Contract No. DE-AC03-83SF11721 Publication No. TR37

HEAT-FLOW MAPPING AT THE GEYSERS GEOTHERMAL FIELD

by Richard P. Thomas

MASTER

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF OIL & GAS

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DIVISION OF OIL AND GAS

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ABSTRACT

Pertinent data were compiled for 187 temperature-gradient holes in the vicinity of The Geysers Geothermal field. Terrain-correction techniques were applied to most of the temperature-gradient data, and a temperature-gradient map was constructed. Cutting samples from 16, deep, production wells were analyzed for thermal conductivity. From these samples, the mean thermal conductivities were determined for serpentinized ultramafic rock, greenstone, and graywacke. Then, a heat flow map was made.

The temperature-gradient and heat-flow maps show that The Geysers Geothermal field is part of a very large, northwesterly-trending, thermal anomaly; the commercially productive portion of the field may be 100 km² in area. The rate that heat energy flows through the surface by thermal conduction is estimated at 1.79×10^9 MJ per year. The net heat energy loss from commercial production for 1983 is estimated at 180.14×10^9 MJ.

Published by the

California Department of Conservation
Division of Oil and Gas

Sacramento
1986

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INTRODUCTION

In 1958, Magma Power Company and Thermal Power Company teamed up with Pacific Gas and Electric Company to produce electricity from steam resources at The Geysers Geothermal field. Since then, geothermal companies have drilled more than 450 deep production wells and 600 shallow- to moderate-depth (30-600 m) temperature-gradient holes in The Geysers area in an effort to delineate the field boundaries. The drilling records for most of the temperature-gradient holes are open to public inspection.

Data from these temperature-gradient holes were studied to learn the lateral extent of the field and the amount of heat energy lost from the reservoir by thermal conduction.

The study methodology follows.

1. A 360 km² area was selected for detailed study (Fig. 1).

2. Temperature-depth data from the 187 temperature-gradient holes within the study area were compiled and plotted.

3. The data were selectively terrain corrected.

4. Rock cuttings from 16 deep production wells were examined and grouped by rock type. The mean thermal conductivities were determined for each of the three most common rock types.

5. Regional temperature-gradient and heat-flow maps were prepared.

6. The reservoir's heat energy loss by thermal conduction was calculated.

7. The net heat energy loss from commercial steam production was calculated.

Units of Measurement

Logging companies at The Geysers Geothermal field universally record units of depth in feet. Since this is the standard measurement, units of measured depth and elevation in Table 1 are in feet. Otherwise, metric units are used in this report. All temperatures in the report are reported in degrees Celsius, rounded to 0.1°C. Metric to English conversion factors are in Appendix A.

SETTING

The Geysers Geothermal field is about 65 km north of Santa Rosa, California, in the rugged, northwesterly-trending Mayacmas Mountains, a part of the Coast Range Geomorphic Province (Fig. 1). Elevations range from 195 m at the bottom of Big Sulphur Creek near the northwestern corner of the study area, to 1440 m at the top of Cobb Mountain. The climate is mild, with an average temperature of 14°C at 975 m. Snow falls occasionally at the highest elevations.

GEOLOGY

The basement rock of the study area is composed of structurally and stratigraphically complex, highly deformed assemblages of pre-Tertiary, metasedimentary, and metavolcanic rocks assigned to the Franciscan Complex. The topographic grain is controlled largely by numerous, northwesterly and west-northwesterly trending, low-angle thrust, and high-angle strike-slip and reverse faults. One particularly significant fault zone, the Quaternary(?) Big Sulphur Creek fault zone (Fig. 1), consists of a throughgoing series of high-angle faults along which four geothermal anomalies are located.¹⁴

^a Manuscript submitted September 1985.

¹⁴ Superior figures refer to a list of Selected References at the end of the report.

Figure 1. Location map showing the boundaries of the study area and The Geysers Geothermal field. Hachured areas represent the Clear Lake Volcanics; the white area represents pre-Tertiary basement rocks. (Modified from McLaughlin, R.J., 1977. The Franciscan Assemblage and Great Valley sequence in The Geysers-Clear Lake region of Northern California, in Field trip guide to The Geysers-Clear Lake area for the Cordilleran Section of the Geological Society of America: April 1977, p. 3-24.)

Quaternary Clear Lake Volcanics both locally overlie and are intruded into Franciscan rocks. Felsic rocks associated with the Clear Lake Volcanics cap Franciscan Complex rocks on Cobb Mountain, Pine Mountain, and Caldwell Pines, and commonly occur as intrusions along the Big Sulphur Creek fault zone (Fig. 1). Chapman⁵ and Isherwood¹⁰ suggest that a partially molten magma body associated with the Clear Lake Volcanic series underlies Mount Hannah at a depth between 6 and 14 km, and may be the heat source for the geothermal field.

Within the reservoir, geothermal fluid (at a typical temperature of 240°C and a pressure of 35 bars) may circulate through near-vertical faults and extensive networks of subhorizontal fractures in an areally extensive, massive graywacke^{14,15}. The brittle nature of this massive graywacke unit may allow for the existence of open fractures. On the other hand, relatively few steam-bearing, open fractures occur in the overlying rock.

TEMPERATURE GRADIENTS

A geothermal temperature-gradient is defined by the linear relationship $\Delta T/\Delta z$, where Δz is a subsurface

depth interval and ΔT is the change in temperature across the interval. When the temperature-depth data from many widely-spaced, temperature-gradient holes are compiled, plotted on a base map, and contoured along lines of equal temperature gradients, a reasonable picture of the underlying thermal regime is produced.

Temperature gradients can also be used to predict depth to the geothermal reservoir. Jamieson¹¹ and Urban et al¹⁶ showed in separate studies at The Geysers that terrain-corrected, shallow-hole, temperature-gradient data can be extrapolated linearly downward through thick sections of graywacke, thereby approximately predicting the depth to the first steam entry in nearby, deep production wells. The first steam entries observed in adjacent production wells occurred at depths corresponding to ~240°C on the shallow-hole continuation profiles. This indicates that the heat flows mainly by conduction through the rocks overlying the reservoir.

Other areas at The Geysers are more complex lithologically, with intercalated sections of greenstone, serpentized ultramafic rock, chert, and schist occurring locally. In these areas, predictions of first steam entries should be considered accurate within 10 percent.

Compilation of Temperature-Depth Data

The first step undertaken in the study was to compile available, temperature-depth data from files of the California Department of Conservation, Division of Oil and Gas. The outline of the study area and the locations of 187 temperature-gradient holes within the study area are in Figure 2.

Pertinent information relating to each nonconfidential, temperature-gradient hole is listed in Table 1*. The temperature-depth data are listed in Appendix B.

Near-Surface Effects on Temperature-Depth Data

The temperature-gradient profiles in Appendix C were plotted from the temperature-depth data. Most of the temperature-gradient profiles are curvilinear. The deflection from a linear gradient is probably due to steady-state and transient effects that manifest themselves in shallow holes. These effects are caused, in part, by:

1. Infiltration of groundwater,
2. Microclimatic variations,
3. Seasonal surface-temperature fluctuations,
4. Thermal recovery time of the borehole, and
5. Topography.

A description follows of these steady-state and transient effects.

*Note: Data from 19 temperature-gradient holes listed as confidential as of July 1, 1985, are not shown in this study.

Figure 2. Map of The Geysers study area, with locations of temperature-gradient holes and deep production wells used in the study. Filled circles show temperature-gradient hole locations; triangles show the mid-depth locations of deep production wells with usable temperature-gradient data; and squares show the surface locations of deep production wells sampled for thermal conductivity. The numbers refer to the temperature-gradient hole numbers in Table 1.

KEY TO LITHOLOGIC ABBREVIATIONS													
Alluv	Alluvium	Chlt	Chlorite	Sh	Shale								
Arg	Argillite	Grnst	Greenstone	Sp	Serpentinized Ultramafics								
Cgl	Conglomerate	Gwke	Graywacke	Ss	Sandstone								
Ch	Chert	Sch	Schist	Volc	Volcanics								

Table 1. Temperature-gradient hole data.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
WELL NO. USED IN STUDY	OPERATOR WELL NO.	LOCATION (latitude) (longitude)		SURF. ELEV.	TOTAL DEPTH	GRADIENT INTERVAL	DATA QUALITY	LOG LAG	TEMP.-GRADIENT (uncorr.) (corr.)	TERRAIN CORP. METHOD	MEAN THERMAL CONDUCT. W/m²K	LITHOLOGY ACROSS GRADIENT INTERVAL	HEAT FLOW
TGI		deg min sec	deg min sec	feet	feet	feet	INTERVAL LENGTH	days	°C/km	°C/km			mW/m2
1	A-CRS-1A	38 47 15 N	122 42 59 W	2400	315	180-300	B	3	137	145	BTC	Melange	
2	A-CRS-1B	38 47 38 N	122 42 59 W	2560	315	200-300	C	2	169			Cgl	
3	A-CRS-2	38 46 50 N	122 43 6 W	2200	303	120-260	A	7	305	320	EST	Sp?	765
4	A-CRS-3A	38 46 53 N	122 42 12 W	1900	133	60-100	C-	1	136			Gwke?	
5	A-CRS-3B	38 47 8 N	122 42 28 W	2050	315	100-300	B+	3	70	73	EST	Melange	
6	A-CRS-4	38 46 26 N	122 43 40 W	3200	243	80-240	B	2	269	335	BTC	Clay & broken rock	
7	A-CRS-5	38 46 8 N	122 42 56 W	2200	315	80-276	B	1	468	394	BTC	Gwke?	1269
8	A-CRS-6	38 46 24 N	122 42 16 W	1760	315	200-280	A-	1	659	629	BTC	Melange	
9	A-CRS-9	38 46 52 N	122 41 22 W	1586	500	160-380	A+	7	130	132	BTC	Gwke	425
10	A-DE-1	38 45 50 N	122 40 25 W	2280	500	160-480	A+	7	72	72	EST	Gwke	232
11	A-DE-2	38 45 20 N	122 40 15 W	2600	450	220-440	A	30	83	83	EST	Gwke	267
12	A-DE-3	38 45 36 N	122 40 57 W	2510	550	260-480	C+	100	135	136	HTC	Gwke	438
13	A-DE-4	38 46 19 N	122 41 9 W	1444	300	100-300	A+	10	157	132	BTC	Gwke	319
14	A-DE-5	38 46 9 N	122 39 37 W	1247	502	100-480	A+	44	80	74	BTC	Grnst-350ft., Gwke-TD	207
15	A-GP-1	38 46 13 N	122 50 52 W	2050	500	220-480	A+	8	68	68	EST	Gwke	219
16	A-GP-2	38 47 8 N	122 50 35 W	1680	443	100-440	B+	11	72	55	BTC	Gwke	177
17	A-GP-3	38 46 45 N	122 51 43 W	2870	500	360-480	A	30	57	72	BTC	Gwke	232
18	A-GP-4	38 46 40 N	122 48 6 W	3455	465	400-460	B-	22	65			Sp	
19	A-GP-5	38 46 48 N	122 47 13 W	2920	460	300-460	A	13	106	111	BTC	Gwke	357
20	A-GP-6	38 46 18 N	122 47 30 W	3445	400	320-380	A-	63	65	72	EST	Melange	
21	A-GP-7	38 45 52 N	122 47 33 W	3117	500	280-480	A+	13	79	83	EST	Sp	198
22	A-GP-8	38 45 59 N	122 46 33 W	2920	468	360-440	B-	28	89			Sp	
23	A-GP-9	38 48 54 N	122 53 28 W	1640	500	160-380	A+	28	53	60	BTC	Gwke	193
24	A-GP-10	38 48 54 N	122 52 16 W	1486	500	440-500	A-	16	82	84	EST	Gwke	270
25	A-GP-12	38 47 45 N	122 53 21 W	1230	495	80-320	A+	23	94	77	HTC	Gwke	248
26	A-GP-13	38 47 53 N	122 52 10 W	1950	500	200-320	A	22	41	41	EST	Gwke	132
27	A-HS-1	38 46 40 N	122 40 8 W	1360	495	220-480	A+	10	96	91	BTC	Gwke	293
28	A-HS-3	38 46 32 N	122 39 20 W	1280	300	200-300	A	23	87	82	EST	Sp & Sh	196
29	A-HS-5	38 46 14 N	122 38 28 W	1220	300	160-300	B	22	106	100	EST	Gwke	322
30	A-NG-1	38 54 5 N	122 51 49 W	1800	295	180-280	A	52	76	76	EST	Gwke	245
31	A-NG-2	38 53 40 N	122 51 31 W	1980	510	380-480	A	30	74	76	BTC	Gwke	245
32	A-NG-4	38 52 55 N	122 51 15 W	2210	300	220-300	A-	68	84	82	BTC	Sp	196
33	A-NG-6	38 52 10 N	122 53 31 W	2340	300	60-220	A	76	72	60	EST	Ss	193
34	A-NG-7	38 52 38 N	122 52 35 W	2940	300	160-300	A	918	54	67	BTC	Gwke	216
35	A-NG-8	38 52 16 N	122 51 37 W	3240	300	200-300	B	69	37	43	BTC	Gwke	138
36	A-NG-9	38 51 47 N	122 50 1 W	3200	302	180-300	A	37	32	36	EST	Gwke	116
37	A-NG-10	38 51 46 N	122 50 45 W	3420	500	260-420	B-	277	80	90	BTC	Gwke	290
38	A-NG-11	38 51 48 N	122 51 16 W	3610	302	100-300	A+	74	20	23	EST	Gwke	74
39	A-NG-12	38 51 27 N	122 52 34 W	3280	300	160-300	A+	78	67	84	BTC	Gwke	270
40	A-NG-13	38 50 43 N	122 53 52 W	2500	438	240-340	A	730	70	70	EST	Gwke	225
41	A-NG-14	38 50 11 N	122 53 3 W	2300	460	280-440	A	935	79	80	EST	Grnst	194
42	A-NG-15	38 50 45 N	122 51 54 W	2600	456	220-300	A	40	45	45	EST	Gwke	145
43	A-NG-16	38 50 25 N	122 51 23 W	1520	480	300-480	A	60	168	158	EST	Gwke	509
44	A-NG-17	38 51 56 N	122 54 6 W	2300	310	160-260	B	39	95	76	EST	Grnst	184
45	A-NG-18	38 50 48 N	122 50 38 W	2300	485	380-480	A	66	122	121	EST	Gwke	390
46	A-NG-19	38 50 23 N	122 49 49 W	2240	480	300-480	A	73	130	130	EST	Grnst	315
47	A-NG-20	38 49 51 N	122 48 52 W	2300	485	420-480	A-	50	164	145	EST	Melange	

