GL00471

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
Box 036 Federal Building, Room 365
550 West Fort Street
Boise, Idaho 83724

June 22, 1982

TO: USERS OF GEOTHERMAL DATA

Enclosed is Open-File Report 82-104, "Thermal Springs in the Salmon River Basin, Central Idaho," by H. W. Young and R. E. Lewis.

This report defines the areal distribution and occurrence of thermal springs in the Salmon River basin, evaluates their chemical and isotopic compositions, and quantifies the amount of heat and water presently discharging.

If you require additional information concerning this report, please contact this office.

Sincerely yours,

Ralph F. Norvitch
R. F. Norvitch
Acting District Chief

Enclosure(s)

LKC/lkc

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

THERMAL SPRINGS IN THE SALMON RIVER BASIN, CENTRAL IDAHO

By H. W. Young and R. E. Lewis

Open-File Report 82-104

Boise, Idaho

February 1982

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THERMAL SPRINGS IN THE SALMON RIVER BASIN, CENTRAL IDAHO

By

H. W. Young and R. E. Lewis

ABSTRACT

The Salmon River basin within the study area occupies an area of approximately 13,000 square miles in central Idaho. Geologic units in the basin are igneous, sedimentary, and metamorphic rocks; however, granitic rocks of the Idaho batholith are predominant.

Water from thermal springs ranges in temperature from 20.5° to 94.0° Celsius. The waters are slightly alkaline and are generally a sodium carbonate or bicarbonate type. Dissolved-solids concentrations are variable and range from 103 to 839 milligrams per liter. Estimated reservoir temperatures determined from the silicic acid-corrected silica, sodium-potassium-calcium, and sulfate-water isotope geothermometers range from 30° to 184° Celsius.

Tritium concentrations in sampled thermal waters are near zero and indicate the waters are at least 100 years old. Stable-isotope data indicate it is unlikely that a single hot-water reservoir supplies hot springs in the basin.

Thermal springs discharged at least 15,800 acre-feet of water in 1980. Associated convective heat flux is 2.7×10^7 calories per second.

INTRODUCTION

Numerous thermal springs (water temperatures greater than 20°C) occur throughout central Idaho, an area encompassing three major basins--the Payette, Salmon, and Boise Rivers. These basins roughly coincide with surface exposures of the Idaho batholith. A map prepared by the National Geophysical and Solar-Terrestrial Data Center (1977) classifies the Idaho batholith and adjacent areas as one of the largest prospectively valuable areas for steam and associated geothermal resources in the Western United States.

This report is the second of three scheduled for central Idaho and describes occurrence and chemistry of thermal springs in the Salmon River basin of central Idaho. This report is part of an overall program by the U.S. Geological Survey to understand better the nature and occurrence of geothermal resources in Idaho. Field work during this phase of study was accomplished during the period October 1979 to September 1980.

Purpose and Scope

Purposes of this report are to: (1) Define the areal distribution and occurrence of thermal springs in the Salmon River basin, (2) evaluate their chemical and isotopic compositions, and (3) quantify the amount of heat and water presently discharging from the springs.

Sixty-four thermal springs and 11 selected nonthermal springs were inventoried in the Salmon River basin. Water temperatures were measured, and measurements or estimates of discharge were made at the time of inventory. Water samples from 57 thermal springs and 11 nonthermal springs were collected for chemical analyses, which include common ions, silica, and the minor elements arsenic, boron, lithium, and mercury. Additional water samples for isotope analyses were collected from selected thermal springs and the 11 nonthermal springs. Isotopes analyzed were deuterium and oxygen-18 (52 springs), tritium (15 springs), and sulfate-water isotopes (8 thermal springs).

Water temperatures and measurements or estimates of discharge were used to determine the amount of thermal water discharging and the associated convective heat flux. Reservoir temperatures were estimated for all sampled thermal springs using the silica and Na-K-Ca (sodium-potassium-calcium) geothermometers. Reservoir temperatures for selected springs were estimated using the sulfate-water isotope geothermometer. Ratios of selected chemical constituents, deuterium and oxygen-18 isotopes, and tritium concentrations were used to characterize and thereby distinguish water from different areas of the basin.

Previous Investigations

The occurrence of thermal springs in the Salmon River basin was noted by Stearns, Stearns, and Waring (1937). Ross (1971) summarized existing data, which included several chemical analyses of thermal-spring waters. Young and Mitchell (1973) included chemical analyses of water from 15 thermal springs and 1 thermal-water well in their assessment of Idaho's geothermal potential. Using chemical geothermometers, Young and Mitchell (1973) estimated that reservoir temperatures in the Salmon River basin ranged from 45° to 205°C.

Acknowledgments

Many landowners in the Salmon River basin cooperated fully in this study by allowing access to their property, supplying information about their springs, and permitting discharge measurements to be made. Special thanks are due to personnel of the U.S. Forest Service, Middle Fork Salmon River Ranger District, who provided transportation and assistance in sampling hot springs along the Middle Fork Salmon River. The following Geological Survey personnel contributed significantly to this investigation: A. H. Truesdell and N. L. Nehring provided sulfate-water isotope analyses; R. H. Mariner aided in the interpretation of geochemical data; and T. A. Wyerman provided tritium isotope analyses. To all the above, the authors are grateful.

Spring-Numbering System

The spring-numbering system (fig. 1) used by the Geological Survey in Idaho indicates the location of springs within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters, a numeral, and the letter "S," which indicates the ¼ section (160-acre tract), the ¼-¼ section (40-acre tract), the ¼-¼-¼ section (10-acre tract), and the serial number of the spring within the tract, respectively. Quarter sections are lettered 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. Spring 8N-17E-32BCA1S is in the NE¼SW¼NW¼ sec. 32, T. 8 N., R. 17 E., and is the first spring inventoried in that tract.

