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OIL FIELD GEOTHERMAL WATERS OF WYOMING

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Wyoming Geothermal Resource Assessment Group
Department of Geology and Geophysics
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Laramie, Wyoming

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Introduction

Over 150 million gallons of water a day are brought to the surface in the oil fields of Wyoming. This water is produced for neither agriculture nor municipal use, but is a by-product accompanying the production of oil and gas. The temperature of this water is nearly always greater than 90° F, and ranges as high as 230° F. Approximately one half of the water is not reused by the oil and gas industry, but is disposed of either by reinjection or, more commonly, by discharge to the surface. The thermal energy of discharged water is simply dissipated, and the water either soaks into the ground or finds its way into natural drainages.

Fifty-two of the largest water producing oil fields in the state (accounting for over 98% of the total oil field water production) were inventoried in 1982 as the basis for this report. Eighty-eight percent of the water produced in these fields is warmer than 100° F; 60% is hotter than 120° F. If the total water production of these 52 fields were cooled to 70° F, approximately 800 megawatts of thermal power would be released.

The purpose of this report is to briefly present the location, volume, temperature, and present use status of co-produced oil field thermal waters. It is hoped that making this information available will focus attention on development of applications for this substantial energy resource which, in spite of ready availability, is virtually unused at present.

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Geothermal Energy In Wyoming: Temperatures, Sources, Applications

As the overall limits of traditional energy supplies have become apparent, attention has increasingly focused on "alternative" energy sources such as geothermal. Since geothermal energy derives from the natural heat of the earth, it is dependent neither on past accumulations of organic material nor on the present, sun-powered systems of wind, water, or direct solar energy. Thus, the geothermal resource in general is uniquely stable, long-lived, and globally distributed.

The quality of this resource varies greatly, however. At the top of the scale are the spectacular hot springs and geysers of Yellowstone National Park and the 1000 megawatt geothermal steam electrical generating station at the Geysers, California. At the lower end, less impressive but much more widespread, is simply a warming of the earth with depth and an occasional warm spring.

The rate at which the earth warms up with depth (commonly expressed in °F per 1000 feet of depth) is called the geothermal gradient. Geothermal gradients vary widely across the state of Wyoming as a function of heat flow, rock thermal conductivities, and hydrologic modifications. The nature, distribution, origin, and significance of subsurface temperatures are extensively evaluated in a series of reports by members of the Wyoming Geothermal Resource Assessment Group and will not be discussed here. For this report it is sufficient to note that normal geothermal gradients in Wyoming generally fall in the 11-16° F/1000 ft.

range. Since most oil and accompanying waters in Wyoming are produced from depths in excess of 5000 feet, the high temperatures encountered are not necessarily anomalous, but are the expected result of deep drilling. Oil well bottom-hole temperatures of 300° F or higher have been measured in most of the sedimentary basins of the state. The drilling depth required to reach these high temperatures, however, far exceeds that which can be economically justified by the hot water resource. Thus, the importance of oil fields is that oil and gas production pays well drilling and pumping costs and the produced geothermal waters represent a potentially valuable by-product.

Two critical parameters for geothermal development in Wyoming are the temperature and available quantity of geothermal waters. In Wyoming, thermal waters presently arrive at the surface via thermal springs, flowing wells, and along with oil and gas in oil and gas wells. Breckenridge and Hinckley (1978) cite a total flow of approximately 20,000 gallons per minute (gpm) of naturally occurring thermal water (excluding Yellowstone Park) with approximately 4500 gpm in excess of 100° F. Heasler et al. (1983) have compiled a partial list of important flowing thermal wells with a total flow of 20,000 gpm, 18,000 gpm over 100° F. In comparison, the 1981 water production of Wyoming oil fields averaged 110,914 gpm (178,918 acre ft/yr) (Petroleum Information Corp., 1981), with approximately 97,000 gpm in excess of 100° F.

Uses for Wyoming thermal waters are as varied as the temperatures. While it is doubtful the type of dry stream-turbine electrical system used at the Geysers, California, will ever be developed in Wyoming, there are technologies for using 180° F and warmer waters to produce electricity through more complex turbine cycles. This represents the high end of potential geothermal energy use in Wyoming and is of doubtful economic viability at that. More widely

applicable uses fall generally into the categories of space conditioning and agricultural and industrial processing. Above approximately 170° F geothermal waters may provide energy to cooling and air conditioning cycles. Geothermal waters may simply replace the boiler-heated water of conventional heating systems down to 130-140° F, and with adaptations, may provide useful direct space heating down to 80-90° F. Through the use of groundwater heat pumps, energy can be economically extracted from waters as cool as 50° F.

