EFFECTS OF DRAIN WELLS ON THE GROUND-WATER QUALITY OF THE WESTERN SNAKE PLAIN AQUIFER, IDAHO

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By Harold R. Seitz, A. M. La Sala, Jr., and Joe A. Moreland, 1943-

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The International System of Units is being adopted for use in reports prepared by the U.S. Geological Survey. To assist readers of this report in understanding and adapting to the new system, many of the measurements reported herein are given in both units. Chemical data for concentrations are given only in milligrams per liter (mg/l) or micrograms per liter (μg/l) because these values are (within the range of values presented) numerically equal to equivalent values expressed in parts per million, or parts per billion, respectively.

Multiply English Units	By	To Obtain SI Units
	Length	
inches (in)	2.54×10^{1}	millimeters (mm)
feet (ft)	3.048×10^{-1}	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	4.047×10^{-3}	square kilometers (km^2)
	Volume	
acre-feet (acre-ft)	1.234×10^{3}	cubic meters (m^3)
gallons (gal)	3.785	liters (l)
	Flow	
acre-feet per year (acre-ft/yr)	1.234×10^{3}	cubic meters per year (m^3/yr)
gallons per minute (gal/min)	6.308×10^{-2}	liters per second (l/s)
gallons per day (gal/d)	3.785	liters per day (l/d)

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ABSTRACT

Approximately 3,100 drain wells are used to inject irrigation waste water, urban runoff, septic-tank effluent, and industrial waste water in Minidoka, Gooding, Jerome, and Lincoln Counties. About 29,000 acre-feet($3.6\text{x}10^7\text{m}^3$) of irrigation waste water, 100 acre-feet ($1.2\text{x}10^5\text{m}^3$) of urban runoff, 400 acre-feet ($4.9\text{x}10^5\text{m}^3$) of septic-tank effluent, and 1,000 acre-feet ($1.2\text{x}10^6\text{m}^3$) of industrial waste water are injected into the Snake Plain aquifer annually in the study area. Irrigation waste water contains significant concentrations of nutrients and bacteria; urban runoff may contain high concentrations of sodium, chloride, and bacteria; and septic-tank effluent contains high concentrations of nutrients, chloride, and bacteria. The only sample of industrial waste water collected was chemically unchanged from its source, but the temperature was significantly increased.

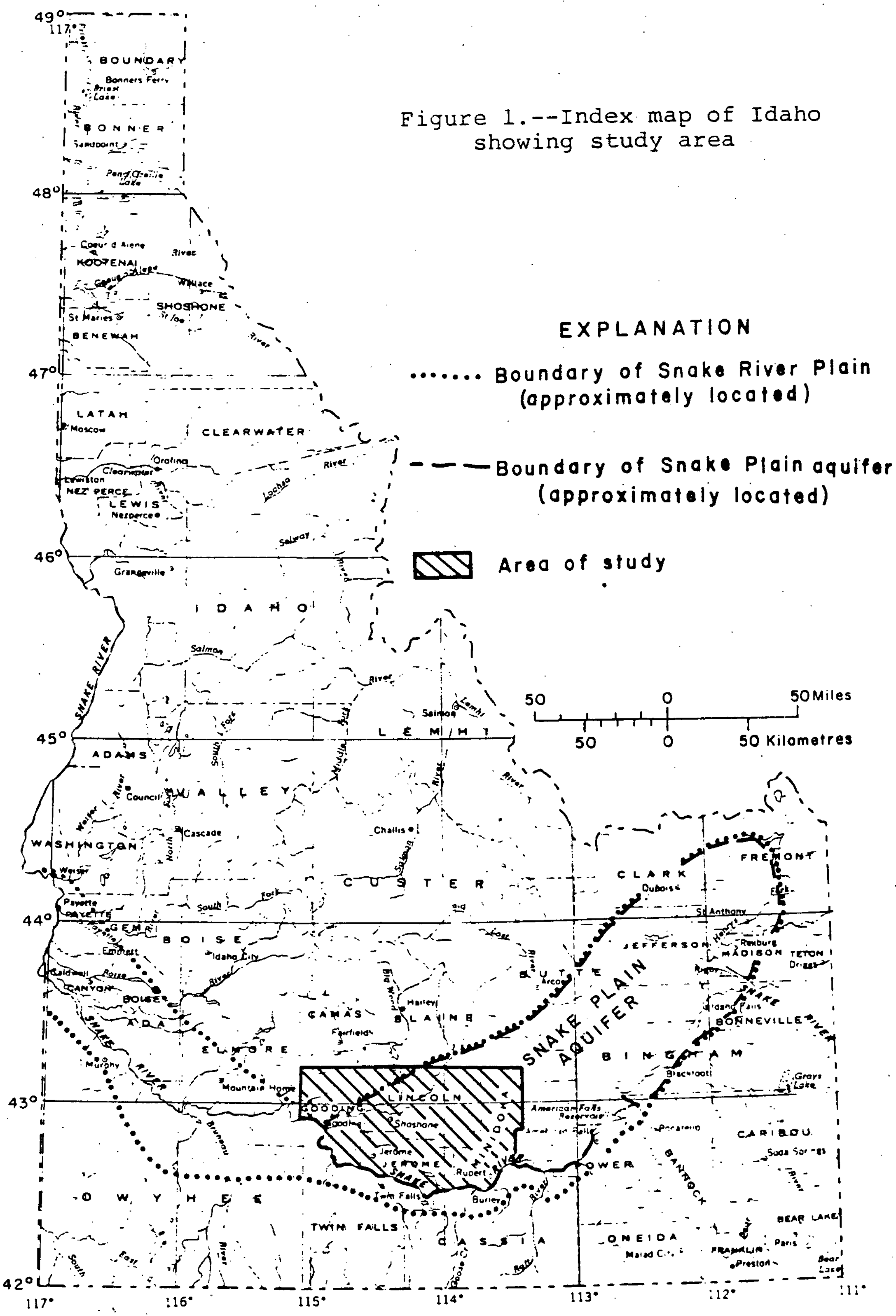
No regional effects of drain-well inflow could be identified within the study area. Several examples of local effects were noted, however. In the observations of local effects, water samples collected from the aquifer before, during, and after injection of waste water through nearby drain wells indicated changes in quality toward the drain-well inflow. In some wells, significant increases in bacterial concentrations were observed.

The data clearly suggest that disposal of toxic wastes or other substances which might have a detrimental effect on water use would be hazardous. One must assume that any water injected into the aquifer through drain wells may, at some future time, affect a downgradient supply well.

INTRODUCTION

In the eastern part of the Snake River Plain of southern Idaho (fig. 1), drain wells, for the past 60 years, have been a means of disposing of irrigation waste water and natural runoff from agricultural lands, storm runoff from

Figure 1.--Index map of Idaho showing study area



urban areas, sewage effluent from domestic septic tanks, and industrial wastes. The use of drain wells came about because other means of disposing of waste water were not readily available in a large part of the Plain. The rolling surface of much of the eastern Snake River Plain has internal drainage. Furthermore, the soils do not readily transmit water downward. Considerable agricultural land in the areas of internal drainage would be inundated and made unusable if a means of disposing of the waste water had not been found. Leach fields generally were not feasible for disposal of septic-tank effluent because of the low permeability of the soils. As an alternative to leach fields, drain wells are widely used to dispose of septic-tank effluent.

The highly permeable basaltic rocks underlying the eastern Snake River Plain readily accept large quantities of waste water for disposal through drain wells. Where saturated, these basaltic rocks compose the Snake Plain aquifer, which is shown in figure 1 and which underlies nearly all of the eastern Snake River Plain. The Snake Plain aquifer is widely used as a source of water for domestic purposes, irrigation, and fish culture. The widespread use of drain wells poses the possibility of the water in the Snake Plain aquifer deteriorating in quality to the extent that the water would become unsuited for some uses.

Purpose and Scope of the Study

In 1971, the Idaho Department of Water Resources was charged by the State legislature with regulating the construction and use of drain wells to protect the water resources of the state from pollution. The Department is studying the effect of drain wells on ground water to determine the policies and regulations necessary to afford the required protection. As a part of its studies, the Department initiated a cooperative project with the U.S. Geological Survey to collect and evaluate data on the effects that drain wells may have on the water in the western Snake Plain aquifer.

The area of study, shown on figure 1, is the western part of the eastern Snake River Plain, which includes Minidoka, Gooding, Jerome, and Lincoln Counties. Abbeglen and others (1970, table 8) estimated that the study area contains 3,100 drain wells, of which 100 are in Minidoka County and 1,000 are in each of Gooding, Jerome, and Lincoln Counties. Abbeglen and others included in their definition natural fissures and sinks in the basalt that receive waste water, though they indicate that most drain wells in the study area are manmade.

The water in the Snake Plain aquifer is of vital importance to the inhabitants of the four-county study area. Practically all the water used for domestic purposes is taken from this aquifer, as is irrigation water for use on approximately 156,000 acres (630 km^2) of land within the study area that are irrigated only by ground water (Idaho Water Resource Board, 1970). In addition to this acreage, much land receives supplemental irrigation water pumped from wells. Any practice that contributes to a deterioration in the quality of the ground water in the Snake Plain aquifer could lead to serious health problems or economic consequences. The widespread use of drain wells to dispose of waste water underground is, therefore, of concern as a potential threat to the public well-being.

