THERMAL GROUND-WATER DISCHARGE AND ASSOCIATED CONVECTIVE HEAT FLUX, BRUNEAU-GRAND VIEW AREA, SOUTHWEST IDAHO

U. S. GEOLOGICAL SURVEY

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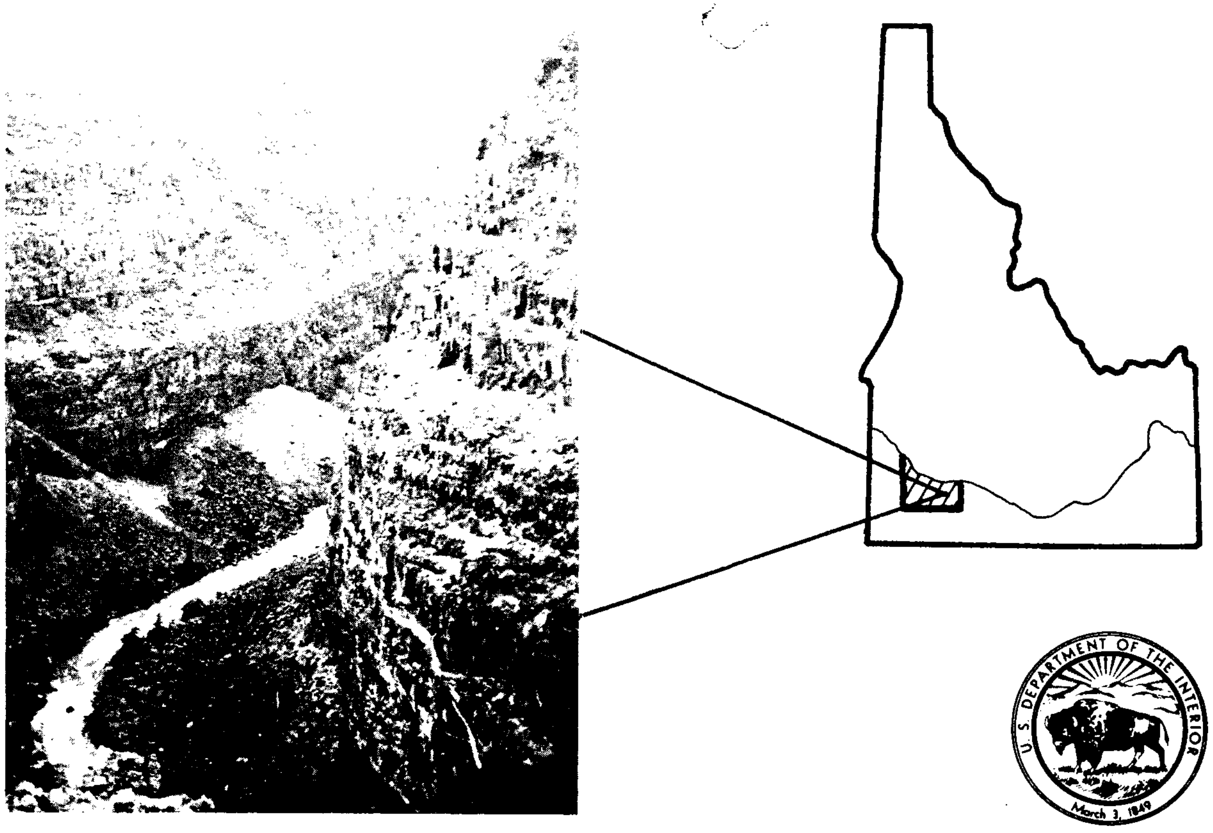

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CECIL D. ANDRUS, Secretary

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H. William Menard, Director

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CONVERSION FACTORS

The following conversion table is included for the convenience of those who prefer to use International System (SI) units rather than inch-pound units. Thermal parameters are reported in "working" units.