8N-17E-32BCA1S

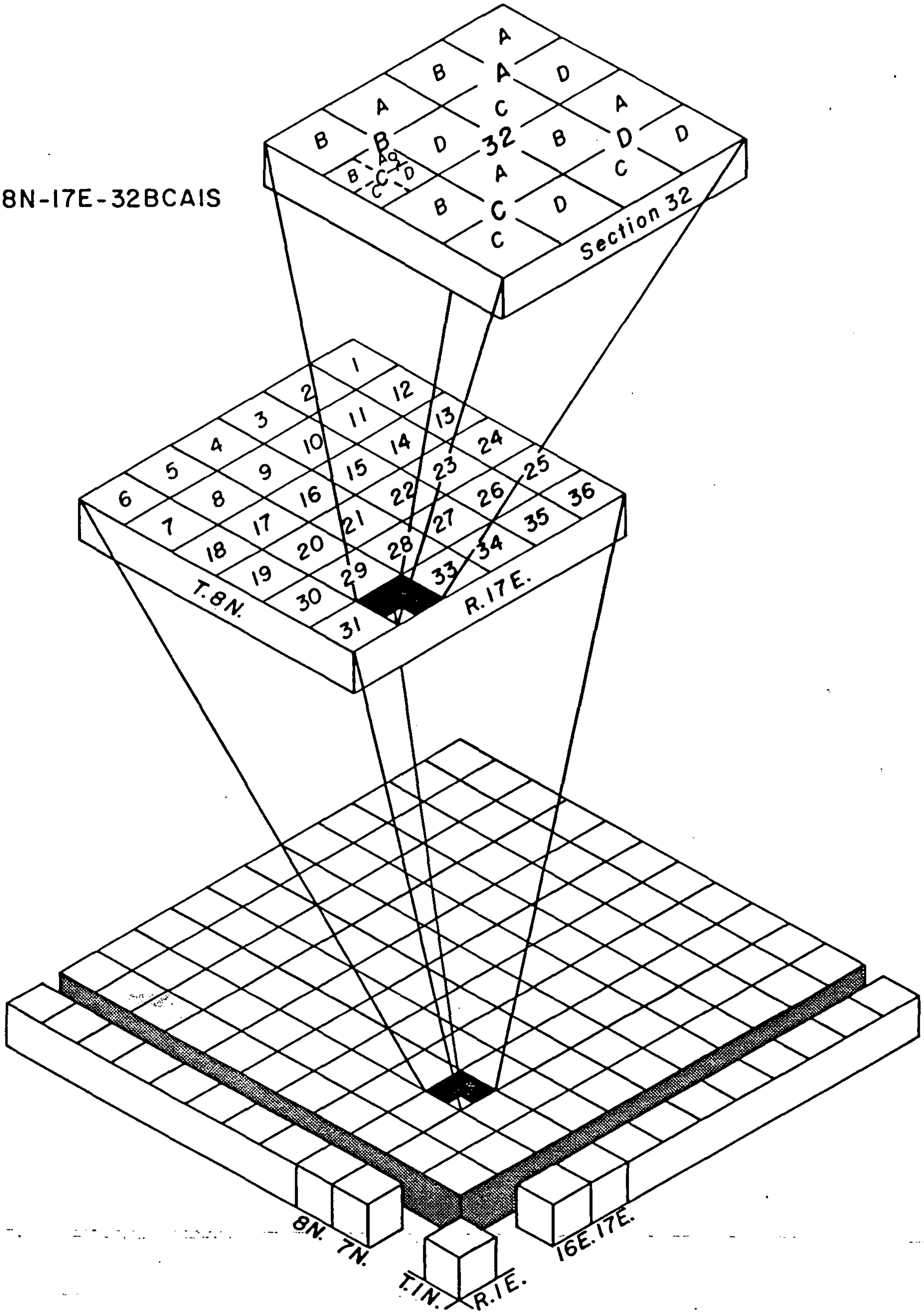

Figure 1.--Spring-numbering system.

HYDROLOGIC AND GEOLOGIC SETTING

Climate in the study area ranges from arid in the eastern part of the Salmon River basin to subhumid in the mountains. The variation in climatic conditions is caused primarily by topographic relief. Mean annual precipitation ranges from less than 8 in. near Challis and Salmon to more than 50 in. in the mountains near Warm Lake (Thomas and others, 1963). Mean annual temperatures, recorded by the National Weather Service, range from 12.3°C at Riggins to 1.9°C at Obsidian.

Topography of the basin is characterized by rugged mountains and narrow river valleys. Several prominant lowlands (river valleys) occur in the eastern part of the basin. These lowlands are along the Salmon River near Stanley and Challis and along the Pahsimeroi and Lemhi Rivers.

Drainage within the basin is provided mainly by the Yankee, East, North, South, East Fork of the South Fork, and Middle Forks of the Salmon River; Pahsimeroi, Lemhi, Little Salmon, and Secesh Rivers; and Valley, Panther, and Johnson Creeks (pl. 1). The major tributaries to Salmon River flow generally northward or northwestward. The Salmon River heads in the south-central part of the basin and flows generally along the southern, eastern, and northern margins of the basin to Riggins. The Salmon River within the study area drains approximately 13,000 mi^2.

Geologic units in the Salmon River basin are divided into: (1) Precambrian metamorphic and sedimentary rocks; (2) Paleozoic sedimentary rocks; (3) Triassic metavolcanic rocks; (4) Cretaceous intrusive and metamorphosed granitic rocks; (5) Eocene intrusive rocks; (6) Tertiary volcanic rocks; (7) Tertiary and Quaternary sedimentary rocks; and (8) Quaternary sedimentary rocks. The areal distribution and descriptions of these rocks are shown on plate 2.

Numerous north- and northeast-trending faults have been mapped in the basin (pl. 2). Most appear to be high-angle, normal faults. Several thrust faults, particularly in the eastern and far western parts of the basin, have also been mapped.

WATER CHEMISTRY

Water samples from 57 thermal and 11 nonthermal springs in the Salmon River basin were obtained for water-quality analyses. Results of the chemical analyses, which include common ions, silica, and the minor elements, arsenic, boron, lithium, and mercury, are given in table 1. In addition, chemical analyses of water from two thermal springs sampled by Young and Mitchell (1973) are included in table 1, along with partial analyses from 13 thermal springs for which only reported locations and water temperatures are available. Spring locations are shown on plate 1.

Chemical Character

Thermal springs in the Salmon River basin discharge fresh water (less than 840 mg/L dissolved solids) at temperatures between 20.5° and 94°C. These waters are slightly alkaline--pH ranges from 7.1 to 9.9. The waters are generally a sodium carbonate or sodium bicarbonate type. However, some sodium sulfate and calcium bicarbonate types are also present. Generally, the higher pH values are associated with the sodium carbonate type waters having low concentrations of dissolved solids. The sodium bicarbonate and calcium bicarbonate type waters generally show decreasing pH values with increasing concentrations of dissolved solids. Concentrations of dissolved solids in the sodium sulfate type waters are variable; however, most high concentrations of dissolved solids are associated with high pH waters.

Concentrations of fluoride are highly variable and show no relation to water temperature, concentrations of dissolved solids, or water type. Concentrations of chloride are variable; however, high concentrations are generally associated with waters having high concentrations of dissolved solids. Several other constituents are highly variable; most noteworthy are boron and sulfate.

Nonthermal springs are a calcium bicarbonate type. Water temperatures range from 5.5° to 14.0°C and are representative of the local, ambient conditions. Concentrations of dissolved solids are less than 154 mg/L. These waters are near neutral or slightly alkaline--pH ranges from 6.4 to 8.7.

Chemical Geothermometers

Reservoir temperatures in the Salmon River basin were estimated using the silica geothermometer (Fournier and Rowe, 1966) and the Na-K-Ca geothermometer (Fournier

(Chemical constituents in milligrams per liter, except where noted;
-- = constituents not analyzed for; < = less than.)

Spring No. or name	Date of collection	Flow rate[1] (gal/min)	Specific conductance (µmho)	pH	Water temperature[2] (°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Percent sodium	Sodium-adsorption ratio (SAR)	Potassium (K)	Bicarbonate[3] (HCO_3)	Carbonate[3] (CO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (calculated)	Nitrite plus nitrate as N (NO_2+NO_3)	Phosphorus, total as P	Arsenic (As) (µg/L)	Boron (B) (µg/L)	Lithium (Li) (µg/L)	[illegible]
Nonthermal																											
Horse Creek Campground Spring	8- 6-80	—	47	6.4	12.0	16	0	4.2	1.4	3.1	29	0.3	0.4	27	0	22	4.1	0.3	0.3	15	42	0.12	0.02	0	30	10	< 0
24N- 4E-19BCA1S	6- 3-80	2	154	7.0	11.0	53	2	18	2.0	7.5	23	.4	2.4	73	0	60	22	.3	0	23	111	.24	< .01	1	0	10	
24N-21E-22CDD1S	8-18-80	150e	158	6.7	7.5	66	8	18	5.1	5.4	15	.3	1.7	76	0	62	11	2.0	.2	17	98	.29	.09	2	60	<4	
22N- 2E-31BBC1S	6- 3-80	15e	56	6.5	5.5	23	15	5.8	2.0	2.5	19	.2	.8	9.8	0	8	.5	.2	.1	24	41	.04	.01	0	9	<4	< .
20N-22E-17AAC1S	8-18-80	—	38	6.9	14.0	12	3	3.1	1.0	2.1	26	.3	1.1	16	0	13	.2	1.1	.1	16	34	.14	.10	2	10	<4	
19N- 6E- 3BBD1S	6- 5-80	—	102	6.8	9.5	36	0	13	.8	6.6	28	.5	.8	56	0	46	2.7	.7	.2	31	83	.09	.02	30	0	10	< .
17N-11E-33DDC1S	6-27-80	30e	206	7.5	9.5	93	0	31	3.9	5.8	12	.3	1.3	130	0	107	4.6	.4	—	10	121	1.4	< .01	0	9	8	< .
15N-10E-13CAB1S	6-26-80	25e	111	7.5	9.0	44	0	15	1.6	5.5	21	.4	.7	63	0	52	2.8	.4	.2	16	73	1.1	.05	3	7	5	<.
14N-26E-10CBC1S	8- 5-80	—	168	8.7	9.5	78	0	16	9.2	2.7	7	.1	.6	84	6	79	2.4	1.9	.4	8.2	89	.12	.02	2	30	7	<.
11N-16E-30DAA1S	8- 8-80	20e	236	7.4	8.5	110	14	33	6.1	4.6	8	.2	2.4	120	0	98	25	1.2	.5	21	153	.14	.03	3	30	10	-
9N-17E-22BCA1S	8- 7-80	—	132	7.5	9.0	52	0	17	2.2	5.0	17	.3	.4	71	0	58	4.3	1.4	.6	16	82	.04	.02	2	20	7	-
Thermal																											
Barth Hot Springs	8-19-80	200e	240	9.4	59.5	4	0	1.5	.1	53	95	11	1.1	24	36	80	13	3.5	.9	68	189	<.01	.01	3	80	100	< .
Unnamed Hot Spring	8-19-80	40e	225	9.5	45.5	4	0	1.5	.1	49	95	10	.7	20	38	80	12	2.7	.8	60	175	<.01	.01	3	50	90	< .
Horse Creek Hot Spring	8- 6-80	50	193	9.0	39.0	7	0	2.6	.1	40	91	6.6	1.1	54	16	71	4.4	2.7	8.6	53	155	.83	.01	1	30	60	-
24N- 2E-14DAC1S	6- 3-80	25e	832	9.4	41.0	17	0	6.3	.2	160	94	17	3.8	5	29	52	290	5.6	.8	68	566	.06	<.01	1	750	20	.
24N- 4E- 7CDA1S[5]	—	—	—	—	59.0																						
Owl Creek Hot Springs	8- 6-80	6	562	8.4	51.0	12	0	4.5	.1	120	93	15	7.4	200	2	167	63	7.0	20	87	409	< .01	.01	1	60	220	-
Big Creek Hot Springs	8- 6-80	75e	1,020	7.6	94.0	12	0	4.9	<.1	220	93	27	17	490	0	402	45	31	16	150	725	< .01	.01	2	460	570	-
22N- 1E-34DAD1S	6- 3-80	20e	248	9.9	27.0	4	0	1.6	<.1	48	96	10	.4	7	38	69	39	4.4	.5	39	174	.06	.01	0	160	6	< .
22N- 2E-23CCB1S	8-28-80	50e	865	8.6	49.0	55	31	22	.1	150	84	8.8	5.2	18	7	26	310	14	2.5	51	570	< .01	.03	34	700	100	.
22N- 4E- 1BDC1S	6- 3-80	160	226	9.7	45.0	4	0	1.5	<.1	45	95	10	.9	15	46	89	16	2.3	2.9	67	189	.08	< .01	4	20	20	<.
21N- 1E-23ABA1S	6- 3-80	30	670	8.8	30.0	34	0	11	1.6	130	88	9.7	4.1	85	10	86	190	22	.8	52	463	< .01	< .01	1	880	40	.
20N- 1E-26DDB1S	6- 3-80	200	954	9.4	64.0	28	0	11	.2	180	92	15	3.6	2	23	40	320	30	.8	61	631	.03	<.01	13	610	50	.