The objectives of this study are (1) to describe the quantity and quality of waste water being introduced into the ground-water system through drain wells; and (2) to assess the regional and local effects of this waste water on the quality of water in the Snake Plain aquifer. Sufficient data were obtained during the study to meet the first objective to the extent of being able to describe in a general way the quantity and quality of waste water entering the ground through drain wells. The second objective was achieved only to the extent of identifying some local effects. Data do not allow the regional effects of drain wells on ground-water quality to be distinguished from the effects of recharge from canal leakage and applied irrigation water.

Sampling Site- and Location-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. This numbering system is used to identify all sites sampled in this study. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters, which indicate the quarter section, the 40-acre (0.16-km^2) tract, and the 10-acre (0.04-km^2) tract, respectively. Quarter sections are lettered a, b, c, and d, in counterclockwise order from the northeast quarter of each section (fig. 2). Within the quarter sections, 40-acre (0.16-km^2) and 10-acre (0.04-km^2) tracts are lettered in the same manner. Wells are identified by a serial number following the three-letter tract designation. Well 7S-15E-33cad1 is in the SE¼NE¼SW¼, sec. 33, T. 7 S., R. 15 E., and was the first well inventoried in that tract. Springs are identified by the letter "S" following the last numeral; for example, 6S-13E-27bb1S.

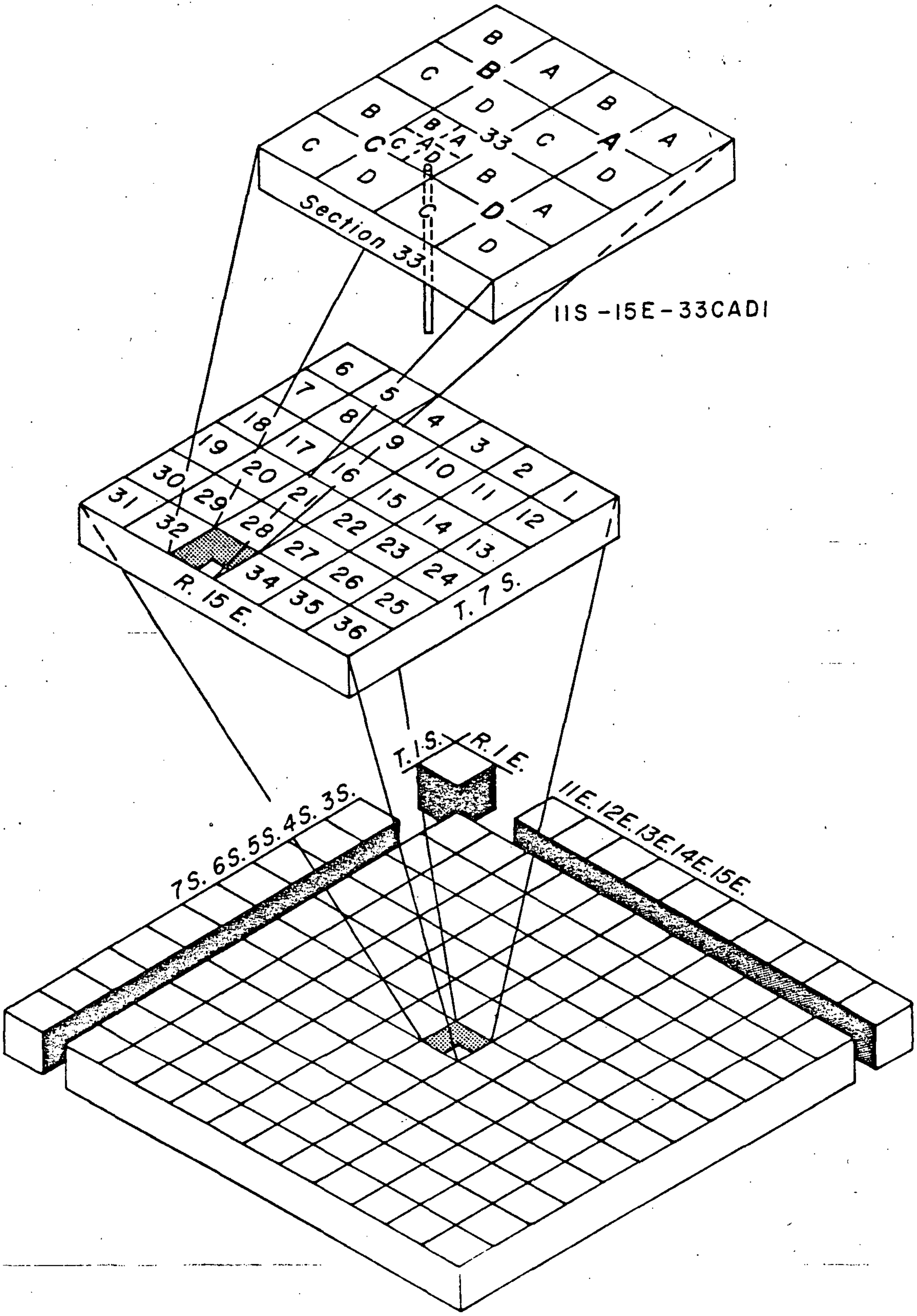


Figure 2.--Diagram showing sampling site- and location-numbering system

Acknowledgments

The information made available by many individuals and several agencies materially aided this study, and the assistance given is gratefully acknowledged. Many well owners supplied useful information and permitted measurement of their wells. Special acknowledgment is made of the cooperation of Robert French and Don Kester, who permitted the installation of gaging stations on their land for use in measuring discharges of waste-runoff water. The assistance of Virgil Temple, manager of the A and B Irrigation District, was especially useful. Personnel of the Idaho Department of Water Resources made many data available and also collected some of the samples for water-quality analyses.

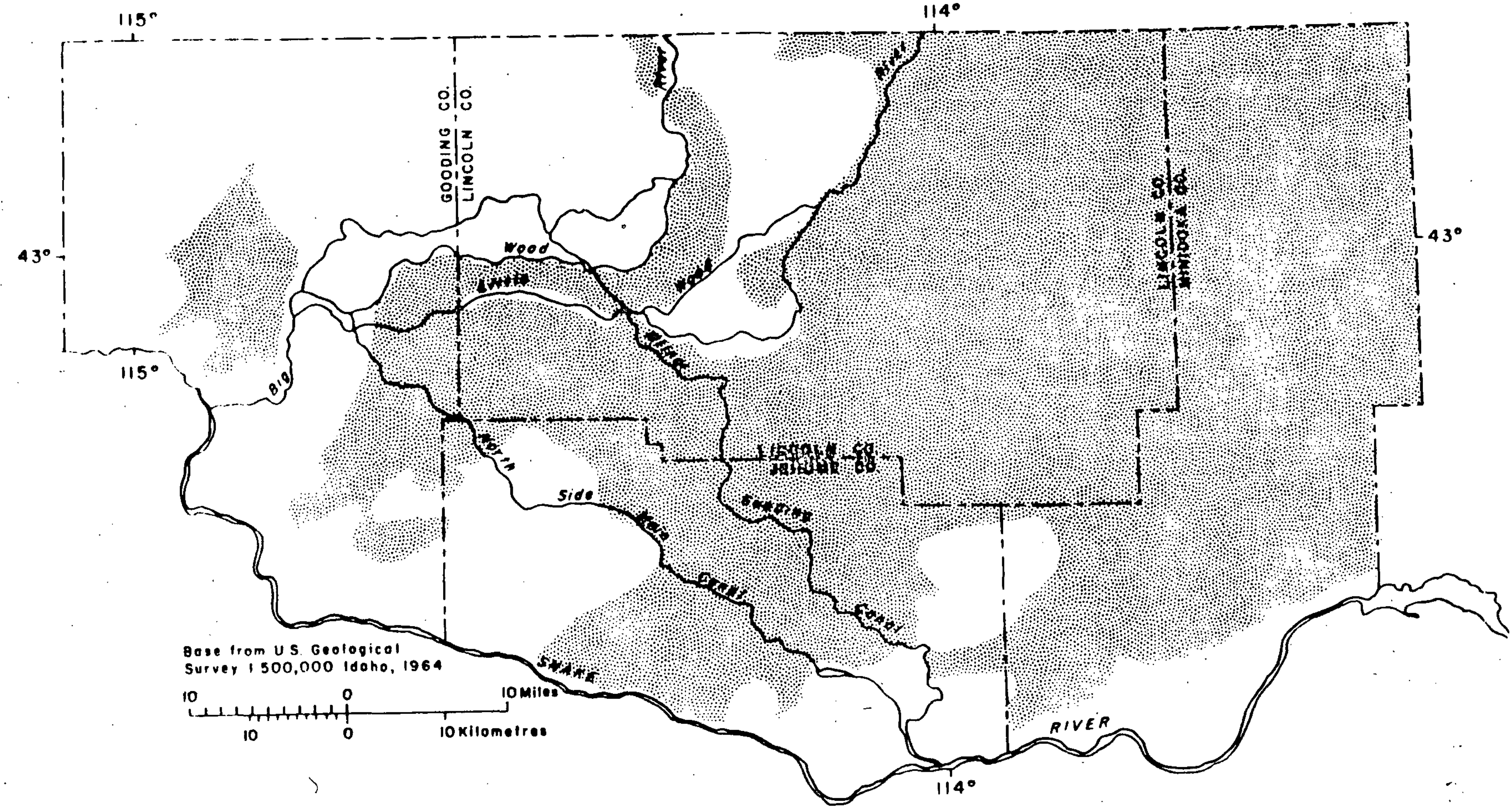
This study was originally done by Kenneth L. Dyer. All data collection and much of their analyses were done by him prior to 1975. Mr. Dyer left the Geological Survey before the final report was completed. Although he was the principal investigator, he is not included as an author because his work was substantially revised after his departure.