Multiply Inch-Pound Unit	By	To Obtain SI Unit
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1233	cubic meter (m^3)
cubic mile (mi^3)	4.166	cubic kilometer (km^3)
	Flow	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Multiply "Working" Unit	By	To Obtain SI Unit
	Heat Flux	
calorie per second (cal/s)	4.187	watt (W)
calorie (cal)	4.187	joule (j)

Temperature Conversion

The conversion of degrees Celsius (°C) to degrees Fahrenheit (°F) is based on the equation, °F=(1.8)(°C)+32.

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ABSTRACT

The Bruneau-Grand View area occupies about 1,100 square miles in southwest Idaho. The area has a rural population dependent on ground-water irrigation. Temperature of the ground water ranges from 15°C to more than 80°C.

Ground water for irrigation is obtained from flowing and pumped wells. Discharge of thermal ground water from 104 irrigation wells and 5 hot springs in 1978 was about 50,500 acre-feet. Convective heat flux from the geothermal system associated with this discharge was 4.97×10^7 calories per second.

INTRODUCTION

The Bruneau-Grand View area occupies the southern margin of the Snake River Plain in southwestern Idaho (plate 1) and, as described by Young and Whitehead (1975), comprises about 1,100 mi² in northern Owyhee County. The climate is semiarid, characterized by dry, hot summers and cool winters. Precipitation averages less than 10 in annually, and the mean annual temperature is 11.0°C.

The area has a predominantly rural population dependent on irrigated agriculture. The principal source of irrigation water is ground water, temperatures of which range from about 15°C to more than 80°C.

For purposes of this report, the Bruneau-Grand View area is divided into four geographic units: Castle Creek, Grand View, Little Valley, and Bruneau Valley. The areal extent of each unit is shown on plate 1.

This report is part of an overall program by the U.S. Geological Survey to better understand the nature and occurrence of the geothermal resources in Idaho. The work accomplished during this phase of study was done during the period October 1977 to February 1978. The report is the first of two scheduled for the area.

Objectives and Approach

The objectives of this study were to determine the rate of discharge of thermal ground water from irrigation wells and springs in the Bruneau-Grand View area and to calculate the associated convective heat flux. No attempt was made to estimate total geothermal heat flux, which may include a substantial amount of conductive heat flux. The approach included inventory of 104 irrigation wells and 5 hot springs, measurements or estimates of their discharges and pumping levels, and measured or reported water temperatures throughout the 1978 irrigation season.

Previous Investigations

Data from known hot springs in the Bruneau-Grand View area are included in Stearns and others (1937). Historical data from thermal wells and springs in Idaho are summarized by Ross (1971); however, few water-chemistry data are presented. One hundred twenty-four thermal wells and springs in Idaho were inventoried and sampled for chemical analyses by Young and Mitchell (1973). Recommendations were made for future geothermal studies in 23 areas of the State, including the Bruneau-Grand View area, on the basis of estimated aquifer temperatures greater than 140°C. On the above recommendations, Young and Whitehead (1975) inventoried and sampled 94 wells and springs in the Bruneau-Grand View area. In addition to compilation of chemical data, their report contains (1) a description of the areal extent and chemical character of the thermal water, (2) estimates of reservoir temperatures using geochemical thermometers, (3) a description of geophysical data available for the area, (4) a description of the geology, and (5) a description of the probable source of the thermal water. Isotopic and geochemical data for the area were collected and analyzed by Rightmire and others (1976) to determine the possible source of recharge to the thermal system. On the basis of an estimated subsurface temperature of 145°C and reservoir volume of 1,300 mi^3, Renner and others (1975) estimated that heat stored in the Bruneau-Grand View geothermal system was about 263×10^{18} calories. A more recent estimate by Brook and others (1979, table 6) places the stored heat at $108 \pm 26 \times 10^{18}$ calories on the basis of a mean reservoir temperature of 107 ± 6°C and a reservoir volume of 439 ± 101 mi^3.

Acknowledgments

Many farmers and landowners in the Bruneau-Grand View area cooperated fully in this study by allowing access to their property, supplying information about their wells, and permitting water-level and discharge measurements to be made in their wells. Officials of Idaho Power Company in Boise were helpful in providing power-use data. To all the above, the authors are grateful.

