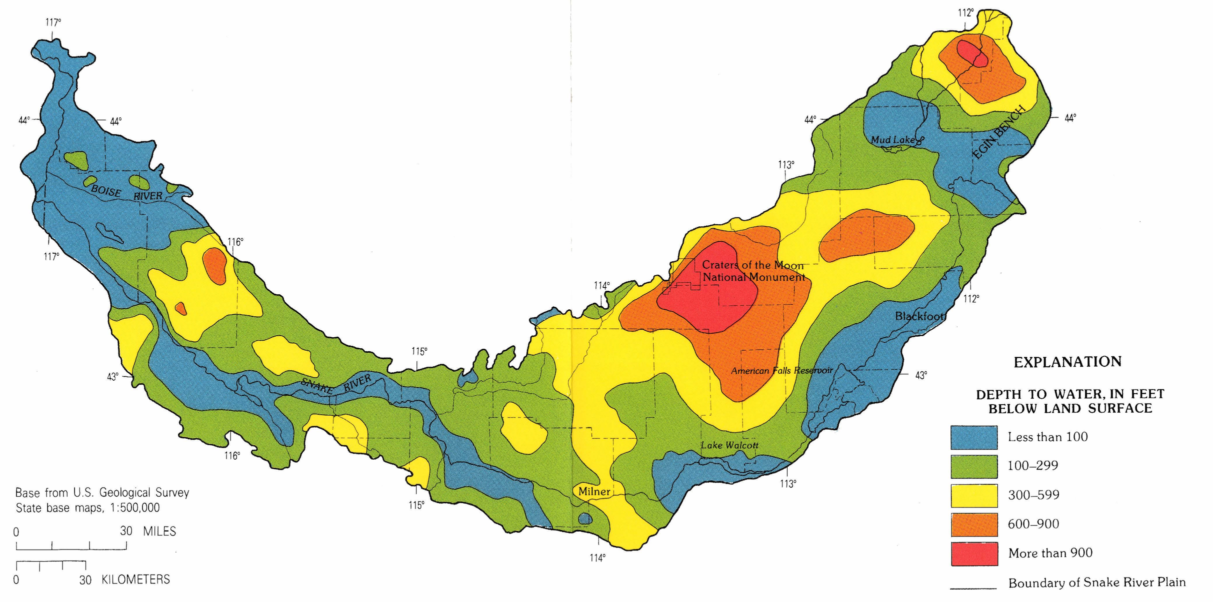
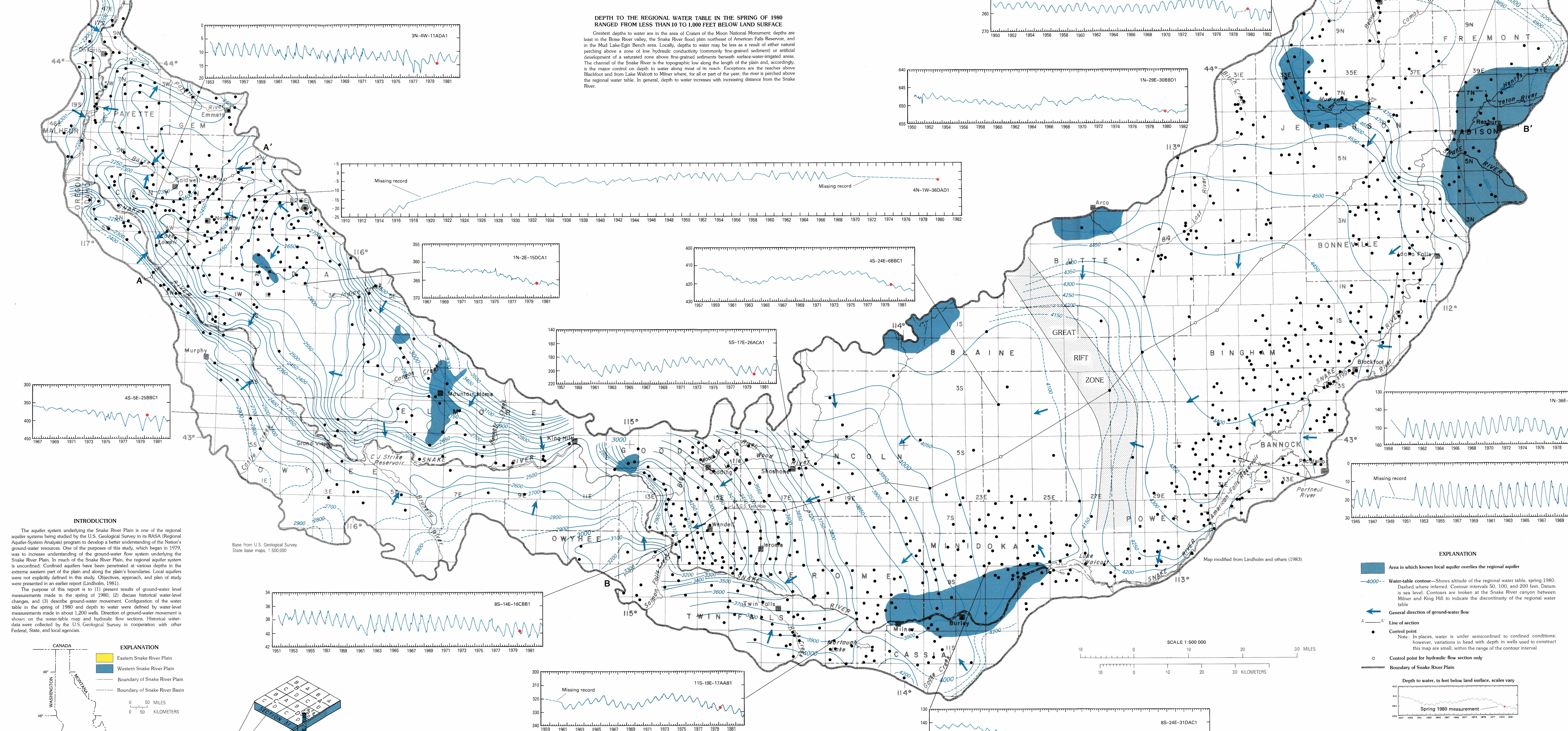
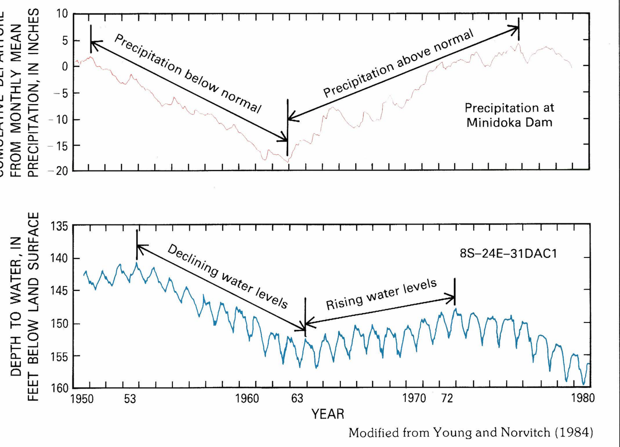