THE STUDY AREA

The study area, which is shown in figure 3, is, in general, a high plain sloping gently southwesterly and lying between 3,500 and 4,500 ft (1,000 and 1,400 m) in altitude. The plain is bounded on the south by the Snake River, which enters a gorge as much as 700 ft (210 m) deep downstream from Milner, and extends northward from the river to a series of mountain ranges. The Big and Little Wood Rivers head in these ranges and flow toward the southwest into Lincoln County. The Little Wood River joins the Big Wood River, which enters Malad River Canyon, and then flows into the Snake River near Bliss (fig. 3). The surface of the plain is rolling and has many areas of internal drainage, as shown in figure 4.

Geology and Soils

The area is underlain by basalt flows and intercalated pyroclastic and sedimentary rocks of the Snake River Group of Pliocene and Pleistocene age, which is loosely termed the "Snake River basalt." These rocks compose the Snake Plain aquifer. The Snake River Group is underlain by older, less permeable volcanic and sedimentary rocks, which crop out in the canyon of the Snake River and in northwestern Lincoln and northern Gooding Counties. Loess, a windblown material



Base from U.S. Geological Survey 1:500,000 Idaho, 1964

Figure 4.--Map of study area showing areas of closed surface drainage (shaded)

consisting mainly of silt, overlies the Snake River Group at places. In the southern part of Minidoka County, adjacent to the Snake River, the basalt is overlain by about 200 ft (60 m) of sedimentary materials. These materials underlie a broad alluvial plain of the Snake River and consist of riverbed sand and gravel grading downward to fine-grained lake deposits at shallow depth.

The Snake River Group consists of flows of basalt, which range in thickness from 10 to 50 ft (3 to 15 m) and average about 20 to 25 ft (6 to 7 m) in thickness. The individual flows are commonly separated by beds of pyroclastic and sedimentary materials. The base of a typical lava flow is generally fine grained, or glassy and dense, whereas the upper part of the flow tends to be fractured and vesicular. The zones of fractured basalt and the interbedded sedimentary and pyroclastic material are the major conduits for movement of water in the Snake Plain aquifer. Interflow zones that contain considerable thicknesses of coarse-grained volcanic ash, cinders, and clinkers are highly transmissive. Other zones that are thin or contain fine-grained sediments may be poorly transmissive. This variability in water-bearing properties is reflected by the yields of wells, which range from a few gallons per minute to as much as 7,000 gal/min (440 l/s) (Mundorff and others, 1964, p. 155).

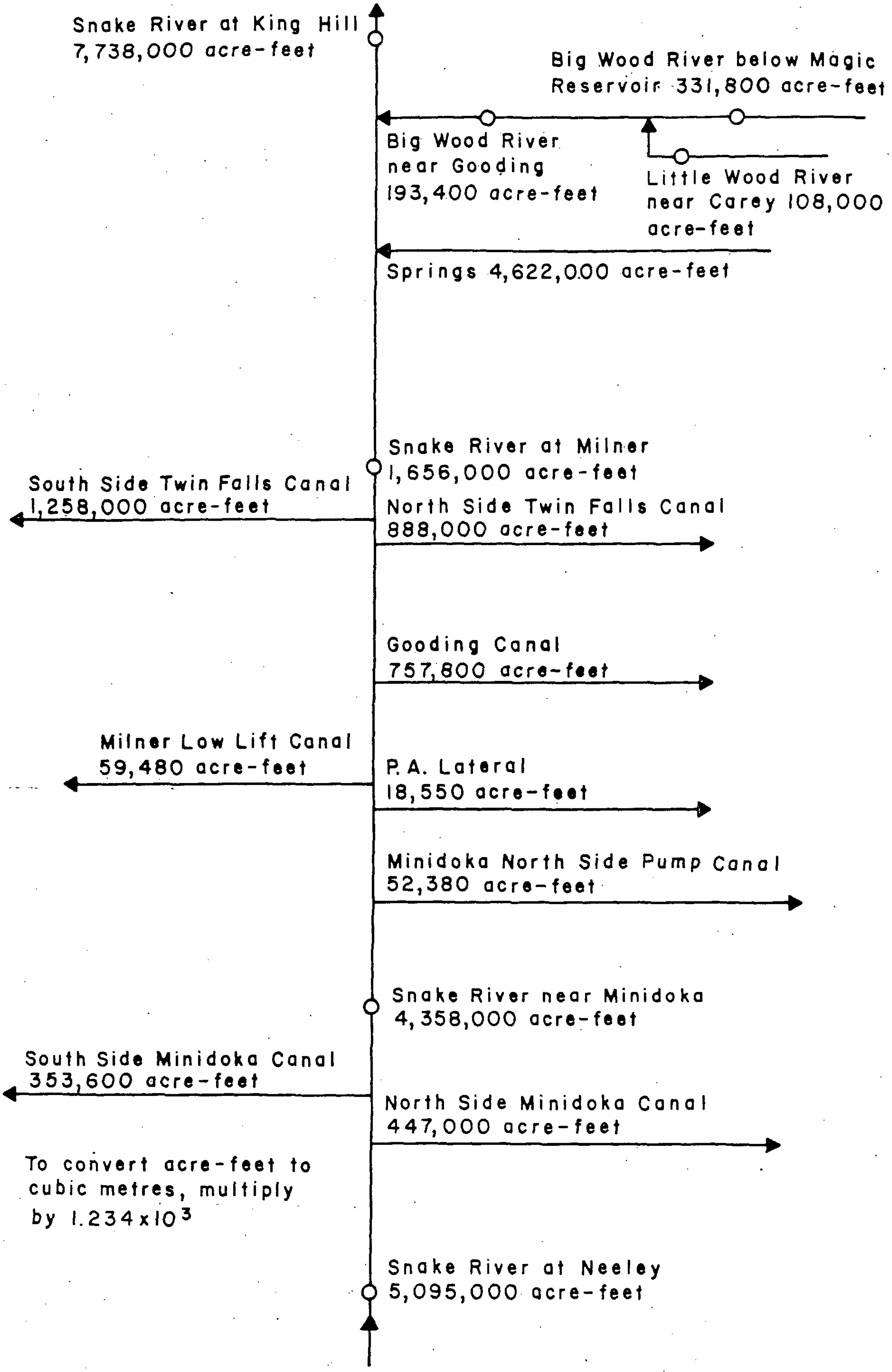
The soils in the four-county study area are developed on the loess. Soils thick enough for agricultural use cover at least 35 percent of the study area. Perhaps 25 percent of the Snake River Plain within the study area consists of bare, broken, and fissured basaltic lava with practically no soil covering. An area of similar size is covered by shallow, rocky soils less than 20 in (500 mm) thick.

Hydrology

Streamflow and Diversions

Recharge to and discharge from the Snake Plain aquifer is partly dependent upon streamflow and diversions to irrigation canals within the study area. The annual average flows of the streams and canals are summarized below and are illustrated schematically on figure 5 to provide background for later discussions.

The Snake River at Neeley, 30 mi (50 km) upstream from the study area, has an average flow of 5,095,000 acre-ft/yr ($6.28 \times 10^9 m^3/yr$). Downstream from Neeley, water is diverted from the river to both the north and south sides. On the north side, an average of 447,000 acre-ft/yr ($5.5 \times 10^8 m^3/yr$)



To convert acre-feet to cubic metres, multiply by 1.234×10^3

Figure 5.--Schematic diagram showing gaging stations, major diversions, and tributary inflow to the Snake River between Neeley and King Hill

is diverted into the North Side Minidoka Canal. Downstream from this diversion, the flow in the Snake River near Minidoka averages 4,358,000 acre-ft/yr (5.37x10^{9}m^{3}/yr). Downstream from Minikoka, additional diversions to the north average 52,380 acre-ft/yr (6.46x10^{7}m^{3}/yr) to the Minidoka North Side Pump Canal, 18,550 acre-ft/yr (2.29x10^{7}m^{3}/yr) to the P. A. Lateral, 757,800 acre-ft/yr (9.34x10^{8}m^{3}/yr) to the Gooding Canal, and 888,000 acre-ft/yr (1.09x10^{9}m^{3}/yr) to the North Side Twin Falls Canal. The diversions to the north and south sides reduce the flow in the Snake River at Milner to an average of 1,656,000 acre-ft/yr (2.04x10^{9}m^{3}/yr).