Spring No. or name	Date of collection	Flow rate[1] (gal/min)	Specific conductance (µmho)	pH	Water temperature[2] (°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Percent sodium	Sodium-adsorption ratio (SAR)	Potassium (K)	Bicarbonate[3] (HCO_3)	Carbonate[3] (CO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (calculated)	Nitrite plus nitrate as N (NO_2+NO_3)	Phosphorus, total as P	Arsenic (As) (µg/L)	Boron (B) (µg/L)	Lithium (Li) (µg/L)	[illegible]
Thermal--Continued																											
20N- 5E-13BCC1S	8-26-80	20e	417	9.0	31.5	7	0	2.6	0.2	90	95	14	2.7	61	19	82	37	26	1.8	75	285	<0.01	0.01	47	150	40	<0.
15DAB1S[5]	---				33.0																						
20N- 7E-35A1S[5]	---				32.0 to 55.5																						
20N-16E-20DCC1S[5]	---				42.0																						
20N-22E- 3ABD1S	8- 7-80	145	1,050	7.1	45.0	93	0	21	9.8	190	76	8.6	30	550	0	451	31	49	1.6	32	635	<.01	.02	22	440	440	<.
20N-24E-34CCC1S	8- 5-80	8.5	1,270	8.0	63.5	14	0	5.8	<.1	270	94	31	17	470	0	385	150	54	11	100	839	.01	.01	22	1,700	430	-
19N- 2E-22CCA1S	6- 3-80	20	677	9.3	43.0	13	0	4.9	.1	130	94	16	3.3	43	19	67	180	25	1.5	73	458	<.01	<.01	8	610	60	1
19N-14E-26DDD1S	6-29-80	20e	246	9.4	47.0	7	0	2.8	<.1	50	93	8.2	.8	32	22	63	29	5.3	8.0	56	190	1.1	<.01	2	30	30	<
18N- 5E-22BCB1S[5]	---																										
18N- 6E- 9ADC1S	6- 4-80	20	299	9.3	62.0	4	0	1.5	.1	71	96	15	1.2	43	31	87	20	11	2.4	74	233	.08	<.01	4	60	30	
18N- 8E-17BDA1S[5]	---				33.0																						
Forge Creek Hot Springs	8- 1-79	40e	334	8.7	36.0	11	0	4.5	<.1	67	92	8.7	.7	100	6	92	36	8.8	10	43	225	.04	.02	2	190	60	<
18N-21E-12BCD1S	8- 5-80	60e	510	7.8	45.0	250	120	73	16	4.9	4	.1	2.5	160	0	131	120	1.5	.4	32	329	.32	.01	6	20	20	
17N- 6E- 2BAB1S	6- 4-80	10	267	9.6	47.0	4	0	1.4	<.1	53	96	12	1.1	32	35	85	17	7.8	2.2	64	198	.01	<.01	7	50	20	<
17N- 7E-31BCB1S	6- 5-80	6e	343	9.7	35.0	4	0	1.6	.1	72	96	15	1.7	41	36	94	32	10	10	68	252	.18	<.01	4	90	30	
Kwiskwis Hot Springs	7-31-79	60e	540	9.0	68.0	6	0	2.3	<.1	120	97	22	2.4	77	22	100	80	17	24	73	379	<.01	.02	1	250	150	<
17N-11E-16ACB1S	7-31-79	65e	498	9.0	87.0	5	0	2.0	<.1	110	96	21	4.4	100	23	120	66	11	22	98	385	<.01	.02	1	180	120	<
17N-13E-27ACC1S	6-28-80	15e	370	9.3	56.0	5	0	1.8	<.1	84	97	17	1.4	46	31	89	40	9.6	15	67	272	1.1	<.01	2	100	90	<
27ADB1S	6-28-80	10e	432	8.9	39.0	4	0	1.8	<.1	100	97	20	1.7	120	16	125	47	12	13	79	330	<.01	<.01	2	130	110	<
Hospital Hot Springs	6-29-80	40	422	8.9	46.0	8	0	3.4	<.1	90	95	13	1.5	110	11	109	41	14	21	52	288	<.01	<.01	1	110	120	<
Lower Loon Creek Hot Springs	6-28-80	30	430	9.0	49.5	4	0	1.8	<.1	94	97	19	1.7	93	19	108	50	11	16	69	308	1.0	<.01	2	100	110	<
16N- 6E-14CCC1S	6- 4-80	40	140	7.7	20.5	11	0	4.0	.2	25	82	3.3	.6	63	0	52	76	1.2	1.3	32	103	.10	.03	26	20	20	<
16N-10E-14CDA1S	8- 1-79	40e	402	9.6	64.0	5	0	1.9	<.1	85	97	17	1.3	5	43	76	63	11	17	69	294	<.01	.02	1	130	50	<
16N-12E- 8DDC1S	6-27-80	15e	475	9.2	47.0	11	0	4.4	.1	97	94	13	2.1	20	22	53	110	13	19	60	337	1.1	<.01	2	120	120	<
15BBA1S	6-28-80	70	353	9.3	66.0	7	0	2.4	.2	75	95	13	2.0	34	29	76	48	8.1	15	77	273	1.1	<.01	2	90	70	<
17DAD1S	6-27-80	100e	410	9.3	62.0	5	0	2.0	.1	86	96	16	2.5	27	36	82	63	9.0	17	85	314	1.1	<.01	2	100	90	<
16N-21E-18ADC1S	8- 5-80	10e	760	7.9	45.5	28	0	9.4	1.0	160	89	13	11	340	0	279	59	26	7.2	36	477	.02	.01	18	760	180	
15N- 6E-14ABB1S	6- 6-80	60	309	9.3	59.0	4	0	1.6	<.1	76	97	16	1.4	41	34	90	15	8.5	11	79	246	<.01	<.01	18	70	60	<
14ACC1S[6]	8- 2-72	30e	309	---	59.0	5	0	2.0	<.1	70	96	14	1.5	48	30	89	17	10	17	87	258	.03	.02	---	---	---	
14CAC1S	6- 2-80	80e	296	9.4	57.0	7	0	2.4	.3	65	94	11	1.9	52	25	84	15	11	3.0	74	223	.24	<.01	16	60	70	

