GROUND-WATER QUALITY IN THE WESTERN SNAKE RIVER BASIN, SWAN FALLS TO GLENNS FERRY, IDAHO

By D. J. Parliman

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CONVERSION FACTORS

For the convenience of those who prefer SI (International System of Units) rather than the inch-pound system, conversion factors for terms used in this report are listed below. Constituent concentrations are given in mg/L (milligrams per liter) or µg/L (micrograms per liter), which are equal to parts per million or parts per billion, respectively. Ion concentrations also are given in meq/L (milliequivalents per liter).

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Flow	
gallon per minute (gal/min)	0.06309	liter per second
	Specific Conductance	
micromho (µmho)	1.00	microsiemens

Temperature: Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8\ °C + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. In this report, altitudes are based on the NGVD of 1929.

WELL-NUMBERING SYSTEM

The well-numbering system (fig. 1) indicates the location of wells sampled within the official rectangular subdivision of public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township (north or south) and range (east or west). The third segment gives the section number, followed by three letters and a numeral, which indicate the ¼ section (160-acre tract), ¼-¼ section (40-acre tract), the ¼-¼-¼ section (10-acre tract), and the serial number of the well within the tract, respectively.

The U.S. Geological Survey in Idaho indicates quarter sections by the letters A, B, C, and D in counterclockwise order from the northeast quarter of each section. Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. For example, well 5S-9E-13ACD1 is in the SE¼SW¼NW¼ sec. 13, T. 5 S., R. 9 E., and is the first well inventoried in that tract.

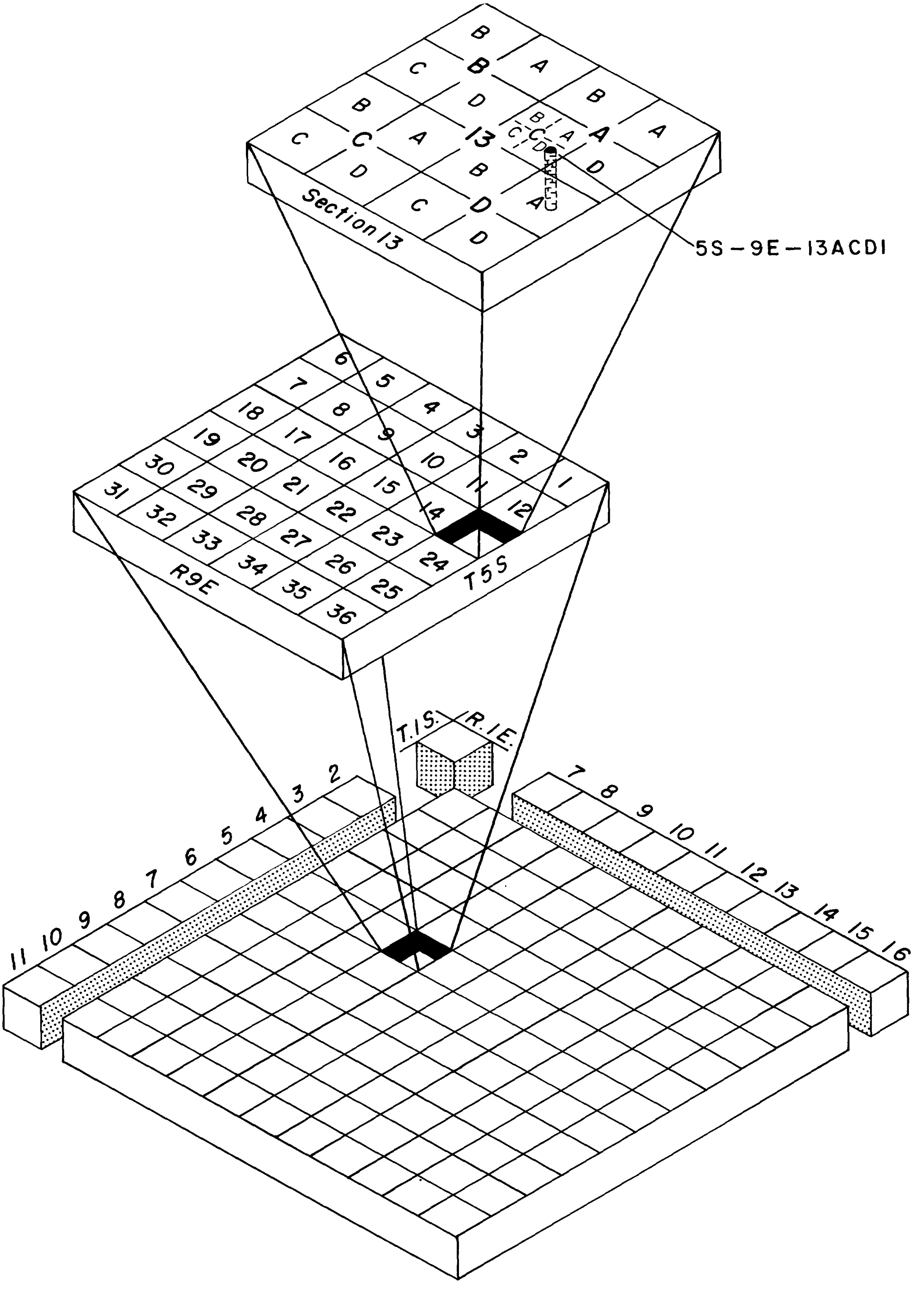

Figure 1.-- Well-numbering system.

GROUND-WATER QUALITY IN THE WESTERN SNAKE RIVER BASIN, SWAN FALLS TO GLENNS FERRY, IDAHO

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ABSTRACT

Water-quality data were collected from 92 wells in the western Snake River basin, Swan Falls to Glenns Ferry, Idaho. Current (1980) data were compiled with historic (pre-1980) data from 116 wells to define water-quality conditions in major aquifers of the area.

Factors affecting water quality in the study area are composition of aquifer materials, water temperature, and source of recharge. Mixing of water from confined, hot water aquifers (40 degrees Celsius or greater) with cold water aquifers (less than 20 degrees Celsius) occurs along regional complex fault systems, by interaquifer flow, and through partially cased boreholes. Cold water generally contains principally calcium, magnesium, and bicarbonate plus carbonate ions; hot water generally contains principally sodium, potassium, and bicarbonate plus carbonate ions. Warm water (between 20 degrees and 40 degrees Celsius) has an intermediate chemical composition.

Ground-water quality in the study area is generally acceptable for most uses, although it locally contains chemical constituents or physical properties that may restrict use.

Effects of thermal irrigation water on quality of shallow ground water are inconclusive. The long-term increase in concentration of several water-quality characteristics in parts of the study area may be due to effects of land- and water-use activities, such as infiltration of septic tank effluent.

INTRODUCTION

Ground-water availability and quality in Idaho become more significant to water users as demand for ground-water supplies increases. An understanding of factors that affect ground-water quality is needed to evaluate potential effects of stresses that will accompany changes in land and water use.

This study is part of a continuing program, in cooperation with the Idaho Department of Water Resources, to obtain ground-water quality data in areas where land- and water-resource development is expected to increase. Similar studies in this program were completed for southeastern Idaho (Seitz and Norvitch, 1979), north Idaho (Parliman and others, 1980), east-central Idaho valleys (Parliman, 1982), and eastern Snake River basin (Parliman, 1983b).

Purposes and Approach of Study

The primary purposes of this study were to: (1) Define, on a reconnaissance level, current (1980) water-quality conditions in major aquifers (water-yielding rock formations) in the western Snake River basin, Swan Falls to Glenns Ferry (fig. 2); (2) summarize and interpret available geologic and hydrologic data to assist in understanding the natural and man-caused factors that affect present and future water-quality conditions; and (3) establish a hydrologic data base on which future data can be compared to evaluate changes. A secondary purpose was to evaluate the possible effects percolation of thermal water applied for irrigation may have on the quality of local, less mineralized, nonthermal ground water. In this report, warm and hot waters are considered thermal; cold water is considered nonthermal. Cold water temperature is less than 20°C, warm water is 20°-40°C, and hot water is greater than 40°C.

To accomplish the stated purposes, ground-water samples and well-inventory data for 92 wells in the study area were collected from August to November 1980. Selection of wells sampled was based on the following considerations: (1) Availability of well-construction and borehole lithologic information, (2) hydrologic and geologic characteristics of the aquifers, (3) availability of historic water-quality data, (4) degree of development of the aquifers, (5) depth to water, (6) potential use of ground water, (7) historic water-quality problems, and (8) potential proneness to pollution, such as from septic-tank drain-field leachates.

Historic (pre-1980) water quality and well-inventory data were compiled for 116 wells to: (1) Provide ground-water quality information in areas where current data were not available, (2) provide comparative data for assessment of the effects

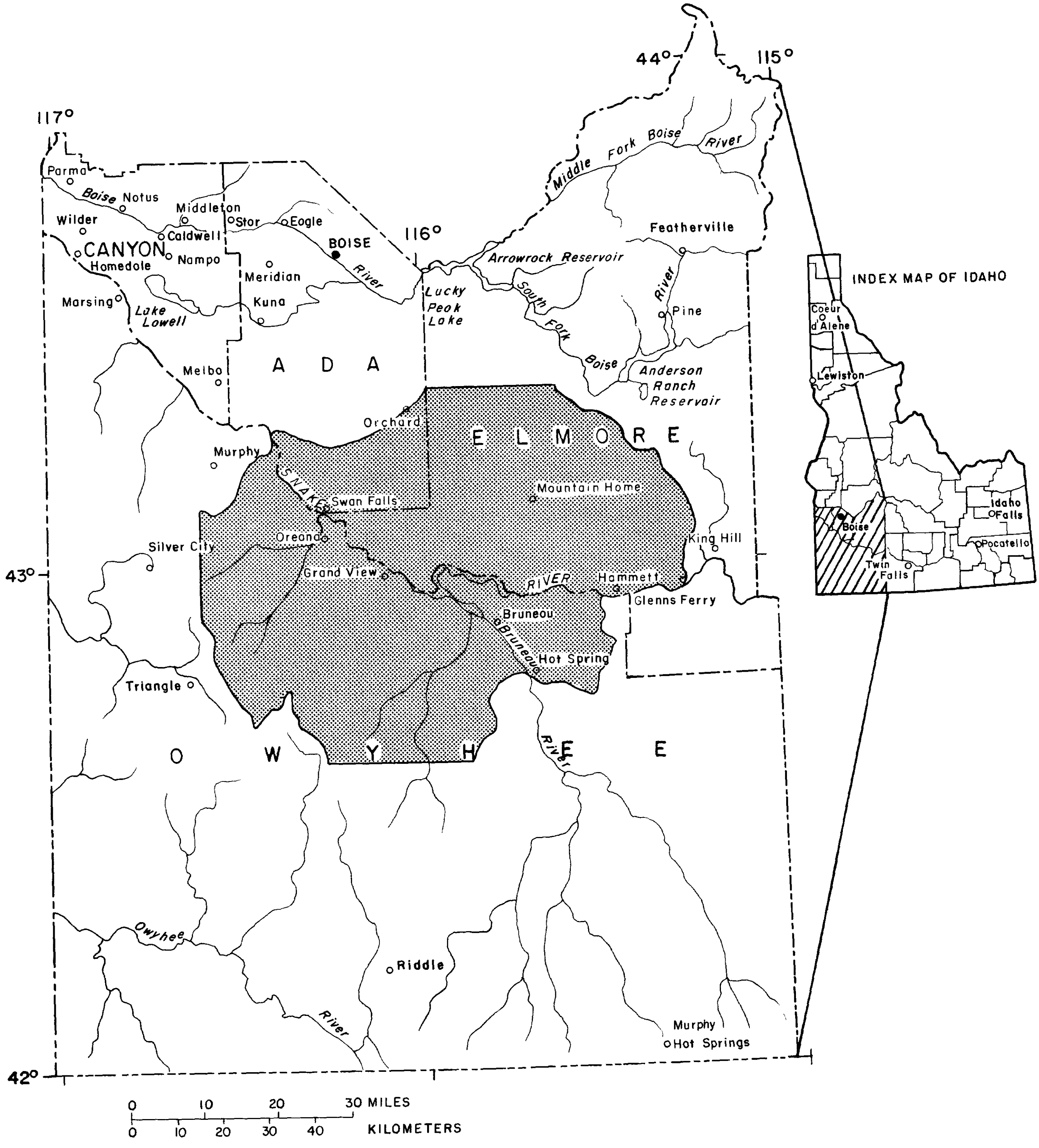

Figure 2. -- Location of study area.

of quality of thermal water on quality of nonthermal water, and (3) assess possible temporal changes of ground-water quality. Wells for which data are available are shown in figure 3. Well data and water-quality and trace-element analyses are presented in a report by Parliman (1983a).

Sampling Methodology

Because certain water-quality characteristics may change with time after sample collection, field determinations of the following were made onsite: air and water temperature, pH, specific conductance, and bicarbonate and carbonate concentrations (by end-point titration method). Well-inventory data collected onsite included measurements of water level and well discharge where possible.

Methods used for collection and preservation of samples, onsite water-quality determinations, and well-inventory data collection are described in publications by U.S. Geological Survey (1977) and Beetem and others (1980). Field sampling equipment used included Sybron/Barnstead[1] conductivity bridge, Sargent-Welch pH meter with Sensorex sealed pH probe, and Millipore 0.45 μm average pore diameter cellulose nitrate membrane filters. Sample analyses were performed at the U.S. Geological Survey, Water Resources Division, Denver Central Laboratory.

DESCRIPTION OF THE STUDY AREA

The western Snake River basin from Swan Falls to Glenns Ferry, as described in this report, comprises about 2,700 mi^2. The area is located in southeastern Ada, southern Elmore, and north-central Owyhee Counties; for use in this report, this area is hereafter referred to as Elmore (areas north of the Snake River) and Owyhee (areas south of the Snake River) Counties. Major landform features, county boundaries, and towns are shown in figure 3.

The study area includes parts of both the Northern Rocky Mountain and Columbia Intermontane geomorphic provinces (Ross and Savage, 1967). Foothills and mountains north and east of Mountain Home in Elmore County are characterized by northwest-trending mountain ranges with deep intermontane valleys. Land-surface altitude in this area ranges from 3,800 ft to more than 7,400 ft.

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[1] Use of brand and trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

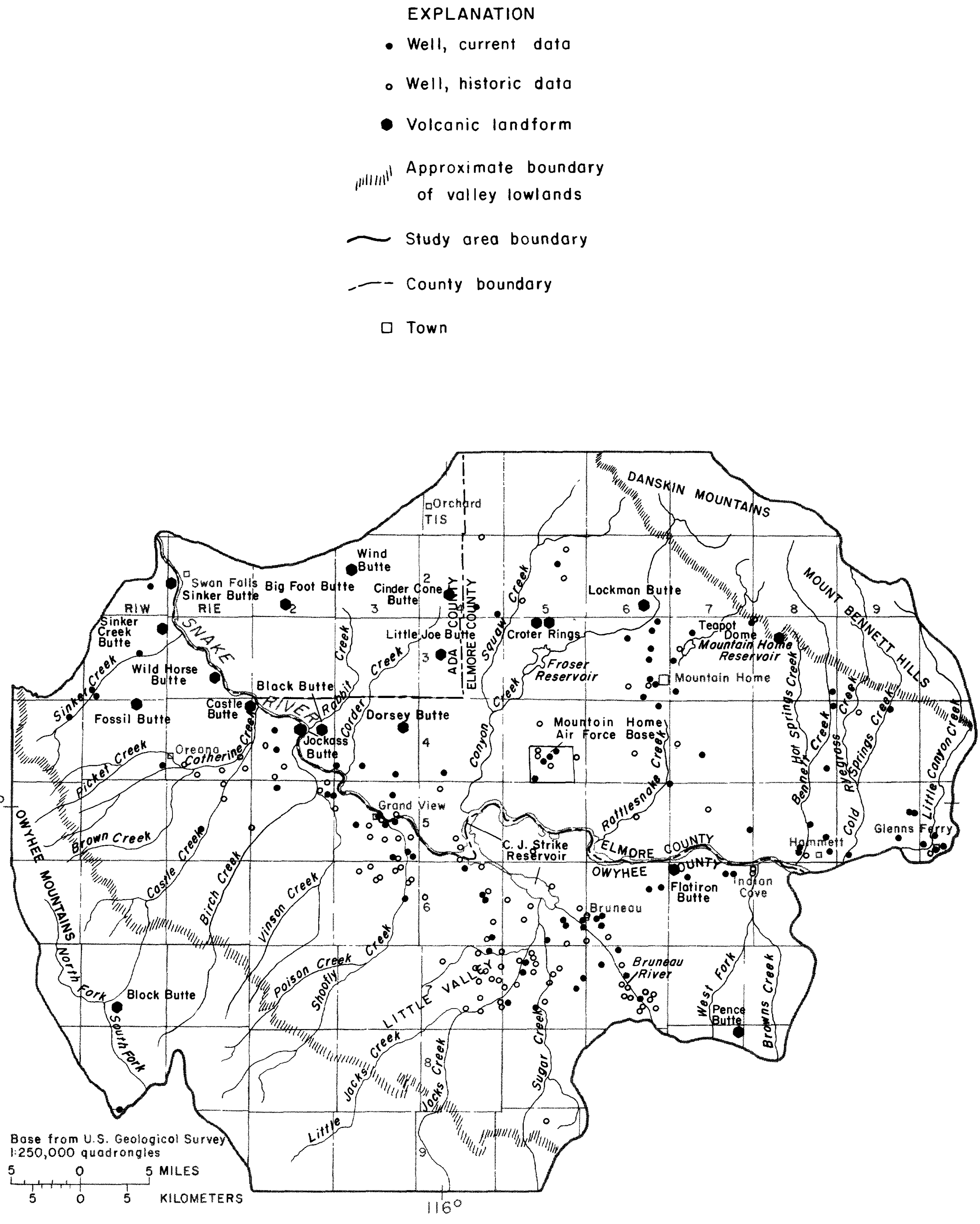


Figure 3. -- Wells for which water-quality data are available and major landform features, county boundaries, and towns.

Lowlands on both sides of the Snake River are characterized by thick lake- and river-origin sediments that are interbedded extensively with basalt flows and generally referred to as the western Snake River Plain or Snake River valley. Land-surface altitude in this section ranges from about 2,300 to 3,800 ft but includes features of volcanic origin as high as 4,000 ft. Snake River valley lowland boundaries indicated in several figures coincide approximately with the 3,800-ft altitude contours on U.S. Geological Survey 1:250,000 maps.

Foothills, high plateaus, and rugged mountainous areas of the southwestern part of the study area are characterized by geologic uplift (Owhyee Uplift), doming, block faulting, and deep, steep-walled canyons. Structural features of the uplifted area trend eastward to southeastward across the southern part of the study area. Land-surface altitude in this section ranges from 3,000 to 8,400 ft.

Climate in the study area ranges from arid in the lowlands to subhumid in the high mountains. Average annual precipitation ranges from less than 10 in. in the lowlands to about 20 in. in the mountains. The average annual temperature in the lowlands ranges from 12°C (54°F) at Swan Falls to 10.5°C (51.5°F) at Glenns Ferry (National Oceanic and Atmospheric Administration, 1980).

Most of the land is federally owned and is managed by the Bureau of Land Management or the National Forest Service. A majority of the private, State, or federally owned land is used as rangeland, but some lowland and foothill areas are used for irrigated agriculture. Crops raised include alfalfa, sugar beets, potatoes, corn, wheat, barley, beans, and mint; nearly all crops must be irrigated. Irrigation water is diverted or pumped from surface water--intermittent streams, the Bruneau and Snake Rivers, and several reservoirs--or from ground-water sources.

The area is sparsely populated. Elmore and Owyhee Counties have estimated populations of 6.4 and 1.0 people per square mile, respectively (Idaho Division of Budget, Policy Planning, and Coordination, 1978). Mountain Home and Glenns Ferry are the largest towns and have populations of approximately 7,500 and 1,400, respectively. Approximately 3,500 service people are stationed at the Mountain Home Air Force Base, located southwest of Mountain Home. Smaller towns (generally less than 500 people) include Swan Falls and Hammett in Elmore County, and Oreana, Grand View, and Bruneau in Owyhee County.

The economy is based on irrigated agriculture, livestock production, tourism and seasonal recreation activities, and military-related jobs. Industry includes potato and vegetable processing and feedlot cattle production.

More comprehensive descriptions of landform features, climate, land ownership and use, population, and economics are reported in Mundorff, Crosthwaite, and Kilburn (1964), and Ralston and Chapman (1968, 1969, and 1970).

Commercial development and population are increasing in most of the area, especially near Mountain Home, where construction of urban subdivisions is most heavily concentrated. Large tracts of federally owned land are being opened for irrigated agriculture development. Continued urban and commercial development, together with increases in irrigated acreage, may affect ground-water availability and quality.

GEOLOGIC AND HYDROLOGIC SETTING

Generalized Geology and Water-Yielding Characteristics of Geologic Units

Surface geology of the Swan Falls to Glenns Ferry area (fig. 4) is generalized from the Idaho State Geologic Map (Bond, 1978). Geologic units (sometimes composed of several geologic formations) include Quaternary alluvium and wind-blown deposits, Quaternary terrace gravels (undifferentiated), Quaternary basalts of the Snake River Group (undifferentiated), Quaternary Bruneau Formation of the Idaho Group, Quaternary and Tertiary Idaho Group (undifferentiated), Tertiary Banbury Basalt of the Idaho Group, Tertiary silicic volcanic rocks (undifferentiated), and Cretaceous intrusive rocks (basement complex). For purposes of this report, these units hereafter will be referred to respectively as alluvium, older gravels, Snake River basalt, Bruneau Formation, Idaho Group, Banbury Basalt, silicic volcanics, and basement complex. Descriptions of these units are shown in table 1. More detailed surface geology of parts of Elmore and Owyhee Counties were described by Malde, Powers, and Marshall (1963), and Ekren, McIntyre, Bennett, and Malde (1981).

Major structural features of the area include the Snake River Plain and a complex regional system of faults. The Snake River Plain is a massive topographic depression or basin (of debated structural origin) occupying the central part of the study area and generally defined by the lowland-foothills boundaries shown in many figures in this report. Faults are numerous throughout the area and trend generally westward or northwestward. Relatively few faults are traceable on the surface, but concealed faults frequently are shown on geologic cross sections (R. L. Whitehead, U.S. Geological Survey, written commun., 1982) or may be implied by the occurrence of numerous hot springs in some areas (Littleton and Crosthwaite, 1957). Spring data are not included in this report but are reported in Littleton and Crosthwaite (1957); Young and Whitehead (1975); Young (1977); and Young, Lewis, and Backsen (1979).

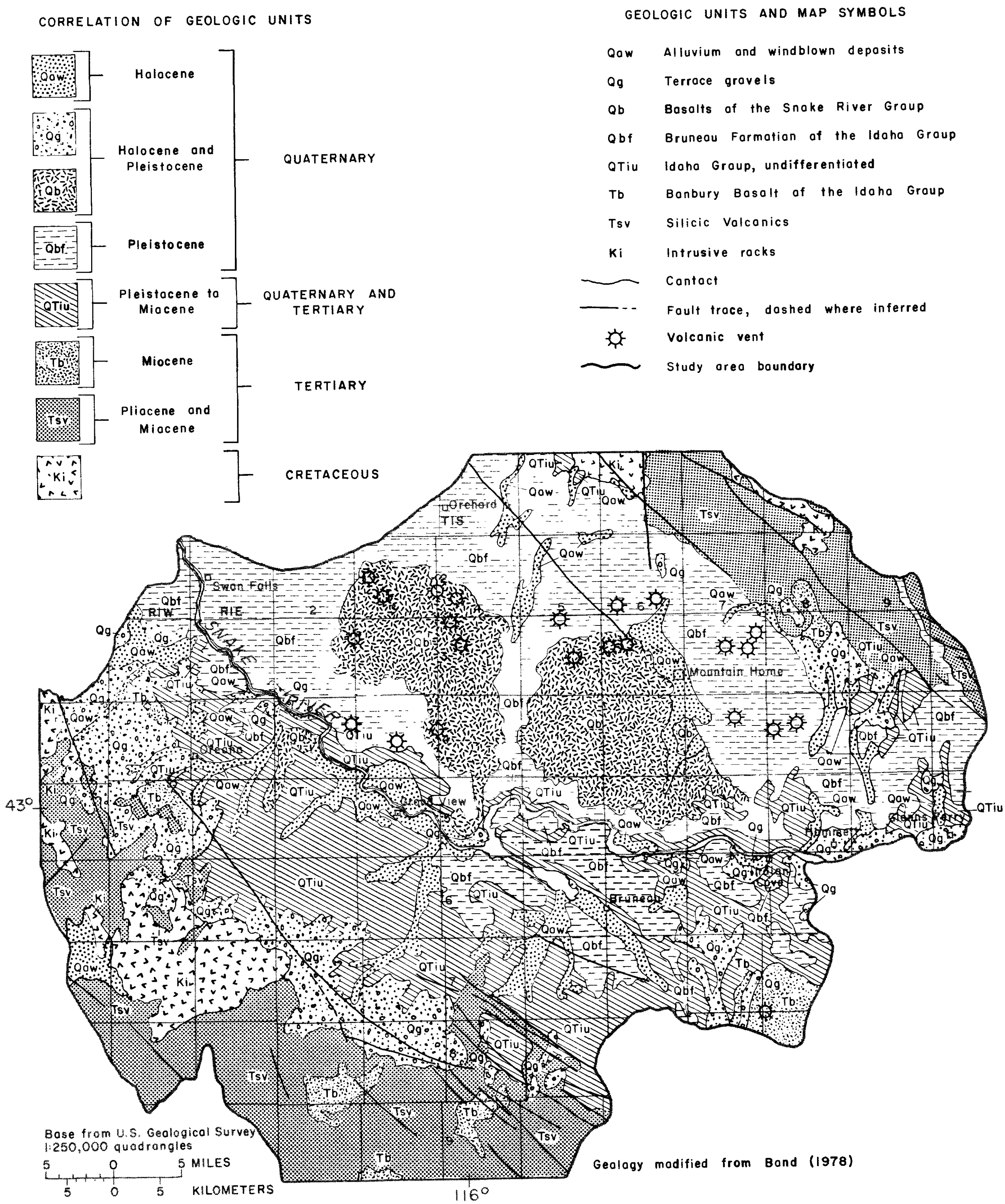


Figure 4. -- Generalized geology.

Table 1.--Correlation, description, and water-yielding characteristics of geologic units

Period	Epoch	Geologic unit and map symbol	Physical characteristics	Water-yielding characteristics
Quaternary	Holocene	Alluvium and windblown deposits (Qaw)	Chiefly flood-plain or windblown deposits. Includes some lake, glacial flood, and colluvium deposits. Clay, silt, sand, gravel, and boulders; unconsolidated to well compacted, not bedded to well bedded; locally contains caliche layers; includes active sand dunes in northern Owyhee County.	Sandy and gravelly alluvium yields moderate to large amounts of water to wells. Beds of fine-grained sediments or caliche may produce perched-water tables in some areas. Windblown deposits are generally above the regional water table.
Quaternary	Holocene and Pleistocene	Terrace gravels, undifferentiated (Qg)	Unconsolidated clay, sand, pebbles, cobbles, and boulders. Unconsolidated to compacted. Gravels occupy terraces along the Snake and Bruneau Rivers. Includes Melon Gravel and Crowsnest Gravel of the Snake River Group.	Surficial deposits are not permanently saturated. Reported well yields range from 20 to 2,700 gal/min (Young, 1977).
Quaternary	Holocene and Pleistocene	Basalts of the Snake River Group, undifferentiated (Qb)	Olivine basalt, light to dark gray, dense to vesicular, fine grained to coarse grained; irregular to columnar jointing; thickness of flows variable; includes beds of basaltic cinders, rubbly basalt, and interflow sediments.	Reported well yields range from 20 to 3,100 gal/min (Young, 1977); basalts are generally above the regional water table in the study area but may contain perched water. Interflow sediments yield little or no water to wells.
Quaternary	Pleistocene	Bruneau Formation of Idaho Group (Qbf)	Includes vesicular olivine basalt, dark gray to black, weathers to reddish gray-brown; fan deposits, largely coarse sands from decayed granitic rocks; and detrital material, chiefly massive lakebeds of white-weathering, fine silt, clay, diatomite, and minor amounts of sand. Includes beds of iron-stained pebble and cobble gravel.	Reported well yields from basalt range from 10 to 3,500 gal/min (Young, 1977), but basalt may be above the regional water table. Fan deposits are generally above the regional water table. Principal water-yielding unit of Mountain Home area but not important in Owyhee County.
Quaternary and Tertiary	Pleistocene and Miocene	Idaho Group, undifferentiated (QTiu)	Poorly to well stratified terrestrial and lake deposits: lenticular beds of sand, sandstone, silt, and clay. Considerable ash disseminated in the silt and clay; thin layers of ash also present. Intercalated basalt layers present in lower part of the formation. Includes oolitic sandstone and thick beds of algal limestone in places. Distinguished by thick, fine-grained sedimentary sequences, with blue clay beds common. Includes Black Mesa Gravel, Tuana Gravel, Glenns Ferry Formation, and Chalk Hills Formation of the Idaho Group.	Generally contains water under artesian pressure; yields to wells range from a few gallons per minute from fine-grained beds to thousands of gallons per minute from sand and gravel (Young, 1977; Mundorff, Crosthwaite, and Kilburn, 1964). Important aquifer.
Tertiary	Miocene	Banbury Basalt of the Idaho Group (Tb)	Basalt and olivine basalt, dark gray and brown, hard to soft, dense, fine to coarse textured; locally vesicular. A series of consolidated flows with interbedded lenses of red, pink, and brown tuff and tuffaceous fine-grained sediments. Exposed in the southern part of the area; dips northward and is deeply buried in the northern part of the area. Basalt commonly altered and may be contemporary with some Glenns Ferry Formation basalts in some areas.	Yields to wells depend on degree of rock alteration present in area penetrated by well; yields from highly altered rocks are significantly lower than yields from unaltered rocks. Contains water under artesian pressure. Yields to artesian wells reportedly range from a few tens of gallons to 3,800 gal/min (Ralston and Chapman, 1969). Important aquifer in Owhyee County.
Tertiary	Pliocene and Miocene	Silicic volcanic rocks, undifferentiated (Tsv)	Intrusive and extrusive igneous rocks in dikes and sheets. Chiefly latite, ranging in color from light reddish-brown to purple and black; glassy to fine grained and porphyritic; mostly dense. Includes Idavada Volcanics. Overlies older rhyolitic and related rocks that are fine- to coarse-grained extrusives rich in quartz and biotite, locally cut by mineralized fault zones.	Joints and fault zones in flows and welded tuff and interstices in coarse-grained ash, sand, and gravel beds yield small to moderate and rarely large amounts (2,000 gal/min, Ralston and Chapman, 1969) of water to wells. Commonly contains warm water under artesian pressure. Important aquifer in Owyhee County.
Cretaceous		Intrusive rocks (Ki)	Intrusive granitic rocks of comparable age and composition to the Idaho batholith.	Yields to wells from joints and fractured zones are small (Young, 1977).

Other structural features of the study area are associated with volcanic events and include dikes, volcanic necks, cinder cones, and shield volcanoes. Effects of these structures on ground-water systems in the area have not been established.

Structural geology of the study area has been studied extensively, owing to the geothermal potential of some ground-water systems and increasing demand for ground-water development for irrigation of arid lowlands. Stratigraphy and structural geology of the area are reported in more detail in several reports, including Piper (1924); Littleton and Crosthwaite (1957); Mundorff, Crosthwaite, and Kilburn (1964); Anderson (1965); Ralston and Chapman (1968, 1969, and 1970); Malde (1972); Young and Whitehead (1975); and Young (1977).

Aquifer Recharge

Recharge to aquifers in foothills, uplands, and mountains of the study area is primarily from infiltration of precipitation. Recharge to aquifers in the lowlands may be from several sources: (1) interaquifer flow; (2) infiltration from rivers, intermittent streams, irrigation canals, drain ditches, reservoirs, applied irrigation water, and precipitation; and (3) leakage from perched-water tables and septic-tank drain fields. The amount of recharge is affected primarily by geologic structure, mineral composition, and rock textures of the geologic units.

Faults are the most important geologic structure that affect aquifer recharge. Vertical downward movement of recharge to deep aquifers occurs along numerous fault zones. Upward leakage of thermal artesian recharge to shallow aquifers, especially from aquifers in Banbury Basalt and silicic volcanics to aquifers in Idaho Group also occurs along fault zones.