At the Big Wood River gage near Richfield, the average flow is 331,800 acre-ft/yr (4.09x10^{8}m^{3}/yr). The Little Wood River has an average flow of 108,000 acre-ft/yr (1.33x10^{8} m^{3}/yr) above its confluence with the Big Wood River. Below the confluence, the average flow is 193,400 acre-ft/yr (2.38x10^{8}m^{3}/yr), which reflects significant losses through channel seepage and diversions. The flow of the Big Wood River is increased significantly in the Malad River Canyon by springs discharging from the Snake Plain aquifer.

Springs (including those flowing into the Malad River Canyon) discharge about 4,622,000 acre-ft/yr (5.70x10^{9}m^{3}/yr) from the Snake Plain aquifer between Milner and Bliss. Nearly all this water enters the Snake River. The flow of the river, derived principally from ground water discharging from the aquifer through these springs, increases significantly from Milner to King Hill (located about 20 mi, or 30 km below Bliss) to an average flow of 7,738,000 acre-ft/yr (9.54x10^{9}m^{3}/yr).

Ground Water

The Snake Plain aquifer, which underlies the study area, extends northeasterly beneath the Snake River Plain from the western boundary of the study area to the vicinity of St. Anthony, Idaho, a distance of about 200 mi (320 km). Ground water moves through the aquifer in a generally southwesterly direction from recharge areas at its eastern end and along its northern flank to discharge areas along the Snake River near American Falls Reservoir and in the western part of the study area. Water enters the aquifer from the Snake River in some reaches. The aquifer receives a large quantity of recharge from irrigation water that is diverted onto the Snake River Plain from the Snake River and its tributaries. This recharge occurs as infiltration from canals and from fields where water is applied. Part of the diverted water also recharges the aquifer through drain wells. The aquifer also receives a small amount of recharge by direct infiltration of precipitation. Besides the flow from springs along the Snake River, water is discharged from the aquifer by pumping from wells for irrigation, municipal, domestic, and industrial water supplies. Part of this pumped water returns to the aquifer after use.

Although many studies have been made of the Snake Plain aquifer, no detailed water budget is available for the four-county study area. However, by combining the results of several studies, a general budget can be obtained.

A study made by the Idaho Water Resources Research Institute (de Sonneville, 1974) developed a water budget for the entire Snake Plain aquifer based on calendar year 1966 data. That study assumed that 1966 was representative of current average conditions. The information obtained during that study was compiled for 9-mi^2 (23-km^2) units over the entire aquifer. By summing up data for all the units covering the four-county area, an approximation of the inflows and outflows can be obtained. The data from that information show:

Pumpage for irrigation - 353,000 acre-ft/yr ($4.35\text{x}10^8 \text{m}^3$/yr)

Percolation of excess irrigation water - 1,271,000 acre-ft/yr ($1.57\text{x}10^9 \text{m}^3$/yr)

Seepage losses from major canals - 156,000 acre-ft/yr ($1.92\text{x}10^8 \text{m}^3$/yr)

Recharge from precipitation - 166,000 acre-ft/yr ($2.04\text{x}10^8 \text{m}^3$/yr)

Young and Harenberg (1971) estimated that pumpage for municipal, rural-domestic, livestock, and industrial uses in the four-county study area totals about 17,000 acre-ft/yr ($2.1\text{x}10^7 \text{m}^3$/yr). Moreland (1975) reported that spring discharges from the aquifer between Milner and Bliss total about 4,622,000 acre-ft/yr ($5.70\text{x}10^9 \text{m}^3$/yr). Assuming that all other items of recharge or discharge from the aquifer within the study area are negligible, summation of the above items indicates that underflow from the upstream area is about 3,399,000 acre-ft/yr ($4.19\text{x}10^9 \text{m}^3$/yr). Figure 6 schematically summarizes these elements of inflow and outflow.

Water Quality

The quality of water diverted to the Snake River Plain from the Big Wood River and the Snake River is exemplified by analytical data listed in table 1. This water is low in

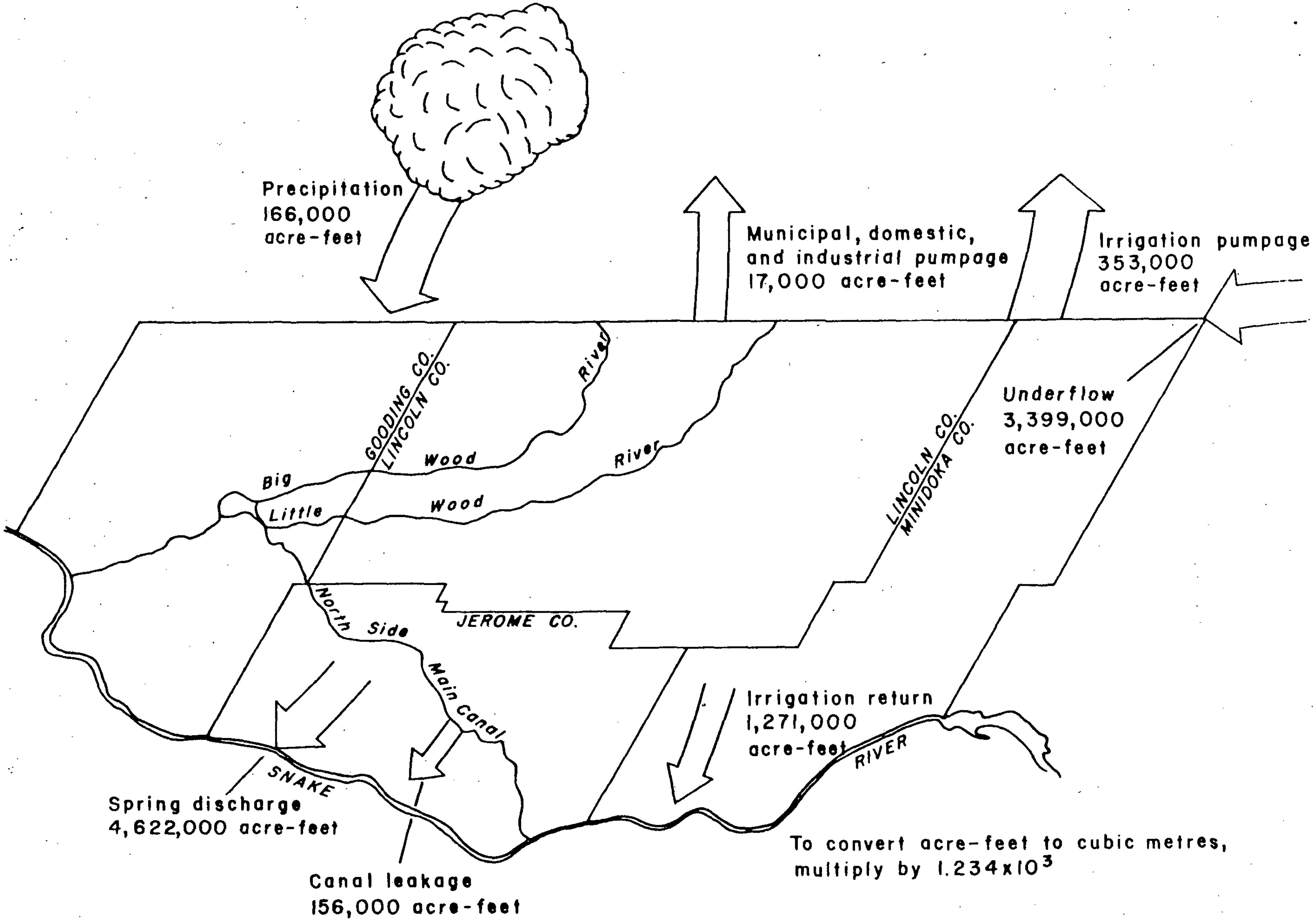


Figure 6.--Schematic diagram of inflows to and outflows from the Snake Plain aquifer within the study area

dissolved solids, with specific conductance values generally less than 450 μmhos (micromhos per centimeter at 25°C). Samples collected from miscellaneous canals are also listed in table 1 to illustrate quality of water applied to croplands.

As shown by table 1, surface water diverted to the Plain is calcium bicarbonate water containing sulfate concentrations of 20 to 50 mg/l and chloride concentrations of 5 to 15 mg/l. Significant numbers of bacteria were present in most of the samples collected.