1	2	3	4	5	6	7	8	9	10	11	12	13	14
WELL NO. USED IN STUDY	OPERATOR WELL NO.	LOCATION (Latitude) (Longitude)	SURF. ELEV.	TOTAL DEPTH	GRADIENT INTERVAL	DATA QUALITY INTERVAL LENGTH	LOG LAG	TEMP.-GRADIENT (uncorr.)(corr.)	TERRAIN CORP. METHOD	MEAN THERMAL CONDUCT.	LITHOLOGY GRADIENT INTERVAL	ACROSS INTERVAL	HEAT FLOW
deg min sec	deg min sec	feet	feet	feet	days	°C/km	°C/km	W/m²K				mW/m2	
48	A-NG-21	38 49 59 N 122 50 26 W	1680	480	400-480	A-	291	122	124	EST	2.42	Grnst	300
49	A-NG-22	38 49 35 N 122 51 2 W	2400	480	120-480	B+	288	119	162	EST	2.42	Grnst	392
50	A-NG-23	38 49 56 N 122 52 28 W	2280	300	80-300	C+	96	120			3.22	Gwke	
51	A-NG-24	38 49 21 N 122 51 47 W	1400	475	400-460	A-	105	128	128	EST	3.22	Gwke?	412
52	A-NG-25	38 50 27 N 122 52 46 W	1200	300	220-300	A-	128	82	81	EST	3.22	Gwke?	261
53	A-NG-26	38 50 47 N 122 48 48 W	2200	300	240-300	A-	42	76	86	EST	3.22	Gwke? or Volc?	277
54	A-NG-32	38 52 38 N 122 51 5 W	2400	597	400-580	A	26	79					
55	A-NG-33	38 51 47 N 122 54 7 W	2320	500	420-500	A-	201	86	81	EST	3.22	Gwke?	261
56	A-NG-34	38 52 12 N 122 51 28 W	3200	600	500-600	A	187	53	62	EST	3.22	Gwke?	200
57	A-T-2	38 44 51 N 122 39 13 W	1600	500	240-500	A+	19	82	84	EST		Melange? or Gwke?	
58	A-T-3	38 44 44 N 122 40 56 W	2200	298	140-240	A	36	120	120	EST	3.22	Melange? or Gwke?	386
59	A-T-4	38 44 3 N 122 40 4 W	1200	300	160-300	A	37	83	83	EST		Landslide? or Sp?	
60	Ch-MSH-4	38 44 2 N 122 39 57 W	1580	500	100-500	A+	13	91	91	EST		Gwke w/ Sp	
61	Ch-MSH-1	38 45 22 N 122 38 49 W	1200	497	120-440	A+	19	83	82	EST	3.22	Gwke w/ Sh	264
62	Ch-MSH-3	38 44 18 N 122 39 44 W	1560	497	320-440	C	5	86	86	EST	3.22	Gwke	277
63	GRI-Dun-2	38 45 54 N 122 47 2 W	3250			A+				BTC			
64	GRI-HS-30	38 46 21 N 122 38 39 W	1100			C-				EST			
65	GRI-HS-31	38 45 17 N 122 38 34 W	1120			C+				BTC			
66	GRI-HS-32	38 46 59 N 122 38 50 W	1120			C-							
67	GRI-HS-35	38 46 25 N 122 38 52 W	1200										
68	GRI-LR-3	38 44 55 N 122 40 44 W	2800			B				EST			
69	GRI-LR-4	38 44 13 N 122 40 29 W	1700			C							
70	GRI-LR-5	38 44 56 N 122 40 19 W	2380			C							
71	GRI-LR-6	38 45 11 N 122 39 48 W	2260			C							
72	GRI-LR-7	38 44 36 N 122 39 32 W	1820			B+				BTC			
73	GRI-LR-8	38 45 7 N 122 39 13 W	1800			C							
74	GRI-NW-2	38 49 41 N 122 49 55 W	2300			A+				EST			
75	GRI-NW-3	38 50 47 N 122 48 55 W	3170			B+				EST			
76	GRI-NW-1	38 51 13 N 122 49 25 W	3202			B+				EST			
77	GRI-NW-2	38 50 53 N 122 51 23 W	2060			B+				BTC			
78	GRI-NW-5	38 51 44 N 122 51 6 W	3065			B+				EST			
79	GRI-NW-1	38 49 48 N 122 51 13 W	2400			B-				BTC			
80	GRI-NW-2	38 49 33 N 122 50 55 W	2600			B+				EST			
81	GRI-NW-3	38 49 20 N 122 52 9 W	1200			B+				EST			
82	Ph-120909-1	38 53 57 N 122 51 40 W	1850	500	120-500	A+	23	79	79	EST	3.22	Gwke	254
83	Ph-120925-1	38 51 54 N 122 48 57 W	2700	500	260-500	C+	125	24	24	BTC		Volc	
84	Ph-120928-1	38 51 27 N 122 52 23 W	3100	480	300-480	A	42	67	85	EST	3.22	Gwke	274
85	Ph-K-9	38 52 30 N 122 46 41 W	2720	500	290-440	B	55	95	91	BTC	2.39	Sp	217
86	R-MN-4	38 42 21 N 122 42 23 W	2120	455	240-440	A+	82	53	60	EST		Melange? or Grnst?	
87	R-MN-5	38 41 40 N 122 43 4 W	880	500	300-500	A+	150	70	70	EST	3.22	Gwke?	225
88	Sh-HH-15	38 42 52 N 122 41 35 W	2980	300	120-300	A	14	44	52	BTC	3.22	Gwke	167
89	Sh-HH-21	38 42 34 N 122 43 17 W	2240	300	180-300	A	14	47	47	BTC	3.22	Gwke	151
90	Sh-HH-22A	38 42 30 N 122 43 52 W	800	300	160-300	A	15	112	112	EST	2.39	Sp	268
91	Sh-HH-23	38 42 19 N 122 45 21 W	1220	300	120-300	A	24	78	87	BTC	3.22	Gwke w/ Sh	280
92	Sh-HH-26	38 44 9 N 122 43 59 W	2520	300	200-300	A	13	91	102	EST	3.22	Gwke	328
93	Sh-HH-31	38 46 55 N 122 40 34 W	1420	295	200-280	A+	17	93	88	EST	3.22	Gwke	283
94	Sh-HH-37	38 45 11 N 122 46 36 W	2030	300	100-300	A+	9	108	99	BTC	3.22	Gwke	319
95	Sh-HH-38	38 49 0 N 122 43 56 W	2090	300	140-300	A	8	28	34	EST	3.22	Gwke	109
96	Sh-HH-39	38 49 17 N 122 54 23 W	1760	300	140-300	A	11	39	51	BTC	3.22	Gwke	164
97	Sh-HH-40	38 49 40 N 122 54 12 W	960	300	140-300	A	11	68	68	EST	3.22	Gwke	219
98	Sh-HH-41	38 49 57 N 122 55 8 W	1880	300	80-210	A	15	83	90	BTC	3.22	Gwke	290
99	Sh-HH-46	38 50 43 N 122 54 45 W	2220	300	100-300	A+	16	17	18	BTC	3.22	Gwke	58
100	Sun-23-76-4	38 52 12 N 122 54 11 W	2340	500	340-500	B	63	47	45	BTC	3.22	Gwke w/ Arg	145
101	Sun-23-76-5	38 51 13 N 122 55 22 W	2460	255	170-240	B-	90	71			2.42	Grnst	
102	Sun-23-76-6	38 51 27 N 122 54 3 W	2500	240	170-240	B-	77	107				Ch	
103	Sun-23-76-11	38 47 2 N 122 42 12 W	1940	300	120-300	A	120	196	204	BTC	3.22	Gwke w/ Sh	657
104	Sun-23-76-12	38 47 36 N 122 41 49 W	2000	250	140-250	A	195	136	114	BTC	3.22	Gwke w/ Sh	367
105	Sun-23-76-13	38 46 55 N 122 41 12 W	1440	265	200-260	B-	198	114			3.22	Gwke	
106	Sun-23-76-15	38 51 52 N 122 52 6 W	2300	280	200-280	B-	14	28			3.22	Gwke	
107	Th-TG-1	38 47 52 N 122 50 13 W	2400	299	100-280	A+	68	57			3.22	Gwke	
108	Th-TG-2	38 47 25 N 122 49 37 W	2380	600	100-600	A+	150	88	88	EST	3.22	Gwke	283
109	Th-TG-3A	38 47 8 N 122 49 2 W	2700	325	100-310	B	26	75	75	EST	3.22	Gwke	242
110	Th-TG-4	38 46 54 N 122 49 7 W	2180	600	210-560	A+	30	113	95	BTC	3.22	Gwke	306
111	Th-TG-5	38 46 44 N 122 48 35 W	3020	318	100-310	A+	22	66	66	EST	3.22	Gwke	213
112	Th-TG-6	38 46 31 N 122 49 32 W	2700	500	390-500	A	53	63	63	EST	3.22	Gwke	203
113	Th-TG-7	38 46 14 N 122 50 21 W	3000	500	340-490	A	46	65	76	BTC	3.22	Gwke	245
114	Th-TG-8	38 46 17 N 122 48 18 W	3050	459	400-450	A-	7	91	95	EST	3.22	Gwke	306
115	Th-TG-9	38 45 52 N 122 48 20 W	2200	348	120-320	A+	21	91	91	EST	3.22	Gwke	293
116	Th-TG-11	38 46 24 N 122 48 54 W	2600	497	320-480	A	35	73	73	EST	3.22	Gwke	235
117	Th-TG-12	38 45 59 N 122 49 10 W	1900	416	200-400	A+	172	117	95	BTC	3.22	Gwke	306
118	Th-TG-13A	38 47 16 N 122 48 42 W	2800	600	450-600	A	144	107	110	EST	3.22	Gwke	354
119	Th-TG-14	38 48 8 N 122 50 16 W	1900	243	100-230	A	262	125	125	EST	3.22	Gwke	403
120	Th-TG-16	38 44 20 N 122 41 50 W	2760	500	280-460	A	37	136	128	BTC	3.22	Gwke	412
121	Th-TG-17	38 44 0 N 122 41 33 W	2840	420	230-410	B	34	102	105	EST	3.22	Gwke-355ft., Sch-420ft.	
122	Th-TG-18	38 43 47 N 122 41 53 W	3200	314	180-300	A	718	64	70	EST	2.39	Sp	167
123	Th-TG-19	38 43 56 N 122 42 28 W	3380	500	280-450	A	21	52	57	EST	3.22	Gwke	184
124	Th-TG-20	38 48 42 N 122 51 34 W	1320	497	100-440	A+	18	119	115	EST	3.22	Gwke	370
125	Th-TG-21	38 48 16 N 122 50 35 W	1480	500	320-500	A	11	150	140	EST	3.22	Gwke	451
126	Th-TG-22	38 48 28 N 122 50 17 W	1100	500	330-500	A	32	236	186	BTC	3.22	Gwke	599
127	Th-TG-23	38 48 12 N 122 51 16 W	2020	500	150-500	A+	36	86	90	BTC	3.22	Gwke	290
128	Th-TG-24	38 47 52 N 122 50 44 W	2420	500	380-500	B	37	51	57	EST	3.22	Gwke	184
129	Th-TG-40	38 43 34 N 122 45 31 W	2000	598	460-560	A	31	74	74	EST	3.22	Gwke	238
130	Th-TG-41	38 44 6 N 122 45 16 W	2180	492	100-490	A+	44	105	98	BTC	3.22	Gwke-278ft., Grnst-290ft., Sch-	316
131	Th-TG-42	38 44 36 N 122 45 6 W	2560	600	100-580	A+	652	104	110	EST	3.22	Gwke	354
132	Th-TG-43	38 45 11 N 122 45 3 W	3000	600	490-600	A	65	121	128	BTC	3.22	Gwke	412
133	Th-TG-44	38 43 50 N 122 44 44 W	2450	529	330-510	A	61	85	87	EST	3.22	Gwke	280
134	Th-TG-47	38 44 8 N 122 47 12 W	2020	575	250-410	A	43	69	82	BTC	2.39	Sp	196
135	Th-TG-48	38 43 34 N 122 46 12 W	1760	594	440-590	A	28	54	61	BTC	3.22	Gwke	229
136	Th-TG-49	38 43 52 N 122 43 44 W	3100	600	410-600	A	28	54	61	BTC	3.22	Gwke	196
137	Th-TG-52	38 47 30 N 122 41 8 W	2210	602	360-530	C	57	99	99	EST	2.39	Sp	237
138	Th-TG-53	38 47 49 N 122 41 11 W	2380	600	370-530	A	50	110	104	BTC	2.39	Sp	249
139	Th-TG-64	38 47 14 N 122 41 25 W	1580	600	340-420	A-	31	129	126	EST	3.22	Gwke	406
140	Th-TG-65	38 43 42 N 122 41 31 W	2975	930	420-790	A+	25	63	69	BTC	3.22	Gwke w/ Sh	222
141	U-71-1	38 49 12 N 122 48 0 W	2520	250	100-225	A	75	206	181	EST	3.22	Gwke	583
142	U-71-2	38 48 31 N 122 47 58 W	3000	250	75-250	B	50	171	205	BTC			