Well- and Spring-Numbering System

The well- and spring-numbering system used by the Geological Survey in Idaho indicates the location of wells or 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 and a numeral, which indicate the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered A, B, C, and D in counterclockwise order from the northeast quarter of each section (fig. 1). Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Well 7S-5E-10BBD1 is in the SE¼NW¼NW¼ sec. 10, T. 7 S., R. 5 E., and is the first well inventoried in that tract. Springs are designated by the letter "S" following the last numeral; for example, 8S-6E-3BDD1S.

GROUND-WATER DISCHARGE

Ground water for irrigation in the Bruneau-Grand View area is obtained from flowing and pumped wells. The pumped wells generally are powered by high-capacity electric motors, although some internal-combustion engines are used. Table 1 includes measurements or estimates of discharge and pumping levels for irrigation wells in the area.

For the purpose of this investigation, all water that is pumped or flows from wells is considered to be consumptively used. Locally, where water-table conditions occur, some applied water undoubtedly returns to the ground-water system, but the amount is probably insignificant in relation to the total volume of ground water withdrawn. In most of the area, ground water is confined, to various degrees, with

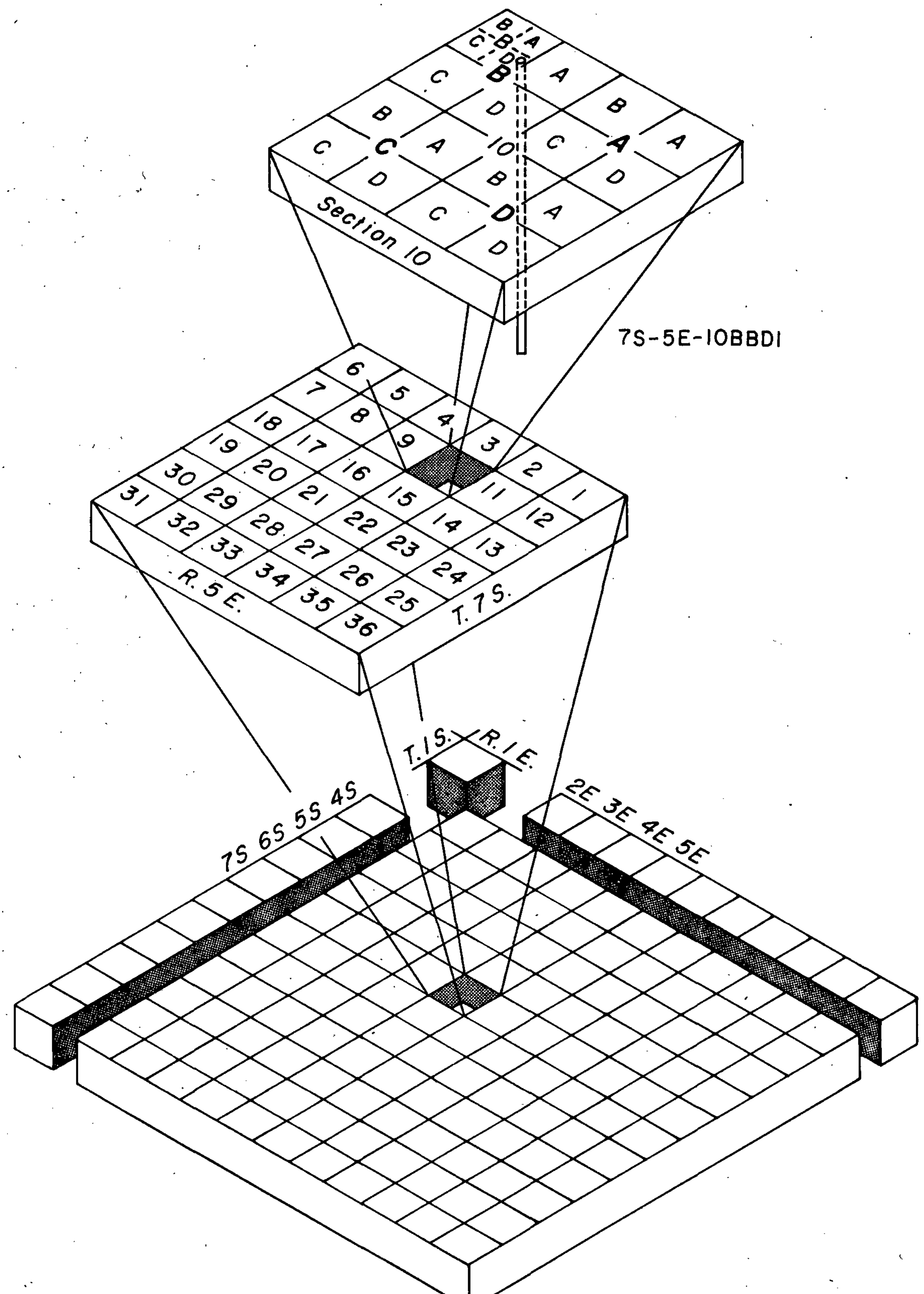

Figure 1. Well- and spring-numbering system

potentiometric heads commonly above land surface, and recharge to the ground-water reservoir from irrigation percolate does not occur.

Pumpage from wells powered by electric motors was calculated by two methods. Where discharge measurements could be made, pumpage was calculated as the product of the measured discharge and the number of hours pumped as derived from power records. Where discharge measurements could not be made, measurements or estimates of the pumping water level and dynamic pressure head at the well were made, and pumpage was calculated using the following equation:

