflow by month is as follows:

Month	Estimated ground-water inflow (cubic feet per second)
November	7.6
December	9.5
January	10.8
February	14.6

The average monthly discharge from the Wheeler Creek drainage at station 10139300 (pl. 1), determined for the base-flow period November through February for water years 1958-84, increased from about 2.1 cubic feet per second in November to 5.0 cubic feet per second in February. The average daily minimum flow, which is the best estimate of ground-water discharge to the stream, fluctuated slightly through the period of analysis.

Average monthly flow and daily minimum flow for Wheeler Creek (station 10139300)

Month	Average monthly flow (cubic feet per second)	Average daily minimum flow (cubic feet per second)
November	2.1	1.3
December	2.1	1.2
January	2.7	1.1
February	5.0	1.4

Evapotranspiration and subsurface outflow from the bedrock can be estimated by comparing precipitation and streamflow records. The 1931-60 average annual precipitation in the South Fork Ogden River drainage area above station 10137500 was 7.54 billion cubic feet. The average annual discharge of the South Fork Ogden River at station 10137500 during 1931-60 was 3.33 billion cubic feet. Thus, an annual average of 4.21 billion cubic feet (133 cubic feet per second) evapotranspired or recharged the valley-fill aquifer system by underflow in the alluvium of the South Fork Ogden River channel. This is an average areal rate of about 13.2 inches per year. The same analysis on the Wheeler Creek drainage for precipitation from 1931-60 and streamflow from 1958-86 yields an average areal rate of about 18.9 inches per year.

The major springs that issue from the consolidated rocks in the study area are Wheeler Spring [(A-6-1)32acc-S1], Monastery Spring and its associated springs [(A-6-2)27dcc-S1], Patio Springs [(A-7-1)22caa-S1], Burnett Spring [(A-7-1)22dad-S1], Causey Spring [(A-7-3)23acb-S1], and Limestone Spring [(A-8-3)34caa-S1] (table 6). Carbonate rocks are the source for Wheeler Spring and Causey Spring. Monastery Spring, its associated springs, and Limestone Spring appear to have their sources in the Wasatch Formation or possibly the carbonate rocks. Patio Springs probably issues from the Wasatch Formation. The water of Burnett Spring is from the Norwood Tuff but ultimately may be derived from the metasedimentary rocks. Liberty Spring [(A-7-1)19dbc-S1] discharges from the valley-fill deposits, but the source of the water probably is subsurface inflow from nearby carbonate rocks (fig. 10).

Innumerable small springs discharge throughout the area. All of the community water-supply systems in the upper drainage area and a number of the municipal water-supply systems in Ogden Valley derive their water from the small springs in consolidated rock. Springs issuing from the Wasatch Formation irrigate about 50 acres in the Sheep Herd Creek valley southeast of Huntsville.

Some wells in Ogden Valley also derive water from the consolidated rocks. Wells completed in the Wasatch Formation include a flowing well at the Wolf Creek Resort north of Eden, a community well west of the resort well, a rarely-used community well southwest of Huntsville, and other individual small-yield wells in the upper South Fork Ogden River drainage. Ground water in the Wasatch Formation commonly is under confined conditions, and several wells flow. One community well and a few domestic wells along the margin and foothills of Ogden Valley yield small quantities of water from the Norwood Tuff. Relatively few wells in the area surrounding Ogden Valley pump water from the bedrock.

A few wells derive water from the other hydrogeologic units (table 7). Well (B-8-1)36dcc-1, which is in the uppermost part of the North Fork Ogden River drainage and yields about 20 gallons per minute, probably is completed in the Mutual Formation of Precambrian age. A few wells south of the South Fork Ogden River canyon mouth may be completed in carbonate rocks.

Figure 10. Liberty Springs (arrow) at Liberty, Utah (looking east from hillside on Wasatch Range toward Bear River Range).

GROUND-WATER HYDROLOGY OF VALLEY-FILL DEPOSITS IN OGDEN VALLEY

The areal extent of the unconsolidated valley-fill deposits in Ogden Valley is about 40 square miles. These deposits are saturated and constitute a major aquifer system which is referred to as the valley-fill aquifer system in this report. Slopewash and other relatively thin saturated deposits on the mountain slopes also are part of the valley-fill aquifer system.

Ground-water conditions vary throughout the valley. In the northern part of Ogden Valley and along the margins of the southern part of the valley, the ground water is unconfined although, locally, perched ground water may occur above the water table. Near the center of the southern part of the valley, two relatively distinct aquifers are separated by an intervening silty clay layer. Ground water in the lower aquifer is confined and is pumped intensively in Ogden Valley. Ground water in the upper aquifer is unconfined and few wells withdraw water from it.

The term "principal aquifer" is used in this report to refer to the confined aquifer in the center of the southern part of the valley as well as the unconfined parts of the aquifer in the northern part of Ogden Valley and along the margins of the southern part of the valley. The term "shallow water-table aquifer" refers to the upper unconfined aquifer that overlies the confined part of the principal aquifer in the center of the southern part of the valley. The term "valley-fill aquifer system" refers to the entire ground-water reservoir in the valley-fill deposits (table 1) of Ogden Valley.

Recharge

Precipitation, seepage from streams and canals, excess irrigation water, and subsurface inflow recharge the valley-fill aquifer system. Direct infiltration from snowmelt and seepage from stream channels are the major sources of recharge during the spring freshet. During the remainder of the year, subsurface inflow from bedrock and infiltration of irrigation water probably are the major sources of recharge.

Table 6. Records of springs

[—, no data]

Location: See figure 2 for description of data-site numbering system.
Aquifer: See table 1 for explanation of code and description of lithology.
Use of water: H, domestic; I, irrigation; P, public supply; R, recreation; U, unused.
Discharge: E, estimated.

Location	User	Aquifer	Use of water	Altitude of land surface (feet)	Discharge (gallons per minute)	Specific conductance (microsiemens per centimeter at 25 degrees Celsius)
(A-6-1)15dbd-S1	Forest Service	123NRWD	P	5,370	—	—
(A-6-1)25aab-S1	Huntsville Water Co.	123NRWD	P	5,120	—	—
(A-6-1)32acc-S1	Snow Basin	300CRSL	P	6,480	240	250
(A-6-2)10ccd-S1		400PCMB	H	5,160	3.3	425
(A-6-2)11ddc-S1	Fraternal Order of Eagles	400PCMB	P	5,160	45 E	—
(A-6-2)12dac-S1	Forest Service	400PCMB	P	5,220	4	295
(A-6-2)17bdb-S1	—	111ALVM	U	4,940	975	450
(A-6-2)27cda-S1	Huntsville Water Co.	124WSTC	P	5,240	17	420
(A-6-2)27dcc-S1	Roman Catholic Church and Huntsville Water Co.	300CRSL	I,P	5,320	710	430
(A-6-2)27dcc-S2	Huntsville Water Co.	300CRSL	P	5,280	27	435
(A-6-3) 5acb-S1	Forest Service	111ALVM	U	5,390	13	345
(A-6-3) 5bdc-S1	Forest Service	111ALVM	P	5,400	—	—
(A-6-3)23acb-S1	Causey Estates	124WSTC	P	7,760	—	—
(A-6-3)23ada-S1	Causey Estates	124WSTC	P	7,680	—	—
(A-6-3)23adb-S1	Causey Estates	124WSTC	P	7,680	—	—
(A-6-3)23daa-S1	Causey Estates	124WSTC	P	8,080	—	—
(A-7-1) 1abb-S1	Powder Mountain Water Dist.	111ALVM	P	8,120	6	53
(A-7-1) 1abd-S1	Powder Mountain Water Dist	300CRSL	P	7,920	9	415
(A-7-1) 1ddb-S1	Powder Mountain Water Dist.	300CRSL	P	7,600	110	405
(A-7-1)12acb-S1	—	300CRSL	U	7,200	100	275
(A-7-1)19dbc-S1	Shupe, Thomas	111ALVM	I	5,170	900 E	280
(A-7-1)22caa-S1	Wolf Creek Resort	124WSTC	I,R	5,260	—	175
(A-7-1)22dad-S1	Eden Water Assoc.	123NRWD	P	5,320	—	—
(A-7-1)30aca-S1	Spring Mountain Ranch	371SCRL	P	5,430	195	340
(A-7-1)30baa-S1	Shupe, Thomas	371SCRL	P,I	5,400	700 E	360
(A-7-3) 4abb-S1	Sourdough Ranch	124WSTC	P	7,660	3.7	390
(A-7-3) 4baa-S1	Sourdough Ranch	124WSTC	P	7,640	4.7	355
(A-7-3)23acb-S1	—	331HMBG	U	6,440	9,800	285
					9,800	365
(A-7-3)26acb-S1	Boy Scouts of America	337LDGP	U	5,750	695	460
(A-7-3)28bba-S1	Nass, Tom	124WSTC	I	5,720	73	360
(A-7-3)34cbc-S1	Weber County	124WSTC	U	5,520	150	400
(A-8-2)35dac-S1	Sunridge, Inc	124WSTC	P	7,800	70	375
(A-8-3)22cdc-S1	—	124WSTC	U	7,030	6	360
(A-8-3)31bd -S1	Sunridge, Inc	124WSTC	P	7,340	5	—
(A-8-3)34caa-S1	—	124WSTC	U	6,660	250 E	415
(B-7-1) 2caa-S1	Cobblecreek Park	400PCMB	P	5,940	33	240
(B-8-1)34daa-S1	Liberty Pipeline Co.	400PCMB	P	6,080	—	—
(B-8-1)34daa-S2	Liberty Pipeline Co.	400PCMB	P	6,120	—	—
(B-8-1)34dab-S1	Liberty Pipeline Co.	400PCMB	P	6,140	—	—
(B-8-1)34dba-S1	Liberty Pipeline Co.	400PCMB	P	6,200	—	—
(B-8-1)36cba-S1	American Baptist Church	400MUTL	P	5,660	5	—

Temperature (degrees Celsius)	Date measured	Name of spring	Remarks
—	—	—	
—	—	Hawkins Spring	
8.0	08/15/1985	Wheeler Spring	
—	08/13/1985	—	
—	08/13/1985	—	
—	09/29/1984	—	
7.0	01/24/1985	—	Greatest point of outflow of Spring Creek.
11.0	09/17/1985	Peterson Spring	
9.5	08/14/1985	Monastery Spring (also called Bennett Spring)	Water sample analyzed (table 9).
10.0	09/17/1985	Lower Bennett Spring	
11.0	09/30/1984	—	
—	—	—	
—	—	Spring 1	Springs 1, 2, 3, and 4 used to supply water to summer homes
—	—	Spring 3	above Causey Reservoir.
—	—	Spring 2	Total discharge ranges from 36 to 60 gallons per minute.
—	—	Spring 4	
10.0	07/19/1985	—	These three springs used to supply water to the Powder Mountain
9.0	07/19/1985	—	ski area and nearby related development.
9.5	07/19/1985	—	
7.0	07/20/1985	—	
10.0	07/06/1985	Liberty Springs	Water sample analyzed (table 9).
24.0	01/24/1985	Patio Springs	Water sample analyzed (table 9).
—	—	Burnett Spring	Discharge varied from about 50 to 150 gallons per minute in 1985.
8.0	07/05/1985	Fisher Spring	Water sample analyzed (table 9). Supplies water to homes.
9.0	07/05/1985	Wester Springs	
6.0	08/13/1985	Cold Spring 2	Supplies water to summer homes.
5.0	08/13/1985	Cold Spring 1	Supplies water to summer homes.
16.5	09/29/1984	Causey Spring	Water sample analyzed (table 9).
7.5	07/21/1985		
9.0	07/21/1985	—	
—	08/02/1985	—	
—	08/15/1985	—	
7.0	07/21/1985	—	Supplies water to summer homes.
9.0	09/30/1984	—	Supplies water to summer homes.
—	08/02/1985	—	
8.5	09/29/1984	Limestone Spring	
7.5	07/18/1985	—	Supplies water to homesites.
—	—	—	Supplies water to Liberty and to North Fork Park,
—	—	—	a county camping and picnic ground.
—	—	—	Do.
—	—	—	Do.
—	07/19/1985	—	

Table 7. Records of wells

[—, no data]

Location: See figure 2 for explanation of data-site numbering system.
Owner: Owner at time well was visited by U.S. Geological Survey personnel or as listed by driller on Utah well-completion report.
Finish: P, perforated casing below depth to first opening; S, screened casing below depth to first opening; X, open hole below
Use of water: C, commercial; H, domestic; I, irrigation (predominately lawn and garden watering); P, public supply; S, stock; U,
Type of lift: C, centrifugal; F, natural flow; J, jet; S, submersible; T, turbine.
Type of power: D, diesel; E, electricity.
Aquifer: See table 1 for explanation of code and description of lithology.
Water level: Below or above (-) land surface; F, reported as flowing, no water level.
Specific capacity: Discharge in gallons per minute per foot of drawdown. Number in parentheses is duration of test in hours. All
Other data collected during study by U.S. Geological Survey personnel: WL (water levels)—C, continuous; M, monthly; O, one
QW (water quality)—A, specific conductance and temperature in table 8; O, chemical analysis done in 1985 shown in table 8; B,

Location	Owner	Date drilled	Depth of well (feet)	Depth to first opening (feet)	Finish	Use of water	Type of lift	Type of power
(A-6-1)1aaa-1	Hinkley Ranch	1932	19.5	—	—	U	—	—
(A-6-1)1baa-1	Graham, Olga	08/25/1977	126	100	P	H,I	S	E
(A-6-1)1dad-1	Argyle, Dell	12/12/1975	100	95	P	H,S,I	S	E
(A-6-1)3dbc-1	Adams, Glen	06/05/1967	187	140	P	H,I	S	E
(A-6-1)10aac-1	Ogden Pineview Yacht Club	—	155	—	—	P,I	S	E
(A-6-1)10dbc-1	Radford, Edward	08/14/1969	142	124	P	P,I	S	E
(A-6-1)10dbd-1	Radford, Edward	09/12/1969	130	114	P	P	—	—
(A-6-1)10dda-1	Forest Service	10/31/1963	169	149	P	U	S	E
(A-6-1)11acb-1	Evergreen Ranch	04/30/1968	151	—	—	U	—	—
(A-6-1)11bdd-1	Ogden City	10/01/1971	400	—	P	P	T	E
(A-6-1)11bdd-2	Ogden City	—	400	—	—	P	T	D
(A-6-1)11cab-1	U.S. Geological Survey	10/11/1952	210	146	P	U	—	—
(A-6-1)11cab-1	U.S. Geological Survey	10/11/1952	323	222	P	U	—	—
(A-6-1)11cab-2	Ogden City	—	229	176	S	P	T	E
(A-6-1)11cab-3	Ogden City	—	511	206	P	P	T	E
(A-6-1)11cab-4	Ogden City	03/16/1971	400	—	P	P	T	E
(A-6-1)11cba-1	Ogden City	02/14/1969	237	202	S	U	—	—
(A-6-1)11cba-2	Ogden City	1970	239	201	S	P	T	D
(A-6-1)11dbd-1	Ogden City	1932	90	90	X	U	—	—
(A-6-1)11dbd-2	Ogden City	09/00/1932	68	68	X	U	—	—
(A-6-1)11dbd-3	Ogden City	09/00/1932	4	4	X	U	—	—
(A-6-1)11dcd-1	U.S. Geological Survey	10/10/1935	152	152	X	U	—	—
(A-6-1)11dcd-2	Forest Service	11/01/1955	190	170	P	P	S	E
(A-6-1)12aad-1	Ogden City	1932	108	108	X	U	—	—
(A-6-1)12dcd-1	Ceibert, Peter	05/20/1960	145	138	P	U	—	—
(A-6-1)13cdd-1	Forest Service	06/28/1961	133	110	P	P	S	E
(A-6-1)14ccd-1	Adams, A. Paul	09/24/1981	335	85	P	U	—	—
(A-6-1)15dbc-1	Forest Service	—	450	—	—	P	—	—
(A-6-1)22dab-1	Webber, John	06/00/1976	122	60	P	H	S	E
(A-6-1)23adb-1	Lakeview Water Co.	04/01/1960	500	—	—	P	S	E
(A-6-1)23dbc-1	Webber, John	1976	250	210	P	H	S	E
(A-6-1)24aba-2	Lakeview Water Co.	07/06/1969	197	130	P	P	S	E
(A-6-2)5bac-1	Jensen Ranch	—	—	—	—	S,Z,H	S	E
(A-6-2)5bbc-1	Jensen, Rick	—	—	54	—	—	H,I	SE
(A-6-2)5bcc-1	Jensen Ranch	10/01/1952	50	30	P	S,Z	S	E
(A-6-2)6aab-1	Hinkley Ranch	—	120	—	—	U	—	—
(A-6-2)6bbb-1	Hinkley Ranch	10/19/1964	227	60	P	S,H,I	T	E
(A-6-2)6cad-1	Erekson, Affel	05/01/1981	103	100	P	U	—	—
(A-6-2)6dad-1	Kotter, David	12/00/1977	100	100	X	H,I	S	E

depth to first opening.
unused; Z, dairy sanitation.

data obtained from Utah well-completion reports unless otherwise specified.
time or random; S, semiannual.
chemical analysis prior to 1985 shown in table 8.

Aquifer	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Date discharge measured	Specific capacity (gallons per minute per foot of drawdown)	Other data available WL	Other data available QW	Remarks
111ALVM	4,920	—	—	—	—	—	S	—	
112ALVM	4,921	30	10/03/1977	7	—	.1(2)	M	—	
112ALVM	4,933	35	—	25	—	.3(2)	S	O	
112ALVM	4,960	28	06/20/1967	10	06/00/1967	—	S	—	
112ALVM	4,925	—	—	—	—	—	S	—	
112ALVM	4,980	38	09/10/1969	15	—	15 (12)	S	—	These two wells supply water to
112ALVM	4,940	30	09/19/1969	20	—	20 (12)	—	—	houses on Forest Service land.
112ALVM	4,907	32	11/29/1963	—	—	—	M	—	Port Ramp well.
112ALVM	4,915	47	05/10/1968	10	—	.6(2)	M	—	
112ALVM	4,900	43	12/15/1971	2,500	—	50 (24)	—	—	Well 5.
112ALVM	4,900	43	—	2,500	—	50 (24)	—	—	Well 6.
112ALVM	4,915	—	—	—	—	—	M	—	Two wells at same site.
112ALVM	4,915	—	—	250	12/11/1952	125	M	—	Water-level data for both wells back to 1953.
112ALVM	4,895	—	—	—	—	—	—	—	Well 2.
112ALVM	4,910	—	—	—	—	—	—	O	Well 3.
112ALVM	4,895	43	—	2,500	—	50	—	—	Well 4.
112ALVM	4,905	30	04/29/1969	2,500	—	26 (6)	—	—	Test well, now plugged.
112ALVM	4,910	—	—	—	—	—	—	—	Well 1.
112ALVM	4,832	-10.06	09/15/1932	—	—	—	—	B	Well 102, now plugged.
112ALVM	4,833	-9.66	09/31/1932	—	—	—	—	B	Well 101, now plugged.
111ALVM	4,832	.14	09/25/1932	—	—	—	—	B	Well 100, now plugged.
112ALVM	4,881	—	—	—	—	—	—	—	Cemetery well, now plugged.
112ALVM	4,915	—	—	180	—	60 (1.5)	M	B	Bluff well.
112ALVM	4,880	7.58	09/20/1932	—	—	—	—	B	Tower well, now plugged.
112ALVM	4,920	42	10/21/1960	8	—	2.6(4)	S	—	
112ALVM	4,921	26	07/01/1961	60	—	—	M	—	Anderson Cove well.
123NRWD	5,240	60.3	07/31/1984	1.5	—	<.1(2)	O	—	
123NRWD	5,439	90	08/01/1985	—	—	—	O	—	
123NRWD	5,950	41.3	08/18/1984	100	—	—	O	—	
123NRWD	5,120	4	—	175	—	1.7	—	B	Secondary well.
123NRWD	5,550	155.6	08/18/1984	45	—	—	O	—	
112ALVM	4,930	29	07/17/1969	164	—	2.4(7)	S	—	Primary well.
—	5,110	—	—	—	—	—	—	—	Provides water to dairy farm.
111ALVM	5,020	—	—	—	—	—	S	—	
111ALVM	5,000	14	—	25	10/16/1952	4.2	—	—	
111ALVM	5,010	—	—	—	—	—	M	—	
112ALVM	4,945	8	02/15/1965	100	05/20/1965	.7(2.5)	S	—	
112ALVM	4,945	18	06/30/1981	15	06/00/1981	3.0(1)	S	—	
111ALVM	4,970	30	12/00/1977	15	—	—	S	O	

Table 7. Records of wells—Continued

Location	Owner	Date drilled	Depth of well (feet)	Depth to first opening (feet)	Finish	Use of water	Type of lift	Type of power
(A-6-2)6dda-1	Montgomery, Norman	01/09/1964	51	36	P	S,H,Z	S	E
(A-6-2)7aab-1	Skeen, Joseph	07/16/1968	92	92	X	H,I	S	E
(A-6-2)7bbb-1	Newey, Dale	12/23/1957	111	85	P	S,Z,H	S	E
(A-6-2)7bbd-1	Casey Acres Subdivision	08/02/1980	110	90	P	U	—	—
(A-6-2)7bbd-2	Casey Acres Subdivision	09/21/1980	130	105	P	P	—	E
(A-6-2)7bcc-1	Quist, Ivan	10/03/1965	102	100	X	H,I	S	E
(A-6-2)7cad-1	Clawson, Jack	01/00/1978	120	105	P	H,I	S	E
(A-6-2)7dac-1	Ekstrom, Don	—	8	—	X	U	—	—
(A-6-2)7ddb-1	McKay, John	05/00/1968	107	—	—	H,S,I	S	E
(A-6-2)8ddb-1	Shafer	05/22/1970	160	100	P	I,H	C	E
(A-6-2)9cac-1	Green Hill Estates	04/01/1979	240	120	P	P	S	E
(A-6-2)14bab-1	Fraternal Order of Eagles	04/00/1972	257	105	P	U	—	—
(A-6-2)14bbd-1	Cox, David	07/31/1984	100	88	P	H	S	E
(A-6-2)14bcc-1	Hunter, David	06/15/1979	112	100	P	H,S,I	S	E
(A-6-2)15acb-1	Utah Dept. of Transportation	1973	285	158	P	H,I	S	E
(A-6-2)15cdb-1	Odekirk, Forrest	06/05/1978	98	82	P	H,I	S	E
(A-6-2)16ada-1	Weems, S.L.	11/02/1954	242	84	—	I,H,S	T	E
(A-6-2)16add-1	Field, Joe	03/23/1979	220	172	P	H,I	S	E
(A-6-2)16bad-1	Verhaal, Richard	03/22/1979	101	80	P	H,I	S	E
(A-6-2)16bdb-1	Carrick, David	08/24/1984	115	105	P	H	S	E
(A-6-2)16cbd-1	Walker, Hugh	10/20/1976	100	90	P	H,I	S	E
(A-6-2)16dad-1	Gay, Larry	10/06/1960	54	54	X	H,I,S	S	E
(A-6-2)17aab-1	Toyn, Robert	11/05/1958	42	37	P	H,I,C	S	E
(A-6-2)17abb-1	Wood, Robert	06/13/1977	100	90	P	H,I	S	E
(A-6-2)17bbb-1	Argyle, Dell	08/08/1956	40	35	P	H,S	F	—
(A-6-2)17cca-1	Schade, Marlon	04/25/1970	124	86	P	H,I	S	E
(A-6-2)17dac-1	Allen, Lila	05/00/1974	102	—	—	H,I	S	E
(A-6-2)17dbd-1	Allen, Garth	—	40	—	—	H,I,S	S	E
(A-6-2)18bad-1	U.S. Bureau of Reclamation	11/08/1955	155	105	P	U	—	—
(A-6-2)18dad-1	American Legion	11/08/1967	87	87	X	C,I,H	S	E
(A-6-2)18dad-2	Andrews, Raymond	07/01/1981	103	82	P	H,I	S	E
(A-6-2)18dbb-1	Deatherage, D.	—	18	18	X	U	—	—
(A-6-2)19abb-1	Forest Service	06/30/1961	69	26	P	P	S	E
(A-6-2)19bda-1	Wangsgard, William	—	120	—	—	C,H,I	S	E
(A-6-2)19bdb-1	Peterson, Chris	08/07/1961	90	—	—	C,P,I	S	E
(A-6-2)20acd-1	Wangsgard, Clark	06/23/1978	86	66	P	U	—	—
(A-6-2)20bad-1	Froerer Dairy Farm	04/25/1969	86	86	X	S,Z,H	S	E
(A-6-2)21aab-1	Lowe, John	—	—	—	—	H,I,S	S	E
(A-6-2)21abc-1	Birch, Ralph	09/23/1942	37	—	—	U	—	—
(A-6-2)21abc-2	Osmond, Dennis	12/26/1979	101	91	P	U	—	—
(A-6-2)21acd-1	Kenley, Wayne	07/30/1971	79	79	X	H,S	S	E
(A-6-2)21bbb-1	Wangsgard Ranch	12/05/1956	81	72	P	S,Z,H	S	E
(A-6-2)21cbd-1	Messerly, Grant	04/21/1970	105	38	P	H,I,S	S	E
(A-6-2)21ccd-1	Mertz, Brian	06/08/1984	170	155	P	H,S,I	S	E
(A-6-2)22bcb-1	Roman Catholic Church	—	36	—	—	H	J	E
(A-6-2)28aaa-1	Russell, Scott	08/00/1976	220	120	P	H	S	E
(A-6-2)28aba-1	Stoddard, Douglas	07/18/1973	140	—	P	H,I	S	E
(A-6-3)5abb-1	Read, Boyd	11/18/1953	74	66	P	P	S	E
(A-7-1)6dda-1	Shaum, Robert	07/10/1972	142	40	P	H,S	S	E
(A-7-1)7abc-1	Elliot, Charles	07/12/1973	160	143	X	H,I	S	E
(A-7-1)7dba-1	Quist, Farley	08/04/1975	102	80	P	H,I	S	E
(A-7-1)7dcb-1	Zwahlen, Carl	07/17/1973	224	—	—	H,I	S	E
(A-7-1)7dda-1	Van Alfen, John	12/00/1978	140	100	P	H,I	S	E
(A-7-1)8cad-1	Roberts, Emil	01/01/1976	180	—	—	S	S	E
(A-7-1)8cbb-1	Nelson, Ralph	06/27/1967	120	57	P	I,H,S	S	E