Mineral composition and rock textures of the geologic units are important factors determining the hydrologic properties (water-yielding characteristics) of aquifers and are of particular importance to infiltration of recharge within geologic units having highly variable lithologies, such as sediments of the Idaho Group. Discussion of the complex hydrologic systems in the Swan Falls to Glenns Ferry area is reported in Littleton and Crosthwaite (1957) and Ralston and Chapman (1968, 1969, and 1970).

All geologic units in the Swan Falls to Glenns Ferry area contain some ground water. Water occurs under either artesian (confined) or water-table (unconfined) conditions, and perched-water table conditions occur in many geologic units, particularly in the Bruneau Formation near Mountain Home. Aquifers in five geologic units are the most common sources of ground water in the study area: alluvium, Bruneau Formation, Idaho Group, Banbury Basalt, and silicic volcanics.

Aquifers in alluvium, Bruneau Formation, and upper beds of the Idaho Group generally contain cold water and are under water-table conditions. Aquifers in many lower beds of the Idaho Group may contain warm water under artesian conditions. Warm water temperatures most often indicate a mixing of cold and hot water, most commonly along fault zones or through well boreholes that penetrate more than one geologic unit. Aquifers in Banbury Basalt and silicic volcanics units have warm to hot water under artesian conditions.

Water-yielding characteristics of geologic units are shown in table 1. Well yields from all aquifers are generally adequate for domestic and stock uses. Well yields from aquifers in Bruneau Formation, Idaho Group, Banbury Basalt, and silicic volcanics units are variable but are adequate for irrigation in many parts of the study area. The quality of water yielded from Idaho Group, Banbury Basalt, and silicic volcanics units may influence water use more than do well yields.

Ground-Water Movement

Ground-water movement is in the direction of the hydraulic gradient, generally from areas of recharge to areas of discharge. Arrows showing the direction of movement in figure 5 are drawn perpendicular to contours on the potentiometric surface. Water-surface contours represent computer-interpolated plots of water-level data collected in spring and summer 1980 (U.S. Geological Survey, unpublished data, Boise, Idaho).

In Elmore County, ground water moves generally southwestward toward the Snake River. West of the Bruneau River in Owyhee County, ground water moves generally northeastward toward the Snake River. East of the Bruneau River in Owyhee County, ground water moves generally northwestward toward the Snake River.

Water in confined aquifers probably moves in about the same direction as that in unconfined aquifers. In general, where hydraulic heads in confined aquifers are above water levels in shallower, unconfined aquifers, some upward leakage may occur. In areas where perched water occurs, movement is generally downward toward the regional potentiometric surface.

GROUND-WATER QUALITY

Variability in chemical and physical characteristics of ground water in the study area is due to several factors, including: (1) Geochemical properties, such as solubility and exchange characteristics of aquifer materials; (2) mixing of water from differing aquifers; (3) contact time of water with aquifer materials; (4) mineral composition of aquifer materials;

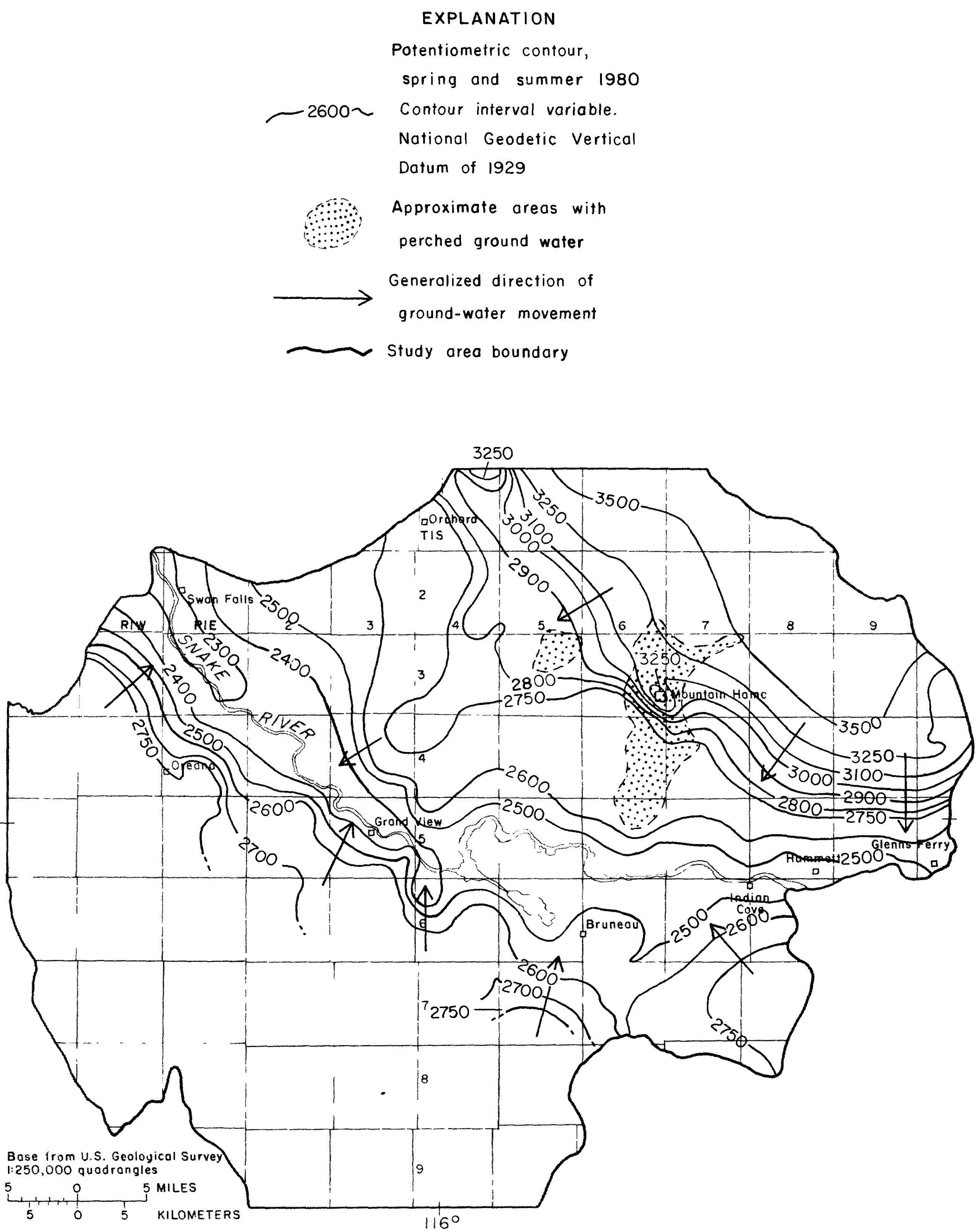


Figure 5. -- Contours on the potentiometric surface, 1980, and generalized direction of ground-water movement.

(5) relative proximity of the sampling site to source(s) of ground-water recharge; and (6) influences of man's activities, such as land- and water-use practices. An in-depth discussion of all factors affecting water quality is in many texts, including Freeze and Cherry (1979) and Krauskopf (1967).

Geochemical properties, mixing of ground water, effects of contact time, and mineral composition of aquifer materials are complexly related factors that may result in relatively long-term changes in ground-water quality. Specific influences of any one of these factors are difficult to determine.

Presentation of water-quality information in this report is designed to show the influences of predominant geochemical and geologic factors--water temperature and composition of aquifer materials. Pairs of figures are used to illustrate specific water-quality characteristics, one figure for cold water and one figure for warm and hot waters. Because many wells in the study area are open to more than one aquifer and mixing of ground waters from differing sources is common, major geologic units yielding water to each well in the study area are shown in figures 6a and 6b.

Proximity to the source of recharge may be important to the variability of ground-water quality. Precipitation is probably the least mineralized source of recharge to aquifers; in general, ground water near a precipitation recharge area has lower dissolved mineral concentrations than ground water farther downgradient. Recharge water from more localized sources of recharge, such as infiltration of irrigation water, septic-tank drain fields, or landfill leachates is of variable quality and may be highly mineralized.

The influence of man's activities on quality of recharge water may result in pronounced local changes in ground-water quality, sometimes over relatively short periods of time. Change in water quality due to man's activities may be difficult to determine in many instances because historic data needed to establish background water quality are not available.

Characteristic ground-water contaminants that may be associated with selected land- and water-use practices include the following (modified from Whitehead and Parliman, 1979):

Source	Characteristic contaminants
Agriculture and feedlots	Fertilizers (chiefly nitrogen, phosphorus, and potassium), pesticides, bacteria, trace elements, organic chemicals

EXPLANATION

Qaw	Alluvium
Qbf	Bruneau Formation of Idaho Group
QTiu	Idaho Group, undifferentiated
Tb	Banbury Basalt of Idaho Group
Tsv	Silicic Volcanics
●	Well, current data
o	Well, historic data
--	No lithologic data available
(hachured line)	Approximate boundary of valley lowlands
(solid line)	Study area boundary

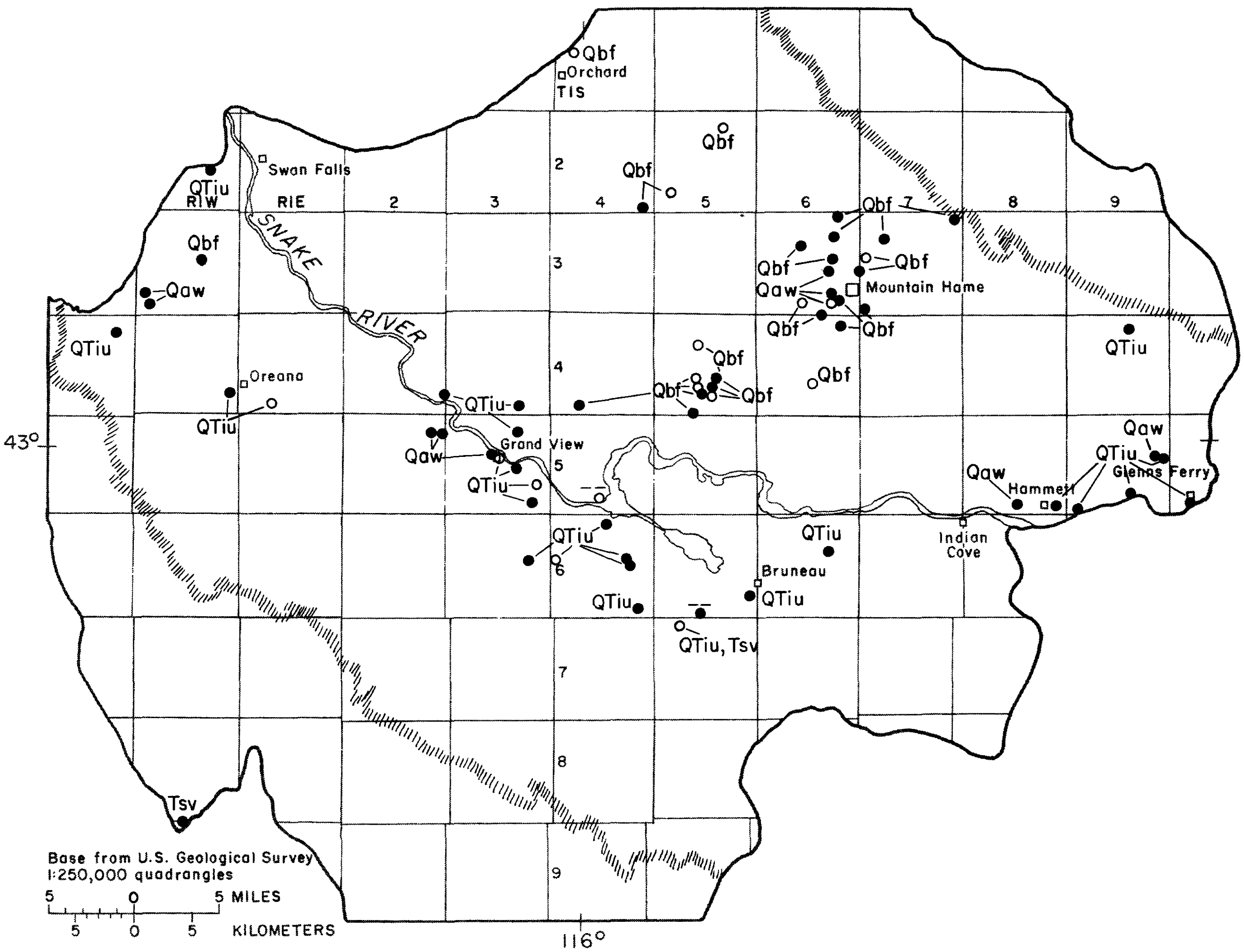


Figure 6a. -- Major geologic units yielding cold water to sampled wells.

EXPLANATION

Qaw	Alluvium
Qbf	Bruneau Formation of Idaho Group
QTiu	Idaho Group, undifferentiated
Tb	Banbury Basalt of Idaho Group
Tsv	Silicic Volcanics
•	Well, current data
o	Well, historic data
✳	Water temperature greater than 40°C
--	No lithologic data available
(hachured line)	Approximate boundary of valley lowlands
(solid line)	Study area boundary

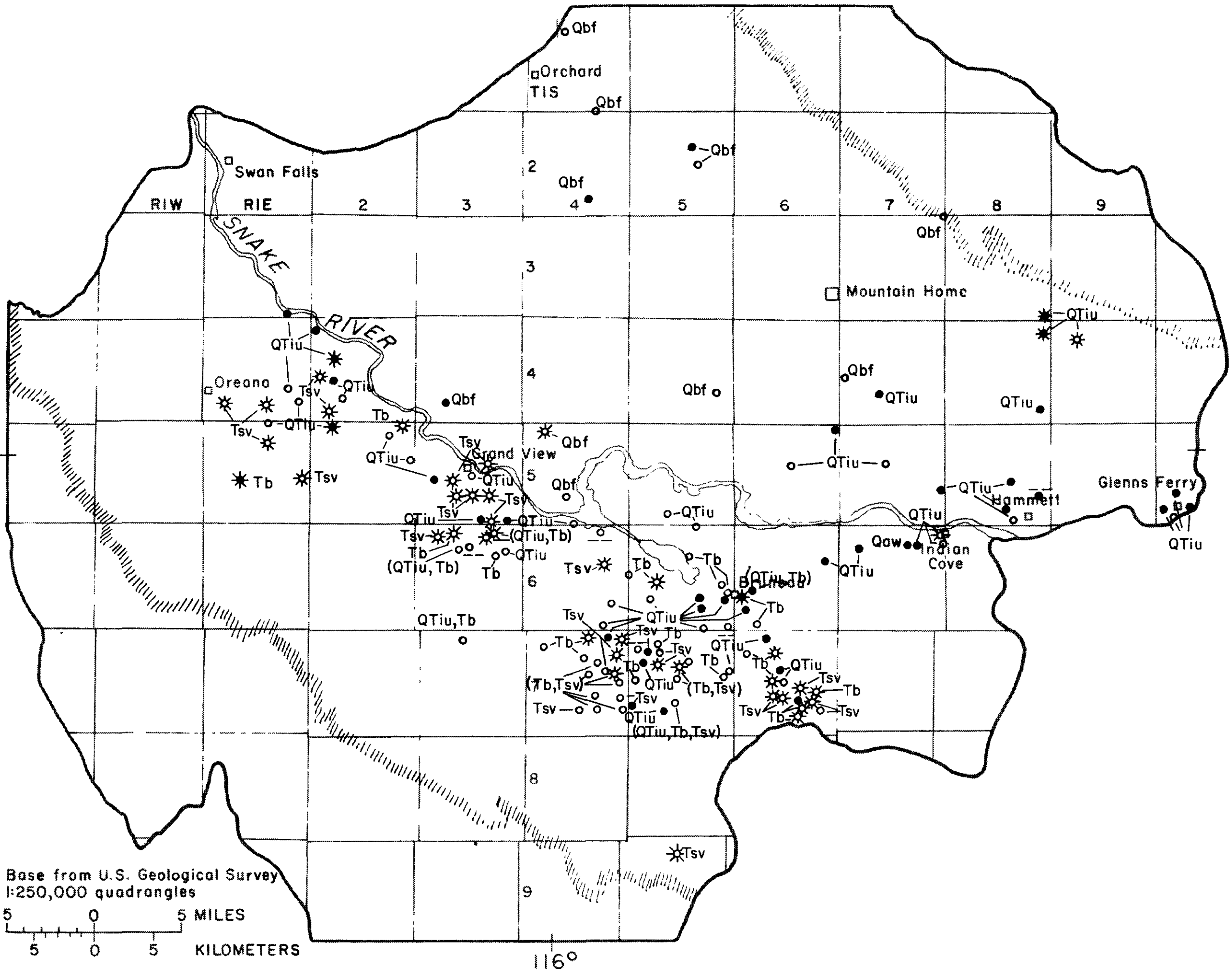


Figure 6b. -- Major geologic units yielding warm and hot water to sampled wells.

Landfills and dumps	Organic compounds, iron, manganese, carbon dioxide, methane, sulfate, phosphates, chloride, nitrogen compounds, trace elements, bacteria
Cesspools, septic-tank drain fields	Dissolved solids, chloride, sulfate, nitrogen compounds, phosphates (detergents), bacteria
Street runoff, commercial waste, irrigation drainage	Dissolved solids, sodium, bacteria, phosphates, bicarbonate, sulfate, chloride, nitrogen compounds, trace elements, pesticides, organic chemicals, radiochemicals

Figure 7 shows the location of selected land-use activities in the study area.

No attempt was made to sample specifically for point-source contamination of ground water in this study. Current sampling locations and water-quality characteristics analyzed for each location were chosen, in part, to show possible areal or nonpoint-source contamination.

Discussion of bacteria is not included in this report because few bacteria data are available for the study area.

Water Temperature

Chemical composition of ground water is directly affected by temperature of the water. Variations in ground-water temperature in the Swan Falls to Glenns Ferry area may be due to many factors, including (1) natural thermal gradients, (2) circulation of heated water from depth and mixing of cold and hot waters, and (3) seasonal changes in air temperature (affects only shallow ground water, less than 40 ft below land surface). Natural thermal gradient is the rate of increase of temperature with depth in the Earth's crust. In many areas of Idaho, the thermal gradient is about 1°C increase for every 100 ft below land surface. In the study area, thermal gradients commonly range from 1° to 2°C per 100 ft, but may be as high as 6.3°C per 100 ft (Young and Whitehead, 1975). High gradients are reported by Young and Mitchell (1973) near Bruneau and Grand View in Owyhee County and east of Mountain Home in Elmore County (Arney and others, 1982). These higher gradients are related to a broad heat source at relatively shallow depth, perhaps owing to a thinning of the Earth's upper crust in the area of the Snake River Plain (Young and Whitehead, 1975).

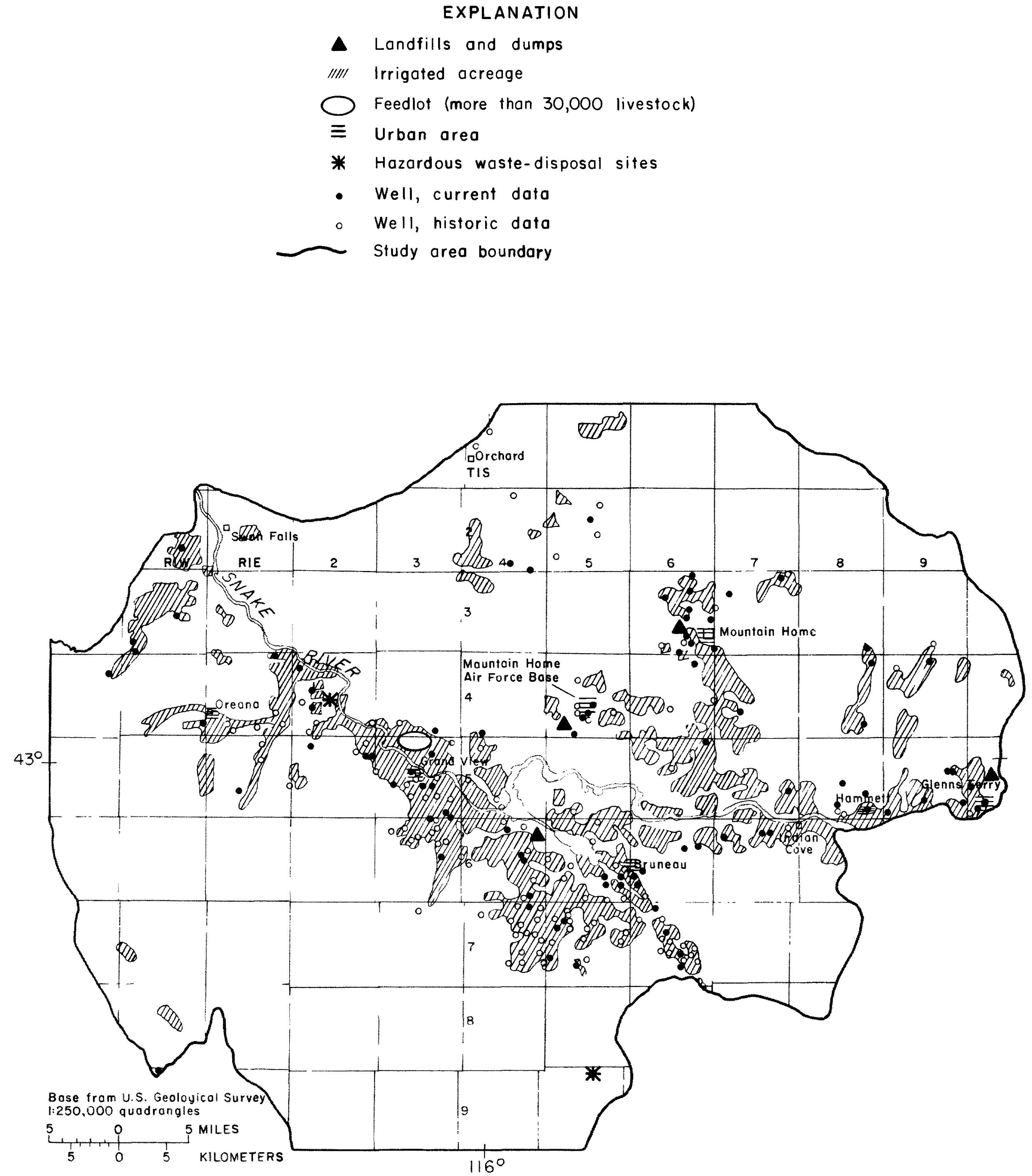


Figure 7. -- Selected land-use activities.

Anomalously hot water in primarily Idaho Group, Banbury Basalt, and silicic volcanics geologic units is probably the result of deep circulation and heating of water. Anomalously warm water from alluvium, Bruneau Formation, and Idaho Group units is probably the result of mixing of hot and cold water. Mixing occurs by leakage from artesian aquifers and partially cased well boreholes. Variations in water temperature in partially cased boreholes may vary seasonally in wells in the study area, especially wells used for irrigation. For purposes of this report, wells with varying water temperatures are classified as cold or warm water sites by averaging all available water temperatures for that site.

Chemical Composition of Ground Water

Generalized trends and diversity of the chemical composition of ground water in the study area are illustrated by means of trilinear diagrams (figs. 8a-8f). In trilinear diagrams, selected cations (positively charged ions--calcium, magnesium, and sodium plus potassium) and anions (negatively charged ions--bicarbonate plus carbonate, sulfate, and chloride) for each ground-water analysis are shown as a percentage of the total cations and anions, in milliequivalents per liter, plotted as single points on each side triangle. Cation and anion plots for each sample then are projected into the central diamond, or quadrilinear, field. Generalized composition of the water is determined by the location of projection intersections in the diamond field. Generalized chemical compositions of ground water in the study area are summarized in table 2.

Cold ground water in the study area contains predominantly calcium, magnesium, and bicarbonate plus carbonate ions. Hot water contains predominantly sodium, potassium, and bicarbonate plus carbonate ions. Warm water generally has an intermediate composition, probably owing to mixing. A large diversity of chemical composition in water from some geologic units, particularly aquifers in the Idaho Group, may be due to mixing of ground water and variability in composition of aquifer materials.

Areal distribution and trends in ground-water composition are shown by means of pattern diagrams (figs. 9a and 9b). To limit the number of diagrams, polygon-shaped pattern diagrams (Stiff, 1951) were constructed only for current ground-water analyses. These diagrams show approximate total ion concentration and the proportion of cations to anions for each sample. Pattern diagrams based on median constituent values for major water-yielding geologic units also are shown in each figure for comparison with samples from individual wells. Geologic units for each site are identified in figures 6a and 6b.

EXPLANATION

SYMBOL	GEOLOGIC UNIT
A	Alluvium
B	Bruneau Formation of Idaho Group
C	Idaho Group, undifferentiated
D	Banbury Basalt of Idaho Group
E	Silicic Volcanics
✱	More than one analysis (geologic unit not specified)

(This explanation applies to all trilinear diagrams in this series)

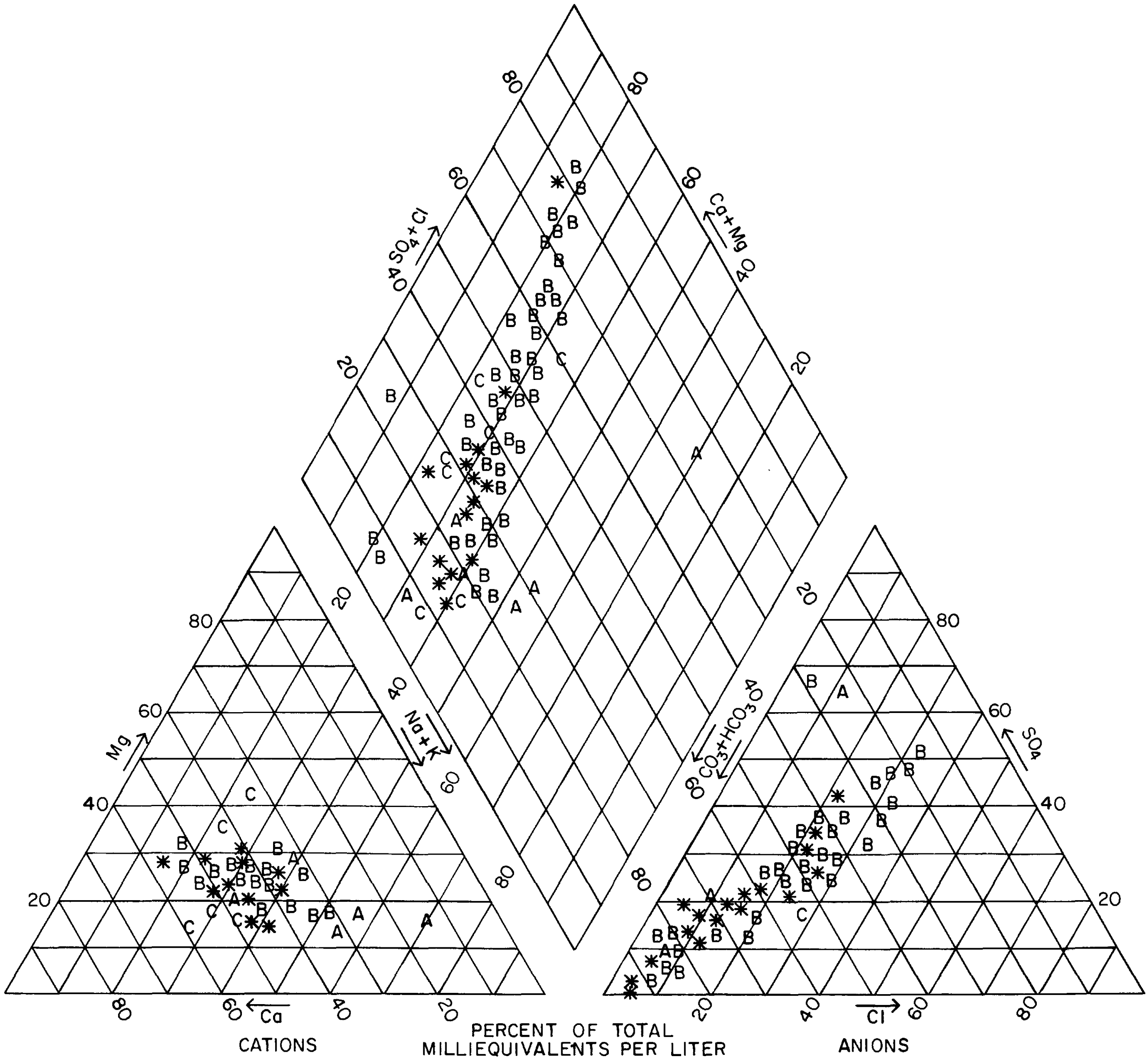


Figure 8a. -- Chemical analyses of cold ground water, Elmore County.

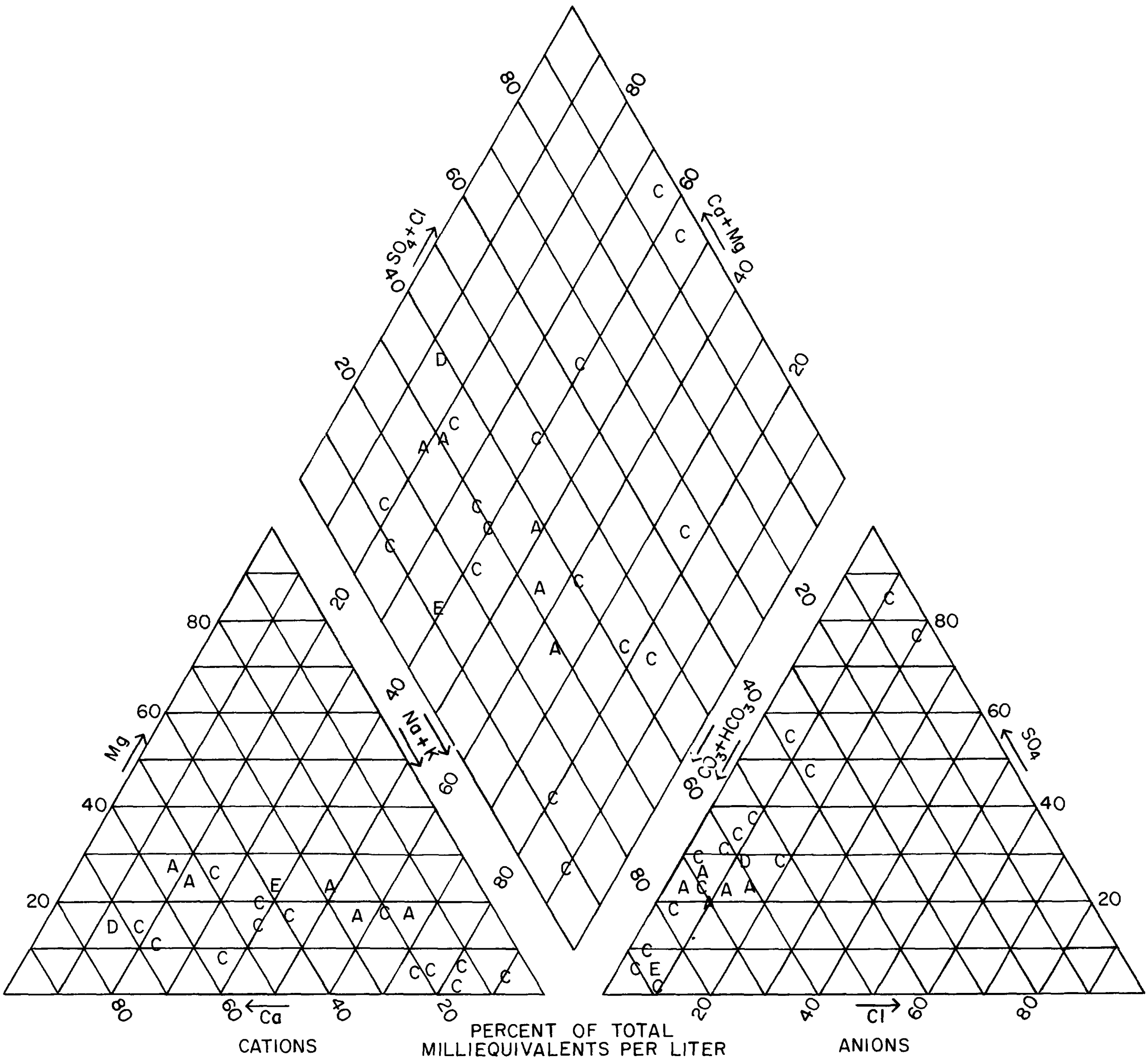


Figure 8b. -- Chemical analyses of cold ground water, Owyhee County.