$$Q = \frac{kWh}{1.8\ (H+P)} \qquad (1)$$ where,

Q = total withdrawals, in acre-feet,
kWh = total power consumed, in kilowatthours,
1.8 = average efficiency of pumping plants, in kilowatthours per acre-foot per foot of lift,
H = depth to pumping water level, in feet, and
P = pressure head at well, in feet of water.

Measurements or estimates of discharge were made for all flowing wells and pumped wells powered by internal-combustion engines. Assuming similar use time for all irrigation wells, the average number of pumping hours (derived from power records) was then multiplied by the discharge values of the internal-combustion-engine wells and flowing wells to obtain total pumpage.

Spring discharges at five hot springs in the Bruneau Valley unit (plate 1) were measured or estimated in 1978 (table 1). Total annual flows from these springs were calculated assuming that the discharges remained constant throughout the year.

Piper (1924) estimated that ground-water discharge from wells in the Bruneau-Grand View area in 1922 was about 7,100 acre-ft. Ground-water discharge in 1954 was estimated to be about 22,500 acre-ft by Littleton and Crosthwaite (1957). They also pointed out that much of the water from flowing wells was not beneficially used, as the wells were allowed to flow throughout the year. In later years, most wells were fitted with a valve to control or shut off the flow as irrigation demands changed.

Table 1. Records of hydrologic data for selected irrigation wells and springs in the Bruneau-Grand View area, southwest Idaho

Local well or spring number: For explanation of numbering system, see text.
Depth of well: Reported depth, in feet below land surface.
Static measurements: Water level, nonpumping level measured in feet below land surface.
Discharge measurements: Water level, pumping level measured in feet below land surface; P, well pumping;, R, reported value; E, estimated value.
Irrigation method: G, gravity; S, sprinkler.
Water temperature: Reported value in whole number; measured value in tenths.