Aquifer	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Date discharge measured	Specific capacity (gallons per minute per foot of drawdown)	Other data available WL	Other data available QW	Remarks
111ALVM	4,970	24	02/03/1964	60	—	20 (2.5)	—	—	Provides water to dairy farm.
111ALVM	4,950	26	07/30/1968	8	—	.6(2)	S	—	
111ALVM	4,924	45	—	20	12/30/1957	1.3	S	—	Provides water to diary farm.
111ALVM	4,926	20	08/02/1980	500	—	—	S	—	
112ALVM	4,930	23	10/09/1980	60	10/09/1980	30 (1)	—	—	
112ALVM	4,922	18	10/26/1965	6	—	—	S	O	
112ALVM	4,940	32	01/00/1978	20	01/00/1978	—	S	—	
111ALVM	4,930	—	—	—	—	—	S	—	
112ALVM	4,920	F	08/02/1968	—	—	—	S	O	
112ALVM	4,970	15	05/12/1970	30	—	2.0(1)	M	O	
123NRWD	5,030	25.3	07/31/1984	90	—	—	O	—	
112ALVM	5,120	7	10/00/1973	5	10/00/1973	<.1(3)	S	—	
111ALVM	5,090	38	08/22/1984	15	08/00/1984	.5(1)	S	O	
111ALVM	5,085	35	06/29/1979	30	—	2.0(1)	S	—	
112ALVM	5,060	43	08/22/1973	50	—	.6(24)	M	O	
111ALVM	5,040	16	06/16/1978	10	—	2.0(2)	S	O	
112ALVM	5,025	39	—	150	12/17/1954	1.2	—	—	
112ALVM	5,025	45	08/25/1979	18	—	.6(1)	S	—	
111ALVM	4,990	26	04/25/1979	10	—	2.0(2)	S	O	
112ALVM	4,980	20	09/26/1984	15	—	1.5(2)	S	—	
111ALVM	4,985	22	11/15/1976	10	—	1.0(2)	S	—	
111ALVM	5,025	37	10/18/1960	5	10/18/1960	.8(2)	S	—	
111ALVM	4,970	11	—	—	—	—	S	—	
112ALVM	4,955	16	—	30	—	—	S	—	
111ALVM	4,930	-5	08/09/1956	20	08/09/1956	—	S	A	
112ALVM	4,940	37	—	25	05/06/1970	.7(1)	S	O	
112ALVM	4,970	2	06/00/1974	150	06/00/1974	—	S	O	
111ALVM	4,970	—	—	—	—	—	S	—	
112ALVM	4,918	35	—	60	11/28/1955	.8	C	B	Well on County Highway property.
112ALVM	4,940	20	12/02/1967	10	—	.4(2)	—	—	
112ALVM	4,935	20	09/18/1981	10	—	.7(2)	M	—	
111ALVM	4,925	—	—	—	—	—	S	—	
112ALVM	4,900	1	07/04/1961	60	—	6.0(1)	S	A	
111ALVM	4,960	—	—	—	—	—	S	—	Trappers Inn Restaurant.
111ALVM	4,960	50	09/01/1961	5	—	.6(1)	—	—	Chris's Gas Station and Bar.
112ALVM	4,950	F	07/14/1978	30	07/14/1978	—	S	A	
112ALVM	4,955	4	05/02/1969	10	—	3.3(2)	—	—	Provides water to dairy farm.
—	5,010	—	—	—	—	—	S	—	
111ALVM	5,000	24	09/00/1942	—	—	—	M	—	
112ALVM	5,000	16	01/28/1979	75	—	1.9(2)	M	—	
112ALVM	4,990	13	08/06/1971	10	—	.5(2)	S	O	
112ALVM	4,980	15	—	25	12/10/1956	2.5	S	—	Provides water to dairy farm.
112ALVM	4,990	12	05/28/1970	10	—	.3(2)	S	—	
111ALVM	5,040	38	10/04/1984	4	—	<.1(2)	S	—	
111ALVM	5,005	—	—	—	—	—	S	—	
124WSTC	5,020	F	08/31/1976	11	08/31/1976	—	M	—	
112ALVM	5,030	—	—	2	—	—	S	O	
124WSTC	5,330	-41	11/00/1953	2.3	08/15/1985	—	—	A	Provides water to summer homes.
111ALVM	5,340	12	08/05/1972	7	08/05/1972	.2(2)	S	—	
111ALVM	5,320	—	—	—	—	—	S	—	
111ALVM	5,250	13	09/22/1975	10	—	1.2(2)	M	O	
123NRWD	5,280	—	—	15	08/21/1973	—	S	—	
111ALVM	5,210	10	12/00/1978	45	—	—	S	—	
111ALVM	5,200	20	01/01/1976	—	—	—	M	O	
111ALVM	5,250	45	07/25/1967	—	—	—	S	—	

Table 7. Records of wells—Continued

Location	Owner	Date drilled	Depth of well (feet)	Depth to first opening (feet)	Finish	Use of water	Type of lift	Type of power
(A-7-1)17bcb-1	White, Donald	09/22/1975	120	104	P	H,I	S	E
(A-7-1)17cba-1	Prier, Peter	1950	300	—	—	H,S	S	E
(A-7-1)18adb-1	Hawks, Monty	10/09/1976	116	95	S	H,I	S	E
(A-7-1)19aad-1	Dawson, Dale	03/00/1972	200	122	P	H,I,S	S	E
(A-7-1)19abb-1	West, Bob	06/00/1976	290	230	P	H,S	S	E
(A-7-1)19acd-1	Finder, Robert	12/02/1971	124	101	P	H,S,I	S	E
(A-7-1)19ddb-1	Anderson, Richard	12/10/1971	140	110	P	H	—	—
(A-7-1)20bab-1	Hogge, Ronald	08/00/1971	127	109	P	H,I	S	E
(A-7-1)20dcd-1	Hadfield, Douglas	—	—	—	—	H,I	S	E
(A-7-1)21bab-1	Hannum, Thomas	08/18/1976	125	95	P	H,I	S	E
(A-7-1)21bbc-1	Pletcher	07/15/1969	81	81	X	H,I,S	S	E
(A-7-1)21cad-1	Burton, Howard	05/01/1968	42	34	P	H	S	E
(A-7-1)21ddc-1	Valley Water Users	—	—	—	—	P	—	—
(A-7-1)22bcd-1	Wolf Creek Resort	09/00/1972	795	—	—	U	—	—
(A-7-1)22cad-1	Wolf Creek Resort	04/30/1982	400	—	—	P	—	—
(A-7-1)27abc-1	Eden Water Assoc.	08/00/1976	300	160	P	P	S	E
(A-7-1)27baa-1	Crandall, Ralph	06/25/1963	395	60	P	H,S	S	E
(A-7-1)28adb-1	Holmstron, Dave	11/00/1979	240	220	P	H,S	S	E
(A-7-1)28baa-1	Nipko, Tuck	09/07/1970	275	255	P	H,I	S	E
(A-7-1)28dbb-1	Chambers, Earl	09/16/1970	89	89	X	H,I	S	E
(A-7-1)28dda-1	Malan, A.B.	06/24/1957	75	—	—	U	—	—
(A-7-1)29acc-1	Bealba, Pete	02/00/1977	300	180	P	H,I	S	E
(A-7-1)29ada-1	Pilcher, John	05/20/1974	146	146	X	H,I	S	E
(A-7-1)29baa-1	Woorlander, Stanley	1916	60	—	—	U	—	—
(A-7-1)29dbc-1	Thatcher, Ben	—	300	—	—	H,I,S	S	E
(A-7-1)29ddc-1	Hensley, Betty	08/24/1971	518	117	P	I	S	E
(A-7-1)30aad-1	Rich, Steve	09/22/1980	170	160	P	H,I	S	E
(A-7-1)32abd-1	Nordic Valley Water Assoc.	—	—	—	—	P	—	—
(A-7-1)32dba-1	Nordic Valley Water Assoc.	12/09/1966	193	50	P	P	S	E
(A-7-1)32dcd-1	Nordic Valley Water Assoc.	06/12/1963	260	40	P	P	S	E
(A-7-1)34aca-1	Carver, David	06/24/1982	144	135	P	I	S	E
(A-7-1)34bab-1	Johnson, Dave	07/10/1949	75	65	P	U	—	—
(A-7-1)34cbb-1	Wolf, Charles	08/00/1974	210	—	—	H,S,I	S	E
(A-7-1)34ccc-1	Ruskin, Harvey	11/00/1976	160	140	P	H	S	E
(A-7-1)34cda-1	Forest Service	07/02/1961	75	53	P	U	S	E
(A-7-1)34dbb-1	Laub, John	05/19/1982	120	120	X	I	S	E
(A-7-1)35bbb-1	Eden Cemetery	11/14/1981	160	100	P	I	S	E
(A-7-1)35cac-1	Vanscoyk, Robert	—	20	—	—	I	C	E
(A-7-1)35cdd-1	Evergreen Ranch	1932	20	—	—	U	—	—
(A-7-1)36bdd-1	BAR-B Ranch	06/20/1949	95	65	P	H,S,I	S	E
(A-7-1)36dca-1	Whitehead, Wilford	12/01/1975	117	95	P	H,I	S	E
(A-7-3)10cda-1	Furlong, Ramona	06/00/1978	283	243	P	H	S	E
(A-7-3)21bda-1	Shupe, Don	1981	166	146	P	H	S	E
(A-7-3)32bbb-1	Neilsen, H. Eugene	10/09/1963	214	100	P	U	—	—
(B-7-1)1bab-2	LDS Church	1968	200	—	—	P,I	S	E
(B-7-1)1daa-1	Tydeck, Robert	09/24/1966	130	110	P	H,I	S	E
(B-7-1)1dda-1	Carlsen, Dean	07/01/1970	253	230	P	H,S,I	S	E
(B-7-1)12bdc-1	Weber County	09/05/1975	205	145	P	P	S	E
(B-8-1)36cab-1	Cronquist, Curt	06/08/1977	160	100	P	H,I	S	E
(B-8-1)36dcc-1	Dufree Creek Estates	06/00/1976	332	272	P	U	—	—

Aquifer	Altitude of land surface (feet)	Water level (feet)	Date water level measured	Discharge (gallons per minute)	Date discharge measured	Specific capacity (gallons per minute per foot of drawdown)	Other data available WL	Other data available QW	Remarks
111ALVM	5,180	50	—	—	—	—	S	O	
111ALVM	5,160	67	12/18/1963	35	12/00/1963	—	S	—	
111ALVM	5,240	30	11/08/1976	10	11/08/1976	—	S	—	
111ALVM	5,135	14	03/00/1972	20	—	.2(2)	S	O	
123NRWD	5,240	3.1	07/05/1985	50	06/30/1976	—	O	—	
111ALVM	5,170	20	12/15/1971	20	12/00/1971	2 (1)	S	—	Flows over casing in spring.
111ALVM	5,150	F	01/18/1972	36	01/18/1972	1.2(2)	—	—	Flows constantly.
111ALVM	5,120	27	01/00/1972	25	1971	1.7(1)	S	—	
—	5,050	—	—	—	—	—	M	O	
111ALVM	5,080	10	—	10	—	.1(2)	S	—	
111ALVM	5,075	18	07/18/1969	8	—	.2(2)	S	O	
111ALVM	5,070	18	10/20/1968	19	—	1.2(1)	M	—	
—	5,100	—	—	—	—	—	—	—	Eden Hills subdivision.
123NRWD	5,230	3.4	08/07/1984	36	—	.1	O	—	
124WSTC	5,240	-4	05/20/1982	600	05/20/1982	—	—	—	
123NRWD	5,120	26.7	08/04/1984	120	—	.4(24)	O	—	Secondary water for Eden.
111ALVM	5,110	40	07/03/1963	8.4	08/28/1975	—	S	—	
111ALVM	5,040	70	11/27/1979	35	—	—	S	—	
111ALVM	5,020	42	09/15/1970	15	—	.5(1)	S	O	
111ALVM	5,000	24	09/25/1970	10	09/00/1970	.5(2)	S	—	
111ALVM	4,990	26	—	20	07/23/1957	—	S	—	
111ALVM	5,190	50	02/00/1977	9	02/00/1977	.1(36)	S	—	
111ALVM	5,080	4	08/07/1974	10	—	.2(2)	S	O	
—	5,120	—	—	—	—	—	S	—	
111ALVM	5,320	—	—	—	—	—	S	—	
111ALVM	5,290	50	12/05/1974	50	—	.3(14)	S	—	
111ALVM	5,300	140	—	15	—	1.2(1)	S	—	
—	5,440	—	—	—	—	—	S	—	Well 3.
111ALVM	5,560	—	—	150	—	1.6(3)	—	—	Well 2.
111ALVM	5,850	—	—	200	—	1.8(5)	—	—	Well 1.
111ALVM	4,955	20	07/10/1982	25	—	2.5(1)	S	O	
111ALVM	4,975	35	—	—	—	—	S	—	
300CRSL	4,930	50	08/00/1974	30	—	—	S	—	
123NRWD	5,230	35.1	08/02/1984	—	—	—	O	—	
112ALVM	4,900	F	07/05/1961	70	—	35 (1)	S	A	
112ALVM	4,950	35	05/21/1982	60	—	—	M	—	
111ALVM	4,970	10	11/17/1981	35	—	—	M	—	
111ALVM	4,935	—	—	—	—	—	S	—	
111ALVM	4,935	—	—	—	—	—	S	—	
111ALVM	4,945	45	—	—	—	—	S	—	
111ALVM	4,920	70	12/11/1975	—	—	—	S	—	
300CRSL	6,320	240	06/12/1978	200	—	—	—	—	
124WSTC	5,960	101.4	07/20/1985	5	—	—	O	—	
124WSTC	5,800	3	11/07/1963	30	—	.3(20)	—	—	
—	5,550	—	—	—	—	—	M	—	
111ALVM	5,420	15	10/15/1966	4	10/15/1966	<.1	S	—	
111ALVM	5,410	60	08/13/1970	10	—	<.1	S	—	
112ALVM	5,670	145.4	08/03/1984	5	—	—	O	—	Provides water to field school.
400MUTL	5,780	77.5	07/18/1985	45	—	—	O	—	
400MUTL	5,620	33.7	07/18/1985	30	06/30/1976	—	O	A	

Little recharge results from rainfall when compared to that from snowmelt. During the summer, any precipitation that infiltrates the soil is retained as soil moisture, and infiltrated water in excess of soil moisture recharges the aquifer. Thomas (1952, p. 94) observed that recharge to the aquifer occurred only when more than 1.5 inches of precipitation fell on moisture-deficient soils.

Field measurements indicate that seepage from certain reaches of the North Fork Ogden River, Middle Fork Ogden River, and South Fork Ogden River recharges the valley-fill aquifer system. Seepage also is likely from eight small perennial creeks and from all ephemeral creeks when they are flowing.

Measurements on the North Fork Ogden River in 1985 indicate seepage from the stream to the valley-fill aquifer system occurs in the upper reaches. Seepage of about 2.4 cubic feet per second is indicated by the first two measurements shown in table 4.

On the Middle Fork Ogden River, all flow for November through February of water year 1964 was lost between station 10137780 and station 10137800 (pl. 2). This loss equalled about 3 cubic feet per second. During the same period in water year 1965, seepage to the aquifer decreased from 5.1 cubic feet per second in November to 1.6 cubic feet per second in February. A net loss of 4.3 cubic feet per second was indicated between the upper bridge across the Middle Fork Ogden River (site M1) and the lower gaging station (site M2) for late February 1985 (table 4).

Seepage from the South Fork Ogden River to the valley-fill aquifer system was calculated from measurements made in the summer of 1925 when the water was returned to the channel after the streamflow had been diverted for several weeks (Browning, 1925, p. 17-20). On the second day after flow was restored, the entire flow of about 48 cubic feet per second seeped into the valley-fill aquifer system within 1 mile. The rate of seepage decreased downstream.

Typically during the winter, the South Fork Ogden River is perennial. During the winter of 1933-34, the entire flow seeped into the valley-fill aquifer system; discharge from the South Fork Ogden River into the valley at that time averaged about 35 to 40 cubic feet per second (Leggette and Taylor, 1937, p. 132-133).

Streamflow records for the South Fork Ogden River for November through February indicate that, in general, seepage to the aquifer decreases during those months. Seepage between station 10137500 near the valley edge and station 10137600 near Pineview Reservoir was calculated for the water years 1960-64.

Discharge and seepage for the South Fork Ogden River between station 10137500 and station 10137600 from November through February, water years[1] 1960-64

Month	Average discharge at station 10137500 (cubic feet per second)	Average discharge at station 10137600 (cubic feet per second)	Seepage to aquifer (cubic feet per second)
November	35.3	10.6	24.7
December	32.9	13.1	19.8
January	32.4	16.4	16.0
February	36.9	26.1	10.8

[1]Data for February 1962 were not included.

Actual seepage from the South Fork Ogden Valley to the valley-fill aquifer system may be greater than the calculated seepage values because of ground-water seepage into the stream channel upstream from station 10137600. The discharge values for February 1962 were not included in the 1960-64 average discharge calculation because of unusually large tributary inflows for this time of year.

Seepage from irrigation canals and ditches to the valley-fill aquifer system does not appear to be substantial in Ogden Valley. Many of the ditches serve as drains, particularly around Eden and east of Huntsville. During the summer of 1985, seepage to the aquifer system of about 4.0 cubic feet per second was measured for the Ogden Valley (or Mountain Valley) Canal from the diversion structure on the South Fork Ogden River to the tail of the canal reach about 9 miles downstream. The seepage occurred near the canal crossing at the Middle Fork Ogden River (Herbert and others, 1987, p. 7-8).

Water that is diverted from streams and used to irrigate fields also results in recharge. In a typical season, the water is applied to about 7,000 acres from late April to early October. Much of the diverted water is consumptively used or returned to streams, but the excess irrigation water recharges the aquifer over a wide region.

Most of the bedrock bounding the valley-fill aquifer system is not permeable except locally where fractures and solution channels are present; however, the cumulative subsurface inflow from the bedrock to

the valley-fill aquifer system is large because of the large area of contact between the bedrock and the valley fill. Therefore, subsurface inflow is a major source of recharge to the valley-fill aquifer system.

The principal aquifer is recharged primarily by downward movement of water near the valley margins. From the analysis of well hydrographs, Thomas (1945, p. 18-19) determined that snowmelt and part of the spring runoff infiltrated the principal aquifer along the valley margins and moved toward the center of the valley. Some recharge moving through the principal aquifer is rejected before it reaches the confined part of the system; rejected recharge probably discharges to stream channels or recharges the shallow water-table aquifer that overlies the confined part of the principal aquifer.

Locally near the Ogden well field, water from the Pineview Reservoir probably recharges the confined aquifer. In this area, the vertical hydraulic gradient is downward because of the drawdown that results from pumping.

Movement

The potentiometric surface of the principal aquifer during June 1985 is shown in figure 11. The direction of ground-water flow generally parallels the land surface; water flows from the valley margins toward Pineview Reservoir in the southern part of the valley. The hydraulic gradient ranges from about 15 feet per mile near Pineview Reservoir to about 80 feet per mile in the northern part of Ogden Valley.

Vertical head gradients have been detected throughout the valley-fill aquifer system. Generally, gradients are downward in the recharge areas and upward in the discharge areas. Near the recharge area along the upper South Fork Ogden River, a downward vertical head gradient in the unconfined part of the principal aquifer is evident by comparing water levels in wells (A-6-2)21abc-1 and 2 (fig. 12). The water level in the deeper well [(A-6-2)21abc-2] is as much as 10 feet lower than the water level in the shallower well [(A-6-2)21abc-1].

A downward vertical head gradient in the confined part of the principal aquifer is evident near the Ogden well field by comparing water levels from a multiple-completion well at (A-6-1)11cab-1 (fig. 13). During the low stage of Pineview Reservoir, the difference in water levels in the shallow and deep wells is as much as 6 feet at this site. The depths of completion for these wells are shown in table 7.

Hydraulic Characteristics

The quantity of water an aquifer can store depends partly on its thickness. The thickness of the valley-fill deposits (fig. 5) was estimated with a combination of electrical resistivity soundings made in 1986 and well-log descriptions. The Norwood Tuff underlies the valley-fill deposits throughout most of the valley and has a resistivity that sharply contrasts with that of the overlying valley-fill deposits. The valley-fill deposits are more than 750 feet thick along the east-bounding fault zone northeast of Huntsville. The deposits also are relatively thick near Liberty where they appear to be underlain by carbonate rocks.

Aquifer tests of the valley-fill aquifer system were conducted during this study because results from previous aquifer tests were not available. A long-term aquifer test of the confined part of the principal aquifer was conducted using wells in the Ogden well field. Well (A-6-1)11cab-3 was pumped for 4 days and allowed to recover for 4 days. Water-level measurements were made in the pumped well and in seven observation wells during the pumping and recovery periods. Three similar transmissivity values were obtained from the test. Storage coefficient values could not be determined because soon after pumping started, boundary effects were observed in the water-level response in the observation wells.

Results from the aquifer test are as follows:

Characteristics obtained from an aquifer test of the confined part of principal aquifer, October 3-10, 1985

[Boundary: D, discharge image; R, recharge image]

Location	Distance from pumped well (feet)	Transmissivity (feet squared per day)		Distance from pumped well to boundary (feet)	
(A-6-1)10aac-1	3,000	No drawdown	—	—	
(A-6-1)10dda-1	2,800	Indeterminate	4,900 D	6,300 D	
			9,900 R	—	
(A-6-1)11acb-1	1,600	No drawdown	—	—	
(A-6-1)11cab-1	125	83,000	530 R	5,600 D	
(A-6-1)11cab-3	—	79,000	—	—	
(A-6-1)11cba-2	475	87,000	4,500 D	—	
(A-6-1)11dcd-2	3,050	Indeterminate	5,300 D	5,800 D	
			6,700 D	6,800 R	
(A-6-2)18bad-1	11,300	Indeterminate	30,000 D	38,000 D	

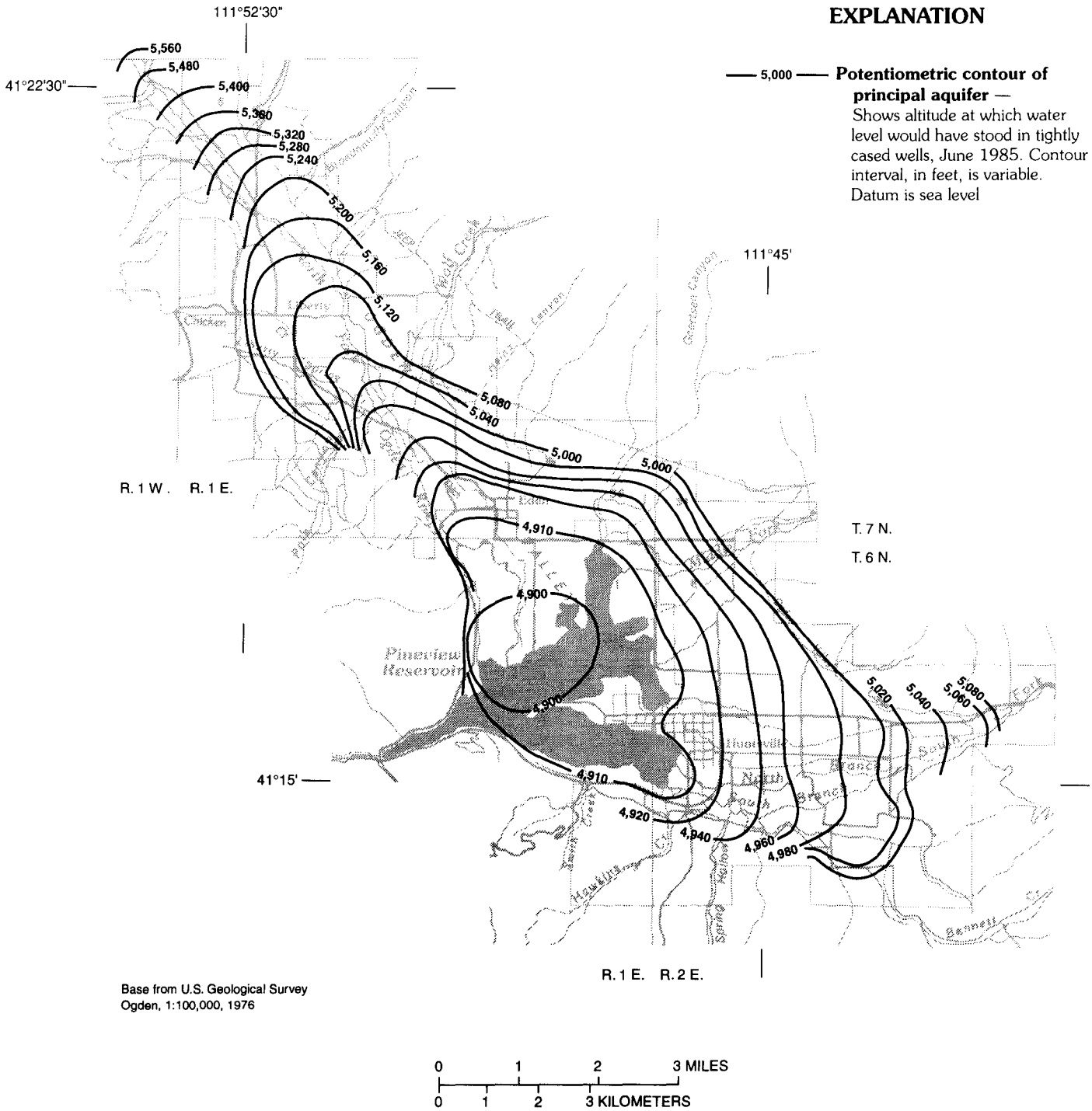


Figure 11. Potentiometric surface of the principal aquifer, June 1985.

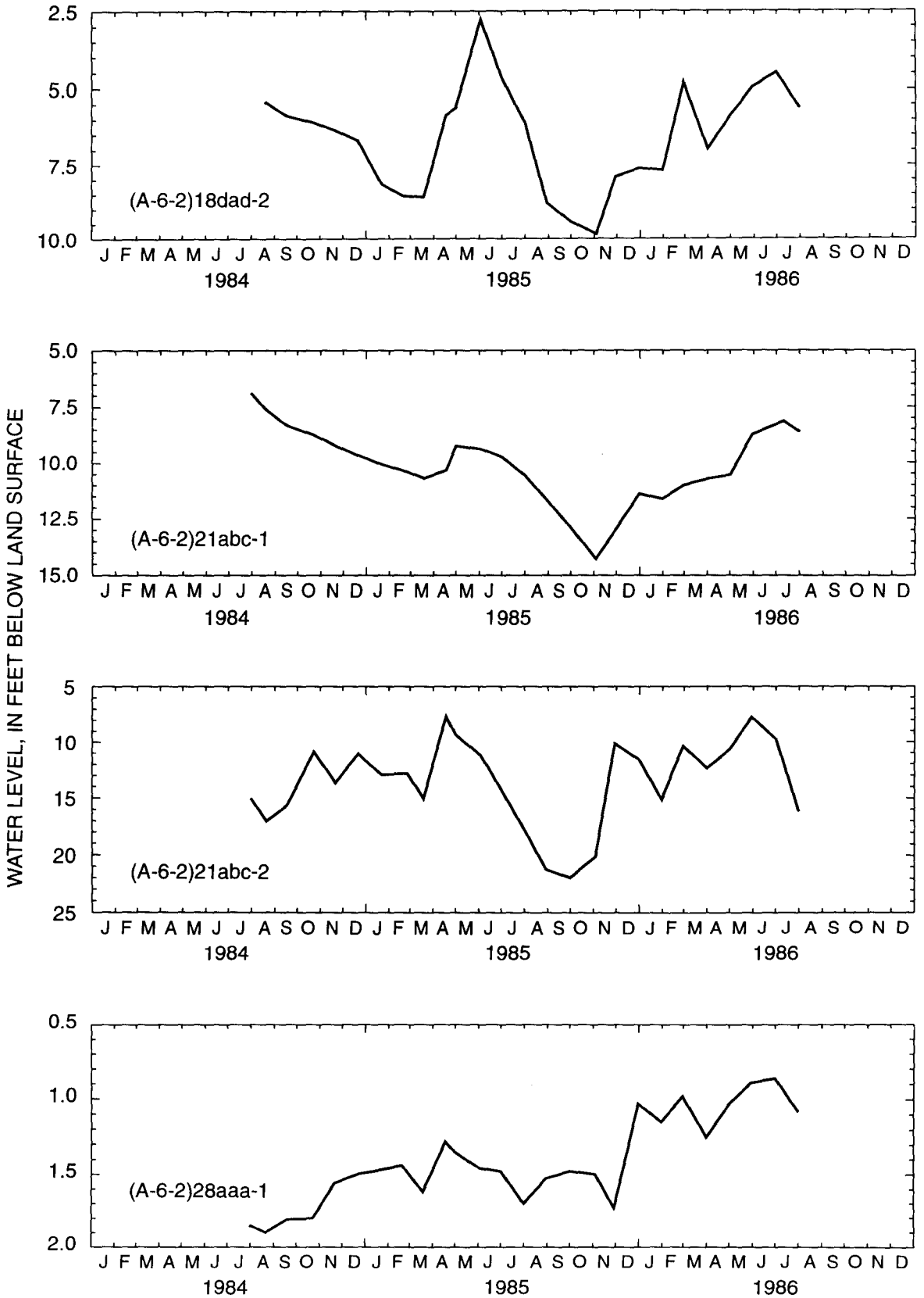


Figure 12. Water level in wells in the upper South Fork Ogden River valley, 1984-86.

