GEOTHERMAL ENERGY IN MONTANA:

SITE DATA BASE AND DEVELOPMENT STATUS

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by

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November, 1979

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FOREWORD

Among the most critical of problems facing our nation is energy resources. Though there may be minor disagreement about the specifics, magnitude, and solutions to these problems, there can be no question about their urgency and of the necessity for immediate action. In an effort to, in part, resolve these questions by accelerating utilization of one of our renewable resources, the U.S. Department of Energy has developed a program of National and Regional Planning and Operations Research of geothermal energy resources.

The OIT Geo-Heat Utilization Center, under contract to USDOE, has evaluated the geothermal energy resource development potential of the six northwest states of Alaska, Idaho, Montana, Oregon, Washington, and Wyoming. Our goal has been to summarize for this region, on a site-specific basis, the various factors affecting development including resource data base, geological description, reservoir characteristics, environmental character, lease and development status, institutional factors, economics, population and market, and finally potential for development. This report summarizes the known data base for the state of Montana.

As so little site-specific geothermal resource data is available, this then represents a progress report in a young, but rapidly developing field of knowledge. The continuation of this project now underway is attempting to complete this core of site information and identify data on new significant sites in Montana, provide accurate information and recommendations to policy and decision-makers, and ultimately to assist in evolving more effective regional and national geothermal energy programs.

R. P. Koeppen
November, 1979

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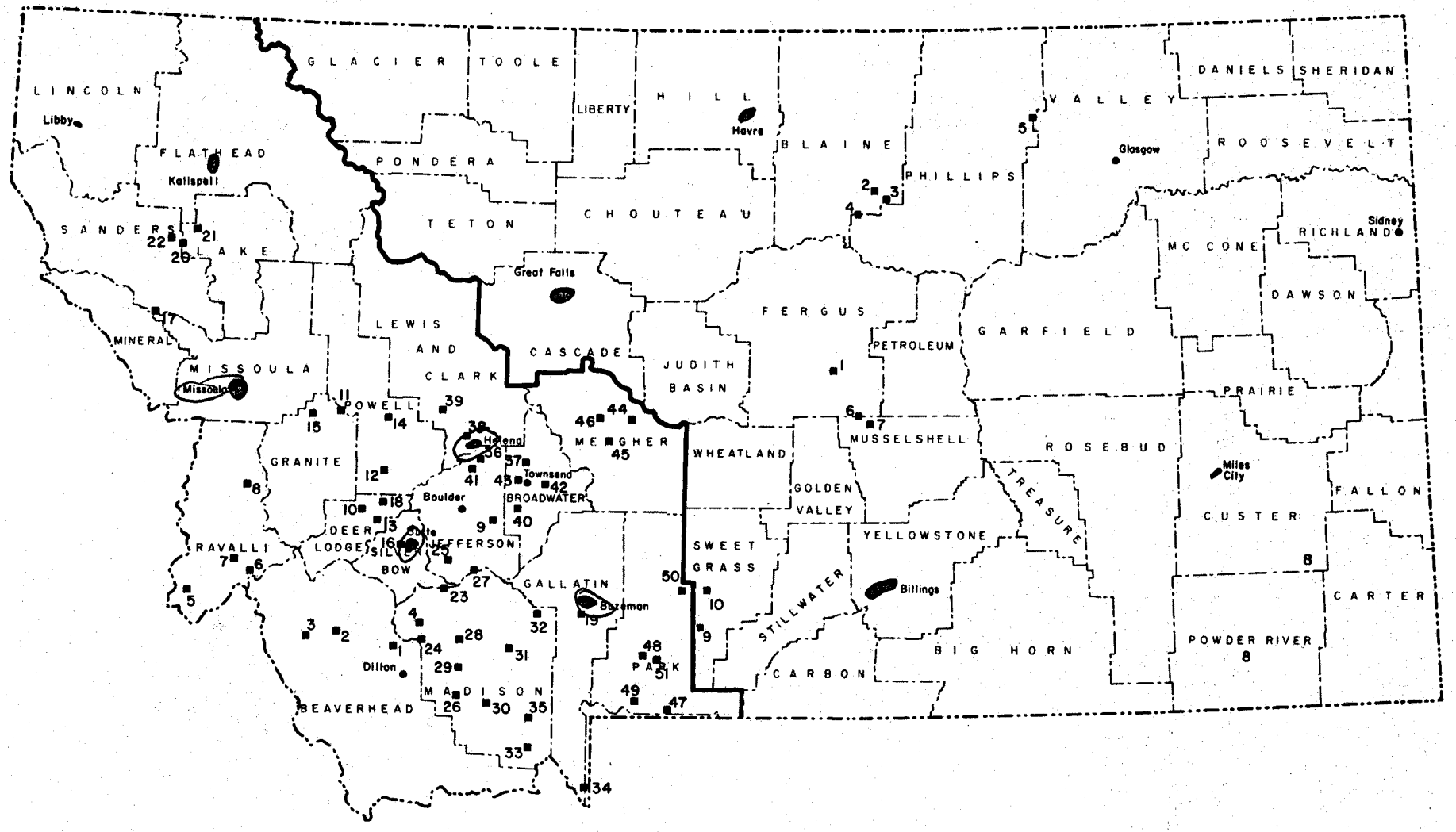


GEOTHERMAL RESOURCES RELATIVE TO POPULATIONS DISTRIBUTION

MAP 1

INTRODUCTION

Surface manifestations of geothermal energy in Montana have been reported from earliest historic accounts. The most widely known area was described by the Indians as a "supernatural place" involved in the "production of the Evil Spirit." Later, it became known as "Colter's Hell" from tales John Colter brought back from trading and trapping expeditions. It is now known as Yellowstone National Park. Another widely known area was discovered by Dr. Andrew Jackson Hunter. He settled Hunter's Hot Springs in 1870 because of the attractive qualities of a continuous hot water supply.

In spite of this early recognition of natural energy in Montana, there has been little exploration for usable geothermal resources. One reason for this may be the relatively low population densities in Montana and, hence, low demand for energy. Until recently, the state has had adequate hydroelectric and fuel-fired electric energy, and oil and gas supplies have been both cheap and readily available. As the energy supply becomes more critical, other forms of energy are being explored. Another reason for the lack of geothermal exploration is the disparity between the population distribution and hydrothermal resource location, as illustrated on Map 1. If the value of energy increases, more interest in this resource will develop.

Many of the state's hottest springs have been analyzed for geothermal reservoir potential, including geological mapping with hydrothermal modeling. A few small drilling projects have occurred at sites such as White Sulphur Springs, Broadwater Hot Springs, Ennis Hot Springs, and the Centennial Valley.

A major drill hole was funded in 1973 by the National Science Foundation for the Marysville area with a resulting depth of 6,600 feet. Several small projects currently are being pursued relative to locating and using hydrothermal sources.

There are over 100 known thermal springs in Montana. Many of these are located on Map 1 and identified in the appropriate planning region section of this report. Temperatures of the hotter springs are well known and a number of the cooler springs have also been measured.

The partial breakdown according to temperature is as follows:

149°F or greater	- 7 springs
130°F to 149°F	- 6 springs
110°F to 129°F	- 13 springs
90°F to 109°F	- 7 springs

The remaining springs are either less than 90°F or temperatures have not been recorded.

The reservoir temperatures have been estimated for the major springs with projections for some as high as 183°C. The geothermometry indicates many more with reservoir temperatures in excess of 100°C.

This publication described the work completed during the first year of OIT Geo-Heat Center's Northwest Geothermal Development and Planning Project. The emphasis for this year has been on identifying the important factors which directly affect geothermal development and the potential for development of a number of the better hot spring sites in Montana.

A short description of the state's geothermal characteristics, economy, and climate is presented to give an overview of the setting in which development must take place. Further, more specific information on these subjects is included under the planning regions and site specific data summaries.

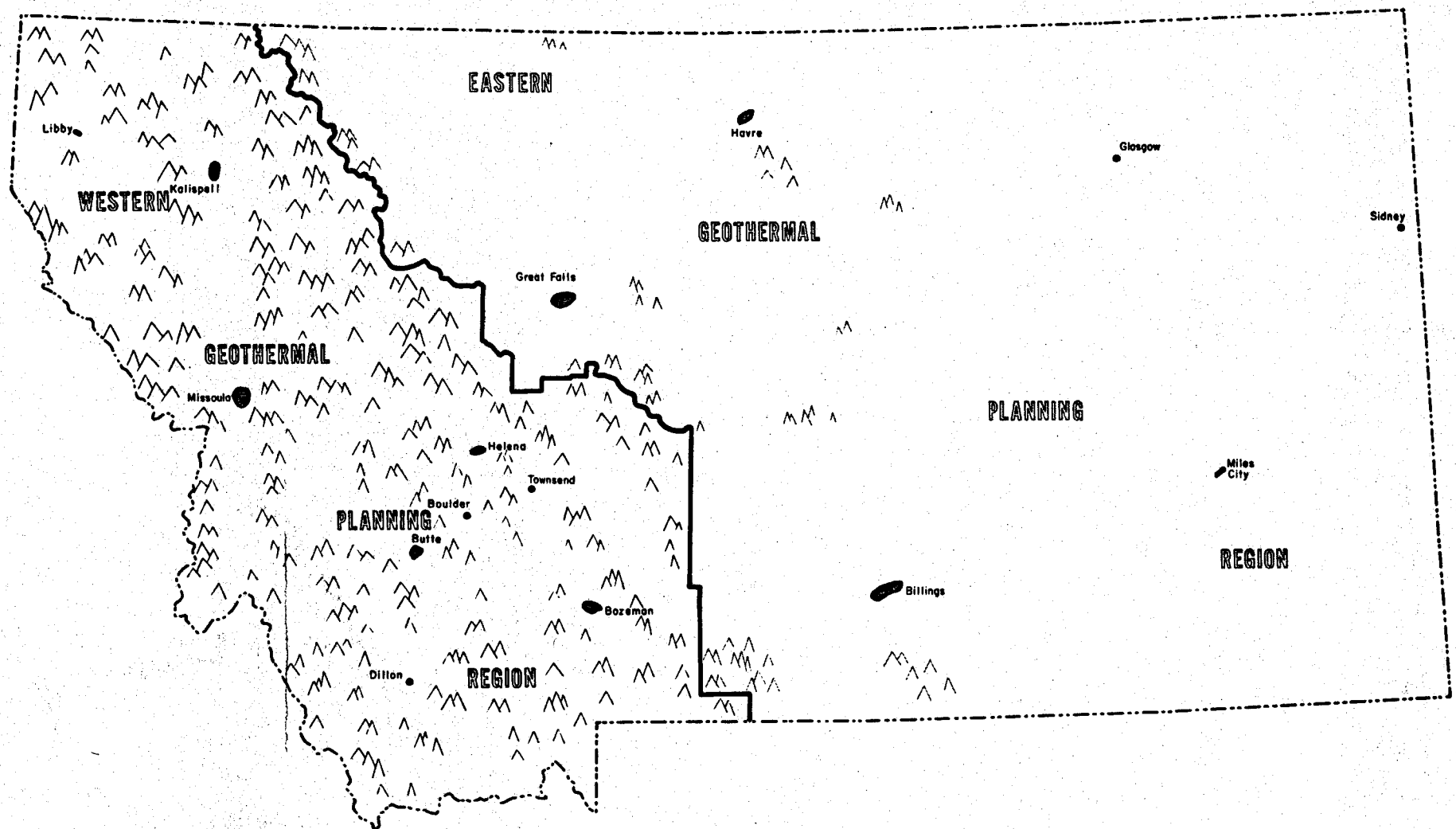
The Western Geothermal Planning Region was the focus of the first year's work, as most of the available information relates to this better known area. A brief discussion of the geothermal characteristics and a listing of a majority of the known hot springs is included. The main body of collected data is presented here in the form of data summaries and prose descriptions.

The Eastern Geothermal Planning Region is our second-state geothermal region division and some preliminary information is included. This consists of a very general discussion of the geothermal characteristics, a listing of the major known warm springs, and a preliminary data sheet for the Madison Formation resource area.

As an illustration of the relative importance of geothermal in relation to Montana's energy needs, a discussion of present and projected demand is included. The results of the site specific studies are addressed within the state energy picture. Possible uses and process requirements of geothermal resources are discussed.

The factors which influence geothermal development were researched and presented according to relative importance. These include: economics, financing, state leasing, federal leasing, direct-use technology, water quality laws, water rights, and Major Facility Siting Act.

Lastly, a discussion of the results of the first year's work, with recommendations for emphasis in future planning and development work, concludes the report.



MONTANA GEOTHERMAL PLANNING REGIONS

MAP 2

METHODOLOGY

Definition of Study Regions

The majority of geothermal resources existing in the state of Montana as defined through surface manifestations occur in the southwestern part of the state. A major, but as yet undefined, resource is the Madison Formation which covers most of eastern Montana. This distribution of resources facilitated the division of the state into the two resource regions shown in Map 2. The first is the Western Geothermal Planning Region which encompasses the mountainous western third of the state. The second is the Eastern Geothermal Planning Region, the eastern two-thirds of the state, which consists mostly of rolling hills and plains. Future studies may choose to subdivide these regions further when specific resource areas can be recognized. The relative availability of data on surface spring manifestations in the southwestern part of the state dictated that the initial investigation emphasizes this area of the state. The Eastern Planning Region has general descriptions, but lacks the site specific data which was gathered for the Western Planning Region. The scarcity of data and large distances inherent with the eastern region dictated that any in-depth study be left for future efforts.