Local well or spring number	Depth of well (feet)	Static measurements		Discharge measurements			Irrigation method	Water temperature (°C)
		Date measured	Water level (feet)	Date measured	Discharge rate (gallons per minute)	Water level (feet)		
				Castle Creek Unit				
4S-1W-25CDC1	335	03-22-78	31.49	07-11-78	968	123.21	G	15.5
				08-23-78	1,270	125.94		
26CBD1	310	02-22-78	182.39		--	280 R	S	18
26DBD1	334	03-22-78	97.77		850 R	--	S	18.0
36ADB1	324	03-23-78	38.54		1,150 R	--	S	17.0
36BDB1	348	03-23-78	56.33		--	--	S	17
4S-1E-29CCD1	3,040		--	03-23-78	148	Flowing	G	70.0
				06-16-78	1,510	Flowing		
				07-11-78	1,510	Flowing		
				08-23-78	1,540	Flowing		
30BDB1	350	03-23-78	17.33	06-20-78	973	--	G	16.0
30CCC1	700	03-23-78	13.97	07-11-78	884	153.81	G	17.5
				08-23-78	825	164.75		
30CCC2	--		--	03-22-78	30	Flowing	G	17.0
				06-20-78	16	Flowing		
				07-11-78	--	Not flowing		
34BAD1	2,980		--	03-28-78	349	Flowing	G	76.5
				06-21-78	302	Flowing		
				07-12-78	2,350	Flowing		
				07-21-78	2,160	Flowing		
				08-23-78	1,880	Flowing		
5S-1E-10BDD1	2,960		--	03-24-78	8	Flowing	G	64.0
				06-21-78	582	Flowing		
				07-12-78	1,390	Flowing		
				08-23-78	1,410	Flowing		
16CDA1	--	03-24-78	4.79	08-23-78	1,180	66.77	G	18.5
21CBD1	660		--	03-24-78	100	Flowing	G	65.0
				06-22-78	73	Flowing		
				07-12-78	632 P	--		
24ADB1	3,120		--	03-27-78	43	Flowing	G	64.5
				06-23-78	627	Flowing		
				06-23-78	1,760 P	--		
				07-12-78	1,510 P	--		
				08-23-78	1,560 P	--		
				Grand View Unit				
5S-3E-26BCB1	2,970		--	06-13-78	100	Flowing		[3]81.0
26BCB2	2,970		--	06-13-78	--	Flowing		
6S-3E-2CCC1	1,940		--	04-19-78	643	Flowing	G	54.0
				06-24-78	526	Flowing		
				07-13-78	210	Flowing		
				08-22-78	144	Flowing		
4BCC1	1,680		--	04-25-78	194	Flowing	S	48.0
				06-23-78	1,220 P	--		
				07-13-78	1,050 P	--		
				08-22-78	1,550 P	--		
5CAC1	3,600		--	04-25-78	1,470	Flowing	G	61.0
				06-23-78	1,280	Flowing		
				07-13-78	1,040	Flowing		
9ACC1	1,425		--	04-25-78	--	165.85	S	39.0
10CAB1	--		--	06-27-78	--	231.70	S	29.5
				07-13-78	--	189.10		
				08-22-78	--	228.85		
13ADD1	--		--	04-19-78	321	--	G	18.5
				07-19-78	211	--		
				08-22-78	141	--		
14BCC1	--	03-30-78	76.77	06-24-78	1,100	96.92	G	18.0
				07-18-78	--	76.15		
				08-22-78	--	95.36		

Table 1. Records of hydrologic data for selected irrigation wells and springs in the Bruneau-Grand View area, southwest Idaho (Continued)