1	2	3	4	5	6	7	8	9	10	11	12	13	14
WELL NO. USED IN STUDY	OPERATOR WELL NO.	LOCATION (latitude) (longitude)	SURF. ELEV.	TOTAL DEPTH	GRADIENT INTERVAL	DATA QUALITY INTERVAL LENGTH	LOG LAG	TEMP. (uncorr.)	-GRADIENT (corr.)	TERRAIN CORR. METHOD	MEAN THERMAL CONDUCT. W/m ² K	LITHOLOGY ACROSS GRADIENT INTERVAL	HEAT FLOW mW/m ²
		deg min sec	deg min sec	feet	feet	feet	days	°C/km	°C/km				
163	U-71-33	38 46 52 N	122 40 16 W	1400	260	175-225	B-	32	109		3.22	Gwke	
164	U-72-1	38 45 50 N	122 49 21 W	2000	250	150-250	A	26	84	81	3.22	Gwke	261
165	U-72-2	38 49 19 N	122 49 46 W	2560	250	175-250	C-	377	143			Landslide	
166	U-72-3	38 48 1 N	122 45 24 W	3400	235	75-225	B	210	75	73	3.22	Gwke	235
167	U-72-4	38 49 25 N	122 45 20 W	3050	235	100-225	B	381	150	153	3.22	Gwke	493
168	U-72-5	38 50 34 N	122 48 21 W	3000	225	75-250	B	17	88	99	3.22	Gwke w/ Ch	319
169	U-72-6	38 50 36 N	122 46 40 W	2550	225	75-225	B	13	109	101	3.22	Gwke	325
170	U-72-7	38 51 24 N	122 47 30 W	2900	250	100-250	C	5	53		2.42	Grnst?	
171	U-72-8	38 52 22 N	122 50 10 W	2600	250	200-250	A	24	73	73	3.22	Landslide & Grnst & Gouge	
172	U-72-9	38 52 30 N	122 48 24 W	2655	235	175-225	B-	24	73			Melange	
173	U-72-10	38 47 33 N	122 45 34 W	3200	235	125-250	B	7	128	127	2.42	Grnst	307
174	U-72-11	38 48 0 N	122 45 54 W	3200	235	100-200	B-	18	80	80	3.22	Gwke	258
175	U-72-14	38 52 11 N	122 48 34 W	2430	175	100-175	C-	6	47		3.22	Gwke	
176	U-72-18	38 46 42 N	122 46 22 W	2800	245	100-250	B	44	159	167	3.22	Grnst	404
177	U-72-19	38 49 23 N	122 44 12 W	3500	245		C	3				Volc	
178	U-72-21	38 47 48 N	122 46 11 W	2950	245	200-250	B-	16	146	146	2.42	Grnst	353
179	U-73-4	38 41 39 N	122 44 10 W	400	250	125-250	C	3	70		3.22	Gwke	
180	U-73-6	38 40 39 N	122 44 22 W	300	250	175-250	C-	2	62		2.39	Sp	
181	U-73-26	38 53 14 N	122 47 38 W	2630	235	175-225	C-	4	91		2.39	Sp	
182	U-73-27	38 44 37 N	122 43 24 W	2910	235	125-225	B	23	200	165	2.39	Sp	394
183	U-73-28	38 45 30 N	122 44 51 W	3120	300	75-275	C-	20	114		3.22	Gwke	
184	U-73-29	38 48 56 N	122 44 49 W	3920	160		C	?				Volc	
185	U-73-30	38 48 58 N	122 44 5 W	2200	175		C	?				Volc	
186	U-73-31	38 49 49 N	122 52 26 W	1250	290	125-275	C	30	75		3.22	Gwke	
187	U-75-17	38 54 37 N	122 50 47 W	1595	400	200-300	C	?	155			Alluv	

1. Infiltration of groundwater. Groundwater flowing through rock may raise or lower in-situ rock temperatures. In the area of The Geysers Geothermal field, landslides, alluvium, Clear Lake Volcanic rocks, fractured chert, and greenstone are particularly susceptible to infiltration by groundwater¹². In areas underlain by these rock types, temperature-depth data may be relatively useless.

In a large landslide near The Geysers Resort, groundwater infiltration is documented... According to Vantine¹⁷, cold meteoric water flows downslope through the slide and is heated before exiting in the form of thermal springs near the toe of the slide. Temperatures recorded in shallow, temperature-gradient holes drilled near the top of the slide are abnormally low, while temperatures recorded in wells drilled near the bottom are abnormally high.

In another area, temperatures recorded from three temperature-gradient holes drilled into the permeable volcanics capping Cobb Mountain approach zero gradient because of the infiltration of cold, meteoric water (TG 177, 184, and 185, Fig. 2).

Fortunately, graywacke (the most common rock type penetrated by temperature-gradient holes at The Geysers) usually appears to be free of flowing groundwater below a depth of 30 m.

2. Microclimatic variations. The mean annual surface temperature is not just a function of elevation, but also a function of prevailing wind patterns, slope angle, and slope orientation. The latter two variables control the total amount of solar radiation to which a site is exposed. As a result, in areas of uneven terrain, the mean annual surface temperature may vary significantly over short distances (tens of meters). According to Blackwell³, the curvature of a temperature-gradient profile recorded in impermeable rocks between 100 and 300 m in depth is due mainly to microclimatic variations and topographic effects.

3. Seasonal surface-temperature fluctuations. Seasonal, surface-temperature fluctuations peri-

odically affect the in-situ rock temperatures in all temperature-gradient holes. However, these temperature changes are limited to relatively shallow depths (to about 20 m).

4. Thermal recovery time of the borehole. Temperatures recorded in the wellbore are dependent on the time span between drilling and logging the wellbore. If the time span is short (generally fewer than 7 days¹), the recorded temperatures may differ significantly from the actual pre-drilling temperatures, since the rock near the wellbore would not have returned to the original temperatures after being cooled (or warmed) by the drilling mud. The lag time between drilling and logging each hole is shown in column 8, Table 1.

5. Topography. At The Geysers, the most common disturbance to a normal, straight-line temperature-gradient profile is caused by rugged topography. The temperature-gradient profile may be concave upward or convex upward, depending on whether or not the temperature-gradient hole is sited on a ridge or in a valley, respectively. The temperature-gradient profile from a temperature-gradient hole sited in midslope is often nearly linear.

In The Geysers area, temperature-gradient holes are frequently sited in the more easily accessible locations such as along the existing roads and trails that follow the ridge tops and valley bottoms. Temperature gradients recorded for these holes may vary by 30 percent from an undisturbed linear temperature gradient.¹¹

Screening and Correcting Temperature-Depth Data

The methods used to exclude or correct temperature-depth data for some of the shallow-hole effects mentioned in the previous section are as follows.

1. Infiltration of groundwater and seasonal surface-temperature fluctuations. To minimize both of these effects, temperature data were not used

from depths above about 20 m.

2. Thermal recovery time of the borehole.

Temperature-depth data from temperature-gradient holes that had less than a 7-day thermal recovery period (time between completing and logging the hole) and a temperature gradient under $120^{\circ}\text{C}/\text{km}$ (about twice the assumed regional gradient) were not used in the study. On the other hand, some temperature-depth data from temperature-gradient holes with less than a 7-day thermal recovery period and a gradient above $120^{\circ}\text{C}/\text{km}$ were used under the assumption that rocks near the wellbore would have returned to almost predrilling temperatures in these areas of higher heat flow.

3. Topography. To correct for the effects of topography, standard Birch terrain-corrections², which have been used at The Geysers with good results, were applied to temperature-depth data from 70 widely distributed, temperature-gradient holes. These terrain-corrected gradient holes are identified as *BTC* in column 11, Table 1. It should be noted that Birch-corrected data must be interpreted with care, since the correction technique will sometimes fail to adequately correct data from shallow temperature-gradient holes sited near steep slopes.

The Birch corrections were generated by considering 10 concentric intervals to a maximum distance of about 1525 m from the well bore (a distance about 10 times the depth of the average hole). An adiabatic lapse rate (change in surface temperature per unit of elevation) of $.00472^{\circ}\text{C}/\text{m}$ was assumed. The resulting terrain-corrected, temperature-gradient data were then plotted and are in Appendix D.

Calculating Temperature Gradients

Temperature gradients were determined by:

1. Visually fitting straight-line segments to various depth intervals on both the uncorrected and the terrain-corrected, temperature-gradient profiles;
2. Choosing one *best* interval; and
3. Calculating the least-squares fit to the temperature-depth data.* The chosen intervals were limited to straight-line segments, with no point shallower than about 20 m.

Most of the temperature-gradient holes were drilled into rocks of uniform lithology. The chosen interval in these temperature-gradient holes was usually in the lower portion of the hole, regardless of lithology. Other temperature-gradient holes were drilled through alternating lithologic units. In such cases, the chosen interval was usually in a graywacke unit, as close to the bottom of the

*The recorded temperature data are only as accurate as the minimum accuracy of the instrument used to measure the temperature. Depending on the operator and the recording tools used, temperatures were reported accurate over a range of $.001^{\circ}\text{C}$ to $.5^{\circ}\text{C}$. This variation was not considered significant in determining temperature gradients as long as the temperature-depth data points were chosen over a long depth interval. In such cases, least-squares, line-fitting techniques tend to yield about the same computed temperature-gradient measurement, regardless of data accuracy.

hole as possible.

Examples of line-fitting methods applied to Birch terrain-corrected data are in Appendix D. The calculated temperature gradients for both uncorrected and Birch-corrected temperature-depth data are listed in columns 9 and 10, Table 1.

Quality of Calculated Temperature Gradients

A quality rating system was used to rank the calculated temperature gradients according to degree of confidence. An *A* rating (column 7, Table 1) was subjectively assigned to data from temperature-gradient holes that appeared to be insignificantly affected by shallow-hole effects in the chosen interval. In addition, the temperature gradients calculated from the *A* data must be consistent with regional gradient trends. Lower and lowest quality temperature gradients are identified as *B* and *C*, respectively.

In general, any calculated temperature gradient was considered suspect if the continuation of the gradient to the surface did not yield a reasonable, ambient surface temperature. Temperature gradients from these wells were placed in the *C* quality level.

Another factor that influences the degree of confidence in the temperature-gradient values is the length of the chosen interval. In general, the longer the straight-line interval, the higher the degree of confidence. To provide a quick look at the relative lengths of the chosen intervals, a grouping system was used. Temperature-gradient holes with a chosen interval longer than 61 m are in one group, and are identified by a plus sign (+) following the letter value in column 7, Table 1. Chosen intervals 30 to 61 m in length have no sign (), while intervals under 30 m are identified by a minus sign (-).

Correcting Temperature Gradients for the Effects of Terrain

A representative group of 70 temperature gradients was previously corrected for the effects of terrain by calculating the gradients using Birch-corrected, temperature-depth data. An interpolation technique was used to terrain-correct most of the remaining 117 temperature gradients. The method of interpolation is as follows:

1. A correction factor was determined for each Birch terrain-corrected, temperature-gradient hole (identified as *BTC* in column 11, Table 1) by dividing the corrected gradient (column 10) by the uncorrected gradient (column 9). (Correction factors are not shown.)
2. Correction factors were estimated for most of the remaining uncorrected, temperature-gradient holes (identified as *EST* in column 11) by considering the elevation and topographic location of each uncorrected temperature-gradient hole and the relative elevations, topographic locations, and the correction factors of nearby Birch terrain-corrected, temperature-gradient holes. (Estimated correction factors are not shown.)

from depths above about 20 m.

2. Thermal recovery time of the borehole.

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hole as possible.

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2. Correction factors were estimated for most of the remaining uncorrected, temperature-gradient holes (identified as *EST* in column 11) by considering the elevation and topographic location of each uncorrected temperature-gradient hole and the relative elevations, topographic locations, and the correction factors of nearby Birch terrain-corrected, temperature-gradient holes. (Estimated correction factors are not shown.)

*The recorded temperature data are only as accurate as the minimum accuracy of the instrument used to measure the temperature. Depending on the operator and the recording tools used, temperatures were reported accurate over a range of $.001^{\circ}\text{C}$ to $.5^{\circ}\text{C}$. This variation was not considered significant in determining temperature gradients as long as the temperature-depth data points were chosen over a long depth interval. In such cases, least-squares, line-fitting techniques tend to yield about the same computed temperature-gradient measurement, regardless of data accuracy.