Spring No. or name	Date of collection	Flow rate[1] (gal/min)	Specific conductance (µmho)	pH	Water temperature[2] (°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Percent sodium	Sodium-adsorption ratio (SAR)	Potassium (K)	Bicarbonate[3] (HCO_3)	Carbonate[3] (CO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (calculated)	Nitrite plus nitrate as N (NO_2+NO_3)	Phosphorus, total as P	Arsenic (As) (µg/L)	Boron (B) (µg/L)	Lithium (Li) (µg/L)	Mercury (Hg) (µg/L)
Thermal—Continued																											
15N- 6E-17DCC1S	6- 6-80	40	262	9.7	51.0	3	0	1.2	<0.1	57	97	14	0.8	29	46	100	4.6	2.2	2.6	68	196	0.03	<0.01	9	4	40	0.1
15N-10E-24BBB1S	6-25-80	300e	270	9.5	49.0	8	0	2.6	.3	55	93	8.6	1.0	10	30	58	36	5.9	17	54	207	1.2	<.01	7	60	30	<.01
29BDA1S	6-24-80	60e	282	9.4	50.0	5	0	2.0	<.1	63	95	12	1.2	29	31	75	31	6.9	15	65	229	1.1	<.01	2	60	50	<.01
Loon Creek Hot Springs	7-30-79	500e	345	9.3	65.0	5	0	2.0	.1	70	96	13	1.5	35	31	80	43	8.7	15	74	262	<.01	.02	2	120	70	.1
Hot Creek Hot Springs	7-30-79	80e	395	9.1	60.0	6	0	2.5	<.1	89	96	16	1.5	61	20	83	52	9.9	17	65	287	.04	.02	1	240	100	<.01
Shower Bath Hot Springs	7-30-79	300e	321	9.3	53.0	5	0	2.1	<.1	70	96	13	.9	41	24	74	36	7.1	17	61	238	<.01	.02	1	170	60	<.01
15N-25E- 8DDB1S[5]	——				33.0																						
15N-26E-21CAD1S	8- 5-80	1,000e	332	8.0	23.5	120	0	29	11	19	25	.8	3.8	150	0	123	32	9.9	.8	20	199	.28	.02	19	160	40	<.01
14N- 6E-11BDA1S	6- 2-80	500e	465	9.1	88.5	4	0	1.7	<.1	95	98	20	.4	63	29	100	41	15	16	100	329	.01	<.01	1	120	90	.5
Sulfur Creek Hot Springs[5]	——				26.5 to 43.5																						
Dagger Creek Hot Springs	6-24-80	10e	277	9.9	42.0	5	0	2.1	<.1	59	95	11	.8	15	26	56	32	8.5	14	58	208	1.1	<.01	0	60	40	<.01
14N-19E-23DDD1S	9-13-79	783	996	7.1	50.0	170	0	44	15	160	72	5	20	440	0	361	150	21	4.3	31	662	.11	.01	20	420	100	<.01
Bear Valley Hot Springs	8- 1-79	200e	365	9.5	65.0	5	0	2.0	<.1	76	96	15	1.6	17	41	82	54	12	15	77	287	<.01	.02	0	90	60	<.01
12N-11E- 2CDB1S	8- 4-80	60e	387	9.6	37.0	4	0	1.4	.1	82	98	18	.3	22	41	86	39	8.7	22	61	266	<.01	.01	0	40	60	——
12N-20E-10CBD1S	9-13-79	2,710	698	7.4	35.0	280	46	66	27	42	24	1.1	14	280	0	232	150	8.6	1.7	26	474	.05	<.01	4	220	90	<.01
11N-13E-25DCC1S[5]	9-14-79	20			55.0 to 60.0																						
36ABB1S	9-14-79	40e			59.0																						
36BAA1S	9-14-79	40	326	9.4	59.0	4	0	1.6	<.1	70	97	15	1.2	22	41	86	31	8.3	17	76	257	<.01	<.01	1	60	130	.2
11N-14E-22CCA1S	9-14-79	4e			57.0																						
29AAA1S	9-14-79	5e																									
Sunbeam Hot Springs	9-14-79	440	400	9.1	77.5	4	0	1.6	<.1	89	96	19	2.6	65	31	105	50	15	16	89	326	<.01	<.01	1	180	60	.1
Robinson Bar Hot Springs	9-13-79	45	351	9.4	56.0	5	0	1.9	<.1	74	95	15	2.4	32	43	98	50	15	9.4	93	304	<.01	.01	0	140	50	.1
11N-17E-27BDD1S	9-13-79	50	1,070	7.1	41.0	160	0	46	9.9	170	67	5.9	19	580	0	476	28	55	3.7	39	656	<.01	.01	1	1,500	320	.2
10N-13E- 3CAB1S[6]	7-12-72	110	293	——	41.0	6	0	2.2	.1	60	95	11	.5	30	28	71	31	5	14	55	211	.05	.01	——	——	——	——
Slate Creek Hot Springs	9-13-79	185	443	8.6	50.0	24	0	9.8	<.1	76	84	6.7	4.8	110	12	112	81	24	9.2	79	351	<.01	<.01	1	250	60	.2
9N-14E-19BAA1S	9-12-79	50	277	9.4	47.0	7	0	2.7	<.1	57	94	9.6	.7	22	34	75	34	6.5	11	54	211	.13	.01	1	50	60	<.01
8N-14E-27DBA1S	9-12-79	5e			29.0																						
27DBD1S	9-12-79	330e	243	9.3	42.0	7	0	2.6	.1	51	93	8.4	1.1	41	24	74	32	3.9	6.1	55	196	<.01	<.01	2	40	60	<.01
8N-17E-31DCB1S	8- 7-80	50e	562	8.5	52.5	85	0	24	6.2	80	64	3.8	10	180	7	159	120	13	9.3	47	405	<.01	.01	1	540	120	——
32BCA1S	8- 7-80	50e	643	8.5	52.5	71	0	20	5.1	110	72	5.7	16	230	17	217	83	39	10	41	454	.23	.01	1	790	160	.1

[1]Flow rate is for entire spring complex (e - estimated)
[2]Water temperature is highest temperature at spring vents or temperature of sampled vent
[3]Total alkalinity distributed as carbonate and bicarbonate at the spring temperature and pH
[4]Water temperature is lower at point of discharge

4 Water temperature in lower point of discharge
5 Reported water temperature
6 Analyses taken from Young and Mitchell (1973)

and Truesdell, 1973). Temperatures estimated by these chemical geothermometers are valid only for hot-water systems and only if the following basic assumptions are met (Fournier and others, 1974): (1) The chemical reactions at depth are temperature dependent; (2) an adequate supply of chemical constituents used for the thermometry is present in the reservoir; (3) chemical equilibrium is established at depth between the hot water and the specific reservoir minerals; (4) there is negligible reequilibration of the chemical composition of the hot water as it rises to the surface; and (5) hot water rises rapidly to the surface with no dilution or mixing of hot and cold waters.

Dissolved silica (SiO_2) reported in chemical analyses is actually present as silicic acid (H_4SiO_4) and various dissociated species, particularly $H_3SiO_4^-$. In neutral to slightly acid waters, dissolved silica ($H_4SiO_4 + H_3SiO_4^-$) consists mostly of H_4SiO_4, and, under these conditions, silica geothermometers give good estimates of reservoir temperatures. In alkaline waters, hydroxide (OH^-) reacts with silicic acid to reduce the proportion of silicic acid to total dissolved silica. The total concentration of dissolved silica measured in the laboratory (H_4SiO_4 + $H_3SiO_4^-$) must therefore be reduced by the concentration of H_3SiO_4 occurring at the pH level of the spring water to obtain an accurate estimate of the reservoir temperature.