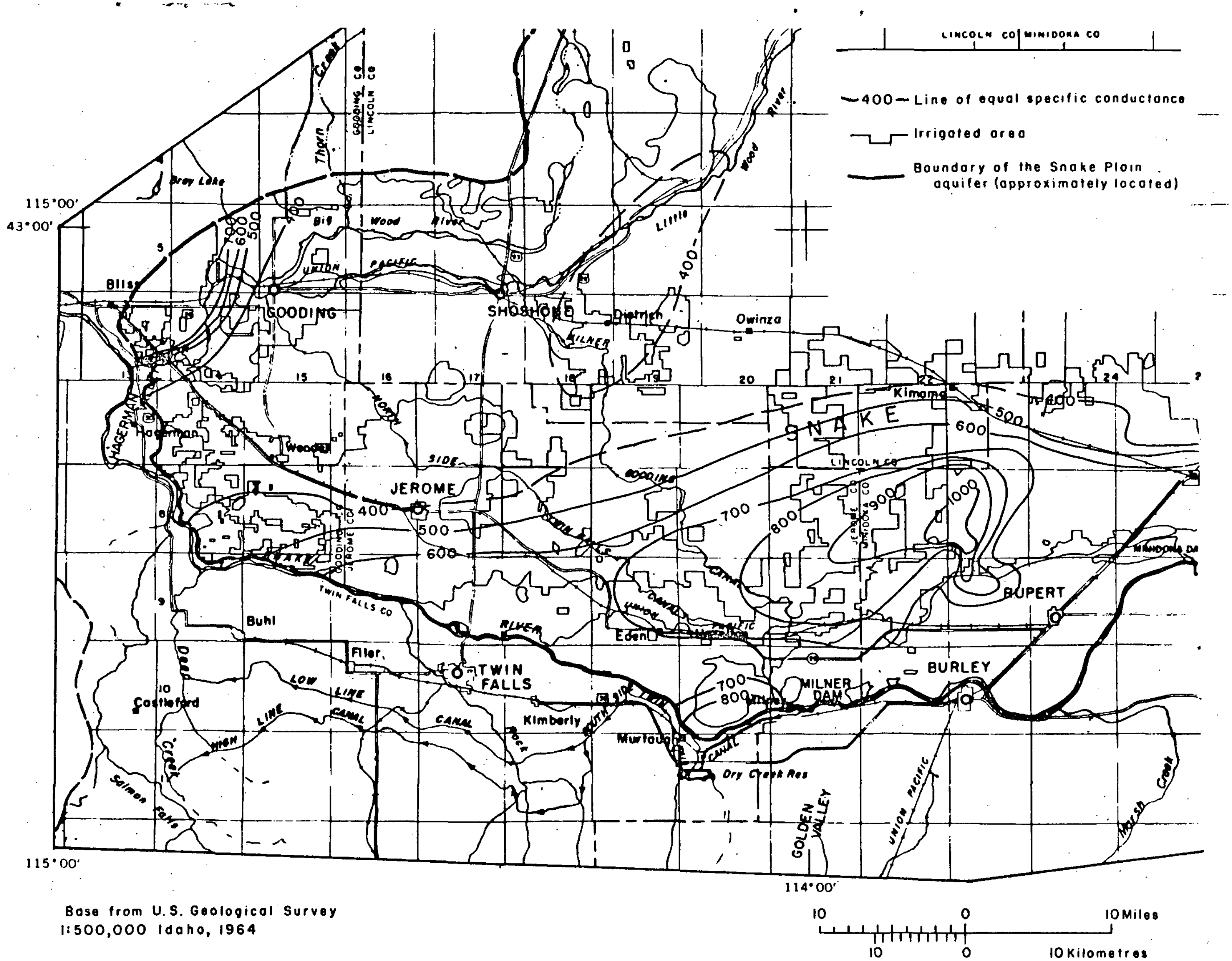
To define water quality in the ground-water system, samples were collected from 59 supply wells (table 2). Many of the wells were sampled several times during the study to define any variations in quality which might occur. In addition, samples from springs discharging from the aquifer are listed in table 3. Many of these samples were collected during earlier studies, but the analyses are helpful in describing the quality of water discharging from the aquifer.

Figure 7 shows the distribution of specific conductance values of samples from the ground-water system. In general, samples from undeveloped areas in the northern part of the study area have specific conductance values of less than 400 μmhos. However, specific conductance values of samples from wells and springs in areas developed to cropland range to more than 1,000 μmhos. The quality is quite variable throughout the aquifer. Sulfate concentrations, for example, range from less than 20 mg/l in the northern part of the area to more than 80 mg/l in the southeastern part.

Quality of water discharging from springs is clearly related to the quality of water in adjacent parts of the aquifer. Near the area of high specific conductance in ground water, spring discharges also have high values of specific conductance relative to the springs downgradient. Other parameters (calcium, sodium, chloride, and dissolved nitrite plus nitrate) also show a direct concentration relation to ground water upgradient from the springs.

QUANTITY AND QUALITY OF WATER ENTERING DRAIN WELLS

Large parts of the study area have internal drainage, as shown in figure 4, in which runoff water accumulates in numerous depressions and swales. In some of these depressions and swales, water drains to the Snake Plain aquifer through natural openings. Generally, however, these depressions have received large quantities of fine-grained sediment in runoff, which has formed layers of low-permeability material over the bottoms. This covering retards



Base from U.S. Geological Survey
1:500,000 Idaho, 1964

Figure 7.--Map of study area showing specific conductance of ground water

the natural percolation of water into the underlying basalt. The application of irrigation water on areas of internal drainage thus causes numerous ponds to form in depressions. Drain wells were put into use in Minidoka County in about 1910 to reclaim some of this poorly drained land for agriculture. Since then, hundreds of drain wells have been drilled in low-lying areas or depressions to dispose of agricultural waste water and natural runoff water.

At least 54 drain wells are also in use to dispose of street and urban runoff, mostly in the communities of Shoshone and Wendell. These wells do not necessarily drain natural depressions, but are used as a matter of convenience in disposing of urban runoff.

Drain wells are used to dispose of septic-tank effluent in much of the rural part of the study area, because poorly permeable materials at shallow depth make leach fields impractical. These drain wells are believed to number more than a thousand, and to comprise more than half of all the drain wells in the four-county study area.

Only two industrial-type drain wells were found during this study. Use of one of these was discontinued before the study ended. A number of other industrial drain wells in the area had previously been in use, but these had clogged and were abandoned before this study began.

Irrigation Drain Wells

Irrigation drain wells are of considerable economic importance in the four-county study area. Without these field drains, some of the lower lying irrigated lands would be flooded part or all of the year. Approximately 300 to 500 irrigation drain wells have been drilled within the study area, perhaps one-third of which have been abandoned because they became clogged with sediment carried down by the waste water.

The quantity of water entering the agricultural drains is of major concern, because this accounts for the major part of all waste water injected into the aquifer through wells. Estimating the total quantity is difficult, however, because the total number of drain wells is unknown, the capacities of the wells to accept water range from 0 to thousands of gallons per minute, the areas each well drains are unknown, and few data are available on rates of irrigation water runoff.

To obtain a reasonable estimate of the quantity of irrigation waste water available for injection by drain wells, three drainage areas were monitored. Recorders were installed to measure the amount of water flowing from the drainage areas. The measuring sites were: 9S-24E-5bcc, (F Main Drain, drainage area 41,400 acres (168 km²); 8S-15E-13aba, French's Drain, drainage area 160 acres (0.65 km²); and 7S-24E-26ddd, drain 26ad724, drainage area 2,800 acres (11 km²).

Two of the drainage areas monitored include both agricultural and nonagricultural land. Part of the waste water within the three drainage areas was repumped for agricultural use before it reached the gaging station. However, reasonable estimates of the drainage water repumped for irrigation were possible. Partial records indicate that winter runoff may be about 0.5 in (15 mm) from precipitation falling on both agricultural and nonagricultural lands. A summary of the total annual runoff and relifted water estimated from the gaged drainages is given in table 4.

Based on the data summarized in table 4, annual runoff from furrow-irrigated lands is assumed to average 5 in (130 mm), of which about 1.5 in (40 mm) is pumped back for reuse, and approximately 3.5 in (90 mm) is waste water. Three in (75 mm) of this waste-runoff water is from irrigation water, and the remaining 0.5 in (15 mm) is from storm and snowmelt runoff. The 5 in (130 mm) of annual runoff assumed for furrow-irrigated lands is reasonably close to the 6.3 in (160 mm) of runoff observed by Bondurant (1971, p. 1,002) from a 536-acre (2.17-km²) irrigated watershed near Paul in Minidoka County during the 1966 irrigation season.

Far less irrigation water is applied to sprinkler-irrigated land than to furrow-irrigated land. Pumpage data supplied by Young and Harenberg (1971) indicate that the amount of water applied to sprinkler-irrigated land is not much more than the crop-evapotranspiration requirements given by Sutter and Corey (1970). For purposes of this study, the only runoff from sprinkler-irrigated fields was assumed to be the 0.5 in (15 mm) of winter-storm and snowmelt runoff. It is further assumed that this small amount of runoff does not constitute a problem; therefore, most of the runoff is probably not disposed of through drain wells.

Topographic maps of the four-county study area were analyzed to delineate areas of internal drainage (fig. 4). Maps showing irrigated croplands were compared with this map to define areas which could contribute irrigation-waste water to closed-basin lowlands. About 82,000 acres (330 km²) of land irrigated with ground water were delineated within the areas of internal drainage. Of this total, about 60,000 acres (240 km²) are furrow irrigated. About 40,000 acres (160 km²) within the areas of internal drainage are

Table 4.--Runoff at three gaging stations

	LOCATION		
	F Main Drain 9S-24E-5bcc	French's Drain 8S-15E-13aba	Drain 26ad724 7S-24E-26ddd
Area irrigated (acres)	26,900	160	2,500
Runoff (acre-feet)	12,270	61	396
Runoff (inches)	5.5	4.6	1.9
Area not irrigated (acres)	14,500	0	300
Runoff (acre-feet)	604	0	12
Runoff (inches)	0.5	0	0.5
Total area (acres)	41,400	160	2,800
Runoff (acre-feet)	12,870	61	408
Runoff (inches)	3.7	4.6	1.7
Water relifted (acre-feet)	5,760	11	38
Water relifted (inches)	1.7	0.8	0.1
Water draining to well (acre-feet)	6,910	50	370
Water draining to well (inches)	2.0	3.8	1.6

irrigated by surface water, all of which are assumed to be furrow irrigated. Thus, 100,000 acres (400 km^2) of furrow-irrigated land lie in areas of internal drainage. Runoff from this land is assumed to collect in low-lying areas and to contribute to drainage problems.