3. The new, corrected temperature gradients for those holes were then computed (column 10) as the products of the uncorrected temperature gradients and the estimated correction factor. This method yields temperature-gradient values that approximate Birch, terrain-corrected values.

Temperature-Gradient Map Construction

The temperature-gradient values used to construct the temperature-gradient map were from three sources:

1. A list of corrected temperature gradients (column 10, Table 1);

2. Published temperature gradients from two, deep production wells drilled by Shell Oil Company⁹; and

3. Temperature gradients calculated from deep production-well, first steam-entry data. Since it is known that heat flows primarily by conduction in the zone above the reservoir, the temperature gradient for a deep production well ($\Delta T/\Delta z$) can be estimated by dividing the numerical difference of the approximate surface temperature and the reservoir temperature by the true vertical depth to first steam entry [$\Delta T/\Delta z = (240^\circ\text{C} - 15^\circ\text{C}) / \text{true vertical depth}$].

The criteria evaluated in the selection of control points for the temperature-gradient map were:

1. Data quality (A, B, or C in column 7, Table 1);

2. Chosen interval length (+, blank, or —, in column 7, Table 1);

3. Correlation with the geologic and topographic grain of the area (the temperature-gradient values for many unselected temperature-gradient holes were assumed to a. be erroneous, b. reflect the disturbances caused by surficial effects, or c. reflect the heat flow from small, localized thermal anomalies); and

4. Correlation with temperature-gradient trends revealed by nearby and distant temperature-gradient holes.

The temperature-gradient map (Fig. 3) was then constructed using the locations (column 3, Table 1) of the selected, temperature-gradient holes as control points.

In some developed areas of the study area, contours are shown as dashes. In these areas, good control was established by choosing as control points the locations of selected, deep production wells, and calculating temperature gradients by the deep-well, temperature-gradient estimation methodology described previously. The interior portion and the margins of the study area were not contoured due to the low density of control points.

HEAT-FLOW

A temperature gradient measured at any interval in a

Figure 3. Map of The Geysers study area showing isolines of temperature gradients in $^\circ\text{C}/\text{km}$. Circles show locations of temperature-gradient holes; filled circles show control points. Isolines shown as dashes are estimated from deep production well data. Isolines that are dashed and queried indicate uncertainty.

temperature-gradient hole is inversely proportional to the conductivity of the rock in which the measurement is taken. This relationship is expressed as $Q = k (\Delta T / \Delta z)$, where Q is heat-flow, k is thermal conductivity, and $\Delta T / \Delta z$ is the temperature gradient.

Some temperature-gradient values, determined from temperature-gradient holes drilled in areas underlain by rocks of differing lithologies, cause distortions in the temperature-gradient contours. One reason for constructing the heat-flow map is to remove such distortions. Another reason is that a heat-flow map can be used to calculate the rate of reservoir heat loss.

Thermal Conductivity

Before determining heat-flow, the thermal conductivity must be known for the rock units in which the temperature gradients were measured. Ideally, the thermal conductivity would be determined in-situ or from rock cuttings taken from the temperature-gradient hole. Unfortunately, cuttings and thermal conductivity data determined in-situ were not available from the temperature-gradient holes. However, representative cuttings of the most commonly occurring rock types—graywacke, greenstone, and serpentinized ultramafic rocks—were available from widely distributed, deep production wells. These cuttings were analyzed for thermal conductivity. The thermal conductivities for less-common rock types were not determined in this study. The procedure used in the analysis follows.

1. Cutting samples were selected from widely spaced intervals in the mud-drilled portions of 16, widely distributed production wells (Fig. 2).

2. Care was taken to exclude samples that were mud-contaminated,³ hydrothermally altered, had more than 10 percent total vein quartz and calcite, or had more than 20 percent contaminants (fragments of other rock types).

3. From 55 to 64 representative samples of each of the three major rock types were ground and analyzed for thermal conductivity by the modified, divided-cell method. A sample porosity of 5 percent was assumed.

The results of the thermal conductivity analysis are shown as histograms in Figure 4. The thermal conductivities of the graywacke and the serpentinized ultramafic rock samples appear to approximate a normal distribution. These have arithmetic mean values of 3.22 and 2.39 $W/m \cdot ^\circ K$, respectively. On the other hand, the thermal conductivities of the greenstone samples appear to have a definite non-normal distribution, with a mean value of 2.42 $W/m \cdot ^\circ K$. This non-normal distribution may be due to sampling error or may be due to the inclusion of more than one sample population in the greenstone cuttings (a distinct possibility since greenstones are variably altered and composed of several facies types). In any case, the overall mean value of 2.42 $W/m \cdot ^\circ K$ is about the same as

that for serpentinized ultramafic rock. Both the greenstone and the serpentinized ultramafic rock have only 75 percent of the overall mean thermal conductivity of graywacke. Apparently, the higher thermal conductivity of graywacke may be due to its greater volumetric percentage of highly conductive quartz.

Figure 4. Histograms showing the thermal-conductivity distributions of graywacke, serpentinized ultramafic rock, and greenstone cuttings samples from deep production wells in The Geysers study area.

Heat-Flow Map Construction

Heat-flow values used in the construction of the heat-flow map were calculated by multiplying the corrected, temperature-gradient values (column 10, Table 1) for selected temperature-gradient holes by the mean thermal conductivity value (column 12, Table 1) for the particular rock type across which the gradient was calculated. Calculated heat-flow values are shown in column 14, Table 1. The chosen, gradient interval and the lithology across the interval are shown in columns 6 and 13, Table 1, respectively. The lithology was not recorded for 11 temperature-gradient holes used in the heat-flow map. For these temperature-gradient holes, the lithology was assumed to be the same as that mapped on the surface. These questionable lithologies are followed by a question mark in column 13, Table 1.

Control points were selected and the heat-flow map (Fig. 5) was constructed using criteria similar to that used in constructing the temperature-gradient map. Since most of the selected heat-flow values were computed from temperature-gradient holes drilled in graywacke, the trends of the heat-flow contours are similar to the trends of the temperature-gradient contours.

CALCULATION OF ANNUAL HEAT LOSS BY THERMAL CONDUCTION

The heat-flow map was used to estimate the total heat

energy lost annually from thermal conduction within the boundaries of the reservoir. Of course, the reservoir boundaries can never be determined absolutely, but they can be estimated if, for purposes of computation, steam is assumed to be present in the area circumscribed by the 350 mW/m² heat-flow contour. This contour was chosen because the area within it closely approximates an area that currently includes all known deep geothermal wells deemed capable of commercial production.

The reason for this correlation may be economic. At The Geysers, the cost of drilling and completing production wells determines a practical completion depth. Since the typical production well is drilled more than 800 m below the 240°C isotherm, a well that is directionally drilled on heat-flow contours of less than 350 mW/m² (equivalent to about 120°C/km gradient) typically would have to be drilled to a depth of 3000 m to intersect a sufficient number of productive fractures to be considered commercial. Therefore, the escalating costs for drilling and completing deeper wells could be the main factor restricting development in the lower heat-flow areas.

To complete the interior portion of the heat-flow map, additional heat-flow contours were projected inward towards the axis of the thermal anomaly in a manner consistent with the spacing of the existing contours and with the heat-flow values computed for widely scattered control points within the interior. To ascertain the amount of heat lost annually through the surface by thermal conduction, the areas between adjacent heat-flow contours were

Figure 5. Map of The Geysers study area showing isolines of heat flow in mW/m². Circles show locations of temperature-gradient holes; filled circles show control points. Isolines shown as dashes are estimated from deep production well data. Isolines that are dashed and queried indicate uncertainty.

determined, multiplied by the geometric average heat-flow value for each area, and added together. The total heat-flow rate was then converted to an annual rate yielding 1.79×10^9 MJ/yr.

CALCULATION OF ANNUAL HEAT LOSS BY STEAM PRODUCTION

The net, heat-energy loss from commercial steam production for the year 1983 is estimated from production and injection data published by the Division of Oil and Gas.⁴ The net, heat-energy loss is expressed as $m_s(h_s - h_0) - m_{iw}(h_{iw} - h_0)$, where m_s and h_s are the mass and assumed specific enthalpy of produced steam; m_{iw} and h_{iw} are the mass and assumed specific enthalpy of injected water; and h_0 is the specific enthalpy of meteoric water at 15°C and .98 bars. The net heat energy lost by production for 1983 is calculated as 180.14×10^9 MJ.

DISCUSSION AND CONCLUSION

The temperature-gradient and heat-flow maps (Figs. 3 and 5) show that the laterally extensive, northwesterly-trending anomaly is composed of two smaller areas of anomalously high heat flow (identified as A and B, Fig. 5). The five, first-reported steam entry anomalies described by Thomas¹⁴ occur in these areas. Three more anomalous areas of high heat flow (C, D, and E) are also identified in the heat-flow map. The anomalously low, heat-flow

area under Cobb Mountain (F) supports the hypothesis that Cobb Mountain may be an area of meteoric water downflow^{8,14}.

The heat energy lost by thermal conduction through the ground surface circumscribed by the 350mW/m^2 heat-flow anomaly is estimated at 1.79×10^9 MJ/yr. The net heat energy lost by production for the year 1983 is estimated at 180.14×10^9 MJ.

Thus, in 1983, the heat energy removed from the reservoir by production was significantly greater than that lost naturally by thermal conduction. And, in turn, the heat energy removed from the reservoir by production is insignificant when compared with the heat energy that remains within the reservoir⁷.

ACKNOWLEDGMENTS

Partial funding for the study was provided by U.S. Department of Energy Grant #DE-AC03-83SF11721. The author gratefully acknowledges the assistance he received from many companies and individuals. The U.S. Geological Survey supplied cuttings samples; EnergyLog provided working facilities; and Geotech Data performed the thermal conductivity analyses and terrain corrections. Phillips Petroleum Company and Grace Geothermal Company agreed to the use of proprietary data. Special thanks are offered to all individuals who reviewed the manuscript.

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APPENDIX A

Commonly-used conversion factors.

COMMONLY USED CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
Length		
meters (m)	3.281	feet (ft.)
kilometers (km)	0.621	miles (mi.)
Area		
square kilometers (km ²)	247.105	acres (acre)
	0.386	square miles (mi ²)
Pressure		
bar	14.504	pounds per square inch (psi)
Temperature		
degrees Celsius (°C)	1.8, then add 32	degrees Fahrenheit (°F)
Temperature gradient		
degrees Celsius per kilometer (°C/Km)	.055	degrees Fahrenheit per 100 feet (°F/100 ft.)
Thermal conductivity		
watts per meter-degree Kelvin (W/m·°K)	2.388	millicalories per centimeter-second-degree Celsius (mcal/cms·°C)
Heat flow		
milliwatts per square meter (mW/m ²)	2.388 x 10 ²	calories per square centimeter-second (cal/cm ² ·s) heat flow units (HFU)
Thermal energy		
megajoules (MJ)	2.388 x 10 ⁵	calories (cal)
Thermal power		
megawatts (MW)	2.388 x 10 ⁵	calories per second (cal/sec.)

APPENDIX B

Temperature-depth data from 168 nonconfidential temperature-gradient holes in The Geysers study area.

TG 1		TG 2		TG 3		TG 4		TG 5		TG 6		TG 7	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
60	14.33	20	13.22	20	17.22	0	5.72	40	15.83	20	15.89	20	20.17
80	15.00	40	12.61	40	17.28	20	17.61	60	17.06	40	16.83	40	23.11
100	15.39	60	12.61	60	17.56	40	17.94	80	18.28	60	17.83	60	27.39
120	16.06	80	12.67	80	18.28	60	18.89	100	19.28	80	19.06	80	30.83
140	16.72	100	12.67	100	19.00	80	19.56	120	20.61	100	21.06	100	34.00
160	17.44	120	12.67	120	23.11	100	20.56	140	21.61	120	22.39	120	36.67
180	18.61	140	12.67	140	25.11	133	21.33	160	22.94	140	24.17	140	39.44
200	19.56	160	12.72	160	26.83			180	24.22	160	25.89	160	42.22
220	20.33	180	12.94	180	28.72			200	25.44	180	27.39	180	45.56
240	21.11	200	13.28	200	30.67			220	26.72	200	28.89	200	48.89
260	21.94	220	14.00	220	32.44			240	27.83	220	30.33	220	51.67
280	22.94	240	15.00	240	34.33			260	29.06	240	32.67	240	53.89
300	23.61	260	16.06	260	36.11			280	30.39	243	33.78	260	56.11
316	24.61	280	17.39					300	31.72			276	58.89
		300	18.61					315	32.44				
		315	20.00										