DEPTH TO THE REGIONAL WATER TABLE IN THE SPRING OF 1980 RANGED FROM LESS THAN 10 TO 1,000 FEET BELOW LAND SURFACE

Greatest depths to water are in the area of Craters of the Moon National Monument; depths are least in the Boise River valley, the Snake River flood plain northeast of American Falls Reservoir, and in the Mud Lake-Egin Bench area. Locally, depths to water may be less as a result of either natural perching above a zone of low hydraulic conductivity (commonly fine-grained sediment) or artificial development of a saturated zone above fine-grained sediments beneath surface-water-irrigated areas. The channel of the Snake River is the topographic low along the length of the plain and, accordingly, is the major control on depth to water along most of its reach. Exceptions are the reaches above Blackfoot and from Lake Walcott to Milner where, for all or part of the year, the river is perched above the regional water table. In general, depth to water increases with increasing distance from the Snake River.





Modified from Young and Norvitch (1984)

LONG-TERM CHANGES IN GROUND-WATER LEVELS REFLECT PRECIPITATION TRENDS, CHANGES IN IRRIGATION PRACTICES, AND GROUND-WATER PUMPING

Hydrographs at left illustrate long-term water-level changes across the Snake River Plain. Hydrographs for other wells on the plain are included in reports by Sisco (1974, 1975, 1976), Young (1983), and Young and Norvitch (1984).