Assuming 3.5 in (90 mm) of runoff from the 100,000 acres (400 km^2), it is estimated that about 29,000 acre-ft ($3.6 \times 10^7 m^3$) of irrigation waste water collects at low points throughout the study area. Some of this water undoubtedly drains through natural fissures or percolates in areas of shallow soil. In a few areas, the water simply collects and evaporates. However, most is disposed of through irrigation drain wells.

To define the quality of water entering irrigation drain wells, samples were collected at 37 field drain wells (table 5). In addition, samples were collected from five surface-water wasteways, which collect field runoff water and feed drain wells (table 6).

As would be expected, the quality of irrigation waste water is highly variable, depending upon the original source of the irrigation water, amount of fertilizer added to the crops, amount of dilution from precipitation, method of application, and numerous other factors. The irrigation waste water entering drain wells generally has higher concentrations of major ions than surface water diverted from the Snake River (table 1). It also has significantly higher concentrations of nitrogen and phosphorus. On the other hand, comparison of irrigation waste water and ground water is difficult because of the variability of ground-water quality. In many areas, the ground water contains higher concentrations of dissolved constituents than the irrigation waste water being injected. Nearly all irrigation waste water entering drain wells, however, contains significantly higher concentrations of indicator bacteria than either surface or ground water.

Urban Runoff Drain Wells

Urban runoff drain wells are located in the four-county study area within the communities of Shoshone, Wendell, and Hagerman. City records indicate that 40 street drain wells are currently in use in Shoshone, 12 in Wendell, and 2 in Hagerman. One of the wells, 7S-13E-14cad2 in Hagerman, carried septic-tank effluent and possibly some irrigation runoff water, as well as street runoff. These street drains, in totality, receive runoff water from a little less than 1 mi^2 (2.6 km^2) of land. Runoff into street drains is probably less than would be supplied by an equivalent area of furrow-irrigated land, but more than would be supplied by a similar area of uncultivated land. It is estimated that approximately 2 in (50 mm) of runoff would drain each year from the land tributary to these drain wells, or a total runoff of about 100 acre-ft ($1.2\text{x}10^5 m^3$) per year.

Because urban-runoff water generally originates as precipitation, the quality differs in most respects from irrigation waste water. Concentrations of calcium, magnesium, potassium, bicarbonate, and sulfate are, in general, lower than runoff from croplands (table 6). However, because of salt used to melt snow and ice from streets and sidewalks, sodium and chloride concentrations are often higher in urban runoff water than in irrigation waste water. Nitrogen and phosphorus are significant, but are lower than in cropped areas where fertilizers are used. Oil, grease, and lead, presumably from automobiles, were detected in samples of street runoff. Indicator bacteria were found in high concentrations, reflecting urban impact on water quality.

Septic-Tank Drain Wells

In 1970, approximately 37,700 people lived in the four-county area of this study (Bureau of the Census, 1973). It is estimated that the septic-tank effluent for about 5,000 of these people is disposed of in approximately 1,000 drain wells within the study area.

Information published by the Public Health Service (1967, p. 44) indicates that about 75 gal (280 l) of sewage effluent are generated per day per person. This amounts to a total of about 400 acre-ft ($4.9\text{x}10^5 m^3$) of septic-tank effluent each year that is probably disposed of through drain wells.

In general, this sewage is passed through a septic tank or equivalent before it is introduced into the aquifer. The sludge of settleable solids remains in the septic tank, but many of the nutrients are carried by the liquid effluent into the aquifer.

Average values for domestic sewage presented by Fair, Geyer, and Okun (1968), combined with a flow of 75 gal/d (280 l/d) per person, extrapolated to a family of four, produce concentrations of 20 mg/l of nitrogen, 2.8 mg/l of phosphorus, and 63 mg/l of chloride. A water sample from septic-tank effluent flowing into drain well 7S-13E-14cad1 (table 6) had concentrations of 18 mg/l of nitrogen, 4.9 mg/l of phosphorus, and 38 mg/l of chloride. Except for chloride, these concentrations are compatible with computed concentrations. As would be expected, indicator bacteria were present in very high concentrations.

Industrial Drain Wells

Only two industrial drain wells were found to be in operation in the study area. One of these (in Richfield) received a mixture of dairy water (whey) and sewage, but its use was discontinued before it could be sampled for chemical analysis. The other well, 8S-16E-24aacl, is in Jerome and receives about 700 acre-ft ($8.6x10^5 m^3$) of cooling water each year. Because there may be other small industrial drain wells within the area, the total industrial drain-well inflow is estimated to be 1,000 acre-ft ($1.2x10^6 m^3$) of water.

The chemical characteristics of the waste water going into the single industrial drain well sampled (table 6) were similar to those of the underlying ground water, as this water had originally been pumped from the aquifer. The temperature of the water had increased from about 14° to 34.5°c.

EFFECTS OF DRAIN WELLS ON GROUND-WATER QUALITY

In considering the regional and local effects of drain wells on ground-water quality, it should be noted that injection of wastes through drain wells differs from introduction of wastes by normal percolation through unsaturated soils in three important ways: (1) injection through wells bypasses the natural filtration, adsorption, and ion-exchange processes afforded by percolation through the soil, which tend to remove some dissolved and suspended constituents; (2) injection into the aquifer at a specific point, often in concentrated form, rather than percolation over a wide area, tends to reduce the opportunity for dispersion and dilution in the vicinity of the injection well; and (3) injection makes it possible to introduce unusually high concentrations of wastes or unusual kinds of materials directly into the aquifer without the normal protection of percolation through a soil or unsaturated zone. Such materials might otherwise never enter the subsurface hydrologic system.

Regional Effects

As discussed earlier, large quantities of water enter the aquifer within the study area. Much of this water (1,271,000 acre-ft, or $1.57x10^9 m^3$) is excess irrigation water diverted to croplands. Only about 29,000 acre-ft ($3.6x10^7 m^3$) of this excess irrigation water enters the aquifer through irrigation drain wells. The other types of drain wells contribute even less water. Bearing in mind that over 4,500,000 acre-ft ($5.5x10^9 m^3$) of water passes through the ground-water system of the study area each year, identifying regional effects of drain wells on the overall quality of ground water should be almost impossible.

Table 7 summarizes the ranges of various constituents in water from surface sources, ground water, spring discharges, irrigation-return flows to drain wells, urban runoff water, and septic-tank effluent. From this summary, a comparison of the various sources of inflow is possible. The information contained clearly indicates the inability to detect regional effects of drain-well inflows on ground-water quality. In general, water quality of the various sources of natural inflow to the aquifer and drain-well inflows are not significantly different.

Although regional effects of drain-well inflow were not identified, some comments on how the inflow could affect ground-water quality are presented for general information. For discussion purposes, the chemical, physical, and biological characteristics of the waste waters have been grouped into major categories which include major dissolved ions, temperature, suspended sediment, nutrients, minor elements, pesticides, and bacteria.

Major Dissolved Ions

The major dissolved ions (sodium, potassium, calcium, magnesium, bicarbonate, carbonate, sulfate, and chloride) are commonly found in all waters. They originate from sources as diverse as the atmosphere, the soil, the rocks, and decaying vegetation. In concentrations normally found in nature, the major ions are of little concern. However, in large concentrations or in unusual ratios, the major dissolved ions can be troublesome. For example, sulfate in concentrations in excess of 250 mg/l can be cathartic; high concentrations of chloride ions can be detrimental to some crops; and a high ratio of sodium to calcium and magnesium can cause clays to defloculate, rendering soil impermeable.

When water percolates through soil, additional salts may be leached, resulting in an increase in some of the major dissolved ions. Depending upon the chemical makeup of the soil and the chemical quality of the waste water, ion-exchange processes may alter the chemistry of the percolating water to some degree. Calcium, for example, can be replaced by sodium as calcium-rich water percolates through sodium-rich clays. No processes other than increases in dissolved solids from leaching and chemical alteration from ion exchange significantly affect the major dissolved ions as water percolates through soil.

However, water used for various purposes can be changed significantly before it becomes waste water available for recharge to the underlying aquifer. In agriculture, fertilizers and soil conditioners added to croplands contribute substantial amounts of the various major ions to the irrigation waste water. Evaporation and transpiration from crops tend to concentrate the dissolved salts. Urban runoff water often contains high concentrations of sodium and chloride from deicing salt spread on streets and walkways. Industrial use of water can result in a myriad of changes in the quality of the water, depending upon the type of industry and the use of the water. Domestic use commonly causes an increase in concentrations of most of the major ions.