TG 8		TG 9		TG 10		TG 11		TG 12		TG 13		TG 14	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
100	27.06	20	18.88	20	13.60	20	12.83	40	14.54	20	16.90	20	17.12
120	30.33	40	19.82	40	14.47	40	12.84	60	11.90	40	15.80	40	17.25
140	33.17	60	20.57	60	14.67	60	12.75	80	12.00	60	16.92	60	17.90
160	36.39	80	21.15	80	14.87	80	13.19	100	12.11	80	17.70	80	18.35
180	40.33	100	21.80	100	15.20	100	13.92	120	12.34	100	18.60	100	18.76
200	43.61	120	22.60	120	15.69	120	14.75	140	12.69	120	19.50	120	19.20
220	47.56	140	23.37	140	16.10	140	15.45	160	13.04	140	20.52	140	19.65
240	51.56	160	24.20	160	16.65	160	16.02	180	13.44	160	21.55	160	20.20
260	55.72	180	24.92	180	17.10	180	16.62	200	13.86	180	22.55	180	20.70
280	59.61	200	25.57	200	17.50	200	17.08	220	14.46	200	23.42	200	21.13
300	62.61	220	26.12	220	17.92	220	17.50	240	15.00	220	24.38	220	21.65
314	66.94	240	26.73	240	18.36	240	18.05	260	15.59	240	25.32	240	22.14
		260	27.30	260	18.79	260	18.60	280	16.34	260	26.32	260	22.70
		280	27.95	280	19.21	280	19.06	300	17.12	280	27.25	280	23.22
		300	28.58	300	19.65	300	19.58	320	17.85	300	28.12	300	23.71
		320	29.18	320	20.10	320	20.10	340	18.57			320	24.17
		340	29.85	340	20.59	340	20.59	360	19.37			340	24.68
		360	30.52	360	21.00	360	21.10	380	20.24			360	25.19
		380	31.15	380	21.42	380	21.55	400	21.16			380	25.66
		400	31.88	400	21.88	400	22.08	420	22.10			400	26.09
		420	32.70	420	22.35	420	22.58	440	22.97			420	26.55
		440	33.42	440	22.76	440	23.06	460	23.79			440	27.02
		460	34.30	460	23.22			480	24.49			460	27.48
		480	35.10	480	23.63							480	28.02
		485	35.30										

TG 15		TG 16		TG 17		TG 18		TG 19		TG 20		TG 21	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	15.75	20	16.10	20	25.55	20	14.15	20	12.96	80	15.78	60	14.40
40	16.15	40	16.44	40	15.22	40	14.69	40	13.81	100	16.02	80	14.65
60	16.47	60	16.45	60	15.46	60	14.80	60	14.10	120	16.24	100	15.05
80	16.81	80	16.55	80	15.70	80	14.89	80	14.42	140	16.51	120	15.49
100	17.05	100	16.84	100	15.98	100	15.04	100	14.80	160	16.80	140	15.90
120	17.36	120	17.30	120	16.25	120	15.22	120	15.29	180	17.10	160	16.34
140	17.73	140	17.63	140	16.50	140	15.36	140	15.87	200	17.42	180	16.79
160	18.07	160	18.08	160	16.76	160	15.62	160	16.47	220	17.72	200	17.21
180	18.44	180	18.49	180	17.00	180	15.83	180	17.02	240	18.05	220	17.64
200	18.80	200	18.89	200	17.20	200	16.07	200	17.53	260	18.42	240	18.08
220	19.15	220	19.25	220	17.48	220	16.36	220	18.17	280	18.80	260	18.56
240	19.52	240	19.70	240	17.74	240	16.65	240	18.82	300	19.17	280	18.97
260	19.97	260	20.24	260	18.04	260	16.95	260	19.41	320	19.53	300	19.43
280	20.35	280	20.68	280	18.32	280	17.29	280	20.06	340	19.90	320	19.91
300	20.74	300	21.00	300	18.62	300	17.63	300	20.66	360	20.30	340	20.44
320	21.15	320	21.20	320	18.90	320	17.97	320	21.23	380	20.71	360	20.87
340	21.56	340	22.13	340	19.20	340	18.31	340	21.88	400	21.17	380	21.35
360	22.00	360	22.56	360	19.50	360	18.65	360	22.50			400	21.85
380	22.44	380	22.93	380	19.83	380	19.02	380	23.14			420	22.35
400	22.83	400	23.40	400	20.20	400	19.35	400	23.77			440	22.80
420	23.25	420	23.63	420	20.51	420	19.75	420	24.48			460	23.30
440	23.69	440	24.32	440	20.87	440	20.14	440	25.16			480	23.77
460	24.10			460	21.22	460	20.55	460	25.82				
480	24.51			480	21.58								

TG 22		TG 23		TG 24		TG 25		TG 26		TG 27		TG 28	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	14.68	20	14.05	20	14.72	20	16.74	20	18.75	20	21.24	20	17.70
60	15.54	40	14.05	40	15.61	40	16.74	40	17.95	40	20.10	40	17.27
80	15.80	60	14.68	60	15.96	60	16.95	60	17.90	60	20.31	60	18.85
100	16.14	80	14.90	80	16.30	80	17.44	80	17.95	80	20.96	80	19.77
120	16.42	100	15.20	100	16.66	100	18.06	100	18.05	100	21.47	100	20.65
140	16.93	120	15.45	120	17.02	120	18.66	120	18.15	120	22.02	120	21.40
160	17.36	140	15.75	140	17.37	140	19.18	140	18.25	140	22.52	140	22.22
180	17.69	160	16.05	160	17.73	160	19.82	160	18.40	160	23.02	160	22.93
200	18.30	180	16.38	180	18.11	180	20.35	180	18.60	180	23.58	180	23.73
220	18.76	200	16.70	200	18.48	200	20.90	200	18.80	200	24.12	200	24.48
240	19.17	220	17.02	220	18.80	220	21.49	220	19.04	220	24.68	220	25.02
260	19.65	240	17.30	240	19.16	240	22.10	240	19.28	240	25.22	240	25.53
280	20.15	260	17.66	260	19.56	260	22.67	260	19.52	260	25.77	260	26.08
300	20.75	280	17.99	280	19.91	280	23.24	280	19.78	280	26.27	280	26.60
320	21.29	300	18.35	300	20.27	300	23.77	300	20.05	300	26.86	300	27.10
340	21.92	320	18.65	320	20.69	320	24.30	320	20.34	320	27.47		
360	22.55	340	18.93	340	21.08					340	28.12		
380	23.08	360	19.29	360	21.50					360	28.70		
400	23.65	380	19.60	380	21.92					380	29.24		
420	24.20			400	22.33					400	29.83		
440	24.70			420	22.78					420	30.50		
				440	23.17					440	31.09		
				460	23.68					460	31.63		
				480	24.19					480	32.17		
				500	24.67								

TG 29		TG 30		TG 31		TG 32		TG 33		TG 34		TG 35	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	18.14	20	15.62	20	13.06	20	14.95	20	15.25	20	11.55	20	12.85
40	17.88	40	16.12	40	16.14	40	16.32	40	15.09	40	11.55	40	13.25
60	18.52	60	16.20	60	16.05	60	16.35	60	15.75	60	11.45	60	12.80
80	19.10	80	16.64	80	16.10	80	16.52	80	15.95	80	11.55	80	12.60
100	19.75	100	17.08	100	16.35	100	16.80	100	16.35	100	11.80	100	12.60
120	20.44	120	17.65	120	16.58	120	17.15	120	16.70	120	12.05	120	12.70
140	21.10	140	18.18	140	16.85	140	17.45	140	17.15	140	12.35	140	12.80
160	22.06	160	18.78	160	17.12	160	17.82	160	17.65	160	12.65	160	12.95
180	22.80	180	19.17	180	17.42	180	18.20	180	18.25	180	12.95	180	13.10
200	23.42	200	19.60	200	17.72	200	18.55	200	18.75	200	13.26	200	13.25
220	24.08	220	20.05	220	18.05	220	18.98	220	19.35	220	13.62	220	13.45
240	24.75	240	20.55	240	18.40	240	19.43	240	20.00	240	13.94	240	13.70
260	25.31	260	21.00	260	18.72	260	19.95	260	20.60	260	14.29	260	13.90
280	25.98	280	21.53	280	19.01	280	20.50	280	21.35	280	14.61	280	14.10
300	26.65			300	19.48	300	21.00	300	21.95	300	14.96	300	14.40
				320	19.82								
				340	20.18								
				360	20.54								
				380	20.87								
				400	21.32								
				420	21.77								
				440	22.02								
				460	22.69								
				480	23.17								

TG 36		TG 37		TG 38		TG 39		TG 40		TG 41		TG 42	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	12.45	100	12.56	20	12.50	20	11.30	100	13.44	160	17.00	40	14.77
40	12.70	120	12.56	40	12.35	40	11.30	120	13.70	180	17.23	60	14.95
60	12.30	140	12.60	60	11.75	60	11.25	140	13.97	200	17.60	80	14.82
80	12.30	160	12.65	80	11.80	80	11.40	160	14.25	220	18.00	100	14.80
100	12.45	180	12.70	100	11.90	100	11.75	180	14.55	240	18.40	120	14.80
120	12.55	200	12.80	120	12.00	120	12.15	200	14.88	260	18.84	140	14.82
140	12.65	220	12.99	140	12.10	140	12.70	240	15.16	280	19.26	160	14.90
160	12.80	240	13.17	160	12.25	160	13.15	260	15.55	300	19.75	180	15.00
180	12.90	260	13.40	180	12.30	180	13.55	280	15.98	320	20.20	200	15.17
200	13.10	280	13.70	200	12.45	200	13.95	300	16.42	340	20.67	220	15.32
220	13.30	300	14.00	220	12.55	220	14.30	320	16.86	360	21.16	240	15.57
240	13.45	320	14.34	240	12.70	240	14.75	340	17.26	380	21.62	260	15.85
260	13.65	340	14.70	260	12.85	260	15.20	360	17.60	400	22.14	280	16.12
280	13.90	360	15.11	280	13.00	280	15.60	380	17.98	420	22.64	300	16.42
300	14.15	380	15.57	300	13.20	300	16.00	400	18.28	440	23.08		
		400	16.05					410	18.58	459	23.54		
		420	16.57					420	18.91				
								438	19.24				

TG 43		TG 44		TG 45		TG 46		TG 47		TG 48		TG 49	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	17.57	20	13.32	20	15.72	20	17.56	20	14.12	100	15.77	100	15.54
40	16.60	40	14.00	40	17.15	40	17.53	60	16.10	120	16.05	120	15.62
60	16.92	60	15.05	100	19.20	60	17.62	80	16.55	140	16.32	140	15.85
80	16.90	80	16.00	120	20.07	80	18.42	100	17.65	160	16.66	160	16.05
100	16.30	100	16.82	140	20.90	100	19.08	140	19.67	180	17.10	180	16.35
140	17.57	120	17.90	160	21.65	120	19.70	160	20.67	200	17.50	200	16.67
160	19.10	160	18.40	180	22.37	140	20.32	180	21.50	220	18.02	220	17.00
180	20.62	180	19.07	200	23.07	160	21.00	200	22.35	240	18.55	240	17.37
200	21.75	200	19.77	220	23.82	180	21.62	240	24.20	260	19.14	260	17.80
220	22.90	220	20.45	240	24.52	200	22.23	260	25.00	280	19.83	280	18.40
240	24.20	240	21.00	260	25.02	220	22.98	280	25.77	300	20.53	300	19.08
260	25.32	260	21.58	280	25.97	240	23.66	300	26.62	320	21.13	320	19.81
280	26.42	280	22.15	300	26.60	260	24.40	320	27.52	340	21.87	340	20.50
300	27.50	300	22.70	320	27.32	280	25.14	340	28.47	360	22.57	360	21.19
320	28.42	310	22.87	340	28.02	300	25.86	360	29.40	380	23.30	380	21.98
340	29.50			360	28.67	320	26.63	380	30.37	400	24.02	400	22.71
360	30.62			380	29.32	340	27.42	400	31.37	420	24.72	420	23.40
380	31.60			400	30.07	360	28.22	420	32.32	440	25.46	440	24.25
400	32.72			420	30.77	380	28.98	440	33.30	460	26.25	460	25.10
420	33.60			440	31.52	400	29.81	460	34.35	480	26.96	480	25.86
440	34.60			460	32.27	420	30.59	480	35.30				
460	35.67			480	33.05	440	31.38	485	35.52				
480	36.67			485	33.22	460	32.22						
485	36.97					480	32.96						

TG 50		TG 51		TG 52		TG 53		TG 54		TG 55		TG 56	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	17.80	20	18.64	40	17.85	0	11.37	120	16.21	20	12.00	40	12.75
40	18.50	40	19.72	60	17.95	20	12.55	140	16.45	40	13.10	60	12.60
60	20.20	60	20.12	80	18.51	40	12.18	160	16.75	60	13.35	80	12.65
80	18.60	80	20.95	100	19.60	60	12.30	180	17.08	80	13.75	100	12.85
100	19.30	100	21.52	120	21.15	80	12.58	200	17.40	100	14.15	120	13.10
120	20.20	120	22.72	140	20.27	100	12.87	220	17.75	120	14.60	140	13.35
140	21.00	140	23.45	160	20.97	120	13.28	240	18.15	140	15.05	160	13.50
160	21.40	160	24.26	180	21.51	140	13.63	260	18.53	160	15.50	180	13.70
180	22.10	180	24.99	200	22.00	160	14.03	280	18.89	180	15.95	200	13.95
200	22.70	200	25.80	220	22.55	180	14.38	300	19.27	200	16.50	220	14.15
220	23.60	220	26.51	240	23.00	200	14.78	320	19.70	220	17.00	240	14.35
240	24.50	240	27.32	260	23.52	220	15.17	340	20.12	240	17.45	260	14.55
260	25.30	260	28.06	280	24.03	240	15.54	360	20.57	260	18.00	280	14.80
280	26.00	280	28.73	300	24.54	260	15.99	380	21.00	280	18.55	300	15.05
300	26.00	300	29.42			280	16.44	400	21.45	300	19.05	320	15.35
		320	30.16			300	16.93	420	21.98	320	19.55	340	15.60
		340	30.83					440	22.47	340	20.10	360	15.85
		360	31.59					460	22.92	360	20.65	380	16.15
		380	32.30					480	23.40	380	21.20	400	16.45
		400	33.01					500	23.86	400	21.70	420	16.70
		420	33.74					520	24.34	420	22.25	440	17.00
		440	34.58					540	24.84	440	22.75	460	17.30
		460	35.33					560	25.32	460	23.25	480	17.60
		475	35.82					580	25.76	480	23.80	500	17.90
								597	26.10	500	24.35	520	18.20
												540	18.55
												560	18.85
												580	19.20
												600	19.50