Ground-water levels change in response to long-term changes in precipitation. An example of the relation between long-term precipitation trends and ground-water levels was given by Young and Norvitch (1984, p. 8) and was modified above.

Water-level highs in 1953 and 1972 and the intervening low in 1963 are related to precipitation trends. The length and points of inflection of precipitation and ground-water level trends do not directly correlate for several probable reasons. Recharge to the ground-water system underlying the eastern part of the Snake River Plain was determined to be about 60 percent from surface-water irrigation, 25 percent from drainage basins tributary to the plain, 10 percent from direct precipitation, and 5 percent from Snake River losses (L.C. Kjelstrom, U.S. Geological Survey, written commun., 1986). Consequently, direct correlation between precipitation at a single station and water levels in a single well is not necessarily expected. However, total quantity of water available over a period of years is reflected by ground-water levels and accounts for the correlation of trends shown. The ground-water low in late 1963 appears to lag the inflection point in precipitation trends by about 1 year. The lag may reflect the length of time necessary for differences in the amount of precipitation to be realized as regional ground-water level changes. Young and Norvitch (1984, p. 9) explained that in the example above, trends on the precipitation cumulative departure curve from monthly mean precipitation curve and trends on the hydrograph deviate after 1973. The deviation is attributed to decreased surface-water diversions for irrigation, more efficient use of water, and increased ground-water withdrawals.

Although details vary, long-term water-level trends in many wells on the eastern plain appear to have a similar relation to precipitation. On the western part of the Snake River Plain, the relation is less apparent and other factors predominate.

Prior to the start of intensive irrigation in the early 1900's, ground-water levels changed only in response to precipitation, both on the plain and on tributary areas. As use of surface water for irrigation increased, more water became available for recharge. Transmission losses from a network of canals and deep percolation from irrigated fields raised ground-water levels in large parts of the plain.

Although preirrigation water-level data are largely unavailable, Mundorff and others (1964, p. 162) reported that from about 1907 to 1959 as a result of irrigation, the water table north of the Snake River between Minidoka and Bliss rose 25–100 ft, and the average rise may have been 60–70 ft. Water-level rise owing to irrigation south of the Snake River were greatest in the Twin Falls area. Within 5 years after the start of surface-water irrigation in 1908, a water-level rise of 186 ft was measured in well 10S–17E–20AD1; the total rise owing to surface-water irrigation may have been nearly 300 ft (Stearns and others, 1938, p. 129). Continued use of surface water for irrigation for more than 100 years in the Boise River valley has raised ground-water levels as much as 140 ft (Nace and others, 1957, p. 1). In much of the Boise River valley, water levels have been fairly stable for a number of years. On the basis of these examples, it is apparent that use of surface water for irrigation has greatly affected ground-water levels in the Snake River Plain.

Changes in irrigation practices also affect ground-water levels. The most obvious is lower water levels resulting from ground-water withdrawals. Since the late 1940's, use of ground water for irrigation has increased steadily. Removal of water from storage lowers ground-water levels within the cone of influence of a well or well field. Given enough properly spaced wells, continued pumping can result in lowering of water levels regionally. Young and Norvitch (1984) analyzed water-level data from several hundred wells in Idaho to determine probable causes of water-level fluctuations from 1971 to 1982. Included were those wells whose hydrographs are shown at left.

On the eastern part of the Snake River Plain, ground-water withdrawals were identified as the probable cause of declining water levels from the early 1970's to the early 1980's in wells 9N–36E–33CBB1, 5N–38E–9BDA1, 1N–29E–30BBD1, 4S–24E–4BBC1, 8S–24E–31DAC1, and 11S–19E–17AAB1.

Water-level declines observed in wells 7N–38E–23DBA1, 1N–36E–1CCB1, and 5S–17E–26ACA1 probably were due to reduced recharge from surface-water irrigation. Well 7N–38E–23DBA1 is on the Egin Bench where, for a number of years, irrigation with surface water has raised ground-water levels to root depths. Since the early 1970's, some irrigators have changed from flood and furrow irrigation to sprinklers, a more efficient use of water. Consequently, recharge from surface water has decreased and ground-water levels have declined.

On the western part of the Snake River Plain, ground-water withdrawals, primarily for irrigation, have caused water levels to decline in wells near Mountain Home (1N–2E–15DCA1 and 4S–5E–25BBC1). In the Boise River valley, the water level in well 4N–1W–36DAD1 rose rapidly from 1915 to about 1925, then rose gradually for many years owing to increased recharge from surface-water irrigation. Nearly all hydrographs show a rapid decline in water levels following the drought of 1976–77, owing to decreased recharge.