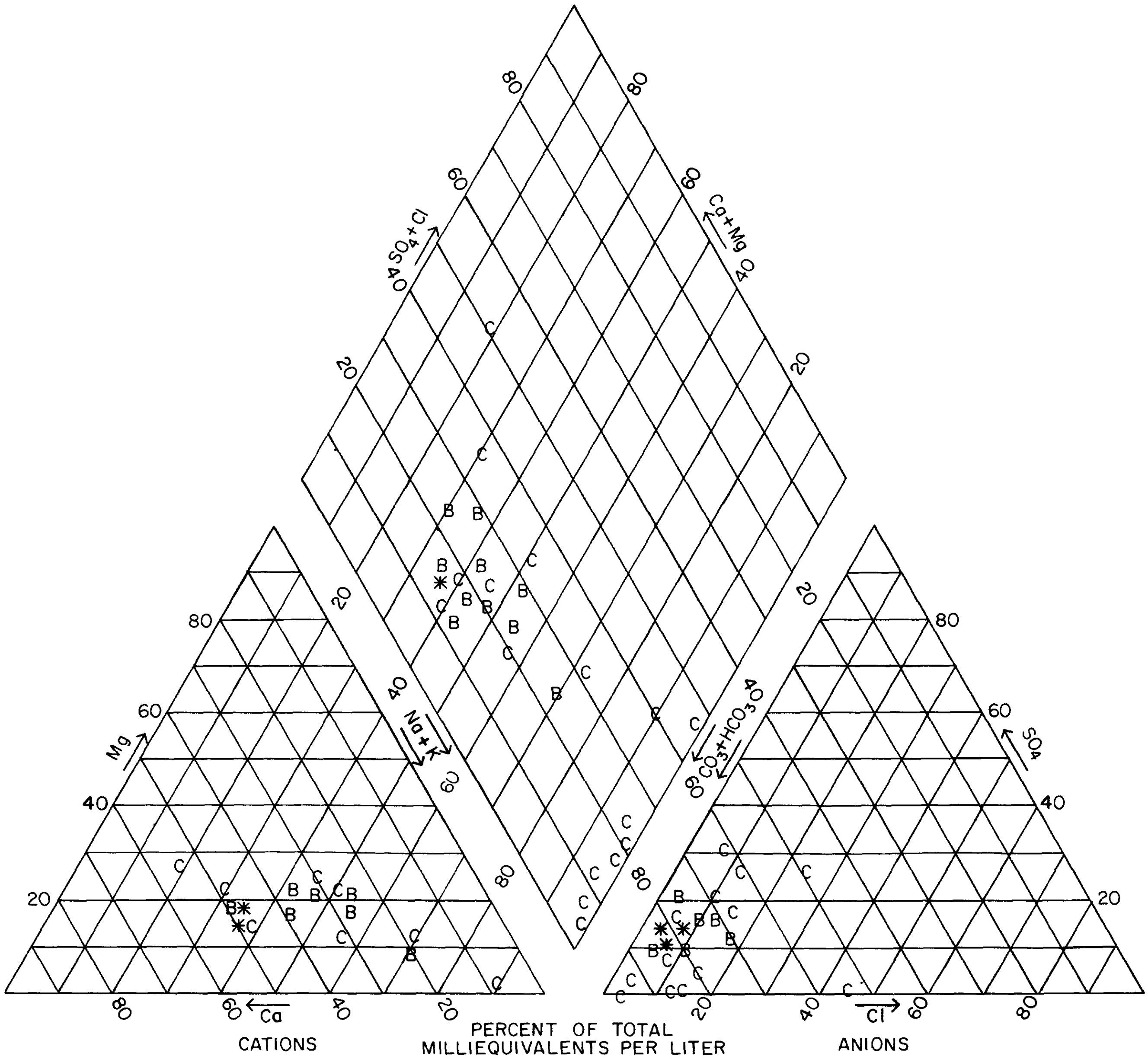


Figure 8c. -- Chemical analyses of warm ground water, Elmore County.

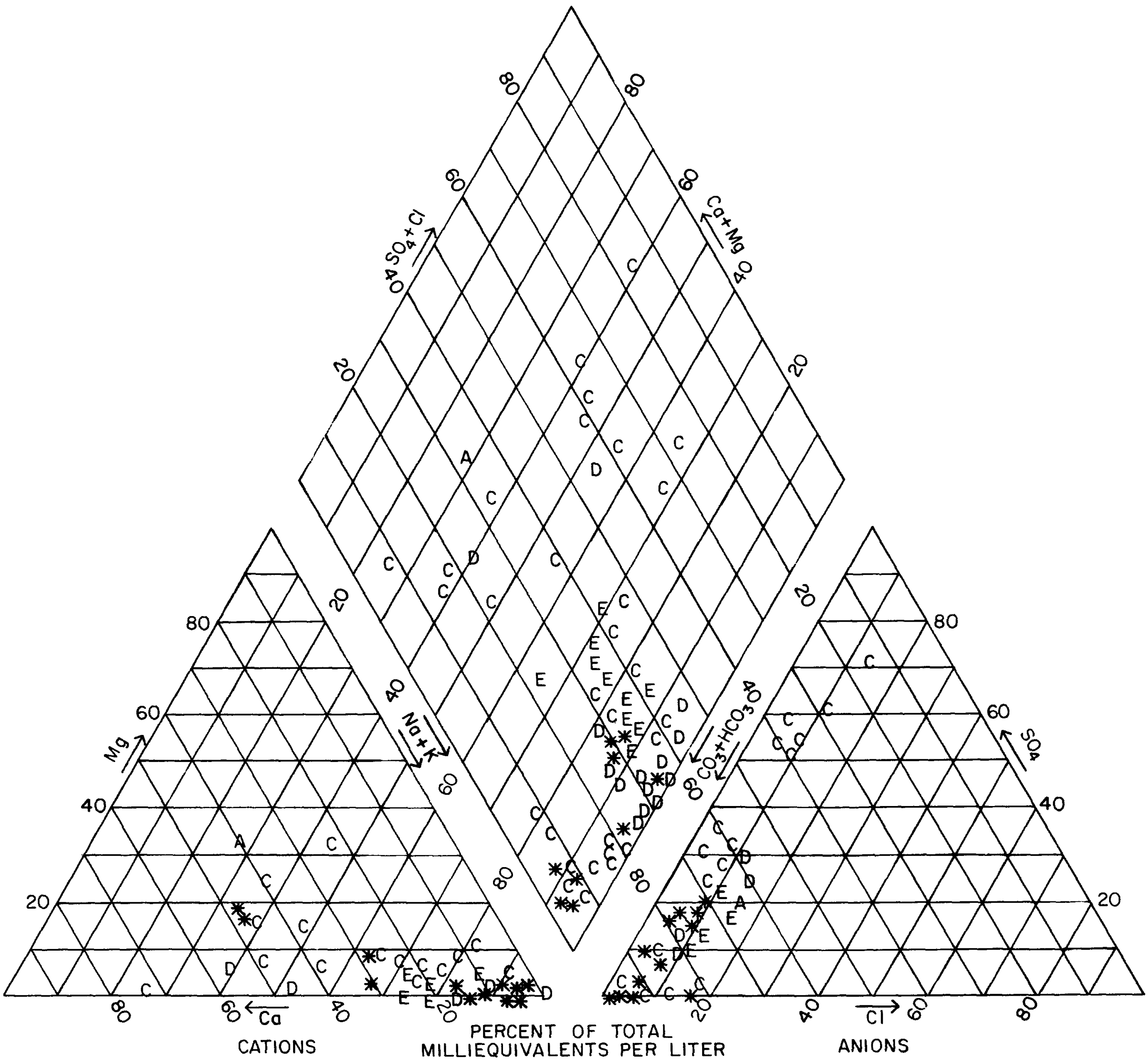


Figure 8d. -- Chemical analyses of warm ground water, Owyhee County.

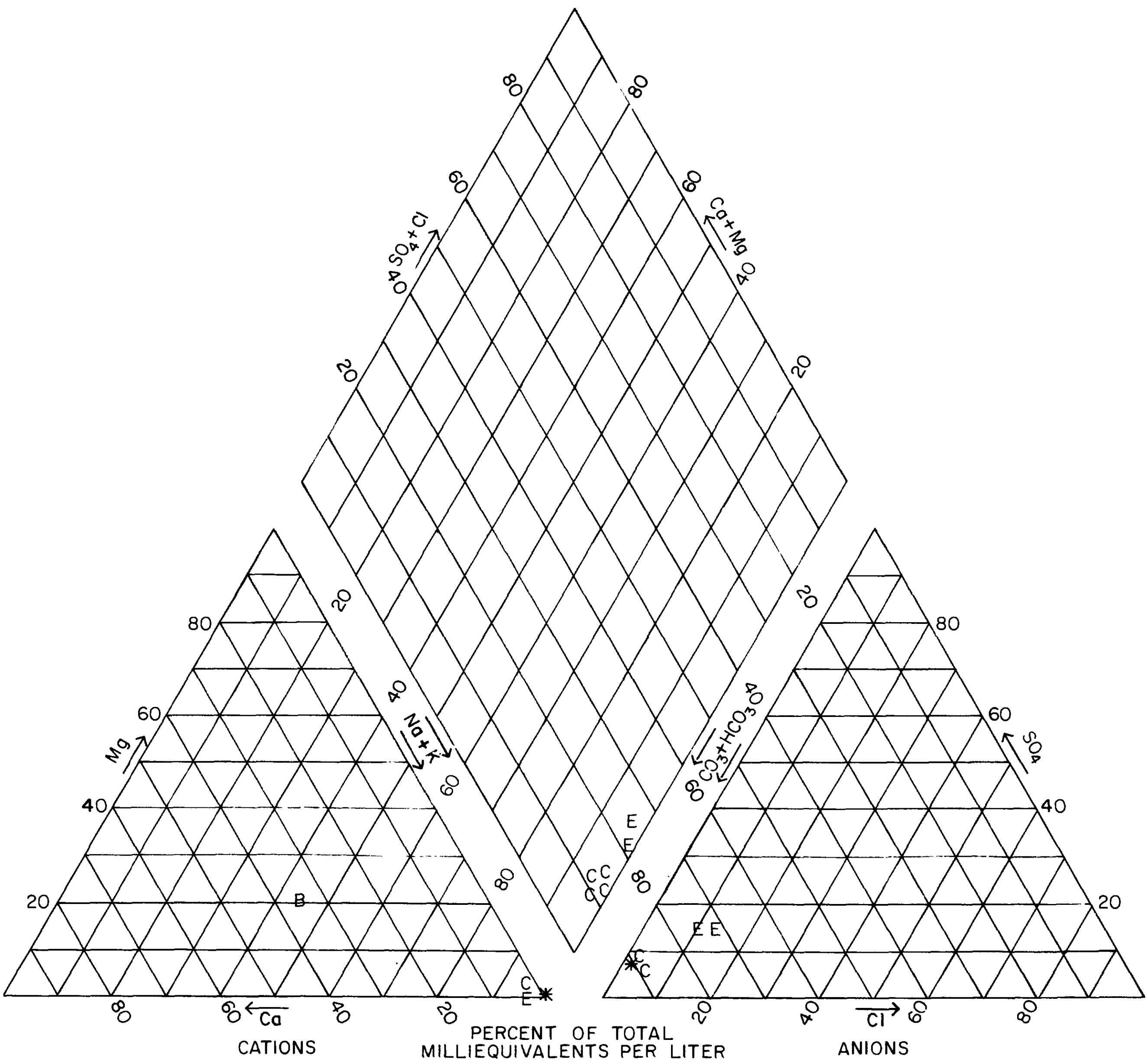


Figure 8e. -- Chemical analyses of hot ground water, Elmore County.

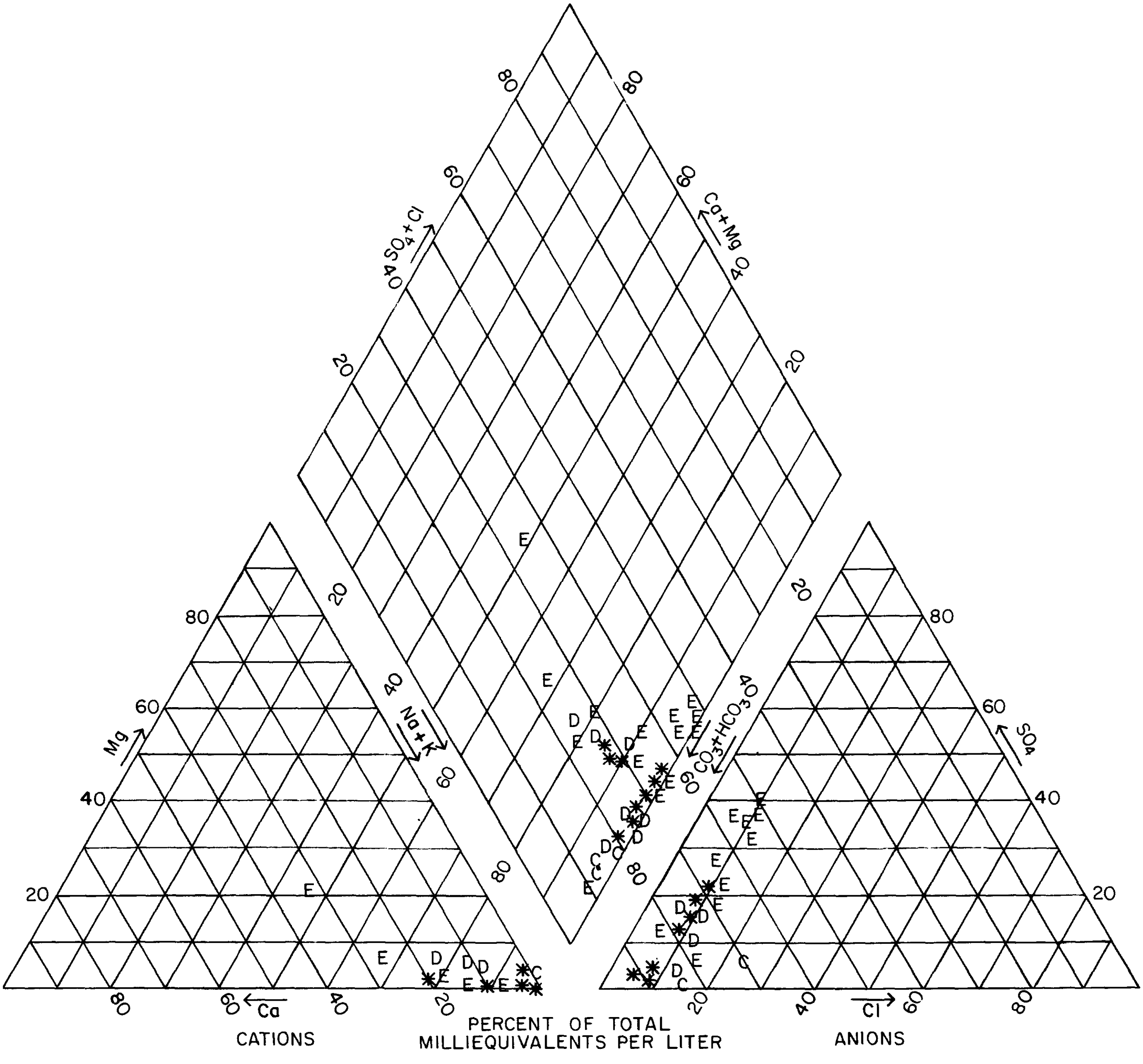


Figure 8f. -- Chemical analyses of hot ground water, Owyhee County.

Table 2.--Summary of the chemical composition of ground water

Area	Water temperature	Geologic unit(s)	Major cations	Major anions	Comments
Elmore	Cold	Alluvium, Bruneau Formation, Idaho Group	Calcium Magnesium	Bicarbonate Carbonate	Greatest diversity of composition in aquifers of Bruneau Formation of Idaho Group (undifferentiated)
		Bruneau Formation[1]	Calcium Magnesium	Sulfate Chloride	
	Warm	Idaho Group, Bruneau Formation	Calcium Magnesium	Bicarbonate Carbonate	Greatest diversity of composition in aquifers of Idaho Group (undifferentiated)
		Bruneau Formation[1] and Idaho Group[1]	Sodium Potassium	Bicarbonate Carbonate	
	Hot	Idaho Group, Silicic volcanics	Sodium Potassium	Bicarbonate Carbonate	
Owyhee	Cold	Alluvium, Idaho Group	Calcium Magnesium	Bicarbonate Carbonate	Greatest diversity of composition in aquifers of Idaho Group (undifferentiated)
		Alluvium[1] and Idaho Group[1]	Sodium Potassium	Bicarbonate Carbonate	
	Warm	Alluvium, Idaho Group, Banbury Basalt, Silicic volcanics	Sodium Potassium	Bicarbonate Carbonate	Greatest diversity of composition in aquifers of Idaho group (undifferentiated)
		Idaho Group[1] and Banbury Basalt[1]	Calcium Magnesium	Bicarbonate-Carbonate or Sulfate-Chloride	
	Hot	Idaho Group, Banbury Basalt, Silicic volcanics	Sodium Potassium	Bicarbonate Carbonate	Greatest diversity of composition in aquifers of silicic volcanics

[1] In some areas

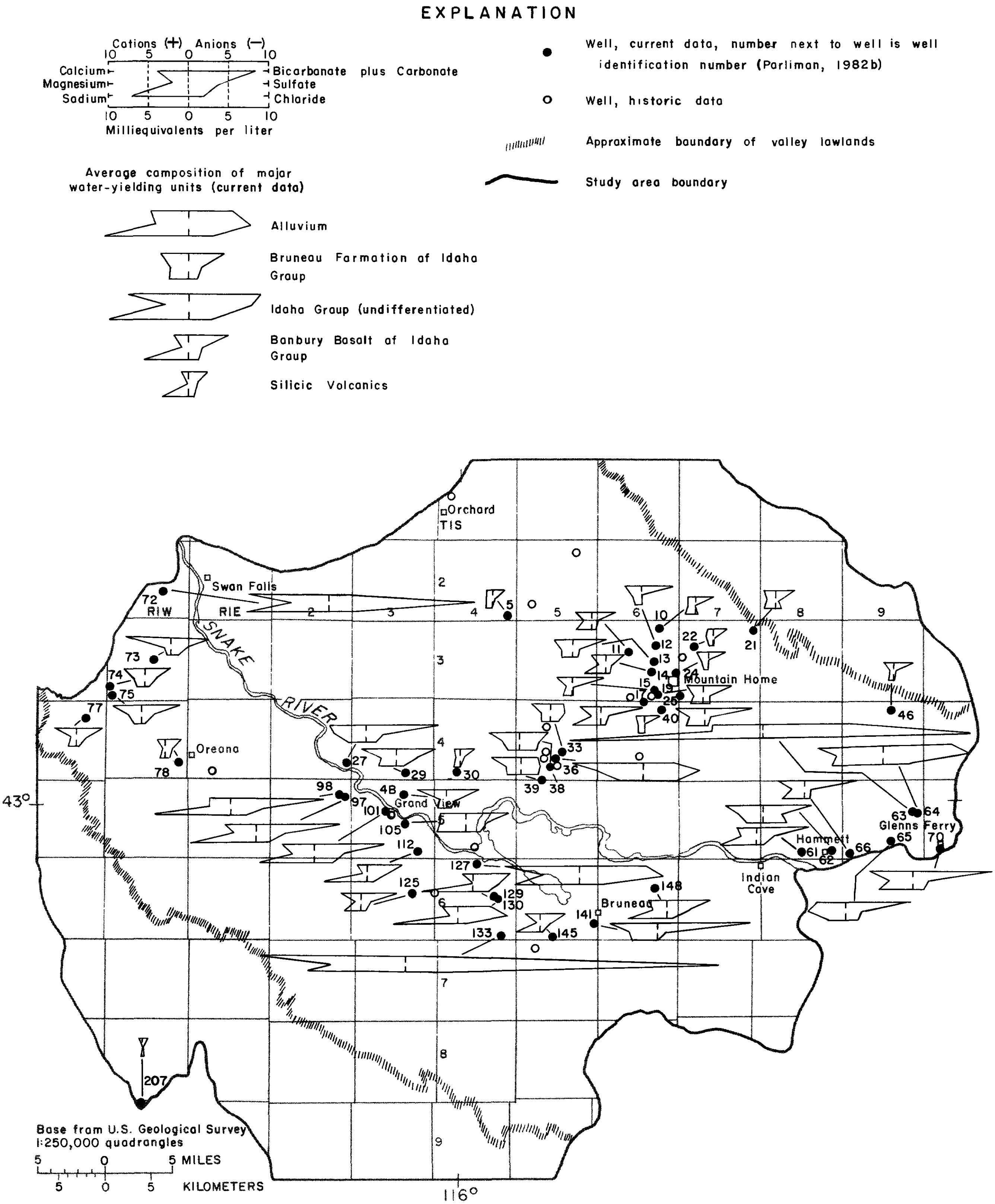


Figure 9a. -- Chemical character of cold ground water, current data.

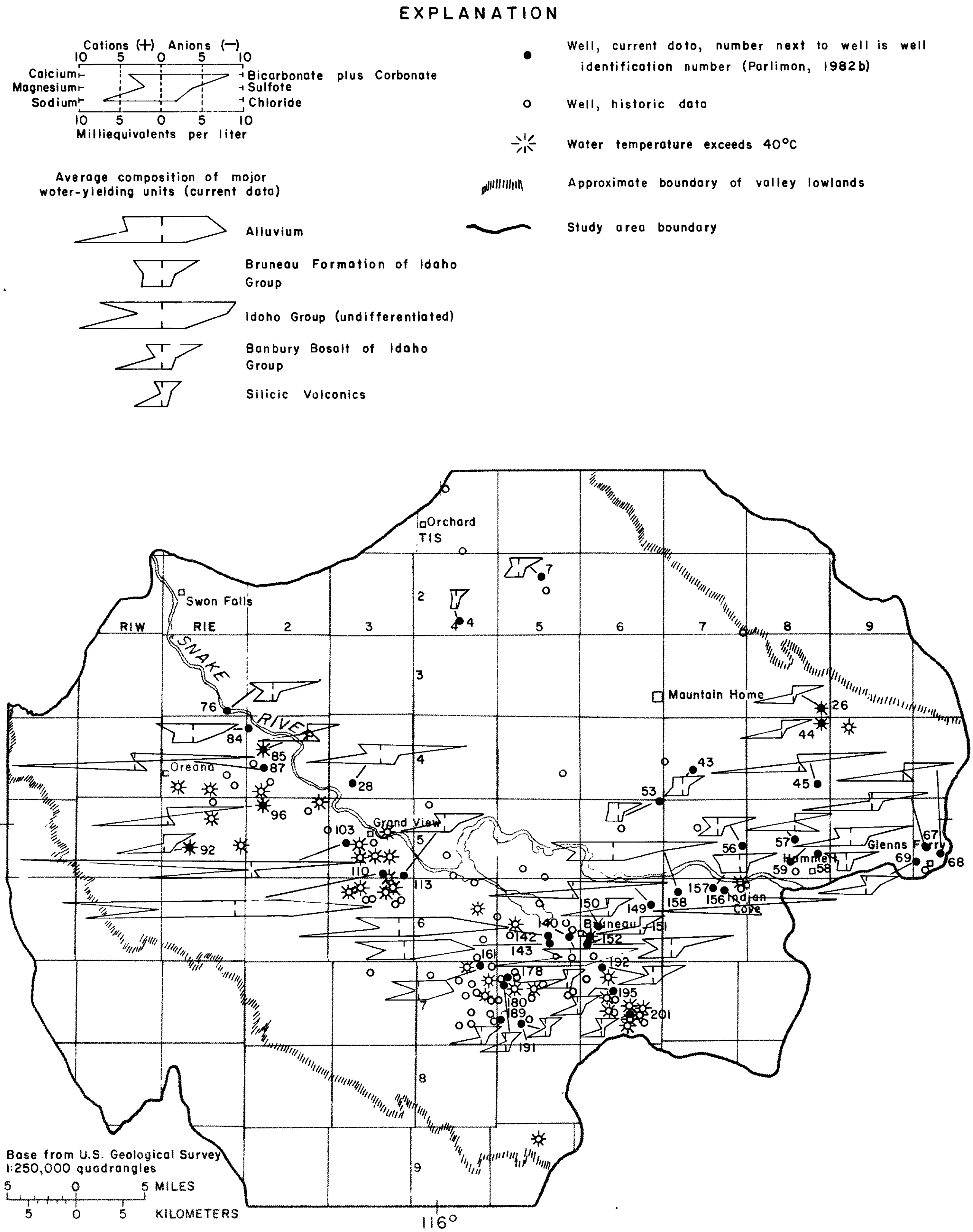


Figure 9b. -- Chemical character of thermal ground water, current data.

Suitability of Water For Use

Ground-water quality characteristics (chemical, physical, and bacterial) determine the suitability of water for use. Principal consumptive demands of ground water in the study area are for domestic, commercial, public supply, and agricultural (irrigation and livestock) uses. Drinking water regulations determined by the U.S. Environmental Protection Agency (1977a and 1977b, hereafter referred to as EPA), describe legally established mandatory (primary) and recommended (secondary) limits for chemical constituents and physical properties for public water supplies. Local natural conditions, esthetic or economic considerations, and resource-protection considerations may result in variations of regulations in different areas. Although Federal drinking water regulations legally apply only to public water supplies, regulation limits provide a comparative base in water-quality discussion for all water uses.

In contrast to mandatory public drinking water regulations, water-quality criteria designate maximum levels of water-quality characteristics that, when not exceeded, will not harm water users or impair water for use. Criteria for the protection of aquatic life and domestic water supplies are determined by EPA (1976). Potentially harmful effects that contaminants in drinking water may have on human health are presented by EPA (1977c). Criteria for public and domestic supplies, fish and wildlife, recreation, agriculture, and industrial (commercial) uses are established by National Academy of Sciences, National Academy of Engineering (1973, hereafter referred to as NASNAE). Criteria for all water uses often are variable, owing in part to differing animal and plant sensitivities, industrial process tolerances, or land- and water-management practices.

Source and significance of selected water-quality characteristics commonly important to domestic, commercial, public supply, and agricultural water users are presented in table 3. Water-quality regulations or criteria for these characteristics are listed in table 4. Range of concentrations of current and historic ground-water data in the study area also is listed in table 4 for reference. Some aspects of quality of water for public and domestic supply or agricultural uses are discussed in more detail later in this report.

Where concentrations of chemical constituents exceed regulation limits or criteria levels or are esthetically or economically undesirable, it may be possible to reduce, remove, or control concentrations through appropriate water-treatment processes. Some methods for treating water are discussed in Nordell (1961).

Table 3.--Source and significance of selected water-quality characteristics

Characteristic	Source	Significance
Temperature (°C)	Variations may be due to deeper water circulation, thermal activity, seasonal air temperature variation, or disposal of surface waste water.	Affects the usefulness of water for many purposes. Temperature may affect palatability of water, solubility of chemical constituents, and coagulation, sedimentation, filtration, or chlorination processes.
pH	Hydrogen-ion concentration.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increased alkalinity; values lower than 7.0 indicate increased acidity. Corrosiveness of water generally increases with decreasing pH, but excessively alkaline water also may be corrosive.
Hardness as calcium carbonate ($CaCO_3$)	In most waters, nearly all hardness is due to calcium and magnesium.	Soap-consuming capacity of a water. Forms white scale on teakettles and plumbing and rings in bathtubs. Although hardness is less of a factor with synthetic detergents than with soap, it is sometimes desirable to soften hard water for esthetic as well as economic reasons.
Alkalinity as calcium carbonate ($CaCO_3$)	Nearly all produced by dissolved bicarbonate and carbonate.	Measure of water's capacity to neutralize acids. May produce objectionable taste.
Bicarbonate (HCO_3), Carbonate (CO_3), Carbon dioxide (CO_2)	Action of carbon dioxide in water on carbonate-cementing material and rocks, such as limestone, dolomite, and travertine.	Produces alkalinity. When heated in the presence of calcium and magnesium, can form scale in pipes and release corrosive carbon-dioxide gas. Aids in coagulation for the removal of suspended matter from water.
Dissolved solids (calculated sum)	Mineral constituents dissolved from rocks and soils.	Water containing more than 1,000 mg/L of dissolved solids is unsuitable for many purposes.
Silica (SiO_2)	Dissolved from practically all rocks and soils.	Together with calcium and magnesium, silica forms a low heat-conducting, hard, glassy scale in boilers and turbines. Silica inhibits deterioration of zeolite-type water softeners and corrosion of iron pipes by soft (0-75 mg/L $CaCO_3$) water.
Calcium (Ca), Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum.	Causes most of the hardness in water. Calcium and magnesium combine with bicarbonate, carbonate, sulfate, and silica to form heat-retarding, pipe-clogging scale in boilers and in other heat-exchange equipment. A high concentration of magnesium has a laxative effect, especially on new users of the supply.
Sodium (Na), Potassium (K)	Dissolved from practically all rocks and soils, especially feldspars, clay minerals, and evaporites. Present in sewage and commercial fertilizers.	More than 50 mg/L sodium and potassium in the presence of suspended matter causes foam in boilers, which accelerates scale formation and corrosion. Dissolved sodium concentrations may be important to sodium-restricted diets.
Fluoride (F)	Dissolved in small quantities from most rocks and soils. Added to many public supplies.	Fluoride concentrations in limited amounts have beneficial effects on the structure and resistance to decay of children's teeth. Excessive concentrations produce objectionable dental fluorosis (tooth mottling). Optimum recommended limits for public water supplies range from 1.4 to 2.4 mg/L and are based on annual average maximum daily air temperatures.

Table 3.--Source and significance of selected water-quality characteristics--Continued

Characteristic	Source	Significance
Nitrite (NO_2) plus nitrate (NO_3) as nitrogen (N)	Atmosphere, legumes, plant debris, animal excrement, nitrogenous fertilizer in soil, and sewage.	Small amounts help reduce cracking of high-pressure boiler steel. Encourages growth of algae and other organisms that produce undesirable taste and odors. Concentrations in excess of 10 mg/L are suspected as cause of methemoglobinemia (blue-baby disease) in infants.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, sulfides, and other sulfur compounds. May be derived from industrial wastes, both liquid and atmospheric.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate, in combination with other ions, imparts bitter taste to water. Some calcium sulfate is considered beneficial in brewing processes.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and industrial wastes.	A salty taste can be detected when concentrations exceed 100 mg/L. In large quantities, chloride increases the corrosiveness of water. Present available removal methods not generally economical for most uses.
Phosphate (P, total)	Dissolved from many rocks and minerals, particularly apatite. Phosphate fertilizers and sodium phosphate in detergent (component of sewage) may be pollution sources of phosphorus.	One of the major nutrients required for plant nutrition and is essential for life. May indicate organic contamination.
Sodium-adsorption-ratio (SAR)	Dissolved calcium, magnesium and sodium from rocks and soils.	Estimates the degree to which sodium in irrigation water tends to enter into cation-exchange reactions in soil. High values indicate that sodium replaces adsorbed calcium and magnesium. This replacement damages soil structure and decreases hydraulic conductivity.
Specific conductance	An indicator of dissolved mineral content of water.	Indicator of dissolved mineral content. A measure of the capacity of the water to conduct a current of electricity, and varies with the concentration and degree of ionization of the different minerals in solution; the more minerals, the larger the specific conductance.