Assuming that waste water enters the aquifer after use, whether by deep percolation or by injection through disposal wells, the question is how the use of disposal wells affects water quality in the aquifer. As previously stated, deep percolation can result in higher concentrations of major ions because of leaching and perhaps some chemical alterations because of ion exchange. Waste water injected through disposal wells bypasses the unsaturated material, thereby entering the aquifer essentially unaltered. Thus, both deep percolation and well injections could affect the concentration of major dissolved ions in the aquifer if concentrations of the introduced waste waters are sufficiently great. However, the data available do not indicate a significant effect from the wastes presently being injected.

If disposal wells were used at some future time to dispose of highly concentrated wastes from industrial uses (pickling brines or acid-bath water, for example) they could have an effect on the major dissolved ions in the ground-water body.

Temperature

The temperature of ground water is generally near the long-term average of the surface temperature. In the Snake Plain aquifer, temperatures range from about 12.5° to 16°C. Ground-water temperature is not important to most users, but fish hatcheries, which obtain their water supply from springs, could be adversely affected by high ground-water temperatures.

The only industrial drain well sampled during this study received cooling water which had a temperature of 34.5°C. The relatively small amount of water injected by this well is probably cooled rapidly to the average ground-water temperature by the underlying large ground-water body.

The well (8S-16E-aacl) is at least 8 mi (13 km) upgradient from the nearest spring used for hatchery water supply (Crystal Spring).

Although other types of drain wells inject water with higher temperatures than the underlying ground water, the temperature difference is generally less than 5°C. No adverse effects are expected to result from this small temperature difference.

Suspended Sediment

Suspended sediment is generally not found in ground water because of the natural filtration which occurs as the water percolates to and through the aquifer. However, in the Snake Plain aquifer, the large openings in fractures, fissures, and contact zones do not necessarily afford the filtration of more common sand and gravel aquifers. One local resident reported pumping sediment-laden water (hair, silt, and other debris) from well 8S-19E-35cccl after a drain well was installed nearby. If factual, this case indicates that, in some places, sediment may move some distance through highly permeable parts of the Snake Plain aquifer before filtration effectively removes the suspended material.

Suspended sediment was present in most samples taken from irrigation waste water entering drain wells. However, this sediment is rarely transported significant distances from the well within the ground-water flow system, and is important to users of the ground water mainly because of the pesticides and heavy metals that may be adsorbed on the sediment and thus carried into the aquifer. Bacteria associated with the sediment may also be of concern. In most places, the sediment is quickly filtered out within the immediate vicinity of the drain well, becoming more a problem of plugging and reducing the usefulness of the well than a threat to ground-water quality. Even small concentrations of suspended sediment affect the life of the drain well, and screens or settling basins are often used to reduce the sediment concentration.

Nutrients

Compounds of nitrogen and phosphorus and organic carbon are essential to plant growth, and are applied to crops in the form of fertilizer. In much of the area, these fertilizers are distributed to the crops through addition to the irrigation water and are thus present in the waste water. The nitrogen compounds (nitrate and nitrite) move freely through soil, the unsaturated rocks, and the aquifer, and are commonly found in the ground water. The phosphorus compounds (phosphate) are more readily sorbed by soil particles and are generally found only in small concentrations in the ground water. Organic carbon mostly occurs as particulate matter that is filtered out and retained generally near the soil surface and in the root zone. Where nutrient-rich waste waters are injected directly through drain wells, there is little opportunity for filtration or sorption before reaching the aquifer, and significant concentrations may be found in the ground water at some localities. Where the aquifer contains large openings with little sediment, the nutrients may move with the ground water and discharge through nearby wells and springs.

Nutrients in ground water of the study area are of concern, primarily as they affect algal and other plant growth in surface-water bodies fed by the ground water. Nitrate concentrations in excess of 10 mg/l (as N) may be a threat to infants and can cause other human health problems, but such concentrations have not been found in the ground water of the study area. Algal blooms caused by high-nutrient ground water discharging to hatchery ponds and the Snake River in the springs area could cause aesthetic and fisheries problems through dissolved oxygen reduction as the algae decompose. The analyses of waste waters entering drain wells indicate that, except where drain wells are very near spring discharges, the nutrient concentrations probably are of limited concern. In most cases, only the nitrogen compounds move large distances with the ground water, and the organic carbon and phosphorus are generally retained near the point of injection.

Minor Elements

Minor elements are of concern in this study because many are highly toxic. Perhaps the greatest hazard to health from drain wells in the four-county study area is not the wastes routinely discharged into them, but the possibility of highly toxic chemicals that may be disposed of accidentally or purposely in a drain well. None of the data indicate that the minor elements in the waste water now being routinely discharged into drain wells in the area are in concentrations sufficient to be hazardous. For purposes of discussion, the minor elements may be divided into two groups based on their chemical properties: (1) those minor elements normally found in solution as cations; and (2) those normally found in solution as anions, complex ions, and chelates.

Minor elements that occur as cations are normally of little concern in ground-water quality, even though some, such as mercury, cadmium, selenium, and lead, are quite toxic. Several reasons why these cations rarely pollute ground water are: (1) natural levels of the elements are generally very low; (2) the activities of man only occasionally introduce significant levels of any into the ground-water environment--particularly in agricultural areas; (3) the chemical compounds in which the elements occur are generally almost insoluble in water; and (4) the elements, when present as cations, are adsorbed by clay and granular aquifer materials and removed from solution. A production well or spring a short distance from a drain well could be contaminated by such wastes if travel distance or time were too short for sorption to be effective.

Minor elements in the form of anions, complex ions, or chelates have far greater contamination potential for ground water than do the cation forms. The more important minor elements in this classification include chromate, arsenate, methyl mercury, the various metal chelates, and a host of other organometal compounds. A number of these are applied as pesticides. Some of the metal chelates may be applied to the soil or vegetation as fertilizers. Elements in these forms may pass through a considerable thickness of aquifer material before they are immobilized by exchange processes, fixation, or bacterial decomposition. Many cases are on record in areas outside the study area where contamination by these elements was detected several years after injection. For example, Robertson and Barraclough (1973, p. 296-297) describe the movement of hexavalent chromium disposed of with other wastes at the National Reactor Testing Station (now Idaho Nuclear Energy Laboratory) near Idaho Falls, Idaho. Here, after a period of 20 years, sorption had not had a major effect on the chromate-ion migrations.

Pesticides

The toxicity of pesticides and pesticide residues poses undeniable threats to the public well-being and the environment, and much has been written about the hazards of pesticides and their stable residues.

Generally, pesticides are not a major cause of concern in ground-water supplies, although they are used extensively throughout the study area on agricultural lands and around homes. Most are relatively insoluble in water and are adsorbed readily by soils. As in the case of phosphates and minor elements, however, the threat of contamination of ground-water supplies is increased when sediment-laden water is injected directly into the aquifer through drain wells.

To examine the presence of pesticides, samples were collected from four springs discharging from the aquifer and from six surface-water sites. As shown in table 8, no pesticides were detected in the ground-water samples. All the surface-water samples contained pesticides, although concentrations were low.

Because of the tendency for pesticides to be adsorbed on soil particles and because of the low concentrations of pesticides detected in irrigation waste water, the threat of ground-water contamination is not great. However, accidental spills of highly concentrated pesticides near a drain well, as with the case of toxic minor elements just discussed, could result in the introduction of dangerous amounts of pesticides into the aquifer. Should this occur, downgradient wells and spring discharges could be contaminated.

Bacteria

Bacteria commonly occur in ground-water systems, although concentrations are generally very low. The mobility of bacteria in aquifers is not well known, but filtration processes, particularly in fine-grained materials, are known to be effective in removing or immobilizing most bacteria in ground water. However, bacteria are known to survive and even multiply in aquifers, given the proper conditions.

Bacteria in ground water are an obvious threat to domestic supplies. Typhoid, hepatitis, and dysentery are well-known diseases caused by pathogenic organisms. Although usually associated with contaminated surface-water supplies, these diseases have been traced to ground-water supplies in other parts of the world and could occur in ground water wherever sufficient contamination occurs.

The use of drain wells to dispose of septic-tank effluent and other types of wastes which contain bacteria bypasses the natural filtration afforded by percolation. Because of the fractures, fissures, and open contact zones between basalt flows in the Snake Plain aquifer, the filtration of bacteria may be limited even after the injected water enters the aquifer. Evidence is available to indicate that bacteria can move fairly long distances through the aquifer (see section on local effects).