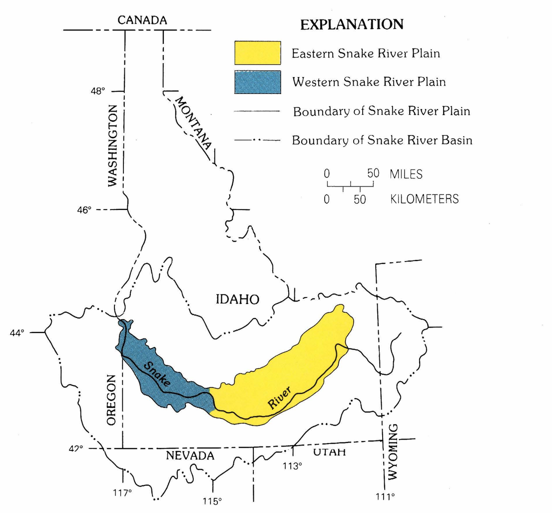
In general, since the start of irrigation, ground-water levels have changed more in response to changes in irrigation practices than to precipitation.

A brief history of irrigation on the Snake River Plain was written by Lindholm and Goodell (1986), and annual recharge from irrigation to 1980 was estimated by Bigelow and others (1984). Young and Norvitch (1984) analyzed seasonal water-level changes (see hydrographs) and showed how water levels differ under natural recharge conditions and in surface- and ground-water-irrigated areas.

INTRODUCTION

The aquifer system underlying the Snake River Plain is one of the regional aquifer systems being studied by the U.S. Geological Survey in its RASA (Regional Aquifer-System Analysis) program to develop a better understanding of the Nation's ground-water resources. One of the purposes of this study, which began in 1979, was to increase understanding of the ground-water system underlying the Snake River Plain. In much of the Snake River Plain, the regional aquifer system is unconfined. Confined aquifers have been penetrated at various depths in the extreme western part of the plain and along the plain's boundaries. Local aquifers were not explicitly defined in this study. Objectives, approach, and plan of study were presented in an earlier report (Lindholm, 1981).

The purpose of this report is to (1) present results of ground-water level measurements made in the spring of 1980, (2) discuss historical water-level changes, and (3) discuss ground-water movement. Configuration of the water table in the spring of 1980 and depths to water were defined by water-level measurements made in about 1,200 wells. Direction of ground-water movement is shown on the water-table map and hydraulic flow sections. Historical water-level data were collected by the U.S. Geological Survey in cooperation with other Federal, State, and local agencies.



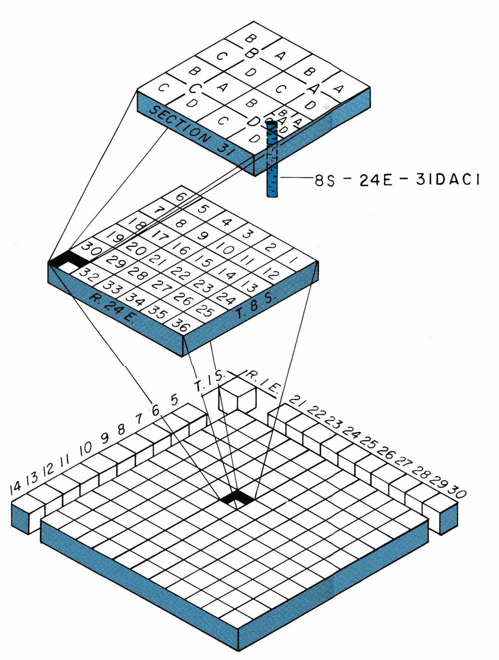
THE TOPOGRAPHY OF THE SNAKE RIVER PLAIN CONTRASTS SHARPLY WITH THE SURROUNDING MOUNTAINS

The Snake River Plain is an arcuate area of about 15,600 mi² that extends across southern Idaho into eastern Oregon. For this study, the extent of the plain was defined on the basis of geology, topography, and hydrology. Along its axis, the plain is about 370 mi long and ranges in width from 30 to 70 mi. The plain's surface altitude rises gradually from about 2,100 ft above sea level at Weiser in southwestern Idaho to 6,000 ft in the northeast near Dubois. Mountains surrounding the plain rise sharply from 7,000 to 12,000 ft.