Table 4.--Regulations or criteria for use of selected water-quality characteristics (Chemical constituents reported in milligrams per liter)
[--, no data available; < , less than]

Water-quality characteristic	Public drinking water limit[1]	Commercial food-canning requirements[2]	Agricultural levels[3]		Range of values	
			Livestock	Irrigation[4]	Current data	Historic data
Temperature (°C)	--	--	--	--	2.5-72.0	12.0-84.5
pH	6.5-8.5	6.5-8.5	--	4.5-9.0	6.5-10.2	6.9-10.0
Sodium adsorption ratio (SAR)	--	--	--	see text p. 58	0.4-26	0.2-35
Hardness ($CaCO_3$)	--	250	--	--	3-1,500	0-490
Alkalinity ($CaCO_3$)	--	--	--	--	0-640	48-830
Dissolved solids	500	500	--	500-1,000	60-2,320	102-1,080
Silica (SiO_2)	--	50	--	--	26-110	29-140
Calcium (Ca)	--	100	[5]1,000	--	0.8-610	<0.1-140
Magnesium (Mg)	--	--	--	--	0-84	<0.1-66
Sodium (Na)	--	--	--	--	5-550	7-330
Potassium (K)	--	--	--	--	0.7-38	0.6-81
Fluoride (F)	[6]1.8	--	2	1,000	0.1-28	<0.1-30
Nitrite plus nitrate (N)	10	10	10	--	0-27	<0.1-5.8
Sulfate (SO_4)	250	250	[5]500	[5]200	0.5-1,400	2-450
Chloride (Cl)	250	250	[5]1,500	[5]100	2-160	1-79
Phosphorus (P)	--	--	--	--	0-0.23	<0.01-0.25

1/ U.S. Environmental Protection Agency (1977a and 1977b)
2/ National Academy of Sciences, National Academy of Engineering (1972)
3/ U.S. Environmental Protection Agency (1976) and National Academy of Sciences, National Academy of Engineering (1972)
4/ Varies with crop tolerances, soil conditions, and land management practices
5/ McKee and Wolf (1963)
6/ Based on an annual average maximum daily air temperature of 19.5°C (67°F)

Comparison of Water-Quality Data

Median and range values (tables 5a and 5b) are used in this report to summarize and compare large numbers of ground-water quality data. No median values are calculated for very small data populations (fewer than four analyses). Data populations are shown in table 5c for reference.

Public and Domestic Water Supplies

Data summaries shown in tables 4 and 5 indicate that ground water locally has water-quality characteristics that could restrict its use. Although no public water-supply limits have been established for hardness or alkalinity, very hard water, very soft water, or high concentrations of alkalinity may be esthetically or economically restrictive or may be a human health concern. Dissolved solids, pH, nitrite plus nitrate, dissolved sulfate, fluoride, arsenic, iron, manganese, and selenium exceed EPA public drinking water limits in several samples and are anomalously high in several other samples. Dissolved chloride, calcium, magnesium, sodium, potassium, and total phosphorus concentrations are anomalously high in several water samples.

Figures presented in this section show selected constituent concentrations for all current data but include only historic data that exceed specified levels or limits. Current data are emphasized because they are representative of the water quality in all major aquifers in the study area sampled over a relatively short period of time.

Dissolved Solids and Major Cations and Anions

DS (dissolved solids) concentrations represent the sum of dissolved mineral constituents calculated for each water sample. DS concentration is calculated as the sum of major cations (calcium, magnesium, sodium, and potassium) and anions (carbonate, bicarbonate, fluoride, nitrate, sulfate, and chloride), plus silica. The most common natural source of DS in ground water is solution of minerals from soils and rocks. Locally, concentrations of DS may be caused by variations in aquifer composition or may indicate possible ground-water contamination. DS concentrations in ground water may be increased by infiltration of irrigation-return flow, waste-water disposal, or leachates from solid waste. A high DS concentration may have an influence on the acceptability of water for use and often is associated with the presence of excessive cation or anion concentrations that would be esthetically or otherwise objectionable to the consumer.

Table 5a.--Median values calculated for selected water-quality characteristics, current and historic data

(Values are in milligrams per liter, unless otherwise specified)

[<, less than; --, no data available; Qaw, alluvium; Qbf, Bruneau Formation of Idaho Group; QTiu, Idaho Group, undifferentiated; Tb, Banbury Basalt of Idaho Group; Tsv, Silicic volcanics]

Ground-water temperature	County/ Geologic unit	Depth of well, total (ft below land surface)	Temper- ature (°C)	pH	Hard- ness (as $CaCO_3$)	Alka- linity ($CaCO_3$)	Bicar- bonate (HCO_3)	Carbon- ate (CO_3)	Dissolved solids (cal- culated sum)	DISSOLVED Silica (SiO_2)	Cal- cium (Ca)	Mag- nesium (Mg)	Sodium (Na)	Potas- sium (K)	Fluo- ride (F)	Nitrite plus nitrate (as N)	Sulfate (as SO_4)	Chloride (Cl)	Phos- phorus, total (as P)	Sodium adsorp- tion ratio (SAR)	Specific conduct- ance (µmhos)
COLD	Elmore	422	14.5	8.0	82	61	74	0	161	39	22	6	14	4	0.2	1.2	21	10	0.04	0.7	238
	Owyhee	293	16.5	7.5	140	180	220	0	454	54	43	10	67	9	.7	.3	68	18	.04	2.4	672
WARM	Elmore	565	22.0	8.0	73	110	140	0	217	47	17	5	31	5	0.8	0.6	15	10	0.03	1.2	310
	Owyhee	1,055	32.5	8.0	27	120	140	0	341	88	10	.7	86	8	7.3	<.1	24	12	.03	5.6	447
HOT	Elmore	1,175	58.5	9.4	4	130	73	48	295	85	2	0.1	87	0.8	18	<0.1	13	4	0.03	20	382
	Owyhee	2,009	50.5	9.2	5	120	78	38	312	91	2	.1	94	3	13.5	<.1	23	12	.02	19	422
COLD	Elmore/Qaw	19.5	12.5	7.0	150	200	240	0	215	49	37	11	42	6	0.4	0.7	24	13	0.07	1.9	508
	Owyhee/Qaw	50	16.5	7.5	210	320	390	0	647	46	56	22	110	8	.7	2	110	32	.08	2.9	943
	Elmore/Qbf	422	14.5	8.0	72	60	72	0	146	39	20	6	13	4	.2	1.6	16	8	.04	.7	213
	Owyhee/Qbf	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Elmore/QTiu	130	17.0	7.6	300	260	320	0	449	63	64	24	35	10	.8	.9	69	27	.03	.9	764
	Owyhee/QTiu	396	17.0	7.7	120	180	220	0	454	58	41	6	79	10	.8	.1	87	17	.03	2.5	698
WARM	Owyhee/Qaw	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Elmore/Qbf	450	22.0	8.0	71	98	120	0	195	48	17	7	18	6	0.6	1.1	19	8	0.03	1	273
	Elmore/QTiu	1,766	22.0	8.1	74	150	190	0	350	46	17	5	42	3	.9	<.1	12	12	.03	1.8	515
	Owyhee/QTiu	906	25.5	7.8	54	300	370	0	656	88	18	2	170	11	2	<.1	24	18	.03	6.8	898
	Owyhee/Tb	1,310	34.0	8.7	11	120	130	16	326	88	4	0.1	93	6	12	<.1	28	11	.03	11.4	433
	Owyhee/Tsv	1,063	36.5	8.4	22	82	100	0	247	91	8	.3	51	8	10	.6	22	10	.04	4.8	290
HOT	Elmore/QTiu	888	60.0	9.1	3	140	74	48	296	86	0.9	0.2	87	0.8	18	<0.1	14	4	0.03	23	376
	Owyhee/QTiu	2,009	41.5	9.3	15	310	220	74	492	91	4	.8	150	7	8.7	<.1	8	33	.04	20.5	667
	Owyhee/Tb	1,001	49.5	9.2	5	130	87	37	319	84	2	.1	97	3	15	<.1	27	11	.02	18.5	433
	Elmore/Tsv	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Owyhee/Tsv	2,555	60.0	9.2	4	110	73	38	304	94	2	.1	92	1	12	<.1	24	12	.02	21	402

Table 5b.—Range of values[1] for selected water-quality characteristics, current and historic data

(Values are in milligrams per liter, unless otherwise specified)

[<, less than; Qaw, alluvium; Qbf, Bruneau Formation of Idaho Group; QTiu, Idaho Group, undifferentiated; Tb, Banbury Basalt of Idaho Group; Tsv, Silicic volcanics]

Ground-water temperature	County/ Geologic unit	Depth of well, total (ft below land surface)	Temperature (°C)	pH	Hardness (as $CaCO_3$)	Alkalinity ($CaCO_3$)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved solids (calculated sum)	DISSOLVED: Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrite plus nitrate (as N)	Sulfate (as SO_4)	Chloride (Cl)	Phosphorus, total (as P)	Sodium adsorption ratio (SAR)	Specific conductance (µmhos)
COLD	Elmore	14-610	9.5-21.0	6.7-8.6	36-520	48-470	58-570	0-7	102-2,320	28-70	8-140	3-66	6-550	2-28	<0.1-2.9	<0.1-27	3-1,100	2-140	0.01-0.20	0.2-10	112-3,170
	Owyhee	20-1,620	14.5-21.0	6.5-8.9	58-1,100	50-730	61-890	0	169-2,316	28-130	17-310	2-84	8-280	3-38	0.1-2.8	<0.1-9	5.4-1,400	2-140	0.01-0.23	0.4-14	194-2,890
WARM	Elmore	60-1,910	15.5-38.0	7.5-10.2	6-220	0-660	0-800	0-94	60-863	26-89	2-58	<0.1-18	9-320	0.8-24	0.2-13	<0.1-2.8	2-81	2-88	0-0.09	0.6-27	128-1,340
	Owyhee	41-2,960	15.0-40.0	7.0-9.4	6-1,500	77-830	59-1,010	0-120	225-1,473	32-140	2-350	<0.1-77	25-330	2-31	0.3-30	<0.1-24	0.5-1,300	7-160	<0-0.25	1-26	267-3,180
HOT	Elmore	600-2,300	52.0-68.0	8.7-9.6	2-6	120-140	0-81	41-77	280-298	81-88	0.8-2.5	<0.1-0.2	82-91	0.7-1	16-24	<0.1	7-14	3-18	0.01-0.05	16-24	360-445
	Owyhee	177-3,600	33.5-84.5	7.2-10.0	0-250	80-500	0-610	0-84	228-719	59-140	0.1-64	0-23	40-260	0.6-10	4-30	<0.1-0.7	3-74	1-62	0-0.23	2.5-35	261-1,240
COLD	Elmore/Qaw	14-60	10.5-17.5	6.9-7.9	84-520	120-470	150-570	0	168-2,320	28-56	23-100	6-66	17-550	6-28	0.1-2.9	0.3-6.7	4.9-1,100	4-140	0.04-0.1	0.7-10	276-3,170
	Owyhee/Qaw	20-80	14.5-18.5	6.5-7.6	150-270	130-400	160-490	0	243-705	38-54	41-64	11-27	15-160	5-13	0.3-1.2	0.3-6.3	48-130	7-55	0.04-0.14	0.5-4.9	377-1,110
	Elmore/Qbf	73-610	9.5-21.0	6.7-8.6	36-510	48-200	58-250	0-7	102-584	30-63	8-140	3-46	6-55	2-9	<0.1-2	0.6-27	3-240	2-110	0.01-0.2	0.2-2	112-1,200
	Owyhee/Qbf	250	16.0	7.5	250	180	220	0	348	28	84	10	14	3	0.2	3.3	77	21	0.04	0.4	590
	Elmore/QTiu	51-560	15.5-18.0	7.2-8.0	69-500	90-340	110-420	0	168-947	36-70	21-120	4-49	14-98	4-21	0.1-1.1	<0.1-4.6	4-360	2-72	0.01-0.1	0.7-1.9	204-1,350
	Owyhee/QTiu	55-1,620	15.5-21.0	6.9-8.9	58-1,100	50-730	61-890	0	169-2,316	36-130	17-310	2-84	8-280	3-38	0.1-28	<0.1-9	5.4-1,400	3-140	0.01-0.23	0.4-14	194-2,890
WARM	Owyhee/Qaw	41	20.5	8.6	200	180	200	12	323	32	46	21	32	5	0.7	1	51	26	0.04	1	515
	Elmore/Qbf	60-1,100	20.0-26.0	7.5-8.4	38-150	59-380	72-470	0-1	60-225	37-65	9-40	3-13	9-150	3-8	0.2-1	0.4-2.6	6-81	2-27	0.01-0.09	0.6-5.3	128-962
	Elmore/QTiu	200-1,910	15.5-38.0	7.5-10.2	6-220	0-660	0-800	0-94	152-863	26-89	2-58	<0.1-18	18-320	0.8-24	0.2-13	<0.1-2.8	2-78	5-88	0-0.09	0.6-27	221-1,340
	Owyhee/QTiu	100-2,460	15.0-38.0	7.0-9.1	12-1,500	77-830	90-1,010	0-39	232-1,473	40-140	3-350	<0.1-77	33-330	6-31	0.3-19	<0.1-24	0.5-1,300	7-160	0-0.25	1.2-26	267-3,180
	Owyhee/Tb	517-2,960	25.0-40.0	7.4-9.4	6-140	78-300	59-210	0-120	225-429	70-140	2-51	<0.1-3	31-120	2-15	0.8-30	<0.1-0.6	16-130	7-20	0.01-0.12	1.1-22	271-520
	Owyhee/Tsv	417-1,700	23.0-39.5	7.0-9.0	16-58	79-110	82-130	0-10	228-319	70-100	5-22	<0.1-5	25-62	6-10	3-16	0.2-1.9	15-54	7-14	<0.01-0.06	2.2-6.2	271-364
HOT	Elmore/QTiu	600-1,440	52.0-68.0	8.7-9.4	2-4	130-140	73-81	41-50	280-295	85-88	0.8-2	<0.1-0.2	82-89	0.7-1	16-17	<0.1	13-14	3-5	0.01-0.04	20-24	360-389
	Owyhee/QTiu	1,000-2,600	40.0-58.0	8.0-9.4	4-20	150-500	37-610	0-77	357-719	73-110	2-7	0-1	100-260	2-9	4-21	<0.1	3-12	19-62	0.01-0.05	16-25	477-1,240
	Owyhee/Tb	350-3,050	40.5-72.0	7.2-9.8	3-35	81-190	46-200	0-74	231-400	59-118	1-12	<0.1-1	46-120	0.6-7	5.4-28	<0.1-0.6	3.7-46	9-19	<0.01-0.06	4-30	272-598
	Elmore/Tsv	2,300	58.5	9.6	4, 6	120, 130	0, 66	42, 77	295, 298	81, 82	2.5, 2.4	<0.1, 0.1	85, 91	0.7, 0.8	23, 24	<0.1, <0.1	7, 10	17, 18	<0.01-0.05	16, 19	419, 445
	Owyhee/Tsv	177-3,600	33.5-84.5	7.5-10.0	0-250	80-320	0-390	0-84	228-493	69-140	0.1-64	0-23	40-150	0.7-10	4-30	<0.1-0.7	5-74	1-19	0-0.23	2.5-35	261-698

[1] Where population is two or fewer, individual values are listed.

Table 5c.--Population of data for selected water-quality characteristics, current and historic data

(Values are in milligrams per liter, unless otherwise specified)

[Qaw, alluvium; Qbf, Bruneau Formation of Idaho Group; QTiu, Idaho Group, undifferentiated; Tb, Banbury Basalt of Idaho Group; Tsv, Silicic volcanics]

										DISSOLVED											
Ground-water temperature	County/ Geologic unit	Depth of well, total (ft below land surface)	Temperature (°C)	pH	Hardness (as $CaCO_3$)	Alkalinity ($CaCO_3$)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved solids (calculated sum)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Fluoride (F)	Nitrite plus nitrate (as N)	Sulfate (as SO_4)	Chloride (Cl)	Phosphorus, total (as P)	Sodium adsorption ratio (SAR)	Specific conductance (μmhos)
COLD	Elmore	124	111	122	124	123	123	100	123	124	124	124	123	124	124	40	124	124	40	123	123
	Owyhee	23	23	23	23	22	22	23	23	23	23	23	23	23	23	23	23	23	23	23	23
WARM	Elmore	29	28	29	28	29	29	27	29	29	29	29	29	28	29	24	28	29	24	28	29
	Owyhee	88	91	91	89	91	91	81	85	90	90	90	81	79	91	76	90	90	71	80	90
HOT	Elmore	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Owyhee	64	60	60	63	61	61	62	57	57	64	64	60	59	64	46	62	64	44	65	64
COLD	Elmore/Qaw	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Owyhee/Qaw	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Elmore/Qbf	110	97	108	110	109	109	86	109	110	110	110	109	110	110	26	110	110	26	109	109
	Owyhee/Qbf	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Elmore/QTiu	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	Owyhee/QTiu	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
WARM	Owyhee/Qaw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Elmore/Qbf	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Elmore/QTiu	19	18	19	18	19	19	17	19	19	19	19	19	18	19	14	18	19	14	18	19
	Owyhee/QTiu	43	46	46	46	46	46	44	43	46	46	46	42	40	46	41	46	46	37	42	46
	Owyhee/Tb	22	22	22	20	22	22	19	19	21	21	21	19	19	22	17	21	21	17	18	21
	Owyhee/Tsv	22	22	22	22	22	22	17	22	22	22	22	19	19	22	17	22	22	16	19	22
HOT	Elmore/QTiu	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Owyhee/QTiu	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Owyhee/Tb	20	21	21	20	21	21	21	20	20	21	21	20	20	21	18	21	21	16	18	21
	Elmore/Tsv	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Owyhee/Tsv	40	35	35	39	36	36	37	33	33	39	39	36	35	39	24	37	39	24	33	39

Median value for DS for all ground waters sampled is 274 mg/L. The highest median values are 454 mg/L for cold water and 341 mg/L for warm water in Owyhee County (table 5a). The lowest median value is 161 mg/L for cold water in Elmore County.

Highest median values (table 5a) generally are for aquifers in alluvium and Idaho Group units. Lowest median values generally are for aquifers in Bruneau Formation units.

Water samples from 39 wells in the study area have current or historic analyses of DS concentrations exceeding the maximum public drinking water limit of 500 mg/L (EPA, 1977b). Although DS concentrations are calculated from several constituent components, excessively high DS concentrations (greater than 500 mg/L) are usually the result of high concentrations of a few components--silica, calcium, sodium, bicarbonate, or sulfate. The major cation and anion components of DS are discussed in later sections of this report.

Water samples from 27 wells with current or historic data contain dissolved silica concentrations that exceed 99 mg/L (upper 10 percent of data). The median value for dissolved silica in the study area is 61 mg/L. Highest median values (greater than 85 mg/L) are for warm water in Owyhee County and hot water in Elmore and Owyhee Counties. Highest silica concentrations (140 mg/L) are generally for warm and hot water in aquifers in Idaho Group, Banbury Basalt, or silicic volcanics units in Owyhee County.

Figures 10a and 10b show (1) ranges of DS concentrations, current data; (2) DS concentrations that exceed 500 mg/L, historic data; and (3) dissolved silica concentrations that exceed 99 mg/L, current and historic data.

Cations

Cation components of ground water include dissolved calcium, magnesium, sodium, and potassium. Of these cations, dissolved sodium may be of most concern to water users. High concentrations of dissolved sodium (106-212 mg/L for irrigation uses, 200 mg/L for drinking water uses; McKee and Wolf, 1963) may restrict use of water for irrigation--see section on "Agricultural Water Uses"--or for domestic use where a sodium-restricted diet is a concern.

Median value for all dissolved sodium data is 47 mg/L. Median values for sodium are highest in cold water, alluvium unit (110 mg/L), and warm or hot water, Idaho Group unit (150 mg/L or greater) in Owyhee County. Lowest median sodium values (18 mg/L or less) are from cold and warm water, Bruneau Formation unit in Elmore County.

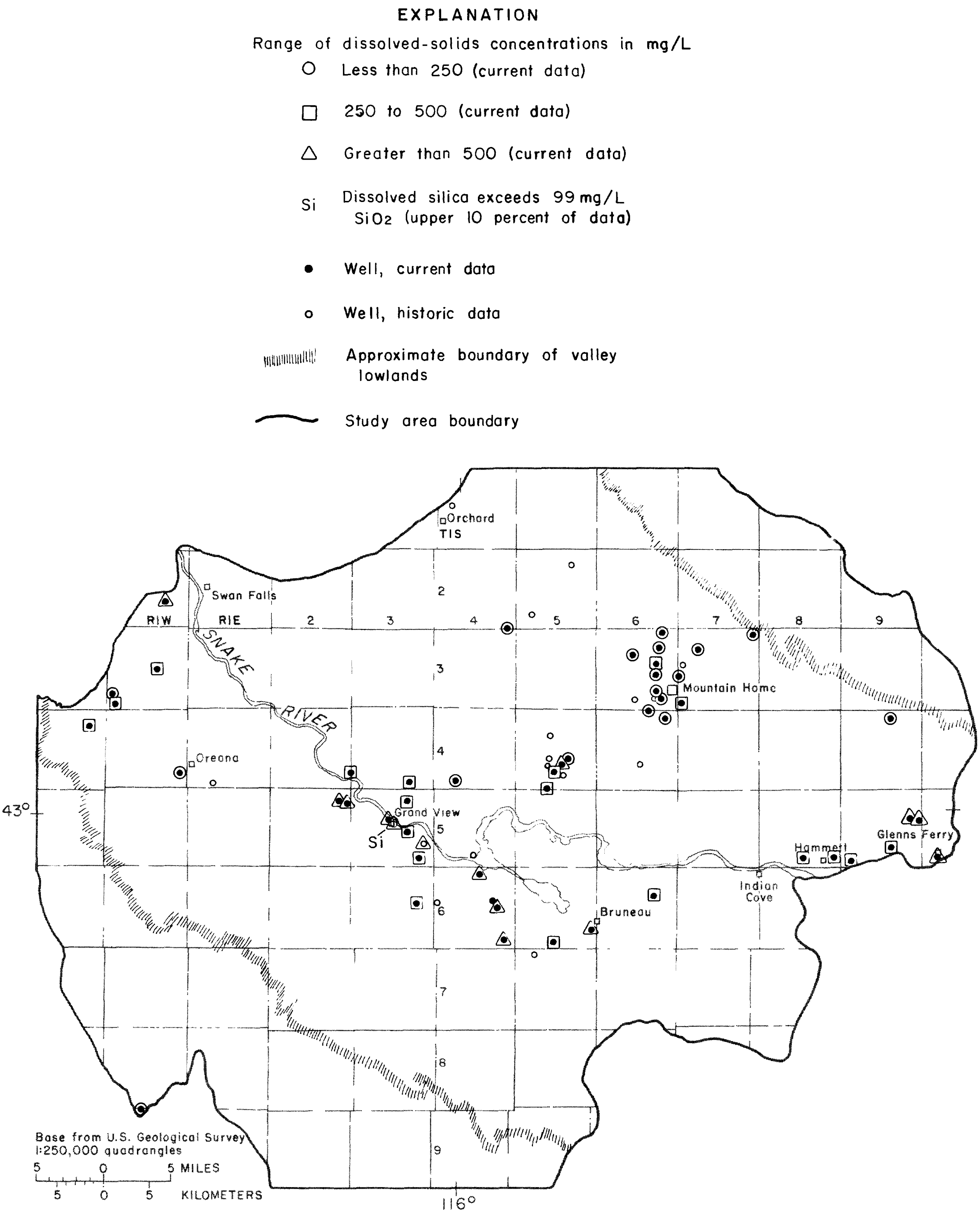


Figure 10a. -- Ranges of dissolved-solids concentrations and dissolved silica exceeding specified levels, cold water.

EXPLANATION

Range of dissolved-solids concentrations in mg/L

- ○ Less than 250 (current data)
- □ 250 to 500 (current data)
- △ Greater than 500 (current data)
- Si Dissolved silica exceeds 99 mg/L SiO_2 (upper 10 percent of data)
- ● Well, current data
- ○ Well, historic data
- ✳ Water temperature exceeds 40°C
- Approximate boundary of valley lowlands
- Study area boundary

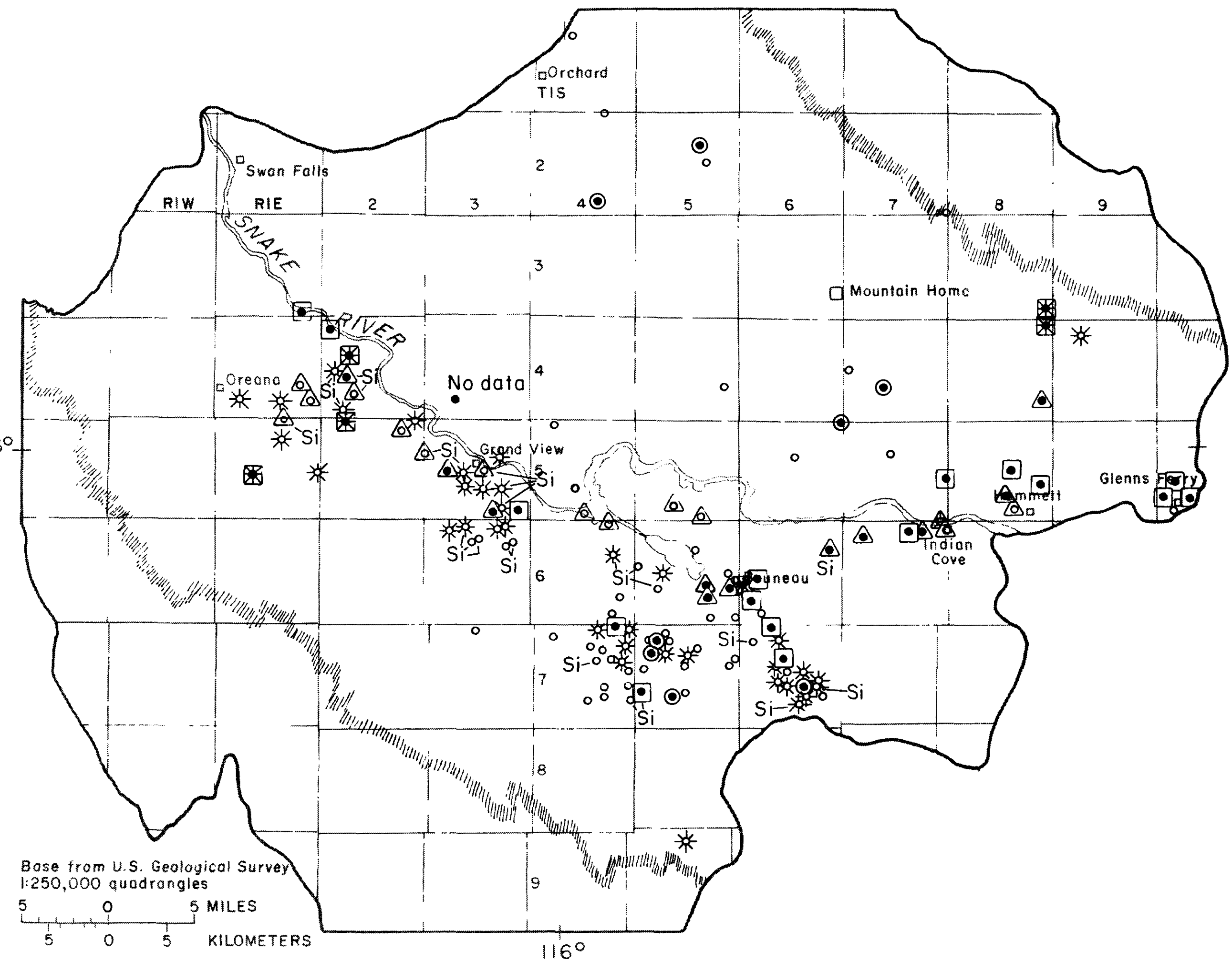


Figure 10b. -- Ranges of dissolved-solids concentrations and dissolved silica exceeding specified levels, warm and hot water.

The highest sodium concentration (550 mg/L) in the study area is from a shallow (37 ft total depth), cold water well, 5S-9E-13ACD1, completed in alluvium in Elmore County.

Dissolved solids in water from this well are excessive (2,320 mg/L), and anomalously high concentrations of most water-quality constituents may be due to variability of aquifer materials and land-surface activities.

Median values for all dissolved calcium, magnesium, and potassium data are 14 mg/L Ca, 3.3 mg/L Mg, and 4.7 mg/L K. Concentrations of these cations generally are not a problem to water users, except where anomalously high concentrations contribute to excessively high dissolved solids or very hard water--see section on "Hardness, pH, and Alkalinity." Well sites with current or historic analyses of calcium, magnesium, sodium, or potassium concentrations exceeding specified levels (the upper 10 percent of data) are shown in figures 11a and 11b.

Anions

Anion components of ground water include dissolved bicarbonate, nitrite plus nitrate, sulfate, chloride, phosphorus, and fluoride. Bicarbonate is the major component in calculating alkalinity and will be discussed in the section on "Hardness, pH, and Alkalinity." Dissolved nitrite plus nitrate or fluoride concentrations are not significant quantitatively (generally less than 20 mg/L) but may be physiologically unacceptable for drinking water uses. Dissolved fluoride concentrations commonly exceed maximum drinking water limits in the study area. Concentrations of sulfate and chloride may be major components of excessive dissolved solids and may be esthetically or physiologically unacceptable for drinking water uses (table 3). Anomalous temporal change in nitrite plus nitrate, sulfate, chloride, and phosphorus concentrations may indicate possible contamination of ground water from land-use activities.

Dissolved nitrite plus nitrate, reported in milligrams per liter dissolved nitrogen (N), is hereafter referred to collectively as nitrate. The maximum public drinking water limit of 10 mg/L N (EPA, 1977a) is based on serious and occasional poisonings of infants ingesting high concentrations of nitrates. Water samples from four wells in the study area have current or historic analyses of nitrate concentrations exceeding the drinking water limit. Nitrate in ground water may be dissolved from natural sources such as atmospheric nitrogen, decaying plants, and soluble compounds or minerals in soils and rock materials. Natural sources are usually minor contributors of nitrogen to most ground water. Anomalous concentrations of nitrate may be an indication of man-caused contamination. In the study area, potential man-caused sources of nitrate in water supplies are municipal and industrial waste, septic-tank efflu-

EXPLANATION

Ca Dissolved calcium exceeds 55mg/L (upper 10 percent of data)

Mg Dissolved magnesium exceeds 17mg/L (upper 10 percent of data)

Na Dissolved sodium exceeds 160mg/L (upper 10 percent of data)

K Dissolved potassium exceeds 13 mg/L (upper 10 percent of data)

• Well, current data

○ Well, historic data

Approximate boundary of valley lowlands

Study area boundary

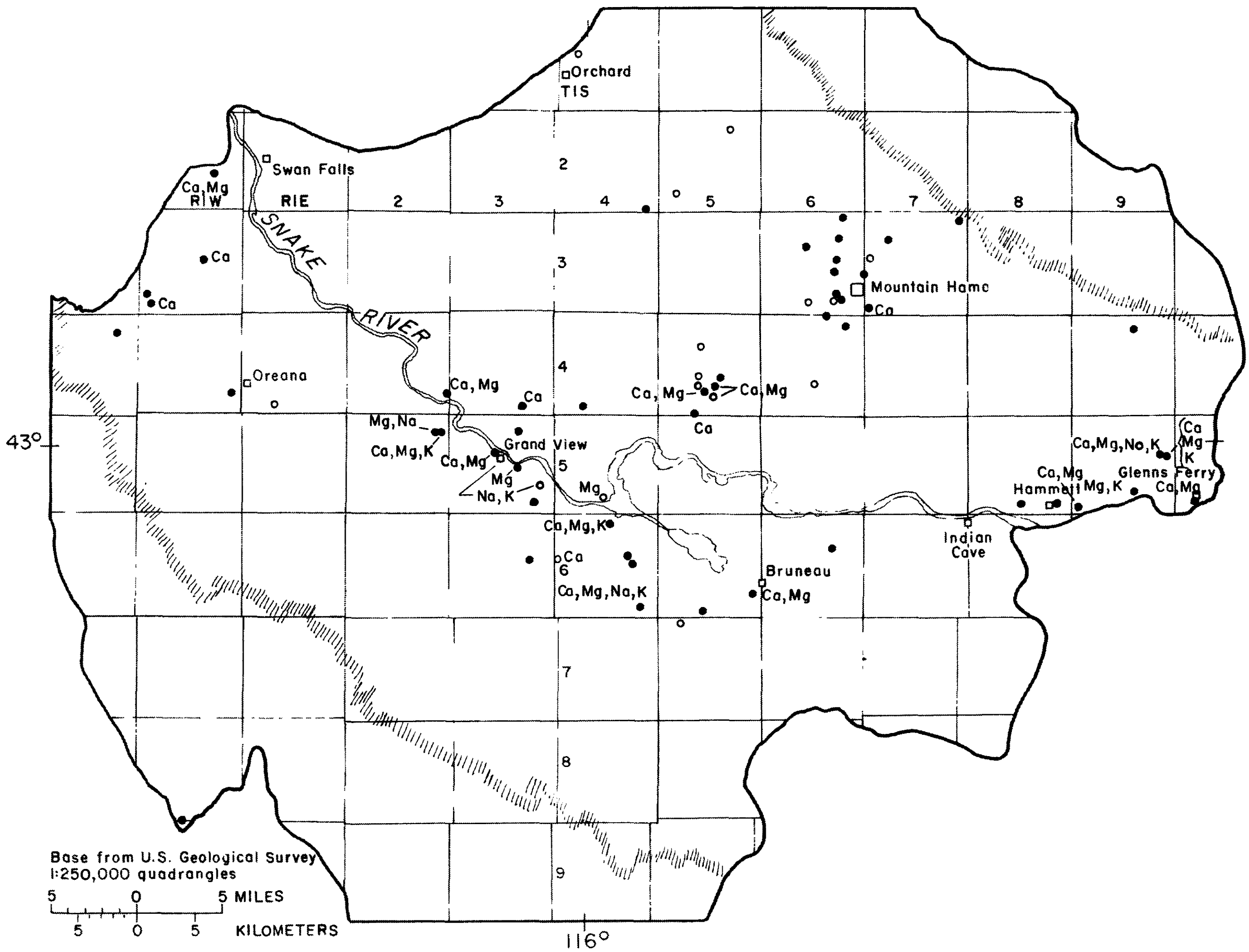


Figure 11a. -- Concentrations of dissolved calcium, magnesium, sodium, and potassium exceeding specified levels, current and historic data, cold water.