Site Selection

In Montana, geothermal resource areas are indicated by specific and isolated springs which seldom appear to have common reservoirs with other spring areas. For this reason, no attempt was made to designate broad-based potential geothermal resource areas, other than the regional breakdowns. Site selection for study was accomplished by evaluation of available data describing the energy potential of the various sites. Of over 100 possible sites, 13 were selected on the basis of higher surface temperatures, ongoing development, or close proximity to population centers. A 14th site entitled the Madison Formation resource area was chosen to address potential in the eastern region.

The Madison Formation cannot be accurately described as a site. It is a single broad-based geothermal reservoir which covers a large area in Montana. In short, it is a water-bearing strata which occurs at depth, with the possibility of providing hot water from simple crustal heat flow occurring normally in Montana. This strata is broken and eroded in the western region by the crust buckling and upheaval coincident with mountain formation. The eastern region has more even topography which left the strata intact and occurring at depths to 10,000 feet.

Data Presentation

The Madison Formation resource area is not defined as were the site specific springs of the previous 13. It is considered from a regional approach. Basic characteristic data, which would define the general characteristics of the Madison Formation, was investigated. The type of information which was sought for the 13 individual sites included present activity, resource definition, site environment, and the suitability of the site for various development options.

All of the technical information and some socio-economic information is presented in the form of data sections. These can be used as a starting point for in-depth development studies. To augment the data texts with information not easily categorized and to include the author's opinions gained from study, a prose description of the site was written. This was designed to provide a condensed version of the data text and give impressions of development potential.

Development Scenarios

It was necessary to construct development scenarios to describe the steps required to harness resource energy. This type of scenario consists of a chart, such as the example shown in figure 1. The scenario includes: leasing phase, exploration phase, permitting phase, and many other development factors on the vertical axis. The horizontal axis shows years into the future, from 1972-2000. Time lines are then drawn across from each step to illustrate the time required for that process, relative to a specific project. This indicates the length of time for the step and its relative position within the project development. The factors which slow down the process by requiring the most time are easily identified.

The results from the scenarios are to be used for planning of the potential of the geothermal resource to supply energy for state consumption. Development of geothermal resource requires that certain steps be followed to comply with the local, state, and federal rules and regulations. In addition, specific physical steps such as geophysical exploration and production drilling can be identified. These development steps were assembled by category. The site was evaluated for future use, social, environmental, and legal factors. Each factor was assigned specific execution time periods. These time frames were incorporated in a step-by-step scenario which describes the development process from initiation to completion with power on line.

The results of the site specific information and constructed time frames associated with resource development were then summarized and compared with present and future state energy requirements. This initial phase of the resource development study is limited to one year and is not designed to comprehensively describe the state's geothermal potential. This first activity was designed to describe the major known geothermal resources. Subsequent planning studies will take a close look at areas other than southwestern Montana.

Execution order and length of time was investigated for all necessary development. Steps to these were compiled in a set of time factors to be used in site specific scenario preparation. A condensed listing of these time factors are shown in Appendix A. Sources for this information were derived almost exclusively from many conversations with agencies involved with geothermal development. Some factors which must be defined from experience were obtained from a previous study done by Mitre-Metrics on the same subject.

The sample scenario (figure 1), mentioned above, illustrates a hypothetical development project which can take place on either federal land or private land with all other considerations being equal. As can be seen, the federal path requires more time to accomplish the same development. The most time-consuming step is the preparation of an EAR or EIS for the federal land. This is important economically because a developer must commit lease money and speculate development money for a project which will be delayed from starting for 2 to 3 years. In addition, there is no guarantee that the finished EAR/EIS will allow development to proceed.

HYPOTHETICAL FEDERAL VS PRIVATE LAND

Nonelectric Geothermal Development Scenario

Summary of Relevant Milestones and Events

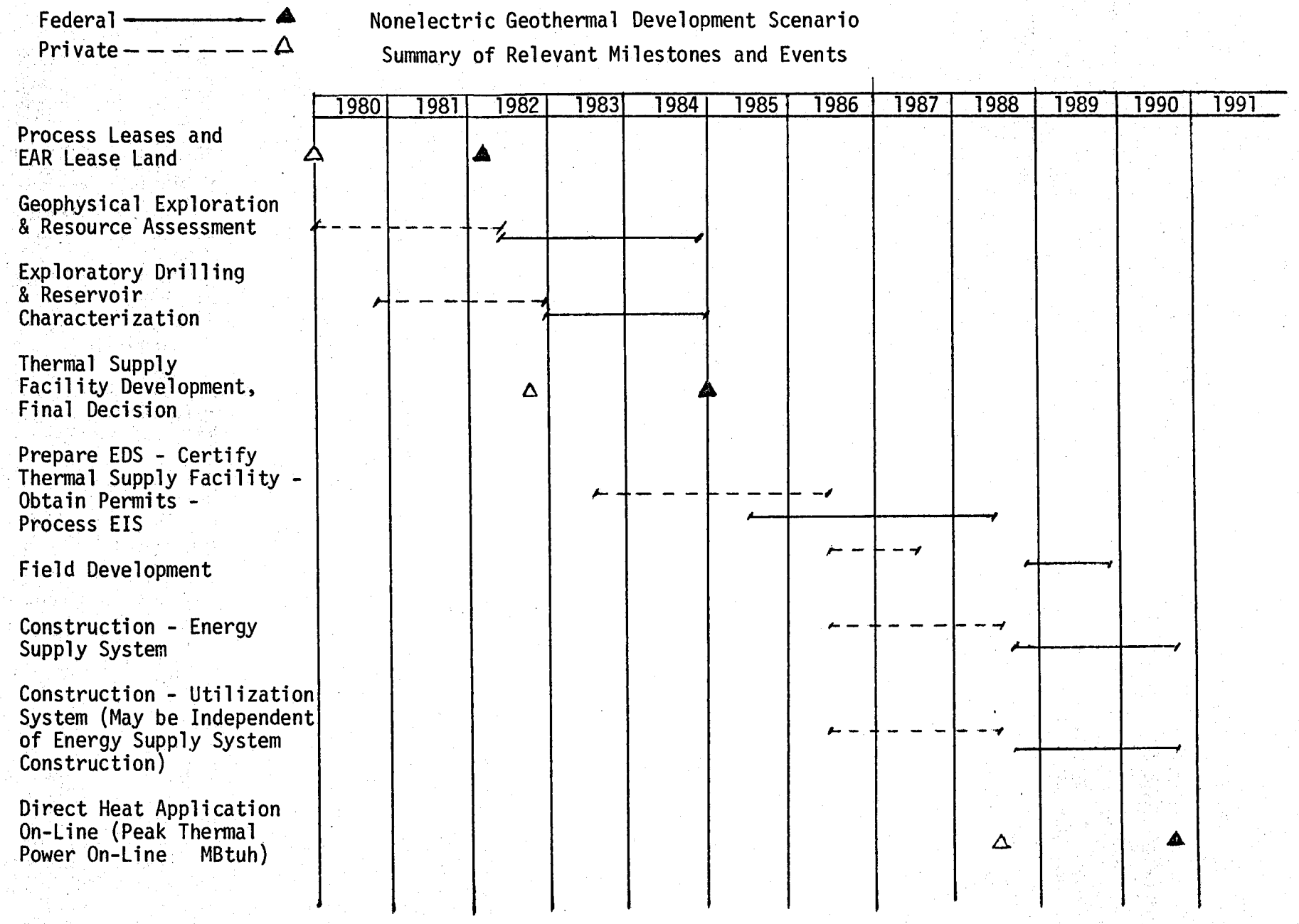


Figure 1

STATE DESCRIPTION

Montana Geothermal Characteristics

Tertiary volcanic or intrusive activity is common to many areas of the state; normal faulting is common in western Montana. Many of the mountain ranges here are fault-block mountains. In addition, high-volume aquifers, such as the Madison Group (Mississippian) and the Dakota Group (Cretaceous) underlie much of the state. These are the necessary components for geothermal systems. The potential for widespread economic geothermal resources in Montana is good.

Thermal springs exist in many areas of the state. The quantitites and temperatures of these springs vary, but generally, the temperature is lower for the higher-volume flows.

The upper Yellowstone River drainage has numerous thermal springs. Tertiary intrusive bodies within the Beartooth Mountains may be the source for these. Faults and fault systems generally provide conduits for the thermal discharge. Other spring areas include the Mocassin-Judith Mountains area, Little Rocky Mountains, and the Castle Mountain Range. The Boulder batholith was the site of prolonged volcanic and intrusive activity during and after Cretaceous time. This area is known to contain anomalous thermal gradients. West of here is located the eastern part of the Idaho batholith, with thermal springs which emanate from its boundaries. South of these two is located the Beaverhead area, where warm water has been located at depth. West of Yellowstone Park is the Snowcrest-Gravelly Range area. It is underlain by rocks from Precambrian to Cretaceous in age. No extrusive or intrusives are shown by outcrops, but this anomalous heat area must have a deep-seated igneous intrusion. Its proximity to the Yellowstone area shows probable association with the Yellowstone Park volcanic rocks.

Economy

Agriculture is Montana's leading industry. The growing world population is expected to put increasing demands on the availability of food stuffs and insures the continued importance of this Montana industry. Many crops grow well in Montana, but only a few have economic viability because of the distance to market. The farming activities can be divided into two types. The first is dryland farming, with wheat production being foremost. Barley, flax, mustard seed, and safflower seed are also grown. The second major division is livestock ranching. Either cattle or sheep or sometimes both are raised. Livestock graze most of their forage from natural grasslands. Hay is cut, dried, and stacked in the summer months for feeding in the winter months. A majority of the agricultural land (67 percent) is located in the eastern two-thirds of the state. Nine percent of this is harvested cropland, and the remaining fifty-eight percent is devoted to livestock grazing or seasonal fallow.

Thirty-three percent of Montana's land area is nonagricultural. Much of this is located in the mountainous western third of the state. Lumber production is the prime economic force in the seven counties of northwestern Montana. White pine is most precious with ponderosa pine and larch following as the most valuable species. Douglas fir is also being

harvested, (due to its accessibility.) A number of related industries such as plywood and veneer, particle board, millwork and heavy products, such as mine timbers and utility poles, also contribute to the economy.

Mineral production is centered in the mountains of southwestern Montana. Practically all known deposits of copper, zinc, lead, silver, and gold in Montana are associated with a single geologic feature called the Boulder batholith, which extends from south of Helena into Beaverhead County. Ninety percent of the five metals listed were mined in Silver Bow County. Copper is the dominant metal mined in tonnage and total value.

There is a wide variety of nonmetal minerals in Montana. Some, such as sand and gravel and stone, are so widespread that they are not considered resources. These are used quite extensively in the building industry. Some of the available nonmetals are limestone (cement), gypsum (wallboard), vermiculite (insulation), phosphate (fertilizer), talc, and bentonite.

The eastern two-thirds of the state is underlain by relatively young sedimentary rocks. Coal is a type of sedimentary rock and was deposited in much of the eastern area about three hundred million years ago. Much of it is close to the surface and can be mined economically. Montana's coal has the added quality of being "clean" or relatively sulfur-free. Many uses of coal are expected to be feasible in the near future, such as substitution for natural gas and motor fuel.

Petroleum and natural gas are present in limited quantities in eastern, central, and north-central Montana. These resources are available in decreasing quantities and are expected to decline in production.

The above economic pursuits are often termed primary production or activities which harvest the products of the earth. This is the most important aspect of Montana's economy. The second contributor is present in the form of service industries. These are all the support services which supply primary producers with goods and services. This service industry employs the majority of the people. Lately, the service industry has grown tremendously while the primary producers have remained the same or have been reduced in quantities of people involved.

Climate

Montana's climate is influenced by two air masses: the cold Arctic air which comes down through Canada into Montana, and the warm air from the northern Pacific Ocean. The colder parts of the state are cold because of elevation or are subjected to more frequent intrusions of the Arctic air masses. This Arctic air does not usually penetrate very far into the western mountains area due to the increase in elevation from east to west. The air cannot ascend to higher elevations since it tends to be dense and shallow in depth, which keeps it to the lower elevations. Although Arctic air can be common to Montana in January, it isn't present all of the time. For the majority of time, the northern Pacific Ocean air covers Montana in January.