TG 57		TG 58		TG 59		TG 60		TG 61		TG 62	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
60	16.56	40	17.50	20	13.22	0	25.90	0	23.80	0	18.81
80	16.67	60	18.06	40	14.56	20	21.48	20	19.91	20	16.12
100	17.17	80	18.83	60	15.33	40	19.30	40	16.44	40	16.18
120	17.56	100	19.44	80	16.06	60	18.57	60	16.83	60	16.83
140	18.17	120	20.11	100	16.67	80	19.21	80	17.33	80	17.16
160	18.56	140	20.83	120	17.22	100	19.82	100	17.78	100	17.98
180	19.17	160	21.50	140	17.89	120	20.20	120	18.51	120	18.12
200	19.61	180	22.28	160	18.47	140	20.97	140	19.07	140	18.32
220	20.17	200	23.06	180	18.86	160	21.48	160	19.59	160	18.90
240	20.89	220	23.72	200	19.44	180	22.05	180	20.11	180	19.22
260	21.50	240	24.56	220	20.00	200	22.49	200	20.49	200	19.72
280	22.00			240	20.42	220	23.03	220	21.18	220	20.18
300	22.50			260	20.94	240	23.58	240	21.60	240	20.62
320	23.06			280	21.47	260	24.24	260	22.14	260	21.08
340	23.56			300	22.03	280	24.77	280	22.63	280	21.47
360	24.06					300	25.32	300	22.98	300	22.23
380	24.56					320	25.90	320	23.58	320	22.60
400	25.11					340	26.55	340	24.08	340	23.06
420	25.61					360	27.04	360	24.52	360	23.46
440	26.11					380	27.56	380	25.07	380	24.22
460	26.56					400	28.16	400	25.53	400	24.72
480	27.06					420	28.62	420	26.09	420	25.13
500	27.39					440	29.14	440	26.58	440	25.67
						460	29.83	450	26.92	460	26.80
						480	30.30			480	27.25
						500	30.93				

Data are confidential
for temperature-gra-
dient holes TG-63
through TG-81.

TG 82		TG 83		TG 84		TG 85		TG 86		TG 87		TG 88	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	17.96	20	17.03	20	15.32	10	19.17	20	15.78	75	18.50	20	14.52
40	16.80	40	17.23	40	14.16	20	15.42	40	15.40	100	18.97	40	13.39
60	16.90	60	17.92	60	13.64	30	16.06	60	15.88	125	19.57	60	13.35
80	17.08	80	18.06	80	13.54	40	16.88	80	16.47	150	20.23	80	13.38
100	17.40	100	18.11	100	13.59	50	17.24	100	17.00	175	20.89	100	13.54
120	17.74	120	18.13	120	13.67	60	17.58	120	17.48	200	21.46	120	13.79
140	18.15	140	18.16	140	13.83	70	17.90	140	17.88	225	21.90	140	14.06
160	18.59	160	18.17	160	14.08	80	18.22	160	18.25	250	22.41	160	14.34
180	19.06	180	18.17	180	14.27	90	18.85	180	18.60	275	23.01	180	14.61
200	19.53	200	18.17	200	14.65	100	19.43	200	18.95	300	23.70	200	14.81
220	20.13	220	18.17	220	15.07	110	19.80	220	19.28	325	24.19	220	15.11
240	20.49	240	18.19	240	15.47	120	20.12	240	19.58	350	24.74	240	15.38
260	21.04	260	18.20	260	15.83	130	20.39	260	19.88	375	25.27	260	15.66
280	21.44	280	18.21	280	16.22	140	20.60	280	20.15	400	25.86	280	15.95
300	22.03	300	18.22	300	16.54	150	20.86	300	20.50	425	26.33	300	16.22
320	22.43	320	18.23	320	16.92	160	21.09	320	20.88	450	26.86		
340	22.92	340	18.44	340	17.36	170	21.34	340	21.15	475	27.39		
360	23.48	360	18.73	360	17.76	180	21.66	360	21.45	500	27.85		
380	23.88	380	18.98	380	18.14	190	21.89	380	21.80				
400	24.37	400	19.13	400	18.55	200	22.14	400	22.13				
420	24.87	420	19.43	420	18.95	210	22.50	420	22.48				
440	25.25	440	19.48	440	19.38	220	22.90	440	22.85				
460	25.81	460	19.48	460	19.83	230	23.06	450	23.07				
480	26.32	480	19.59	480	20.20	240	23.45						
500	26.89	500	19.65			250	23.65						
						260	23.97						
						270	24.17						
						280	24.33						
						290	24.51						
						300	24.78						
						310	25.04						
						320	25.42						
						330	25.64						
						340	25.90						
						350	26.25						
						360	26.56						
						370	26.88						
						380	27.15						
						390	27.47						
						400	27.69						
						410	27.93						
						420	28.24						
						430	28.54						
						440	28.86						

TG 89		TG 90		TG 91		TG 92		TG 93		TG 94		TG 95	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	14.54	20	17.04	20	15.84	20	15.65	20	16.64	20	15.70	20	15.64
40	15.54	40	17.00	40	15.11	40	15.09	40	17.31	40	13.53	40	15.64
60	15.75	60	17.41	60	16.01	60	15.67	60	18.05	60	13.83	60	16.02
80	15.75	80	17.96	80	16.74	80	16.34	80	18.76	80	14.34	80	16.36
100	16.06	100	18.43	100	17.45	100	16.96	100	19.34	100	14.84	100	16.54
120	16.28	120	19.01	120	18.04	120	17.58	120	19.88	120	15.58	120	16.64
140	16.47	140	19.61	140	18.51	140	18.21	140	20.52	140	16.27	140	16.81
160	16.72	160	20.19	160	19.02	160	18.78	160	21.10	160	16.90	160	16.98
180	16.94	180	20.77	180	19.52	180	19.34	180	20.77	180	17.57	180	17.12
200	17.20	200	21.39	200	19.99	200	19.98	200	21.39	200	18.21	200	17.35
220	17.49	220	22.18	220	20.49	220	20.53	220	22.18	220	18.85	220	17.51
240	17.78	240	22.89	240	20.99	240	21.08	240	22.89	240	19.51	240	17.66
260	18.04	260	23.55	260	21.39	260	21.66	260	23.55	260	20.17	260	17.96
280	18.33	280	24.20	280	21.85	280	22.22	280	24.20	280	20.84	280	18.05
300	18.69	300	24.82	300	22.31	300	22.74			300	21.54	300	18.30

TG 96		TG 97		TG 98		TG 99		TG 100		TG 101		TG 102	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	16.35	20	16.75	0	18.88	20	14.46	10	13.49	10	16.15	10	13.27
40	14.91	40	15.27	20	17.84	40	13.59	20	15.44	20	16.53	20	14.36
60	15.16	60	15.66	40	16.18	60	13.72	30	16.19	30	15.84	30	14.48
80	15.37	80	16.08	60	16.54	80	13.89	40	16.34	40	15.63	40	14.50
100	15.52	100	16.53	80	17.09	100	13.91	50	16.66	50	15.51	50	14.62
120	15.67	120	16.94	100	17.67	120	14.09	60	16.77	60	15.47	60	14.87
140	15.85	140	17.39	120	18.12	140	14.21	70	17.04	70	15.33	70	15.22
160	16.09	160	17.72	140	18.59	160	14.30	80	17.18	80	15.27	80	15.74
180	16.32	180	18.11	160	19.06	180	14.42	90	17.33	90	15.18	90	16.12
200	16.53	200	18.50	180	19.61	200	14.48	100	17.48	100	15.13	100	16.53
220	16.81	220	18.96	195	20.09	220	14.54	110	17.62	110	15.14	110	16.95
240	17.00	240	19.39	235	20.19	240	14.61	120	17.75	120	15.21	120	17.34
260	17.26	260	19.82	205	20.27	260	14.71	130	17.92	130	15.33	130	17.73
280	17.49	280	20.26	210	20.36	280	14.90	140	18.07	140	15.48	140	18.12
300	17.77	300	20.72	290	20.54	300	15.09	150	18.17	150	15.69	150	18.51
				370	20.91			160	18.49	160	15.92	160	18.87
				450	21.30			170	18.74	170	16.15	170	19.24
				530	21.70			180	18.89	180	16.33	180	19.62
				610	22.69			190	19.04	190	16.57	190	19.96
								200	19.24	200	16.80	200	20.30
								210	19.43	210	17.01	210	20.63
								220	19.62	220	17.22	220	20.94
								230	19.80	230	17.44	230	21.27
								240	19.98	240	17.66	240	21.50
								250	20.16	250	17.84		
								260	20.36	255	17.94		
								270	20.61				
								280	20.78				
								290	20.93				
								300	21.09				
								310	21.29				
								320	21.48				
								330	21.63				
								340	21.83				
								350	21.97				
								360	22.13				
								370	22.27				
								380	22.43				
								390	22.57				
								400	22.74				
								410	22.86				
								420	22.99				
								430	23.11				
								440	23.28				
								450	23.51				
								460	23.61				
								470	23.73				
								480	23.84				
								490	23.99				
								500	24.11				

TG 103		TG 104		TG 105		TG 106		TG 107		TG 108		TG 108 CONT.	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
10	15.91	10	19.35	10	17.84	10	12.88	60	17.01	20	18.20	310	24.92
20	16.31	20	15.43	20	17.18	20	14.87	70	17.09	30	17.67	320	25.23
30	16.61	30	15.95	30	17.54	30	15.43	80	17.20	40	17.78	330	25.49
40	16.89	40	16.19	40	18.04	40	15.47	90	17.32	50	18.08	340	25.63
50	17.41	50	16.47	50	18.20	50	15.32	100	17.46	60	18.41	350	25.71
60	18.05	60	16.76	60	18.34	60	15.24	110	17.62	70	18.70	360	26.34
70	18.74	70	17.16	70	18.54	70	15.22	120	17.76	80	18.97	370	26.58
80	19.37	80	17.59	80	18.84	80	15.22	130	17.90	90	19.24	380	26.86
90	19.92	90	18.07	90	19.11	90	15.27	140	18.06	100	19.47	390	27.14
100	20.47	100	18.56	100	19.47	100	15.31	150	18.23	110	19.76	400	27.38
110	21.02	110	19.28	110	19.86	110	15.36	160	18.40	120	20.03	410	27.65
120	21.56	120	19.51	120	20.23	120	15.42	170	18.58	130	22.67	420	27.87
130	22.13	130	19.80	130	20.68	130	15.47	180	18.75	140	20.53	430	28.14
140	22.68	140	20.12	140	21.17	140	15.53	190	18.93	150	20.78	440	28.39
150	23.34	150	20.57	150	21.58	150	15.58	200	19.11	160	21.02	450	28.72
160	23.92	160	20.91	160	21.97	160	15.64	210	19.29	170	21.29	460	28.98
170	24.55	170	21.38	170	22.33	170	15.69	220	19.47	180	21.57	470	29.27
180	25.15	180	21.77	180	22.78	180	15.77	230	19.65	190	21.81	480	29.54
190	25.76	190	22.17	190	23.13	190	15.82	240	19.83	200	22.08	490	29.81
200	26.32	200	22.53	200	23.89	200	15.92	250	20.01	210	22.31	500	30.13
210	26.89	210	22.91	210	24.32	210	15.99	260	20.20	220	22.56	510	30.41
220	27.47	220	23.57	220	24.68	220	16.08	270	20.39	230	22.83	520	30.68
230	28.06	230	23.94	230	25.00	230	16.15	280	20.59	240	23.09	530	30.93
240	28.71	240	24.26	240	25.33	240	16.24	290	20.78	250	23.37	540	31.21
250	29.30	250	24.61	250	25.67	250	16.33			260	23.61	550	31.52
260	29.92			260	26.01	260	16.41			270	23.85	560	31.81
270	30.49					270	16.52			280	24.13	570	32.10
280	31.07					280	16.62			290	24.42	580	32.39
290	31.67									300	24.69	590	32.68
300	32.28											600	32.91