FXPLANATION

Ca Dissolved calcium exceeds 55mg/L (upper 10 percent of data)

Mg Dissolved magnesium exceeds 17mg/L (upper 10 percent of data)

Na Dissolved sodium exceeds 160mg/L (upper 10 percent of data)

K Dissolved potassium exceeds 13 mg/L (upper 10 percent of data)

• Well, current data

o Well, historic data

Water temperature exceeds 40°C

Approximate boundary of valley lowlands

Study area boundary

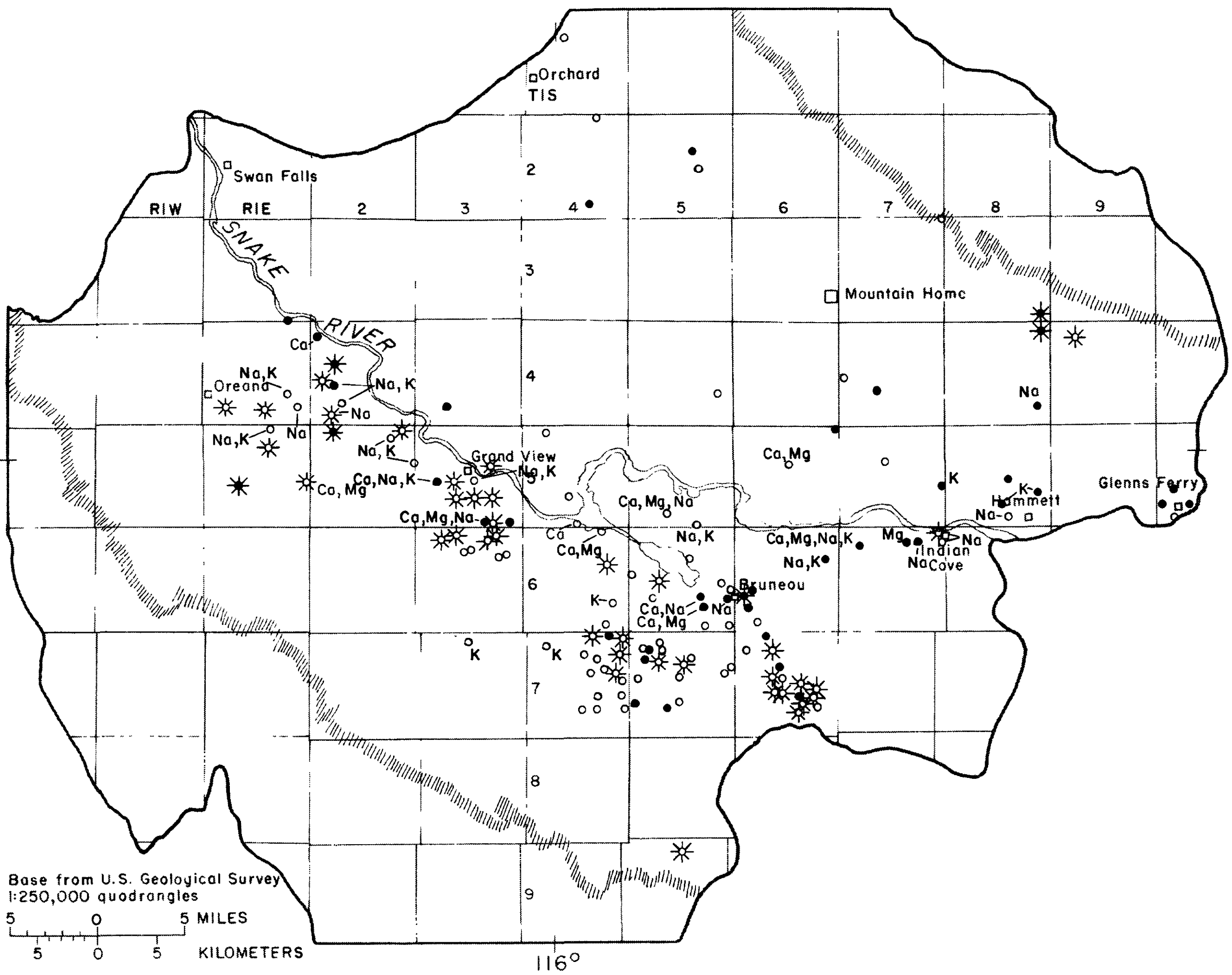


Figure 11b. -- Concentrations of dissolved calcium, magnesium, sodium, and potassium exceeding specified levels, current and historic data, warm and hot water.

ent, cropland and lawn fertilizers, and leachates from barnyards, feedlots, garbage dumps, and landfills. Concentrations as high as 27 mg/L N in Elmore County and 24 mg/L N in Owyhee County probably are due to contamination from land-use activities.

The maximum public drinking water limit of 250 mg/L sulfate (EPA, 1977b) is based on possible adverse esthetic and physiological effects on new users. Water samples from 10 wells in the study area have current or historic sulfate concentrations exceeding the drinking water limit. At concentrations of 300-400 mg/L or more, sulfates may cause a detectable taste, and at concentrations above 600 mg/L, dissolved sulfate may have laxative effects (EPA, 1977b). Extremely high concentrations in the study area (1,100 mg/L or greater) probably are due to localized differences in mineral compositions of water-bearing zones. Sulfate in ground water may be dissolved from soluble compounds or minerals (gypsum and anhydrites in particular) in rock materials, created by sulfate-reducing bacteria, or may be due to man-caused sources such as industrial waste water, septic-tank effluents, or landfill leachates.

The maximum public drinking water limit of 250 mg/L chloride (EPA, 1976) is based on possible adverse esthetic (taste) effects upon users. However, dissolved chloride may produce a salty taste in water in concentrations as low as 100 mg/L (McKee and Wolf, 1963). Chloride in ground water may be dissolved from soluble minerals (evaporites in particular) in rocks or may be due to man-caused sources such as septic-tank effluents, landfill leachates, or agricultural, municipal, or industrial wastes. Concentrations of chloride do not exceed 250 mg/L in study area samples, and concentrations exceeding 100 mg/L are rare. Because anomalous increases in chloride may indicate ground-water contamination and concentrations are generally low, chloride generally is important to the water quality of the area comparatively rather than quantitatively.

Phosphorus is a major plant nutrient and is essential for plant and animal life. The effects of high concentrations of phosphorus in surface water (0.025 to 0.1 mg/L P or more, depending on flow rate) are important because phosphorus and phosphate compounds promote the eutrophication of water bodies (EPA, 1976). In ground water, effects of phosphorus concentrations are highly variable depending on the use of the water. Maximum drinking water limits have not been established for concentrations of total phosphorus or phosphate compounds.

In both surface and ground water, anomalous concentrations of total phosphorus may result from the decomposition of phosphate-bearing rocks or from the activities of man. Potential sources of man-caused phosphorus in ground water are from infiltration of or drain-well disposal of sewage effluent (including phosphate detergents), and animal- and plant-processing, industrial, and agricultural waste (especially where phosphate fertilizers are used).

Median values from all analyses for nitrate, sulfate, chloride, and total phosphorus in the study area are 0.24 mg/L N, 23 mg/L SO_4, 11 mg/L Cl, and 0.03 mg/L P. Highest median nitrate value (1.2 mg/L N) is for cold water, Bruneau Formation unit in Elmore County. Highest median sulfate, chloride, and phosphate values (68 mg/L SO_4, 18 mg/L Cl, and 0.04 mg/L P) are for cold water in Owyhee County (table 5a) and are from aquifers in alluvium or Idaho Group units.

Figures 12a and 12b show (1) ranges of nitrate concentrations, current and historic data; (2) concentrations of dissolved sulfate that exceed 250 mg/L, current and historic data; (3) concentrations of dissolved chloride that exceed 36 mg/L (upper 10 percent of data population); and (4) concentrations of total phosphate that exceed 0.09 mg/L (upper 10 percent of data population). Ranges of nitrates were chosen arbitrarily to emphasize areas where nitrate concentrations may be anomalously high but less than drinking water limits. Ranges of dissolved chloride concentrations were chosen to emphasize the upper 10 percent of data rather than the drinking water limit, because no sample exceeded the drinking water limit.

Fluoride

Excessive fluoride in drinking water may produce mottling of teeth or bone damage. Effects of varying fluoride concentrations in drinking water are discussed in detail by EPA (1977c). For more than 30 years, fluoride has been added to public drinking water supplies to help reduce dental cavities, especially in children. Optimum fluoride concentrations in a community water supply are determined by the local annual average maximum daily air temperature because the amount of water that children drink (the amount of fluoride ingested) depends largely on air temperature. On the basis of an annual average maximum daily air temperature of 67°F (19.5°C) for the study area (National Oceanic and Atmospheric Administration, 1980), the maximum public drinking water limit for fluoride is 1.8 mg/L. The median fluoride value in the study area is 1.0 mg/L, and the range of concentrations is from less than 1 to 30 mg/L.

Highest median fluoride values (7.3 mg/L or greater) are for warm water in Owyhee County and hot water in Elmore and Owyhee Counties (table 5a). Lowest median fluoride values (0.8 mg/L or less) are for cold water in Elmore and Owyhee Counties and warm water in Elmore County.

Aquifers in Banbury Basalt or silicic volcanics units generally contain highest fluoride concentrations, and aquifers in alluvium or Bruneau Formation generally contain lowest fluoride concentrations.

EXPLANATION

SO_4 — Dissolved sulfate exceeds drinking water limit of 250 mg/L (current and historic data), U.S. Environmental Protection Agency, 1977a

Cl — Dissolved chloride exceeds 36 mg/L (upper 10 percent of data), current and historic data

P — Total phosphorus exceeds .09 mg/L (upper 10 percent of data), current and historic data

Range of nitrate, mg/LN

○ Less than 1 (current data)

□ 1 to 9.9 (current data)

△ Greater than 9.9 (current and historic data)

● Well, current data

o Well, historic data

Approximate boundary of valley lowlands

Study area boundary

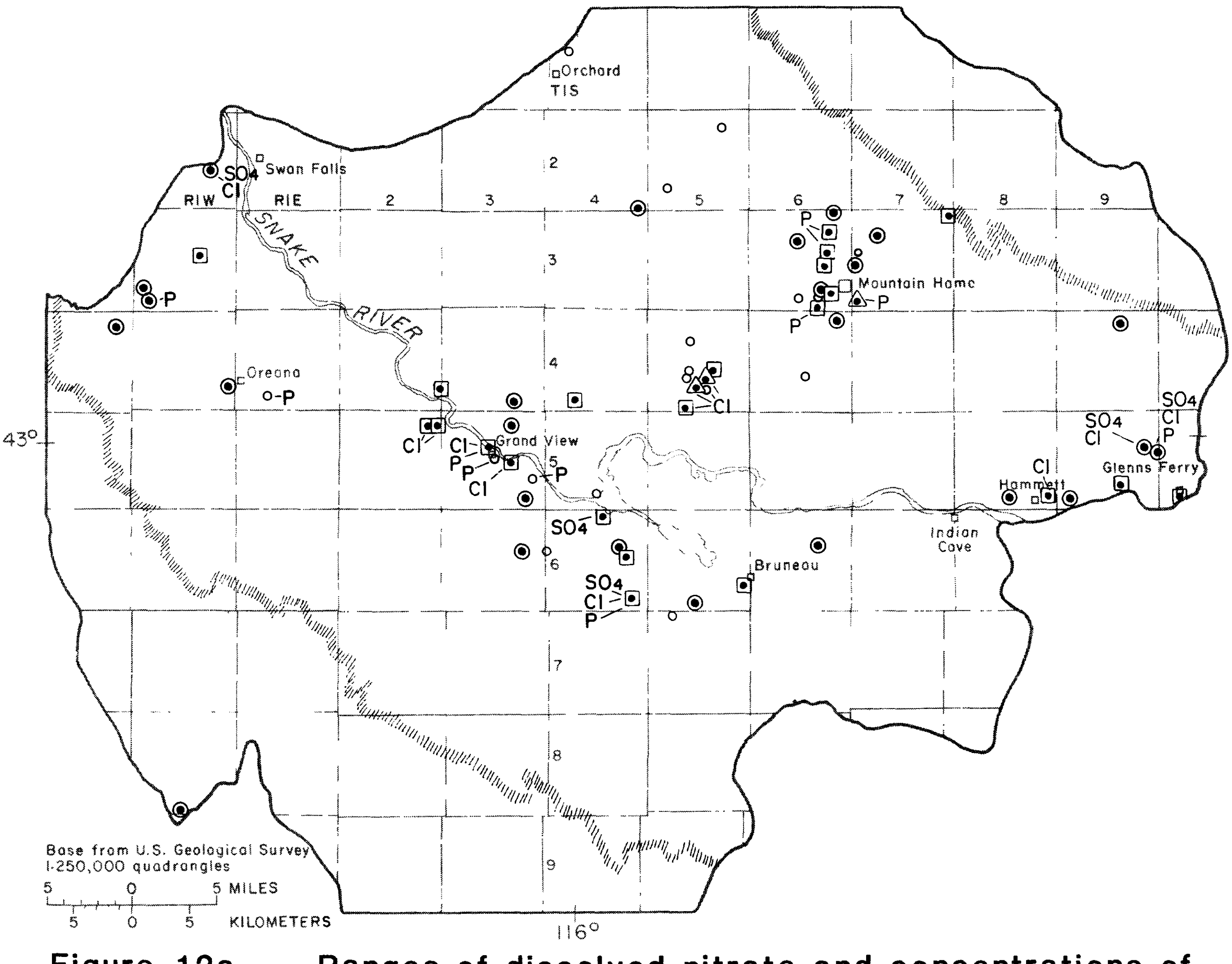


Figure 12a. -- Ranges of dissolved nitrate and concentrations of dissolved sulfate, chloride, and total phosphorus exceeding specified levels, cold water.

EXPLANATION

SO_4 Dissolved sulfate exceeds drinking water limit of 250 mg/L (current and historic data), U.S. Environmental Protection Agency, 1977a

Cl Dissolved chloride exceeds 36 mg/L (upper 10 percent of data), current and historic data

P Total phoshorus exceeds .09 mg/L (upper 10 percent of data), current and historic data

Range of nitrate, mg/LN

○ Less than 1 (current data)

□ 1 to 9.9 (current data)

△ Greater than 9.9 (current and historic data)

● Well, current data

o Well, historic data

☼ Water temperature exceeds 40°C

Approximate boundary of valley lowlands

Study area boundary

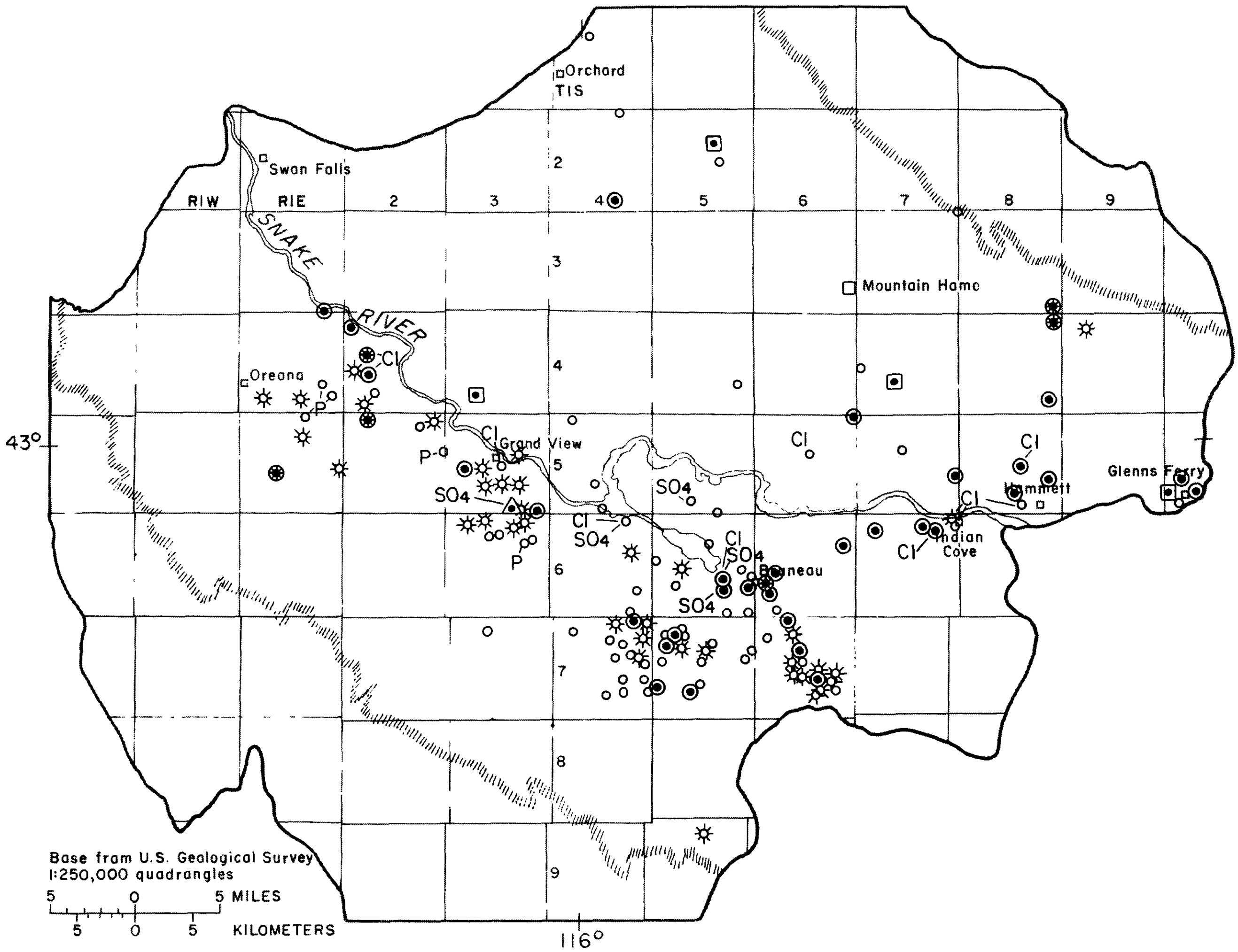


Figure 12b. -- Ranges of dissolved nitrate and concentrations of dissolved sulfate, chloride, and total phosphorus exceeding specified levels, warm and hot water.

Figures 13a and 13b show ranges of dissolved fluoride for current and historic data. Ranges chosen are subjective and are based on the following significant factors: 1.8 mg/L is the maximum drinking water limit for the area; concentrations of 1.8-12 mg/L may cause tooth mottling and some bone damage, but water-treatment processes may reduce fluoride concentrations (Nordell, 1961); and concentrations greater than 12 mg/L increase the severity of physiological damage, and water treatment may not be economically feasible.

Hardness, pH, and Alkalinity

Hardness, expressed in milligrams per liter as calcium carbonate ($CaCO_3$), is caused principally by dissolved calcium and magnesium in water. Hardness is often defined in terms of grains of hardness: 1 grain per U.S. gallon = 17.12 mg/L $CaCO_3$ hardness (Johnson Division, Inc., 1966). The consumer often judges hardness by the amount of soap required to produce a lather and by scale buildup in water-supply pipes, plumbing fixtures, and cookware.

On a national basis, EPA (1976) has established the following water hardness categories: 0-75 mg/L is soft, 76-150 mg/L is moderately hard, 151-300 mg/L is hard, and more than 300 mg/L is very hard.

Hardness in domestic supplies probably is not objectionable at concentrations less than 100 mg/L (McKee and Wolf, 1963). Chemically softened water may be preferable for esthetic reasons or for industrial uses but may be expensive. Also, use of sodium compounds in some water-softening processes may increase the sodium content of drinking water, a concern to people on sodium-restricted diets (EPA, 1977a).

An increasing number of research articles that discuss the importance of water hardness and health are being published. Current research (EPA, 1977c) of particular interest to many water users in the study area suggests that the incidence of cardiovascular disease may be higher in areas with soft water than in areas with hard water.

The median value for all hardness data in the study area is 49 mg/L $CaCO_3$. In general, cold water (except in Bruneau Formation) is moderately hard to hard, warm water is soft, and hot water is very soft (table 5a). Aquifers in Idaho Group units generally contain the hardest water, and aquifers in Bruneau Formation, Banbury Basalt, and silicic volcanics units contain the softest water. Figures 14a and 14b show ranges of hardness values for current data and hardness values exceeding 300 mg/L for historic data.

EXPLANATION

Ranges of dissolved fluoride in mg/L

○ Less than 1.8 (current data)

□ 1.8 to 12 (current and historic data)

△ Greater than 12 (current and historic data)

● Well, current data

o Well, historic data

Approximate boundary of valley lowlands

Study area boundary

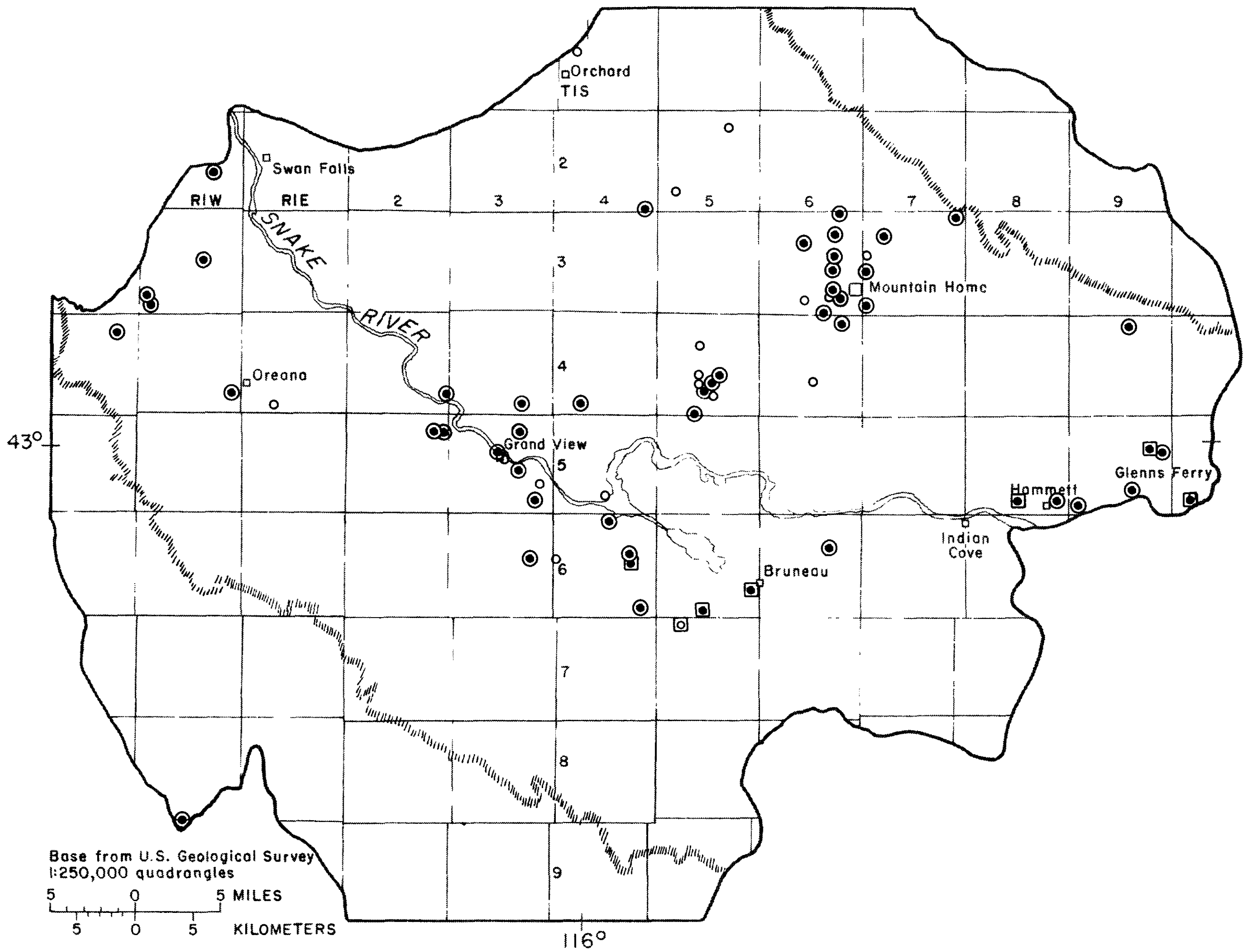


Figure 13a. -- Ranges of dissolved fluoride, cold water.

EXPLANATION

Ranges of dissolved fluoride in mg/L

○ Less than 1.8 (current data)

□ 1.8 to 12 (current and historic data)

△ Greater than 12 (current and historic data)

• Well, current data

∘ Well, historic data

⁂ Water temperature greater than 40°C

Approximate boundary of valley lowlands

Study area boundary

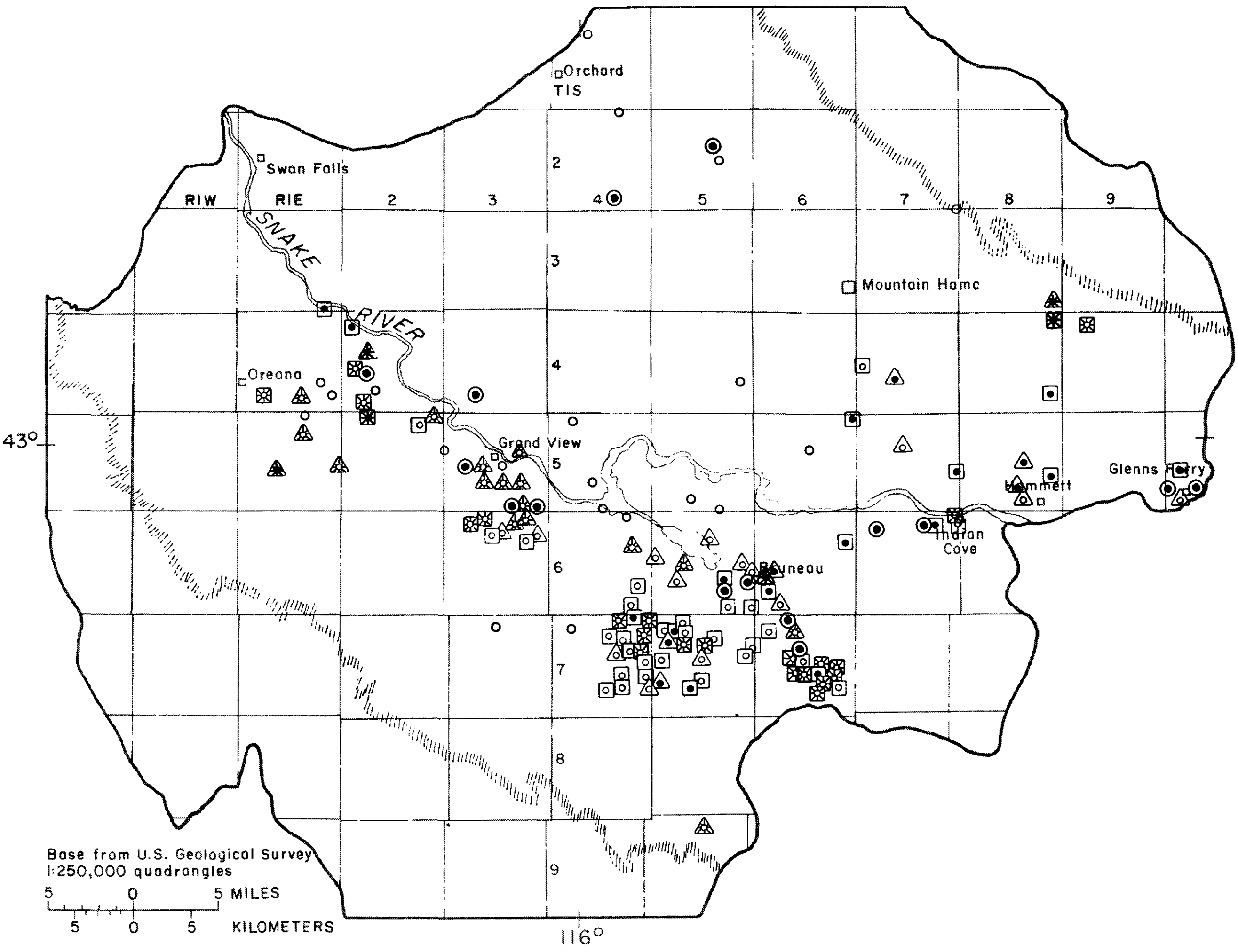


Figure 13b. -- Ranges of dissolved fluoride, warm and hot water.

EXPLANATION

Range of Hardness in mg/L $CaCO_3$

- ○ Less than 76, soft water, current data
- □ 76 to 150, moderately hard water, current data
- △ 151 to 300, hard water, current data
- ◇ Greater than 300, very hard water, current data and historic data
- A Alkalinity exceeds 300mg/L $CaCO_3$, current and historic data
- pH pH exceeds drinking water limit of 8.5, current and historic data (U.S. Environmental Protection Agency, 1977b)
- • Well, current data
- ∘ Well, historic data
- Approximate boundary of valley lowlands
- Study area boundary

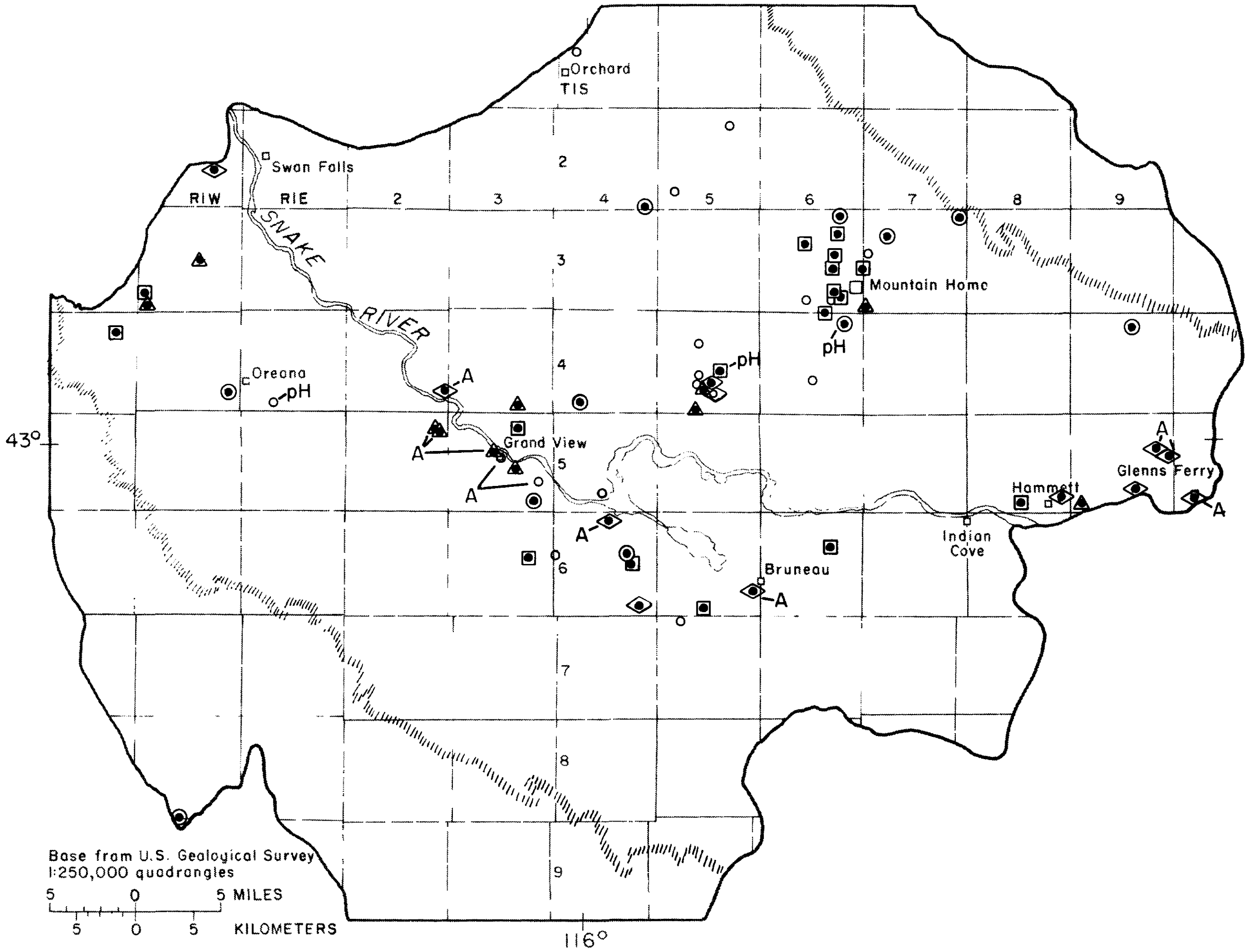


Figure 14a. -- Range of hardness, selected range of alkalinity, and pH exceeding drinking water limit, cold water.