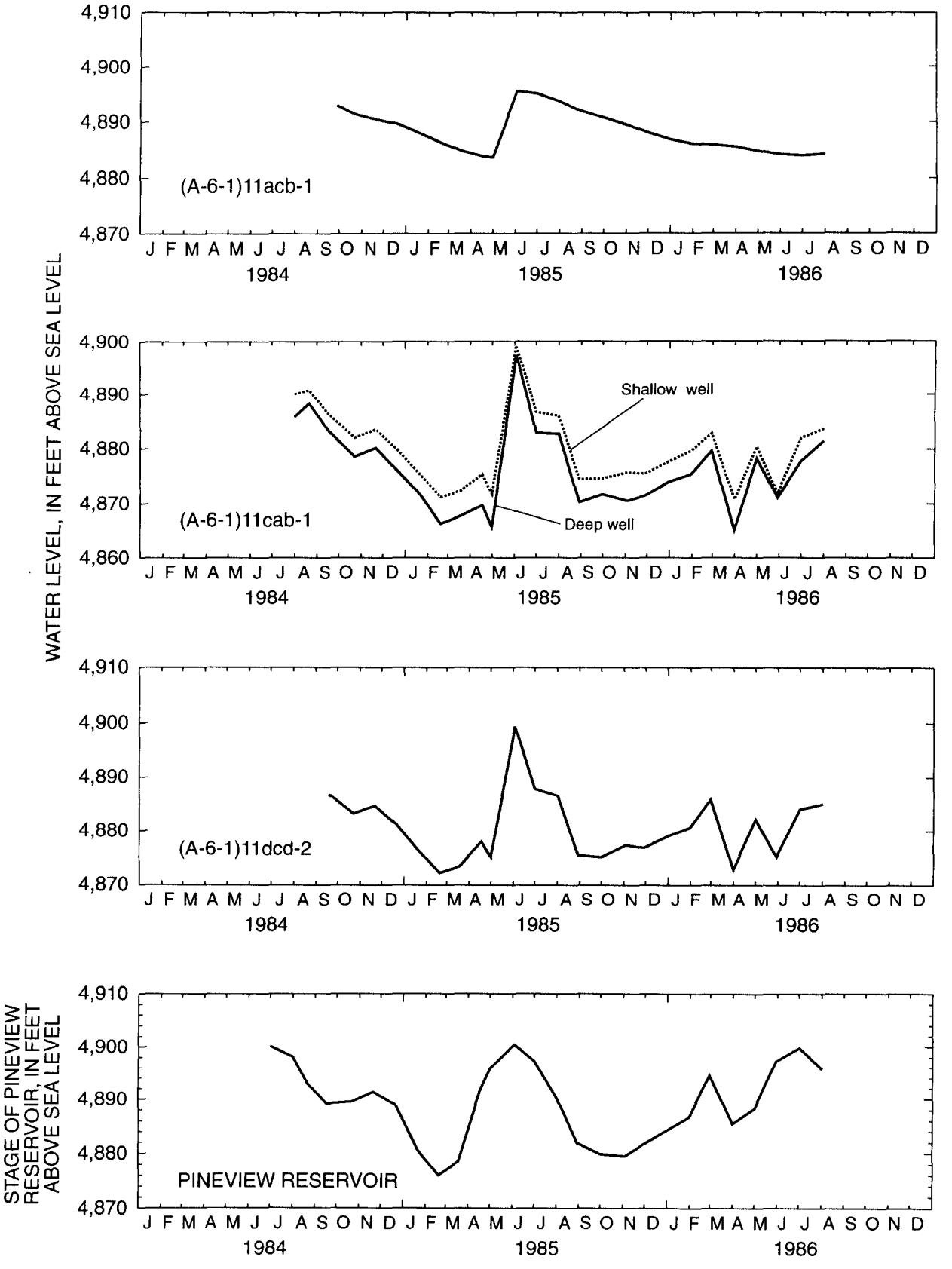


Figure 13. Water level in wells near the Ogden well field and Pineview Reservoir, and stage of Pineview Reservoir, 1984-86.

Drawdown data were analyzed from the observation wells; recovery data were analyzed from the pumped well. The early-time data, before boundary effects occurred, were analyzed with the straight-line solution to the Theis equation (Lohman, 1972, p. 23-27). The apparent transmissivity determined from the observation wells increased with increased distance from the pumped well. The apparent increase in transmissivity indicated that leakage was occurring through the confining layer. Thus, the transmissivity of about 79,000 feet squared per day determined from the pumped well probably is the most representative value for the aquifer.

The boundary effects that occurred during the aquifer test also were interpreted. The distances to the discharge image and to the recharge image were estimated with the image-well theory (Lohman, 1972, p. 59-61). An impermeable boundary that coincided with the concealed fault zone on the west side of the valley at the mouth of Ogden Canyon (pl. 1) was defined. An additional impermeable boundary oriented in a northwest direction was defined on the east side of the well field. This boundary was interpreted as a previously unknown fault (pl. 1). The two observation wells that did not show any drawdown are on the opposite side of the faults from the pumped well. The coincidence of faults with impermeable boundaries indicates that flow through the aquifer is retarded by the faults.

Several short-term aquifer tests were conducted on five different wells, each of which was pumped for 1 hour. The drawdown in each pumped well was analyzed with the straight-line solution to the Theis equation (Lohman, 1972, p. 23-27). All of the short-term aquifer tests apparently were affected by drainage from the gravel pack in the well annulus. In the following table, the first transmissivity value listed was determined from the early part of the test, and the second value was determined from the later part of the test. The transmissivity values have not been adjusted for partial penetration and perforated interval of the well.

Specific-capacity values determined from the well discharge and water-level declines given on well-drillers' reports submitted to the Utah State Engineer's Office are shown in table 7. The specific-capacity values ranged from less than 0.1 to 125 gallons per minute per foot of drawdown.

Transmissivity values determined from 1-hour aquifer tests

[Transmissivity: First value determined from early part of aquifer test; second value from later part of aquifer test]

Location	Transmissivity (feet squared per day)	Time of boundary effect (minutes)	Discharge (gallons per minute)
(A-6-2)15acb-1	140; 110	6	33
(A-7-1)8cad-1	40; 15	20	16
(A-7-1)19aad-1	310; 50	14	23
(A-7-1)28baa-1	30; 15	13	8.2
(A-7-1)34aca-1	20; 480	7	13

The confining layer between the principal aquifer and the shallow water-table aquifer in Ogden Valley extends over an area of about 10 square miles in the southern part of Ogden Valley (Leggette and Taylor, 1937, pl. 36). Leggette and Taylor (1937, p. 110) described samples of the confining layer as thin layers of dense, sticky, putty-like clay and silt, usually grayish-blue and brown. Lofgren (1955, p. 81) indicated that the confining layer commonly is silt and fine sand. Maximum thickness of the layer is about 100 feet; average thickness is about 70 feet (Thomas, 1945, p. 8). The stream channels that were inundated by Pineview Reservoir were entrenched about 25 feet into the confining layer.

Laboratory tests on samples of the confining layer indicated hydraulic-conductivity values of less than 0.013 foot per day (Leggette and Taylor, 1937, p. 137). Reservoir-bed seepage measurements made in July 1986 with a method described by Lee (1977) indicated that vertical hydraulic conductivity ranged from 0.01 to 0.04 foot per day. These values are typical for silt beds and indicate that the layer is a leaky confining layer.

Along the now-inundated stream channels, the confining layer is relatively thin, and upward leakage to Pineview Reservoir may be substantial. Before the reservoir was constructed, springs and seeps were common in the stream valleys along the contact of the confining layer and the overlying sand layer comprising the shallow water-table aquifer (Leggette and Taylor, 1937, p. 136).

The water level in well (A-7-1)34aca-1, completed at a depth of 144 feet, does not seem to be affected by the presence or absence of water in a nearby canal. Thus, the confining layer may exist farther north than is indicated in previous reports, to about 1 mile

northwest of Eden in the North Fork Ogden River drainage.

Storage

Historic changes in storage, as indicated by long-term water-level measurements, can be attributed predominately to man-induced changes in the hydrologic regime. The most prominent change is the impoundment of water in Pineview Reservoir. Filling of the reservoir began in 1936, and capacity was reached in 1938. In 1957, Pineview Reservoir dam was raised 30 feet. Maximum storage capacity in the enlarged reservoir was reached in 1962. These changes mostly affected water levels in the confined part of the principal aquifer. The long-term water-level rise in wells near the reservoir averaged 10 to 15 feet. Seasonal changes in water levels typically were 15 to 25 feet (figs. 14, 15, and 16).

In the upper South Fork Ogden River valley, water levels fluctuated a maximum of about 26 feet in 1986 (fig. 17). In the North Fork Ogden River valley, water-level fluctuations were as much as 15 feet in 1985 (fig. 18). The lowest ground-water levels near the major stream channels occurred in the late fall as streamflow continued to be diverted for irrigation (fig. 19).

The water-level rise in the principal aquifer from late February to early June 1985 is shown in figure 20. The largest water-level increases in the principal aquifer occurred beneath Pineview Reservoir, in the North Fork Ogden River valley near Liberty, and east of Huntsville. The large water-level changes in the confined part of the principal aquifer do not represent large volume changes because of the small storage coefficient. The storage coefficient of the confined part of the principal aquifer is assumed to be 0.0001. The specific yield of the unconfined part of the principal aquifer is assumed to be 0.10. Because of water-level changes in the spring of 1985, the quantity of water added to storage in the entire unconfined part of the principal aquifer was about 8,900 acre-feet. The quantity of water added to storage in the confined part of the principal aquifer during this same period was about 8.5 acre-feet.

Water levels in the shallow water-table aquifer typically fluctuate 10 to 15 feet during the year (fig. 21). The quantity of water added to storage in the spring of 1985 in the shallow water-table aquifer is estimated to be 4,600 acre-feet.

Discharge

Ground-water discharge occurs by seepage to streams, springs, drains, and Pineview Reservoir; by well discharge; and by evapotranspiration. Each of these is important in the water balance during some part of the year.

Few data are available for the water discharged naturally from the aquifer to the streams in Ogden Valley. Spring Creek is east of Huntsville along the margin of the confining layer that overlies the principal aquifer, and the creek derives most of its flow from ground water. The average flow of Spring Creek ranged from 7.0 to 9.4 cubic feet per second from November through February of water years 1958-65. This flow likely represents ground-water discharge to the creek.

Observations of streamflow in Bennett Creek by Browning (1925) indicated that the creek was dry from July until sometime in the late fall. Now, the creek flows perennially, with much of the summer flow probably derived from irrigation return water. A flow of 8.9 cubic feet per second was measured in February 1985 just upstream from the confluence of Bennett Creek with Bally Watts Creek (table 4). Part of this flow represents discharge from the Wasatch Formation.

Liberty Springs, (A-7-1)19dbc-S1 (table 6), and Liberty Spring Creek derive most of their flow from ground-water seepage, but long-term discharge has not been measured. Liberty Spring Creek was measured in February 1985 just above its confluence with the North Fork Ogden River. A flow of 13 cubic feet per second was measured (table 4).

The original Ogden artesian well field consisted of 46 flowing wells located just north of the juncture of the three forks of the Ogden River. The first well was drilled in 1914. The artesian well field was inundated by Pineview Reservoir in 1936 but continued to be used until 1970. Because of contamination problems from iron bacteria entering either the underwater pipeline or the wells, the artesian well field was abandoned, and six replacement wells were drilled on the nearby shore of the reservoir. The wells at the new location have to be pumped to yield water. Pumpage from the Ogden well field from 1970 to 1985 averaged 10,290 acre-feet per year or about 14.2 cubic feet per second.

Many wells in Ogden Valley are used for domestic purposes and for stock water. Lately, many new wells have been permitted in Ogden Valley for individual domestic use. Wells also are used by small community systems to provide water to individual housing

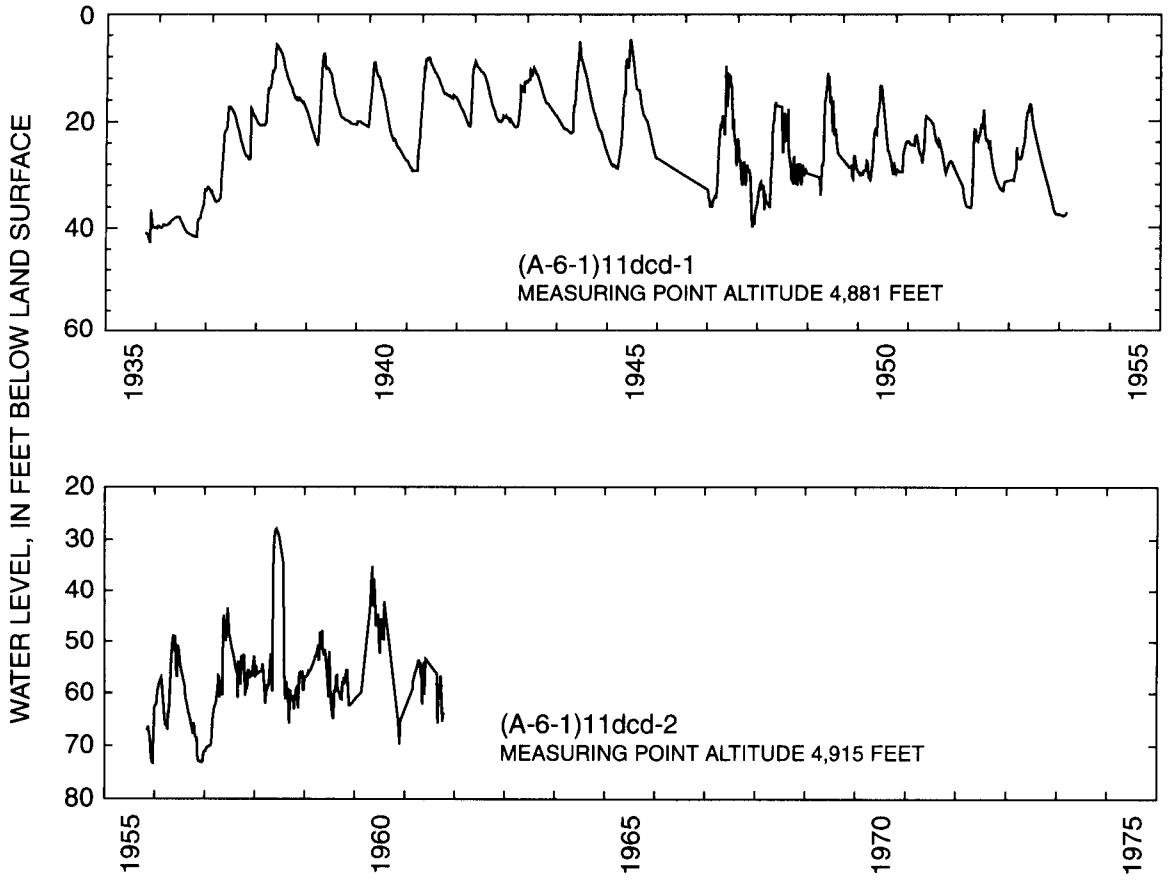


Figure 14. Water level in wells in the principal aquifer near Pineview Reservoir, 1935-61.

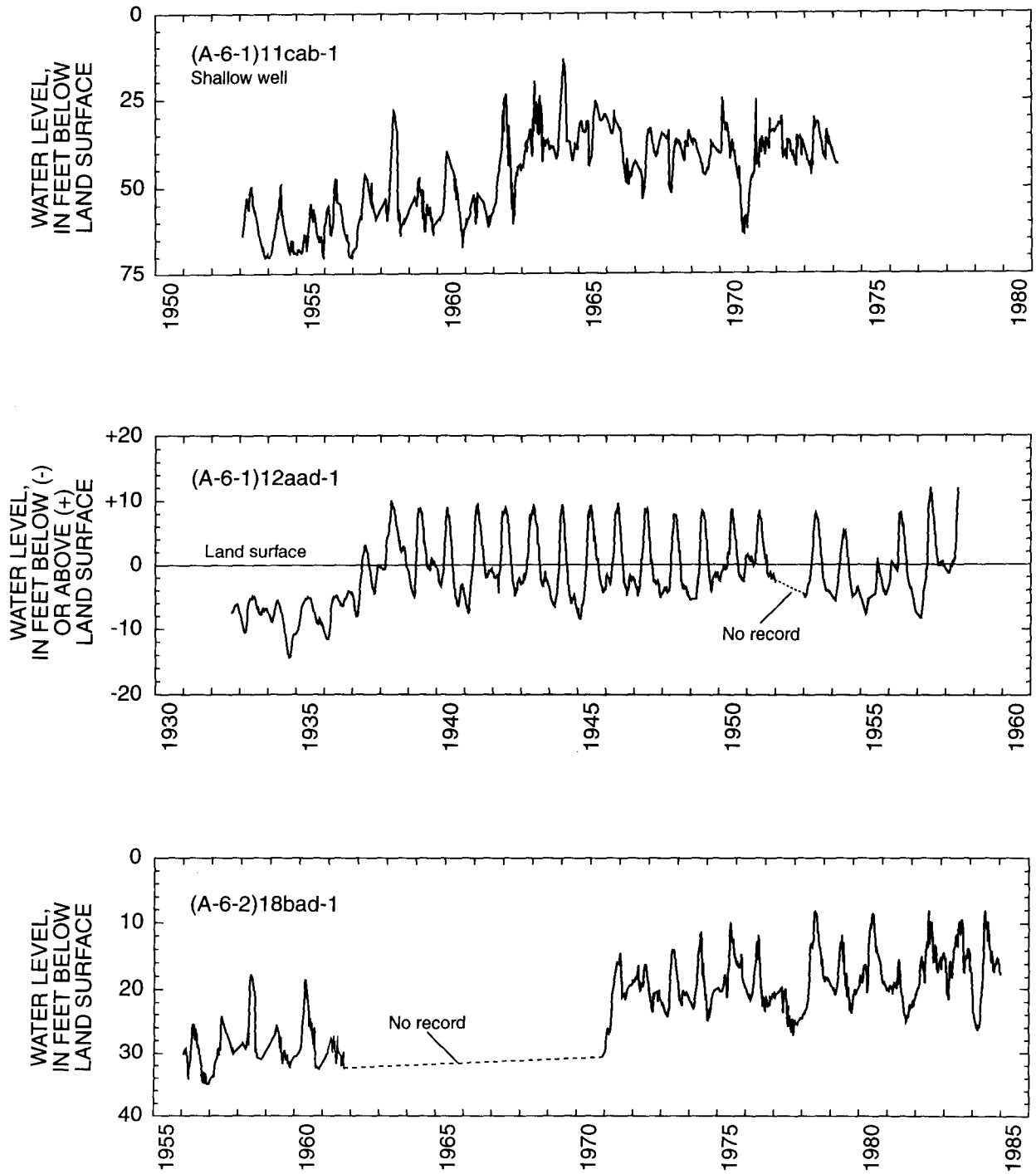


Figure 15. Water level in wells in the principal aquifer near Pineview Reservoir, 1932-84.

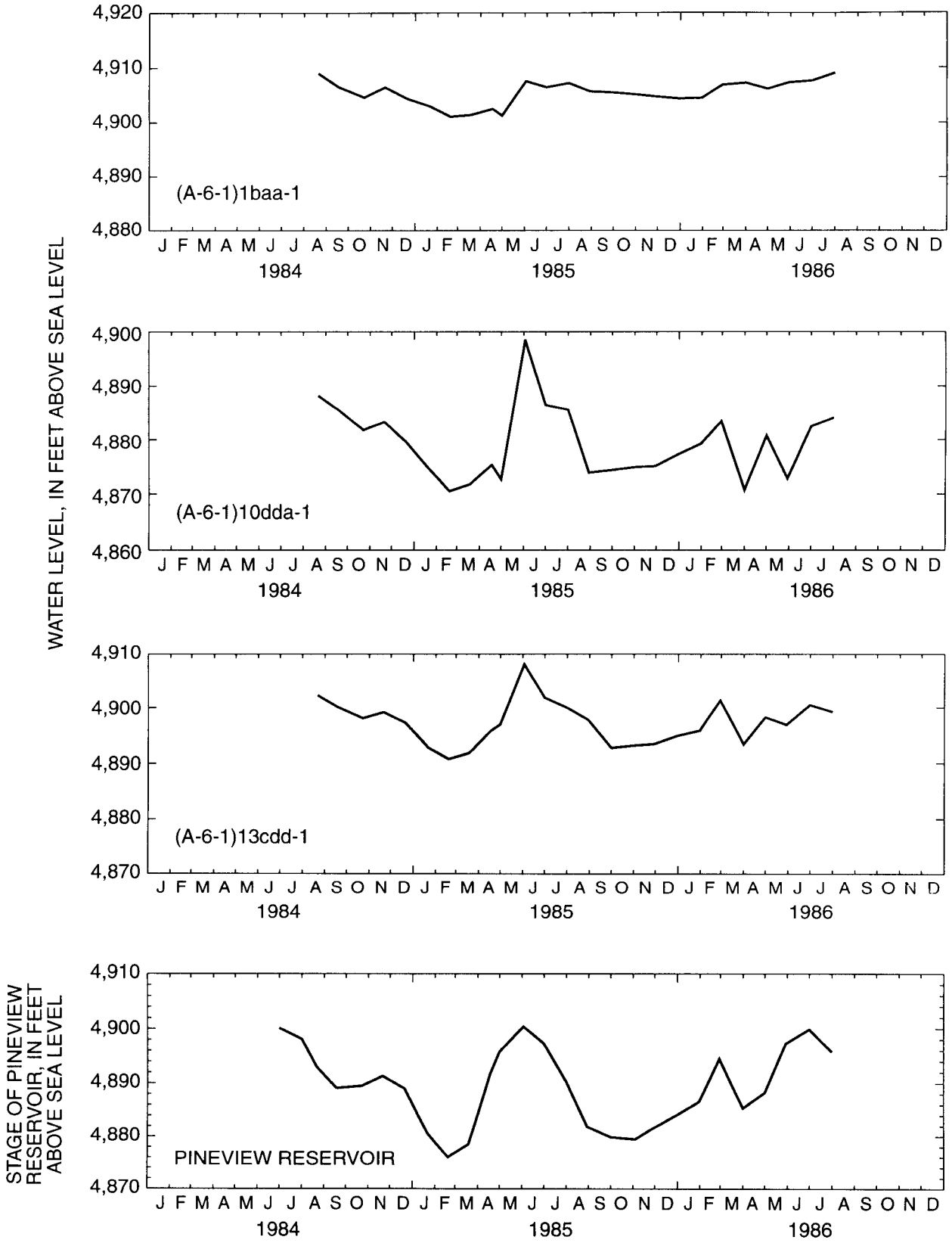


Figure 16. Water level in wells in the principal aquifer, and stage of Pineview Reservoir, 1984-86.

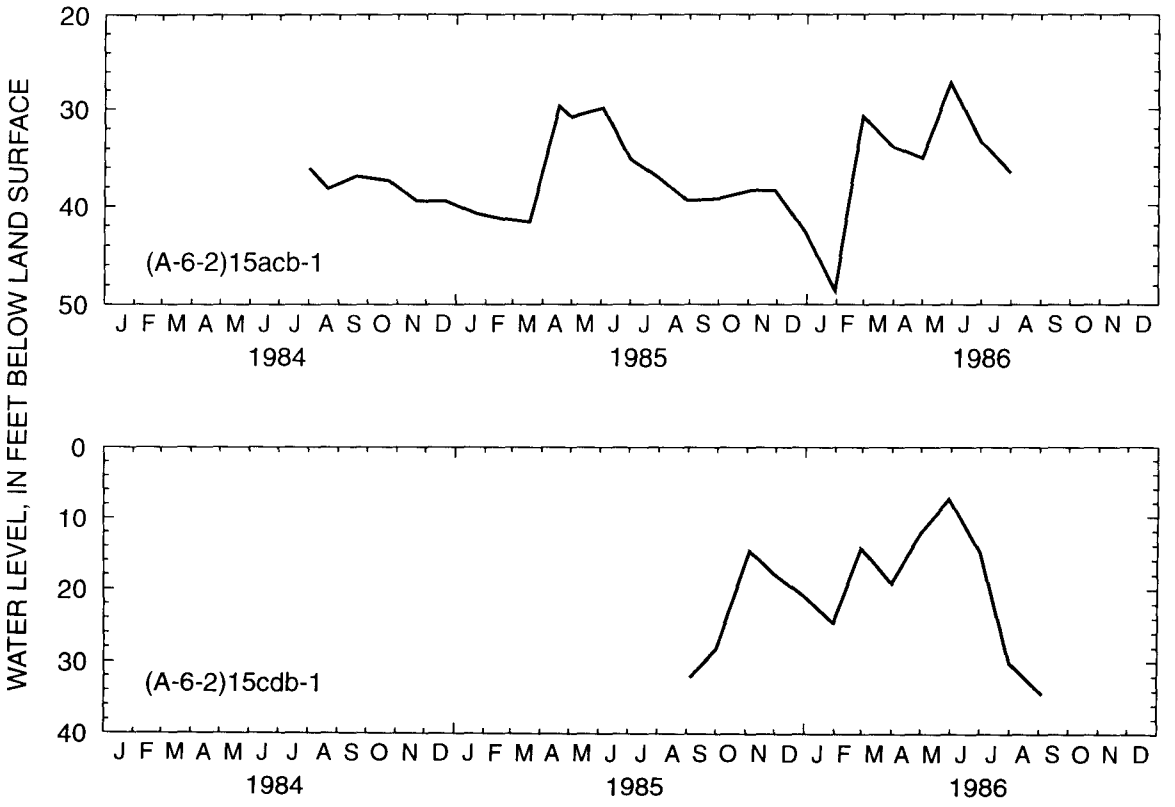


Figure 17. Water level in wells in the upper South Fork Ogden River valley, 1984-86.