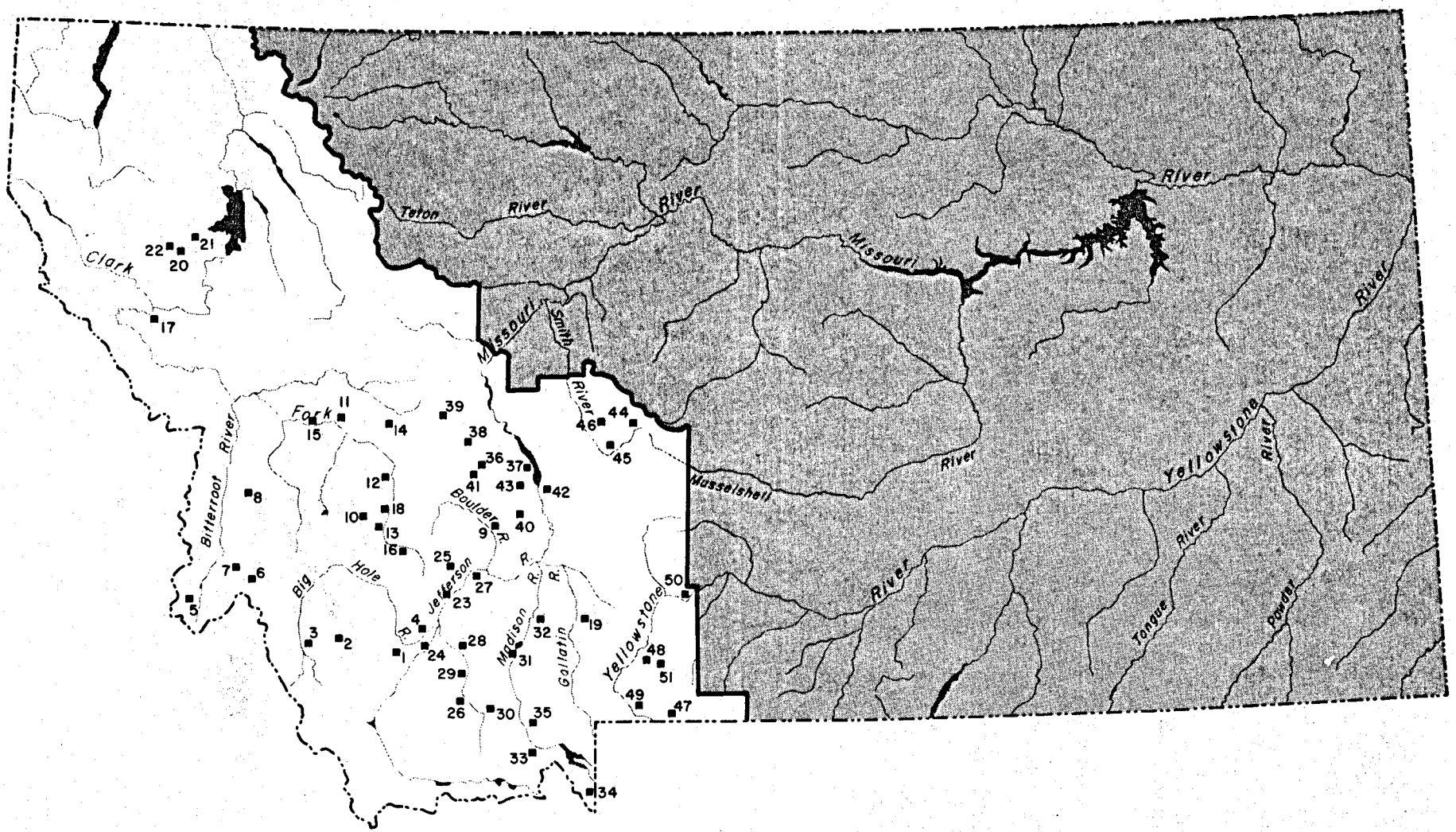
The change from Arctic air to Pacific air is a drastic difference characterized by not unusual temperature increases of 30°F to 40°F in a few day's time. This occurrence is called a chinook. The reverse change from Pacific air to Arctic air is equally dramatic.

The coldest temperature ever officially recorded in Montana and also the 48 contiguous states was northeast of Roger's Pass. The thermometer dropped to -70°F in January, 1954, at this location. Though not noted for being hot, the eastern portion of the state is subjected to occasional high temperatures. The highest temperature officially recorded in Montana was 117°F in July 1937, at Medicine Lake.

Mountains have an important effect on precipitation distribution in Montana. Elevation and distance from the mountain range are important. For example, the eastern edge of a valley will receive more rainfall than the rest of the valley. This is caused by lifting of air by the mountain and prevailing westerly winds present in Montana.

The western region of the state contains higher mountains which characteristically get more rain. Much of this region receives 20 or more inches of precipitation per year. Isolated areas in the extreme western parts can get up to 100 inches per year. Distribution of precipitation for these high-rate locations indicates that more than 50 percent occurs during winter months. The normal distribution for the rest of the region allows more than half to fall during the growing season. On the average, June is the wettest month of the year for almost all of Montana. The winter precipitation in the high mountain areas is stored in the form of "snowpack." This snowpack melts during spring and early summer and supplies water for the many streams which keep the major river systems flowing.

Much of the eastern region receives from less than 12 inches to as much as 16 inches of precipitation per year. Precipitation tends to be highly variable in these dry areas. Dry periods or wet periods lasting for months, or even years, are not uncommon in Montana. The majority of the eastern region receives at least half of the annual precipitation during the growing season. The northeastern section receives as much as 85 percent during the local growing season.



WESTERN PLANNING REGION SITES

MAP 3

WESTERN GEOTHERMAL PLANNING REGION

REGIONAL INTRODUCTION

The Western Geothermal Planning Region, shown on Map 3, includes the mountainous western third of the state. The region was arbitrarily drawn along county boundaries, and generally follows the Continental Divide from Helena to the Canadian border. South of Helena, the divide heads southwest, while the mountainous terrain continues south and east. The southern portion of the western region was drawn to include this mountainous area.

Population

The estimated 1975 population of the Western Planning Region is 356,500 persons, as shown in table 1. The most populous counties are Missoula, Silver Bow, and Flathead. Silver Bow (population density 61 persons/mile^2) and Missoula (26 persons/mile^2) counties are the most densely populated.

The six most populous cities are also shown in table 1. As can be seen, all are under 30,000 persons, with two in the 10,000 persons range. These populations are small as compared to more densely settled areas of the U.S., but large for Montana. Outside of the few major cities, the population is distributed sparsely throughout the valleys and basins in small communities, most of which have less than 2,000 people.

The population of the Western Planning Region is projected by the Montana Department of Community Affairs to grow by 18.4 percent or 65,400 persons by the year 2000. Most of the increases will occur in four of the six major cities.

Physiography

The Western Planning Region is a part of the Northern Rocky Mountain Region physiographic province. The northern portion of this region is characterized by parallel mountain ranges and narrow river valleys trending northwest-southeast. A major valley, the Rocky Mountain Trench, stretching from Whitefish and Columbia Falls in the north to Darby in the south, breaks this pattern. Flathead Lake occupies its lowest level. The southern portion of the Western Planning Region shows more irregularity in mountain range and drainage patterns. This area is characterized by narrow portions of mountain range and clusters with generally wider valleys. Both mountains and valleys of this area are higher than those in the north, but the local topographical relief is approximately the same.

Geology

The Western Rocky Mountain Region can be roughly divided by surface geology. The southwest is composed of mostly crystalline rock, while the northwest is almost completely sedimentary.

The crystalline rocks consist of three main types: intrusive igneous, extrusive igneous, and metamorphic, and are all represented in the southwest. Montana metamorphic rocks are dominantly very old (early Precambrian) rocks which have been changed by heat and great pressure. Gneiss is a common example. These old metamorphic rocks are exposed only in the southwestern portion of the state. The great majority of surfacing geothermal phenomenon present in Montana occurs in this southwestern area.

Table 1.

WESTERN REGION POPULATION STATISTICS

County	Area Mi²	Population 1970	Est. 1975	1980	Projected 1990	2000	Pop. Den.	Change in Pop. % 1960-1970	Projected Change in Pop. % 1970-1980
Beaverhead	5,551	8,187	8,300	8,200	8,200	8,300	2	13.8	.2
Broadwater	1,193	2,526	2,800	3,100	3,100	3,100	2	-9.9	22.7
Deer Lodge	740	15,652	15,200	13,500	13,000	12,400	21	-16	-13.8
Flathead	5,137	39,460	44,300	48,900	55,600	62,100	9	19.7	23.9
Gallatin	2,517	32,505	38,800	40,200	46,300	51,700	15	24.8	23.7
Granite	1,733	2,737	2,700	2,700	2,800	2,800	2	-15.2	-1.4
Jefferson	1,652	5,238	7,300	7,300	8,200	10,200	4	21.9	39.4
Lake	1,494	14,445	17,000	18,000	18,900	20,000	11	10.2	25.6
Lewis & Clark	3,476	33,281	36,900	40,900	48,800	57,500	11	18.8	22.9
Lincoln	3,714	18,063	15,800	17,900	18,300	17,500	4	26	-.9
Madison	3,528	5,014	5,800	5,700	5,800	5,700	2	-3.8	13.7
Meagher	2,354	2,122	2,200	2,300	2,300	2,300	1	-18.9	8.4
Mineral	1,222	2,958	3,500	3,700	3,900	4,100	3	-2.6	25.1
Missoula	2,612	58,263	66,600	69,500	78,300	89,000	26	14.9	14.3
Park	2,626	11,197	12,000	12,800	13,500	14,200	5	-15	14.3
Powell	2,336	6,660	7,400	8,000	8,300	8,600	3	4.9	20.1
Ravalli	2,382	14,409	18,500	20,500	22,700	2,500	8	16.8	42.3
Sanders	2,778	7,093	8,100	8,600	8,900	9,400	3	3.1	21.3
Silver Bow	715	41,981	43,300	40,900	40,500	40,500	61	-9.6	-2.6
WESTERN REGION TOTAL	44,046	324,791	356,500	372,700	407,400	421,900	8	10.9%	14.8%
Major Cities									
Anaconda	-	9,771	-	8,550	8,250	7,850	-	-	-12.0
Bozeman	-	18,670	-	21,300	24,550	27,400	-	-	14.1
Butte	-	23,368	-	22,950	22,750	22,750	-	-	-1.8
Helena	-	22,730	-	27,500	32,800	38,650	-	-	21.0
Kalispell	-	10,526	-	16,150	18,350	20,500	-	-	53.4
Missoula	-	29,497	-	31,300	35,250	40,050	-	-	6.1

The northwestern part of the Rocky Mountain Region is covered by old sedimentary rocks of late Precambrian age, shales and limestone formed intermittently over a period covering perhaps 400 million years. These sediments are over 45,000 feet thick in some areas. Fossils are rare. Building stone is the only useful material presently utilized from these rocks. Both sedimentary and crystalline rocks were formed during late Mesozoic and early Cenozoic times. During this time, several major tectonic events occurred which left their mark in the form of volcanic rocks and severely deformed strata. Eastern Montana was relatively undisturbed except for being covered by layers of sediment deposited by rivers flowing from the mountains.

During the last million years, glaciers covered northern Montana and extended northwest into Canada, deepening valleys and carving sharp peaks and ridges. Fine silts, mud, sand, and gravel were deposited in large meltwater lakes.

Geothermal Resources

The Western Planning Region contains the majority of Montana's surface geothermal resources. Most of those can be further grouped into the southern portion of that area. The surface manifestations are primarily isolated, low volume hot springs.

So little is known about detail subsurface geology in the complicated western region that estimates of reservoir capacity are, at best, generally very questionable. A formation could be limited to slightly fractured granitic rocks which allow transport of minor amounts of water to deep levels, or a major fault system with massive fracturing and recent intrusives which could supply significant quantities of hot water. In addition, valley sediments which allow little surface indication of geothermal activity could contain large resources of hydrothermal energy. Geothermetry, for the major spring areas, indicate subsurface temperatures as high as 400°F are possible. Presently, the highest surface temperature of any spring in Montana, outside of Yellowstone Park, is a little over 180°F.

A partial listing of geothermal springs in the Western Planning Region is included to illustrate the quantity and variety of the resource. Location, temperature, and flow are given where available. Map 3 shows the approximate locations using numbers corresponding to the sequence in the above-mentioned list. The springs and wells are located according to drainage basins where possible. The sites chosen for in-depth evaluation are also listed to illustrate basin drainage relationships.

Bighole River Valley

1. Apex Warm Springs, township 5 S., range 9 W., section 10. Temperature unknown, flow unknown.

2. Elkhorn Hot Springs, township 4 S., range 12 W., section 29. The temperature is 48.5°C with 6.7 liters per second flow. These springs issue in the vicinity of exposed Boulder batholith at an elevation of 7,200 feet. Mineral analyses are available.

3. Jackson Hot Springs--sometimes called Jardine, township 5 S., range 15 W., section 25. The temperature is 58°C. The flow is greater than 16.7 liters per second. Elevation is 6,470 feet. The water issued from alluvium, Tertiary sediments, Missoula strata.

4. New Biltmore Hot Springs. See text.

Bitterroot River Valley

5. Bluejoint 1 and 2, township 2 S., range 23 W., section 1. Temperature 29°C, flow 17 liters per second, springs issued from Idaho batholith Precambrian Rivalli. Mineral analyses are available.

6. Galloagly Warm Springs, township 1 S., range 19 W., section 15. It's 49°C with a flow of 7.6 liters per second. Altitude 5,400 feet, springs issue from Idaho batholith. Additional mineral analyses are available.

7. Medicine Warm Springs, township 1 N., range 20 W., section 12. The temperature is 45°C with 6.7 liters per second flow. Water issues from the Idaho batholith at an altitude of 4,440 feet. Additional mineral analyses are available.