EXPLANATION

Range of Hardness in mg/L $CaCO_3$

○ Less than 76, soft water, current data

□ 76 to 150, moderately hard water, current data

△ 151 to 300, hard water, current data

◇ Greater than 300, very hard water, current data and historic data

A Alkalinity exceeds 300mg/L $CaCO_3$, current and historic data

pH pH exceeds drinking water limit of 8.5, current and historic data (U.S. Environmental Protection Agency, 1977b)

• Well, current data

∘ Well, historic data

✲ Water temperature greater than 40°C

Approximate boundary of valley lowlands

Study area boundary

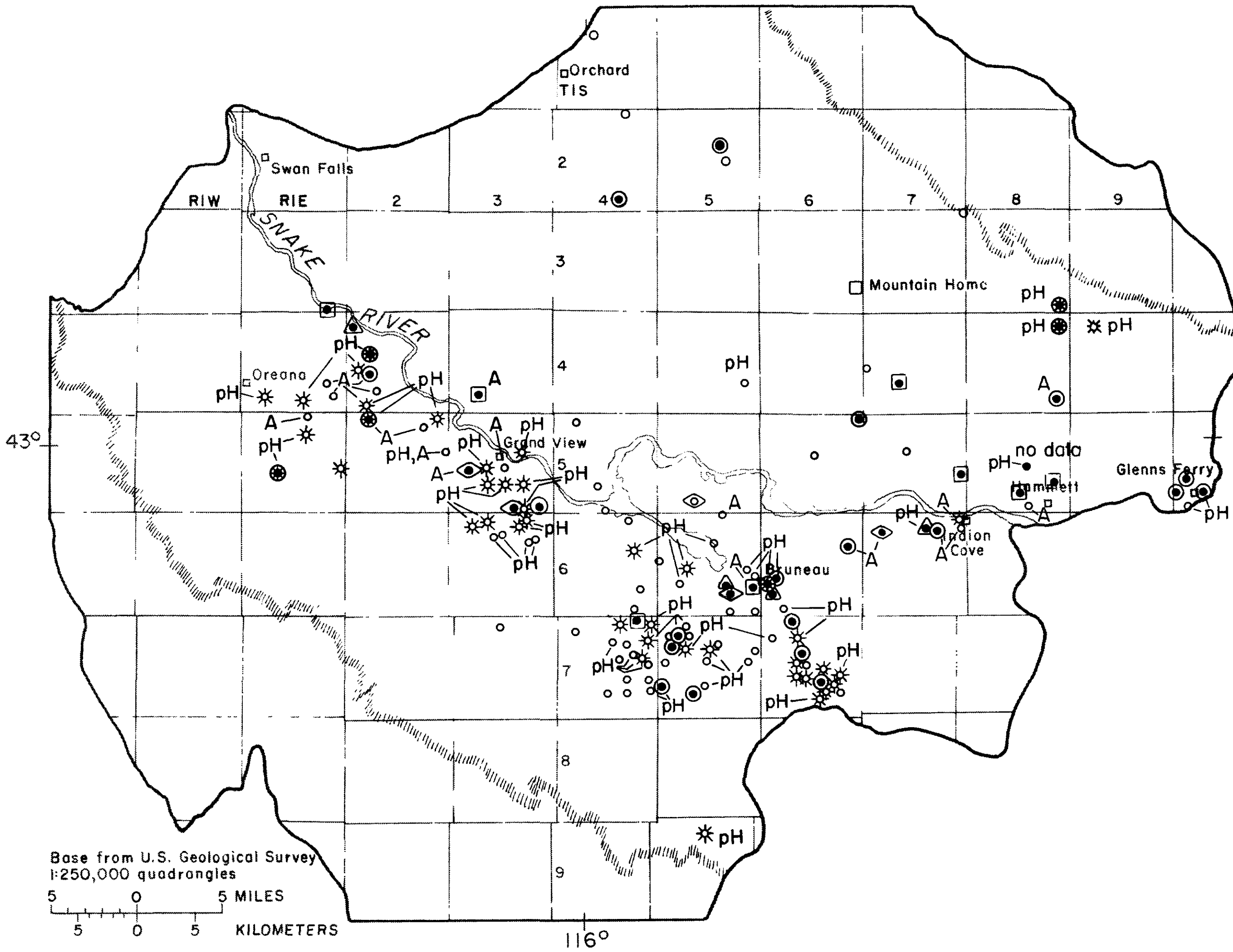


Figure 14b. -- Range of hardness, selected range of alkalinity, and pH exceeding drinking water limit, warm and hot water.

Hydrogen ion activity in water is measured in pH units. In general, pH describes whether a water is neutral (pH 7), acidic (pH less than 7), or basic (pH greater than 7). The pH is controlled primarily by chemical reactions and equilibria among the ions in solution and is an indicator of the chemical behavior certain solutions may have toward minerals (Hem, 1970).

Most natural waters have pH values within the range of 5.0-9.0 (NASNAE, 1972), but the range of minimum and maximum pH recommended for public water supplies (EPA, 1977b) is 6.5-8.5. Water samples from 64 wells in the study area have current or historic pH values exceeding the maximum public drinking water range. Corrosion commonly is associated with pH values below 6.5. Bitter taste may occur in water with a pH greater than 8.5. The impact of pH on the use of any water varies depending on the overall chemistry and composition of the water. Importance of pH to ground-water chemistry is reported in many texts, including those by Krauskopf (1967) and Freeze and Cherry (1979).

Median value for all pH data in the study area is 8.0. The highest median pH values occur in hot water in all aquifers and lowest median pH values occur in cold water in all aquifers. Highest pH value (10.2) is in warm water, Idaho Group unit, Elmore County. Lowest pH value (6.5) is in cold water, alluvium unit, Owyhee County.

Alkalinity indicates the capacity of a water to neutralize acid and is therefore a measure of the chemical ability of a water to resist a pH change. In most natural water, alkalinity is produced chiefly by dissolved bicarbonate and carbonate ions and is expressed as concentrations of bicarbonate plus carbonate as $CaCO_3$.

In itself, alkalinity is not considered to be a health hazard, but it is generally associated with high pH values, hardness, and excessive dissolved solids. Water having concentrations of about 400 mg/L alkalinity or greater may have an unpleasant, bitter taste (NASNAE, 1972). Alkalinity of water used for municipal and industrial supplies is important because it affects the amounts of chemical additives needed for coagulation, softening, and control of corrosion in distribution systems and manufacturing processes. EPA (1976) reports the maximum alkalinity concentration for food-canning industries, important to the economy of the study area, to be 300 mg/L.

Median value for all alkalinity data in the study area is 110 mg/L $CaCO_3$. Highest median alkalinity values (180 mg/L or more) generally are for cold water aquifers in alluvium and Idaho Group, Elmore and Owyhee Counties; and warm and hot water aquifers in Idaho Group, Owyhee County. The lowest median value (61 mg/L $CaCO_3$) is for cold water, Bruneau Formation, Elmore County (table 5a).

Values of pH less than 6.5 or more than 8.5 for current and historic analyses, and alkalinity concentrations greater than 300 mg/L for current and historic analyses are shown in figures 14a and 14b.

Trace Elements

Concentrations of arsenic, iron, manganese, and selenium exceed EPA public drinking water limits of 50, 300, 50, and 10 µg/L, respectively, in several wells in the study area. Most concentrations of trace elements are probably natural, a result of the geologic conditions of the area. Trace-element data are sparse, however, and mineral analyses of geologic unit material generally are not available. Source and significance of selected trace elements are shown in table 6, and water-quality regulations, criteria for selected water uses, and ranges of current and historic trace-element data are shown in table 7. Table 8 shows median, range or value, and sample population size for available trace-element data by county and major geologic unit. Medians are not calculated for populations of less than four analyses.

Locations of ground-water samples with trace-element concentrations that exceed EPA drinking water limits or that are anomalously high (upper 10 percent of data population) are shown in figures 15a and 15b.

Agricultural Water Uses

Major agricultural uses of ground water in the Swan Falls to Glenns Ferry area are for livestock and irrigation. Concentrations of most chemical constituents and physical properties are within tolerance levels for livestock uses (tables 4 and 7). Fluoride concentrations exceed the recommended criteria of 2 mg/L for livestock drinking water in a few samples from cold water wells and in more than 50 percent of samples from warm and hot water wells (figs. 13a and 13b). A median of 2 mg/L fluoride is exceeded in hot water samples from wells completed in Banbury Basalt and silicic volcanics units in Owyhee County and in warm and hot water samples from wells completed in Idaho Group units in both Elmore and Owyhee Counties.

Dissolved selenium concentrations exceed the recommended 50 µg/L criteria for livestock in samples from two wells in Idaho Group units in Owyhee County. Few selenium analyses are available, however, for comparison.

The suitability of a water supply for irrigation depends on soil characteristics, land-management practices, environmental conditions, crop tolerances for varying constituents, and the quality of water. Soil characteristics, land-management prac-

Table 6.--Source and significance of selected trace elements

Characteristic	Source	Significance
Arsenic (As)	Common in nature. Insoluble in water. Used in some herbicides and pesticides.	Most compounds of arsenic are toxic to humans and may be carcinogenic. Drinking water criteria for arsenic and arsenic compounds currently are being revised.
Boron (B)	Constituent of some minerals in igneous rocks. Not easily dissolved. May be liberated in volcanic gases. Water in volcanic areas may contain considerable concentrations of boron.	Potentially toxic to sensitive plants.
Iron (Fe)	Dissolved from practically all rocks and soils, especially igneous and sedimentary rocks. Also caused by corrosion of pipes, pumps, and other cast iron or steel equipment or the presence of iron bacteria.	When concentrations are more than 100 μg/L, iron commonly precipitates on exposure to air causing turbidity; stains plumbing fixtures and laundry; and results in tastes and colors objectionable in food and beverages.
Lead (Pb)	Occurs in nature commonly as lead compounds. Relatively insoluble. Incorporated into ground-water systems through precipitation, lead dust fallout, urban runoff, and municipal wastes.	A toxic metal that tends to accumulate in animal tissues. No beneficial or desirable nutritional value. Lead intoxication and lead poisoning most seriously affect children.
Lithium (Li)	Concentrated in igneous pegmatites and sedimentary evaporite rocks. When brought into solution by weathering reactions, tends to remain dissolved.	Potentially toxic to plants.
Manganese (Mn)	Occurs in various salts and minerals in nature, frequently in association with iron compounds.	A micronutrient vital for plants and animals. Rarely toxic. Concentrations in excess of 50 μg/L may produce objectionable esthetic qualities similar to iron and sometimes intensified by the presence of iron.
Selenium (Se)	Occurs in elemental or oxidized forms in nature. Oxidized compounds are more soluble than elemental forms.	Biologically essential and beneficial element in trace amounts. Larger quantities are potentially toxic to animals. Low amounts may produce toxic levels in forage crops. Toxicity symptoms are similar to those of arsenic poisoning. Not removed from water by treatment processes.
Zinc (Zn)	Common mineral often associated with sulfides of other metals, especially lead, copper, cadmium, and iron. May be dissolved from galvanized pipe.	Essential to human metabolism. More than 5,000 μg/L produces a bitter or astringent taste.

Table 7.--Regulations or criteria for selected trace elements

(Chemical constituents reported in micrograms per liter)

[--, no data available; <, less than]

Trace element	Public drinking water limit[1]	Commercial food-canning requirements[2]	Agricultural levels[3]		Range of concentrations observed in study area	
			Livestock	Irrigation[4]	Current data	Historic data
Arsenic (As)	50	--	2,000	100- 2,000	0- 110	<1- 80
Boron (B)	--	--	5,000	750- 2,000	20-2,100	<20-1,900
Iron (Fe)	300	200	--	5,000-20,000	10-6,100	<10-2,500
Lead (Pb)	50	--	100	5,000-10,000	0- 40	--
Lithium (Li)	--	--	--	2,500- 5,000	4- 690	<10-1,100
Manganese (Mn)	50	200	--	200-10,000	1-7,700	<10- 50
Selenium (Se)	10	--	50	20	0- 62	--
Zinc (Zn)	5,000	--	25,000	2,000-10,000	3-1,300	<20- 250

1/ U.S. Environmental Protection Agency (1977a and 1977b)
2/ National Academy of Sciences, National Academy of Engineering (1972)
3/ U.S. Environmental Protection Agency (1976) and National Academy of Sciences, National Academy of Engineering (1972)
4/ Varies with crop tolerances, soil conditions, and land management practices

Table 8.--Median, range or value, and statistical population for trace-element data

(Data in micrograms per liter)

[--, no data available; <, less than]

County	Statistical parameter	Water temperature	Arsenic, dissolved (as As)	Boron, dissolved (as B)	Iron, dissolved (as Fe)	Lead, dissolved (as Pb)	Lithium, dissolved (as Li)	Manganese, dissolved (as Mn)	Selenium, dissolved (as Se)	Zinc, dissolved (as Zn)
ELMORE	Median	Cold	2	70	20	2	10	1	0	100
		Warm	3	70	30	2	20	1	0	40
		Hot	18	500	--	--	<10	--	--	--
	Range or value	Cold	0-110	<20-1,200	0-6,100	0-17	<4-390	0-7,700	0-3	<3-1,300
		Warm	0- 24	40-1,100	<10-1,900	0.4-24	5-600	0- 250	0-2	<3- 130
		Hot	<1- 40	100-1,100	<10, 20	--	<4-<10	<1	--	<3
	Statistical population, in number of analyses	Cold	30	11	85	11	9	80	12	22
		Warm	13	7	10	5	7	10	6	7
		Hot	4	4	2	--	4	2	--	2
OWYHEE	Median	Cold	17	90	10	2	40	10	0	35
		Warm	13	250	30	2	40	45	0	4
		Hot	13	270	60	--	10	0	--	--
	Range or value	Cold	0-45	<20-1,100	0- 160	1- 4	8-1,100	<1-510	0-50	<3-580
		Warm	<1-68	<20-2,100	0-1,600	0-40	7- 950	0-500	0-62	<3-460
		Hot	<1-80	60-1,500	0-2,300	0	0.1- 260	0- 7	0	7
	Statistical population, in number of analyses	Cold	23	13	13	9	12	11	9	8
		Warm	72	66	23	12	61	14	10	15
		Hot	39	42	15	1	37	11	2	1

EXPLANATION

As — Dissolved arsenic exceeds drinking water limit of 50 µg/L (U.S. Environmental Protection Agency, 1977a)

B — Dissolved boron exceeds 1,000 µg/L (upper 10 percent of data)

Fe — Dissolved iron exceeds drinking water limit of 300 µg/L (U.S. Environmental Protection Agency, 1977b)

Pb — Dissolved lead exceeds 18 µg/L (upper 10 percent of data)

Li — Dissolved lithium exceeds 435 µg/L (upper 10 percent of data)

Mn — Dissolved manganese exceeds drinking water limit of 50 µg/L (U.S. Environmental Protection Agency, 1977b)

Se — Dissolved selenium exceeds drinking water limit of 10 µg/L (U.S. Environmental Protection Agency, 1977a)

Zn — Dissolved zinc exceeds 472 µg/L (upper 10 percent of data)

● Well, current data

o Well, historic data

Approximate boundary of valley lowlands

Study area boundary

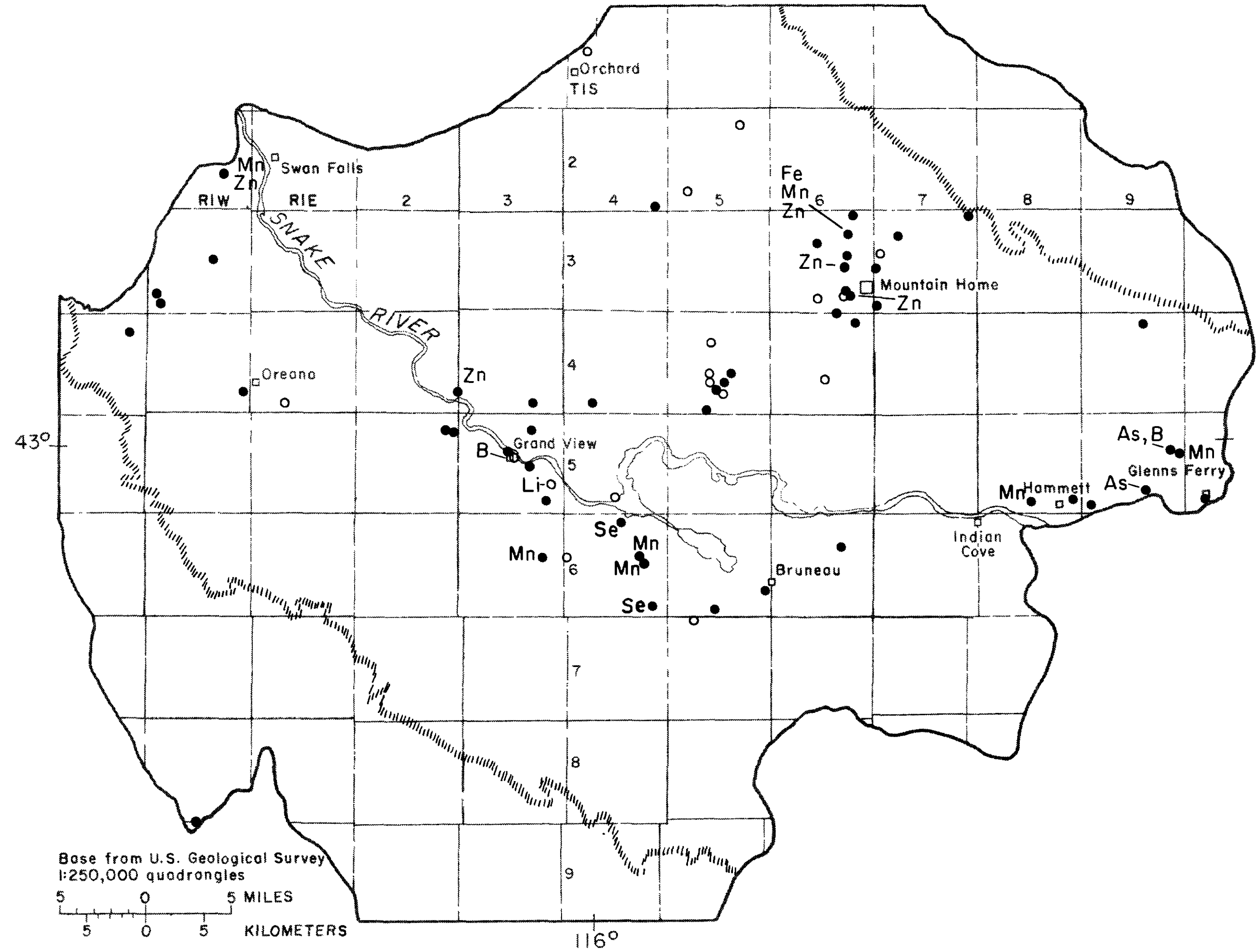


Figure 15a. -- Concentrations of selected trace elements exceeding specified levels, current and historic data, cold water.

EXPLANATION

As	Dissolved arsenic exceeds drinking water limit of 50 µg/L (U.S. Environmental Protection Agency, 1977a)	Mn	Dissolved manganese exceeds drinking water limit of 50 µg/L (U.S. Environmental Protection Agency, 1977b)
B	Dissolved boron exceeds 1,000 µg/L (upper 10 percent of data)	Se	Dissolved selenium exceeds drinking water limit of 10 µg/L (U.S. Environmental Protection Agency, 1977a)
Fe	Dissolved iron exceeds drinking water limit of 300 µg/L (U.S. Environmental Protection Agency, 1977b)	Zn	Dissolved zinc exceeds 472 µg/L (upper 10 percent of data)
Pb	Dissolved lead exceeds 18 µg/L (upper 10 percent of data)	●	Well, current data
		o	Well, historic data
Li	Dissolved lithium exceeds 435 µg/L (upper 10 percent of data)	✳	Water temperature exceeds 40°C
			Approximate boundary of valley lowlands
			Study area boundary

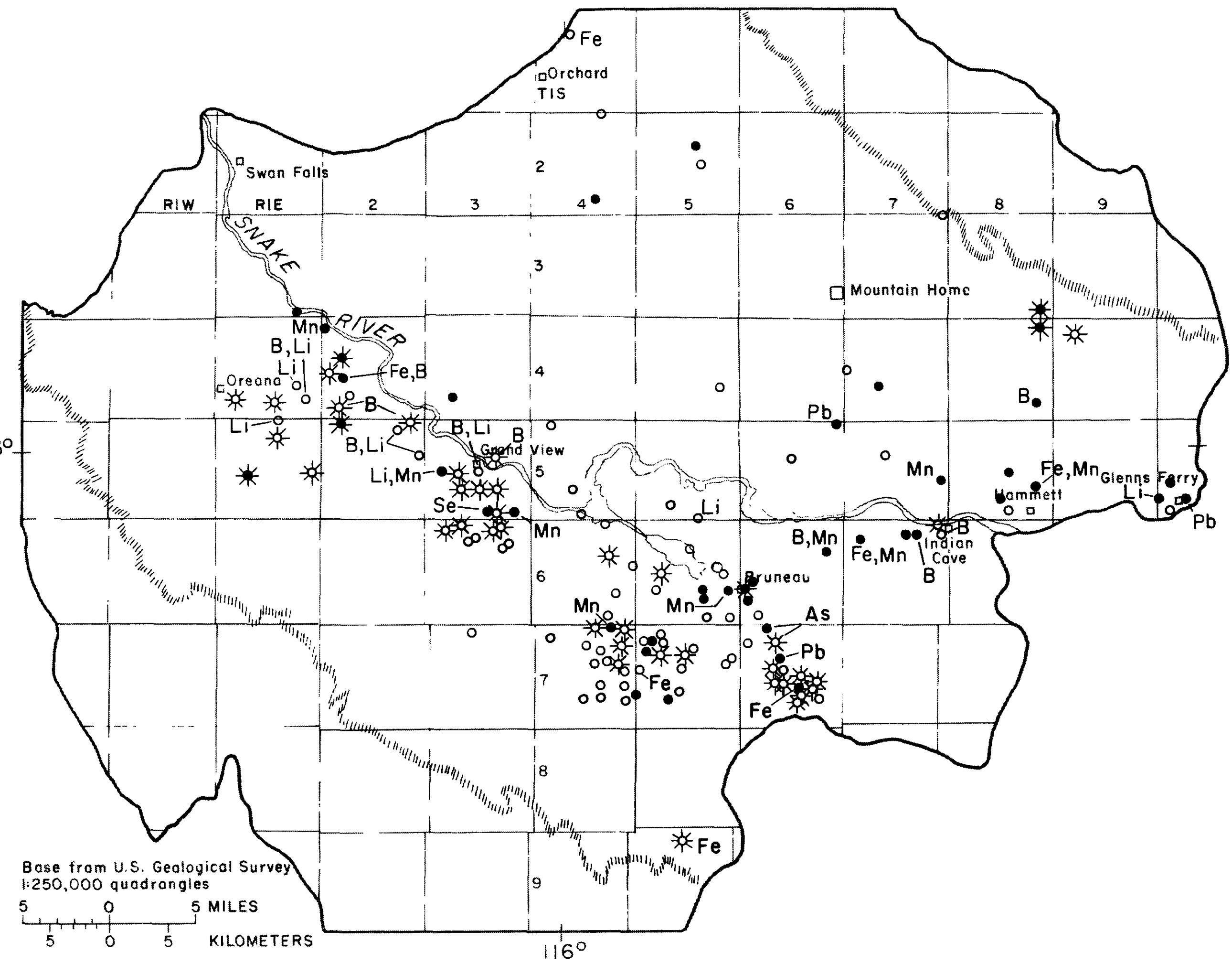


Figure 15b. -- Concentrations of selected trace elements exceeding specified levels, current and historic data, warm and hot water.

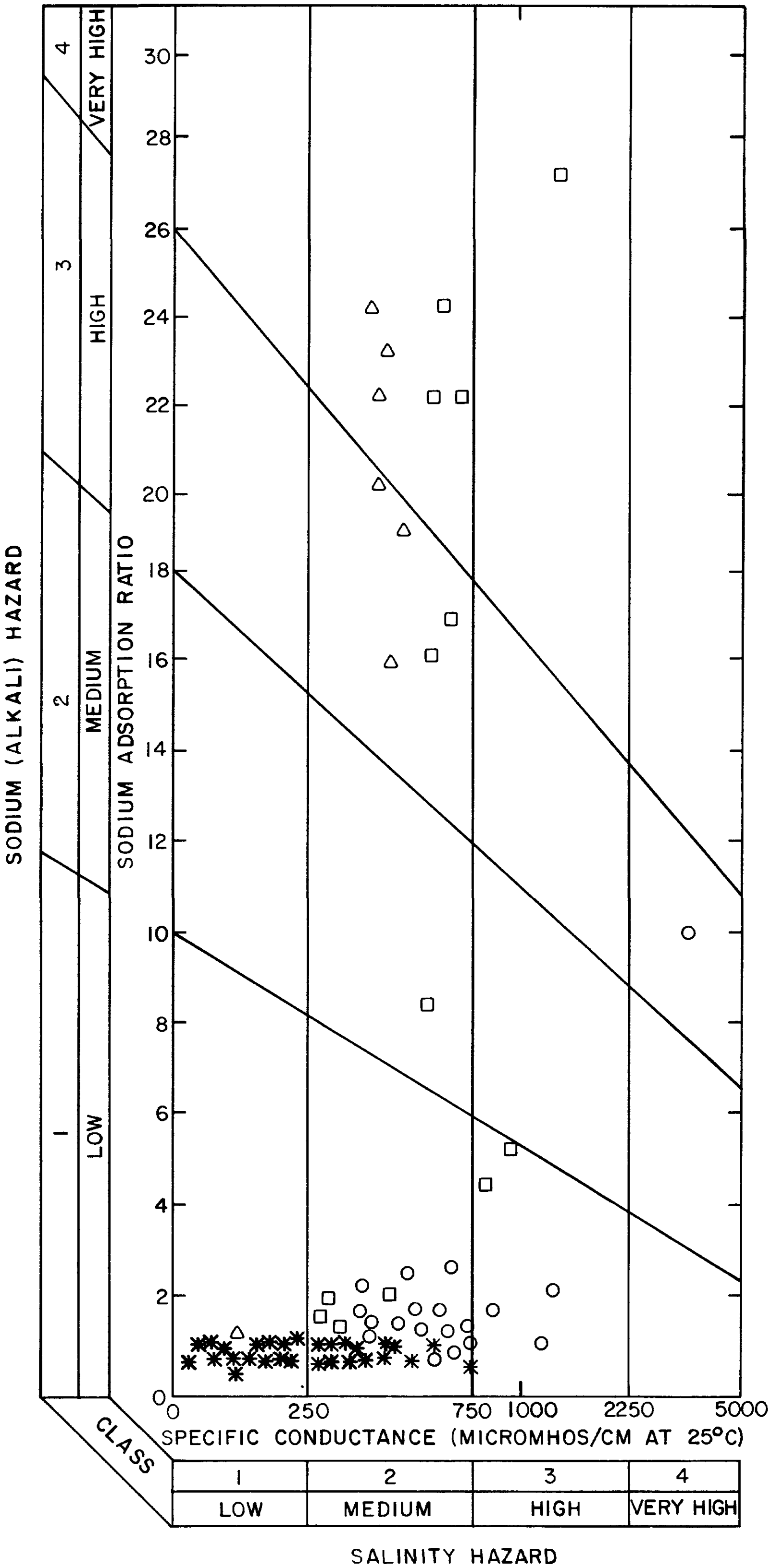
tices, environmental conditions, and crop tolerance are discussed in depth in publications by NASNAE (1972) and U.S. Salinity Laboratory Staff (1954).

In the semiarid lowlands and foothills of the study area, ground-water quality for irrigation is influenced by the concentration of dissolved cations and anions (salts), the relative proportion of sodium to other cations, and concentration of boron and other trace elements that may be toxic to plants.

Many chemical constituents of irrigation waters react with soils as ions rather than as molecules. Ions largely responsible for salinity in water in the study area include sodium, calcium, magnesium, carbonate, bicarbonate, sulfate, chloride, and fluoride. The total concentration of soluble salts, or the salinity hazard, in irrigation waters is measured in terms of specific electrical conductance, in micromhos per centimeter at 25°C. Sodium hazard or alkali hazard is determined by the relative concentrations of the cations sodium, calcium, and magnesium and is expressed in terms of SAR (sodium-adsorption ratio). On the basis of specific conductance (conductivity) and SAR, the U.S. Salinity Laboratory Staff (1954) has developed a general classification to illustrate the salinity and sodium hazard of water used for irrigation. The suitability of ground water for irrigation in the study area, based on this classification, is shown in figures 16a-16d.

Most ground water in the study area has a low to medium salinity hazard, a low sodium hazard, and can be used for irrigation on most soils with most crops if a moderate amount of soil leaching occurs. In Elmore County, water from all hot water wells and some warm water wells completed in Idaho Group units has a medium salinity hazard and a high to very high sodium hazard. Water from these sources may produce harmful levels of exchangeable sodium in soils and may require special soil-management practices. Lowest salinity and sodium hazards in Elmore County occur in cold water wells completed in Bruneau Formation units. Highest salinity and sodium hazards occur in hot and warm water wells completed in Idaho Group units.