Local well or spring number	Depth of well (feet)	Static measurements: Date measured	Static measurements: Water level (feet)	Discharge measurements: Date measured	Discharge measurements: Discharge rate (gallons per minute)	Discharge measurements: Water level (feet)	Irrigation method	Water temperature (°C)
Grand View Unit (Continued)								
6S-3E-14BDA1	--		--	06-28-78	1,540	80.67	G	19.0
				07-19-78	1,490	80.05		
				08-22-78	1,500	84.71		
14CAA1	--	04-19-78	81.40		--	100 R	S	17.5
23CDD1	1,241	04-26-78	86.50		--	--	S	30.0
34CDD1	--	04-26-78	192.83	06-26-78	318	224.00	G	30.5
				07-19-78	--	219.58		
				08-22-78	572	231.37		
6S-4E-18BCC1	455	03-30-78	64.98	06-24-78	1,120	101.89	G	18.0
				07-19-78	1,230	105.48		
				08-22-78	1,100	110.45		
7S-3E-4ADC1	804	04-26-78	187.96	06-26-78	784	--	G	33.5
				08-22-78	706	--		
Little Valley Unit								
6S-4E-14ABC1	1,905		--	05-23-78	1,350	--	G	54.5
				07-21-78	777	98.18		
				08-21-78	--	97.25		
25BCC1	1,705	05-22-78	58.51	07-05-78	668	188.40	G	26.0
32DBC1	645		--	07-25-78	--	382.73	S	28.0
33CAC1	1,176	05-25-78	250.34	06-27-78	--	360.80	S	30.0
				07-20-78	--	315.70		
				08-20-78	--	367.37		
35ACC1	865		--	05-11-78	--	215.35	S	29.5
				07-05-78	--	248.51		
				07-21-78	--	280.50		
				08-21-78	--	277.47		
35ADD1	329	05-11-78	59.61	07-05-78	--	189.87	S	23.0
				08-21-78	--	200.93		
35CDA1	955		--	06-27-78	--	211.00	S	33.0
				08-20-78	--	216.74		
36CCC1	2,000		--	05-11-78	2,340	--	G	40.0
				06-29-78	2,100	--		
				07-21-78	1,750	--		
				08-21-78	2,080	--		
36CCC2	820	05-11-78	49.91	07-05-78	275	--	G	20.0
6S-5E-34BDB1	884		--		(metered)	--	S	28
7S-3E-12BAD1	--	04-26-78	323.35	06-26-78	--	353.80	S	36.0
7S-4E-1ACC1	1,800		--	05-22-78	688	Flowing	G	39.0
				06-28-78	540	Flowing		
				07-20-78	409	Flowing		
1CDC1	--		--	05-22-78	510	Flowing	G	42.0
				06-28-78	280	Flowing		
				07-20-78	117	Flowing		
2ABB1	342	06-27-78	98.27		--	200 R	G	20
2ACD1	--		--	08-21-78	--	190.30	S	42.5
2CAB1	890	05-02-78	27.38	07-20-78	--	219.46	S	30.5
				08-21-78	--	218.33		
3AAC1	--		--	06-28-78	1,620	--	G	37.0
				07-20-78	2,470	--		
3BBC1	1,142		--	06-27-78	1,320	--	G	32.5
				07-20-78	1,220	--		
				08-20-78	1,110	--		
3CAB1	1,050		--	06-27-78	--	222.04	G	32.0
				07-20-78	--	268.86		
				08-20-78	--	278.04		
7S-4E-4ADC1	1,503		--	05-02-78	--	141.68	S	33.5
				06-26-78	--	254.85		
				07-19-78	--	215.27		
				08-20-78	--	217.80		

Table 1. Records of hydrologic data for selected irrigation wells and springs in the Bruneau-Grand View area, southwest Idaho (Continued)