TG 109		TG 110		TG 111		TG 112		TG 113		TG 114		TG 115	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
30	15.28	100	15.67	50	15.20	160	13.90	140	14.05	80	15.45	20	16.04
40	14.83	110	15.96	60	15.46	170	14.12	150	14.20	90	15.55	30	16.90
50	14.72	120	16.28	70	15.71	180	14.24	160	14.35	100	15.63	40	16.30
60	14.78	130	16.57	80	15.92	190	14.40	170	14.52	110	15.79	50	16.69
70	14.81	140	16.88	90	16.08	200	14.55	180	14.70	120	15.92	60	17.14
80	14.89	150	17.16	100	16.28	210	14.71	190	14.88	130	16.29	70	17.56
90	15.09	160	17.43	110	16.47	220	14.85	200	15.03	140	16.48	80	17.92
100	15.30	170	17.73	120	16.66	230	14.98	210	15.21	150	16.68	90	18.28
110	15.50	180	18.08	130	16.86	240	15.12	220	15.37	160	16.86	100	18.43
120	15.71	190	18.45	140	17.05	250	15.27	230	15.56	170	17.06	110	18.90
130	15.88	200	18.69	150	17.22	260	15.40	240	15.74	180	17.25	120	19.28
140	16.06	210	18.91	160	17.41	270	15.53	250	15.92	190	17.43	130	19.58
150	16.34	220	19.32	170	17.62	280	15.68	260	16.10	200	17.61	140	19.86
160	16.50	230	19.66	180	17.80	290	15.82	270	16.28	210	17.79	150	20.15
170	16.63	240	19.98	190	18.00	300	15.97	280	16.46	220	17.98	160	20.46
180	16.80	250	20.29	200	18.22	310	16.13	290	16.60	230	18.17	170	20.72
190	16.97	260	20.63	210	18.42	320	16.29	300	16.77	240	18.36	180	21.02
200	17.13	270	20.96	220	18.62	330	16.46	310	16.96	250	18.55	190	21.27
210	17.34	280	21.32	230	18.81	340	16.62	320	17.11	260	18.77	200	21.55
220	17.61	290	21.66	240	19.01	350	16.76	330	17.29	270	18.98	210	21.82
230	17.79	300	21.99	250	19.27	360	16.91	340	17.47	280	19.18	220	22.08
240	17.99	310	22.33	260	19.44	370	17.08	350	17.66	290	19.39	230	22.36
250	18.21	320	22.71	270	19.63	380	17.26	360	17.82	300	19.62	240	22.62
260	18.46	330	23.04	280	19.85	390	17.38	370	18.03	310	19.83	250	22.94
270	18.67	340	23.40	290	20.06	400	17.57	380	18.22	320	20.08	260	23.22
280	18.94	350	23.76	300	20.27	410	17.77	390	18.42	330	20.30	270	23.51
290	19.20	360	24.08	310	20.50	420	17.97	400	18.62	340	20.51	280	23.78
300	19.42	370	24.42	315	20.59	430	18.16	410	18.85	350	20.76	290	24.02
310	19.64	380	24.78			440	18.32	420	19.00	360	20.98	300	24.32
320	19.80	390	25.12			450	18.54	430	19.21	370	21.21	310	24.62
		400	25.47			460	18.73	440	19.40	380	21.44	320	24.88
		410	25.81			470	18.90	450	19.62	390	21.68	330	25.12
		420	26.15			480	19.12	460	19.84	400	21.92		
		430	26.49			490	19.31	470	20.02	410	22.16		
		440	26.88			500	19.51	480	20.22	420	22.42		
		450	27.19					490	20.43	430	22.70		
		460	27.57					500	20.63	440	23.00		
		470	27.91							450	23.30		
		480	28.25										
		490	28.60										
		500	28.92										
		510	29.29										
		520	29.62										
		530	30.01										
		540	30.35										
		550	30.66										
		560	31.00										

TG 116		TG 117		TG 118		TG 119		TG 120		TG 121		TG 122	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	14.58	90	16.65	120	13.73	40	14.87	60	13.71	190	14.13	40	11.78
40	15.37	100	16.85	130	14.04	50	15.39	70	14.14	200	14.56	50	12.00
60	16.77	120	17.49	140	14.30	60	15.79	80	14.40	210	15.18	60	12.18
80	16.97	130	17.82	150	14.59	70	16.26	90	14.60	230	15.80	70	12.40
90	17.09	140	18.22	160	14.86	80	16.65	100	14.92	240	16.30	80	12.58
110	17.87	150	18.61	170	15.13	90	16.98	110	15.34	250	16.53	90	12.72
120	18.11	160	18.99	180	15.46	100	17.36	120	15.79	260	16.87	100	13.05
130	18.28	170	19.38	190	15.75	110	17.77	130	16.33	270	17.14	110	13.27
140	18.55	180	19.75	200	16.02	120	18.15	140	16.77	280	17.51	120	13.52
150	18.80	190	20.17	210	16.38	130	18.49	150	17.25	290	17.86	130	13.76
160	19.03	200	20.54	220	16.67	140	18.95	160	17.67	300	18.17	140	13.98
170	19.28	210	20.88	230	16.98	150	19.36	170	18.11	310	18.53	150	14.18
180	19.44	220	21.19	240	17.29	160	19.71	180	18.50	320	18.89	160	14.40
190	19.72	230	21.58	250	17.57	170	20.12	190	18.83	330	19.22	170	14.63
200	19.95	240	21.95	260	17.88	180	20.53	200	19.28	340	19.48	180	14.84
210	20.18	250	22.36	270	18.16	190	20.88	210	19.69	350	19.80	190	15.03
220	20.42	260	22.70	280	18.48	200	21.21	220	20.04	360	20.07	200	15.20
230	20.64	270	23.11	290	18.77	210	21.53	230	20.48	370	20.32	210	15.40
240	20.81	280	23.46	300	19.11	220	21.89	240	20.88	380	20.59	220	15.63
260	21.22	290	23.81	310	19.39	230	22.26	250	21.24	390	20.84	230	15.81
270	21.46	300	24.19	320	19.70	240	22.60	260	21.64	400	21.05	240	16.01
280	21.70	310	24.56	330	19.98			270	22.04	410	21.25	250	16.19
290	21.95	320	24.89	340	20.28			280	22.42	420	21.50	260	16.40
300	22.19	330	25.20	350	20.56			290	22.83			270	16.60
310	22.43	340	25.54	360	20.90			300	23.22			280	16.79
320	22.69	350	25.89	370	21.22			310	23.66			290	16.97
330	22.93	360	26.25	380	21.55			320	24.07			300	17.17
340	23.17	370	26.57	390	21.83			330	24.50			310	17.33
350	23.38	380	26.90	400	22.16			340	24.90				
360	23.58	390	27.34	410	22.47			350	25.30				
370	23.82	400	27.64	420	22.78			360	25.75				
380	24.00			430	23.09			370	26.13				
390	24.22			440	23.37			380	26.56				
400	24.42			450	23.66			390	26.95				
410	24.62			460	24.03			400	27.36				
420	26.81			470	24.37			410	27.77				
430	25.01			480	24.62			420	28.20				
440	25.20			490	24.94			430	28.63				
450	25.60			500	25.28			440	29.06				
460	25.61			510	25.60			450	29.46				
470	25.84			520	25.95			460	29.86				
480	26.07			530	26.26								
490	26.31			540	26.57								
				550	26.91								
				560	27.27								
				570	27.63								
				580	27.94								
				590	28.27								
				600	28.58								

TG 123		TG 124		TG 125		TG 126		TG 127		TG 128		TG 129	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
50	15.18	80	16.99	60	15.65	60	22.68	100	14.12	80	15.31	100	18.81
60	15.17	90	17.38	70	16.15	70	23.70	110	14.47	90	15.35	110	19.01
70	15.23	100	17.78	80	16.72	80	24.68	120	14.90	100	15.38	120	19.25
80	15.28	110	18.14	90	17.26	90	25.66	130	15.27	110	15.41	130	19.50
90	15.35	120	18.50	100	17.82	100	26.74	140	15.59	120	15.48	140	19.71
100	15.43	130	18.91	110	18.38	110	27.65	150	15.93	130	15.63	150	19.92
110	15.50	140	19.28	120	19.11	120	28.65	160	16.20	140	15.74	160	20.18
120	15.61	150	19.73	130	19.54	130	29.61	170	16.49	150	15.87	170	20.34
130	15.75	160	20.00	140	20.09	140	30.61	180	16.77	160	16.01	180	20.63
140	15.87	170	20.40	150	20.64	150	31.55	190	17.06	170	16.17	190	20.87
150	15.94	180	20.76	160	21.24	160	32.48	200	17.31	180	16.32	200	21.09
160	16.03	190	21.12	170	21.75	170	33.40	210	17.54	190	16.48	210	21.31
170	16.17	200	21.42	180	22.34	180	34.37	220	17.80	200	16.63	220	21.54
180	16.32	210	21.81	190	22.94	190	35.27	230	18.07	210	16.85	230	21.80
190	16.53	220	22.18	200	23.50	200	36.20	240	18.33	220	17.11	240	22.29
200	16.69	230	22.56	210	24.08	210	37.18	250	18.63	230	17.27	250	22.48
210	16.86	240	22.92	220	24.61	220	38.21	260	18.89	240	17.38	260	22.66
220	17.02	250	23.27	230	25.21	230	39.24	270	19.20	250	17.60	270	22.83
230	17.20	260	23.67	240	25.73	240	40.10	280	19.43	260	17.77	280	22.97
240	17.40	270	24.02	250	26.24	250	41.05	290	19.70	270	18.01	290	23.18
250	17.55	280	24.35	260	26.79	260	41.97	300	19.98	280	18.25	300	23.34
260	17.75	290	24.68	270	27.28	270	42.79	310	20.20	290	18.51	310	23.52
270	17.96	300	25.05	280	27.81	280	43.00	320	20.48	300	18.78	320	23.69
280	18.13	310	25.39	290	28.34	290	44.35	330	20.71	310	18.94	330	23.90
290	18.37	320	25.70	300	28.80	300	45.09	340	20.99	320	19.02	340	24.16
300	18.47	330	26.01	310	29.30	310	45.83	350	21.23	330	19.20	350	24.38
310	18.60	340	26.40	320	29.79	320	46.57	360	21.51	340	19.39	360	24.63
320	18.89	350	26.85	330	30.22	330	47.26	370	21.75	350	19.59	370	24.87
330	18.99	360	27.25	340	30.73	340	47.97	380	22.02	360	19.83	380	25.07
340	19.12	370	27.64	350	31.16	350	48.66	390	22.28	370	20.02	390	25.30
350	19.30	380	28.00	360	31.61	360	49.38	400	22.49	380	20.24	400	25.52
360	19.44	390	28.38	370	32.10	370	50.11	410	22.73	390	20.44	410	25.73
370	19.60	400	28.77	380	32.55	380	50.83	420	23.00	400	20.62	420	25.91
380	19.73	410	29.13	390	32.99	390	51.57	430	23.28	410	20.78	430	26.10
390	19.92	420	29.48	400	33.38	400	52.27	440	23.60	420	20.92	440	26.27
400	20.10	430	29.85	410	33.90	410	52.94	450	23.88	430	21.09	450	26.55
410	20.27	440	30.19	420	34.46	420	53.63	460	24.16	440	21.22	460	26.80
420	20.42			430	34.84	430	54.37	470	24.46	450	21.37	470	26.98
430	20.59			440	35.26	440	55.12	480	24.70	460	21.50	480	27.22
440	20.73			450	35.75	450	55.87	490	24.96	470	21.66	490	27.48
450	20.89			460	36.22	460	56.61	500	25.25	480	21.83	500	27.67
				470	36.72	470	57.32			490	22.00	510	27.91
				480	37.13	480	58.05			500	22.18	520	28.30
				490	37.58	490	58.80					530	28.57
				500	37.98	500	59.49					540	28.80
												550	29.03
												560	29.25