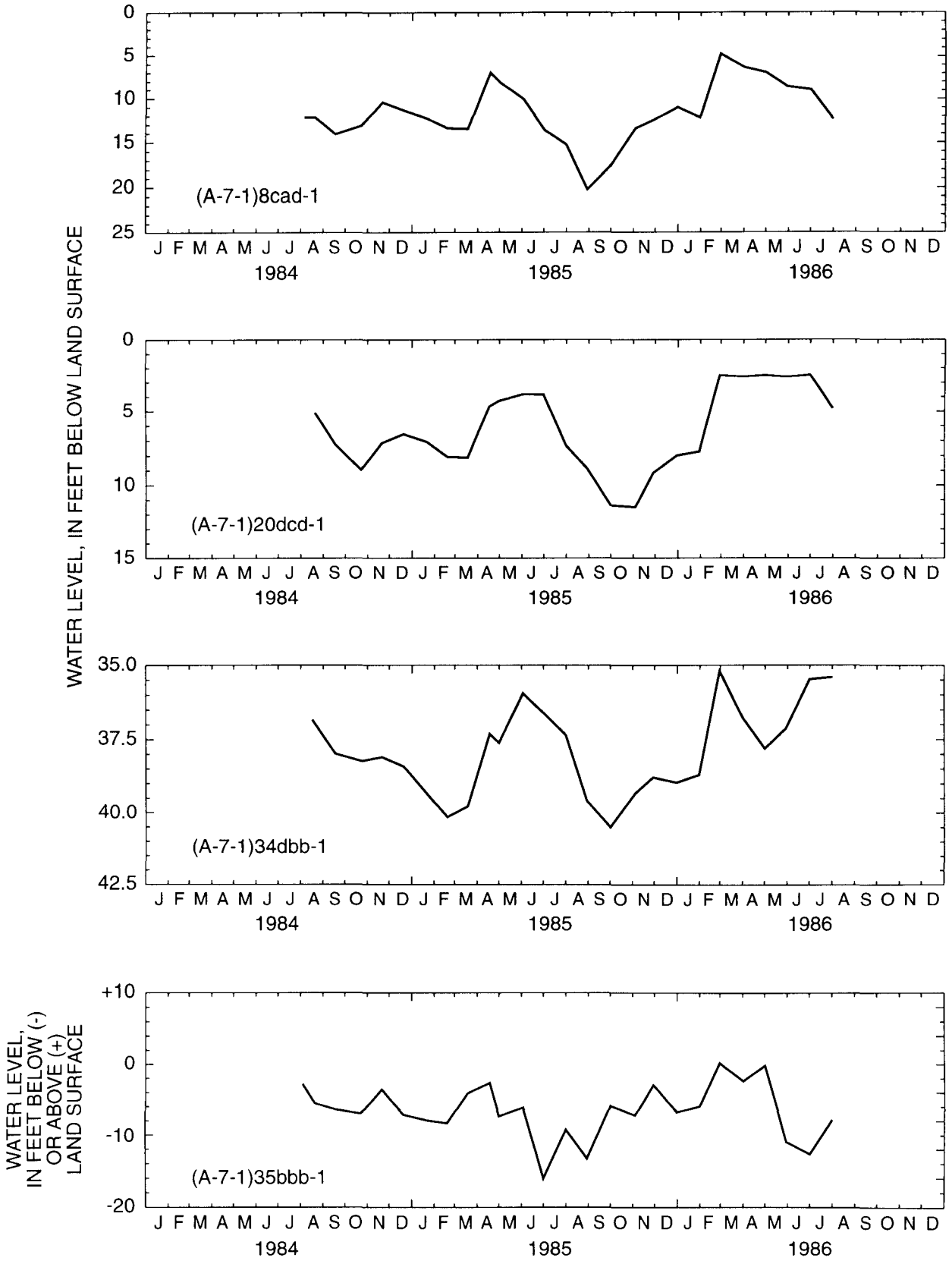


Figure 18. Water level in wells in the North Fork Ogden River valley, 1984-86.

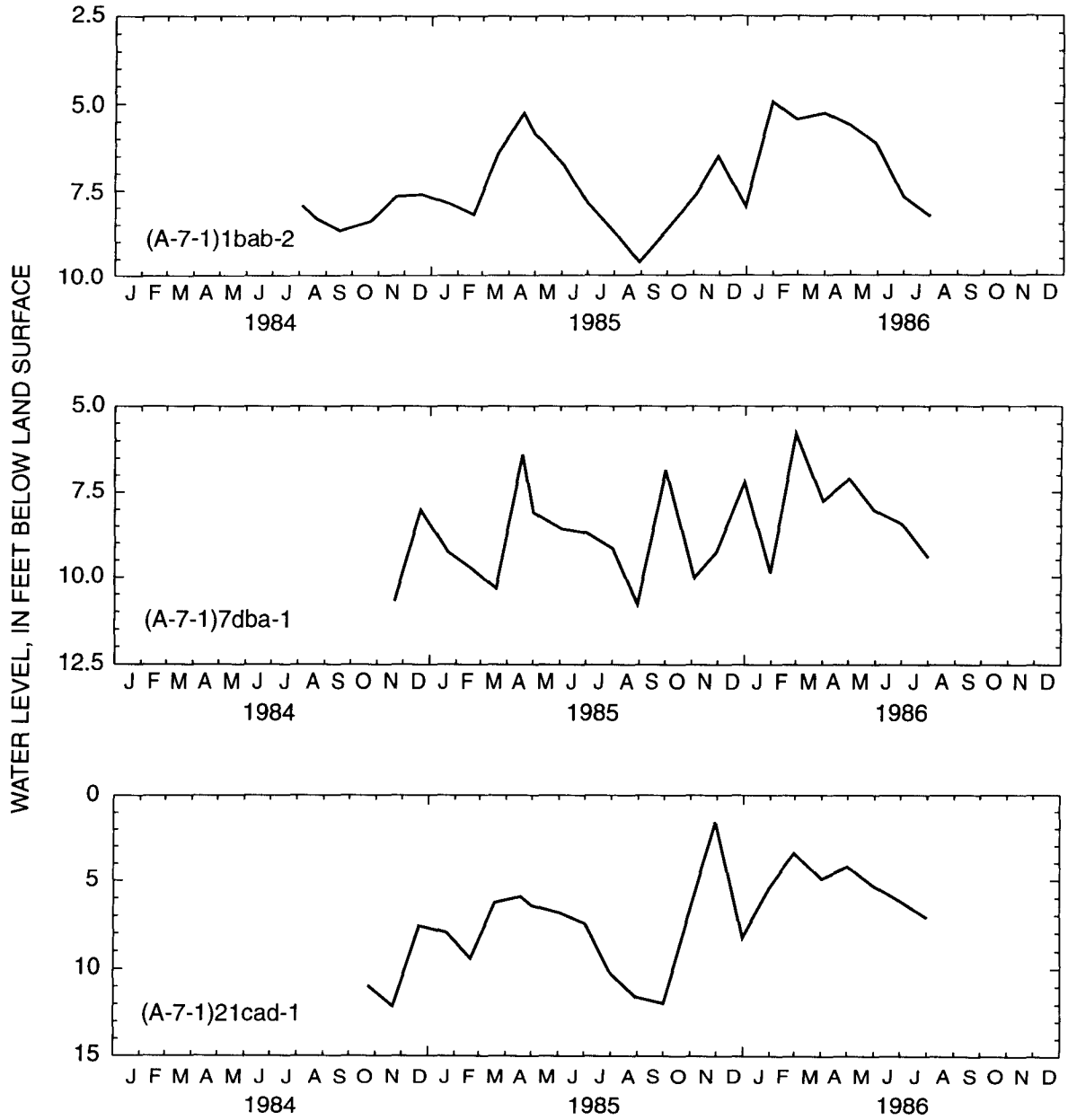


Figure 19. Water level in wells in the North Fork Ogden River channel, 1984-86.

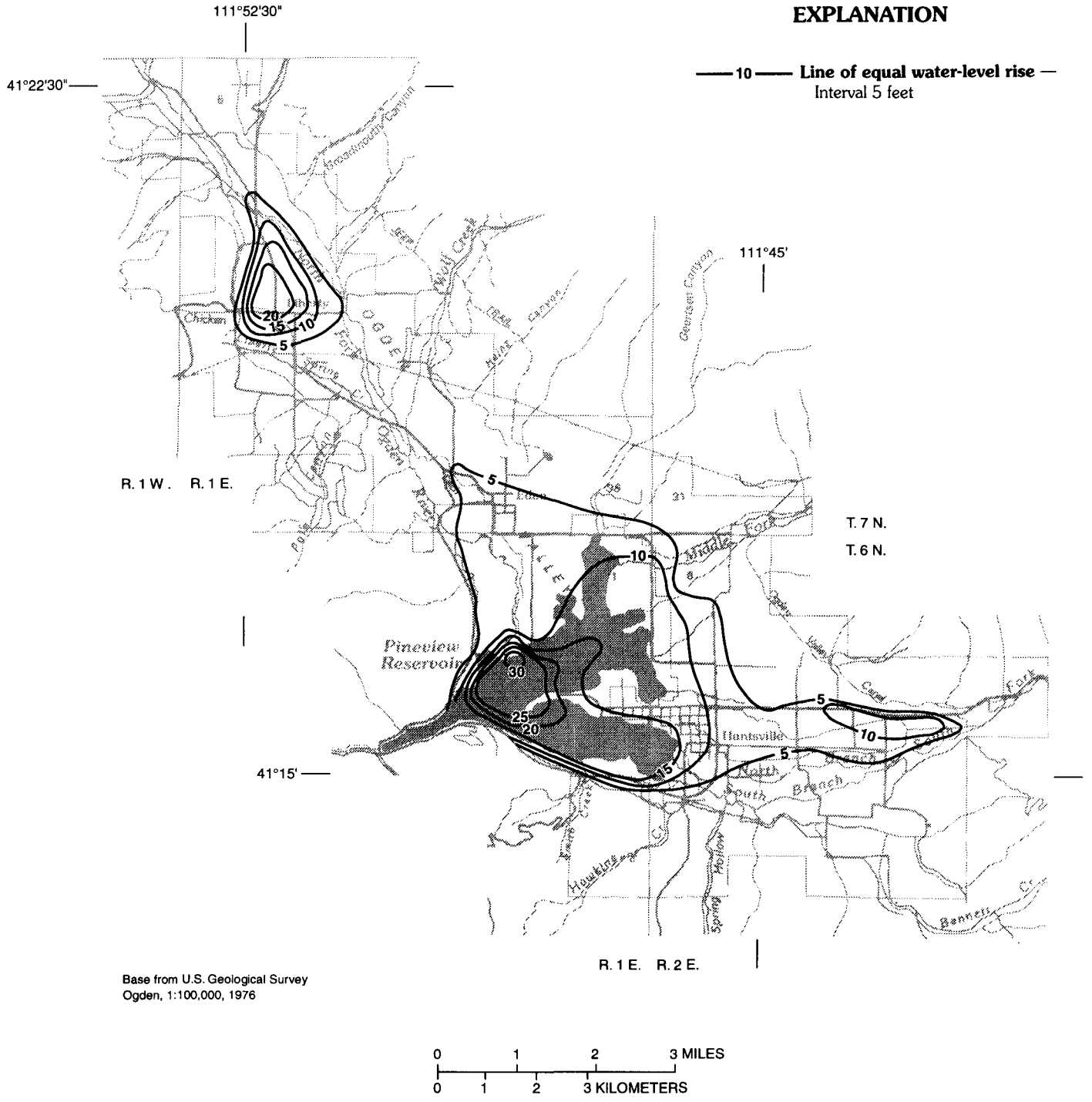


Figure 20. Water-level rise in the principal aquifer from late February to early June 1985.

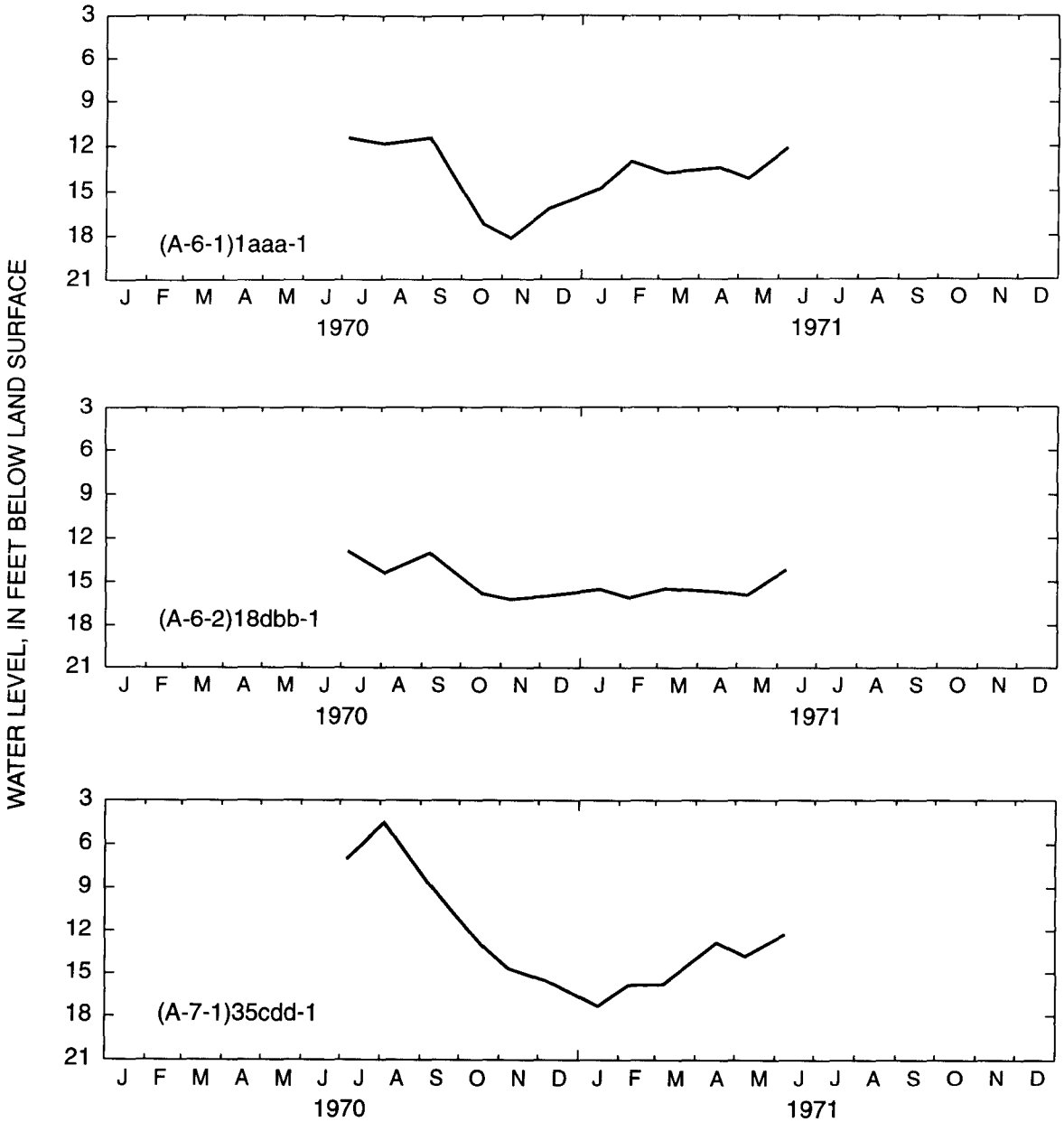


Figure 21. Water level in wells in the shallow water-table aquifer, 1970-71. (Data collected by V. Doyuran.)

tracts. There may be as many as 2,000 small-yield wells in the valley, although it is not known how many actually are used. The greatest concentration of individual wells is east of Huntsville.

Crops, natural phreatophytes, and other vegetation transpire water. Crops grown in Ogden Valley include alfalfa; spring grains (wheat, barley, oats); corn; and grass pasture. Major phreatophytes are cottonwoods, willows, and cattails. Other vegetation includes big sagebrush, gamble oak, and various grasses. The area covered by naturally occurring phreatophytes and subirrigated cropland is about 4,100 acres. Of this area, 1,450 acres has more than a 50-percent density of cottonwoods and willows. Cottonwoods, willows, and cattails consume an average of 5.1 feet of water per year; grasses and small phreatophytes consume an average of 2.1 feet of water per year (Feth and others, 1966, p. 69). These rates were determined for the East Shore area of Great Salt Lake assuming 100-percent density.

The annual consumptive use in Ogden Valley by the phreatophytic vegetation and subirrigated cropland was determined using the above rates and assuming 100-percent density for grasses and associated plant communities and 80-percent density for cottonwoods and willows. The estimated annual consumptive use is about 11,500 acre-feet. Doyuran (1972, table 13) estimated annual evapotranspiration by crops and vegetation at 20,000 acre-feet.

Effects of Pineview Reservoir

After its construction in 1936, Pineview Reservoir affected the ground water of Ogden Valley, especially in the confined part of the principal aquifer. The southern part of Ogden Valley was marshy before construction of the dam. All leakage from the principal aquifer was upward to the land surface and either was consumed by evapotranspiration or ran off in stream channels. After the dam was completed, upward leakage from the principal aquifer flowed into the reservoir and was released downstream or evaporated. The natural discharge of ground water from exposures of the valley-fill deposits in the southern part of Ogden Valley was captured by Pineview Reservoir. Natural discharge before completion of the reservoir was estimated to be less than 5 cubic feet per second (Leggette and Taylor, 1937, p. 139). Flowing-well discharge in the area inundated by the reservoir, except for the Ogden well field, was shut off as a result of a U.S. Bureau of Reclamation plugging program.

Because the area inundated by Pineview Reservoir is completely underlain by the confining layer, the early perception was that hydraulic connection between Pineview Reservoir and the confined aquifer did not exist (Leggette and Taylor, 1937, p. 143-144). The observed effect of Pineview Reservoir on water levels was attributed to mechanical loading of the confined part of the principal aquifer resulting from the weight of surface water in the reservoir. Water levels at the maximum springtime level in well (A-6-1)12aad-1 increased about 14 feet shortly after the initial filling of the reservoir in 1938 (fig. 15). Maximum water levels in well (A-6-2)18bad-1 increased about 10 feet after the reservoir filled to its expanded storage capacity in 1962.

It is now thought that loading had an initial effect on the water levels in the principal aquifer and that upward leakage to Pineview Reservoir from the confined part of the principal aquifer controls ground-water levels. Leakage through the confining layer is driven by the difference in water levels between Pineview Reservoir and the confined part of the principal aquifer. A seepage rate to Pineview Reservoir ranging from 0.17 to 0.20 foot per day was measured at three sites (pl. 2) by use of seepage meters installed underwater on the lakebed in July 1986. The seepage was assumed to be moving upward through the confining layer in the bottom of Pineview Reservoir.

Most water movement is upward into Pineview Reservoir, but some downward leakage may occur near the current Ogden well field because water levels in the wells usually are below the stage of Pineview Reservoir (fig. 13).

Water Quality

Selected drinking-water standards set by the U.S. Environmental Protection Agency (USEPA) (1986) for human health are:

Dissolved solids concentration	should not exceed 250 milligrams per liter for chloride and sulfate
Iron	should not exceed 300 micrograms per liter
Manganese	should not exceed 50 micrograms per liter
Nitrate and nitrite	should not exceed 10 milligrams per liter

Fluoride	should not exceed 1.4 to 2.4 milligrams per liter depending on air temperature
pH	should be between 5.0 to 9.0
Fecal coliform bacteria	should not exceed 1 count (or colony) for every 100 milliliters of water

Analyses of water samples from wells in the valley-fill aquifer system are shown in table 8 and analyses from springs are shown in table 9. Water quality of the samples collected in 1985 is diagrammatically shown on plate 2. Few water samples have been collected in Ogden Valley by the U.S. Geological Survey since the 1950's. In 1971, Doyuran (1972) collected and analyzed water samples. In general, dissolved-solids concentration of water in the valley-fill aquifer system does not exceed 350 milligrams per liter, and most of the water is a calcium-bicarbonate type. Wells that have other than a calcium bicarbonate type water are (A-6-2)7ddb-1 and (A-7-1)28baa-1, which have a calcium-sodium bicarbonate type water; (A-7-1)29ada-1, which has a calcium-magnesium-bicarbonate type water; and (A-6-2)21acd-1 and (A-7-1)8cad-1, which have a calcium-magnesium-sodium-bicarbonate type water.

Generally, ground water in the North Fork Ogden River valley is characterized by small dissolved-solids concentrations. Slightly more mineralized ground water is present in the Middle Fork Ogden River and South Fork Ogden River valleys. Analyses by Doyuran (1972) generally correspond with this distribution.

The water type shown for each analysis in table 8 was determined from values converted from the actual concentrations of each ion, in milligrams per liter, to a value in milliequivalents per liter. This conversion makes all of the ions chemically equivalent by adjusting for different molecular weights and electrical charges. More than 50 percent of a single cation or a single anion, in milliequivalents per liter, indicates predominance of that ion; otherwise, percentages for each of the predominant cations and anions are added together until the combination is greater than 50 percent.

Analyses for nitrate are shown in tables 8 and 9. Water from one well, (A-6-2)6dad-1, had a nitrate concentration that exceeded the USEPA standards for drinking water.

Analyses for MBAS (Methylene-Blue Active Substances), which is an indicator of manmade surfactants or sudsing agents, are shown in table 9. Analyses for MBAS were used to determine if ground-water seepage from the base of hillsides on the north and south sides of Huntsville originates, in part, from septic tank outflow. The concentration of surfactants in untreated wastewater would be about 8 to 10 milligrams per liter (Duthie, 1972, p. 341); however, the MBAS values of 0.03 milligrams per liter for seepage samples indicate that little of the seepage is derived from septic tank outflow.

Water from two wells sampled by Doyuran (1972) had a concentration of nitrate in excess of the USEPA recommended limit of 10 milligrams per liter. One sample was from a shallow well southeast of Eden and the other was from a well south of Liberty. Water from wells sampled by Doyuran (1972) near well (A-6-2)6dad-1, which was sampled for this study, had elevated nitrate concentrations but did not exceed 10 milligrams per liter. The large nitrate concentration in water from the well southeast of Eden could be derived from chemical fertilizer because water from that well did not show a high coliform count; however, unsatisfactory counts of coliform were found by Doyuran (1972) in water from the well south of Liberty and in water from the wells near well (A-6-2)6dad-1.

Water that has a pH value of less than 7.0 may cause pipe corrosion and solubility of trace elements from natural sources into the water. Water samples from two wells, (A-7-1)7dba-1 and (A-7-1)17bcb-1, had pH values of less than 7.0, which indicate an area where the water recharging the aquifer is slightly acidic. Larger-than-typical concentrations of some trace elements may occur in water in this area because trace elements have greater solubility at small pH values. However, iron and manganese, the only trace elements analyzed for in this study, were not detected in unusually large concentrations. The concentration of dissolved iron approaches 300 micrograms per liter in two wells, (A-6-2)28aba-1 and (A-7-1)7dba-1, but does not exceed the USEPA recommended limit.

Because snowmelt recharges the aquifer, the pH of snow in the valley was measured at three locations in January 1985. Cores that were 2 inches in diameter and about 3 feet long were taken from the snowpack at least 500 feet from any road. The snow was melted slowly in sealed tubes for 2 days before the pH measurement was taken. The specific conductance of all snowmelt samples was below detection on the conductance meter, which had a minimum scale reading of 1.0 microsiemen per liter. The pH values of the snowmelt samples are as follows:

pH values of snowmelt

Sample location	pH value (standard units)	General site description
Lat. 41° 21' 27" N., long. 111° 52' 47" E	5.2	Near well (A-7-1) 7dba-1
Lat. 41° 19' 22" N., long. 111° 49' 38" E	6.7	Near well (A-7-1)27baa-1
Lat. 41° 14' 01" N., long. 111° 43' 26" E	6.2	Near well (A-6-2)28aaa-1

According to Messer and others (1982, fig. 2), the pH value of 5.2 is low for snowmelt in the region. This pH value was determined for the snowmelt sample collected near well (A-7-1)7dba-1, which yielded the smallest pH value of all samples from wells (table 8).

The temperature of all ground-water samples exceeded 7.0 °C, which is about the annual mean air temperature for Ogden Valley and the temperature to which shallow ground water usually equilibrates. Ground water from well (A-6-2)16bad-1 had a temperature of 14.0 °C (table 8). This well is in the area where Doyuran (1972) measured the highest water temperature. The elevated temperatures indicate deep circulation of ground water in the valley-fill aquifer system. Because the highest temperatures are along the projected east-bounding fault zone, it is possible that upwelling of warm water from the bedrock along the fault is contributing to the elevated water temperatures in the valley-fill aquifer system.

Iron bacteria in Ogden wells was first recorded in 1951, but a sudden worsening of the problem occurred in 1964 (Doyuran, 1972). At that time, the artesian well field was located under Pineview Reservoir and was inaccessible for periodic treatment, so the wells were plugged and abandoned. Replacement wells were drilled nearby above the level of the reservoir.

WATER BUDGET FOR THE VALLEY-FILL AQUIFER SYSTEM

A periodic water budget of all recharge to and discharge from the valley-fill aquifer system was prepared for mid-February 1985 through January 1986 (table 10). The time interval was divided into 12 periods that were about 30 days in duration. The budget provided estimates of seasonal variations in recharge and discharge that are large compared to annual variations. Values in the budget were used for data entry and for calibration of a ground-water model that simulated flow in the valley-fill aquifer system. Details of the model are described later in this report. Values determined on a monthly basis for each component of the water budget can vary from year to year, so the values presented in this report are unique for the indicated time period. The budget values will vary because of climatic conditions such as the time and duration of snowmelt, the summer temperature, and the quantity of precipitation.

Recharge

The valley-fill aquifer system is recharged from various sources. Each source was analyzed separately to provide detailed analysis of the ground-water-flow system.

Precipitation

Recharge from snowmelt occurs during the spring. In 1985, the snowmelt occurred from late February through early April. It was assumed that 33 percent of the total snowpack recharged the aquifer.

Recharge from rainstorms in 1985 occurred during October to December. Recharge from rainstorms was assumed to occur when the total rainfall in a storm exceeded 1.5 inches, the threshold value determined by Thomas (1952, p. 74). It was assumed that 33 percent of the net rainfall recharged the aquifer.

The areal distribution of recharge from snowmelt and rainstorms was based on the contours showing normal annual precipitation (pl. 1). The estimated rates of recharge during various periods are shown in table 10.

Irrigation and Irrigation Distribution Losses

Irrigated acreage in Ogden Valley was mapped from high-altitude, infrared aerial photographs taken in 1981. The mapping was field checked twice in 1985. During the May-July irrigation season, about 7,000 acres were irrigated. The irrigated acreage declined to about 6,400 acres in August when the small grains were harvested.

All of the irrigation water is derived from surface-water sources and springs, but the method of water application and the consequent recharge potential vary substantially. Pressurized side-roll and hand-pipe sprinkler systems and ditch and field-flooding systems are used. It is assumed for the preparation of the water

Table 8. Chemical analyses of water samples from wells

[uS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data;

Location: See figure 2 for description of data-site numbering system.
Sampling method, codes: 4040, submersible pump; 4090, jet pump; 8010, turbine pump.