For thermal waters having pH greater than 8.2, reported values for dissolved silica were corrected for dissociation of silicic acid at the spring pH, and silica-reservoir temperatures were estimated assuming equilibrium with both quartz and chalcedony (table 2). The pH of water in the thermal reservoir would be slightly lower than the pH measured at the spring, and calculation of reservoir pH might increase the $H_3SiO_4^-$-corrected quartz temperature by 5° or 10°C (R. H. Mariner, U.S. Geological Survey, written commun., 1980). Calculation of reservoir pH requires consideration of acid-base equilibria, distribution of acidic gases between steam and water, and the effect of temperature on the equilibria (Ellis and Mahon, 1977). Most of the calculations are time consuming and require computer methods, such as those presented by Truesdell and Singers (1973).

Corrections for the adverse effect of magnesium upon the Na-K-Ca geothermometer were applied using the method of Fournier and Potter (1979), where reservoir temperatures estimated using the Na-K-Ca geothermometer were greater than 70°C and magnesium concentrations exceeded 1 mg/L. Although the method is empirical, a better agreement between reservoir temperatures estimated using the silica and Na-K-Ca geothermometers is generally achieved when the magnesium correction is applied.

Table 2.--Estimated reservoir temperatures and free energy of formation for selected thermal springs

Spring No. or name	Water temperature at the surface	Estimated reservoir temperatures, in °C, on the basis of geothermometers						Free energy of formation[1]				Reference number (figure 2)
		Silica quartz-conductive	Silica quartz-conductive H_4SiO_4 corrected	Sodium-potassium-calcium	Silica-chalcedony	Silica-chalcedony H_4SiO_4 corrected		Aragonite	Calcite	Chalcedony	Quartz	
Barth Hot Springs	59.5	117	72	76	88	41		0.1	0.2	-0.3	0.2	1
Unnamed Hot Springs	45.5	112	70	61	81	38		0	.1	- .1	.4	2
Horse Creek Hot Spring	39.0	104	89	62	75	58		- .4	- .3	.3	.8	3
24N- 2E-14DAC1S	41.0	117	82	98	88	51		- .1	0	.1	.7	4
Owl Creek Hot Springs	51.0	130	123	162	102	94		0	.1	.6	1.1	5
Big Creek Hot Springs	94.0	161	159	184	137	134		.1	.2	.4	.8	6
22N- 1E-34DAD1S	27.0	91	46	44	60	14		-1.1	-1.1	- .2	.4	7
22N- 2E-23CCB1S	49.0	103	94	80	73	63		- .1	- .1	.2	.7	8
22N- 4E- 1BDC1S	45.0	116	70	64	87	30		0	.1	- .2	.3	9
21N- 1E-23ABA1S	30.0	104	95	85	74	65		.1	.2	.5	1.1	10
20N- 1E-26DDB1S	64.0	111	65	85	82	33		- .6	- .5	- .5	0	11
20N- 5E-13BCC1S	31.5	122	108	[2]100	94	78		- .3	- .3	.6	1.2	12
20N-22E -3ABD1S	45.0	82	82	[3]57	51	51		- .4	- .3	- .1	.6	13
20N-24E-34CCC1S	63.5	137	133	175	110	106		.2	.3	.5	1.0	14
19N- 2E-22CCA1S	43.0	120	89	97	92	58		- .3	- .3	.2	.8	15
19N-14E-26DDD1S	47.0	107	72	53	78	40		- .4	- .3	- .1	.4	16
18N- 6E- 9ADC1S	62.0	121	81	82	93	50		- .7	- .6	- .2	.3	17
Forge Creek Hot Springs	36.0	95	87	44	64	56		- .2	- .1	.3	.8	18
18N-21E-12BCD1S	45.0	82	81	[3]68	51	50		.7	.7	.1	.6	19
17N- 6E- 2BAB1S	47.0	114	65	77	85	34		0	0	- .2	.3	20
17N- 7E-31BCB1S	35.0	117	70	92	88	39		- .6	- .6	.1	.6	21
Kwiskwis Hot Springs	68.0	120	93	[2]102	92	62		0	.1	- .1	.4	22
17N-11E-16ACB1S	87.0	136	102	146	109	72		.4	.5	- .2	.2	23
17N-13E-27ACC1S	56.0	116	79	85	87	48		- .3	- .2	- .1	.4	24
27ADB1S	39.0	124	110	94	96	81		- .4	- .4	.6	1.1	25
Hospital Hot Springs	46.0	104	89	74	74	58		.1	.1	.2	.7	26
Lower Loon Creek Hot Springs	49.5	118	97	93	89	66		- .3	- .2	.2	.8	27
16N- 6E-14CCC1S	20.5	82	82	33	51	50		-2.0	-1.9	.4	1.0	28
16N-10E-14CDA1S	64.0	118	58	81	89	26		-1.2	-1.1	- .6	- .1	29
16N-12E- 8DDC1S	47.0	110	84	80	81	52		- .6	- .6	.1	.6	30

Table 2.--Estimated reservoir temperatures and free energy of formation for selected thermal springs--Continued

Spring No. or name	Estimated reservoir temperatures, in °C, on the basis of geothermometers: Water temperature at the surface	Silica quartz-conductive	Silica quartz-conductive H_4SiO_4 corrected	Sodium-potassium-calcium	Silica-chalcedony	Silica-chalcedony H_4SiO_4 corrected	Free energy of formation[1]: Aragonite	Calcite	Chalcedony	Quartz	Reference number (figure 2)
16N-12E-15BBA1S	66.0	123	80	89	95	49	-0.2	-0.1	-0.2	0.2	31
17DAD1S	62.0	128	86	[2]103	101	55	- .7	- .6	- .1	.4	32
16N-21E-18ADC1S	45.5	87	85	[3]132	56	54	0	.1	.1	.7	33
15N- 6E-14ABB1S	59.0	124	85	86	96	54	- .6	- .5	- .1	.4	34
14ACC1S	59.0	130	82	83	102	52	.1	.2	- .1	.4	35
14CAC1S	57.0	121	77	86	93	46	- .1	- .1	- .1	.3	36
17DCC1S	51.0	117	60	71	88	27	0	.1	- .4	.1	37
15N-10E-24BBB1S	49.0	105	64	62	76	32	-1.3	-1.2	- .2	.3	38
29BDA1S	50.0	114	75	75	86	44	.1	.2	- .1	.4	39
Loon Creek Hot Springs	65.0	121	79	83	93	48	- .3	- .2	- .2	.2	40
Hot Creek Hot Springs	60.0	114	86	80	86	55	0	0	- .1	.4	41
Shower Bath Hot Springs	53.0	111	77	66	82	45	- .3	- .2	- .1	.4	42
15N-26E-21CAB1S	23.5	63	62	44	31	30	0	.1	.1	.7	43
14N- 6E-11BDA1S	88.5	137	97	49	110	67	.4	.5	- .3	.1	44
Dagger Creek Hot Springs	42.0	109	45	60	80	14	- .5	- .5	- .5	.1	45
14N-19E-23DDD1S	50.0	81	80	[3]52	50	49	0	.1	0	.5	46
Bear Valley Hot Springs	65.0	123	69	86	95	37	-1.1	-1.0	- .4	.1	47
12N-11E- 2CDB1S	37.0	111	70	44	82	39	-1.0	-1.0	0	.6	48
12N-20E-10CBD1S	35.0	74	73	74	42	42	.1	.2	.1	.7	49
11N-13E-36BAA1S	59.0	122	77	80	94	46	-1.0	- .9	- .2	.3	50
Sunbeam Hot Springs	77.5	131	94	[2]111	103	64	- .2	- .1	- .2	.2	51
Robinson Bar Hot Springs	56.0	133	87	[2]101	106	56	-1.0	- .9	0	.5	52
11N-17E-27BDD1S	41.0	91	90	[3]78	60	60	0	.1	.3	.8	53
10N-13E- 3CAB1S	41.0	106	74	46	77	43	-2.0	-2.0	0	.5	54
Slate Creek Hot Springs	50.0	124	114	87	96	86	.4	.5	.5	1.0	55
9N-14E-19BAA1S	47.0	105	70	52	76	38	- .4	- .4	- .1	.4	56
8N-14E-27DBD1S	42.0	106	78	64	77	47	- .3	- .2	.1	.6	57
8N-17E-31DCB1S	52.5	99	91	[3]72	69	61	1.1	1.2	.1	.6	58
32BCA1S	52.5	93	85	[3]80	62	54	1.2	1.3	0	.6	59

[1]Values are departure from theoretical equilibrium in kilocalories; (+) values indicate supersaturation, (-) values indicate unsaturation. Calculations from computer program SOLMNEQ (Kharaka and Barnes, 1973).
[2]Sodium-potassium-calcium reservoir temperature estimated using 4/3 calcium.
[3]Magnesium-corrected sodium-potassium-calcium reservoir temperature (Fournier and Potter, 1979).