TG 130		TG 131		TG 132		TG 133		TG 134		TG 135		TG 136	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
100	18.10	10	17.67	100	16.19	100	17.08	10	17.58	50	19.41	20	19.17
110	18.45	20	14.75	110	16.69	110	17.42	20	15.61	60	19.60	30	18.44
120	18.73	30	14.82	120	17.27	120	17.84	30	15.67	70	19.76	40	17.90
130	19.03	40	14.95	130	17.76	130	18.07	40	15.83	80	19.91	50	15.40
140	19.37	50	15.64	140	18.31	140	18.38	50	16.01	90	20.06	60	15.41
150	19.70	60	15.98	150	18.81	150	18.65	60	16.12	100	20.20	70	15.53
160	20.07	70	16.25	160	19.24	160	18.98	70	16.40	110	20.31	80	15.62
170	20.42	80	16.65	170	19.66	170	19.27	80	16.60	120	20.41	90	15.72
180	20.75	90	16.94	180	20.06	180	19.58	90	16.83	130	20.62	100	15.82
190	21.10	100	17.32	190	20.46	190	19.98	100	17.05	140	20.76	110	15.94
200	21.41	110	17.61	200	20.86	200	20.17	110	17.29	150	20.82	120	16.08
210	21.75	120	17.93	210	21.30	210	20.45	120	17.51	160	21.07	130	16.19
220	22.05	130	18.26	220	21.69	220	20.74	130	17.80	170	21.22	140	16.35
230	22.40	140	18.55	230	22.09	230	21.00	140	18.03	180	21.40	150	16.53
240	22.73	150	18.87	240	22.47	240	21.29	150	18.27	190	21.69	160	16.67
250	23.02	160	19.25	250	22.82	250	21.55	160	18.51	200	21.86	170	16.87
260	23.37	170	19.53	260	23.20	260	21.84	170	18.65	210	22.05	180	17.04
270	23.74	180	19.88	270	23.55	270	22.12	180	18.95	220	22.23	190	17.16
280	24.05	190	20.25	280	23.96	280	22.42	190	19.20	230	22.42	200	17.17
290	24.42	200	20.52	290	24.33	290	22.69	200	19.46	240	22.68	210	17.26
300	24.68	210	20.82	300	24.72	300	23.00	210	19.69	250	22.82	220	17.51
310	25.00	220	21.12	310	25.15	310	23.29	220	19.95	260	23.01	230	17.66
320	25.27	230	21.50	320	25.56	320	23.60	230	20.19	270	23.23	240	17.84
330	25.59	240	21.80	330	25.93	330	23.87	240	20.44	280	23.45	250	17.99
340	25.88	250	22.07	340	26.28	340	24.16	250	20.65	290	23.59	260	18.13
350	26.15	260	22.38	350	26.65	350	24.43	260	20.90	300	23.79	270	18.33
360	26.43	270	22.67	360	26.99	360	24.73	270	21.15	310	23.98	280	18.49
370	26.80	280	22.98	370	27.35	370	24.97	280	21.37	320	24.20	290	18.67
380	27.24	290	23.25	380	27.69	380	25.24	290	21.60	330	24.58	300	18.84
390	27.47	300	23.61	390	28.03	390	25.53	300	21.91	340	24.79	310	19.05
400	27.83	310	23.96	400	28.37	400	25.78	310	22.12	350	24.96	320	19.22
410	28.13	320	24.24	410	28.72	410	26.01	320	22.40	360	25.18	330	19.40
420	28.47	330	24.50	420	29.11	420	26.27	330	22.69	370	25.41	340	19.58
430	28.77	340	24.87	430	29.41	430	26.56	340	23.00	380	25.63	350	19.75
440	29.07	350	25.16	440	29.79	440	26.78	350	23.25	390	25.83	360	19.94
450	29.38	360	25.52	450	30.12	450	27.06	360	23.35	400	26.02	370	20.08
460	29.70	370	25.81	460	30.46	460	27.29	370	23.67	410	26.19	380	20.26
470	30.01	380	26.15	470	30.81	470	27.54	380	23.94	420	26.39	390	20.42
480	30.36	390	26.43	480	31.18	480	27.80	390	24.20	430	26.58	400	20.61
490	30.60	400	26.77	490	31.51	490	28.05	400	24.43	440	26.80	410	20.78
		410	27.08	500	31.85	500	28.31	410	24.70	450	26.99	420	20.96
		420	27.41	510	32.17	510	28.58			460	27.24	430	21.11
		430	27.75	520	32.55	520	28.91			470	27.42	440	21.27
		440	28.07	530	32.92					480	27.63	450	21.42
		450	28.36	540	33.28					490	27.80	460	21.61

TG 137		TG 138		TG 139		TG 140		TG 141		TG 142		TG 143	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
20	18.03	20	21.43	20	14.36	420	19.75	25	18.61	25	12.50	25	17.22
30	17.24	30	20.82	30	14.42	430	19.90	50	18.89	50	11.39	50	9.17
40	16.76	40	20.04	40	15.62	440	20.05	75	18.06	75	12.22	75	8.06
50	16.53	50	19.04	50	16.50	450	20.30	100	17.78	100	13.33	100	8.89
60	16.42	60	18.52	60	17.22	460	20.40	125	19.44	125	15.00	125	9.72
70	16.37	70	18.18	70	18.15	470	20.65	150	20.83	150	15.83	150	9.72
80	16.47	80	17.92	80	18.96	480	20.85	175	22.78	175	17.78	175	10.28
90	16.52	90	17.96	90	19.72	490	21.00	200	24.17	200	18.89	200	10.56
100	16.64	100	18.01	100	20.32	500	21.20	225	25.56	225	20.00	225	11.39
110	16.75	110	18.29	110	20.64	510	21.40	250	26.67	250	21.11	250	11.94
120	16.92	120	18.58	120	21.18	520	21.55						
130	17.10	130	19.18	130	21.75	530	21.75						
140	17.32	140	19.60	140	22.37	540	21.95						
150	17.60	150	19.98	150	22.90	550	22.15						
160	17.86	160	20.40	160	23.28	560	22.30						
170	18.19	170	20.74	170	23.82	570	22.55						
180	19.01	180	21.14	180	24.18	580	22.75						
190	19.33	190	21.53	190	24.71	590	22.95						
200	19.76	200	21.92	200	25.10	600	23.15						
210	20.08	210	22.29	210	25.49	610	23.25						
220	20.43	220	22.67	220	26.21	620	23.55						
230	20.84	230	23.05	230	26.62	630	23.80						
240	21.30	240	23.42	240	27.02	640	23.95						
250	21.67	250	23.78	250	27.47	650	24.15						
260	21.93	260	24.13	260	27.80	660	24.30						
270	22.15	270	24.49	270	28.25	670	24.55						
280	22.47	280	24.86	280	28.71	680	24.70						
290	22.80	290	25.24	290	29.12	690	24.90						
300	23.12	300	25.55	300	29.54	700	25.10						
310	23.47	310	25.86	310	30.03	710	25.25						
320	23.60	320	26.23	320	30.45	720	25.45						
330	23.92	330	26.61	330	30.81	730	25.60						
340	24.07	340	26.98	340	31.32	740	25.80						
350	24.24	350	27.30	350	31.75	750	25.95						
360	24.53	360	27.67	360	32.15	760	26.05						
370	24.78	370	28.02	370	32.57	770	26.35						
380	25.24	380	28.40	380	32.97	780	26.60						
390	25.57	390	28.74	390	33.33	790	26.80						
400	25.95	400	29.06	400	33.70	800	27.05						
410	26.09	410	29.41	410	34.11	810	27.25						
420	26.48	420	29.76	420	34.48	820	27.40						
430	26.92	430	30.08	430	34.88	830	27.65						
440	27.34	440	30.48	440	35.28	840	27.90						
450	27.78	450	30.78	450	35.64	850	28.10						
460	28.28	460	31.10	460	36.04	860	28.40						
470	28.57	470	31.41	470	36.46	870	28.60						
480	29.03	480	31.77	480	36.84	880	28.90						
490	29.59	490	32.10			890	29.10						
500	30.02	500	32.40			900	29.35						
510	30.62	510	32.80			910	29.60						
520	31.13	520	33.12			920	29.80						
530	31.48	530	33.47			930	29.90						
540	31.77	540	33.70										
550	32.08	550	34.01										
560	32.39	560	34.33										
570	32.69	570	34.63										
580	32.99	580	34.96										
590	33.28	590	35.27										
600	33.52	600	35.44										

TG 144		TG 145		TG 146		TG 147		TG 148		TG 149		TG 150	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
25	16.11	25	11.11	25	15.30	25	16.39	25	20.02	25	31.11	25	10.28
50	16.11	50	11.11	50	15.55	50	16.11	50	22.94	50	15.28	50	10.00
75	14.72	75	9.72	75	16.25	75	13.89	75	26.67	75	13.89	75	10.28
100	14.44	100	9.72	100	17.85	100	15.00	100	30.55	100	13.89	100	10.56
125	15.56	125	9.72	125	19.35	125	16.11	125	34.27	125	14.44	125	11.11
150	15.56	150	10.28	150	20.80	150	16.94	150	38.94	150	14.72	150	11.67
175	16.11	175	10.56	175	22.00	175	17.50	175	43.72	175	15.56		
200	17.22	200	11.94	200	23.20	200	18.33	200	48.21	200	16.11		
		225	12.78			225	19.72	225	52.66	225	16.94		
		250	13.89			250	20.83	250	56.84	250	17.78		
								275	58.83				

TG 151		TG 152		TG 153		TG 154		TG 155		TG 156		TG 157	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
25	13.89	25	18.94	25	15.00	25	14.44	25	14.70	25	16.94	50	11.39
50	13.89	50	19.31	50	14.72	50	14.44	50	15.34	50	16.94	75	11.39
75	15.00	75	20.49	75	14.72	75	16.11	75	16.97	75	16.67	100	11.39
100	16.67	100	21.82	100	15.00	100	17.78	100	18.59	100	17.22	125	11.94
125	17.50	125	22.75	125	15.56	125	19.44	125	20.27	125	18.33	150	12.22
150	18.89	150	24.53	150	16.11	150	20.83	150	21.93	150	18.06	175	12.78
175	20.00	175	26.20	175	17.78	175	22.22	175	23.61	175	18.89	200	13.33
200	20.83	200	27.82	200	18.33	200	24.17	200	25.22	200	20.00	225	13.89
225	22.22	225	29.62	225	18.61	225	26.39	225	26.83	225	20.83	250	14.44
250	23.89	250	31.20	250	19.44	250	28.06	250	28.39	250	21.39		
				275	20.28								
TG 158		TG 159		TG 160		TG 161		TG 162		TG 163		TG 164	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
50	11.11	25	14.11	150	16.11	25	14.00	50	14.05	25	16.39	25	14.44
75	12.78	50	14.78	175	16.11	50	15.20	75	15.70	50	16.94	50	14.44
100	13.61	75	16.22	200	16.67	75	16.25	100	17.10	75	17.78	75	15.00
125	15.00	100	17.39	225	17.22	100	17.05	125	18.45	100	18.89	100	15.56
150	15.56	125	18.78	250	17.78	125	17.85	150	19.60	125	20.00	125	16.11
175	16.67	150	20.11			150	18.75	175	20.90	150	21.11	150	16.94
200	18.06	175	21.22			175	19.45	200	22.30	175	22.22	175	17.50
225	18.33	200	22.39			200	20.25	225	23.40	200	23.06	200	18.33
250	19.72	225	23.67			225	21.15	250	24.80	225	23.89	225	18.89
		250	24.93			250	21.95			250	24.44	250	19.44
TG 165		TG 166		TG 167		TG 168		TG 169		TG 170		TG 171	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
50	21.11	25	12.80	25	15.00	25	11.67	25	16.67	50	13.89	25	12.78
75	13.33	50	13.90	50	15.00	50	12.78	50	15.56	75	15.00	50	12.22
100	13.33	75	13.90	75	16.11	75	15.00	75	16.11	100	15.00	75	12.22
125	13.89	100	14.20	100	17.78	100	15.56	100	17.22	125	15.56	100	12.78
150	14.44	125	15.00	125	19.44	125	15.89	125	17.78	150	16.39	125	13.33
175	15.56	150	15.80	150	20.56	150	16.11	150	18.06	175	16.11	150	13.33
200	17.22	175	16.10	175	21.67	175	17.22	175	18.61	200	16.94	175	13.89
225	17.78	200	16.70	200	22.22	200	18.33	200	19.44	225	17.22	200	13.89
250	20.00	225	17.20	225	23.89	225	18.89	225	20.28	250	17.50	225	14.44
						250	19.44					250	15.00
TG 172		TG 173		TG 174		TG 175		TG 176		TG 177		TG 178	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
25	12.22	50	13.33	25	13.89	25	15.56	50	10.00	50	10.00	25	12.78
50	11.67	75	13.33	50	13.89	50	15.83	75	10.28	75	9.72	50	13.06
75	11.67	100	15.00	75	14.44	75	16.11	100	11.11	100	10.28	75	13.61
100	11.94	125	17.22	100	14.72	100	16.11	125	12.22	125	10.00	100	13.89
125	12.22	150	18.06	125	15.28	125	16.39	150	13.33	150	9.44	125	15.00
150	12.50	175	19.44	150	15.83	150	16.67	175	14.44	175	9.17	150	15.83
175	12.78	200	20.00	175	16.39	175	17.22	200	15.56	200	9.44	175	16.67
200	13.33	225	21.39	200	17.22			225	17.22	225	9.44	200	17.22
225	13.89	250	21.94	225	18.33			250	18.33	250	8.89	225	18.33
												250	19.44
TG 179		TG 180		TG 181		TG 182		TG 183		TG 184		TG 185	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
50	18.06	50	15.56	50	13.33	25	11.67	25	14.44	100	7.78	50	8.89
75	18.61	75	16.39	75	13.33	50	12.78	50	13.61	125	7.22	100	8.06
100	19.44	100	16.94	100	13.89	75	13.89	75	13.61	150	8.06	125	9.44
125	19.44	125	17.50	125	14.44	100	15.00	100	14.44	175	7.78	150	8.33
150	20.28	150	18.61	150	16.67	125	16.11	125	15.28	200	7.22	175	8.33
175	20.56	175	19.17	175	16.67	150	17.50	150	16.11	225	7.78	200	7.22
200	21.11	200	19.44	200	17.22	175	19.44	175	17.22	250	7.78	225	7.78
225	21.67	225	20.00	225	18.06	200	20.56	200	18.06	275	6.67	250	8.33
250	22.22	250	20.56			225	22.22	225	18.33	300	8.33	275	7.78
								250	19.44	325	7.78	300	8.33
								275	20.83	350	7.78	325	8.89
												350	8.33

TG 186		TG 187	
DEPTH (feet)	TEMP (°C)	DEPTH (feet)	TEMP (°C)
50	19.44	25	20.40
75	22.78	50	20.70
100	23.33	75	22.10
125	23.61	100	22.90
150	25.28	125	24.00
175	26.11	150	25.10
200	26.67	175	25.80
225	26.67	200	26.50
250	26.67	225	27.50
275	27.22	250	28.80
		275	30.00
		300	31.10
		350	33.10
		400	34.90

APPENDIX C

Temperature-gradient profiles from 168 nonconfidential temperature-gradient holes in The Geysers study area.

APPENDIX D

Uncorrected and corrected temperature-gradient profiles from 59 nonconfidential temperature-gradient holes in The Geysers study area.