Location	Date of sample	Flow rate, instantaneous (gallons per minute)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
(A-6-1) 1dad-1	09-13-85	6.2	185	7.2	12.0	88	5	83	100	27	5.1	4.0
(A-6-1)11cab-3	10-06-85	2,300	320	7.1	9.0	150	20	129	170	43	10	12
(A-6-1)11dbd-1	09-17-32	—	—	—	—	100	—	—	150	30	7.3	11
(A-6-1)11dbd-2	09-24-32	30	—	—	—	160	—	—	210	47	10	14
(A-6-1)11dbd-3	10-12-32	—	—	—	—	250	—	—	300	73	17	7.2
(A-6-1)11dcd-2	11-04-55	180	415	7.3	9.0	210	16	—	230	55	17	6.3
(A-6-1)12aad-1	10-12-32	—	—	—	—	72	—	—	210	13	9.5	47
	06-17-53	—	570	7.5	11.0	180	18	—	320	46	16	49
(A-6-1)23adb-1	04-04-60	5.0	780	9.4	13.5	10	0	—	500	4.0	<.1	[1]190
	04-06-60	175	760	8.8	—	0	0	—	510	<.1	<.1	[1]195
(A-6-2) 6dad-1	09-03-85	18	540	7.0	10.5	240	75	163	270	69	16	14
(A-6-2) 7bcc-1	09-03-85	9.0	390	7.8	12.0	160	9	151	250	46	11	22
(A-6-2) 7ddb-1	09-03-85	11	455	7.5	10.5	170	0	181	260	48	11	35
(A-6-2) 8ddb-1	09-03-85	16	360	7.1	9.5	180	7	171	200	50	13	7.3
(A-6-2)14bbd-1	09-13-85	9.0	435	7.6	9.0	210	25	187	240	57	17	14
(A-6-2)15acb-1	08-21-85	31	470	7.7	12.0	220	27	195	260	61	17	15
(A-6-2)15cdb-1	09-04-85	27	340	7.9	8.0	180	10	171	190	51	13	4.8
(A-6-2)16bad-1	09-03-85	5.8	440	7.6	14.0	220	28	191	250	63	15	10
(A-6-2)17cca-1	08-29-85	7.8	370	7.8	9.0	190	14	176	210	53	14	7.2
(A-6-2)17dac-1	09-03-85	9.5	355	7.5	11.0	190	15	173	200	52	14	5.6
(A-6-2)18bad-1	11-30-55	43	415	7.5	10.0	200	0	—	240	54	15	<13
(A-6-2)21acd-1	09-03-85	6.7	590	7.7	10.0	210	34	172	330	53	18	43
(A-6-2)28aba-1	09-17-85	14	315	7.1	11.0	150	5	140	180	40	11	8.6
(A-7-1) 7dba-1	09-05-85	9.0	140	6.7	11.0	63	11	52	84	18	4.5	3.6
(A-7-1) 8cad-1	08-29-85	18	190	7.3	11.0	73	0	73	110	18	6.8	12
(A-7-1)17bcb-1	09-05-85	5.1	155	6.8	10.0	72	12	60	93	21	4.7	3.9
(A-7-1)19aad-1	08-26-85	23	365	7.8	9.0	180	13	170	200	57	9.9	5.4
(A-7-1)20dcd-1	09-05-85	4.6	280	7.5	9.0	150	24	123	160	44	8.9	5.4
(A-7-1)21bbc-1	09-05-85	7.7	245	7.4	9.5	110	12	96	150	32	6.7	9.1
(A-7-1)28baa-1	08-20-85	8.2	280	8.3	12.0	90	0	115	200	23	8.0	23
(A-7-1)29ada-1	09-13-85	6.8	240	7.2	11.0	100	6	94	150	24	9.7	13
(A-7-1)34aca-1	08-22-85	14	240	7.8	10.0	110	12	94	130	29	8.2	6.9

[1] Sodium plus potassium.

<, constituent concentration less than indicated detectable limits]

Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3	Carbonate (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, Nitrate, dissolved (mg/L as NO_3)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as MN)	Sampling method, codes	Water type
0.9	—	—	4.6	3.6	0.1	6.5	—	0.26	19	<1	4040	Ca-HCO_3
.7	—	—	9.4	12	<.1	10	—	.92	<3	2	8010	Ca-HCO_3
2.3	130	0	8.7	10	.6	14	1.3	—	20	—	—	—
2.0	200	0	2.5	22	1.1	18	<.1	—	40	—	—	—
6.0	290	0	17	12	.8	27	6.0	—	20	—	—	—
1.2	230	0	12	12	.1	10	2.7	—	<10	—	—	—
4.3	50	7	32	61	.4	4.8	<.1	—	10	—	—	—
1.9	200	0	20	72	.2	17	1.1	—	40	—	—	—
—	320	57	24	29	—	42	.6	—	—	—	—	—
—	370	18	39	34	—	38	.4	—	—	—	—	—
2.7	—	—	17	36	<.1	13	—	11	100	22	4040	Ca-HCO_3
1.6	—	—	16	27	.3	32	—	.66	6	14	4040	Ca-HCO_3
1.0	—	—	8.0	33	.1	17	—	.98	5	<1	4040	Ca-Na-HCO_3
1.2	—	—	8.3	6.9	.1	15	—	1.10	140	27	4090	Ca-HCO_3
1.0	—	—	11	22	.1	7.5	—	.31	<3	7	4040	Ca-HCO_3
1.3	—	—	9.2	30	.1	11	—	.96	8	4	4040	Ca-HCO_3
.9	—	—	7.7	6.2	.1	7.2	—	.27	5	<1	4040	Ca-HCO_3
.9	—	—	13	18	<.1	15	—	1.30	<3	1	4040	Ca-HCO_3
.7	—	—	9.0	9.1	<.1	7.4	—	.43	<3	<1	4040	Ca-HCO_3
1.2	—	—	8.8	7.3	<.1	7.4	—	.53	4	<1	4040	Ca-HCO_3
1.0	240	0	6.9	14	<.1	17	2.0	—	10	100	—	—
1.8	—	—	25	75	.2	11	—	1.10	10	2	4040	Ca-Mg-Na-HCO_3
2.0	—	—	11	5.5	.1	19	—	.13	240	20	4040	Ca-HCO_3
1.1	—	—	15	3.9	<.1	6.5	—	.32	210	19	4040	Ca-HCO_3
.9	—	—	7.4	11	<.1	13	—	.27	110	4	4040	Ca-Mg-Na-HCO_3
.6	—	—	11	4.5	<.1	11	—	.99	21	3	4040	Ca-HCO_3
.6	—	—	8.4	7.7	<.1	9.1	—	.47	5	12	4040	Ca-HCO_3
.4	—	—	9.9	7.3	<.1	11	—	1.70	4	<1	4040	Ca-HCO_3
1.9	—	—	6.3	12	.2	24	—	.31	18	26	4040	Ca-HCO_3
5.2	—	—	18	6.5	.7	49	—	.11	33	7	4040	Ca-Na-HCO_3
.7	—	—	16	8.4	.1	17	—	.41	17	3	4040	Ca-Mg-HCO_3
1.5	—	—	8.6	10	.1	12	—	.97	4	8	4040	Ca-HCO_3

Table 9. Chemical analyses of water samples from springs

[ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms

Location: See figure 2 for description of data-site numbering system.
Sampling method codes: 70, dip sample.

Location	Date of Sample	Flow rate, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)
(A-6-2)27dcc-S1	09-17-85	1.6	430	7.5	9.5	220	17	207	240
(A-7-1)19dbc-S1	09-11-85	.25	280	7.8	10.0	140	21	123	160
(A-7-1)22caa-S1	01-24-85	—	175	7.2	24.0	58	0	61	100
(A-7-1)30aca-S1	09-11-85	—	350	8.0	7.0	190	21	173	200
(A-7-3)23acb-S1	09-17-85	[1]20	390	8.2	6.5	220	17	201	220
Seepage from unconfined aquifer southwest of Huntsville	10-31-85	[1].04	445	7.7	12.0	260	10	246	280
Seepage from unconfined aquifer northwest of Huntsville	10-31-85	.01	450	8.4	12.0	250	23	232	270

[1]Estimated value.

budget that the application rate is the same for all irrigation techniques. This rate is estimated to be 1 acre-foot per acre per month. The rate is based on specifications given for the Causey project, which provided irrigation water from Causey Reservoir (N.W. Plummer, Regional Director, U.S. Bureau of Reclamation, oral commun., 1981). The total delivery rate necessary for an application rate of 1 acre-foot per acre per month on the early-season irrigation acreage is 118 cubic feet per second. The desired delivery rate from August through September decreased to 107 cubic feet per second.

The delivery rate from May through July 1985 was fully met by surface-water flows. The desired delivery rate from August through September was not met by surface-water flows during that entire period, but the consumptive-use needs of the crops were assumed to be fully satisfied. The monthly delivery rate for 1985 was estimated as the greater of either the desired delivery rate for the acreage irrigated or the average monthly surface-water flow into Ogden Valley, as determined from a proportion of the South Fork Ogden River streamflow.

Not all of the water diverted for irrigation is lost to crop-consumptive use. Part of the water is lost to evaporation from canals or ditches, part runs out the tail end of the ditches into Pineview Reservoir, part infiltrates the soil and recharges the aquifer directly beneath the canals or ditches, and the remainder infiltrates the soil beneath irrigated acreage and recharges the valley-fill aquifer system.

For this study, it was assumed that 5 percent of the delivered water was lost to evaporation and 10 percent ultimately flowed into Pineview Reservoir and out of Ogden Valley. Crop consumptive use in Ogden Valley was determined by G.E. Pyper (U.S. Geological Survey, oral commun., 1986) with a method that accounted for crop type and acreage, daylight hours, air temperature, and precipitation.

Seepage to the aquifer from irrigation canals (irrigation distribution losses) is small and varies throughout the irrigation season. Some canals did not receive water throughout the season; other canals continued to receive water after the irrigation season was over. Water from the Mountain Valley (or Ogden Valley) Canal did not flow past the Middle Fork Ogden River until sometime in June; in the summer, the measured net loss was 4.0 cubic feet per second (Herbert and others, 1987). The West Ditch lost 0.8 cubic feet

per liter; <, constituent concentration less than indicated detectable limit]

Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Methylene blue active substance (mg/L)	Sampling method, codes
60	18	7.7	1.3	8.9	9.4	<0.1	10	0.65	<3	<1	—	70
41	10	3.1	.7	16	4.9	.6	6.7	.32	6	<1	—	70
14	5.5	12	2.1	10	9.8	.2	13	.17	—	—	—	70
43	20	4.6	.7	15	4.0	.1	7.5	.23	12	3	—	70
64	15	2.6	.8	9.4	2.9	<.1	6.0	.84	<3	<1	—	70
76	16	7.0	5.4	1.0	6.1	.2	12	.54	—	—	.03	70
74	17	7.4	3.9	9.8	8.2	.1	11	.26	—	—	.03	70

per second, but was dry after the first of August. The upper Eden Canal lost 1.2 cubic feet per second, and Wolf Creek Ditch lost 0.4 cubic feet per second. The Huntsville South Bench Canal and the Eden Canal diverted water for livestock until sometime in November. Other canals and ditches showed minor losses.

The quantity of irrigation water recharging the aquifer in 1985 was estimated with the following equation:

$$IR = DR - L - CCR \qquad (1)$$

where IR = the quantity of irrigation water recharging the aquifer, in cubic feet per second;

DR = the quantity of delivered water, in cubic feet per second;

L = loss of delivered water, in cubic feet per second, by evaporation and canal flow into Pineview Reservoir; and

CCR = crop consumptive use, in cubic feet per second.

The quantity of irrigation water recharging the aquifer and the approximate percentage of delivered water recharging the aquifer was determined for each month of irrigation in 1985 as follows:

Month	DR	L	CCR	IR	
May	118	-(0.15)(118)	-12.5	= 87.8	(75 percent)
June	118	-(0.15)(118)	-40.7	= 59.6	(50 percent)
July	118	-(0.15)(118)	-65.5	= 34.8	(30 percent)
August	101	-(0.15)(101)	-46.6	= 39.3	(40 percent)
September	79	-(0.15)(79)	- 8.9	= 58.3	(75 percent)

Losing Streams

Miscellaneous measurements made in February and March 1985 (table 4) can be used to identify reaches where recharge takes place and the quantity of flow that recharges the aquifer system from streams during the winter months. In the first reach of the North Fork Ogden River, about 2.4 cubic feet per second seeped to the aquifer; in the second reach of the North Fork Ogden River, about 7.6 cubic feet per second seeped to the aquifer. Although the last measured reach of North Fork Ogden River indicates a net gain from the aquifer, it was estimated that the upper part of this reach actually loses about 2 cubic feet per second to the aqui-

Table 10. Water budget for the valley-fill aquifer system, mid-February 1985 through January 1986

[Values are in cubic feet per second]

	Winter 1985	Mid-February to mid-March (period 1)	Mid-March to mid-April (period 2)	Mid-April to May (period 3)	May (period 4)
		Estimated recharge			
Precipitation	0	9	120	0	0
Irrigation	0	0	0	0	88
Irrigation distribution losses	0	0	0	0	6
Losing streams	67	69	140	140	105
Subsurface inflow	48	48	48	48	72
Total	115	126	308	188	271
		Estimated discharge			
Gaining streams	48	48	93	93	93
Springs and drains	22	27	32	29	51
Ogden well field	15.0	14.4	15.4	18.4	13.9
Other wells	.1	.1	.1	.1	.3
Evapotranspiration	0	0	0	1	13
Pineview Reservoir	45	45	60	78	88
Total	130.1	134.5	200.5	219.5	259.2

fer. In the measured reach of the Middle Fork Ogden River, about 4.3 cubic feet per second seeped to the aquifer. Recharge from the South Fork Ogden River was estimated at 46 cubic feet per second (Browning, 1925, p. 17-20).

Starting in May, diversions from streams into canals decreased water depths in the stream channels; the estimated recharge to the aquifer system was 25 percent less than the pre-diversion value. The North Fork Ogden River above the first diversion structure was estimated to lose 4 cubic feet per second to the aquifer, but the flow was entirely diverted at the first diversion structure. Flow in the Middle Fork Ogden River was entirely diverted in June. Flow in the South Fork Ogden River exceeded the capacity of the diversion structure in June, and water flowed down the entire reach of the stream channel. It was estimated that about 46 cubic feet per second from the South Fork Ogden River recharged the aquifer during June 1985.

Estimated recharge from the remaining perennial streams during the winter months is as follows:

Estimated recharge from minor perennial streams during late winter 1985

Stream	Recharge (cubic feet per second)
Bally Watts Creek	0.5
Maple-Kelley Canyon creek	.7
Wolf Creek	1.0
Pole Canyon Creek	.5
Sheep Creek	1.0
Cold Canyon Creek	.5
Cobble Creek	.5
Geertsen Canyon creek	.5

Spring snowmelt on the hillsides surrounding Ogden Valley was assumed to temporarily increase flow in the minor perennial streams. Some channels that were dry all winter also had flow during the snowmelt period. Spring snowmelt increases the potential for increased recharge during the early spring. It was estimated that recharge from flow in minor perennial streams doubled during the snowmelt period. Starting in June, all minor streams except Geertsen Canyon

June (period 5)	July (period 6)	August (period 7)	September (period 8)	October (period 9)	November (period 10)	December (period 11)	January (period 12)
			Estimated recharge				
0	0	0	0	34	80	10	0
60	35	39	58	0	0	0	0
6	6	5	5	2	2	0	0
51	16	16	16	39	75	67	67
96	154	91	72	48	48	48	48
213	211	151	151	123	205	125	115
			Estimated discharge				
103	73	45	42	33	41	89	48
50	34	22	21	14	25	18	32
14.1	14.6	15.1	10.1	9.3	13.6	13.0	12.7
.3	.3	.3	.3	.1	.1	.1	.1
44	71	50	10	3	0	0	0
88	78	78	60	60	60	60	78
299.4	270.9	210.4	143.4	119.4	139.7	180.1	170.8

creek and Wolf Creek were entirely diverted at the valley margin for irrigation.

From July through September, all streams except for short reaches above the upper diversion structures on the North Fork Ogden River and the South Fork Ogden River were entirely diverted or otherwise dry at the valley margin. It was estimated that 2 cubic feet per second recharged the aquifer system above the upper diversion structure on the North Fork Ogden River, and 14 cubic feet per second recharged the aquifer above the diversion structure on the South Fork Ogden River.

In October, the diversions generally were stopped, and flow was restored. Minor perennial streams again flowed in their channels and recharged the aquifer at their previously estimated rates for February. Water still was partially diverted at the upper North Fork Ogden River and the South Fork Ogden River diversion structures. It was estimated that 7 cubic feet per second passed the diversion structure on the North Fork Ogden River, and subsequently recharged the aquifer system. On the South Fork Ogden River, where water also passed the diversion structure, a small amount of flow was observed at the first county bridge. Browning (1925) indicated that 24 cubic feet per second recharged the aquifer in that reach. In November, conditions generally were back to those of the previous winter.

Pineview Reservoir

It was initially assumed for the preparation of the water budget that seepage downward from Pineview Reservoir into the principal aquifer did not occur. If downward seepage does occur, it would be the water induced from Pineview Reservoir by pumpage from the Ogden well field; the amount of seepage could not be greater than the amount of pumpage.

Subsurface Inflow

Much of Ogden Valley is underlain by the Norwood Tuff, which is not permeable in most areas. In a few areas, either Paleozoic carbonate rocks or the Wasatch Formation probably underlie the valley-fill deposits, facilitating ground-water inflow from the bedrock.

Little information is available to derive the inflow from bedrock to the valley-fill deposits. The Darcy equation was used to estimate the inflow during

stable conditions for the winter when snowmelt was not occurring. It was assumed that all inflow from the bedrock occurred along the valley perimeter, which is about 208,000 feet long. The hydraulic conductivity of the bedrock was estimated to be 1 foot per day. When infiltration of snowmelt was not occurring, the average hydraulic gradient was estimated to be 0.2 foot per day, and the average saturated thickness of the bedrock-flow system contributing to the valley-fill deposits was 100 feet. Using the Darcy equation,

$$Q = K I A$$

where Q = discharge,
K = hydraulic conductivity,
I = hydraulic gradient, and
A = cross-sectional area through which flow occurs;

subsurface inflow when snowmelt was not contributing to the ground-water system was about 48 cubic feet per second.

Subsurface inflow from the bedrock to Ogden Valley increases dramatically because of snowmelt infiltration in the area surrounding the valley. Burnett Spring [(A-7-1)22dad-S1], which supplies Eden with much of its municipal water, discharges from the valley fill, but the actual source of the water is thought to be the underlying bedrock of Norwood Tuff or metasedimentary rocks. The average rate of spring flow in 1985, before snowmelt occurred, was 48 gallons per minute (National Water Use Data System, Division of Water Rights, Utah Department of Natural Resources, written commun., 1986). For May through September, the average monthly rate of spring flow was as follows:

Average monthly rate of flow of Burnett Spring [(A-7-1)22dad-S1] for May through September 1985

Month	Average monthly rate of spring flow (gallons per minute)
May	71
June	98
July	154
August	89
September	74

The variability in subsurface inflow from the bedrock (table 10) was estimated from the changes in flow of Burnett Spring.

Discharge

The valley-fill aquifer system loses water because of various types of discharge. Each type of discharge was analyzed separately to provide detailed analysis of the ground-water-flow system.

Gaining Streams

Miscellaneous measurements made in February 1985 (table 4) indicate discharge from the valley-fill aquifer system to a number of stream channels. Many of the gaining reaches are located in the southern part of Ogden Valley. The reach of the North Fork Ogden River above site N11 gained about 7.3 cubic feet per second. The next downstream reach on the North Fork Ogden River gained 3.9 cubic feet per second after accounting for a possible loss of 2 cubic feet per second in the upper part of the reach. Bennett Creek showed a gain of about 5.1 cubic feet per second.

The remaining gaining reaches are along the major stream channels upstream from Pineview Reservoir. From existing gaging station records, it was estimated that the North Fork Ogden River gained 6 cubic feet per second in the unmeasured reach just above Pineview Reservoir, the Middle Fork Ogden River gained an estimated 4.5 cubic feet per second, Geertsen Canyon creek gained an estimated 1.5 cubic feet per second, and the South Fork Ogden River gained an estimated 19 cubic feet per second. These gains were assumed constant from February through mid-March.

From mid-March through May, it was assumed that discharge from the valley-fill aquifer system to the downstream reaches of the streams increased. Discharge to all the streams, except Bennett Creek, was estimated to have doubled compared to the discharge during winter conditions. Bennett Creek mostly drains water from the Wasatch Formation during mid-March through May, and flow is steady.

Discharge from the aquifer system to the streams decreases from June through October as shown in table 10. Declining water levels in wells in the southern part of the valley also indicate that discharge from the aquifers is declining. Flow in the North Fork Ogden River downstream from the springs is estimated to have decreased by 5 cubic feet per second. Flow in Bennett Creek doubled from seepage of irrigation water applied over much of its drainage in the valley. Discharge from the aquifer system to Geertsen Canyon creek is assumed to remain fairly constant.

From August to November, discharge to streams was reduced further. Discharge to the lower reach of the North Fork Ogden River is estimated to have decreased another 5 cubic feet per second. Flow in Bennett Creek decreased to about 5 cubic feet per second after seepage of irrigation water ceased. Discharge to Geertsen Canyon creek remained fairly constant as estimated during this study.

In December, increases in flow recorded at the gaging stations were estimated to equal gains made by the streams in the southern part of the valley. Discharge to Bennett Creek and Geertsen Canyon creek stayed fairly constant from the previous period.

Springs and Drains

Springs and drains in Ogden Valley consist of perennial springs and spring-fed reaches of stream channels including Liberty Springs, Liberty Spring Creek, Bailey Spring, Spring Creek, small seeps that emerge in the draws near the edge of the confining layer, and seeps that occur in the area periodically inundated by Pineview Reservoir.

Measurements made in February 1985 (table 4) and estimates of the reservoir seeps give a total discharge from springs and drains of about 22 cubic feet per second. The total discharge by springs and drains for Ogden Valley during each water-budget period was determined by the proportion that Spring Creek differed from its base-flow rate during the winter (table 10).

Wells

The average monthly pumpage rate of the Ogden well field fluctuated during 1985 as shown in table 10. The fluctuation for a 5-day interval is shown in figure 22. Pumpage is erratic but generally increases in the spring when water demand increases in Ogden. The pumpage stabilizes when the filtration plant opens for the summer and starts treating water diverted from Pineview Reservoir. Pumpage decreases in the fall when water demand begins to decline. The filtration plant usually continues to treat reservoir water until late October.

Hydrographs for water-level altitudes in a well completed in the confined part of the principal aquifer near the Pineview Reservoir and for the stage of Pineview Reservoir are shown in figure 22. The water level in the well rose during increased pumpage from the Ogden well field. The rise resulted from a combination of increased natural recharge in the spring and reduced ground-water discharge to the reservoir because of the increased stage of the reservoir. The water-level rise suggests that additional pumpage from the Ogden City well field is feasible because an increase in natural recharge and in the stage of Pineview Reservoir have a greater effect on water levels than an increase in pumpage.

Total pumpage from other wells was small when compared to pumpage from the Ogden well field (table 10). Pumpage from wells in the smaller public systems was obtained from the National Water-Use Data System (Division of Water Rights, Utah Department of Natural Resources, written commun., 1986). Pumpage from the unmeasured community systems was estimated on a per-user basis. Pumpage from each of the remaining wells, which are used for domestic purposes or stock watering, was estimated as 1 acre-foot per year. Very few wells are used exclusively for stock watering (table 7). Half of the annual total water pumped from these wells was assumed to be used during May through September because of the increase in lawn and garden watering.

Evapotranspiration

About 11,500 acre-feet of water is consumed annually by natural vegetation and subirrigated cropland. In order to adjust this annual rate for the monthly conditions that occurred in 1985, the proportional rates of monthly crop consumption were determined by G.E. Pyper (U.S. Geological Survey, written commun., 1986). The monthly proportion of annual evapotranspiration, the monthly evapotranspiration, and the evapotranspiration rates determined by monthly crop consumption for 1985 and adjusted for variable climatic conditions are as follows:

Monthly proportion of annual evapotranspiration, monthly evapotranspiration, and evapotranspiration rates for 1985

Month	Monthly proportion of annual evapotranspiration	Monthly evapo-transpiration (acre-feet)	Evapo-transpiration rate (cubic feet per second)
Late April	0.005	58	1.0
May	.07	805	13.5
June	.23	2,645	44.4
July	.37	4,255	71.5
August	.26	2,990	50.2
September	.05	575	9.7
October	.015	172	2.9
Total	1.000	11,500	193.2

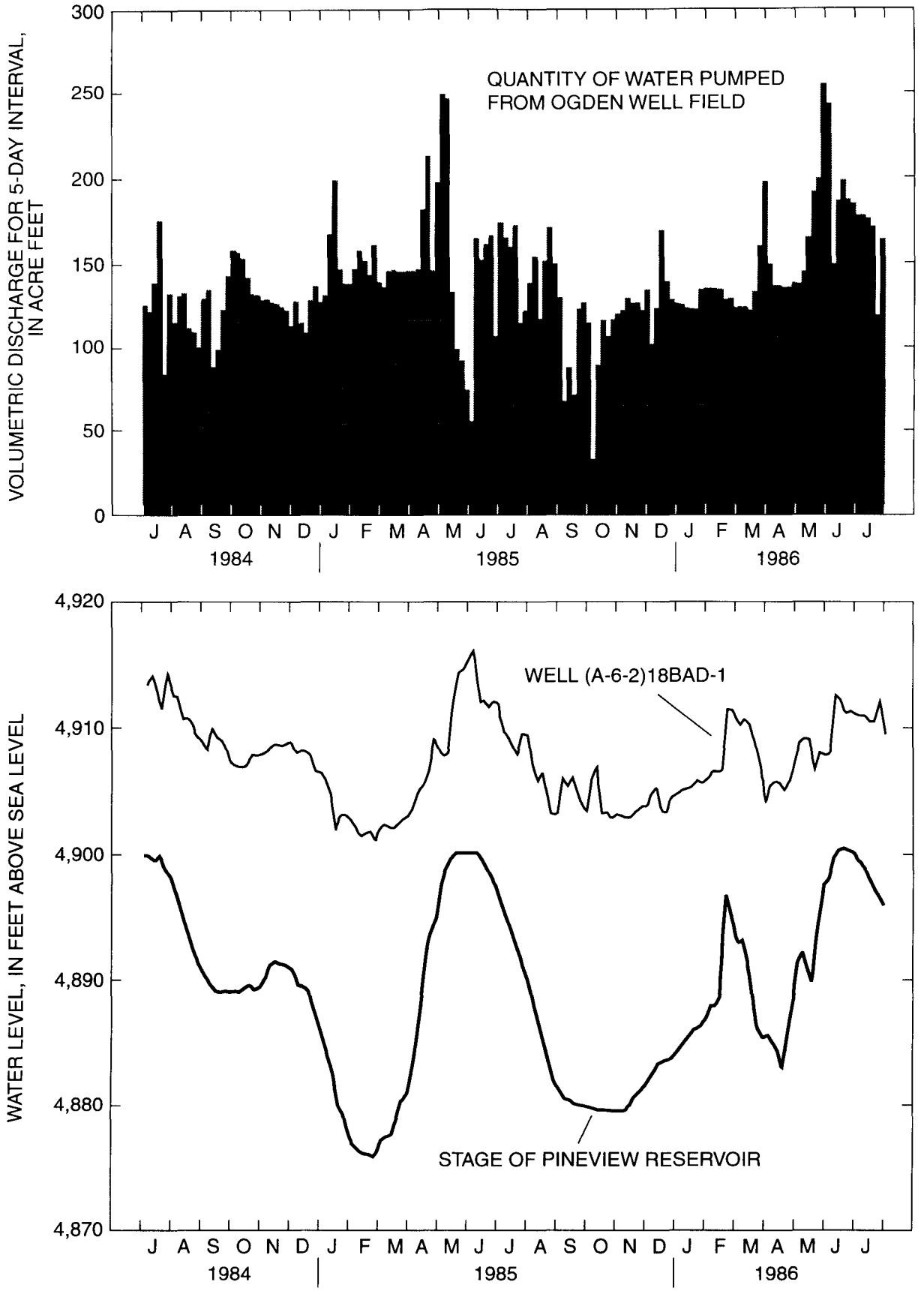


Figure 22. Ogden well-field pumpage, water level in well (A-6-2)18bad-1, and stage of Pineview Reservoir, July 1984 through July 1986.