8. Sleeping Child Warm Springs, township 4 N., range 19 W., section 7. The temperature is 51°C with a flow of larger than 33.3 liters per second. Water issued from the Idaho batholith at two sources. Additional mineral analyses are available.

Boulder River Valley

9. Boulder Hot Springs. See text.

Clark Fork River Valley

10. Anaconda. Location is approximately 3 miles east of Anaconda. No further information is known about this source.

11. Bearmouth One and Two, township 11 N., range 14 W., section 11. Little is known about this spring. It's of low temperature in the Madison aquifer.

12. Deerlodge Warm Springs. See text.

13. Fairmont Hot Springs (Gregson), township 3 N., range 10 W., section 2. Temperature 70°C with 16.7 liters per second flow. The source of the water is the tertiary volcanics of the Boulder batholith. Additional mineral analyses are available.

14. Garrison Warm Springs, township 10 N., range 9 W., section 19. Flow is unknown. Temperature is 25°C. Issues apparently from the Madison strata. The water is currently not used. Additonal spring analyses are available. Ph-7.3 specific conductance 737. Total dissolved solids 558 mg/ℓ.

15. Nimrod Warm Springs, township 11 N., range 15 W., section 14. Discharge is 6.3 liters per second. Temperature is 22°C. Source is either Cambrian or Mississippi limestone along faults. The spring issues from Tertiary sediments. PH-7.63, specific conductance 8.56. Total dissolved solids 715 mg/ℓ. Additional analyses are available.

16. Nissler Junction, township 3 N., range 8 W., section 19. These warm springs stopped flowing approximately 1920. They did issue at 5,375 feet Tertiary sediments over the Boulder batholith.

17. Quinns Warm Springs, township 18 N., range 25 W., section 9. The temperature is 43°C and the flow is 1.3 liters per second. The source water is apparently the Precambrian Piegan. Additional analyses are available.

18. Warm Springs. See text.

Gallatin River Valley

19. Bozeman Hot Springs. See text.

Little Bitterroot River Valley

20. Camas Hot Springs, township 21 N., range 24 W., section 3. Temperature is 45°C with a flow larger than 3.3 liters per second. Source of the water is probably a diorite sill. Additional mineral analyses are available.

21. Camp Aqua. Very high potential for direct use.

22. Symes, township 21 N., range 24 W., section 4. Temperature is 46°C. Flow is unknown. Issued from Precambrian rock. Additional analyses are available.

Jefferson River Valley

23. Barkells Hot Springs (Silver Star). See text.

24. Beaverhead Rock, township 5 S., range 7 W., section 22. Temperature 27.2°C at 6.3 liters per second. Issues at an elevation of 4,810 and Tertiary sediments probably over Madison formation. No additional information is available.

25. Pipestone One and Two, township 2 N., range 5 W., section 28. The temperature is 51.1°C at 5.0 liters per second. The source of water is the Boulder batholith at an elevation of 4,530 feet. Additional analyses are available.

26. Pullers, township 8 S., range 5 W., section 1. Temperature is 42.2°C at a flow of 9.5 liters per second. The source of water is apparently the Tertiary sediments over pre-belt rocks.

27. Renova Warm Springs, township 1 N., range 4 W., section 32. Temperature and flow are unknown at this time. Little additional information is available.

28. Silver Spring, township 5 S., range 5 W., section 14. Temperature and flow are unknown. Little additional information is available.

29. Trudau, township 7 S., range 4 W., section 7. Temperature and flow are unknown. Little additional information is available.

30. Vigilantee, township 9 S., range 3 W., section 22. Temperature is higher than 32°C, with a flow of between 31.7 and 32.6 liters per second. Issues at an altitude of 6,200 feet apparently from the Madison-Kootenai Formations.

Madison River Valley

31. Ennis Hot Springs. See text.

32. Norris Hot Springs, township 3 S., range 1 W., section 14. Temperature is 52.5°C. Flow is 6.7 liters per second. Issues at an altitude 4,805 in pre-belt Tobacco Root stock. Additional analyses are available.

33. West Fork Swimming Hole, township 12 S., range 1 E., section 18. Temperature is 28.3°C and the flow is 31.3 liters per second. Springs issue at 6,700 feet and alluvium Pleistocene volcanics. Additional analyses are available.

34. West Yellowstone. See text.

35. Wolf Creek, township 10 S., range 1 E., section 9. The temperature is 66.1°C with a flow of 31.3 liters per second. It issues at 6,100 feet elevation from Tertiary sediments overlying Precambrian rocks. Additional analyses are available.

Missouri River Valley

36. Alhambra Hot Springs, township 8 N., range 3 W., section 16. The temperature is 56.5°C and the flow is about 12.7 liters per second. The source of the water is Boulder batholith at an altitude of 4,360 feet. Additional water analyses are available.

37. Bedford, township 7 N., range 1 E., section 23. The temperature is 23.3°C, with a flow of 95 liters per second. Water issues from Precambrian, Spokane Formation. Additional water analyses are available.

38. Broadwater Hot Springs. See text.

39. Marysville. See text.

40. Plunketts, township 4 N., range 1 E., section 27. Temperature 16.7°C, flow is 253 liters per second. Issues at 4,180 feet per minute from Precambrian Spokane rocks.

41. Sunnyside, township 8 N., range 3 W., section 16. Temperature and flow are unknown at this time. They do not issue from the Boulder batholith. Additional water quality analyses are available.

42. Toston, township 4 N., range 3 E., section 6. The temperature is 14°C and the flow is 569 liters per second. Issues at an altitude of 3,960 feet from Pennsylvanian Madison formations. Additional water quality analyses are available in some detail.

43. Warner, township 5 N., range 1 E., section 22. Temperature is 19°C. The flow is unknown. Issues at 4,100 feet elevation from alluvium Tertiary sediments over Precambrian.

Smith River Valley

44. Lucus Flowing Well, abandoned petroleum exploration well. Location 46°, 21 minutes, 30 seconds, 110°, 40 minutes, 41 seconds. Temperature is 42.2°C, with a flow of 6.3 liters per second. Specific conductance--3,300; total dissolved solids--3,150 mg/ℓ. Additional analyses are available.

45. Ringling Flowing Well area, abandoned petroleum exploration well. Location 46°, 20 minutes, 22 seconds, 110°, 47 minutes, 11 seconds. Temperature is 48°C, with a flow of 51 liters per second. The pH is 6.8. Specific conductance of 1,630 and the total dissolved solids are 1,360 mg/ℓ. Additional mineral analyses are available.

46. White Sulfer Springs. See text.

Yellowstone River Valley

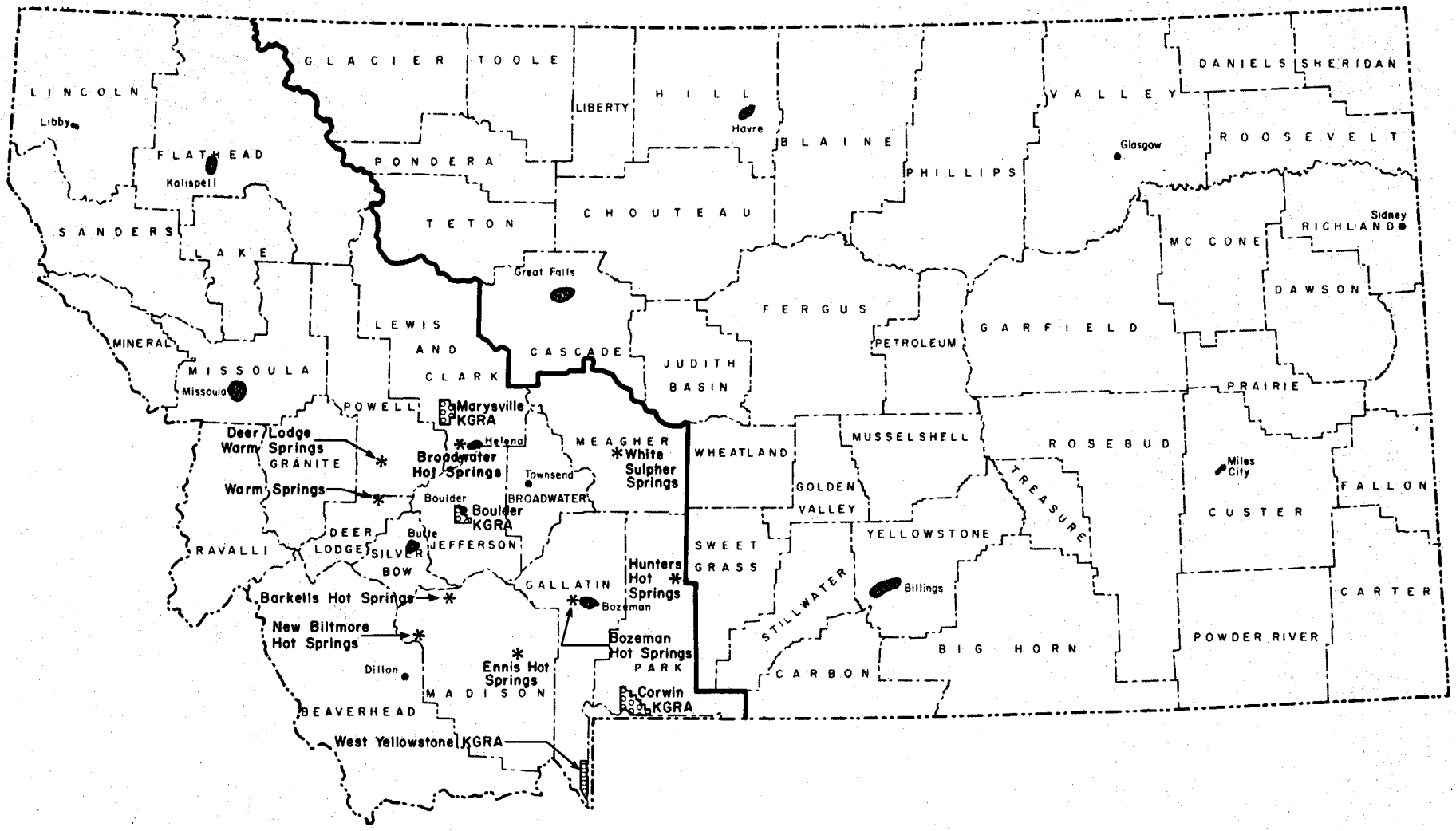
47. Bear Creek, township 9 S., range 9 E., section 19. The temperature is 32°C and the discharge is 2 liters per second. The source appears to the Madison aquifer. Little additional information is available.

48. Chico Hot Springs, township 6 S., range 8 E., section 1. Temperature is 48°C, with a discharge greater than 8.2 liters per second. Springs issued through Tertiary volcanics and sediments. The water is currently used for resort purposes. The waters are thought to originate from the Madison aquifer. The pH is 7.38, specific conductance is 370. Total dissolved solids were 256 mg/ℓ. Additional mineral analyses are available.

49. Corwin Springs. See text.

50. Hunter Hot Springs. See text.

51. Montanapolis, township 6 S., range 10 E., section 29. Little is known about the flow or the temperature. The source is the Madison through Tertiary granite, underlain by Cambrian rock.