For study purposes, the plain was divided into eastern and western parts on the basis of geology and hydrology. Quaternary volcanic rocks, chiefly basalt with minor amounts of intercalated sediments, predominate in the eastern plain; Quaternary and Tertiary sedimentary rocks with minor amounts of volcanic rocks predominate in the western plain. The geohydrologic framework of the Snake River Plain is discussed in a companion report (Whitehead, 1984). The hydrologic dividing line between eastern and western parts of the plain is largely the Snake River and one of its tributaries, Salmon Falls Creek (map at center). The Snake River from Milner to King Hill receives about two-thirds of the eastern plain's ground-water discharge, largely as spring flow. Thousand Springs, just below the mouth of Salmon Falls Creek, is the largest group of springs. Flow characteristics of the Snake River and the water budget for the Snake River Plain are discussed in another companion report (Kjelstrom, 1984).

CONVERSION FACTORS

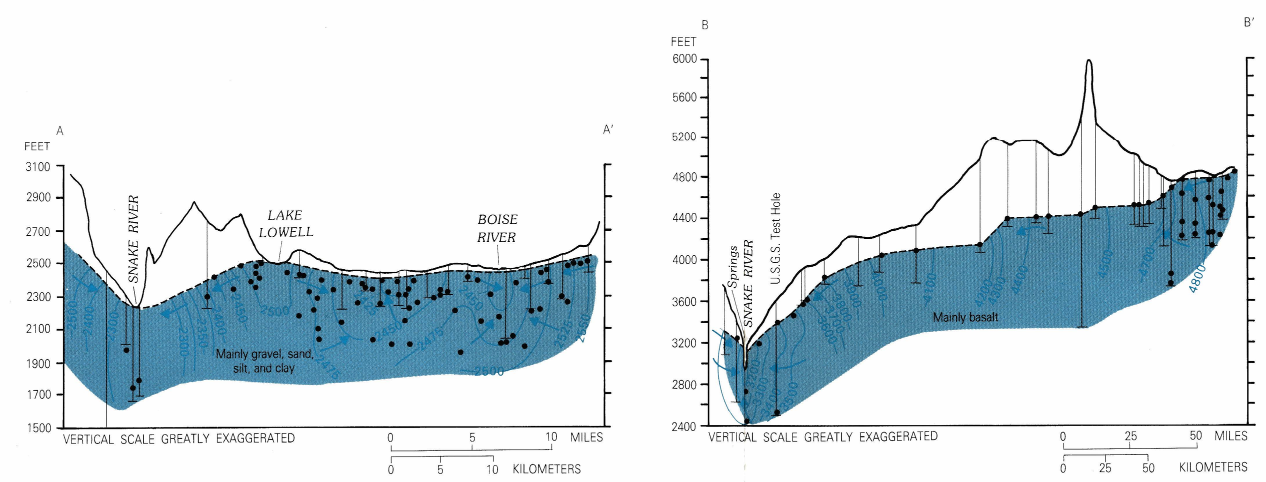
Multiply	By	To obtain
acre	4,047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer



WELLS AND TEST HOLES ARE REFERENCED BY A WELL-NUMBERING SYSTEM

The well-numbering system used by the U.S. Geological Survey in Idaho indicates the location of wells within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number; three letters, which indicate the ¼ section (160-acre tract), ¼–¼ section (40-acre tract), and ¼–¼–¼ section (10-acre tract); and serial number of the well within the tract. Quarter sections are lettered A, B, C, and D in counterclockwise order from the northeast quarter of each section. Within quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. For example, well 8S–24E–31DAC1 is in the SW¼NE¼SE¼, sec. 31, T. 8 S., R. 24 E., and is the first well inventoried in that tract. The well-numbering system in Oregon is referenced to the Willamette base line and meridian.

In addition, a unique identification number is assigned to each well. This number is based on the well's location with respect to latitude and longitude. For example, the number 424053113412801 indicates well 8S–24E–31DAC1 is at latitude 42°40′53″ and longitude 113°41′28″. The sequential ending number (01, etc.) allows for additional wells at the same general location.