Reservoir temperatures calculated from water analyses for 59 thermal springs in the Salmon River basin are given in table 2, along with selected chemical reaction coefficients. In applying the $H_3SiO_4^-$-corrected silica geothermometer for thermal springs having water temperatures at the land surface greater than 65°C, estimates of reservoir temperatures were obtained by assuming that quartz was controlling the SiO_2 concentration. For springs having water temperatures at the surface less than 65°C, estimates of reservoir temperature were obtained by assuming that chalcedony was controlling the SiO_2 concentration. If, however, the calculated free energy of formation showed the waters were unsaturated with respect to chalcedony, or, if the estimated temperature was less than the temperature of the spring, then quartz was assumed to be controlling the SiO_2 concentration.

Using a plot of reservoir temperatures estimated by the silica and the Na-K-Ca geothermometers, Fournier, Sorey, Mariner, and Truesdell (1979) showed waters that plot on or near the equal-temperature line ($T_{SiO_2}=T_{Na-K-Ca}$; slope=1) are likely to be unmixed waters or waters that have reequilibrated with the reservoir minerals after mixing. Waters that plot significantly above the equal-temperature line probably contain anomalous concentrations of silica, owing to evaporation or to dissolving amorphous silica from the reservoir material. The Na-K-Ca geothermometer uses ratios of constituents and is less sensitive to concentration changes that occur during evaporation than is the silica geothermometer. Waters that plot significantly below the equal-temperature line may result from: (1) Mixing with another type water without sufficient time to equilibrate with the surrounding rock (in mixed waters, silica-estimated temperatures are generally decreased more than Na-K-Ca-estimated temperatures); (2) precipitation of silica during cooling, whereas Na-K-Ca proportions remain unchanged; or (3) precipitation of calcite or aragonite due to loss of carbon dioxide without adjustment of sodium and potassium through reaction with clays, zeolites, or other minerals (Fournier and others, 1979).

A plot of reservoir temperatures estimated from silica and Na-K-Ca geothermometers for thermal springs in the Salmon River basin is shown in figure 2. Most thermal springs plot on or near the equal-temperature line. As suggested by Fournier and others (1979), these waters are probably unmixed waters or are mixed waters that have had time to reequilibrate. Several springs (samples 4, 5, 6, 12, 14, 15, 21, 23, 27, 29, 30, 49, 52, and 59) plot

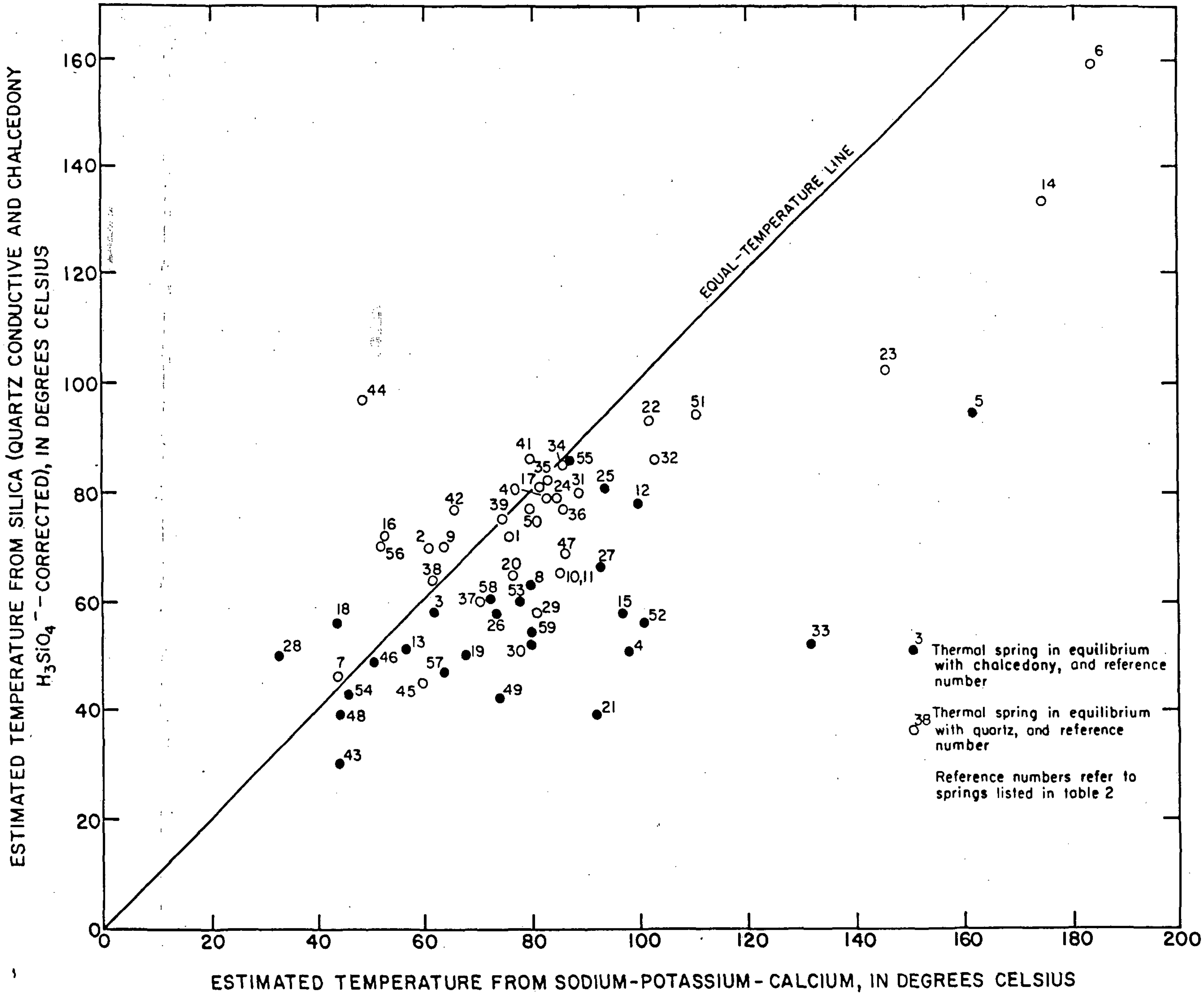

Figure 2.--Comparison of reservoir temperatures estimated by the silica and sodium-potassium-calcium geothermometers.

nificantly below the equal-temperature line and may indicate a mixed water or water from which calcite and aragonite have precipitated. Table 2 shows that waters from samples 4, 5, 6, 14, 23, 49, and 59 are supersaturated with respect to calcite or aragonite, which may indicate a possible loss of calcium without an adjustment of the sodium and potassium concentration. For these springs, the silica geothermometer probably gives the better estimate of reservoir temperature. Samples 12, 15, 21, 27, 30, and 52 are probably mixed waters.

Only one spring (sample 44) plots significantly above the equal-temperature line in figure 2. Owing to the unsaturation of amorphous silica and the supersaturation of calcite and aragonite, the silica geothermometer probably gives the better estimate of reservoir temperature.

Estimated reservoir temperatures determined from the silica and Na-K-Ca geothermometers, although generally in good agreement for individual springs, are highly variable and range from 30° to 184°C. Only three springs, Owl Creek Hot Springs, Big Creek Hot Springs, and spring 20N-24E-34CCC1S, have estimated reservoir temperatures exceeding 150°C as determined by one or both of the geothermometers. Assuming conductive heat loss, reservoir temperatures for eight thermal springs were estimated using the sulfate-water isotope geothermometer described by McKenzie and Truesdell (1977): Big Creek Hot Springs, 127°C; 20N-24E-34CCC1S, 108°C; Kwiskwis Hot Springs, 103°C; 17N-11E-16ACBB1S, 95°C; 16N-12E-17DAD1S, 88°C; Hot Creek Hot Springs, 106°C; 14N-6E-11BDA1S, 65°C; and Sunbeam Hot Springs, 74°C.