Pineview Reservoir

Upward seepage through the lakebed was measured in July 1986 when the stage of Pineview Reservoir was slightly below its maximum of 4,900 feet. A seepage-measurement site was located in each of the "arms" of Pineview Reservoir (pl. 2). The total amount of seepage was estimated by integrating the seepage rates at the measurement sites over the entire reservoir area. The total amount of seepage to Pineview Reservoir from the principal aquifer at the time of the seepage measurements was estimated to be 86.7 cubic feet per second.

Estimated seepage to Pineview Reservoir, July 1986

Reservoir arm	Upward seepage (cubic feet per second)
North Fork Ogden River	16.5
Middle Fork Ogden River	35.0
South Fork Ogden River	19.2
Lower area (southwestern part of reservoir exclusive of the three arms)	16.0
Total	86.7

The quantity of seepage during the winter was estimated using the same seepage rates for a smaller area of the reservoir. The quantity of seepage to Pineview Reservoir during the winter was estimated to be 45.5 cubic feet per second.

Estimated seepage to Pineview Reservoir during winter

Reservoir arm	Upward seepage (cubic feet per second)
North Fork Ogden River	9.0
Middle Fork Ogden River	14.0
South Fork Ogden River	14.4
Lower area (southwestern part of reservoir exclusive of the three arms)	8.0
Total	45.4

The quantity of seepage for spring and fall reservoir levels of 4,876; 4,880; 4,890; and 4,900 feet was estimated by integrating seepage rates over the area of the reservoir. The quantity of possible downward seepage was not subtracted from these estimates (table 10).

Subsurface Outflow

Outflow from the valley-fill aquifer system to the bedrock surrounding Ogden Valley is unlikely. It is possible that water drains into the carbonate rocks or the Wasatch Formation where the Norwood Tuff is absent. It also is possible that water drains into permeable bedrock 3.5 miles west of Liberty and 5 miles south of Huntsville. Because of the lack of evidence of any outflow, it was presumed to be negligible.

SIMULATION OF GROUND-WATER FLOW IN THE VALLEY-FILL AQUIFER SYSTEM

A finite-difference, three-dimensional computer model was used to simulate ground-water flow in the valley-fill aquifer system of Ogden Valley. The computer program used was developed by McDonald and Harbaugh (1984). Most of the data used for calibration of the steady-state and transient model simulations are presented in previous sections of this report.

The computer-model simulation was done in order to improve understanding of the hydrology of the valley-fill aquifer system, including the areal distribution and range in values of the hydraulic properties. Few data on the subsurface geology have been collected and analyzed other than data for the now-abandoned Ogden artesian well field and vicinity. Adjustments to the initial hydraulic-property values of the aquifer system during calibration were made on the basis of flow rates to and from streams and Pineview Reservoir and the agreement between measured and computed ground-water levels.

Two hypothetical changes to the water budget were simulated to observe the resulting effects on streamflow and ground-water levels. A 1-year drought and withdrawals from three additional wells were simulated to estimate the magnitude and distribution of the effects from such conditions.

Model Design and Assumptions

The valley-fill aquifer system in Ogden Valley was simulated using two layers (fig. 23). The upper layer, layer 1, represented the shallow water-table aquifer and was active only in the southern part of the valley above the confining layer. Layer 1 was not simulated in the area perennially inundated by Pineview Reservoir because the bottom of the reservoir is incised into the confining layer. The lower layer, layer 2, represented the principal aquifer and was active throughout the simulated area. Layer 2 was simulated with an option in the computer model (McDonald and Harbaugh, 1984, p. 151) that allows the use of either the storage-coefficient value or specific-yield value. If the water level is

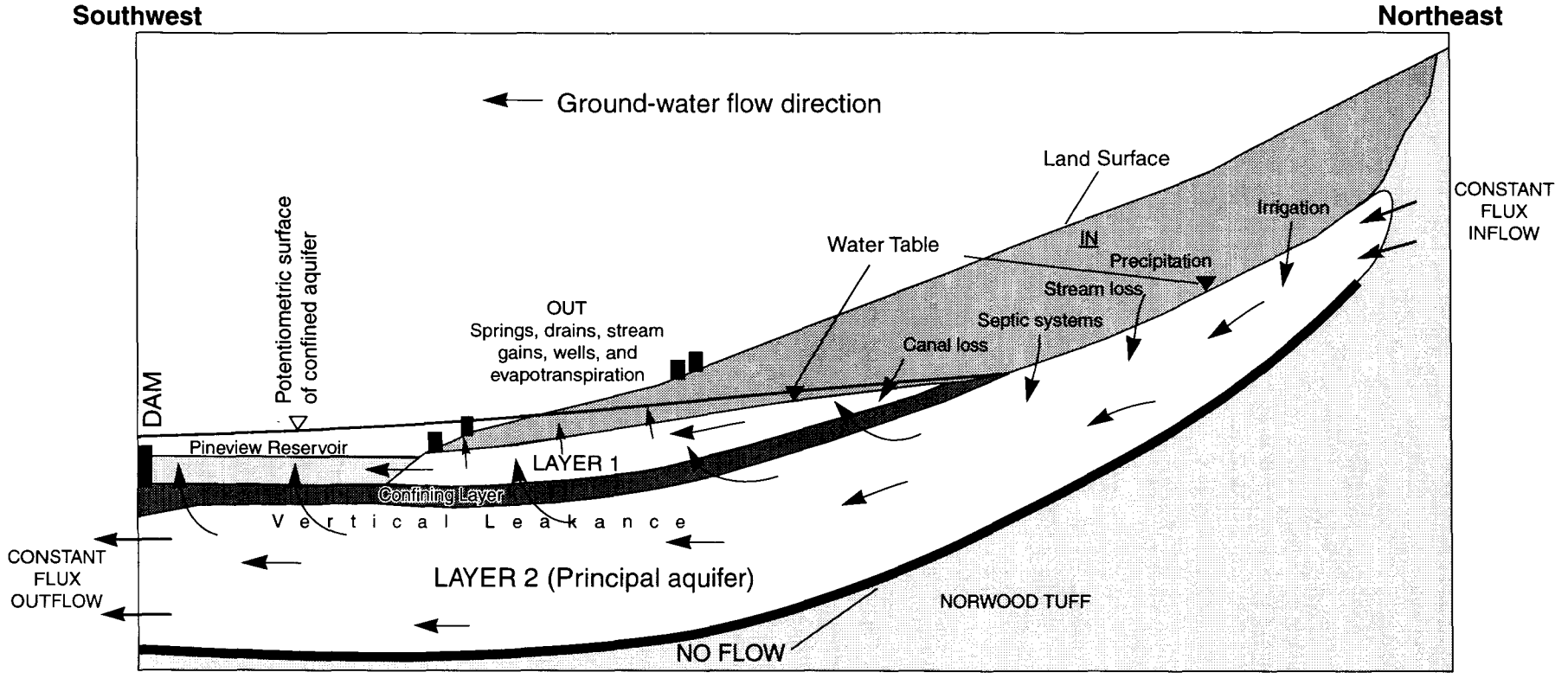


Figure 23. Schematic section of the two-layer ground-water flow model simulating the aquifer system in Ogden Valley.

above the top of layer 2, the storage-coefficient value is used. If the water level is below the top of layer 2, the specific-yield value is used. Flow between layer 1 and layer 2 through the confining layer was simulated using values of vertical hydraulic conductivity of the confining layer divided by the average thickness of the confining layer (vertical conductance) (McDonald and Harbaugh, 1984, p. 151). In this case, vertical conductance of the aquifer material does not slow vertical ground-water movement, compared to the confining layer, and thus, can be ignored.

A block-centered grid with variable spacing was used to divide a map of the valley-fill aquifer system into discrete cells (fig. 24). The grid spacing was smaller on the west side of the model grid to allow accurate location of hydrologic boundaries and stresses. The grid consists of 59 rows and 23 columns. The rows are spaced 1,340 feet apart. The columns are spaced from 1,320 to 1,340 feet apart on the west side of the grid and from 1,540 to 1,640 feet apart on the east side of the grid. Of the 1,357 total cells in each layer in the grid, 782 cells in layer 2 are active and 139 cells in layer 1 are active.

Model Boundary Conditions

The entire model area was surrounded by constant-flux cells. The active cells at the periphery of the model represented consolidated rock and valley fill that is mainly slopewash with a relatively small hydraulic conductivity along the edge of the valley. Recharge at most of the periphery cells simulated subsurface inflow from the bedrock to layer 2, the principal aquifer.

Subsurface inflow was estimated to be generally small. It is larger where the valley fill is underlain by permeable carbonate rock or faults that transmit water in consolidated rock.

Initially, the simulated subsurface inflow was 48 cubic feet per second distributed uniformly to the constant-flux cells. The inflow was kept relatively constant but was redistributed until simulated water levels were similar to measured water levels in the aquifers. The hydraulic conductivity of the cells at the periphery, which represent the thin valley fill and underlying consolidated rock, generally was kept to a value that produced a transmissivity of less than 200 feet squared per day. The two constant-flux cells located at Pineview Reservoir simulated discharge from the ground-water-flow system to the south end of Pineview Reservoir.

The general-head-boundary feature of the model (McDonald and Harbaugh, 1984, p. 343-369) was used to simulate variable leakage between the confined part of the principal aquifer and Pineview Reservoir. General-head-boundary cells were specified in layer 2 to delineate the area inundated by Pineview Reservoir during each stress period. General-head-boundary cells were added or removed during successive stress periods as the area inundated by Pineview Reservoir expanded or contracted. Layer 1 was kept active in the area not perennially inundated by Pineview Reservoir, but it did not account for much storage in the aquifer.

The top boundary of the model was the water-table surface in layer 1, or layer 2 where layer 1 was absent; and the bottom boundary was a no-flow boundary (fig. 23) representing the Norwood Tuff in most of the valley underlying layer 2. Water-table conditions existed throughout layer 1 and in layer 2 where layer 1 was not simulated, except in the area that was perennially inundated by Pineview Reservoir. In the part of the model where layer 1 was active, flow between the two layers was controlled by a vertical leakance value that simulated the hydraulic characteristics of the confining layer.

Streams

The North Fork Ogden River, Middle Fork Ogden River, and South Fork Ogden River were simulated by river cells. Because of the substantial changes that occur in flow of streams in Ogden Valley, the stage height and distribution of active streams sometimes change abruptly. Data used in the simulation to describe these changes were based on field observations of streams throughout the valley.

In their upper reaches, an unsaturated zone separated many streams from the unconfined part of the principal aquifer. When the streambed was above the water level in the aquifer, simulated leakage from the river cell was directly proportional to the streambed conductance (McDonald and Harbaugh, 1984, p. 214). The use of river cells enabled a precise quantity of leakage to be allowed from those river cells, and leakage was used as a calibration tool to adjust simulated water levels. The quantity of leakage was not varied if it had been determined either by seepage runs made in February 1985 or by analysis of other previously collected data.

Canals and ditches that were not surrounded by irrigated fields also were simulated by river cells.

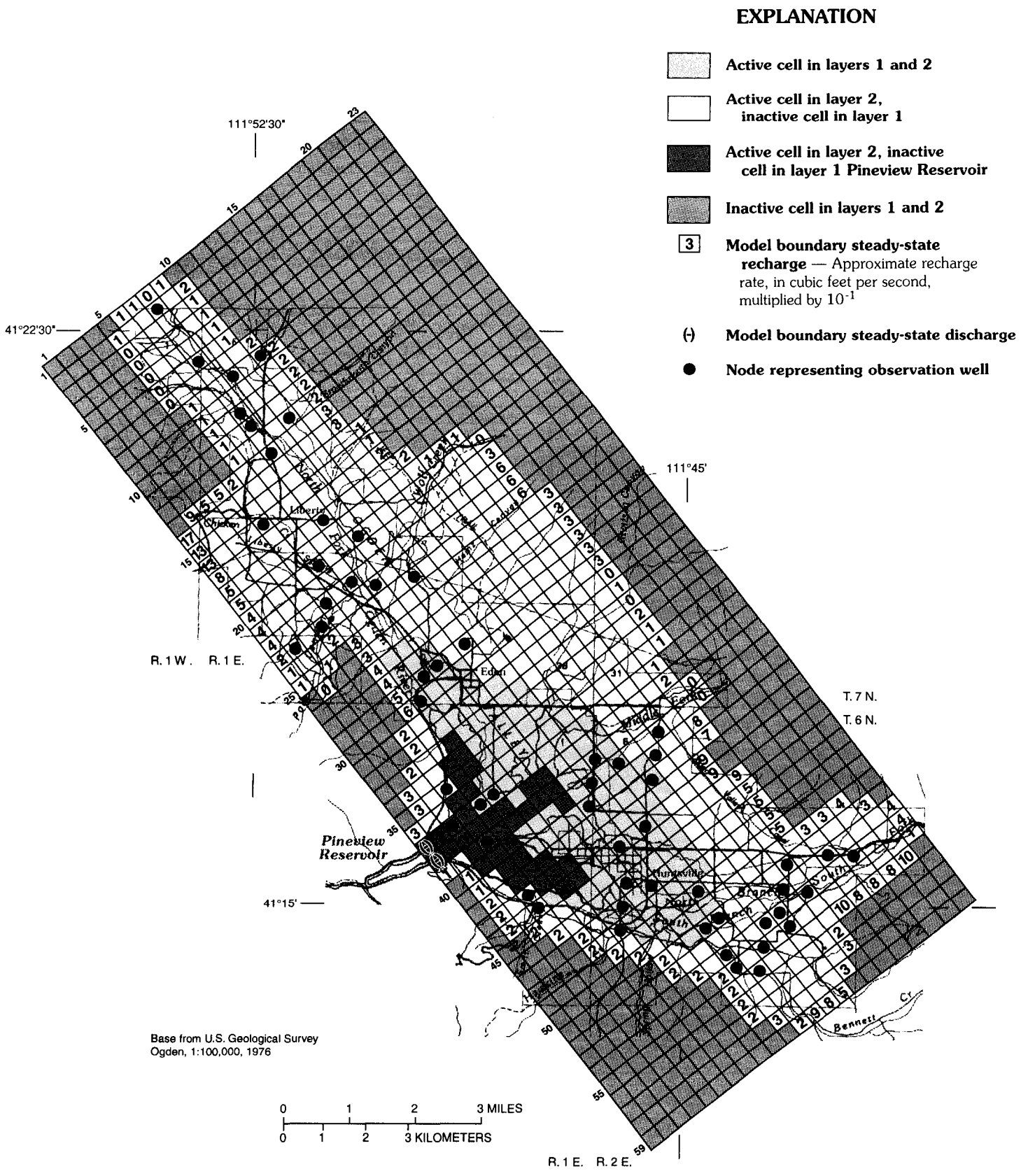


Figure 24. Model grid, areal distribution of active cells, and boundary steady-state recharge and discharge for the model of the ground-water system in Ogden Valley.

Recharge from canals and ditches was considered minimal when compared to recharge from irrigated fields.

Drains

Drain cells were used in the model to simulate outflow from the aquifer to drains, but they did not allow flow from drains to the aquifer. Thus, the drain cells also can be used to simulate streams that are perennially gaining as well as simulating irrigation drains. Liberty Spring Creek and most of Spring Creek were simulated by drain cells. Most of the flow of these creeks originates from ground-water discharge within Ogden Valley. Drain cells also were used to simulate irrigation drains and small seeps that were near Pineview Reservoir in the low-lying areas, when the seeps were not inundated by the reservoir. The lower reaches of some irrigation ditches probably drain some ground water during the irrigation season; however, the affected reaches were not identified, and this drainage was not incorporated into the model.

Wells

Nearly all of the ground water pumped in Ogden Valley is from the Ogden well field located on the southern tip of the promontory between the North Fork Ogden River and the Middle Fork Ogden River arms of Pineview Reservoir. The measured discharge for each of the periods simulated by the model was used as the rate for that water-budget period (table 10).

Discharge from wells for the three known community systems and all other known domestic and stock wells also was simulated, although the total withdrawal was minimal compared to the withdrawal from the Ogden well field. Withdrawals by the Nordic Valley system were measured; withdrawals by the Eden Hills and Lakeview systems, in addition to the domestic and stock wells, were estimated by per capita and seasonal use. All other community water systems and individual users obtain their water from sources other than wells in the valley-fill aquifer system, and their use was not incorporated into the model.

Evapotranspiration

Evapotranspiration was simulated throughout the uppermost active model layer, although the rate was adjusted for several factors. The maximum possible evapotranspiration rate was adjusted for the proportional density of mapped phreatophytes in each cell and the proportional monthly consumptive use. An evapotranspiration rate of 3 feet per year was determined by G.E. Pyper (U.S. Geological Survey, written commun., 1986). The model program also adjusted the evapotranspiration rate according to the depth of the water table below land surface. The rate was reduced by a straight-line proportion to an extinction depth of the water table, which was specified as 30 feet below land surface.

Areal Recharge

Recharge from precipitation was assumed to occur in March and April from infiltration of snowmelt and from October into December before the first lasting snowpack. A total of 33 percent of the precipitation during each period was recharged to the ground-water-flow system. All precipitation bound up in snow accumulation from December into March was recharged during March and April. Precipitation was distributed throughout the valley as shown by the U.S. Weather Bureau (1963) map of average annual distribution.

Recharge from irrigated fields was determined by several factors. The mapped irrigated acreage was used to determine the proportional area of irrigated fields to the total area that would be in each model cell. The rate of water recharging the ground-water-flow system was determined by the delivery rate of surface water minus the losses by evaporation, canals, and crop-consumptive use. These two factors were combined to determine an adjusted recharge rate from irrigated fields during each period. The recharge rate varied from 30 to 75 percent of the available surface-water supply.

Recharge from septic systems occurs throughout the valley. The only substantial recharge from septic systems is at Huntsville. An average recharge rate of 0.2 cubic foot per second from septic systems was divided among seven cells representing the Huntsville area.

Hydraulic Properties

The ground-water-flow system in Ogden Valley is controlled partly by the hydraulic characteristics of the aquifers. The estimated values of these characteristics were included in the model data and adjusted during model calibration.

Hydraulic conductivity

A uniform hydraulic-conductivity value, the value determined from the aquifer test of the Ogden well field, was used initially for most of the cells in the

computer model. Modifications of the hydraulic-conductivity distribution were made during calibration. Hydraulic-conductivity values were adjusted concurrently with changes in the boundary recharge until the calculated transmissivity values of the cells at the periphery, which represent a veneer of slope-wash deposits and bedrock comprised of either Norwood Tuff or carbonate rocks, were less than 200 feet squared per day.

Hydraulic-conductivity values were changed to adjust the rate that stresses were propagated through the system in order to generally match water-level altitudes at observation wells during steady-state simulation and to match water-level changes during the transient simulation. The resulting hydraulic-conductivity values for layer 2 ranged from less than 1 foot per day in the areas around the margin of the valley to slightly greater than 300 feet per day in the area east of Huntsville (fig. 25). The range of hydraulic-conductivity values for layer 1 was less than 10 to 50 feet per day (fig. 26). The model simulation was relatively sensitive to different hydraulic-conductivity distributions, particularly near recharge or discharge areas.

The hydraulic-conductivity values and the saturated thickness were used to calculate transmissivity values for the principal aquifer. On the basis of drillers' logs and a surface-water resistivity survey, the saturated thickness of layer 1 (shallow unconfined aquifer) was generally less than 90 feet. Saturated thickness of layer 2 (principal aquifer) ranged from about 100 feet near the valley margins to about 700 feet in the area east of Huntsville. Saturated thickness and hydraulic-conductivity values used in the model were initially extrapolated from only a few data points. During model calibration, these values were adjusted, within reasonable limits, to allow simulated heads to more closely match measured water levels. Transmissivity values ranged from 20 to 230,000 feet squared per day. The largest transmissivity values were assigned to the area north of the South Fork Ogden River channel east of Huntsville. Other areas of relatively large transmissivity values were beneath Pineview Reservoir and near Liberty. The transmissivity values in the main valley and near Liberty typically were equal to or greater than 50,000 feet squared per day; however, the transmissivity values in the area near Eden that separates the Liberty area from the main valley typically were less than 500 feet squared per day.

Storage coefficient

A constant storage-coefficient value of 1×10^{-4} was used during the calibration process for the areas where the principal aquifer was confined. A constant specific-yield value of 0.10 was used for the areas where water-table conditions prevailed.

Vertical hydraulic conductivity

Vertical hydraulic-conductivity values are a measure of the ability of ground water to flow in a vertical direction. The principal aquifer was separated from the shallow water-table aquifer by a leaky confining layer, and a vertical hydraulic-conductivity value was assigned to each active cell in layer 1 to control the exchange of water between layer 1 and layer 2.

Data obtained from reservoir-bed seepage experiments enabled a vertical hydraulic-conductivity value to be estimated for each of three seepage-measurement sites (pl. 2). Because the values differed slightly at each of the sites, different values of vertical hydraulic conductivity were used for the three arms of Pineview Reservoir. The vertical hydraulic-conductivity values used for the transient simulation were 0.04 foot per day in the North Fork Ogden River arm, 0.03 foot per day in the Middle Fork Ogden River arm, and 0.01 foot per day in the South Fork Ogden River arm. These values are about three to four orders of magnitude less than the horizontal hydraulic-conductivity values of the principal aquifer in the area. Each vertical conductivity value was divided by 70 ft [the average thickness of the confining layer according to Thomas (1945)] to determine the model value "VCONT" (McDonald and Harbaugh, 1984, p. 151), which allows for the simulation of vertical leakance of water through a confining layer.

Model simulation was fairly sensitive to differences in vertical hydraulic conductivity. A decrease in vertical hydraulic-conductivity values caused an increase in hydraulic head in layer 2, an increase in discharge to the river and drain reaches just upstream from Pineview Reservoir, and a decrease in discharge from layer 2 to the reservoir.

Initial Conditions

Actual pre-development steady-state conditions are unknown. For the purposes of this investigation and computer simulation, it was assumed that the ground-water-flow system was in a steady-state condition during the low-flow period in mid- to late-February 1985. The water levels in the principal aquifer, the stage of

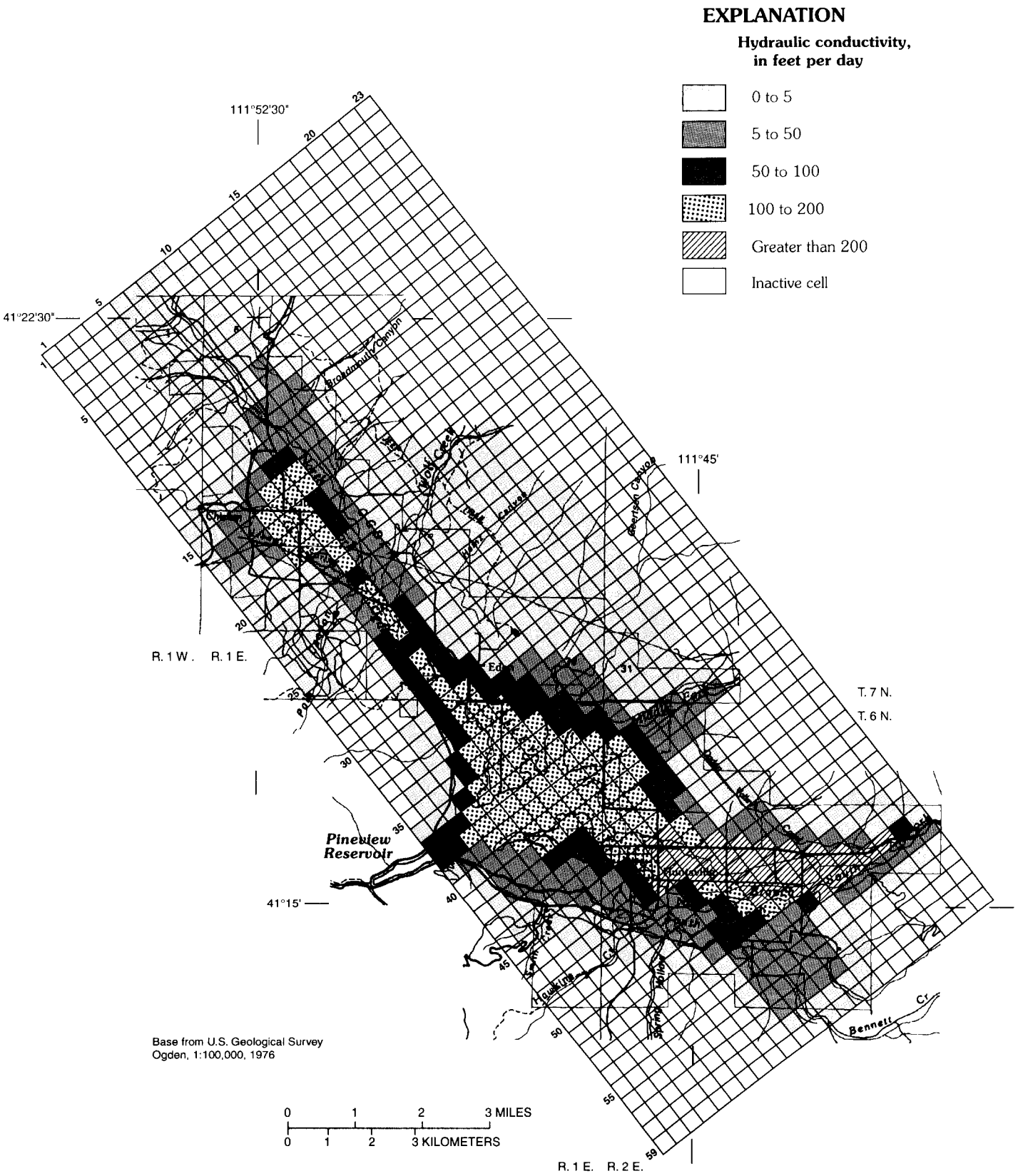


Figure 25. Distribution of hydraulic-conductivity values for layer 2 (principal aquifer) of computer model for Ogden Valley.