GROUND WATER MOVES VERTICALLY AND HORIZONTALLY TO THE SNAKE AND BOISE RIVERS

Within the geohydrologic framework defined by Whitehead (1984), water moves vertically then horizontally from areas of recharge to areas of discharge. Movement is approximately perpendicular to lines of equal hydraulic head, as shown on the sections above and map at center. Complexities of flow, owing to local lithologic differences and geologic structure, are poorly defined and are not shown.

In the western part of the Snake River Plain, ground water discharges as seepage to the Snake and Boise Rivers. West of the Snake River and in the vicinity of Lake Lowell, hydraulic heads decrease with depth. In those areas, water moves downward and recharges the ground-water system. East of Lake Lowell, hydraulic heads increase with depth and ground water discharges mainly to the Boise River as shown in section A-A′. In the Boise River valley, a well-developed network of surface drains (ditches) intercepts ground water that otherwise would be discharged to the river. The water table in much of the Boise River valley is shallow (several feet to several tens of feet below land surface) and the upward component of hydraulic head causes many wells to flow. Although head data demonstrate upward movement of water in the Boise River valley, use of surface water for irrigation adds temporary recharge to the system.

Section B-B′ approximates a regional ground-water flowpath along the longitudinal axis of the eastern plain. Near the boundaries of the plain, as shown on the northeastern end of the section, hydraulic head decreases with depth and recharge occurs. Upward flow, about 25 mi from the northeastern end of the section, is probably due to the confining effect of sediments that locally are intercalated with basalt.

Two-thirds of total ground-water discharge from the eastern plain is spring flow and seepage to the Snake River between Milner and King Hill. Included in that reach are 11 of the 65 known springs in the United States that discharge an average of more than 100 ft^3/s (Meinzer, 1927, p. 44). Piezometers in a U.S. Geological Survey test hole, about 12 mi northeast of the springs, verify upward, as well as horizontal, flow in the vicinity of the Snake River. Additional evidence of upward water movement to the Snake River is springs that discharge directly into the river.

In the central part of the eastern plain, most ground water flow is horizontal; no significant upward or downward movement is evident.

The north wall of the Snake River canyon from Milner to King Hill was mapped during the study (R.R. Covington, U.S. Geological Survey, written commun., 1983) to determine spring locations, and relative amounts of discharge from individual springs or groups of springs.

WATER-TABLE GRADIENTS RANGE FROM 3 TO 200 FEET PER MILE AND INDICATE THE RELATIVE ABILITY OF AQUIFERS TO TRANSMIT WATER

Regionally, ground water moves at approximately right angles to lines of equal hydraulic potential or head, as shown on the map above. Locally, variations in flow direction can be expected because of the anisotropy of basaltic rocks that underlie much of the Snake River Plain. The water-level altitude map is based on water levels in wells completed in the regional aquifer system and measured in the spring of 1980. A companion report (Bassick, 1985) includes site-specific data on depth to water, water-level altitude, geohydrologic unit, and well construction.

Ground-water movement in the western part of the Snake River Plain is mainly toward the Snake and Boise Rivers. Water-table gradients range from 100 to 200 ft/mi along the northeastern boundary of the plain from King Hill to near Boise. In that area, the regional aquifer system is thin and consists largely of fine-grained Quaternary and Tertiary sedimentary rocks. Water-table gradients are commonly 50–100 ft/mi within 5 mi of the Snake River. In much of the Boise River valley, water-table gradients are 10–20 ft/mi toward the river. The unconfined aquifer in the Boise River valley consists largely of coarse-grained alluvium. South of the Snake River from Salmon Falls Creek to Murphy, water-table gradients are generally 50–100 ft/mi but are poorly defined. Most wells in that area are completed in confined silicic volcanic–rock aquifers and yield thermal water with hydraulic heads that average about 100 ft higher than heads in the overlying cold-water system.

Ground-water movement in the eastern part of the Snake River Plain is generally from northeast to southwest. Deviations are apparent near the margins of the plain, owing to underflow from tributary drainage basins, and along gaining reaches of the Snake River. Water-table gradients range from about 3 to 100 ft/mi and average about 12 ft/mi. Gradients are lowest in the central part of the eastern plain, which is underlain by thick highly transmissive basalt. Horizontal movement of water in basalt is primarily through rubbly tops of flows where hydraulic conductivities are high. Consequently, if the basalt sequence is thick and consists of numerous flows, aquifer transmissivities are extremely high. Areal variations in transmissivity in the eastern plain were determined by Mundorff and others (1964, pl. 6), who used flow-net analysis; by Norvitch and others (1969, p. 37) and Mantei (1974, fig. 3), who used electric-analog models; and by deSonneville (1974, p. 203–206), Newton (1978, p. 67–71), and Garabedian (1984, p. 48), who used digital ground-water flow models.