Isotopes

Samples of nonthermal and thermal waters from selected springs in the Salmon River basin were collected for analysis of tritium, deuterium, and oxygen-18. Concentrations of tritium for eight nonthermal springs and seven thermal springs are given in table 3. Isotopic compositions of 11 nonthermal springs and 41 thermal springs are given in table 4 and are shown in figure 3. Interpretations of the isotopic compositions of these waters concerning age or relation of the various waters are offered only insofar as they apply to the Salmon River basin and are considered preliminary.

Table 3.--Tritium in water from selected springs

Spring No. or name	Water temperature at surface (°C)	Tritium (TU)	Reference No. (table 4)
	Nonthermal		
Horse Creek Campground Spring	12.0	75.2±3.6	1
24N- 4E-19BCA1S	11.0	33.2±3.3	2
24N-21E-22CDD1S	7.5	62.4±3.5	3
20N-22E-17AAC1S	[1]14.0	74.3±3.6	5
19N- 6E- 3BBD1S	9.5	25.6±3.3	6
17N-11E-33DDC1S	9.5	23.7±3.3	7
14N-26E-10CBC1S	9.5	72.3±3.6	9
9N-17E-22BCA1S	9.0	25.6±3.3	11
	Thermal		
Horse Creek Hot Spring	39.0	4.1±0.5	13
24N- 2E-14DAC1S	41.0	0 ± .4	14
Owl Creek Hot Springs	51.0	0.1± .4	15
22N- 4E- 1BDC1S	45.0	.4± .4	17
17N-13E-27ADB1S	39.0	.1± .4	29
Lower Loon Creek Hot Springs	49.5	.7± .5	32
Loon Creek Hot Springs	65.0	1.0± .5	42

[1]Measured temperature is probably higher than at point of discharge.

Table 4.--Stable-isotope analyses from selected springs--Continued

Spring No. or name	t°C	δ D SMOW	$\delta^{18}O$ SMOW	$\Delta^{18}O$	Reference No. (fig. 3)
		Thermal--Continued			
17N-13E-27ADB1S	39.0	-149	-19.4	+0.48	31
Hospital Hot Springs	46.0	-149	-19.6	+ .28	32
Lower Loon Creek Hot Springs	49.5	-149	-19.5	+ .38	33
16N-10E-14CDA1S	64.0	-147	-19.2	+ .42	34
16N-12E- 8DDC1S	47.0	-149	-19.4	+ .48	35
15BBA1S	66.0	-147	-19.6	+ .02	36
17DAD1S	62.0	-149	-19.6	+ .28	37
16N-21E-18ADC1S	45.5	-151	-19.2	+ .92	38
15N- 6E-14ABB1S	59.0	-136	-17.9	+ .35	39
17DCC1S	51.0	-136	-18.3	- .05	40
15N-10E-24BBB1S	49.0	-141	-19.0	- .12	41
29BDA1S	50.0	-140	-19.0	- .25	42
Loon Creek Hot Springs	65.0	-152	-19.8	+ .45	43
Hot Creek Hot Springs	60.0	-152	-19.9	+ .35	44
14N- 6E-11BDA1S	88.5	-140	-18.6	+ .15	45
Dagger Creek Hot Springs	42.0	-141	-19.1	- .22	46
Bear Valley Hot Springs	65.0	-144	-18.9	+ .35	47
12N-20E-10CBD1S	35.0	-145	-19.0	+ .38	48
Sunbeam Hot Springs	77.5	-149	-19.8	+ .08	49
Slate Creek Hot Springs	50.0	-147	-19.7	- .08	50
9N-14E-19BAA1S	47.0	-150	-19.9	+ .10	51
8N-17E-31DCB1S	52.5	-149	-19.4	+ .48	52

[1] Measured temperature is probably higher than at point of discharge.

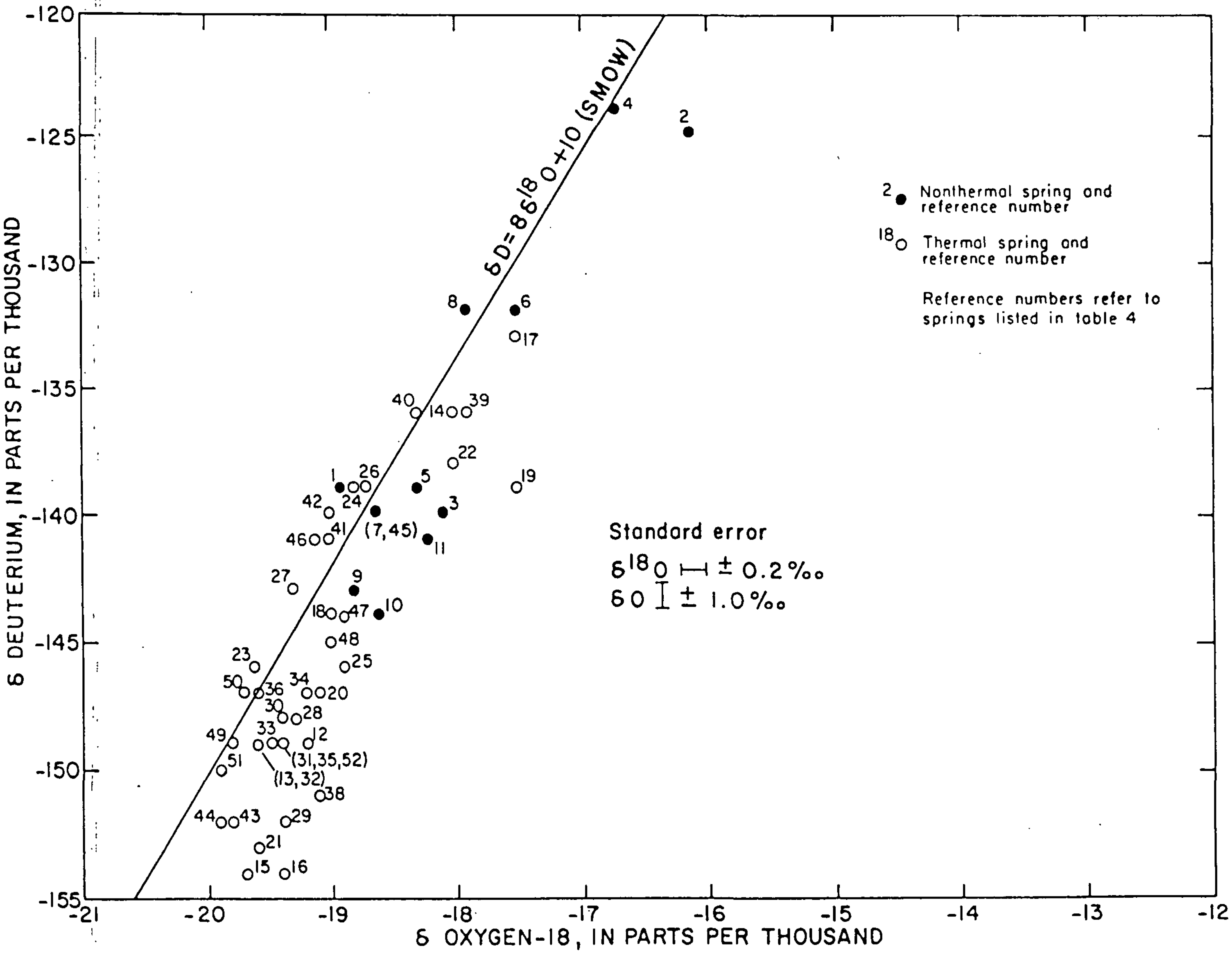

Figure 3.--Relation between concentrations of deuterium and oxygen-18.

Tritium

Tritium (^{3}H) is produced naturally in small quantities in the upper atmosphere during bombardment by subatomic particles. The tritium, incorporated in water molecules, enters the water cycle in rain and snow. Having a half life of about 12.3 years, tritium can be used to determine how long a particular water may have been stored out of contact with the atmosphere. The transit or residence time can be determined from the concentration of tritium in the discharge water, if the amount of tritium in the recharge water and the nature of the subsurface flow regime are known.