Agricultural/industrial applications which have been successfully implemented in many areas of the world include greenhouse heating and agricultural product drying. Success has also been widespread in applying geothermal waters to the raising of fish and other aquatic food sources.

Basically, any energy use for which sub-boiling temperatures are adequate may be a potential application for Wyoming geothermal resources. The intention of this report is not to present an exhaustive list of these applications; the above discussion is provided simply to outline the possibilities. For an excellent treatment of the direct utilization of geothermal energy, including full discussion of the above, see Anderson and Lund (1979).

OIL FIELD THERMAL WATERS: MONITORING, LOCATIONS, VOLUMES, QUALITY TEMPERATURES, DISPOSITION

Monitoring

There is no systematic monitoring of oil field thermal waters in Wyoming at this time. The Wyoming Oil and Gas Conservation Commission maintains the largest data base on oil and gas activity in the state, including the water production reports from which Petroleum Information Corporation compiles their summaries (see References). The Oil and Gas Commission also maintains cursory records (primarily cumulative volumes) on projects involving the injection of

water into oil fields to maintain reservoir pressures. This water may be produced water, surface water, or groundwater developed specifically for this purpose.

Where produced waters are discharged to the surface, chemical characteristics and volumes are monitored at irregular intervals by the Water Quality Division of the Wyoming Department of Environmental Quality. Both the Oil and Gas Commission and the Department of Environmental Quality are becoming involved in the regulation and monitoring of water injected simply for disposal. All waters in the state are also under the jurisdiction of the Wyoming State Engineer. Where waters are considered to be beneficially used, as in reinjection for pressure maintenance, water appropriation permits are required. Produced waters which are not used in this way, are considered by the State Engineer only beyond the point at which they may contribute to the flow of existing natural streams.

None of the agencies cited above gathers data on water temperature. (If the temperature of discharged waters were high enough to be a significant environmental concern, the Department of Environmental Quality is empowered to regulate such discharges.) Therefore, it has been necessary to contact oil field operators directly for the information of this report. Information on water production, temperature and disposition is that provided by the operators unless otherwise noted. The essence of this report is assembled in Table 1. The discussion which follows is an explanation and discussion of the Table and proceeds on a column by column basis, including notes on table format and interpretation.

County/Location/Field. Due to the modest temperature of geothermal waters in Wyoming, most applications need to be near the point of availability, and location is therefore an important constraint. The Salt Creek field in Natrona

County, for example, surrounds the town of Midwest and might contribute thermal energy to a wide variety of residential and commercial space heating systems, to industrial and perhaps agricultural processing applications, and to greenhouse and aquaculture projects supplying the readily accessible markets in Midwest and Casper. The Lance Creek field in Niobrara County, in contrast, is in an area of very low population density and is therefore more restricted to application in processes not dependent on community development or local markets.

Operator. In most cases, operations of a single field have been taken over by a single operator. Where this is not the case, the operator (or operators) responsible for the preponderance of the water production are listed, followed by an asterisk.

Water Volume. Oil fields are generally defined on the basis of the geologic conditions creating a more or less continuous oil reservoir. Thus, field sizes will vary greatly as will the number of wells contributing to total production. Since the oil/water production of many wells is commonly collected at oil separation facilities, thermal waters will be concentrated at various locations within each field. The total production figures listed do not reflect in-field distribution; how much water is actually collected at any one point will vary widely depending on specific field characteristics. All volumes are listed in gallons per minute (gpm); 1 gpm = 1.6 acre-ft/yr. Water production values enclosed by parentheses in Table 1 are average 1981 values calculated from Petroleum Information Corp. Production Summaries (see References); no reports were received directly from field operators in these cases.

Since the value of oil field geothermal resources is small relative to the petroleum resources, oil fields will continue to be managed for optimum oil and gas revenues. It is unlikely this will generally lead to optimum geothermal

production as well, so geothermal applications will be largely dependent upon petroleum production strategies. The range in water production (based on monthly averages for all operators in the field) has therefore been compiled from the published Production Summaries (see References). Fields with relatively constant water production are certainly the most attractive candidates for geothermal development; development would have to be carefully coordinated with field operators to establish a secure energy source in any case.