In Owyhee County, medium to high salinity hazard and high to very high sodium hazard are common for warm and hot water wells completed in Banbury Basalt units. Salinity and sodium hazards for water in Idaho Group and silicic volcanics units are highly variable, probably due to mixing of different waters and varying composition of aquifer materials. Lowest hazards in Owyhee County occur in cold water wells completed in alluvium and warm water wells completed in Idaho Group, Banbury Basalt, and silicic volcanics units. Highest hazards occur in hot water wells completed in Banbury Basalt and silicic volcanics units and warm water wells completed in Idaho Group units. Use of medium-

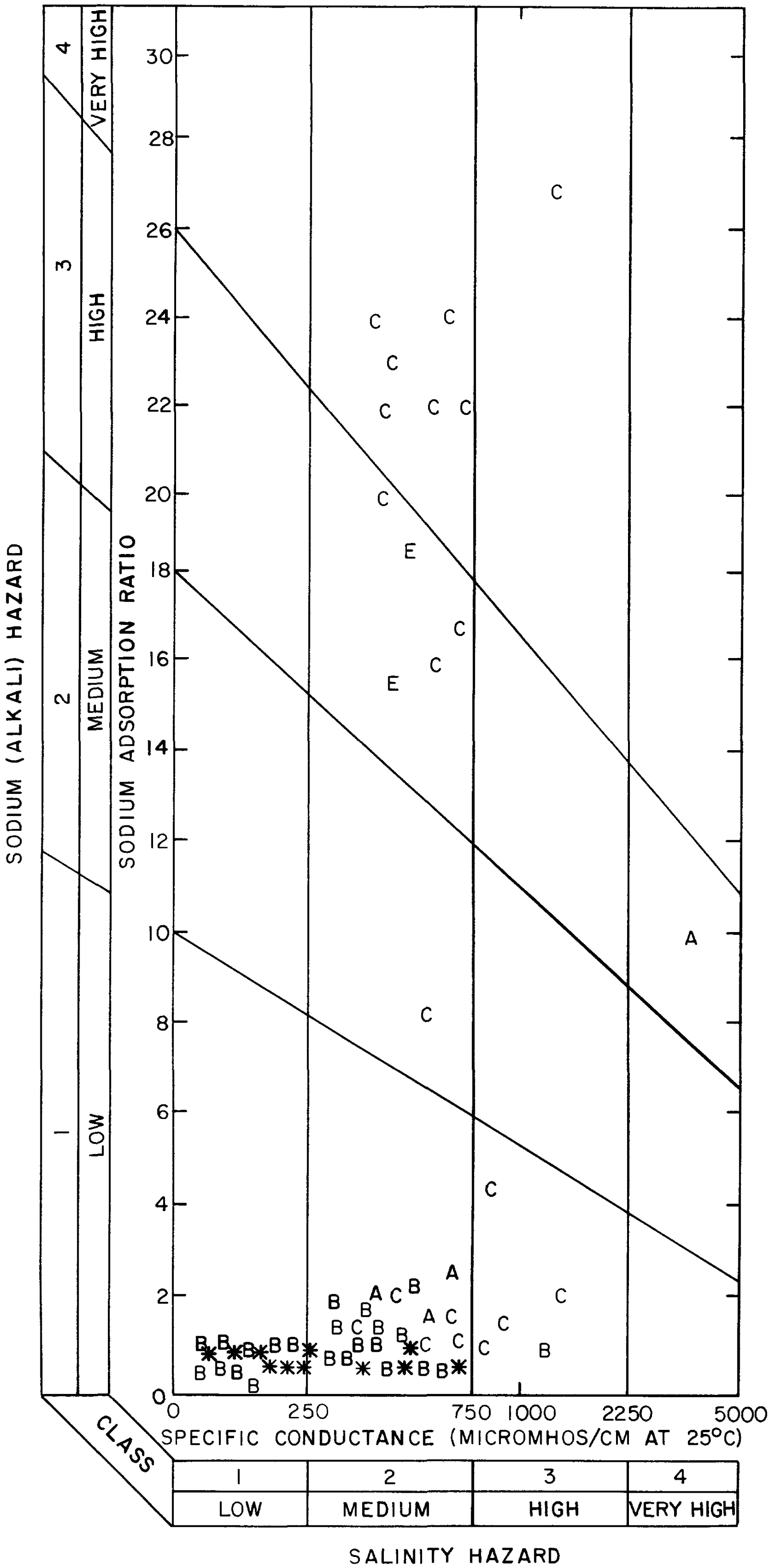


EXPLANATION

- ✱ More than one sample, variable temperature
- ○ Cold
- □ Warm
- △ Hot

	MEDIAN CONDUCTANCE	MEDIAN SAR
COLD	238	.7
WARM	310	1.2
HOT	382	20

Figure 16a. -- Salinity and sodium hazards of ground water, Elmore County, by water temperature class.



EXPLANATION

* More than one sample, geologic unit varies

A Alluvium

B Bruneau Formation of Idaho Group

C Idaho Group, undifferentiated

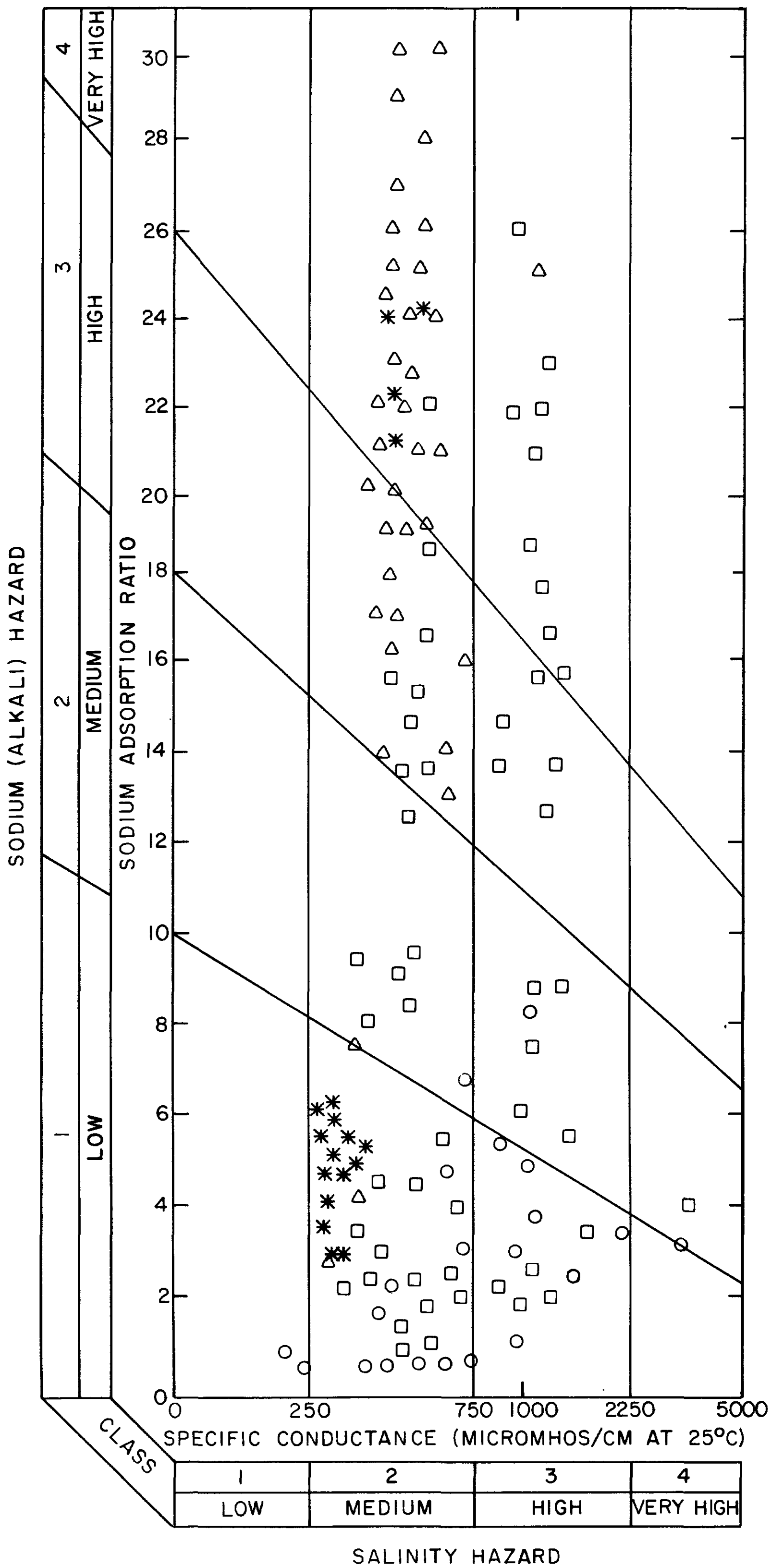
D Banbury Basalt of Idaho Group

E Silicic volcanics

GEOLOGIC UNIT	MEDIAN CONDUCTANCE	MEDIAN SAR
A	508	1.9
B	212	.7
C	565	1.9
D	1/--	1/--
E	1/--	1/--

1/ Less than four analyses available

Figure 16b. -- Salinity and sodium hazards of ground water, Elmore County, by geologic unit.



EXPLANATION

✱ More than one sample, variable temperature

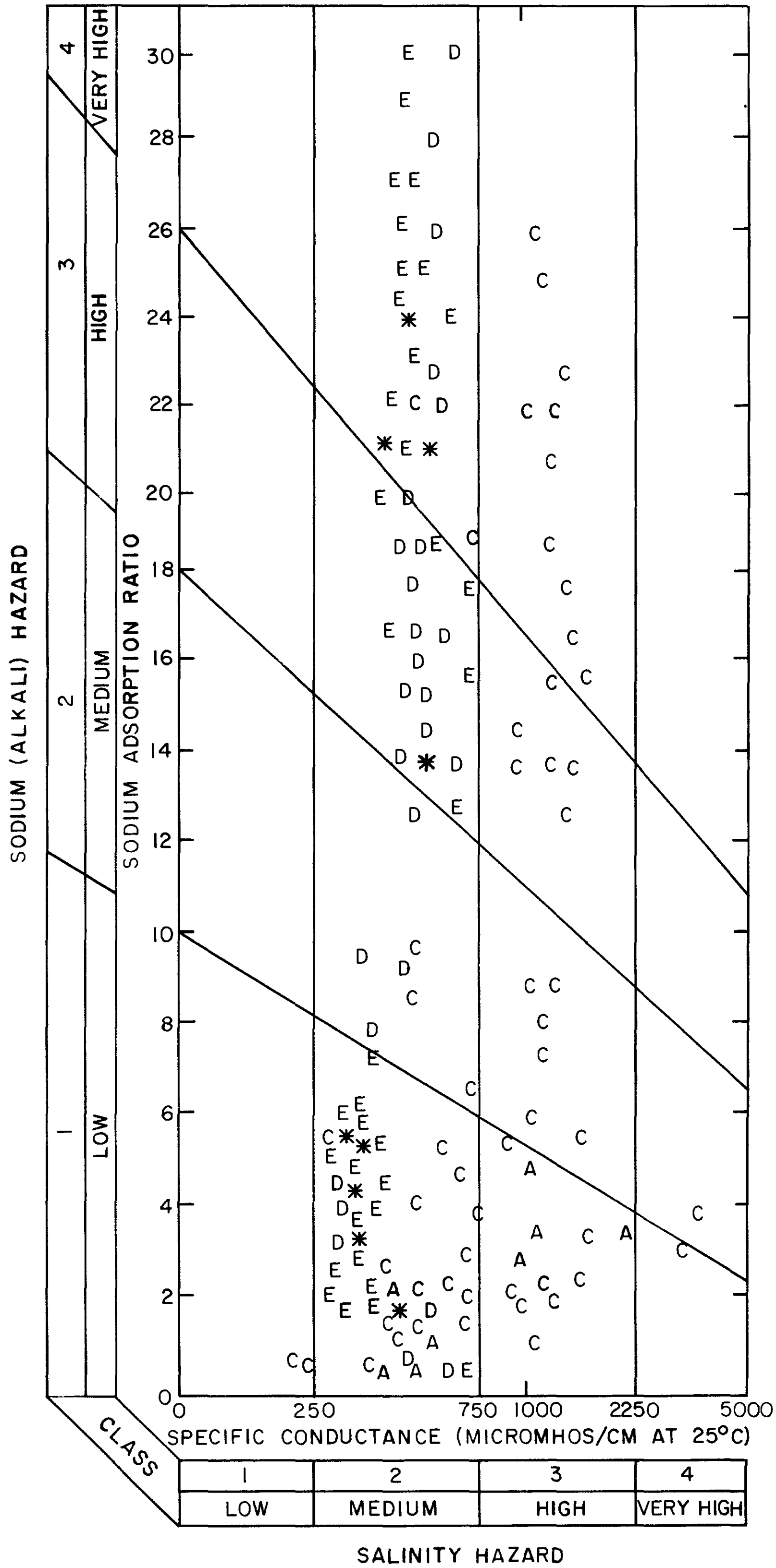
○ Cold

□ Warm

△ Hot

	MEDIAN CONDUCTANCE	MEDIAN SAR
COLD	672	2.4
WARM	447	5.6
HOT	422	19

Figure 16c. -- Salinity and sodium hazards of ground water, Owyhee County, by water temperature class.



EXPLANATION

- ✱ More than one sample, geologic unit varies
- A Alluvium
- B Bruneau Formation of Idaho Group
- C Idaho Group, undifferentiated
- D Banbury Basalt of Idaho Group
- E Silicic volcanics

GEOLOGIC UNIT	MEDIAN CONDUCTANCE	MEDIAN SAR
A	729	2
B	1/--	1/--
C	715	5.6
D	433	14
E	359	6.2

1/ Less than four analyses available

Figure 16d. -- Salinity and sodium hazards of ground water, Owyhee County, by geologic unit.

to high-hazard water in Owyhee County for irrigation may be limited to salt-tolerant crops (table 9) in areas that have adequate drainage for soil-salinity management.

Dissolved boron is essential to the normal growth of all plants but the amount required is very small. Excess boron may injure plants. Boron requirements and tolerance to excessive boron vary among plant species (table 10). Lowest boron concentrations are in cold and warm water wells completed in alluvium, Bruneau Formation, and Idaho Group units, Elmore County. Highest boron concentrations are in warm and hot water wells completed in Idaho Group, Banbury Basalt, and silicic volcanics units, Elmore and Owyhee Counties.

Trace-element concentrations that exceed criteria (table 7) for irrigation water include dissolved arsenic, iron, manganese, and selenium (figs. 15a and 15b). Available trace-element data may be used as the basis for future ground-water quality studies but are not discussed further in this report, owing to the relatively few analyses available for comparison.

Temporal Variation in Water-Quality Characteristics

An analysis of a water sample represents the quality of water in a very small part of an aquifer at a particular instant in time. Quality of ground water is not constant, and a comparison of current and historic data for a particular sampling site may show temporal change in one or more quality characteristics.

Short-term changes most often are due to seasonal fluctuations in volume or quality of recharge to aquifers. Long-term changes are also the result of varying volume or quality of recharge to aquifers but are observed as trends in data over extended periods of time (several years or more). Trends may show either improvement or degradation of water quality, but in most instances, reflect the effects of changing land- and water-use practices.

Reliability of available data is an important consideration when comparing analyses. Some apparent change in water-quality characteristics may be based on inaccuracies in data, the result of improvements in water-data collection techniques or onsite and laboratory analytical methods, or perhaps errors in data transcription or recording. Accuracy of data in this report has been checked by several techniques that include cation-anion balance, specific conductance to DS ratio, and comparison of characteristic concentrations (to detect possible gross reporting errors). Some historical analyses, however, lack one or more components necessary for these data checks.

Table 9.--Relative tolerance of selected crops to salt[1/]
(Modified from U.S. Salinity Laboratory Staff, 1954)

FRUIT CROPS

High salt tolerance	Medium salt tolerance	Low salt tolerance
	Grape	Pear
	Cantalope	Apple
		Plum
		Apricot
		Peach
		Strawberry

FIELD CROPS

High salt tolerance	Medium salt tolerance	Low salt tolerance
Barley	Rye (grain)	Field beans
Sugar beet	Wheat (grain)	
	Oats (grain)	
	Corn (field)	
	Sunflower	

VEGETABLE CROPS

High salt tolerance	Medium salt tolerance	Low salt tolerance
Garden beets	Tomato	Radish
Asparagus	Broccoli	Celery
Spinach	Cabbage	Green beans
	Bell pepper	
	Cauliflower	
	Lettuce	
	Sweet corn	
	Potatoes	
	Carrot	
	Onion	
	Peas	
	Squash	
	Cucumber	

FORAGE CROPS

High salt tolerance	Medium salt tolerance	Low salt tolerance
Salt grass	Sweet clover(s)	White Dutch clover
Alakali grass	Perennial ryegrass	Red clover
Bermuda grass	Alfalfa	
Fescue grass	Fescue	
Western wheatgrass	Rye (hay)	
Barley (hay)	Wheat (hay)	
	Oats (hay)	
	Milkvetch	

[1/] Salt tolerance decreases down each list

Table 10.--Relative tolerance of selected crops to boron[1/]
(Modified from U.S. Salinity Laboratory Staff, 1954)

FRUIT CROPS			FIELD CROPS		
Tolerant[2/]	Semitolerant[3/]	Sensitive[4/]	Tolerant[2/]	Semitolerant[3/]	Sensitive[4/]
		Pecan	Sugar beet	Sunflower	
		Black walnut		Barley	
		English walnut		Wheat	
		Plum		Corn	
		Pear		Oats	
		Apple			
		Grape			
		Cherry			
		Peach			
		Apricot			
		Thornless blackberry			

VEGETABLE CROPS			FORAGE CROPS		
Tolerant[2/]	Semitolerant[3/]	Sensitive[4/]	Tolerant[2/]	Semitolerant[3/]	Sensitive[4/]
Asparagus	Potato	Jerusalem artichoke	Alfalfa	Barley	
Garden beet	Tomato	Navy bean		Wheat	
Broad bean	Radish			Corn	
Onion	Field pea			Oats	
Turnip	Pumpkin				
Cabbage	Bell pepper				
Lettuce	Sweet potato				
Carrot	Lima bean				

1/ Tolerance decreases down each list
2/ 2,000 µg/L boron maximum
3/ 1,000 µg/L boron maximum
4/ 750 µg/L boron maximum

Thirty-nine of the total 208 wells for which water-quality data are available (Parliman, 1983) have been resampled periodically since 1950. Locations of the 39 wells are shown in figure 17. Intervals of time between samples (sampling periods) and number of times a particular site has been sampled are highly variable. Sampling periods range from less than 1 month to 19.5 years, and the number of analyses from each site ranges from 2 to 17. Data for comparison are generally sparse.

Twelve of the 39 wells have four or more analyses (fig. 17). Graphical comparisons of specific conductance and concentrations of dissolved chloride and sulfate for samples from these 12 wells are shown in figures 18a-18ℓ. Graphs are grouped by well location; scales for x and y axes vary by graph, depending on sampling period and range of constituent concentrations.

Relatively small variations depicted in figures 18a-18g probably are due to changes in source or amount of recharge to aquifers. Larger variations and trends of increasing concentrations also may be due to recharge fluctuations but more likely are the result of the effects of land- and water-use practices.

Concentrations of selected constituents in figures 18b-18g show long-term increases, which in several instances, exceeded maximum drinking water limits during the sampling period. Land-use activities such as concentrated urban housing and septic-tank usage may be influencing ground-water quality in this area.

A program of periodic resampling of selected wells, such as that suggested in Whitehead and Parliman (1979), would be helpful in evaluating changes in major dissolved constituents in study area aquifers.

EFFECT OF THERMAL IRRIGATION WATER ON QUALITY OF SHALLOW AQUIFERS

Warm or hot water (thermal) wells are used throughout the study area for irrigation purposes because wells completed in the thermal water aquifers have generally higher yields than wells completed in cold water aquifers (table 1). Thermal water used for irrigation in excess of that consumptively used by the crop may recharge and affect the quality of shallow aquifers, and excessive concentrations of some constituents in thermal water, such as fluoride, sodium, or boron, may contaminate shallow aquifers.

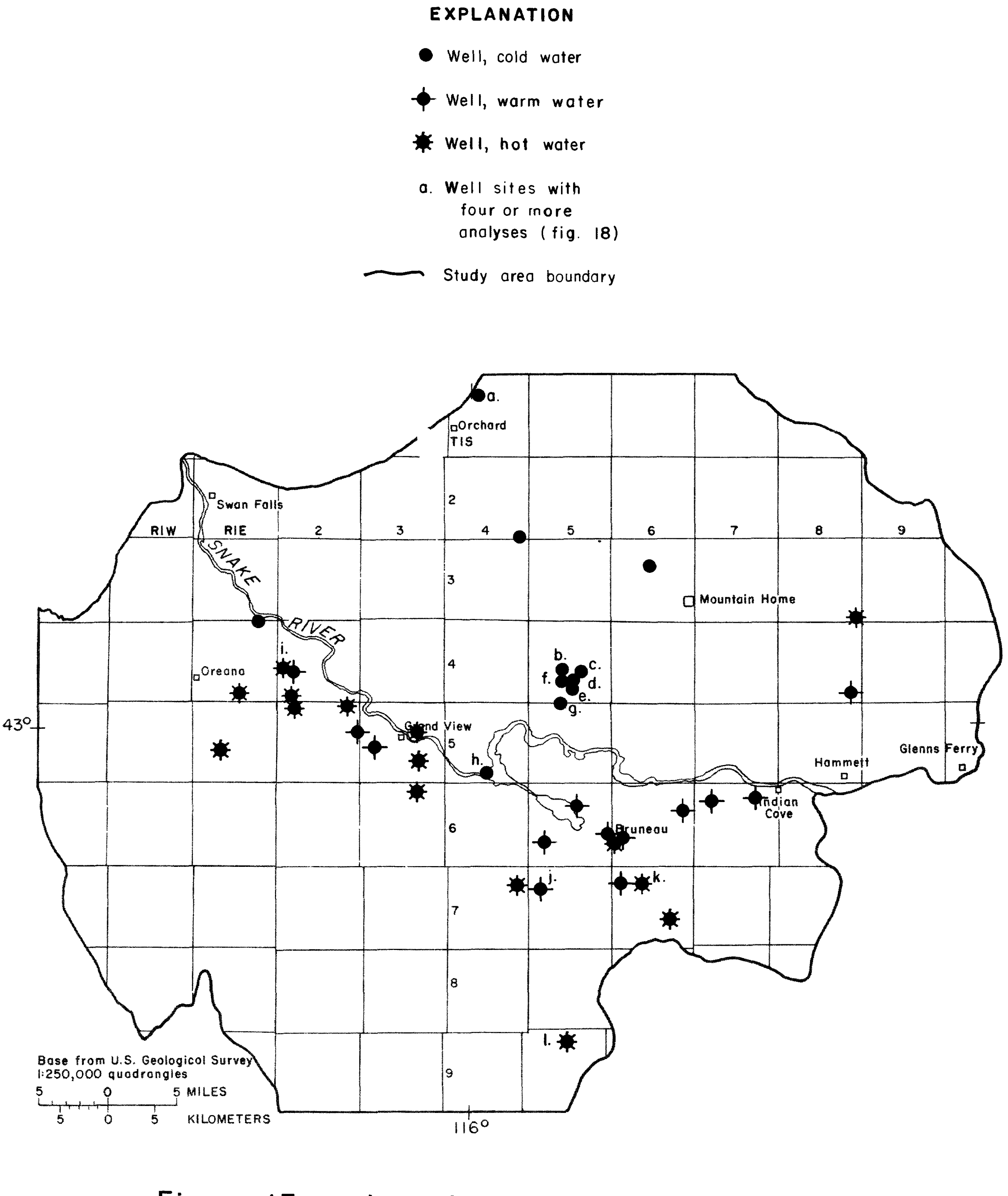


Figure 17. -- Locations of wells with multiple water-quality analyses.

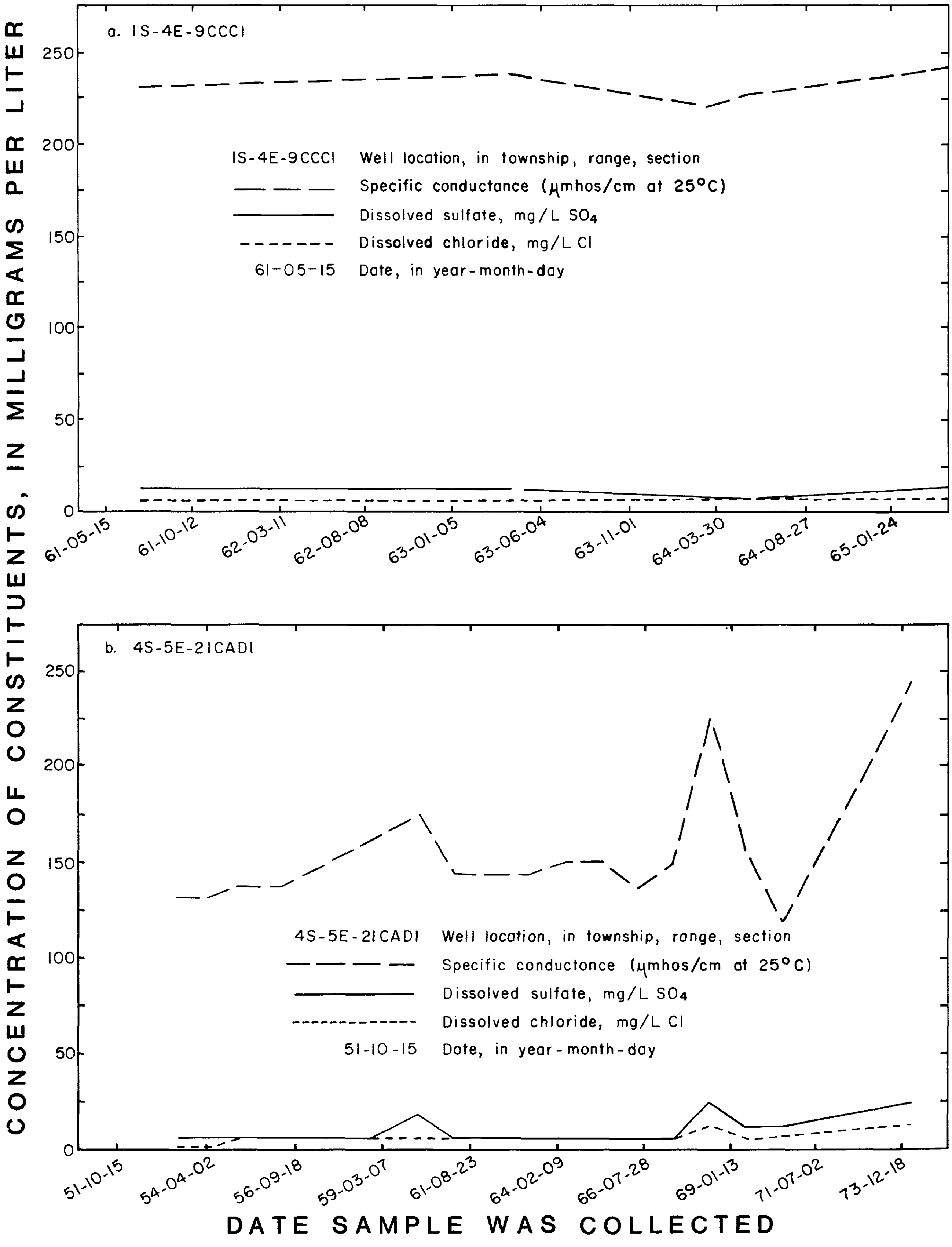


Figure 18. -- Temporal variation in specific conductance and concentrations of dissolved sulfate and chloride, selected wells.

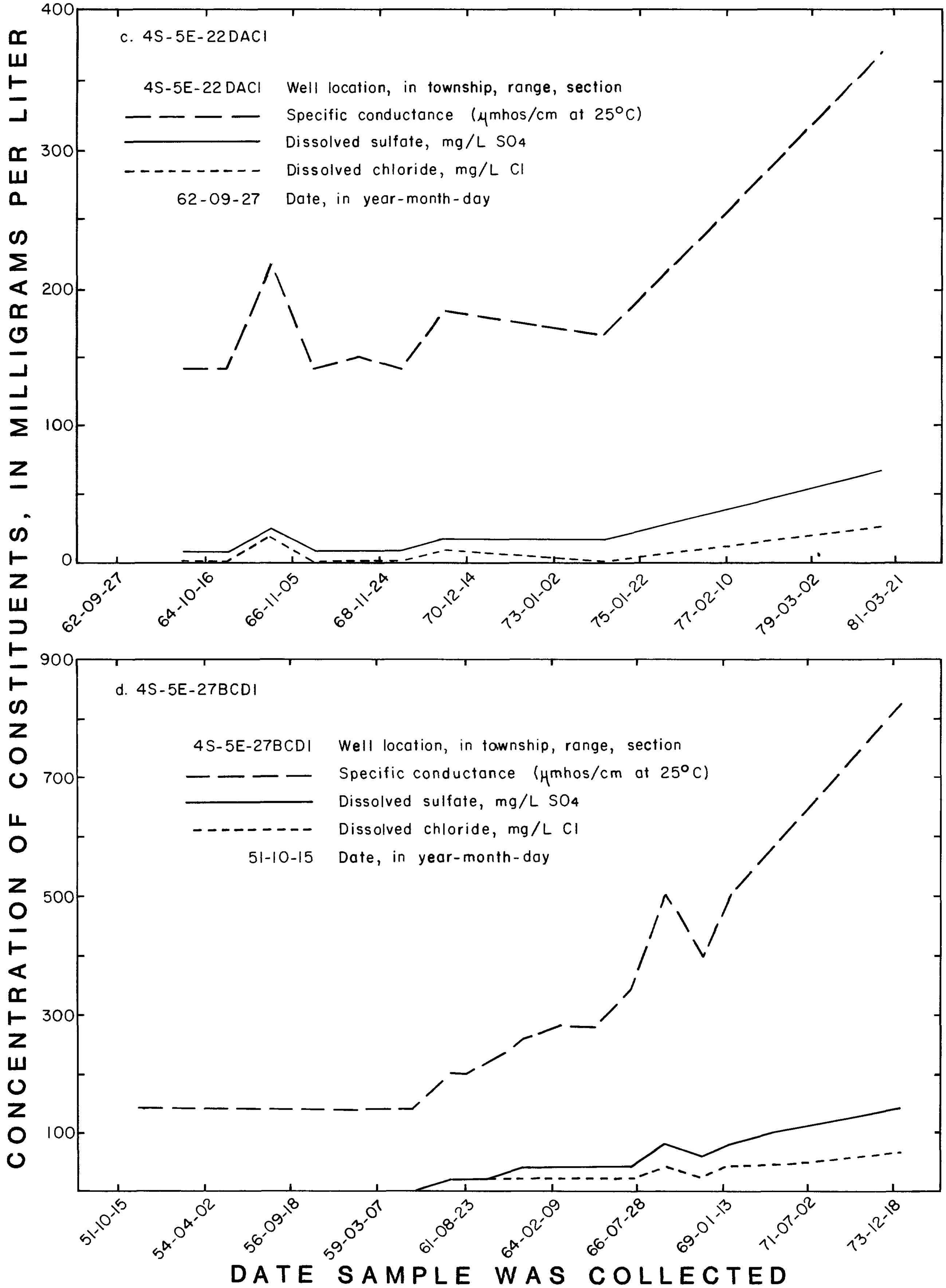


Figure 18. -- Temporal variation in specific conductance and concentrations of dissolved sulfate and chloride, selected wells--continued.

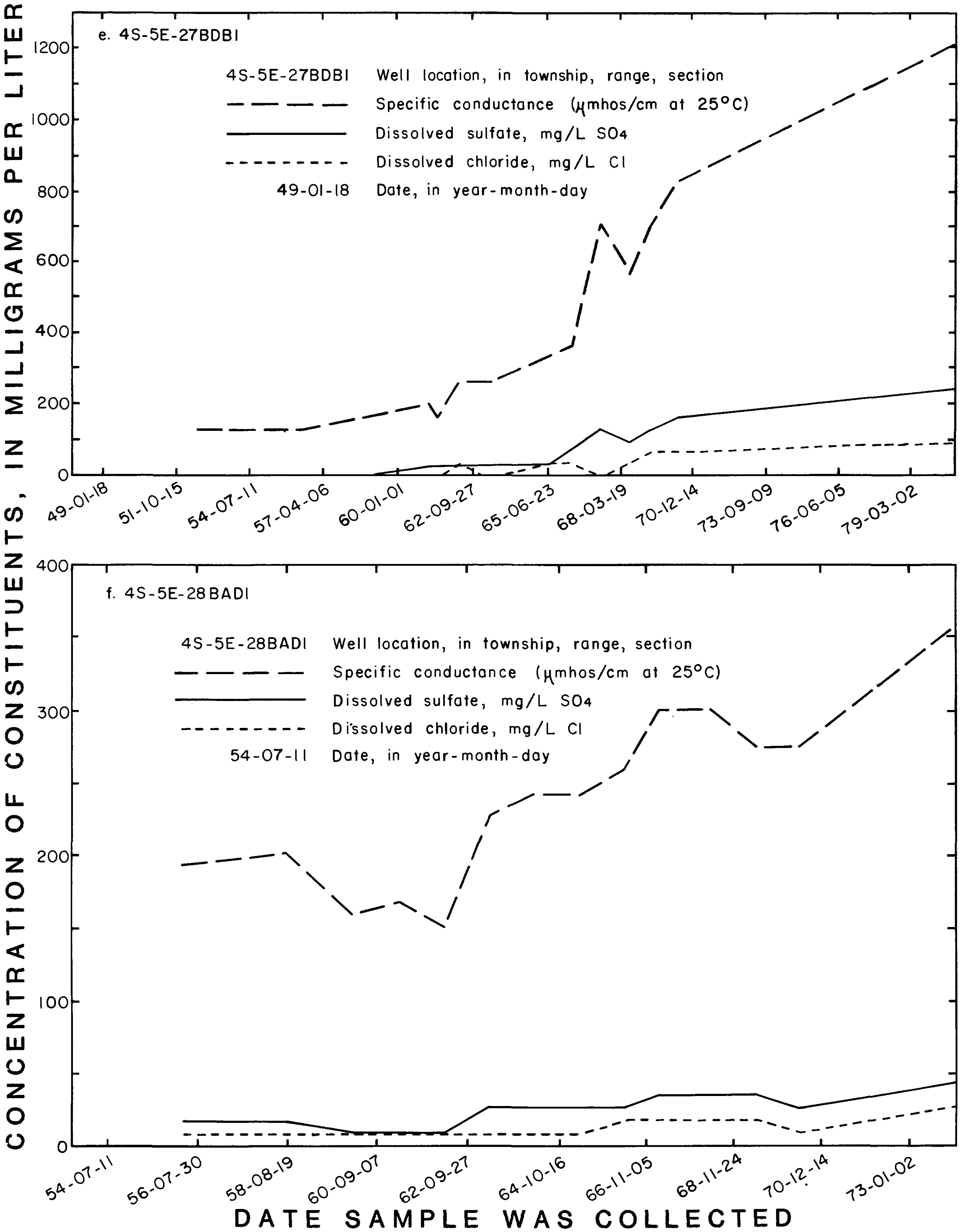


Figure 18. -- Temporal variation in specific conductance and concentrations of dissolved sulfate and chloride, selected wells--continued.