GEOTHERMAL STUDY SITES

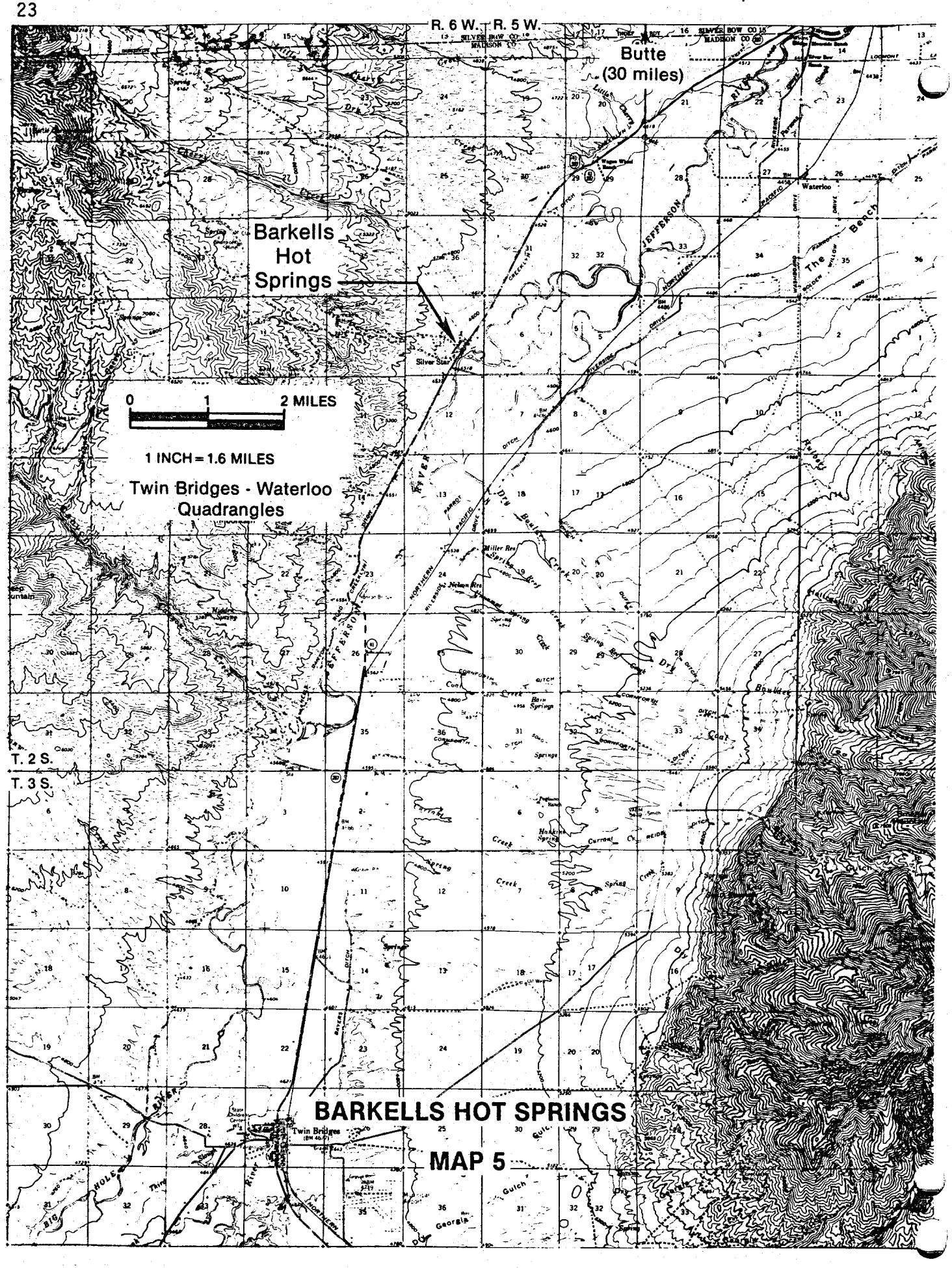
MAP 4

Specific Sites

The 13 Western Planning Region sites shown on Map 4 were chosen for in-depth study. Each was investigated to obtain all of the existing site information, and this data is assembled in the data sheet section of each site subchapter. A simplified presentation of relative facts from the data sheets are composed in the Site Discussion. More detailed information is included in the data sheet, or can be obtained from the sources noted in the bibliography.

A number of the spring sites have potential for commercial applications of their hydrothermal resource. The most common use which can be applied to many sites is commercial greenhouse production of food products. Other useful applications include drying processes for hay, grain, or vegetables. Alfalfa is a likely candidate for conversion into valuable animal feed pellets which are easily transportable. Potatoes and onions lend themselves to drying and processing for shipment to other parts of the U.S.A. Few of the springs are located near enough to populated areas for direct-use space heating of homes.

Many additional geothermal resource areas may exist which are not obvious from surface indications. Exploration for these should be concentrated near urban areas or sites where manufacturing endeavors are likely to occur. One must keep in mind that resource confirmation of suspected potential is a prerequisite for specific geothermal resource planning to be effective.


R. 6 W.
R. 5 W.
Butte
(30 miles)
Barkells
Hot
Springs
Silver Star
0
1
2 MILES
1 INCH = 1.6 MILES
Twin Bridges - Waterloo
Quadrangles
T. 2 S.
T. 3 S.
Twin Bridges
Waterloo
BARKELLS HOT SPRINGS
MAP 5

Western Region

Subchapter A

BARKELL'S HOT SPRINGS

Barkell's Hot Springs is located near the small community of Silver Star in southwestern Montana. The water is the second hottest surface source in the state. The springs discharge from gravels in a cow pasture about 300 m from Barkells Plunge. Presently, shallow flowing wells tap the hot water and collect it in underground reservoirs, from which it is piped underground to a cooling tank used to fill a commercial swimming pool in Silver Star.

The historic use of this area began with use by many Indian tribes, and it was a heavily contested hunting ground. Lewis and Clark were the first recorded whites to visit the area. Exploration for gold and silver was begun in the mid-1800's. Silver Star was one of the oldest mining towns in the state and was a major supply point between Virginia City and Helena.

Possible uses of this hydrothermal system include: some space heating of homes, agricultural uses such as greenhouses and heat processing, and expanded resort facilities. The Silver Star area is not well suited for community space heating, due to the sparseness of the local population. Resort and agricultrual uses of the resource are more likely. The most likely energy use potential appears to be with greenhouse installations on the site of the springs.

There appears to be no major restrictions on development of this hydrothermal site. Concerns for visual esthetics and surface water quality is always present in Montana. However, this location, although well traveled, is not a highly sensitive tourist route. Furthermore, the impact from such direct-use applications would most certainly be very small.

Site Description

The rectilinear location of the springs site is section 1 of township 2, S., range 6 W., about 22 miles (35.2 km) southeast of Butte. Barkell's is privately owned and includes about 200 acres (81 hec.) on which the springs originate. A combination bar and swimming pool is also on the property. Silver Star, of which Barkell's is a part, has a population of 75. Twin Bridges, population 613, is 10 miles (16 km) to the south and Whitehall, population 1,035, is 14 miles (22.4 km) to the north.

The topography consists of rolling hills generally trending north-south. The elevation in the vicinity vary from 4,800 feet to 5,300 feet (1,463 m to 1,615 m) with gentle slopes. After joining the Big Hole River south of Silver Star, the Jefferson River flows east to become part of the Missouri River, which continues northward. Sagebrush is the major vegetative cover.

Present land uses include grazing, watershed, and recreation, including Blue Ribbon fishing on the Jefferson River. There is no major change in land use anticipated for this area. The population is primarily engaged in ranching. Gold claims were once abundant in the area.

The local energy uses are small and limited to domestic heating and lighting. Fuel oil is trucked in via State Highway 41 from the Butte area, and electrical energy is available from a 50-kv line adjacent to Silver Star. Some of the space heating requirements in the core area of Silver Star could be met with the hot water. Geothermal resources may exist near Twin Bridges further south, which has a larger population. New or expanded industry, such as a larger resort facility or greenhouse production, would require additional quantities of hot water.

Within 3 3/4 miles (6 kilometers) of the Hot Springs, 71 percent of the land is privately owned, 10 percent state owned, and 19 percent federally owned by the Bureau of Land Management (BLM).

Area residents are generally interested in direct use of geothermal resources. Utilization of the hydrothermal resource could be promoted successfully if economic cost benefits can be demonstrated.

Geothermal Resource Description

The surface temperature of the hot springs is 160°F (71°C). Relative chemical concentration for specific elements were analyzed to obtain temperature of the geothermal reservoir at depth. There are four temperatures which can be calculated using different assumptions for geochemical equilibrium. This process of predicting base temperatures is called geothermometry and is important because of the possibility of drilling down to hotter reservoir water than is available on the surface. These temperature predictions are not particularly reliable because of mixing of the hot water with cold ground water, but they do serve for comparison purposes. The predicted reservoir temperatures for the Barkell's site are 230°F to 290°F (110°C to 143°C) for equilibrium with silica and 228°F to 282°F (109°C to 139°C) for the NA-K-Ca indicators. 230°F (110°C) seems most likely for that reservoir. The TDS concentration of the spring is 612 mg/ℓ. The flow has been measured as high as 150 gallons per minute.

This area is interesting because it falls into the northern extension of an elongated belt of high intensity historic earthquakes. Areas of recent earthquake activity have high potential for the deep faults that may be associated with some forms of geothermal reservoir systems. Highly damaging earthquakes corresponding to intensity VIII and higher on the modified Mercalli scale have occurred within this belt. No faults of recent movement have been measured. Most of the faults which do exist in the area were established during and after the emplacement of the Boulder batholith. Zones of extensive hydrothermal alteration and mineralization are common.

There has been some geophysical reconnaissance work done for the Barkell's area. Regional gravity, site gravity, and resistivity surveys of the region including 10 kilometers around the springs have been performed. Site specific soil temperature, seismic and resistivity surveys have also been conducted. Drilling of temperature gradient holes is the next step toward identification of the reservoir potential.

Potential for Geothermal Development

The range of applications using the known surface temperature of 160°F (71.5°C) are shown in figure 2, presented on page 27. Many of these would not be feasible in the Silver Star area. Some suggested uses would include: aquaculture, soil warming, limited space heat, animal husbandry, and greenhouse and increased recreational uses. Geothermometry estimates temperatures as high as 289°F (143°C) to be available at depth. This temperature is high enough for commercial processing applications for such agricultural products as potato and onion drying and animal feed pelleting. Various animal feeds are currently produced in this area.

The most economically feasible potential use is for commercial greenhouse operations. There are populous areas within marketable distance, plenty of sun and water, and an adequate heat supply.

Interest in Development

Barkell's Hot Springs is within a U.S. Geological Survey Potential Geothermal Resource Area (PGRA). In areas, federal leases classified as such, need not be let on a competitive basis unless overlapping applications are received.

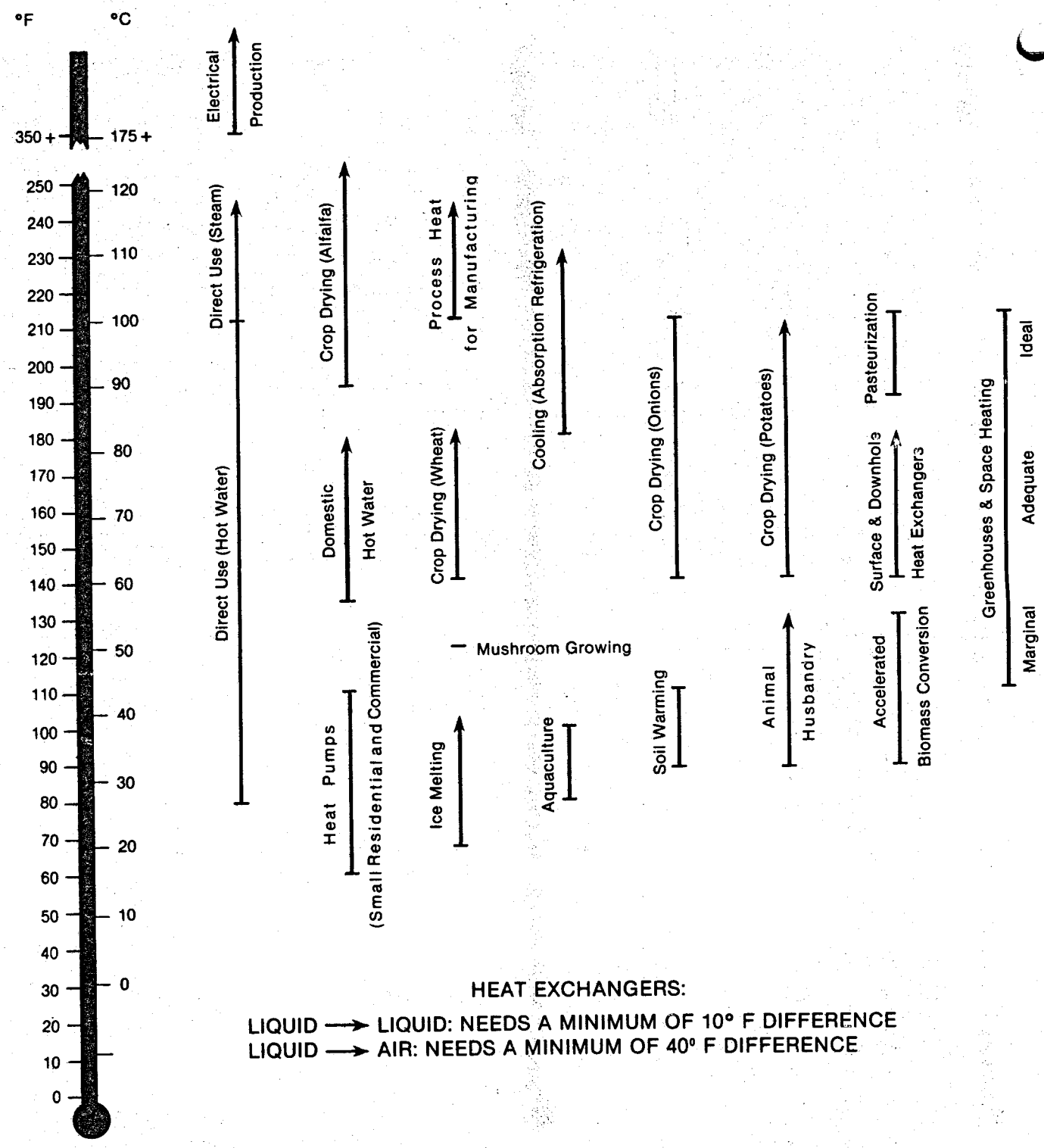
In 1973, Phillips Petroleum applied for leases in an area between Silver Star and New Biltmore Hot Spring, a few miles northeast of Dillon, Montana. An environmental analysis which covered much of the BLM land in this area was prepared. Federal land was certified for noncompetitive leasing, and six leases were issued to Phillips Petroleum in 1975. No further leasing interest has developed.

According to local sources, Phillips Petroleum drilled one or more wells on their leases shortly after permission was given. The company has not released the results of that test drilling at this writing. It can be assumed that the resource doesn't appear to be outstanding for electrical generation when compared to other areas of the west. Phillips Petroleum is exploring other sites and has done no further work in the Barkell's area, although leases have been kept current.