Water Temperature. The temperature of produced water will generally decrease from the bottom-hole temperature to the point of final disposition. Geothermal applications which follow oil-water separation processes and in-field water uses will have to depend on somewhat lower temperatures than will applications which can extract heat from produced waters before or during separation processes. It should also be noted that all the thermal energy in produced waters is not an unused by-product. In some fields these waters are used to provide energy to treater facilities, which is of course a geothermal application itself. While the main value of water reinjected to enhance oil recovery derives from the simple pressure of the water, temperature may be of some benefit in terms of altering oil viscosity and mobility.

Water Quality. The chemical quality of oil-field waters is generally quite poor. For space heating applications this may not be a significant problem if scaling and corrosion can be controlled. For agricultural/aquacultural applications, it may be necessary to use heat exchangers to transfer thermal energy to waters of more acceptable chemistry.

Water Disposition. Water produced with oil and gas is disposed of in one of three ways: 1) It may be discharged to the surface to either soak in, evaporate, or run into natural drainages; 2) It may be reinjected into an

acceptable formation via waste disposal wells; 3) It may be reinjected into oil-producing strata to improve reservoir drive mechanisms and so to enhance oil recovery.

Water discharged to the surface is clearly the most readily available for geothermal development. Once waters enter a surface drainage they are no longer under the control of the field operator, but are regulated like any other surface water through the Wyoming State Engineer's Office. Heat is recognized as a beneficial use of water in Wyoming and can therefore justify a water appropriation. In many cases discharged oilfield waters are presently used for stock watering and irrigation. Where such uses have appropriated water rights they would take precedence over geothermal applications in the event of a conflict.

Question marks in the "Discharge Water" column of Table 1 indicate the partitioning of produced waters between the 3 options listed above is unclear. A question mark following a value indicates produced water was assumed to be surface discharged because there were no injection projects reported for these fields. Values enclosed by parentheses are taken from the files of the Water Quality Division of the Wyoming Department of Environmental Quality (DEQ). The number of discharge permits has also been extracted from these files. Numbers followed by an asterick denote permits which DEQ has noted as covering discharges greater than 1 million gallons per day (700 gallons/minute). Many discharge permits are filed against the contingency of possible discharge. Discharge may rarely occur under there permits, so the number of permits listed for a field is a maximum number of discharge points.

Second to waters discharged to the surface, the most available waters for geothermal applications are those destined for waste reinjection. These waters

are presumably of no value to the oil and gas operations; examination of DEQ files reveals that in many cases waste waters which were previously surface discharged have been converted to reinjection due to tightening discharge water quality standards. Thus, geothermal applications which took over disposal of these waters would actually save the field operator the expense of reinjection. (Geothermal applications will, of course, themselves be subject to the same waste disposal regulations as any other water use.) As with the number of surface discharge points, the number of disposal wells reflects the degree of water concentration within the field. (The number of wells and formation data of Table 1 on both waste and enhanced recovery injection come from the Wyoming Oil and Gas Conservation Commission (1980)).

Of the three water disposition possibilities, waters used in enhanced recovery injection operations would be the most logistically difficult to utilize in geothermal applications. Depending on how the field operators view the value of temperature to the recovery processes, however, it may be possible to extract significant heat in "closed loop" processes which return the water for injection. While some portion of injected waters may cycle back through the system as produced water, this does not necessarily decrease their geothermal value. This recycling of cooled waters is an accepted way to usefully extract energy from very large subsurface heat sources.

Unlike the numbers of discharge permits or waste disposal wells, which represent the concentration of co-produced waters, the number of injection wells represents the dispersal of waters to create the proper injection pattern. The maximum concentrations of thermal waters in these fields will occur at separation facilities.

The "formations" involved in enhanced recovery operations are coded as follows: Ams - Amsden, Cam - Cambrian, Cur - Curtis, Dak - Dakota, Emb - Embar,

Fox - Fox Hills, Frn - Frontier, Lan - Lance, Leo - Leo, Mad - Madison, Min -
Minnelusa, Mor - Morrison, Msv - Mesaverde, Mud - Muddy, Phs - Phosphoria, Shn -
Shannon, Sun - Sundance, Sus - Sussex, Ten - Tensleep.