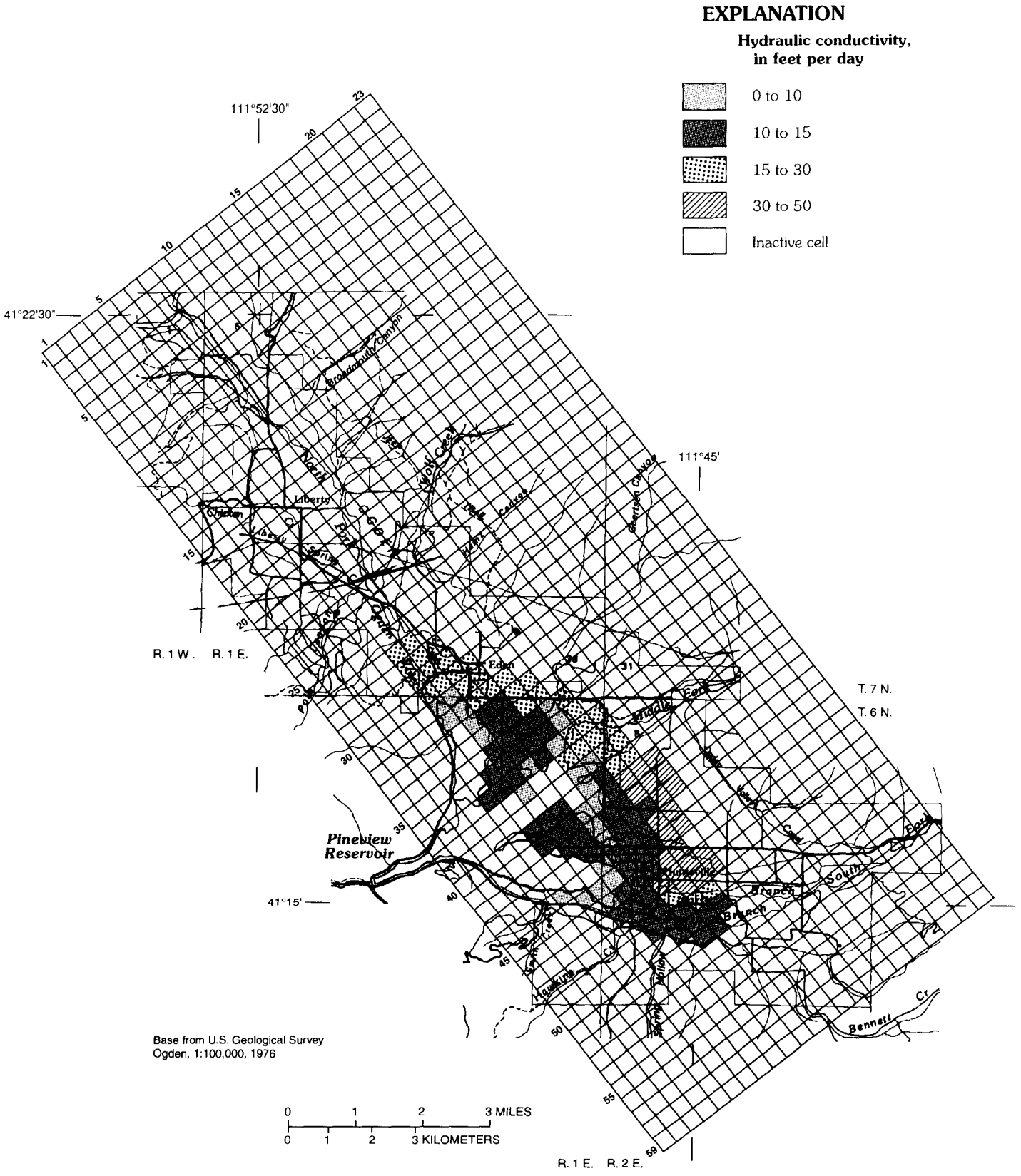


Figure 26. Distribution of hydraulic-conductivity values for layer 1 (shallow water-table aquifer) of computer model for Ogden Valley.

Pineview Reservoir, and the pumpage from the Ogden well field had been fairly steady for about a month (fig. 22). The surface-water inflow to Ogden Valley also was steady during February 1985 (fig. 9). Flow in the South Fork Ogden River remained fairly stable for about a month, although flow during February was substantially greater than that earlier in the winter. Wheeler Creek, a smaller, unregulated watershed, showed very little change in flow during the same period.

This assumption of steady state may introduce some error into the simulated water-level changes for 1985-86. The steady-state assumption was checked by running the transient-state model simulating uniform February 1985 conditions for a 12-month period. This simulation indicated that simulated water levels continued to change slightly throughout the 12-month simulation, but that these changes are, for the most part, negligible (less than 1 foot). Users of the model should be aware of the potential source of error when simulating periods of many years.

Model Calibration and Simulation

Simplifications and assumptions are needed to approximate a complex three-dimensional flow system using a digital model. The discretization of hydraulic properties over space and surface-water changes over time attenuated changes in simulated water levels and flow rates that, in actuality, were large though short-lived. Errors resulting from lack of knowledge about the flow system, discretization, and simplification of the hydraulics of the flow system for modeling can be noticed by comparing model-generated values of water-level altitude, water-level change, or flow rate with measured values. Nevertheless, the model integrates the complex parts of the flow system and provides insight into the behavior of the system under observed and hypothetical conditions.

Because of the interdependence of variables involved in the ground-water-flow model, calibration is an iterative process whereby one hydraulic variable is revised while holding the other variables constant. During calibration of the hydraulic properties, a step-by-step process was used to obtain acceptable values of water-level altitude, water-level change, and flow rate.

Steady-State Calibration

Distribution of recharge by subsurface inflow from the bedrock was the first adjustment made in the model data. Next, flow rates to and from the major stream channels were adjusted by iteratively adjusting the streambed conductance values (McDonald and Harbaugh, 1984, p. 209-217) and the hydraulic conductivity of the underlying aquifer. Last, the water-level altitudes in observation wells were simulated to match measured water-level altitudes to within one-half of the contour interval from the 7.5-minute topographic maps of the area near the well. These calibration criteria were flexible in areas that had relatively large hydraulic gradients.

A steady-state calibration was obtained; but, during transient calibration, minor changes in hydraulic conductivity were made that caused changes in water levels or in discharge. The steady-state simulation was run each time a change in hydraulic properties was made while calibrating the transient simulation. This was done in order to provide an initial potentiometric surface that was in equilibrium with the hydraulic properties that were in place at the beginning of the transient simulation. The steady-state simulation resulting from this iterative process is described in the following sections.

Water levels

Water levels in 72 observation wells measured from mid-to late February 1985 (table 11) were used to calibrate the steady-state model. The error, the difference between the measured and simulated water levels, ranged from -34 feet to 24 feet. The sum of the differences for all 72 water levels was 4 feet. The simulated water levels were lower than the measured or interpolated water levels in cells in the North Fork Ogden River drainage around Eden, in an area south of the Middle Fork Ogden River, and in an area south of the upper reach of the South Fork Ogden River. The simulated water levels were higher than the measured or interpolated water levels in cells in the area near Huntsville.

Gains and losses in streams and drains

Steady-state calibration was accomplished partly by comparing the measured and computed gains in streamflow for which data were available. Flow data either were obtained from Browning (1925) or are listed in table 3. The computed gains were within 50 percent of the measured gains for nearly all the reaches.

A few reaches could not be simulated reasonably by the model. The losses measured in the uppermost

Table 11. Water level in selected observation wells during February and June 1985 and May 1986

[Actual date of measurement can be obtained from WATSTORE, the U.S. Geological Survey informational data base; R, recently pumped; D, dry; F, flowing; —, no measurement]

Well location	Water level, in feet below or above (-) land surface		
	February 19-28, 1985	June 3-7, 1985	May 27-31, 1986
(A-6-1)1aaa-1	14.3	11.0	13.3
(A-6-1)1baa-1	19.9	13.4	13.7
(A-6-1)1dad-1	36.5	21.7	25.9
(A-6-1)3dbc-1	—	36.9	34.9
(A-6-1)10aac-1	33.5	28.8	31.4
(A-6-1)10dbc-1	60	46.1	44.7
(A-6-1)10dda-1	36.5	8.5	34.2
(A-6-1)11acb-1	28.7	19.6	30.8
(A-6-1)11cab-1	43.9	16.1	43.3 Shallower well.
(A-6-1)11cab-1	48.7	17.7	43.9 Deeper well.
(A-6-1)11dcd-2	42.8	15.6	39.9
(A-6-1)12dcd-1	25.9	14.5	—
(A-6-1)13cdd-1	30.2	12.9	24.1
(A-6-1)24aba-2	36.5	20.9	30.8
(A-6-2)5bbc-1	12.1	12.9	11.3
(A-6-2)6aab-1	6.2	2.6	4.4
(A-6-2)6bbb-1	14.8	5.9	14.4
(A-6-2)6cad-1	22.3	19.6	20.8
(A-6-2)6dad-1	27.7	24.2	24.7
(A-6-2)7aab-1	32.0	25.6	26.9
(A-6-2)7bbb-1	28.8	14.7	18.5
(A-6-2)7bbd-1	28.4	15.8	19.2
(A-6-2)7bcc-1	25.9	14.0	17.5
(A-6-2)7cad-1	—	30.7 R	32.5 R
(A-6-2)7dac-1	3.6	4.3	4.1
(A-6-2)7ddb-1	—	0	2.0
(A-6-2)8ddb-1	7.3	4.3	4.9
(A-6-2)14bab-1	—	39.7	35.0
(A-6-2)14bbd-1	32.8	31.4	24.5
(A-6-2)14bcc-1	34.9	31.3	31.5
(A-6-2)15acb-1	41.3	29.9	27.3
(A-6-2)15cdb-1	18.4	15.5	7.4
(A-6-2)16add-1	34.9	23.0	20.5
(A-6-2)16bad-1	20.5	7.0	6.7
(A-6-2)16bdb-1	16.6	7.4	7.0
(A-6-2)16cbd-1	14.5	9.3	7.6
(A-6-2)16dad-1	21.3	14.8	9.7
(A-6-2)17aab-1	9.0	3.9	4.0
(A-6-2)17abb-1	4.5	1.2	2.6
(A-6-2)17bbb-1	-4.0	-5.5	-5.2
(A-6-2)17cca-1	—	7.6	8.2
(A-6-2)17dac-1	—	4.8	3.8
(A-6-2)17dbd-1	7.9	6.0	5.5
(A-6-2)18bad-1	22.0	8.0	16.3
(A-6-2)18dad-2	8.5	2.8	4.9
(A-6-2)18dbb-1	12.8	11.3	—
(A-6-2)19abb-1	-3.4	-10.1	-7.0
(A-6-2)19bda-1	49.2	50.3	47.4
(A-6-2)20acd-1	-4.4	-5.6	-6.5
(A-6-2)21aab-1	16.1	13.9	9.8
(A-6-2)21abc-1	10.4	9.4	8.7
(A-6-2)21abc-2	12.9	11.2	7.8
(A-6-2)21acd-1	6.6	5.5	3.3
(A-6-2)21bbb-1	8.2 R	6.3 R	6.3 R
(A-6-2)21cbd-1	5.1	4.7	4.1
(A-6-2)21ccd-1	38.2	25.1	28.3
(A-6-2)22bcb-1	15.2	13.1	9.7
(A-6-2)28aaa-1	1.4	1.5	.9
(A-6-2)28aba-1	23.2	29.3 R	19.6
(A-7-1)6dda-1	12.4	11.7	13.2
(A-7-1)7abc-1	18.3	20.8 R	20.8 R
(A-7-1)7dba-1	9.8	8.6	8.0
(A-7-1)7dcb-1	—	50.5 R	24.3
(A-7-1)7dda-1	19.3	12.3	8.6
(A-7-1)8cad-1	13.4	10.1	8.6
(A-7-1)8cbb-1	—	34.8	32.6
(A-7-1)17bcb-1	46.7	32.3	27.5
(A-7-1)17cba-1	—	47.1	42.1
(A-7-1)18adb-1	—	19.7	19.1
(A-7-1)19aad-1	65.2	43.1	40.8
(A-7-1)19acd-1	—	— F	— F
(A-7-1)20bab-1	—	34.6	30.5
(A-7-1)20dcd-1	8.1	3.8	2.6
(A-7-1)21bab-1	—	4.9	2.3
(A-7-1)21bbc-1	9.7	3.7	2.4
(A-7-1)21cad-1	9.4	6.9	5.3
(A-7-1)27baa-1	31.9	31.3	32.5
(A-7-1)28adb-1	59.3	56.7	56.2
(A-7-1)28baa-1	20.8	20.2	20.2
(A-7-1)28dbb-1	—	26.5	23.2
(A-7-1)28dda-1	—	24.6	21.6
(A-7-1)29acc-1	—	79.5	79.2
(A-7-1)29ada-1	5.1	1.3	1.5
(A-7-1)29baa-1	—	16.5	12.4
(A-7-1)29dbc-1	—	38.4	37.3 R
(A-7-1)29ddc-1	42.3	53.1 R	59.4
(A-7-1)30aad-1	—	125.4	118.3
(A-7-1)32abd-1	43.8	41.9	40.0
(A-7-1)34aca-1	50.6	44.4	46.9
(A-7-1)34bab-1	39.1	33.8	33.7
(A-7-1)34cbb-1	—	11.6	11.3
(A-7-1)34cda-1	-.8	-4.9	-2.2
(A-7-1)34dbb-1	40.2	35.9	37.1
(A-7-1)35bbb-1	8.3	6.1	11.0
(A-7-1)35cac-1	D	8.1	14.2

Table 11. Water level in selected observation wells during February and June 1985 and May 1986—Continued

Well location	Water level, in feet below or above (-) land surface		
	February 19-28, 1985	June 3-7, 1985	May 27-31, 1986
(A-7-1)35cdd-1	—	6.3	13.1
(A-7-1)36bdd-1	13.1	9.4	4.6
(A-7-1)36dca-1	—	4.5	4.5
(B-7-1)1bab-2	8.2	6.8	6.2
(B-7-1)1daa-1	—	22.2	21.9
(B-7-1)1dda-1	70.9	69.5	69.8

reaches of the North Fork Ogden River and the South Fork Ogden River and the gains measured in the lowest reach of the North Fork Ogden River and at Liberty and Bailey Springs southwest of Liberty were not accurately simulated because of the interaction of ground water in the consolidated rock and the valley fill, which was not properly accounted for in the model. The simulated distribution of ground-water seepage to the individual channels of Spring Creek was inaccurate, but the total quantity of seepage to Spring Creek was closely simulated.

Water budget

The steady-state water budget developed by model simulation (table 12) was reasonably similar to the water budget developed by extrapolation of the collected data (table 10). Although simulated flow from Pineview Reservoir to the confined aquifer near the Ogden well field was included in the simulated water budget, the calculated water budget did not include this component of recharge.

The steady-state water budget indicated that about 115 cubic feet per second of water is recharged to and discharged from the valley-fill aquifer system. Losing streams accounted for more than one-half of the recharge. Subsurface inflow from the consolidated rocks accounted for most of the remaining recharge. The major components of discharge are gaining streams, springs and drains, and Pineview Reservoir. The Ogden well field accounts for the remainder of the simulated discharge during steady state.

Transient Simulation

Because of the small areal extent and relatively large transmissivity of the valley-fill aquifer system, the shallow depths to the water table in the recharge areas, the relatively large seasonal changes in water levels, and the lack of areally distributed historical data, a transient simulation period of about 1 year was chosen. The simulation represented hydrologic conditions from February 15, 1985, to January 31, 1986. The 12 stress periods represent intervals between water-level measurements, which were made about once a month at observation wells. The climatic conditions during the simulation period were near normal, although precipitation during the previous water year had been much in excess of normal.

Water-level changes in observation wells were the only reliable data available with which to calibrate the transient simulation. Water levels in 101 observation wells were measured in June 1985 and compared to the simulated water levels at that time. Monthly water-level measurements at 22 observation wells were used during each stress period to calibrate the transient simulation.

During the transient simulation period, surface-water data that indicated seepage to streams were available only for Spring Creek. Data describing seepage to Spring Creek during the snowmelt and irrigation seasons could not be used to calibrate the transient model because some of the flow in Spring Creek was derived from sources other than ground-water seepage. Observations of the current conditions of the river channels were made at the same time the observation-well measurements were made. These observations were used to qualitatively adjust the model for the transient simulation of the ephemeral streams.

In general, calibration of the transient simulation was accomplished by adjusting the hydraulic-conductivity values of the underlying aquifer and the conductance of the streambed. Some adjustment of the river stage, within reasonable limits, was made in order to adjust the ground-water recharge from streams or the discharge to streams.

Water-level changes

Simulated water-level changes in cells that represent observation-well sites were compared to measured water-level changes in each observation well. The simulated and measured water-level changes for selected wells are shown in figures 27 and 28. The simulated water-level changes were similar to the measured water-level changes.

Table 12. Simulated water budget for the valley-fill aquifer system, mid-February 1985 through January 1986

[Values are in cubic feet per second, except as indicated]

	Winter 1985 (steady state)	Mid-February to mid-March (period 1)	Mid-March to mid-April (period 2)	Mid-April to May (period 3)	May (period 4)
Simulated recharge					
Precipitation and irrigation	0	16	119	0	76
Losing streams and irrigation distribution losses	67	80	116	142	123
Pineview Reservoir	2	2	3	12	6
Subsurface inflow	46	46	46	46	68
Total	115	144	284	200	273
Simulated discharge					
Gaining streams	47	50	60	46	63
Springs and drains	28	29	39	35	42
Wells	15.1	14.5	15.5	18.5	14.2
Evapotranspiration	0	0	1	4	21
Pineview Reservoir	25	23	34	19	33
Total	115.1	116.5	149.5	122.5	173.2
Simulated change in storage, in acre-feet. (Negative values indicate decrease in storage.)					
Periodic	—	1,600	9,800	2,500	7,900
Cumulative	—	1,600	11,400	13,900	21,800

An areal distribution of simulated water-level changes was compared to a map of measured water-level changes. The simulated water-level changes through stress period 4, mid-February through May 1985, are shown in figure 29. Overall, these simulated water-level changes (fig. 29) compare favorably with the measured water-level changes shown in figure 20. The measured water-level change map was developed from about 72 data points, and contours were interpolated where data were lacking. Some of the differences between simulated and measured water-level changes may result from interpolation of measured water-level changes where few data were available. In each of the observation wells, the simulated water-level change generally was within 50 percent of the total measured water-level change during the period of the study.

Spring Creek drainage

Simulated discharge to the channels of Spring Creek from layer 1 is shown in table 13. The approximate measured discharge for the same periods (fig. 8) also is shown. Although the data sets were compared, they were not used in calibrations.

The simulated and measured discharge values are similar. The differences in values and trends may result in part because the model does not simulate the storage of ground water in the confining layer.

Water budget

The water budget determined for the transient simulation is shown in table 12. The comparison of the simulated values and the independently determined values is reasonably good. The areal recharge, subsurface inflow, discharge from wells, and subsurface outflow were entered directly into the model data set. Interchange between the aquifer and streams, drains, and Pineview Reservoir and discharge by evapotranspiration were computed by the model.

Several discrepancies between the simulated and independently determined values can be used to yield information on certain aspects of the hydrology of the valley-fill aquifer system. More water probably recharges the aquifer system from the irrigation canals and ditches (particularly during July and thereafter) than was recognized by the seepage measurements.

June (period 5)	July (period 6)	August (period 7)	September (period 8)	October (period 9)	November (period 10)	December (period 11)	January (period 12)
			Simulated recharge				
68	39	38	54	36	85	13	0
66	51	49	46	73	76	76	60
5	4	3	0	0	1	2	3
91	146	87	69	46	46	46	46
230	240	177	169	155	208	137	109
			Simulated discharge				
40	27	19	34	42	57	52	40
34	27	24	33	35	36	36	30
14.4	14.9	15.4	10.4	9.4	13.7	13.1	12.8
75	104	82	15	4	1	0	0
39	36	50	48	46	44	35	45
202.4	208.9	190.4	140.4	136.4	151.7	136.1	127.8
			Simulated change in storage, in acre-feet. (Negative values indicate decrease in storage.)				
1,000	900	-1,500	1,700	1,100	2,900	100	-1,200
22,800	23,700	22,200	23,900	25,000	27,900	28,000	26,800

The independently determined values for seepage to streams did not take into consideration the effects of river stage on seepage. The river stage was higher during the months of May through July than during steady state. The greater river stage in the discharge areas during the periods of greater flow would have decreased the rate of seepage from the aquifer system to the river.

The model indicated that water levels in the confined part of the principal aquifer do not respond immediately to, nor as much as, the changing stage of Pineview Reservoir. During stress period 3, the stage of Pineview Reservoir rose abruptly, but water levels in the confined part of the principal aquifer did not increase as much. Nearly half of the interchange of water between Pineview Reservoir and the confined part of the principal aquifer was as downward seepage. Interchange between the principal aquifer and Pineview Reservoir did not appear to increase substantially with the increased area of the reservoir, as was assumed when discharge from Pineview Reservoir was independently determined for May through August.

Simulated recharge for the 12 stress periods ranged from 109 to 284 cubic feet per second (table 12). Simulated discharge ranged from 115 to 209 cubic feet per second.

The simulated periodic change in storage in the valley-fill aquifer system (table 12) increased every stress period except for periods 7 and 12. The cumulative change from steady state through stress period 12 was nearly 27,000 acre-feet (table 12). These values for change in storage probably are too large and are greater than those values calculated for February to June 1985 (see "Storage" section). The discrepancy may result because storage changes in the shallow water-table aquifer (layer 1) and in the principal aquifer north of Eden were included in the model but were not considered in the original calculations.

Simulation of Hypothetical Conditions

The model also was used to simulate the hydrologic effects of two hypothetical changes in the hydrologic system. The hypothetical changes were: (1) reduced recharge resulting from a drought and (2) increased discharge from wells.

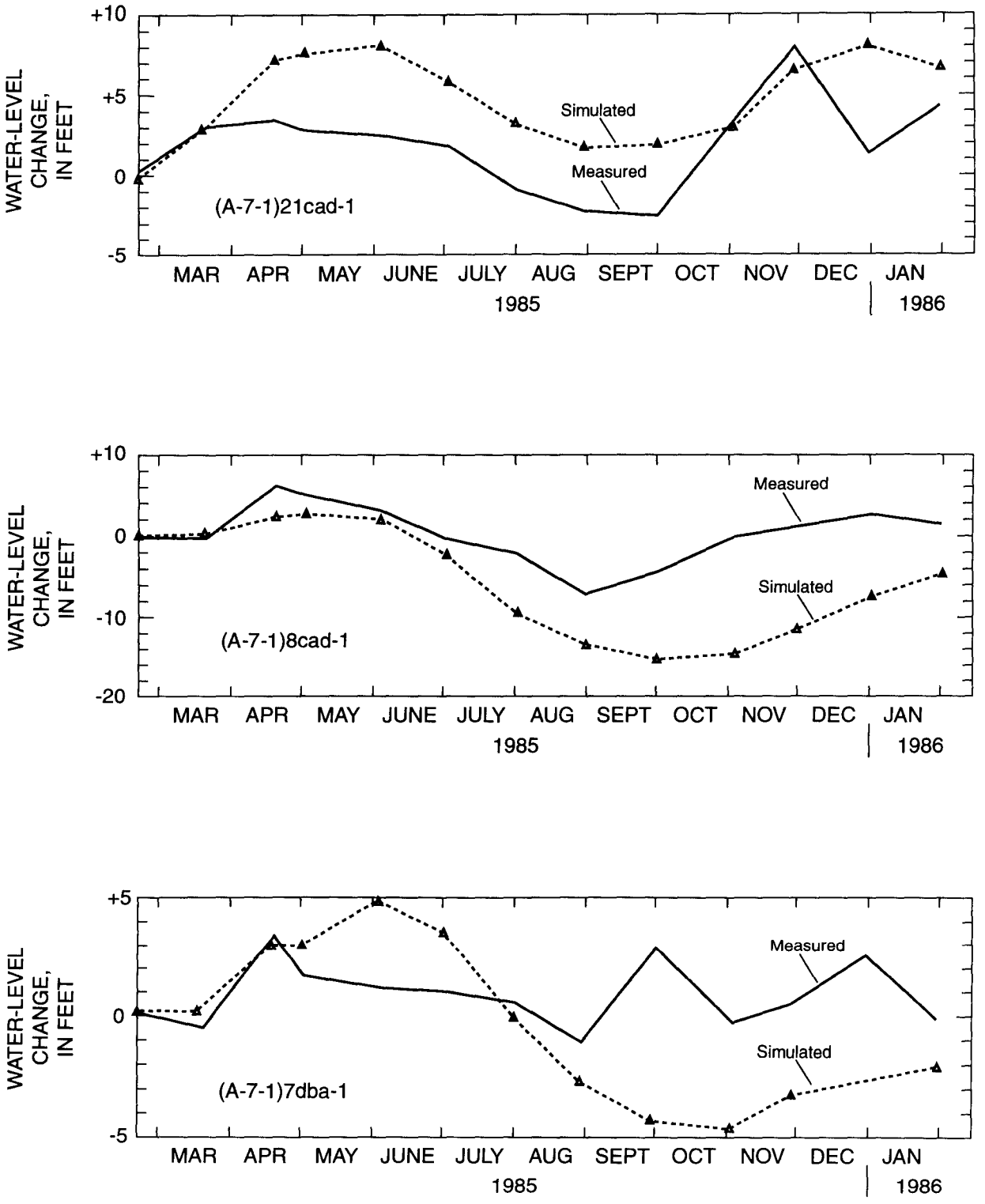


Figure 27. Simulated and measured water-level change for three observation wells in the upper North Fork Ogden River valley, 1985-86.