The owners of Barkell's Hot Springs have been approached about the possibility of selling the spring area for the purpose of constructing a greenhouse facility.

Scenario Discussion

A developmental scenario for an electrical generating plant of 100-megawatt capacity was formulated for the Silver Star (Barkell's) area. This level of development seems possible in light of the commercial interest expressed by Phillips Petroleum which has been renewing their lease for the past three years. In addition, the U.S. Geological survey has provided funds for geophysical measurements and temperature gradient holes at the site. Thus, sufficient commercial interest for development exists, and federal



NOTE: (1) These temperature ranges are not meant to be absolute, special applications can extend a use range higher or lower. An attempt was made to illustrate average temperatures in use.

(2) An open-ended temperature range is represented by an arrow, and a closed boundary is shown by a horizontal dash.

TEMPERATURES FOR GEOTHERMAL APPLICATIONS.

Figure 2.

land has already been leased (Phillips Petroleum Corp.). Scenario assumptions are that:

1. A high-quality resource, sufficient for electrical production of at least 100 MW, would be discovered.
2. Adequate financing of the electrical production could be developed.

The beginning date for this development is estimated to be 1987, and the entire process should take eight years to obtain power-on-line. This projected development is illustrated by assuming a single event (i.e., one plant). No additional plants are postulated because of the large uncertainty of the existence of an adequate resource. If exploration of this area does indicate that a large resource is available, then additional events could be planned. The time lines for these plants would follow essentially the same format, with a reduced exploration phase. The total development time for the Barkell's area is less than for other sites since the federal E.A.R. has been completed.

A direct-area scenario involving a 5-acre commercial greenhouse facility for tree seedlings and produce was also postulated. Again, leasing of private land has already occurred, and commercial interest exists. The assumptions which were made for this scenario to take place are as follows:

1. Increased flow of hot water could be found.
2. Necessary financing would be available.

This development could begin in 1980 and would require 6 years to become operable. The total energy used by this facility would be approximately 40×10^6 Btu/hr, maximum demand.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 41' 47" (31)

..Longitude: 112 17' 42" (31)

..Rectilinear: T. 2 S., R. 6 W., sec. 1, CBD (55)

..County: Madison

..Adjacent Counties: Beaverhead, Silver Bow, Jefferson, Gallatin

..Topography: The topography is one of rolling, generally north-south trending hills. The elevations vary from 4,800 feet to 5,300 feet (1,463 to 1,615 meters). The Big Hole River joins the Jefferson River south of the community of Silver Star. Sagebrush is the bulk of the vegetative cover. (71)

..Present Land Use: The area is currently being used for grazing, watershed recreation and Blue Ribbon fishing. (71)

..Future Land Use Plans: No change in land use is anticipated. (71)

..Aesthetics: Most of the land of interest is not exposed to visual scrutiny from traveled roads. The previous human impact is quite severe due to mining in some areas, so this area will not be subjected to strict aesthetic requirements. (71)

..Historical/Archaeological Significance: This area lies within the area that was generally heavily contested hunting grounds by many different tribes of Indians. The first white men to enter the area were Lewis and Clark. Much mineral exploration and some mining occurred in the 1800's. Robber's Roost was located 24 kilometers southwest of Twin Bridges at Laurin (in 1864). It was reputed to be a hangout for the Plummer Gang. The Rochester Historic District between Twin Bridges and Melrose was an important mining town from 1863 to 1938.

One of the oldest mining towns in the state was Silver Star. It is located 14.4 kilometers northeast of Twin Bridges and was a major supply point between Virginia City and Helena.

No archaeological inventory was made of the area, but adjacent areas have several known archeological sites. At least one pictograph site is present in the adjacent area. Fifty-two archeological sites have been identified in Madison County and the potential for future archaeological finds is high. (43.71)

..Geologic Description: The oldest exposed rocks at Barkell's Hot Springs are Precambrian gneiss, schist, and amphibolite. The Cambrian strata, which is commonly exposed through much of southwest Montana, is not present here. Paleozoic and Mesozoic strata have been folded, faulted, and altered by heat from the Boulder batholithic intrusion.

The Jefferson Formation is the oldest sedimentary rock present. This carbonate formation, though normally dolomitic, is mostly limestone at Barkell's. The appearence of the rock is coarsely crystalline and weathers to a sandy yellow color. Fractures are prolific and are found filled with limonite and calcite. A sequence of Paleozoic and Mesozoic sedimentary rocks were deposited over the Jefferson Formation.

Slightly consolidated Tertiary alluvium is present near the hot springs. This strata is a few meters thick near the springs, but increases to a kilometer or more thick in the valley to the east. These beds of locally derived conglomerate with layers of sand, silt, and ash are known as the Bozeman Group.

A section of the basin fill, about 300 meters north of the hot springs, is impregnated with calcite and silica which probably was deposited by hot water from an extinct hot spring.

Barkell's Hot Spring is located along the Galena fault. The fault trends toward Barkell's Hot Springs, but cannot be identified closer than about 100 meters from the springs. (48)

..Geophysical Summary:

Regional Gravity - Contours at the Valley Margin near Silver Star (Burfeind, 1967).
Soil Temperature - Soil Temperature Map of Barkell's Hot Springs (Goering, 1975).
Seismic Survey - Hammer Seismograph at Barkell's (O'Haire, 1976) (Weinheimer, 1977).
Resistivity Surveys - Direct Current Resistivity of Barkell's (O'Haire, 1976, 1977).
Regional Gravity and Resistivity - Broad Gravity and Resistivity Survey of an Area 10km^2 Around Barkell's Hot Springs (Malic 1977).

..Geologic Hazards: This area falls into the northern extension of an elongated belt of historic, high-intensity earthquake activity. Highly damaging earthquakes corresponding to intensity VIII and higher on the modified Mercalli Scale have occurred within this belt. No indication of probable recurrence interval within this zone is available. (71)

No recent fault movements have been measured. Most of the faults which do exist in the area were established during and after the emplacement of the Boulder batholith. These are commonly zones of extensive hydrothermal alterations and mineralization. (71)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 161°F or 71.5°C (55)

..Subsurface: 293°F or 145°C (80)

..Geochemical

SiO_2: Chalcedony 230°F or 110°C Quartz 289°F or 143°C

Na-K-Ca: Na-K-1/3Ca 282°F or 139°C Na-K-4/3Ca 228°F or 109° C (80)

..Flow Rates: 150 gpm or 568 l/m (55)

..pH: 8.2 (31)

..Total Dissolved Solids: 612 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	808
Hardness (Ca, Mg)	26 mg/ℓ
Ca	9.6 mg/ℓ
Mg	0.5 mg/ℓ
Na	170 mg/ℓ
Bicarbonate	190 mg/ℓ
SO_4	190 mg/ℓ
Cl	31 mg/ℓ
F	5.4 mg/ℓ
SiO_2	110 mg/ℓ
B	450 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Completely unknown.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	100%	19%	10%	71%	0%
..Land Leased	10687 4325 hec	10687 4325 hec			

..Highest Priced Leases (Dollars/Acre) $1.00

..$/Acre	Lessee
$1.00/acre	Phillips Pet.

..Tentative Lease Sale Dates: Area not in KGRA designation. Noncompetitive leasing open any time.

..Number of Sales Offered But No Bids: 0

..Number of Bids Rejected Resulting in No Lease: 0

..Summary of Leasing Status and Needs: Phillips Petroleum has six leases in the Barkell's/Biltmore Spring areas. No activities ongoing. No further lease activity in any form is present in this area.

LEASE DATA FOR BARKELL'S-BILTMORE PGRA

The following are issued leases:

Sec 2	(Partial)	T2S	R6W		
Sec 3	(Partial)	T2S	R6W	2272.57 acres	M27444
Sec 4	(Partial)	T2S	R6W		
Sec 9	(Partial)	T2S	R6W		
Sec 10	(Partial)	T2S	R6W		
Sec 11	(Partial)	T2S	R6W	2175.56 acres	M27445
Sec 14	(Partial)	T2S	R6W		
Sec 15	(Partial)	T2S	R6W		
Sec 22	(Partial)	T2S	R6W	637.21 acres	M27446
Sec 12	(Partial)	T1S	R6W		
Sec 14		T1S	R6W	1280 acres	M27447
Sec 32	(Partial)	T1S	R6W		
Sec 7	(Partial)	T4S	R7W		
Sec 8		T4S	R7W	2349.91 acres	M27448
Sec 10	(Partial)	T4S	R7W		
Sec 18	(Partial)	T4S	R7W		
Sec 19	(Partial)	T4S	R7W		
Sec 20		T4S	R7W	2041.87 acres	M27449
Sec 30	(Partial)	T4S	R7W		
Sec 32	(Partial)	T4S	R7W		

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: Barkell's Hot Spring is a resort facility that is presently using the hot water to supply a swimming pool. Phillips Petroleum drilled some wells in the area of their leases, but dates and results are unknown.

Present use involves shallow wells which tap the hot water and collect it in an underground reservoir. From here, hot water is piped underground to the swimming pool in Silver Star. (48)

..Projected or Planned Development: The Barkell's Hot Spring and surrounding land may be sold to people interested in greenhouse applications.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: Geothermal development is generally limited to enforcement of all regulations governing water and air quality, and protection of basic environmental quality. (17)

Status of Requirements (i.e., EIA/EIS Requirements): An Environmental Assessment Record has been completed. No specific mitigating measures were included. Noncompetitive leasing is open for bids.

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds:

..Precipitation (Annual): 13 in/year or 33 cm/year (67)

..Days of Sunshine (Annual):

..Average Temperature:

Minimum: 1.8°F or 1°C (67)
Maximum: 66.2°F or 19°C (67)

..Degree Days (Annual):

..Relative Humidity (Seasonal Peaks):

Summer: 35% (67)
Winter: 50% (67)

..Air Quality: No data available for this immediate area. General air quality is high. Some land is susceptible to wind erosion creating dust. These dust storms are generally mild and infrequent. Smoke is sometimes generated from range fires and trash burning. (71)

..Comments and Critical Issues: The Jefferson River is a major watershed. It is a class three fishery. The surrounding area is a crucial winter habitat for mule deer. (71)

..Water Quality: Water quality is excellent. The rivers are snowmelt supplied. Two excellent fishing rivers are present including the Jefferson which is classified as $B\text{-}D_1$, which requires a minimum of 7.0 mg/ℓ of dissolved oxygen and is suitable for swimming, fishing, drinking, and food processing after pretreatment. Water is used extensively for irrigation. Mostly private water rights. (39)

..Noise: No major industry gives a noise level picture representative of a fairly isolated woodland and prairies, except near the populated areas. (71)

..Biological:

..Dominant Flora: The majority of vegetative cover is big sagebrush and some varieties of bunchgrass. There is a small amount of lodgepole pine forest. (71)

..Dominant Fauna: Game animals include mule deer, elk, antelope. There are several varieties of trout available for fishing. (71)

..Endangered Species:

Flora: None (71)
Fauna: None (71)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities

Electrical Transmission Lines:

50 KV	Adjacent	
100 KV	10 miles (16 km)	
230 KV	14 miles z(23 km)	(42)

..Transportation Corridors or Facilities

Highways:

State Highway 41	Adjacent
U.S. Highway 15	20 miles (32 km)