Local well or spring number	Depth of well (feet)	Static measurements: Date measured	Static measurements: Water level (feet)	Discharge measurements: Date measured	Discharge measurements: Discharge rate (gallons per minute)	Discharge measurements: Water level (feet)	Irrigation method	Water temperature (°C)
			Little Valley Unit (Continued)					
7S-4E-5CCA1	1,040		--	06-27-78	--	300.81	S	31.5
				07-19-78	--	313.04		
				08-20-78	--	332.04		
10BDB1	1,145	05-02-78	82.97		--	200 R	S	37.5
10DBD1	--		--		--	200 R	S	32.0
11CBC1	1,500		--	05-03-78	1,720	--	G	36.0
				07-06-78	1,590	--		
				07-22-78	1,680	--		
				08-20-78	1,590	--		
12BDD1	1,105		--		1,400 R	--	G	43.0
12CCC1	900		--		1,500 R	--	G	43
12DDC1	1,350		--	05-03-78	403	Flowing	G	40.5
13BCC1	1,060		--	05-04-78	1,300	Flowing	G	39.5
13DCD1	1,000		--	05-08-78	900	Flowing	G	40.0
				07-06-78	987	Flowing		
				07-22-78	812	Flowing		
14ABC1	1,146		--	07-22-78	1,470	--	G	38.0
14CDC1	950		--	06-13-78	1,310	--	G	29.0
				07-05-78	1,310	--		
				07-22-78	1,300	--		
				08-20-78	1,460	--		
15ACD1	1,065		--	07-06-78	1,880	--	G	33.0
				07-22-78	2,030	--		
				08-20-78	2,090	--		
22ACC1	--		--	05-10-78	2,550	--	G	38.0
				07-07-78	2,940	--		
				08-19-78	2,860	--		
22BBD1	1,000		--	05-10-78	--	201.50	S	40.5
23CBB1	810		--	05-10-78	3,420	--	G	38.5
				07-07-78	3,360	--		
				08-19-78	3,420	--		
23DAB1	--		--	05-09-78	1,440	--	G	37.0
				07-07-78	1,440	--		
24DCB1	750	05-08-78	16.71	07-23-78	165 R	27.47	S	38
25ADC1	735		--	09-07-78	2,030	--	S	36.5
26ACB1	--		--	07-07-78	1,200 R	--	G	35.5
26BCB1	867	05-09-78	66.65	07-23-78	--	127.69	G	32.0
27BCC1	1,390	05-09-78	95.97	07-07-78	1,150	222.92	G	27.0
7S-5E-1DAC1	--		--		2,100 R	--	S	24
1DCD1	--		--		2,100 R	--	S	24
2BBD1	476	04-25-78	73.84	07-10-78	--	207.55	S	23.5
4ACD1	1,100		--		800 R	--	G	15
7ABB1	1,625		--	05-31-78	3,080	Flowing	G	39.5
				06-28-78	2,990	Flowing		
				07-20-78	3,350	Flowing		
				08-18-78	3,240	Flowing		
8BCC1	--		--	08-18-78	1,310	Flowing	G	39.0
8CCC1	1,500		--		400 R	Flowing	G	38.5
9DCD1	--		--	07-25-78	1,510	Flowing	G	40.0
				08-17-78	1,320	Flowing		
9DDD1	2,065		--	07-10-78	1,440	Flowing	G	40.0
				07-25-78	1,370	Flowing		
				08-17-78	2,170	Flowing		
10BBD1	564	04-20-78	92.60	07-10-78	--	114.13	S	19.0
				07-25-78	--	124.77		
				08-17-78	--	113.34		
10BDC1	190		--	07-10-78	200	--	S	23.5
				08-17-78	200	--		
11ABC1	--		--	06-01-78	299	--	G	27.5
11BAC1	300	06-01-78	131.57		450 R	--	G	27
11BBC1	300		--	06-01-78	976	--	G	20.0
				07-10-78	842	--		
				07-25-78	1,410	--		
13AAC1	400		--		1,400 R	--	S	25.5
13CBB1	1,954		--	06-01-78	--	339.60	S	31.5
				07-09-78	--	363.00		
13CDB1	--		--	06-08-78	1,060	274.30	G	33.0
				07-09-78	822	278.68		
				07-24-78	--	263.91		

Table 1. Records of hydrologic data for selected irrigation wells and springs in the Bruneau-Grand View area, southwest Idaho (Continued)