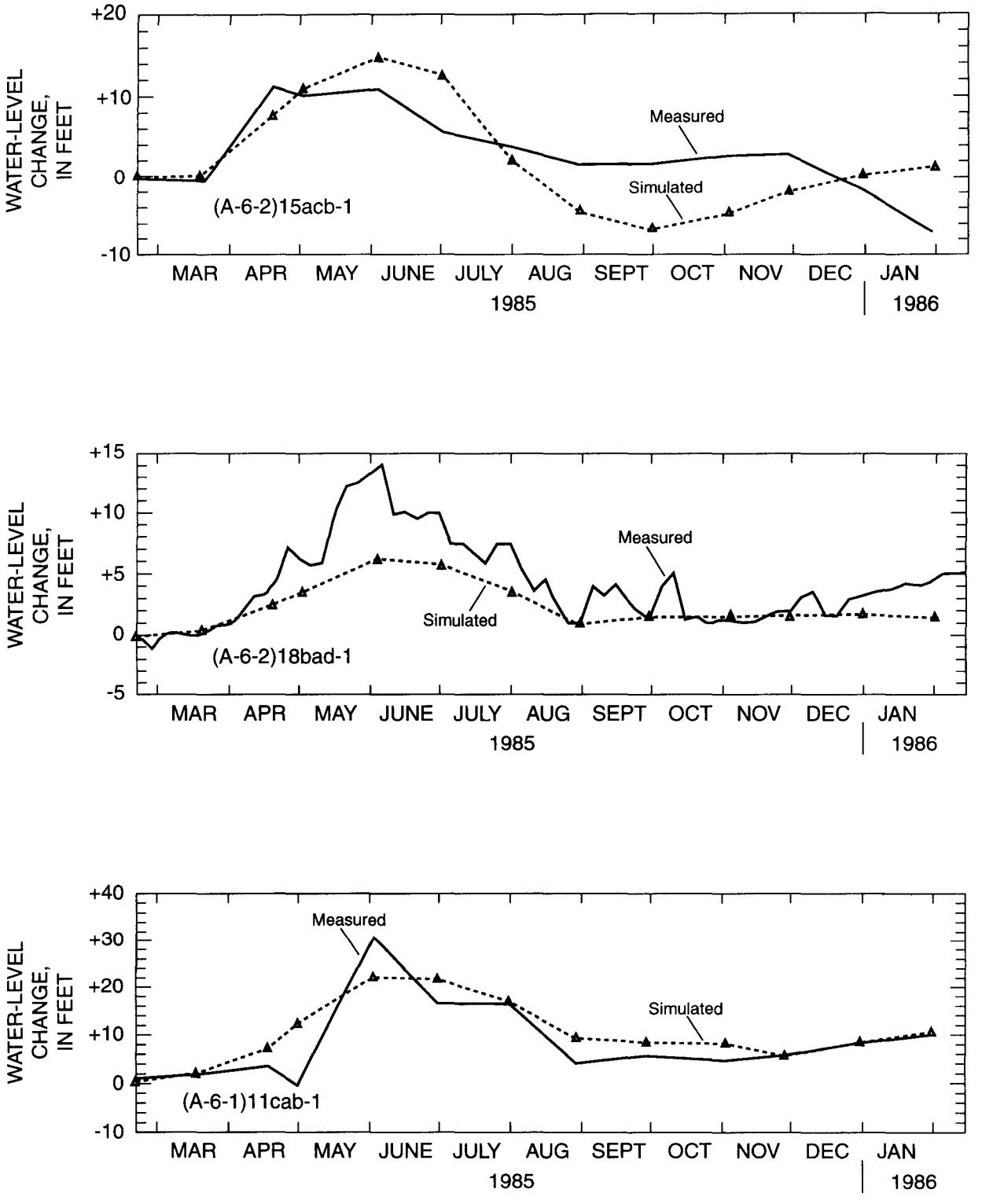


Figure 28. Simulated and measured water-level change for three observation wells in the south part of Ogden Valley, 1985-86.

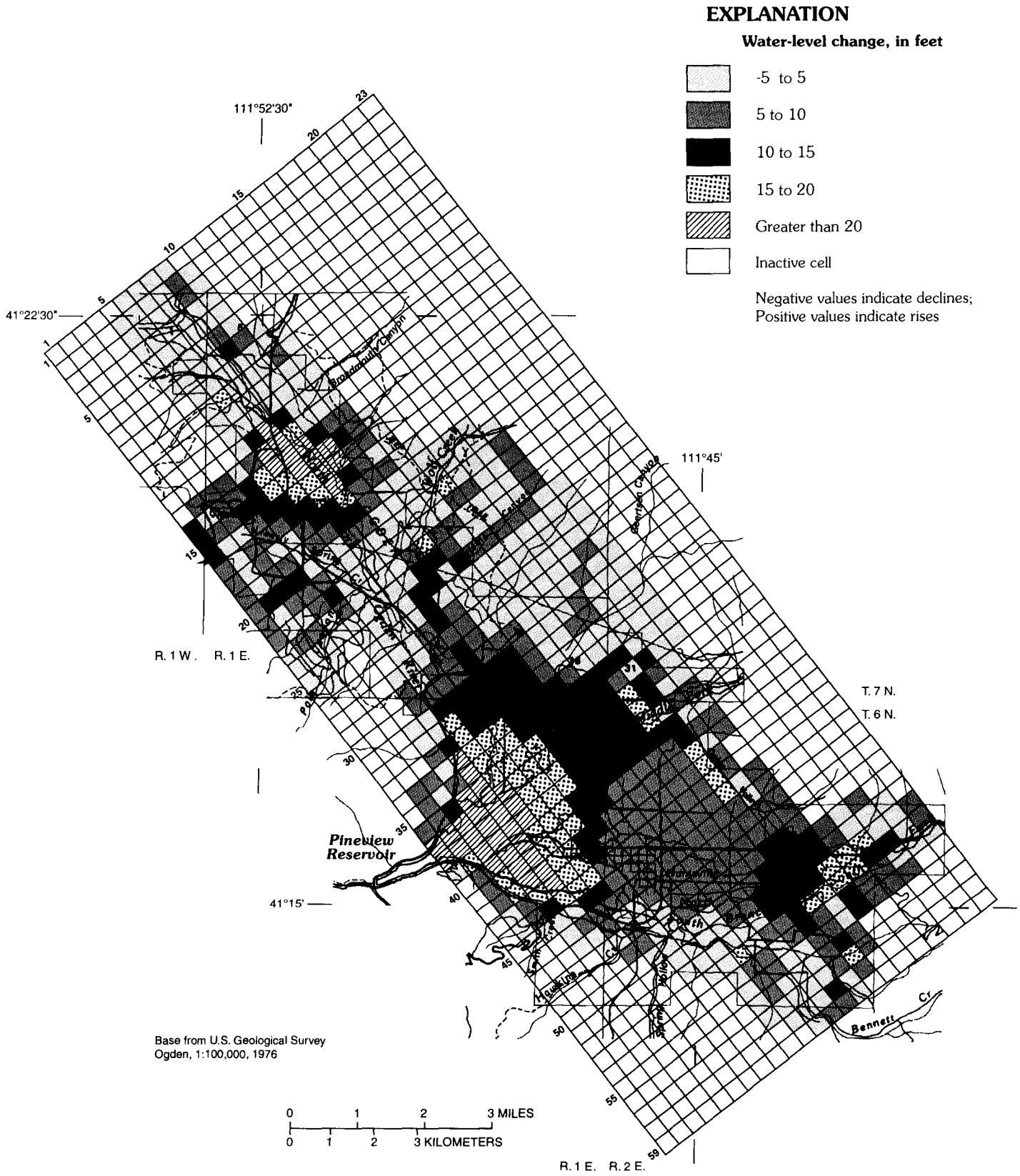


Figure 29. Simulated water-level change in the principal aquifer, mid-February through May 1985.

Table 13. Simulated and measured discharge to Spring Creek

Stress period	Monthly period	Simulated discharge (cubic feet per second)	Measured discharge (cubic feet per second)
1	Mid-February to mid-March	10.8	11
2	Mid-March to mid-April	15.4	17
3	Mid-April to May	15.5	12
4	May	21.4	15
5	June	16.6	20
6	July	10.7	16
7	August	9.0	11
8	September	11.1	8
9	October	12.3	7
10	November	12.6	7
11	December	12.4	8
12	January	12.0	9
	Mean discharge	13.3	11.8

Drought

Ogden Valley has experienced several droughts, but little information is available on the hydrologic effects of drought over a wide area of the valley. Therefore, computer simulation of a drought year, with conditions similar to those during 1977, was made with the hydraulic properties used in the transient calibration. Fewer active river reaches in the recharge area, lower river stages, lower Pineview Reservoir stages, less recharge from bedrock, and lower rates of areal recharge from precipitation and irrigation were included in the model data based on probable conditions. Data collected in 1977 were used to help conceptualize the probable conditions.

The water budget and water levels for the 1985-86 simulation period were compared to the water budget and water levels of the simulated drought period to observe water-level declines and storage changes. Water levels for the simulated drought period were lower than those for the 1985-86 simulation period and did not show as much seasonal fluctuation (fig. 30). Water levels near Pineview Reservoir and in the South Fork Ogden River drainage east of Huntsville showed the greatest declines from 1985-86 levels. The greatest declines for the simulated drought occurred during the spring and early summer months.

Water budgets for the 1985-86 simulation period and the simulated drought period showed some substantial differences. Overall storage losses during the simulated drought occurred during stress periods 5 through 7 (June-August). The most substantial storage increases occurred during stress periods 2 (mid-March to mid-April) and 10 (November). Considerably less water was exchanged between the confined part of the principal aquifer and Pineview Reservoir during the simulated drought period. Recharge from streamflow diminished, most likely because fewer stream reaches were active in the recharge areas, and the river stages were not as high. During the simulated drought, total recharge varied from 113 to 204 cubic feet per second, and total discharge varied from 103 to 173 cubic feet per second.

Increased Discharge from Wells

Withdrawals from three additional wells, each discharging at a rate of 1 cubic foot per second, also were simulated. The simulated wells were located northwest of Liberty, northwest of Eden, and east of Huntsville. All three wells derived their water from layer 2; the Eden and Huntsville wells were in the confined part of the principal aquifer, and the Liberty well was in the unconfined part of the principal aquifer.

The simulation of additional discharge and the original 1985-86 simulation were compared using the water levels in observation wells, the storage changes, and the overall water budget. The water levels in observation wells did not change noticeably, indicating that very little of the additional water came from storage in the aquifer. The rate of increase in storage in the aquifer declined by about 1 cubic foot per second during stress periods 5 through 8, as indicated by the water budget.

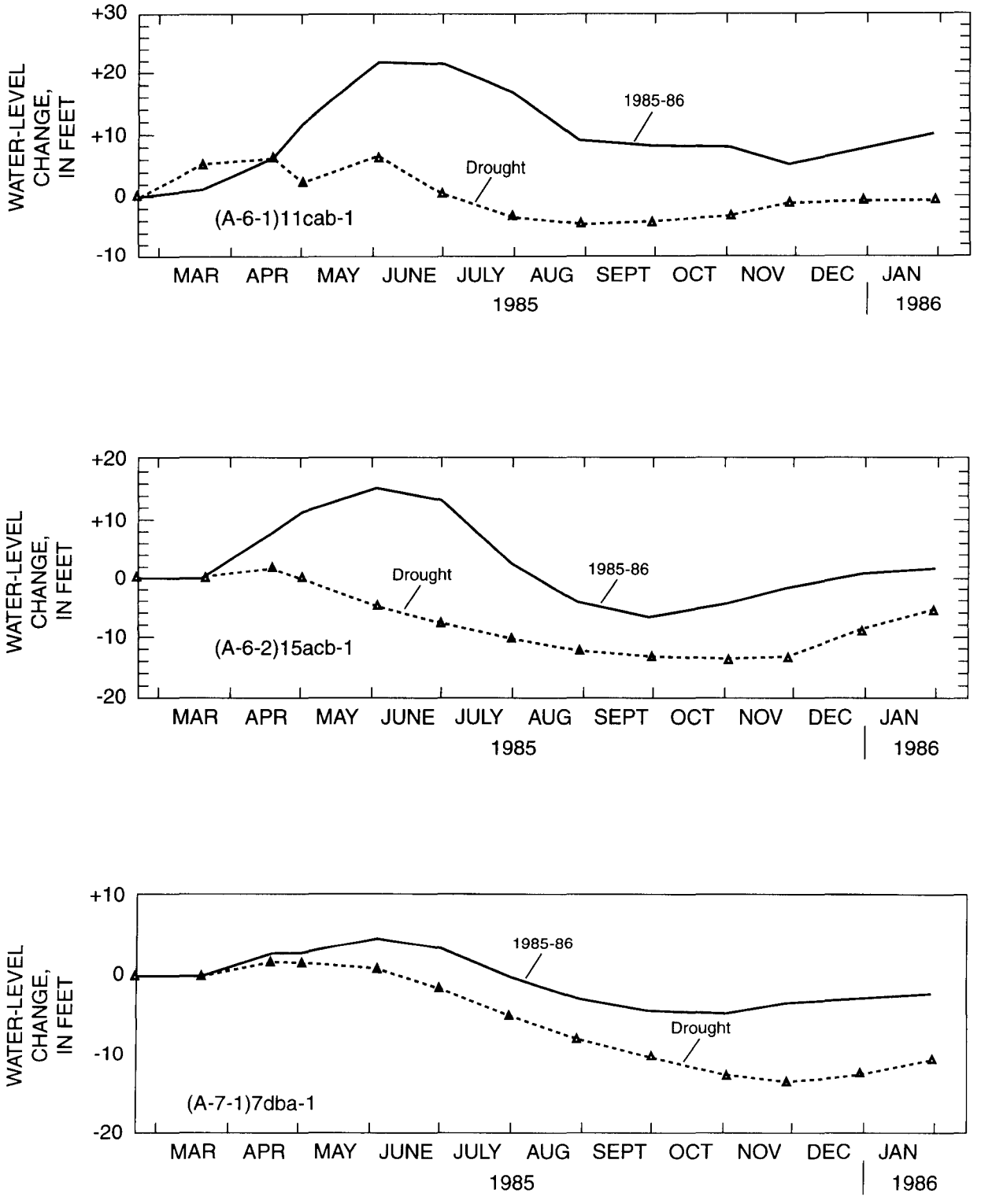


Figure 30. Water-level change in wells in Ogden Valley for 1985-86 simulation and for drought simulation.

The two water budgets were compared for each stress period even though the total quantity of change in the water budget during each stress period could not exceed the total additional well discharge of 3 cubic feet per second. Evapotranspiration was slightly affected. Reduced seepage to Pineview Reservoir during the later stress periods probably was caused by pumping of the simulated Eden well. Pumping of the simulated Huntsville well appeared to divert water that would have discharged to Spring Creek and to drains in the immediate area. Pumpage of the simulated Liberty and Eden wells caused reduced ground-water storage and reduced discharge to streams. The simulated Liberty well likely induces streamflow from the North Fork Ogden River channel to recharge the aquifer; the simulated Eden well probably intercepts water that normally discharges to the North Fork Ogden River channel.

NEED FOR FURTHER REFINEMENT OF THE COMPUTER SIMULATION

The computer simulation presented in this report accomplished the purpose of estimating the probable range in values and distribution of hydraulic properties and provided an estimate of the rates of the various recharge and discharge components of the aquifer system. The available data are not adequate to accurately simulate ground-water flow in the hydrologic system over a lengthy period of time and for changing hydrologic conditions.

The ground-water-flow model could not accurately define the surface-water influence on the ground-water system. More data on surface-water conditions are needed. Better definition of river and drain seepage, improved timing and location of dry reaches in the river channels, and a better definition of the distribution and rate of leakage to Pineview Reservoir are needed.

The observation-well network established for this study was adequate for the monthly observations of most substantial water-level changes but not for several areas of probable large water-level changes. Therefore, additional observation wells are needed in many areas, such as near Liberty.

Subsurface inflow, probably one of the largest contributors of recharge to the ground-water system, was not and probably cannot be measured. Better definition of the distribution of recharge, particularly the seasonal change in rate, is needed.

The discretization of streams into cells led to problems with calibration using water levels in observation wells. In the model, some wells were in the same cell as a river reach. When the river reach went dry, water levels in wells from these river cells declined more than could be expected realistically. The use of a more detailed grid in a finite-difference model or a finite-element model probably would minimize this problem.

SUMMARY AND CONCLUSIONS

The area surrounding Ogden Valley is consolidated rock. The consolidated rocks that transmit and yield the most water in the area are the carbonate rocks and the Wasatch Formation. Infiltration of snowmelt, mostly on the widespread Wasatch Formation, is the predominant source of recharge. Discharge from consolidated rocks is by streams, evapotranspiration, springs, subsurface outflow, and wells.

The unconsolidated valley-fill deposits in Ogden Valley are more than 750 feet thick and comprise the valley-fill aquifer system. The valley-fill aquifer system includes a principal aquifer with confined and unconfined parts and a shallow water-table aquifer that overlies the confined part of the principal aquifer and is separated from it by a silty clay layer.

Ground-water movement in the valley-fill aquifer system is from the area along the margins of the valley toward Pineview Reservoir in the southern part of the valley. The vertical head gradients are downward in the recharge areas and upward in the discharge areas. Upward movement of water occurs from the confined part of the principal aquifer through the confining bed to Pineview Reservoir and Spring Creek.

A water budget for the valley-fill aquifer system was estimated for mid-February 1985 through January 1986. Because of the substantial seasonal variation in hydrologic conditions resulting from climatic variations, the budget presented is unique for that time period. In general, the water-budget indicates that the majority of recharge is from irrigation, losing streams, and subsurface inflow. Precipitation and irrigation distribution losses are relatively minor contributors to recharge. Discharge is to streams, springs, drains, wells, evapotranspiration, and Pineview Reservoir.

The range and distribution of hydraulic properties were clarified using a combination of field and laboratory data. An aquifer test completed for this study indicated that a transmissivity value of about 79,000 feet squared per day was the most representative value for the confined part of the principal aquifer. Hydrau-

lic-conductivity values from laboratory tests were less than 0.013 foot per day for the confining layer. Vertical hydraulic conductivity of the confining layer ranged from 0.01 to 0.04 foot per day according to reservoir-bed seepage measurements.

Water in the valley-fill aquifer system has a dissolved-solids concentration that does not exceed 350 milligrams per liter, and most of the water is a calcium bicarbonate type. The water is slightly more mineralized in the Middle Fork Ogden River and South Fork Ogden River valleys. Relative to the general water quality in the valley, nitrate, pH, and water temperature were slightly anomalous in localized areas.

A three-dimensional, finite-difference computer model was used to simulate ground-water flow in the valley-fill aquifer system and thus, enable a better understanding of the system. Two hypothetical changes in the aquifer system, a 1-year drought and withdrawals from 3 additional wells, were simulated to estimate the effects of these changes on streamflow and ground-water levels.

Drought conditions similar to those during 1977 were simulated to estimate the hydrologic effects of drought on Ogden Valley. Water levels in the principal aquifer were lower for the simulated drought period than for the 1985-86 simulation period and did not show as much seasonal fluctuation. Interchange of water between the confined part of the principal aquifer and Pineview Reservoir during the simulated drought period was reduced.

Withdrawals from three additional wells also were simulated, and water levels in observation wells did not change noticeably, indicating very little additional water came from storage. Reduced seepage to Pineview Reservoir and reduced discharge to streams also were noted.

In order to simulate ground-water flow for varying hydrologic conditions, more data need to be collected on surface-water conditions. More wells are needed in several areas in order to add control points for water-level measurements. Additional observation wells in the Liberty area, in particular, would provide useful control data.

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Geology, precipitation, and selected hydrologic-data sites—PLAT
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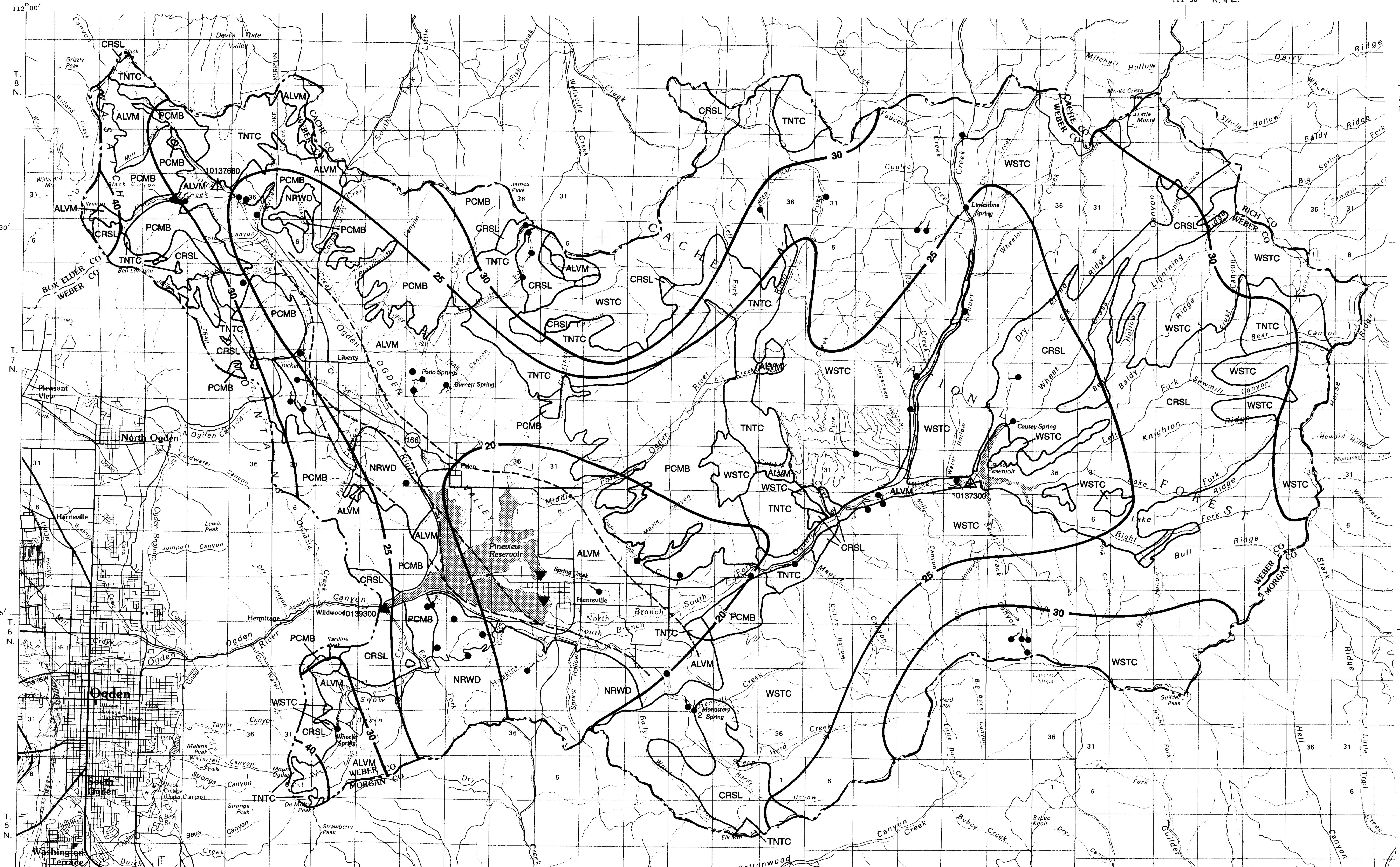

EXPLANATION

Hydrogeologic unit

Symbol	Unit
ALVM	Valley fill
NRWD	Norwood Tuff
WSTC	Wasatch Formation
CRSL	Carbonate rocks
TNTC	Clastic rocks
PCMB	Metasedimentary rocks
(shaded)	Surface-water reservoir

- Contact
- Approximate location of faults bounding Ogden Valley
- Drainage divide for Ogden River above Pineview Reservoir Dam and Wheeler Cre
- 30 — Line of equal normal annual precipitation (1931-60)—Interval, in inches, is variable. Data from U.S. Weather Bureau (1963)
- 10139300 ▲ Active gaging station
- 10137300 △ Discontinued gaging station
- ▼ Miscellaneous water-quality sampling site
- ● Well
- Spring—Tail oriented in direction of flow. Number indicates multiple springs at this locatio

Base from U.S. Geological Survey
Ogden 1:100,000, 1976

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

Geology modified from W.L. Stokes, 1963; T.E. Mullens, 1969, M.D. Crittenden, 1972; and F.D. Davis 1985, Hydrology by Charles Avery, 1986

MAP SHOWING GEOLOGY, PRECIPITATION, AND SELECTED HYDROLOGIC-DATA SITES IN OGDEN VALLEY, UTAH, AND SURROUNDING AREA

By

Charles Avery

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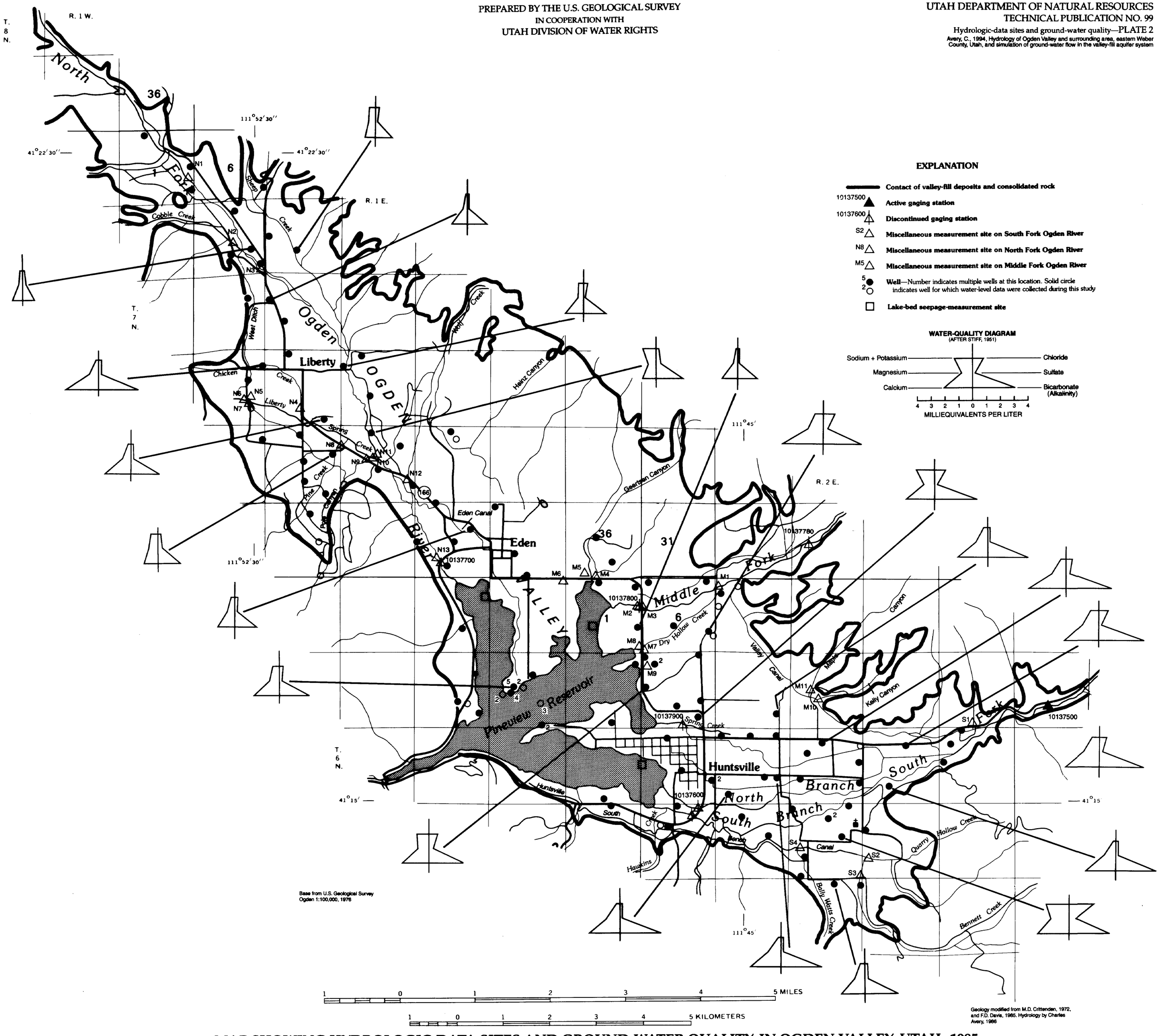

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By
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1994