Before extensive thermonuclear testing began in 1954, tritium in the atmosphere ranged from 10 to 20 TU (tritium unit). One TU equals a $^{3}H/H$ ratio of about 10^{-18} or about 3.2 picocuries per liter. By 1963, worldwide tritium levels had increased several orders of magnitude. Tritium levels in precipitation have since declined and now (1980) average about 50 TU.

Tritium content in a ground-water system is a function of tritium content in the recharge water and the residence time and nature of flow in the system. Two basic types of flow models were discussed in detail by Nir (1964): (1) The piston-flow model, which has parallel flow lines of constant and equal velocity, so that a water sample taken at some point would include only water originating at the point of recharge; and (2) the well-mixed reservoir model, where it is assumed that the recharge water is continually and instantly mixing throughout the entire system.

Water samples were obtained from eight nonthermal and seven thermal springs and were analyzed for concentrations of tritium by the U.S. Geological Survey laboratory in Reston, Va. Samples were predistilled and enriched by electrolysis, and the enriched samples were counted by a gas proportional counter. Results of tritium analyses are shown in table 3. All samples were corrected for tritium decay to the collection date, using a half life of 12.361 years.

Concentrations of tritium in cold springs ranged from near 20 to more than 70 TU and indicate all are relatively young waters. Concentrations of tritium in thermal springs are, for the most part, near zero. Thermal waters having virtually no tritium probably contain no water younger than about 100 years. Assuming pre-1954 tritium levels of about 10 TU, water from Horse Creek Hot Spring, which has a tritium content of 4.1±0.5 TU, could be as young as 40 years, or may consist of a mixture of predominantly older, tritium-depleted water with a small (less than 5 percent) component of younger, cooler water. To a somewhat lesser degree, mixing with younger, colder water may also occur in the thermal waters of Loon Creek and lower Loon Creek Hot Springs.

Deuterium and Oxygen-18

Concentration of the stable isotopes, deuterium (D) and oxygen-18 (^{18}O) in water from different sources is used to characterize and indicate the origin and mixing patterns of individual waters. Atmospheric water derived from the ocean is depleted in ^{18}O and D. Isotopic composition of precipitation depends on the fraction of water remaining in and temperature of the air mass from which the rain or snow is derived.

Isotopic compositions of water from thermal and nonthermal springs are listed in table 4. Data are expressed in the δ notation,

$$\delta = \left[\frac{R-R_{std}}{R_{std}}\right] 10^3,$$

where R=(D/H) or ($^{18}O/^{16}O$) of the sample, and R_{std} is the corresponding ratio for standard mean ocean water (SMOW).

A plot of δ D versus $\delta^{18}O$, along with the SMOW line, is shown in figure 3 for waters sampled from the Salmon River drainage basin. Waters from the nonthermal springs are enriched in D and ^{18}O relative to the thermal waters, and there is a general depletion of stable-isotope concentrations in the cold water from west to east. Nonthermal waters that plot off the SMOW line probably have undergone evaporation prior to their being recharged. None of the cold waters appear to be representative of a single source of recharge for all the thermal springs.

During passage through the aquifer, thermal water and nonthermal water retain the deuterium composition characteristic of precipitation in the recharge area. The ^{18}O content in thermal water, however, is normally enriched (becomes less negative) to varying degrees during circulation within the system, due to reaction with the more enriched ^{18}O of the aquifer material.

Waters from 20N-1E-26DDA1S and Big Creek Hot Springs (samples 19 and 16 in figure 3) show the most enrichment in ^{18}O of all the thermal waters, which may indicate a reservoir temperature in excess of that measured at the surface. Reservoir temperatures estimated from the silica and Na-K-Ca geothermometers appear to substantiate an elevated reservoir temperature for the Big Creek waters but not for the other hot spring. Water from Owl Creek Hot Spring (sample 15 in figure 3) is enriched in ^{18}O only to a slightly lesser degree. The geothermometers applied to the Owl Creek waters indicate a relatively high reservoir temperature; water temperature at the surface was only 51°C, but, with a discharge of only 6 gal/min, considerable heat could be lost through conduction.

On the basis of preliminary analysis of the stable-isotope data, there seems to be no evidence for a single area of recharge or that a single, hot-water reservoir supplies the hot springs in the Salmon River drainage basin.

THERMAL GROUND-WATER DISCHARGE AND ASSOCIATED HEAT FLUX

Annual thermal water discharge in the Salmon River basin was estimated for 64 thermal springs. Although most of these springs are unused, several supply water for swimming pools and bathhouses. For purposes of this report, all water discharging from the springs and the heat contained therein is assumed to be consumptively used. Discharge for each spring was estimated or measured during inventory, and annual discharge was computed (table 1) assuming that the measured discharge was representative of annual discharge. Because measurements or estimates of discharge of several springs were not available (see table 1), thermal ground-water discharge in the Salmon River basin in 1980 totaled at least 15,800 acre-ft.

Heat from the Salmon River basin is removed convectively by hot water that discharges from the thermal springs. The convective heat flux from the basin can be calculated as the product of the volume rate of discharge and the enthalpy (heat content) of the water in excess of the ambient (surrounding) air temperature, or

$$H=M(h_r-h_0)$$

where,

- H = heat loss, by convection, in calories per second,
- M = mass discharge,
- h_r = enthalpy of the hot water, and
- h_0 = enthalpy of cold recharge water (2.0° to 12.0°C, depending on spring location).

To estimate the total convective heat flux, the volume of discharge in 1980 for each thermal spring was converted to an instantaneous flow rate, and the mass discharge, M, was calculated. In the convective heat-flow equation, h_0 is approximately equal to the mean annual air temperature. Subsequent percolation of spring water after discharge is considered negligible, and no heat is returned to the system. Convective heat flux for inventoried thermal springs from the Salmon River basin in 1980 was estimated to be 2.7×10^7 cal/s.

SUMMARY

The Salmon River basin within the study area drains approximately 13,000 mi^2 in central Idaho. The basin is characterized by rugged mountains and narrow river valleys. Several large river valleys occur in the eastern part of the basin. Geologic units in the basin are igneous, sedimentary, and metamorphic rocks; however, granitic rocks of the Idaho batholith are predominant.

Water temperatures of thermal springs range from 20.5° to 94°C. The waters are generally a sodium carbonate or bicarbonate type; however, some sodium sulfate and calcium bicarbonate waters are also present. The waters are slightly alkaline--pH values range from 7.1 to 9.9. Dissolved-solids concentrations range from 103 to 839 mg/L.

Estimated reservoir temperatures determined from the Na-K-Ca and $H_3SiO_4^-$-corrected silica geothermometers range from 30° to 184°C. Estimated reservoir temperatures determined from the sulfate-water isotope geothermometer range from 65° to 127°C. Only three springs in the basin have estimated reservoir temperatures greater than 150°C. Generally, the estimated temperatures for springs are in good agreement among the chemical geothermometers, indicating the waters are probably unmixed or have reequilibrated in the system.

Concentrations of tritium in thermal springs are, for the most part, near zero, which indicates the presence of little or no water younger than about 100 years.

Stable-isotope data indicate it is unlikely that a single hot-water reservoir supplies hot springs in the Salmon River basin. None of the sampled cold waters appear to be representative of recharge to the thermal springs.

Annual (1980) thermal ground-water discharge in the Salmon River basin is at least 15,800 acre-ft, and the heat convectively discharging from the springs is 2.7×10^{7} cal/s.

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CONVERSION FACTORS

For the convenience of those who prefer to use SI (International System of Units) rather than the inch-pound system of units, conversion factors for terms used in this report are listed below. Chemical data are given in mg/L (milligrams per liter) or µg/L (micrograms per liter). These values are, within the range of values presented, numerically equal to parts per million or parts per billion, respectively. Specific conductance is expressed in µmho (micromhos per centimeter at 25°C. Thermal parameters are reported in "working" units.

Multiply inch-pound unit	By	To obtain SI unit
	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4047	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
acre-foot (acre-ft)	1233	cubic meter
	Flow	
gallon per minute (gal/min)	0.06309	liter per second

Multiply working unit	By	To obtain SI unit
	Heat Flux	
calorie per second (cal/s)	4.187	watt
calorie (cal)	4.187	joule

Conversion of °C to °F is based on the equation, °F=(1.8)(°C)+32. All water temperatures are reported to the nearest one-half degree.