POPULATION

..General Description of Population

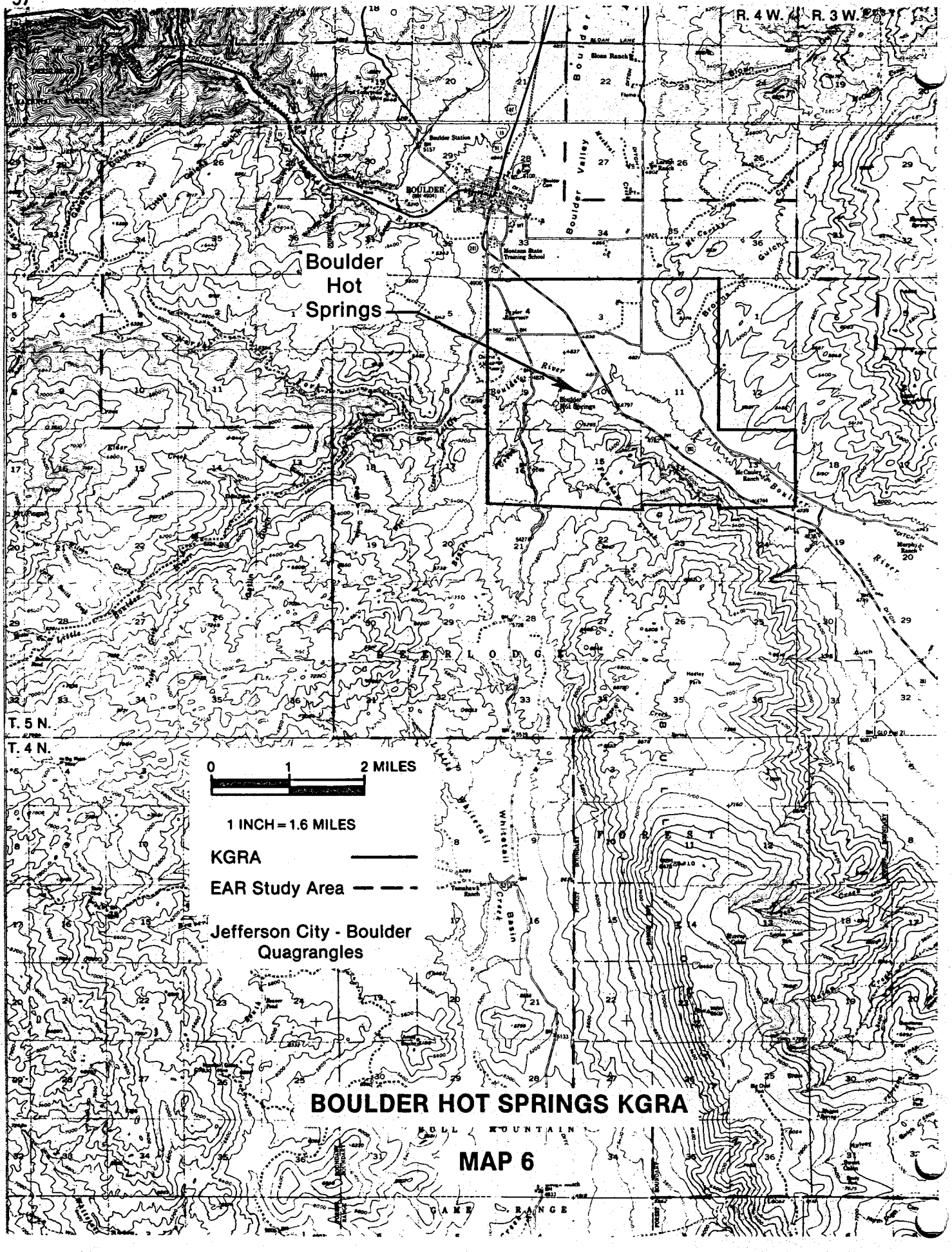
Closest communities to the site:

Butte	30 miles (48 km)
Whitehall	16 miles (26 km)
Twin Bridges	14 miles (23 km)

..Economics

..Present Land Use: The majority of the area inhabitants earn their living from ranching and associated agriculture. The surrounding area is used for grazing and recreation. (71)

..Future Land Use: No change from the above anticipated. (71)


R. 4 W.
R. 3 W.
Boulder Hot Springs
BOULDER
Boulder Valley
Montana State Training School
Boulder River
T. 5 N.
T. 4 N.
0
1
2 MILES
1 INCH = 1.6 MILES
KGRA
EAR Study Area
Jefferson City - Boulder Quagrangles
BOULDER HOT SPRINGS KGRA
MAP 6

Western Region

Subchapter B

BOULDER HOT SPRINGS KGRA

Boulder Hot Springs is located in southwestern Montana about two miles (3.2 km) south of the town of Boulder. This resource area has surface manifestations ranking it among the top 10 sites in Montana. The nature of the discharge and the geology of the area make the site one of the most promising for maximum use of the energy potential. Its proximity to a population center gives it a higher use potential than many other sites. The resource range of applications includes individual and district space heat, greenhouse complexes, aquaculture, growing season extension, and light industrial and manufacturing uses.

There has been sporadic interest expressed in the Boulder Hot Springs area for development of the energy resource. The hot springs resort has been operating for many years in this location. When the nearby area was opened for leasing, a number of lease applications were received. All were since withdrawn and no further interest has been shown.

Any development which does occur on federal lands will be subject to strict environmental controls. Visual aesthetics, slope erosion, wildlife habitat and water quality will be of prime importance.

Site Description

Boulder Hot Springs, along with the resort facility, is located in the center of the KGRA area which begins about four-tenths of a mile (.65 km) south of the town of Boulder (population 1,350) and thirty miles (48 km) south of Helena, Montana (population 23,000). The nearest communities to Boulder are Basin (population 96), nine miles (14.4 km) to the northwest, and Jefferson City (population 100), eleven miles (17.6 km) to the northeast.

The Little Boulder River is adjacent to the hot springs site and joins the Boulder River nearby. There are some 26 vents discharging hot water at this site, all within a two-and-a-half acre (0.01 km^2) zone. This discharge has been present for many years with seemingly no change in temperature. The discharge from a number of the larger springs is gathered with piping and delivered to the hotel for space heating, indoor hot baths, and an outdoor warm pool.

The Boulder area is characterized by two distinct topographic styles. The first has mountainous terrain with steep slopes of 10 percent to over 50 percent. The elevation ranges from 5,000 feet to 8,609 feet (1524 km to 2624 km) in the study area. The second topography is characterized by a broad valley bottom with slopes of zero to ten percent. The valley exposure is generally east and west and has good solar exposure.

The valley is used primarily for ranching with associated farming activities. Timber is managed on steeper areas with forest recreation a significant use. The normal complement of roads, utility corridors, ditches, wells, fencing, and building sites are present. The future land use will probably continue much the same as it is now, with the addition of a reservoir for irrigation to be constructed in the near future.

The economic base for the area includes ranching, employment at the Boulder River School and Hospital (state supported), tourism, a small number of local service jobs, and commuting to Helena for state and local employment. The tourism is based on the presence of uranium and radon health mines that people visit to receive "curing" doses of radiation for various ailments.

An area within 3-8/10 square miles (6 km) was centered around the hot springs, and used to obtain a breakdown of land ownership in the immediate vicinity. Ownership records show that 43 percent is privately owned, 9 percent is state owned, 9 percent is BLM administrated, and the Forest Service controls 39 percent.

Present energy sources include electricity and natural gas. The electricity is supplied with a KV line, while natural gas is piped into the city.

The general attitude on the part of the local public is one of acceptance or, at worst, uninformed lack of interest towards direct usage of geothermal energy. The town fathers are interested in pursuing conversion to district space heat if it is economical. Electric generation would stir up more interest since visibility and noise would be present with this form of use.

Geothermal Resource Description

The surface temperature of the primary spring is 160°F (71°C). Geothermometry has been performed on samples of this spring water with resulting temperature estimates of 241°F to 289°F (116°C to 143°C). The total dissolved solids are approximately 610 mg/ℓ. This is a low concentration bur corrosion of iron pipe noted along with build-up of solids where leaks are encountered. Many springs exist in the vicinity of the resort (Diamond S Ranchhotel). Montana State University studies have mapped the surface geology and the results predict joint control of the main spring. The reservoir is thought to be unconfined although some self-sealing due to deposition of solids has occurred. Nearby surface waters appear to be the recharge source with circulation to depth providing the heat.

The total volume of the main springs is estimated at more than 1,000 gallons per minute (3,800 l/pm) at times of the year which can be correlated with surface runoff. The other springs are much lower in flow. The pH of the springs is slightly alkaline at 8.8. No geophysical data other than water quality has been published as of the present investigation.

Structural studies indicate a fault system which could provide much more water than is currently seeping to the surface. The only known well in the immediate area is one which was drilled in hopes of finding cold water for the resort. The depth and temperature is not known at this time but it did not produce cold water.

Potential for Geothermal Development

A range of applications using the surface temperature of 159.8°F (71°C) are shown in figure 2 on page 27. A number of these are possible with the Boulder community. The suggested uses include aquaculture, space heating

districts, and greenhouses. The geothermometry predicts temperatures as high as 289°F (143°C) may be available in the reservoir at depth. If drilling generates data confirming the presence of reservoir temperatures approaching this level, other uses such as wood processing, animal feed processing, and many other commercial activities would be possible.

The possible uses which are economically feasible for the study area include space heat for the Boulder River School and Hospital, a heating district for all or part of the town of Boulder, and a greenhouse complex located on or near the source of a quantity of hot water. Of particular interest for the Boulder area would be the production of fresh garden vegetables which could be marketed in nearby areas and production of containerized tree seedlings.

Interest in Development

The Boulder Hot Springs have been used for many years in the resort for pool heating and also building heating. The new owner would like to expand his use of the water to include a greenhouse and more efficient use of the water in the buildings for heat.

The land around, and including, Boulder Hot Springs was classified "Valuable Prospectively for Geothermal Resources" in 1971 by the USGS. Federal lands, including the Boulder Hot Springs area, were opened up for geothermal lease applications in January, 1974. Applications were received from a number of companies for this area. Union Oil Company and Phillips Petroleum Company filed overlapping lease applications. The KGRA designation was a result of this overlap. The Boulder Hot Springs area was designated as a KGRA by the central region of the U.S. Geological Survey on March 19, 1975. This area includes 6,343 acres of federal, private, and Bureau of Land Management managed property. Over one-half of the total KGRA is privately owned. Since much of the Forest Service and BLM land is restricted to use, the remaining private land is very important.

As noted above, the initial commercial interest was in the form of federal lands applications. The resulting Environmental Assessment Record study and recommendations curtailed interest drastically, due to prescribed restrictions. When the federal land was finally put out for competitive and noncompetitive lease bids, all previous lease applications were withdrawn and no new bids were received. There are no leases on federal land in the Boulder KGRA as of this study.

Restrictions to Development

Development in the Boulder KGRA is restricted by "No Surface Occupancy" designations for much of the area. This was deemed necessary as a result of the study of the fragile, mountain slope environments.

Any development which would take place on federal or private land would be subject to strict regulations limiting water pollution. The aesthetics of the area, relative to noise and visual change, are also very important.

Scenario Discussion

The social and economic environment of the Boulder area, along with the available data for local geothermal potential, have been analyzed to obtain realistic time frames for possible resource development. The proximity of the resource to Boulder (population 1,350) provides a user for a district heating system. The Boulder River School, a major state facility located between the site and Boulder, is another prime consideration for conversion to geothermal space heat.

A development profile was constructed for a district heating system to be installed for the city of Boulder. This scenario used one event as a model to illustrate probable development time requirements. In reality, the heating district may be constructed stepwise with one portion operable before a second is started. The only addition needed to the given scenario would be additional time lines for actual system construction, which would be of approximately the same length but staggered in occurrence.

Federal land was postulated as the resource site for this scenario. This mode requires a process of bid applications, lease sale if within the KGRA, and structured developmental requirements. The development of private land would be easier with acquisition of private leases or complete ownership.

The federal oriented time frame, as shown, would require about nine years for a full-scale project from start to finish. The project is postulated to begin in 1982 and completion with power-on-line by 1988.

The private mode would take seven years or less. The times for private development are highly variable since one or more of the steps could be shortened or eliminated. The maximum energy supplied is designed at 14×10^6 Btu/hr.

A second development profile was done for a greenhouse facility. Again, the use of federal land would take longer with four years as opposed to a projection of three years on private land. This project is predicted to begin in 1980, with a maximum heat supply of 40×10^6 Btu/hr. In both scenarios, location of an adequate resource is assumed.

In reality, small projects could be gotten "on line" in as little as two years depending on the extent of community impact. The area around Boulder Hot Springs has been studied by the BLM and an EAR finalized.

It appears that for the present no electrical production projects can be economically justified. This is a result, in part, of the strict lease stipulations which were thought to be necessary to protect the local environment.

The direct use of this resource will be the most likely approach. The prospect for development of the resource for district heating should be very good within the next five years. A heating district, including much of the town of Boulder, could be realized within the next ten years. The area will probably see a small greenhouse facility within the next three years with commercial capabilities increasing by 1985.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 11' 53" (31)

..Longitude: 112 05' 37" (31)

..Rectilinear: 5 N., 4 W., 10 CAB (31)

..County: Jefferson

..Adjacent Counties: Broadwater, Lewis and Clark, Powell, Silver Bow, and Madison.

..Topography: Two distinct, nearly equal, topographies are present. Steep mountainous portions range from 5,000 feet to 8,609 feet (1524 m to 2624 m) in elevation with slopes ranging from 10 percent to over 50 percent. The broad valley bottoms have slopes from 0 percent to 10 percent. All aspects, except the south, are well represented in the mountainous areas. The valley aspect is generally east and west. (72)

..Present Land Use: The present land uses include ranching with associated agriculture, silvaculture, and recreation.

..Future Land Use Plans: The future should continue with the present uses with the addition of a reservoir for irrigation.

..Aesthetics: Visual aesthetics are important in this area. As in most of the mountainous areas of Montana, scenic beauty is a resource acknowledged by everyone and must not be abused. Water quality and unwarranted noise are also important.

..Historical/Archaeological Significance: Human activity has been evident in this area for the last 8,000 years. The Indians were the only inhabitants until gold was discovered in Jefferson County in 1862. The real influx of people occurred after gold was discovered in Helena in 1864.

In 1883, the completion of the Northern Pacific Transcontinental Railroad gave new impetus to the mining industry. Mining has continued on an intermittent basis to recent times.

Livestock grazing began with the influx of miners in the 1860s. Horses, cattle, and sheep were raised in this area, with cattle gradually replacing the other two by 1934.

Forty prehistoric archaeological sites are recorded for the small area inventoried. This area should have a relatively high density of prehistoric resources. (43)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: Boulder Hot Springs is located in the Boulder batholith about five miles (8 km) west of the eastern edge of the batholith. The eastern margin has been described as a shallow, west-dipping contact between batholithic and prebatholithic floor.