		Static measurements		Discharge measurements				
Local well or spring number	Depth of well (feet)	Date measured	Water level (feet)	Date measured	Discharge rate (gallons per minute)	Water level (feet)	Irrigation method	Water Temperature (°C)
Little Valley Unit (Continued)								
7S-5E-16ACD1	1,515		--		--	200 R	S	39.0
18BCD1	517		--		540 R	Flowing	G	34
18DBA1	937		--		1,400 R	Flowing	S	40.0
19CCC1	760		--		1,170 R	--	S	36.5
21DCD1	1,130		--	05-26-78	--	102.25	S	36
				07-08-78	--	102.45		
				07-23-78	--	103.60		
				08-19-78	--	104.26		
28ACD1	1,003		--	05-26-78	1,300	--	G	33.5
				07-08-78	1,440	--		
				07-23-78	1,540	--		
				08-19-78	1,400	--		
7S-6E-18BBC1	1,480		--		1,000 R	--	S	22.0
Bruneau Valley Unit								
7S-6E-9BAD1	910		--	06-13-78	120	Flowing	G	51
9BAD2	960		--	10-03-78	120	Flowing	G	50.0
16CDC1	513		--	07-09-78	660	Flowing	S	42.5
21DBC1	760		--	07-09-78	447	Flowing	G	43.0
				07-24-78	518	Flowing		
				08-16-78	630	Flowing		
21DBC2	611		--		100 R	Flowing	S	43.0
22AAD1	1,410		--	06-13-78	1,490	Flowing	G	47.0
				07-08-78	2,250	Flowing		
				07-24-78	2,470	Flowing		
				08-16-78	2,130	Flowing		
23CAD1	1,300		--		1,000 R	--	G	41.0
23CCA1	1,030		--		600 R	Flowing	S	41
26ADA1	1,000		--		2,000 R	Flowing	S	38.0
27ADB1	400		--		500 R	--	S	43.0
34CDD1S				07-19-78	12 E			35.0
34DCB1S				07-19-78	120 E			40.5
8S-6E-3ACD1S				07-20-78	10 E			35.5
3ADB1S				07-19-78	35 E			35.5
3BDD1S				06-27-78	144			37.0
				07-09-78	162			
				07-20-78	130			
				07-24-78	130			

[3] Water used to heat greenhouse

Total discharge from flowing and pumped wells for each geographic unit is shown in table 2. Total discharge for the entire area in 1978 was about 50,500 acre-ft. Spring discharge in the Bruneau Valley unit was about 500 acre-ft.

CONVECTIVE HEAT FLUX

Heat from the Bruneau-Grand View system is discharged convectively by hot water, which discharges naturally from hot springs or artificially through pumped or flowing wells. Prior to any development in the area, all convective heat flux was by hot-spring discharge. At present, only a few hot springs discharge in the Bruneau Valley unit, and almost all convective heat flux is by hot-water discharge from irrigation wells.

The convective heat flux from the system 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:

$$H = Q \rho_1 (c_1 - c_o) \qquad (2)$$ where,

H = heat loss, in calories per second,
Q = volumetric flow rate,
ρ_1 = density of the hot water,
c_1 = enthalpy of the hot water, and
c_o = ambient air temperature.

To estimate the total convective heat flux, the volume of hot water discharged from each irrigation well and hot spring in 1978 was converted to an instantaneous flow rate for use in equation (2). In this calculation, c_o is taken as the mean annual air temperature. In this section, irrigation percolate is considered negligible for reasons previously mentioned, and no heat is returned to the system. Total convective heat flux calculated for each of the four geographic units (plate 1) is shown in table 2.

Historic data from Stearns and others (1937, p. 148) showed 11 hot springs or groups of hot springs within the boundaries of the four geographic units included in this study. Temperatures of the springs ranged from about 38° to 49°C, and discharges ranged from about 25 to 1,800 gal/min. From these data, the natural convective heat flux from the

Table 2. Ground-water discharge and convective heat flux in the Bruneau-Grand View area, southwest Idaho

Geographic unit	Ground-water discharge (acre-ft)	Convective heat flux (cal/s)
Castle Creek	5,390	8.01×10^6
Grand View	6,100	4.73×10^6
Little Valley	36,100	33.4×10^6
Bruneau Valley	2,920	3.56×10^6
Total	50,500	4.97×10^7

Bruneau-Grand View area was about $9x10^6$ cal/s. Subsequent development and utilization of the hot-water system for irrigation has dried up most of the hot springs. At present, the natural convective heat flux is about $0.54x10^6$ cal/s from the remaining hot springs in the Bruneau Valley unit.

Total convective heat flux from the Bruneau-Grand View area was about $4.97x10^7$ cal/s in 1978. Only about 1 percent of this total was natural discharge from the hot springs in the Bruneau Valley unit; 99 percent was contained in water pumped or flowing from wells. Sixty-seven percent of the total convective heat flux was from irrigation wells in the Little Valley unit. Wells in the Castle Creek and Grand View units accounted for about 16 and 10 percent, respectively, of the total. Irrigation wells in the Bruneau Valley unit accounted for only about 6 percent of the total.

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