Bacteria were detected in all samples of drain-well inflow, including irrigation waste water, urban runoff, industrial waste water, and septic-tank effluent. Concentrations of immediate coliforms (defined as total coliforms analyzed immediately after sample collection) ranged from about 30 col/100 ml (milliliters) for a sample of irriga-

Table 8.--Pesticide concentrations in spring discharges and irrigation waste water
(Chemical constituents in micrograms per litre)

Location number	Date	Aldrin	Chlordane	DDD	DDE	DDT	Diazinon	Dieldrin	Dyfonate	Endrin	Heptachlor	Heptachlor epoxide	Lindane	Malathion	Methyl parathion	Parathion	PCB	2,4-D	2,4,5-T	Silvex
								SPRING DISCHARGES												
6S-13E-27bbb1S	04-21-70	.00		.00	.00	.00	†	.00		.00	.00	.00	.00		†	†		.00	.00	.00
8S-14E-08dba1S	04-21-70	.00		.00	.00	.00	†	.00		.00	.00	.00	.00		†	†		.00	.00	.00
9S-14E-03cba1S	04-21-70	.00		.00	.00	.00	†	.00		.00	.00	.00	.00		†	†		.00	.00	.00
9S-17E-28add1S	04-21-70	.00		.00	.00	.00	†	.00		.00	.00	.00	.00		†	†		.00	.00	.00
								IRRIGATION WASTE WATER												
7S-15E-33cad1	10-05-72	.00	.16	.00	.00	.02	.06	.00		.00	.00	.00	.00	.00	.00	.00	.0	1.9	.00	.00
7S-17E-16baa1	07-12-72	.00	.0	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	#	.33	.00	.00
9S-23E-10bcb	07-25-73	.00	.0	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	.0	.66	.00	.00
	08-16-73	.00	.0	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	.0	.29	.00	.00
9S-23E-10bcb1	08-30-73	.00	.0	.00	.00	.00	.00	.00		.00	.00	.00	.00	.00	.00	.00	.0	.48	.00	.00
9S-24E-05bcc	07-13-72	.00	.0	.00	.00	.00	.00	.02		.00	.00	.00	.00	.00	.00	.00	#	.00	.00	.00
	07-24-73	.00	.0	.00	.00	.01	.00	.02	.03*	.00	.00	.00	.00	.00	.00	.00	.0	.92	.00	.00
	08-30-73	.00	.0	.00	.00	.01	.01	.01	.03*	.00	.00	.00	.00	.00	.00	.00	.0	.35	.00	.00
10S-18E-21ccd1	12-19-72	.00	.1	.03	.00	.01	.06	.18		.00	.00	.00	.00	.00	.00	.00	.0	.00	.00	.00

†Not detected, but screened for this compound
#Not detected, limit of detection about 0.5 micrograms per litre
*This is a minimal value for dyfonate. The true value is probably higher.

tion waste water to 20,000,000 col/100 ml for a sample of septic-tank effluent. Although the total volume of water injected through drain wells is small (particularly septic-tank effluent) compared to other sources of inflow to the aquifer, the high concentrations of bacteria clearly are a matter of concern. No cases of infection by pathogenic organisms have been attributed to ground-water supplies within the study area, but the threat is real.

Local Effects

Although regional effects of disposal wells on the overall quality of water in the Snake Plain aquifer are not identifiable or separable from the effects of other inflows, data are available which indicate that quality of water from specific supply wells is affected by drain-well inflow. Apparently, water-quality changes in some supply wells can be related to flows entering nearby drain wells. The word "apparently" is stressed.

Several factors other than drain-well inflow can contribute to fluctuations in water quality in specific wells. Percolating water of different quality than that of the ground-water body could cause fluctuations, particularly if depth to water is small and the well penetrates only the uppermost part of the aquifer. Poor well construction, which might allow surface water to enter the well directly, could be the cause of sudden water-quality changes. If observed changes in water quality are small, the differences could even be caused by analytical error in measuring the chemical constituents. However, if observed changes in water quality in a specific well can be related to inflow to a nearby drain well, it is probable that the drain well is the cause.

Realizing that other factors may be involved, data from the following wells suggest influence from drain-well inflow:

1. 6S-17E-2abb1--On February 14, 1973, a water sample from this well had a specific conductance of 331 μmhos. On February 15, 1973, urban runoff from a storm event was observed entering nearby drain wells 6S-17E-2bad1, 2bad2, and 2bbd1. Specific conductance of the water entering the drain wells ranged from 264-282 μmhos. A second sample was collected from supply well 2abb1 on February 15, and the specific conductance was observed to be 323 μmhos. Although the apparent reduced specific conductance of 8 μmhos approaches the accuracy limits of the measuring device used, it does suggest that the drain-well inflow was diluting the ground water in the area.

2. 7S-17E-16aabl--This well was sampled on April 12, 1973. Analysis showed a sulfate concentration of 28 mg/l, a chloride concentration of 12 mg/l, and a specific conductance of 354 μmhos. A sample of irrigation waste water entering nearby drain well 7S-17E-15bccl in August 1973 showed that the drain-well inflow had a sulfate concentration of 42 mg/l, a chloride concentration of 19 mg/l, and a specific conductance of 428 μmhos. A second sample from supply well 16aabl collected on August 1, 1973, showed an increase in both sulfate and chloride concentrations of 2 mg/l and an increase in specific conductance to 369 μmhos. The sample collected on August 1 also had coliform bacteria which were not noted in the April sample. The increases in sulfate and chloride ion concentrations, the increased specific conductance, and the presence of indicator bacteria suggest a direct influence from drain-well inflow.

3. 8S-23E-28dadl--A sample from this well collected on February 16, 1973, had a specific conductance of 956 μmhos and was free of all indicator bacteria. Nearby drain well 8S-23E-28dccl had inflowing water with a specific conductance of 126 μmhos on May 9, 1973. By August 29, 1973, water from supply well 28dadl had decreased in specific conductance to 796 μmhos, and total coliform and fecal streptococci bacteria were present. A dilution by drain-well inflow may have caused the decrease in specific conductance and the appearance of bacteria.

4. 9S-23E-9aaal, 9baal, 10cccl, and 10cdc--These four wells all display similar fluctuations in water quality. Sulfate concentrations ranged from 60-80 mg/l in April 1973 but decreased in all four wells an average of 13 mg/l to 48-67 mg/l by September 1973. Chloride concentrations also decreased, though not as markedly. Specific conductance decreased significantly from more than 700 μmhos to 536 μmhos. In general, samples from the wells also had higher bacteria counts at the end of the irrigation season. These wells are near Goyne Sump, an area which relies heavily on drain wells for disposal of irrigation water. A sample of inflow to one of these drain wells (9S-23E-10bcbl) showed sulfate, chloride, and specific conductance values significantly lower than the underlying ground water. The decreases in these constituents and the increases in bacteria counts in the four supply wells suggest a direct relation to drain-well inflow.

5. 9S-24E-6acdl, 6cbdl, 6cddl--These wells display opposite changes in water quality to the wells in 9S-23E, secs. 9 and 10. While the previous wells displayed reductions in sulfate, chloride, and specific conductance, the wells in 9S-24E, sec. 6 showed marked increases in the same constituents. Wells 6acdl and 6abdl also had material increases in bacteria. These wells are located in the Camp Holly Lake area, which also has a large number of drain wells. The drain wells in this area (exemplified by wells 9S-24E-6ddbl and 6dddl) inject water with specific conductance in the range of 660-730 μmhos, which is significantly higher than that in the underlying ground water. The increases in sulfate, chloride, and specific conductance (together with high bacteria concentrations) indicate direct influence of drain-well inflow.

SUMMARY AND CONCLUSIONS

Approximately 3,100 drain wells inject irrigation waste water, urban runoff, septic-tank effluent, and industrial waste water into the Snake Plain aquifer in Minidoka, Gooding, Jerome, and Lincoln Counties. About 29,000 acre-ft ($3.6\text{x}10^7$ m^3) of irrigation waste water, 100 acre-ft ($1.2\text{x}10^5\text{m}^3$) of urban runoff, 400 acre-ft ($4.9\text{x}10^5\text{m}^3$) of septic-tank effluent, and 1,000 acre-ft ($1.2\text{x}10^6\text{m}^3$) of industrial waste water are injected annually. In comparison to the more than 4,500,000 acre-ft ($5.5\text{x}10^9\text{m}^3$) of water that passes through the ground-water system each year, these amounts are quite small.

The quality of irrigation waste water is highly variable, depending upon its source, method and rate of application, amount of fertilizer added, and other factors. In general, dissolved solids are increased because of leaching of minerals from the soil and from application of fertilizers. Nutrient concentrations are generally significantly higher in irrigation waste water than in the applied water. Bacteria concentrations are also significantly higher.

The quality of urban runoff water is generally much better than irrigation waste water. However, sodium and chloride concentrations are often higher because of salt used to deice roads and sidewalks. Oil, grease, and lead were detected in significant concentrations in urban runoff water. Bacteria concentrations were also high.

Septic-tank effluent, characterized from one sample and from calculations based on average domestic water use, is relatively high in nutrient concentrations. Chloride concentrations are also high. Bacterial concentrations were exceedingly high, as one would expect.

The only industrial waste water sampled during this study had been used for cooling. No chemical changes were noted, but temperature was significantly increased. Some indicator bacteria were detected.

Because of the relative magnitudes of the amount of drain-well inflow entering the aquifer and the amount of water flowing through the aquifer, no regional effects were noted. However, several instances of apparent local effects were observed. Ground water sampled before, during, and after injection of wastes into nearby drain wells showed chemical changes which could be related to the drain-well inflow. In some cases, dilution of various constituents was observed, and in others, concentrations of constituents increased. In all cases reported, the ground-water quality changed toward the drain-well inflow. Bacterial concentrations showed marked increases in several of the examples, which further indicates direct influence from nearby drain wells.

Although no serious health hazards were noted during this study (with the exception of bacterial concentrations, which could indicate the presence of pathogenic organisms), the threat of pollution is apparent. The data indicate that drain-well inflow does move appreciable distances through the aquifer and can be detected in downgradient wells.

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