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME			WATER TEMPERATURE		WATER QUALITY Total Dissolved Solids (ppm or mg/l)	WATER DISPOSITION							
			Water Production (gpm)	1991 Range in Water Production: Low (gpm) High (gpm)	Bottom-hole (B) or Wellhead (W) Temperature (°F)	Injection (I) or Discharge (D) Temperature (°F)	Discharged Water (gpm)		Number of Discharge Permits	Water Injected Water (gpm)	Number of Disposal Wells	Water Injected for Enhanced Recovery (gpm)	Number of Active In- jection Wells	Source Formation	Formation Injected	
Big Horn																
49N-91W	Bonanza	Conoco*	303	290	722	78(W)	50(D)	1224	303	2	---	---	---	---	---	---
55,56N-96,97W	Byron	Marathon	1121	0	1198	120-125(B)	52-60(D) 110-115(I)	3090	168	1	---	---	953	19	Ten	Ten/Emb
55,56N-97,98W	Garland	Marathon*	6397	1132	6952	136-143(B)	78(D) 120-125(I)	3787	3360	3,1*	1222	1	1816	24	Ten	Ten/Phs
		Texaco*	718			---	95(I)	3898	---	2	718	2	---	---	---	---
47N-97,98W	Sage Creek	Sohio*	287	89	366	95(B) 80(W)	60(I)	3330	---	0	---	---	287	2	Ten	Ten
31N-92,93W	Torchlight	Amoco	1750	1408	2859	95	---	---	1750	1*	---	---	---	---	---	---
Campbell																
54N-72W	Gas Draw	Chevron*	671	771	1264	182(B)	150(I)	---	---	0	---	---	671	15	Fox/Lan	Mud
45N-71W	Hillight	Inexco*	2042	1760	2205	230(B)	210(I)	---	---	12	---	---	2042	38	Fox	Mud
48,49N-69W	Raven Creek	Mobil	369	157	390	135(W)	120(I)	---	---	0	---	---	369	13	Fox	Min
56,57N-69W	Rocky Point	Amoco*	(948)	1044	1325	---	115-127(D)	2374	(955)	1*	---	---	---	---	---	---
50N-69,70W	Rozet	Arco*	329	336	418	---	110-155(I)	6,792-31,519	---	0	329	1	---	---	---	---
Carbon																
21N-79W	Big Medicine Bow	Marathon	217	0	3697	152(W)	---	2497	217	1	---	---	---	---	---	---
26N-89,90W	Wertz	Amoco	1458	428	1427	145(B)	135	10,404	77	1	---	---	1458(7)	27	Ten/Mad	Ten
Converse																
32,33,34N-75,76W	South Glenrock	Conoco*	510	590	736	128(W)	100(I)	1333	---	1	---	---	510	59	Mad/Ten	Mud/Dak
Fremont																
23,34N-96W	Beaver Creek	Amoco	715	255	626	230-234(B)	90-140	1975	248	2	---	---	467	6	Mad	Mad
32N-95W	Big Sand Draw	Amoco	3500	2849	5260	220(B)	135-170(D)	2163	3500	3	---	---	---	---	---	---
36,37N-82W	Casper Creek North	Kathleen	(244)	0	311	---	---	---	244(7)	1	---	---	---	---	---	---
6,7N-2,3W	Circle Creek	Conoco	636	0	631	74(W)	56	1768	563	2	---	---	73	10	Ans	Ans
28N,92,93W	Crooks Gap	Amoco	758	512	775	150(B)	120(B)	6466	758	1	---	1	---	---	---	---
32N-99W	Dallas	Union	642	0	693	---	61-79	---	642	1	---	---	---	---	---	---
33N-99W	Lander	Amoco	379	287	407	96(B)	80(I)	---	---	11	---	---	379	26	Ten	Phs
25-1,2E																
6N-2W	Maverick Springs	Crown- Central*	(460)	111	1853	---	---	---	460(7)	1	---	---	---	---	---	---
4N-1W	Steamboat Butte	Gulf*	(760)	692	769	---	99-154	---	192	0(7)	---	---	578	7	Ten/Phs	Ten/Phs
2N-1,2W	Winkelman Dome	Amoco*	3159	2437	3134	125-220(B)	100-180	---	207	1	---	---	2952	59	Ten/Phs	Ten/Phs
Hot Springs																
42,43N-91W	Black Mtn.	Texaco	744	53	619	---	90	750	---	1	744	1	---	---	---	---
44N-95W	Gebo	Conoco	510	0	508	120(W)	90(D)	3186	510	1	---	---	---	---	---	---
46N-98W	Grass Creek	Marathon	3305	2721	3584	70-120(B)	69-110(I)	5279	---	6	343	1	2962	99	Hsv/Mad	Cur/Frn/Ten
44N-97,98W	Hamilton Dome	Arco	3379	4154	8181	---	143(D)	3546	3379	1,1*	---	---	---	---	---	---
		Petro-Lewis	3183			96-124	103(I), 90(D)	3528	2538	1,1*	---	---	645	21	Ten/Phs	Phs
43N-91,92W	Lake Creek/W	Getty	(405)	145	410	---	---	---	405(7)	4	---	---	---	---	---	---
47,48N-99,100W	Little Buffalo Basin	Amoco	4181	3376	4322	118-120	---	---	233	11	---	---	3936	110	Emb/Ten	Emb/Ten