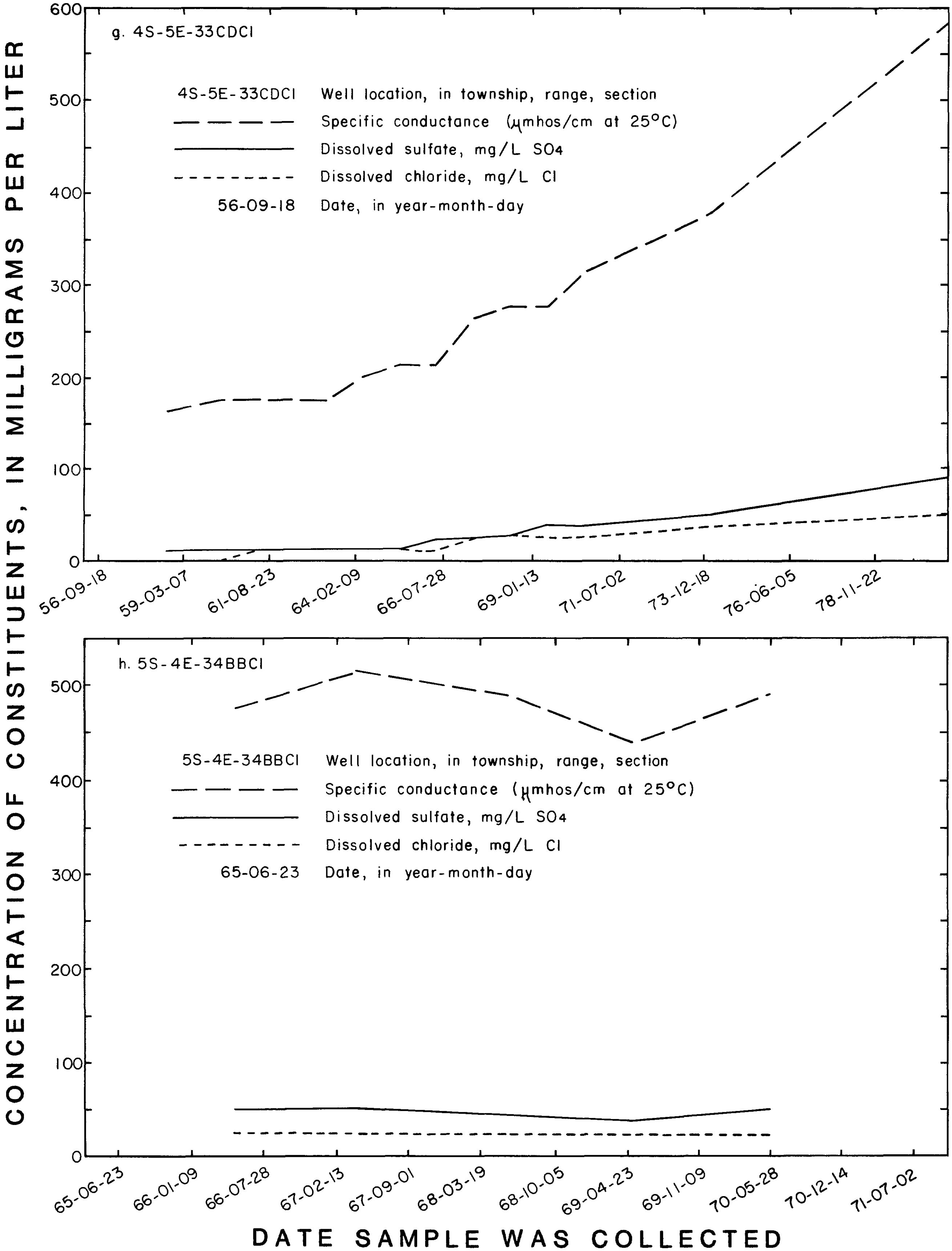


Figure 18. -- Temporal variation in specific conductance and concentrations of dissolved sulfate and chloride, selected wells--continued.

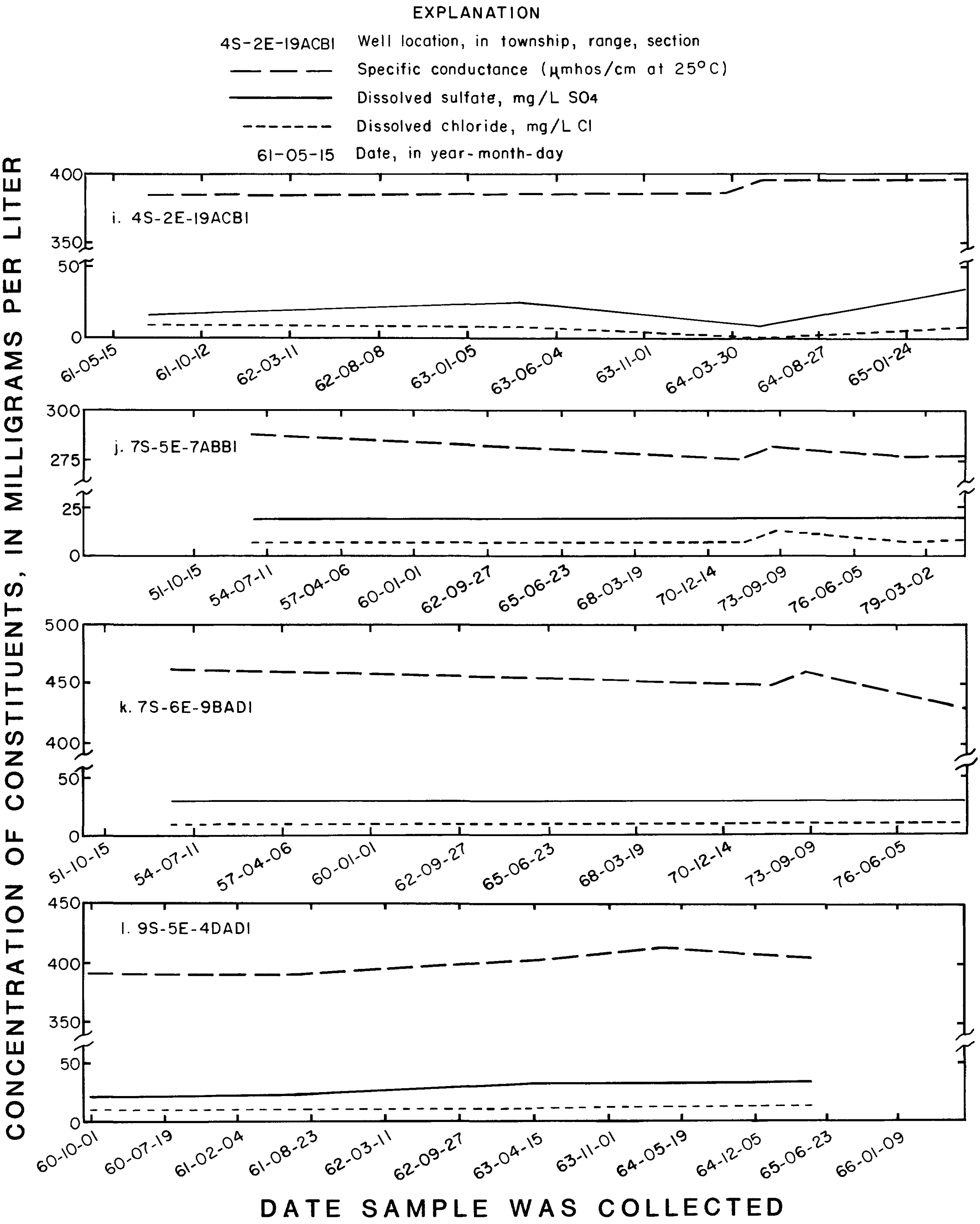


Figure 18. -- Temporal variation in specific conductance and concentrations of dissolved sulfate and chloride, selected wells--continued.

Effects of thermal irrigation water on quality of shallow ground water are difficult to define because (1) mixing of thermal water and cold water by upward leakage or interaquifer flow is relatively common; (2) shallow ground water is susceptible to contamination from many land- and water-use activities besides irrigation; and (3) historic, pre-irrigation water-quality data from shallow aquifers for background comparison are sparse. Generalized observations may be made, however, on the basis of comparisons of available data from shallow, cold water aquifers and deep, thermal water aquifers in the study area (table 11 and figure 19):

1. Chemical constituents shown in table 11 most often have high concentrations in thermal water and low concentrations in cold water.

2. Cold ground water in Owyhee County contains generally higher overall concentrations of silica, fluoride, and sodium than cold ground water in Elmore County (dissolved boron concentrations are not compared because there are so few data for cold ground water). In Owyhee County, more land is irrigated with thermal water, cold water wells are more often adjacent to or downgradient from thermal water wells, and fault systems may be more frequent or complex than in Elmore County.

3. Cold ground water in areas where land generally is not irrigated with thermal water (northeast of Oreana, north of Grand View, or near Mountain Home) contains relatively low concentrations of dissolved fluoride and sodium. Exceptions are in the Hammett and Glenns Ferry area in Elmore County, where fluoride and sodium concentrations may be relatively high in shallow ground water. Elevated fluoride and sodium concentrations in shallow wells in easternmost Elmore County probably are due to near-surface interaquifer mixing or infiltration of thermal water from springs or flowing, unused wells near shallow well sites.

4. On the basis of available data, dissolved fluoride concentrations may be more useful as indicators of thermal water effects than pH, dissolved silica, or sodium. The pH and solubility of silica are reduced rapidly with lowering water temperatures and atmospheric pressure. Dissolved sodium concentrations may be reduced during infiltration by the interaction of sodium with cations in soils. Dissolved fluoride is more stable than pH, dissolved silica, or sodium, but also may be complexed by soils during infiltration. If further ground-water quality samples are collected in the study area, dissolved boron concentrations would be preferred indicators of thermal water effects because boron is generally more stable under changing environmental conditions than pH, dissolved silica, sodium, or fluoride.

Headnotes for Table 11

Notations: --, not analyzed or data not available

Units: DEG C, degrees Celsius; water temperature reported to the nearest 0.5 degree

MG/L, milligrams per liter
UG/L, micrograms per liter (milligrams x 1/1,000)

Geologic unit: Computer notation for major water-yielding formations (see table 1)

110ALVM, alluvium (Qaw)
111ALVM, alluvium (Qaw)
112BRUN, Bruneau Formation of Idaho Group (Qbf)
112GLFR, Idaho Group undifferentiated (QTiu)
112MEON, terrace gravels (Qg)
112IDHO, Idaho Group (QTiu)
121BNBR, Banbury Basalt of Idaho Group (Tb)
121IDVD, silicic volcanics (Tsv)

Depth to first perforation or end of casing:

X, open hole
Ø, open end
P, perforated
S, screen
G, gravel

Table 11.--Comparison of selected water-quality characteristics by water temperature

Well location	DATE OF SAMPLE	GEO-LOGIC UNIT	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO FIRST PER-FORATION OR END OF CASING (FEET)	PH (UNITS)	TEMPER-ATURE (DEG C)	SILICA, DIS-SOLVED (MG/L AS SIO2)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SODIUM, DIS-SOLVED (MG/L AS NA)	BORON, DIS-SOLVED (UG/L AS B)
ELMORE COUNTY: Cold water (less than 20°C)										
03S 06E 23BDD1	80-11-25	110ALVM	19	—	6.9	10.5	28	.1	39	--
03S 06E 26CAC1	80-11-21	110ALVM	19	—	6.9	12.5	49	.3	17	--
03S 06E 35ABB1	76-08-09	111ALVM	14	14Ø	7.0	12.5	37	.4	42	--
03S 07E 31CAB1	80-11-20	112BRUN	73	15X	7.4	11.0	53	.1	34	--
05S 03E 10AAA1	80-08-20	112GLFR	120	97X	7.7	17.0	59	.3	19	--
05S 08E 34BDC2	80-09-12	112MEON	60	—	7.7	17.0	56	2.6	75	140
05S 08E 36BDD1	80-09-17	112GLFR	51	39P	7.4	16.0	68	.8	33	--
05S 09E 13ACD1	80-09-11	110ALVM	37	35X	7.9	17.5	50	2.9	550	1200
05S 09E 27DBB1	80-09-15	112GLFR	130	30P	6.8	18.0	70	1.1	35	--
05S 09E 31ACC1	80-09-16	112GLFR	117	77X	7.7	16.0	67	1.0	48	--
05S 10E 32BBA1	80-09-15	112GLFR	150	72S	7.6	15.5	36	.1	65	--
ELMORE COUNTY: Warm water (20° to 40°C)										
04S 07E 19BDB1	76-08-10	112BRUN	605	380X	8.0	26.0	65	1.0	27	--
05S 04E 05CAA1	76-08-11	112BRUN	600	225P	8.4	21.0	37	.3	12	--
ELMORE COUNTY: Hot water (greater than 40°C)										
03S 08E 36CDA1	72-08-14	112GLFR	600	470X	8.8	58.0	86	17	87	--
	80-09-10	112GLFR	600	--	9.4	58.5	86	18	87	130
04S 08E 01DBA1	80-09-10	112GLFR	1440	932X	9.4	52.0	88	18	89	100
04S 09E 08AB1	72-08-29	112IDHO	1175	175X	8.7	62.0	85	16	82	--
OWYHEE COUNTY: Cold water										
03S 01W 30CDD1	80-08-20	110ALVM	32	32Ø	6.5	15.0	38	.3	15	40
03S 01W 31BAA1	80-08-20	110ALVM	80	11.25	6.7	14.5	--	.3	17	70
05S 02E 12ACA1	80-08-20	110ALVM	50	—	7.6	16.5	47	.8	140	--
05S 02E 12BBD1	80-08-20	110ALVM	74	74Ø	7.5	17.0	54	.7	160	270
05S 03E 22BBB2	80-08-21	112IDHO	131	104S	7.8	19.0	46	.6	55	--
06S 04E 03BCC1	80-09-11	112IDHO	98	95X	7.3	17.5	59	.7	130	--
06S 04E 35ADD2	80-09-03	112IDHO	110	75P	7.0	16.5	45	1.5	250	--
06S 06E 11CCC1	80-08-26	112IDHO	160	67S	8.1	17.0	42	1.3	79	--
06S 05E 25AAA1	80-09-03	112IDHO	55	45X	7.4	16.5	68	2.7	42	--
OWYHEE COUNTY: Warm water										
04S 01E 25CCD1	73-07-24	112IDHO	--	—	7.3	30.0	120	.6	310	1000
04S 01E 26ABC1	73-06-08	112IDHO	1700	1700Ø	7.3	27.0	96	.6	250	780
05S 02E 02CDA1	73-06-07	112IDHO	2460	160X	7.6	36.5	89	6.4	250	1200
06S 04E 25BCC1	73-06-26	112IDHO	1750	290X	7.8	20.0	73	3.9	95	130
06S 04E 35CDA1	73-06-26	112IDHO	955	730P	8.5	32.5	96	8.0	47	100
06S 05E 35CCA1	73-07-19	112IDHO	460	352X	9.1	22.0	73	6.9	54	100
06S 06E 12CCB1	72-06-15	112GLFR	990	915G	7.3	37.0	100	5.6	170	--
	73-07-06	112GLFR	990	--	8.2	37.0	120	5.9	180	1100
	80-08-26	112GLFR	990	--	8.0	37.0	110	6.2	170	1300
07S 03E 04ACD1	73-06-08	121BNBR	804	300X	7.4	34.0	94	1.7	31	80

Table 11.--Comparison of selected water-quality characteristics by water temperature--Continued

Well location	DATE OF SAMPLE	GEO-LOGIC UNIT	DEPTH OF WELL, TOTAL (FEET)	DEPTH TO FIRST PER-FORATION OR END OF CASING (FEET)	PH (UNITS)	TEMPER-ATURE (DEG C)	SILICA, DIS-SOLVED (MG/L AS SIO2)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)	SODIUM, DIS-SOLVED (MG/L AS NA)	BORON, DIS-SOLVED (UG/L AS B)
OWYHEE COUNTY: Warm water--cont'd.										
07S 04E 05CCA1	73-06-27	121BNBR	1040	292X	7.7	30.0	96	2.0	54	120
07S 04E 10BDB1	73-06-11	121BNBR	1145	537P	8.6	37.5	99	9.4	47	110
07S 04E 11CBC1	73-06-12	121IDVD	1500	720X	8.3	36.0	99	8.2	45	100
07S 04E 14ABC1	73-06-12	121IDVD	1146	223X	8.6	39.0	96	6.0	45	110
07S 04E 15ACD1	73-06-12	121IDVD	1065	246X	8.0	33.0	100	14	48	110
07S 04E 23CBB1	73-06-13	121IDVD	810	326X	8.4	38.5	96	10	58	--
07S 05E 05DBC1	73-06-25	121BNBR	2405	1300	9.0	32.0	75	8.2	63	170
07S 05E 07ABB1	53-11-23	121IDVD	1625	632	7.0	39.0	88	10	52	--
	72-06-14	121IDVD	1625	--	8.5	39.0	81	9.7	50	--
	73-07-06	121IDVD	1625	--	8.5	39.0	91	9.7	51	90
	78-06-13	121IDVD	1625	--	8.7	39.5	77	9.4	52	100
	80-08-27	121IDVD	1625	--	8.8	39.0	80	11	52	120
07S 05E 07ABD2	53-11-23	121IDVD	500	300X	7.8	23.0	78	6.0	--	--
07S 05E 16ACD1	73-05-30	121IDVD	1515	389X	8.7	39.5	90	16	56	90
07S 05E 18BCD1	53-11-24	121BNBR	517	254X	8.2	33.5	90	9.0	50	80
07S 05E 19CCC1	73-07-23	121IDVD	760	309X	8.4	36.5	95	12	55	110
	80-08-27	121IDVD	760	--	8.7	25.0	100	13	62	110
07S 06E 07AAC1	53-11-24	121BNBR	1086	342X	9.4	32.0	120	12	--	--
	73-07-19	121BNBR	1086	--	9.2	25.0	100	10	61	140
OWYHEE COUNTY: Hot water										
04S 01E 29CCD1	73-06-05	121IDVD	3040	517X	9.2	70.0	83	12	100	150
04S 01E 34BAD1	72-06-06	121IDVD	2980	2160X	7.9	75.0	83	12	98	--
	73-07-09	121IDVD	2980	--	9.2	--	91	13	99	150
	78-06-13	121IDVD	2980	--	9.2	76.5	77	13	110	150
	82-04-30	121IDVD	2980	--	9.5	75.5	--	--	--	--
	82-07-16	121IDVD	2980	--	9.2	76.0	77	13	98	140
04S 02E 32BCC1	57-04-24	121IDVD	2704	700X	8.8	43.0	99	10	--	--
	72-06-06	121IDVD	2704	--	8.2	42.0	94	7.7	150	--
	73-07-09	121IDVD	2704	--	8.8	43.0	110	8.7	150	1000
05S 03E 20ADA1	73-07-12	121IDVD	2420	1620X	9.6	60.0	110	19	85	780
05S 03E 25BCB1	72-06-12	121IDVD	2970	1970X	7.6	84.5	110	30	110	--
	73-06-07	121IDVD	2970	--	9.3	83.0	110	15	110	570
	78-06-13	121IDVD	2970	--	9.3	81.0	110	15	120	550
	82-04-30	121IDVD	2970	--	9.5	81.5	--	--	--	--
	82-07-16	121IDVD	2970	--	9.0	81.0	110	13	110	550
05S 03E 28BCC1	73-05-31	121IDVD	2540	1860X	9.4	65.0	98	21	97	620
06S 03E 05CAC1	73-06-04	121IDVD	3600	1120X	8.6	51.0	94	11	59	150
06S 04E 14ABC1	73-05-30	121IDVD	1905	1600X	9.5	54.0	140	24	110	540
07S 04E 01ACC1	73-05-21	121IDVD	1800	1800Ø	8.6	40.0	83	9.7	53	100
07S 04E 03ABD1	73-06-26	121BNBR	1142	399X	8.4	42.0	95	8.9	46	120
07S 04E 12BDD1	53-11-23	121IDVD	1105	675X	7.5	33.5	94	7.0	54	150
	73-05-21	121IDVD	1105	--	8.7	43.0	96	8.7	51	100
07S 05E 08CCC1	73-05-21	121IDVD	1500	200X	8.7	40.0	90	11	55	110
07S 05E 09DDD1	73-06-14	121IDVD	2065	550X	9.0	40.0	89	11	50	60
07S 06E 16CDC1	73-06-14	121BNBR	513	389X	8.5	42.5	81	8.9	49	60
07S 06E 22AAD1	73-05-22	121IDVD	1410	400X	8.0	45.0	86	3.7	40	90
07S 06E 23DCB1	53-11-23	121BNBR	1220	365	8.2	40.5	86	4.0	--	--

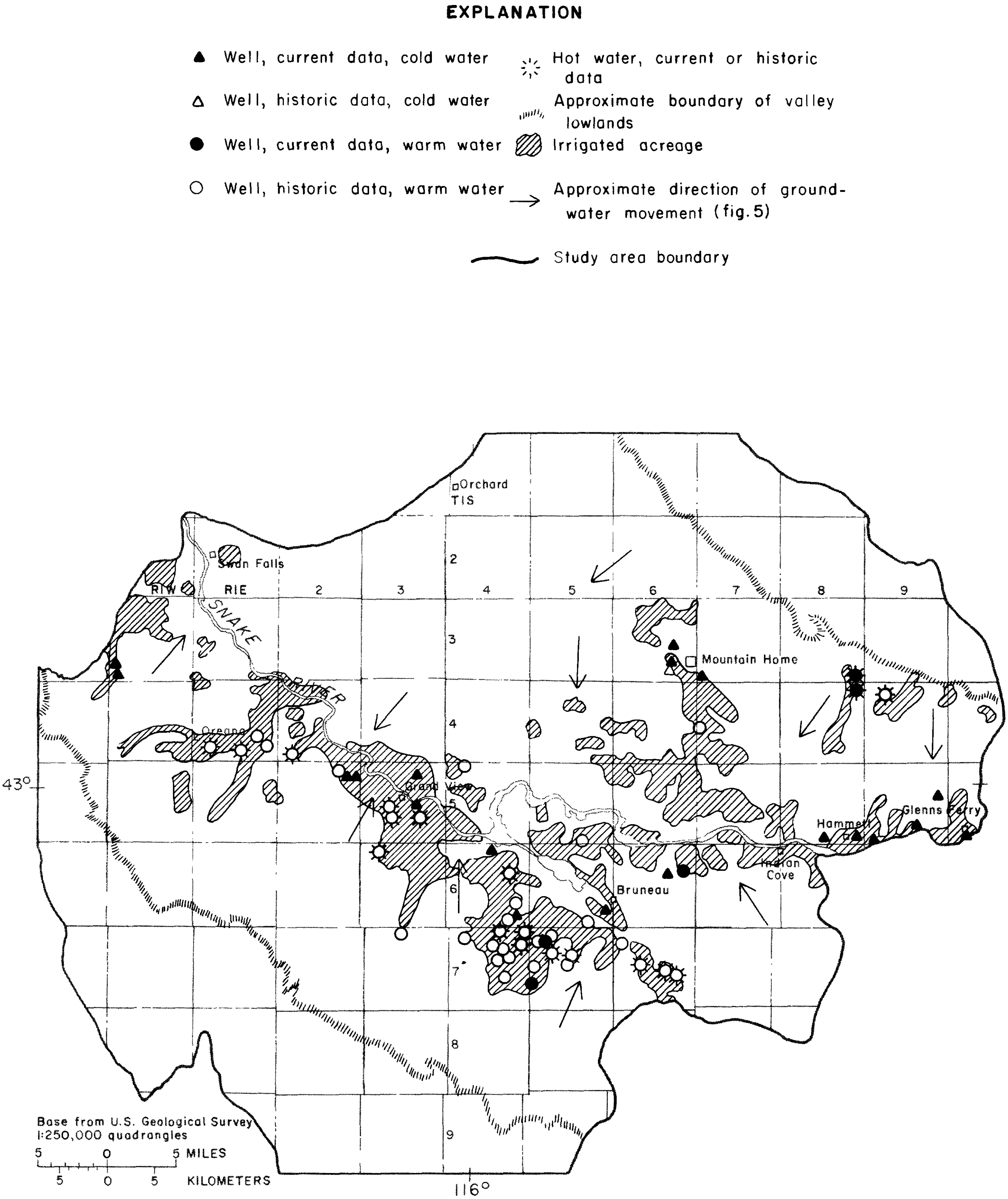


Figure 19. -- Locations of cold water wells, less than 150 feet total depth, and warm or hot water wells, total depth of casing exceeding 175 feet below land surface.

SUMMARY

From August to November 1980, water-quality, geologic, and well-inventory data were collected from 92 wells in the western Snake River basin, Swan Falls to Glenns Ferry. Historic water-quality and well-inventory data were compiled for 116 wells to provide data in areas where current data were not available. Current and historic data also were used to assess possible changes in water quality with time or owing to infiltration of thermal irrigation water to shallow aquifers.

The study area comprises 2,700 mi^2 and includes southeastern Ada, southern Elmore, and north-central Owyhee Counties. Geomorphic features include northwest-trending mountain ranges, foothills, high plateaus, and lowlands (the western Snake River Plain).

Geologic units in the area include Quaternary alluvium, terrace gravels, basalts of the Snake River Group, and Bruneau Formation of the Idaho Group; Quaternary and Tertiary Idaho Group, (undifferentiated) Banbury Basalt of the Idaho Group, and silicic volcanics; and Cretaceous intrusive rocks (basement complex). Major structural features include complex regional systems of generally northwest-trending faults and a massive topographic depression or basin, the Snake River Plain. Structural features associated with volcanic events include dikes, volcanic rocks, cinder cones, domes, and shield volanoes.

Recharge to aquifers in foothills, uplands, and mountains is primarily from infiltration of precipitation. Recharge to aquifers in lowlands is primarily from interaquifer flow and infiltration of water from the land surface. The amount of recharge to ground-water systems is affected primarily by fault structures and composition of geologic units. Faulted areas are highly permeable zones and allow vertical downward movement of recharge to deep aquifers and upward leakage of thermal, artesian recharge to shallow aquifers.

All geologic units contain some ground water. Aquifers in alluvium, Bruneau Formation, Idaho Group, Banbury Basalt, and silicic volcanics units are the most common sources of ground water in the study area. Quality of water yielded from thermal, highly mineralized aquifers in Idaho Group, Banbury Basalt, and silicic volcanics units may limit water use more than well yields.

Ground-water movement is generally toward the Snake River. Movement in confined aquifers is probably similar to that in unconfined aquifers. Movement in perched-water tables is downward.

Factors affecting ground-water quality include geochemical environment, geochemical properties of aquifer materials, mixing of aquifer waters, proximity to source of recharge, and influences of man's land- and water-use practices. Composition of aquifer materials, ground-water temperature, and mixing of aquifer waters are most important to the quality of ground water in the study area.

Hot water in primarily Idaho Group, Banbury Basalt, and silicic volcanics units is probably the result of deep circulation of water along regional fault systems. Warm water from alluvium, Bruneau Formation, and Idaho Group units is probably the result of mixing of hot and cold waters.

Cold water contains predominantly calcium, magnesium, and bicarbonate plus carbonate ions. Hot water contains predominantly sodium, potassium, and bicarbonate plus carbonate ions. Warm water generally has an intermediate chemical composition, owing to mixing of hot and cold waters.

Ground-water quality in the study area is generally acceptable for most uses, although ground water locally contains chemical constituents or physical properties that may restrict its use.

Median DS for all data is 274 mg/L. Highest medians (341 mg/L or greater) are for cold and warm water in alluvium and Idaho Group units, Owyhee County; lowest median (146 mg/L) is for cold water in Bruneau Formation units. Although DS concentrations are calculated from several constituent components, excessively high DS concentrations are usually the result of high concentrations of silica, calcium, sodium, alkalinity, or sulfate. Concentrations of dissolved magnesium, potassium, fluoride, or nitrate rarely exceed 20 mg/L and are minor contributors to DS but may be important to the quality and usability of ground water.

Median nitrate, sulfate, chloride, and total phosphorus values are 0.24 mg/L N, 23 mg/L SO_4, 11 mg/L Cl, and 0.03 mg/L P. Highest median nitrate value (1.2 mg/L N) is for cold water in Bruneau Formation units, Elmore County. Highest median sulfate, chloride, and phosphorus values (68, 18, and 0.04 mg/L, respectively) are generally for cold water in alluvium and Idaho Group units, Owyhee County. Areas where dissolved nitrate concentrations exceed 1 mg/L and concentrations of sulfate, chloride, or total phosphorus are anomalously high may indicate ground-water contamination.

Median fluoride for all data is 1.0 mg/L and range of concentrations is less than 30 mg/L. Highest medians (7.3 mg/L or greater) are for warm water in Owyhee County and hot water in Banbury Basalt or silicic volcanics units, Elmore and Owyhee Counties. Lowest medians (0.8 mg/L or less) are for cold water in Elmore and Owyhee Counties and warm water in alluvium and Bruneau Formation units, Elmore County.

Median hardness for all data available is 49 mg/L $CaCO_3$, soft water. Cold water is moderately hard to hard, warm water is soft, and hot water is very soft. Aquifers in Idaho Group units generally contain the hardest water, and aquifers in Bruneau Formation, Banbury Basalt, and silicic volcanics units contain the softest water.

Median pH for all data is 8.0. Lowest median pH, 7.0, is for cold water in Elmore County. Highest median pH, 9.3, is for hot water in Owyhee County. Warm water has moderate pH.

Median alkalinity for all data is 110 mg/L $CaCO_3$. Highest median alkalinity (180 mg/L or greater) is for cold water in alluvium and Idaho Group units, Elmore and Owyhee Counties, and for warm and hot water, Idaho Group units, Owyhee County. Lowest median (60 mg/L) is for cold water in Bruneau Formation units, Elmore County.

Concentrations of dissolved arsenic, iron, manganese, and selenium exceed EPA public drinking water limits in several ground-water samples in the area. Most concentrations are probably natural--a result of geologic conditions of the area.

Concentrations of most chemical constituents are within tolerance levels for livestock uses. Dissolved fluoride and selenium exceed recommended criteria for livestock in a very few wells in the study area.

Most ground water has a low to medium salinity hazard, a low sodium hazard, and can be used for irrigation on most soils with most crops if a moderate amount of soil leaching occurs. Warm and hot water, from Idaho Group units in particular, may have harmful levels of exchangeable sodium, requiring careful soil and water management. Concentrations of dissolved boron, arsenic, iron, manganese, and selenium may exceed criteria levels for irrigation uses, restricting water use in some areas.

Temporal variations in ground-water quality most often are due to fluctuations in source or amount of recharge to aquifers. Selected constituents in cold water wells south of Mountain Home show consistently increasing concentrations with time, possibly as a result of land-use activities such as septic-tank usage in areas of concentrated urban housing.

Effects of thermal irrigation water on shallow ground-water quality are difficult to define, owing to mixing of cold and thermal water at depth, susceptibility of shallow ground water to contamination from many land- and water-use activities, and the lack of pre-irrigation water-quality data for comparison. Chemical constituent indicators of thermal water contamination are high concentrations of dissolved silica, fluoride, sodium, or boron. Dissolved silica, sodium, and fluoride concentrations are relatively poor long-term indicators because they may be complexed by soils and plants during infiltration. Dissolved boron is a relatively stable indicator, but boron data for cold water in the study area are sparse.

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