The water-table gradient in nearly half of the eastern plain is less than 5 ft/mi. Steepest gradients are in recharge areas in the northeastern part of the plain, along the northwestern boundary, and upgradient from springs discharging to the Snake River in Gooding and Jerome Counties. Steep gradients in Gooding and Jerome Counties are due largely to thinning of the basalt aquifer. Zones of steep gradient (25–30 ft/mi) that cross the plain are coincident with or near zones of rapid transmissivity change, perpendicular to the general direction of flow. Most notable are steep gradient zones in the vicinity of Mud Lake and the Great Rift zone. The steep gradient in the vicinity of Mud Lake approximately coincides with an area in which highly transmissive basalts interfinger with relatively poorly transmissive fine-grained sediments. The steep gradient in the vicinity of the Great Rift zone is immediately upgradient from and generally parallel to a zone of decreased transmissivity that may be attributable to healing of fractures or the presence of dikes that impede water movement.

In some areas, particularly near the boundaries of the plain, sedimentary rocks are intercalated with the basalt. Where fine grained, they impede the vertical movement of water and perched aquifers have formed. Under surface-water-irrigated areas, perched water is common and local flow systems, independent of the regional system, have developed. Some water in perched aquifers is withdrawn for various uses; the remaining water eventually percolates to the regional system. Areas of perched aquifers, usually shallow, are shown on the map above. Effects of leakage from these aquifers to the regional aquifer system are not apparent at the scale shown. Irrigated acreage and other land uses on the Snake River Plain in 1980 were delineated from Landsat data (Lindholm and Goodell, 1984).

SUMMARY

Long-term changes in ground-water levels on the Snake River Plain are due more to irrigation practices than to climatological changes. The extensive use of surface water for irrigation made more water available for ground-water recharge. Consequently, after the start of irrigation, ground-water levels began to rise, rapidly in places. Water levels rose several tens of feet in large areas and several hundred feet in places. In the early 1950's, water-level trends reversed owing to increased use of ground water, decreased surface-water diversions, and more efficient use of water.

Ground-water levels also change in response to cyclical variations in the amount of precipitation. Periods of below-normal precipitation correlate with periods of several years' duration when water levels declined, and periods of above-normal precipitation correlate with periods of rising water levels.

Regional ground-water movement is to the Snake River. In the eastern part of the plain, water movement is generally southwestward, except near the Snake River and the margins of the plain. Water-table gradients range from about 3 to 100 ft/mi and average about 12 ft/mi. Gradients are least in the central part of the plain, which is underlain by thick, highly transmissive Quaternary basalt. Water movement in the central part of the plain is largely horizontal. Along the margins of the plain and near the Snake River, water moves vertically as well as horizontally. Where basalt is intercalated with low-transmissivity sediments, vertical movement is impeded and, in surface-water-irrigated and recharge areas, perched aquifers have developed above the regional aquifer system.

Ground-water movement in the western part of the Snake River Plain is to the Snake and Boise Rivers. Hydraulic gradients are steep: 100–200 ft/mi along the northeastern boundary and 50–100 ft/mi along the Snake River. Hydraulic head increases with depth in the Boise River valley, resulting in upward ground-water movement.

Depth to water is greatest in the central part of the eastern Snake River Plain where the regional water table is as much as 1,000 ft below land surface. In the Boise River valley, in the Mud Lake-Egin Bench area, and northeast of American Falls Reservoir, water levels are less than 50 ft below land surface.

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CONFIGURATION OF THE WATER TABLE AND DEPTH TO WATER, SPRING 1980, WATER-LEVEL FLUCTUATIONS, AND WATER MOVEMENT IN THE SNAKE RIVER PLAIN REGIONAL AQUIFER SYSTEM, IDAHO AND EASTERN OREGON

By

G.F. Lindholm, S.P. Garabedian, G.D. Newton, and R.L. Whitehead

1988

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