COUNTY/ LOCATION (Twp-Rng)	FIELD	OPERATOR	WATER VOLUME			WATER TEMPERATURE		WATER QUALITY Total Dissolved Solids (ppm or mg/l)	WATER DISPOSITION							
			Water Production (gpm)	1981 Range in Water Production: Low (gpm) High (gpm)	Bottom-hole (B) or Wellhead (W) Temperature (°F)	Injection (I) or Discharge (D) Tempera- ture (°F)	Dischar- ged Water (gpm)		Number of Discharge Permits	Waste Injected Water (gpm)	Number of Disposal Wells	Water Injected for Enhanced Recovery (gpm)	Number of Active In- jection Wells	Source Forma- tion	Forma- tion In- jected	
Hot Springs (continued)																
44N-96W	Little Sand Draw	Husky	688	349	688	---	123(D)	2840	688	2	---	2	---	---	---	---
Johnson																
41N-78W	Meadow Creek	Conoco	338	0	337	182(W)	160(I)	2348	---	5	---	---	358	30	Mad	Shn/Ten
44N-81,82W	North Fork	Amoco*	513	527	598	170(B)	90(D)	7191	513	1	---	---	---	---	---	---
42N-78,79W	Sussex	Conoco*	475	0	522	174(W)	150(I)	3313	---	3	---	---	475	39	Mad	Sus/Ten
Natrona																
33,34N-83W	Casper Creek South	Union	875	482	2184	---	90	---	875	2	---	---	---	---	---	---
37N-85W	Notches	Terra Resources	1021	1030	1093	115	95(D)	1484	1021	1,1*	---	---	---	---	---	---
39,40N-78,79W	Salt Creek	Amoco*	29983	4044	23240	90-180(B)	85-90	3900	17675	8,8*	---	---	12,309	515	Mad	Frn
		Terra Resources*	2246			188	140(I)	2986	(914)	11,1*	---	---	1246	103	Mad	Frn
38,39N-78W	Teapot East	Union	467	3	12	---	179	---	467	1	---	---	---	---	---	---
36,39N-78W	Teapot Naval	Fenix & Scission*	(300)	274	350	---	---	---	??	9	---	---	??	33	Mad	Frn
Niobrara																
35,36N-65W	Lance Creek	Marathon	1272	481	1919	155(W)	110(D)	3304	1272	6	---	---	---	1	Leo	Mor
		Grace	467			140(W)	50-80(D)	3089	467	2	---	---	---	---	---	---
Park																
57,58N-99,100W	Elk Basin	Amoco	4364	1106	2770	115	---	---	1273	3	---	---	3092	34	Mad/Ten	Mad/Ten
56,57N-99W	Elk Basin South	Conoco	572	0	588	148(W)	140(I)	5131	---	1	---	---	572	6	Ten	Ten
47,48N-103W	Four Bear	Amoco	933	3	2377	130	---	---	---	3	933	6	---	---	---	---
58N-98W	Frannie	Conoco	2158	0	2234	90(W)	84(I)	3200	---	2	---	---	2158	30	Mad	Phs/Ten
51N-102W*	Halfmoon	Husky	601	408	627	---	103(D)	2620	601	1	---	2	---	---	---	---
50,51,52N-100W	Oregon Basin	Marathon	14893	13301	14829	110-120(B)	63-90(D) 100-110(I)	1545	1489	8	---	---	13,403	129	Mad/Emb/ Ten	Mad/Emb/ Ten
48N-102W	Pitchfork	Husky	944	367	972	---	81(D)	2600	941	1	---	6	---	---	---	---
49N-102W	Spring Creek South	Texaco	2112	1264	2279	---	100	2897	---	0	2112	2	---	---	---	---
56N-98W	Whistle Creek	Texaco	779	758	873	---	95	2602	779	1	---	---	---	---	---	---
Sweetwater																
26N-90W	Lost Soldier	Amoco	3558	2882	3723	159-165(B)	140	7591	438	1	---	---	3121	56	Sun/Cam/Mad	Cam/Ten/Mad
Washakie																
47,48N-90,91W	Cottonwood Creek	Amoco*	292	203	317	110	---	---	58	1	---	---	233	25	Mad/Phs	Phs

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