Two north-south trending late Cenozoic faults occur south of the hot springs. The Bull Mountain fault, which is parallel to the Whitetail Basin, could be the major structural control for that basin. The amount of displacement along this fault is not known. A fault located along the western margin of the Boulder River Basin and parallel to the Bull Mountain fault, may control this portion of the basin. This fault displacement is also not known.

The Boulder batholith in the hot springs area is a medium-grained quartz monzonite, composed of orthoclase, quartz, plagioclase, biotite, and hornblende. Magnetite, sphene, and apatite are also present. The quartz monzonite is extremely altered in much of the spring area. Surface deposits include a veneer of soil, colluvium, and gruss. The alluvium deposited in the many small streams is minimal.

The springs emanate from cracks in the granite on the west side of the Boulder River. The fissures are nearly sealed at the surface by deposition of silica and calcite which have precipitated from the hot water over many years. The hot water is leaching sodium, silica, and calcium from the granite along the fissure wells and depositing calcareous and siliceous material on the sides of the conduits.

There are 26 vents discharging hot water within a 90,000 square-foot (0.01 km^2) zone. One other vent is located about 131 feet (40 m) lower and 1,312 feet (0.4 km) north of the other vents. The vents issue from altered quartz monzonite and various veins within a bowl-shaped area between the 4,920 feet (1500 m) and the 4,970 feet (1515 m) levels. Most of the vents are clustered at the heads of three gulches. The total flow has been estimated at 1,000 gpm (3800 l/m), but exact measurement cannot be obtained with the present system. (22)

..Regional Hydrology: The Boulder River is the major surface drainage in the Boulder area. The flow is southeast and has a gradient of 7.6 m/km. Peak discharges are related to spring and early summer snowmelt. Low summer discharge is supplied by recharge from shallow ground water in fluvial deposits. (22)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 71°C at the main spring

..Subsurface:

..Geochemical:

SiO_2: Chalcedony 104°C Quartz 143°C

Na-K-Ca: Na-K-1/3 Ca 135°C Na-K-4/3 Ca 116°C (80)

..Flow Rates: Estimates range from 250- 1000+ gpm (31)

..pH: 8.8 (31)

..Total Dissolved Solids: 410 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	622
Hardness (Ca, Mg)	0 mg/ℓ
Ca	2.3 mg/ℓ
Mg	0 mg/ℓ
Na	120 mg/ℓ
Bicarbonate	169 mg/ℓ
SO_4	74 mg/ℓ
Cl	18 mg/ℓ
F	12 mg/ℓ
SiO_2	96 mg/ℓ
B	570 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Completely unknown.

LAND OWNERSHIP AND LEASING

..Land Ownership

..Land Leased

..Highest Price Leases (Dollars/Acre)

..Tentative Lease Sale Dates: 1/12/77

..Number of Sales Offered But No Bids: 1,607.74

..Number of Bids Rejected (Resulting in No Lease): 12 19,040 acres

..Summary of Leasing Status and Needs: Lease sales were offered. There were no bids. There appears to be no further interest in leasing federal lands. The KGRA area could be offered for lease sale again if interest warrants.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The site containing the hot springs is presently a hotel resort facility. Hot water is used to heat the buildings and for indoor and outdoor bathing pools. Ownership has changed hands recently and the new management is interested in further development.

..Projected or Planned Development: The new owner of the hot springs site wishes to renovate the hotel heating system and the water supply system. He wishes to build a greenhouse facility on the site for commercial production.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: Activity on the hot spring site area is relatively unrestricted at this time. Activities which will deposit warm water in running surface waters will face very restrictive water quality regulations.

..Agency and Public Attitudes: Public support is low at this time, but information dissemination could easily build support. Most of the populace thinks only in terms of electrical production. BLM attitudes are rather negative at this point since no one was interested enough to bid on the lease sale.

..Status of Requirements (i.e., EIA/EIS Requirements): The Environmental Impact Statement has been written and the stipulations for lease use established. These stipulations are very restrictive and removed much of the available land from use. This was accomplished with the "no Surface Occupancy" stipulation. Apparently, the commercial interests found the requirements to be too restrictive for economic development.

The North Boulder Drainage District and Jefferson Valley Conservation District have filed a draft EIS on the Boulder River Watershed Project. The plans include a 350-acre reservoir and associated irrigation ditches. The proposed site covers parts of the noncompetitive lease areas, and some private land within the KGRA. (72)

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds:

..Precipitation (Annual): 11.3 inches/year (67)

..Average Yearly Snowfall: 53.7 inches/year

..Days of Sunshine (Annual): 221 days of clear and partly cloudy weather. Helena (69)

..Average Temperature:

Minimum:	January 8.4°F	July 53.3°F	(67)
Maximum:	January 28.8°F	July 84.4°F	

..Degree Days (Annual): 8,572 (67)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: The entire area is in the Upper Missouri Air Shed. Little monitoring data is available. Based on site observations, air quality is assumed to be high. Minor and generally localized air pollution results form wind-raised dust during the dry season. Upper air inversions may occur, but dissipate shortly after sunrise.

..Geologic Factors:

..Water Quality: The entire area drains into the Boulder River which is classified as B-D_1 by the state's Water Quality Bureau. This classification requires a minimum of 7.0 mg/ℓ of dissolved oxygen and is suitable for swimming, fishing, drinking, and food processing after pretreatment. The Boulder River is a typical snowpack fed stream. Average peak flow is 1100 cfs. The total water appropriation is 3100 cfs. The river is polluted somewhat by mine drainage and has total dissolved solids of 90 mg/ℓ to 330 mg/ℓ. Ample groundwater is available from the valley-fill sediments. (39)

..Noise: No monitoring data is available but normal ranching and recreational activities are present. There will be occasional logging. The higher levels of noise would be sporadic and temporary.

ENVIRONMENTAL FACTORS
(continued)

..Biological:

..Dominant Flora: Lodgepole pine is the major species in forested areas. The rangeland areas support sagebrush and several varieties of bunchgrass. The cropland grows alfalfa, some grains, and a variety of hay crop grasses. (72)

..Dominant Fauna: The area supports whitetail deer, mule deer, antelope, and elk. (72)

..Endangered Species:

Flora: None (72)

Fauna: None (72)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities

..Power Transmission Lines:

..Transportation Corridors or Facilities

Roads:	U.S. Interstate 15	Within 1 mile of Boulder
	State Highway 281	Adjacent to area

There is a higher-than-normal complement of roads within the area due to past mining activities.

POPULATION

..General Description of Population

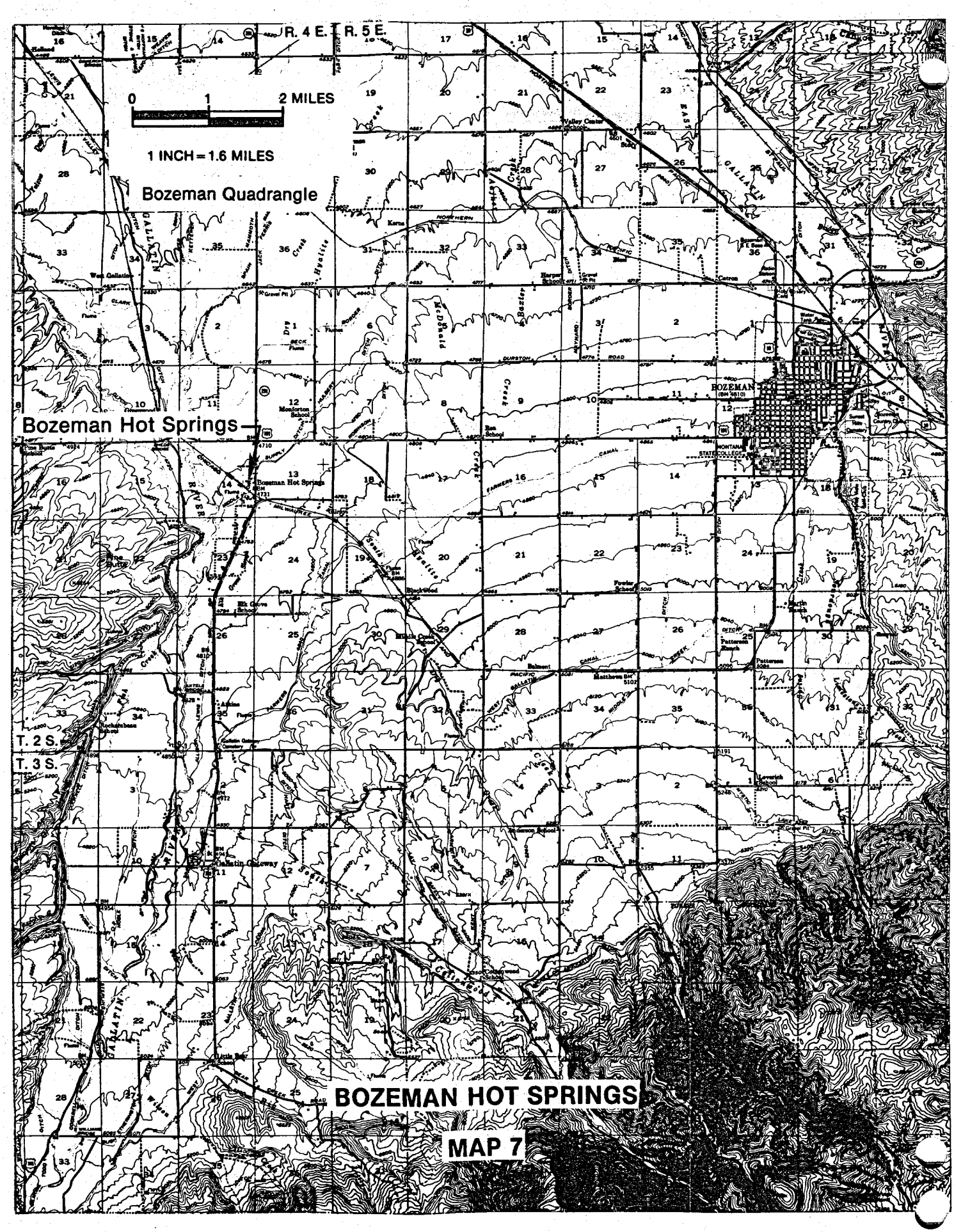
Population centers near the site:

	Miles	Population
Boulder	3	1,342
Jefferson City	12	100
Clancy	18	230
Helena	30	22,730
Basin	10	96
Whitehall	41	1,035
Butte	37	23,368

..Economics

..Present Land Use: The surrounding land is primarily for ranching and associated activities. The town of Boulder has little economic activity. Economic pursuits include employment at the Boulder River School and Hospital (state supported), a small number of local service jobs and commuting to Helena for state and local employment. No major industry is located in or near Boulder.

..Future land Use: No change anticipated.



BOZEMAN HOT SPRINGS

MAP 7

Western Region

Subchapter C

BOZEMAN HOT SPRINGS

Bozeman Hot Springs are located about seven miles (11.3 km) west of the city of Bozeman in Gallatin County, Montana. The springs issue from a thick deposit of valley sediment, about a mile (1.6 km) from the Gallatin River. The hot water is used in a swimming pool and laundry, and to space heat a skating rink and a warehouse.

This site has a potential for geothermal use as rated among the best geothermal sites in Montana. The reasons for this rating include the close proximity of the springs to a population source (Bozeman), the usable surface temperature and flow of the source, and the valley geology of the area which may allow large-scale development of a geothermal reservoir. Some other uses for this site include district space heat and greenhouses.

There has been interest demonstrated for additional development of the hot spring area. The Montana Stata University is located in Bozeman, providing a source of technical and geological capability. There appears to be no major restrictions to development of the geothermal resource in this area.

Site Description

The owner of the spring runs a K.O.A. campground, located at the "Four Corners" intersection of U.S. 191 and State Highway 289 and 291. The surrounding area makes up a broad valley containing the main east-west federal highway U.S. I-90. U.S. 191 is a major tourist route to Yellowstone Park, 50 miles (80 km) to the south. The springs are used for recreation facilities within a commercial campground.

The area economy is based on ranching and agriculture with strong reliance on seasonal tourism by the local businesses. The larger regional area uses Bozeman for a major trade center, bringing in people and products from miles around.

The land at the spring site is 100 percent privately owned. The surrounding valley area is also privately owned with a few parcels of state land near Bozeman. The mountain ranges are primarily federal managed land. The nearest population center is Bozeman with 18,670 people. Although the city limits are seven miles to the east, suburban housing pressure is pushing development west, and housing is presently within four miles of the spring site.

The city of Bozeman has major electric supply lines and also natural gas supply lines. Natural gas is used for heating, where available, with some construction of new all-electric houses. Fuel oil and propane is freighted in via rail or truck.

The public is particularly interested in alternative energy sources in this area. This is partially attributable to the large contingent of college students and the awareness to overall energy problems and options.

Geothermal Resource Description

The springs flow from a thick sequence of loosely consolidated Tertiary and Quanternary ash and sediment. The sediments are underlain by Precambrian-age crystalline gneiss at unknown depth. A fault trending N. 85° W., is thought to cross the valley floor at the northern edge of occurrence of Precambrian outcrops, dropping the valley floor down on the north. Area wells indicate that Precambrian rock could lie at 700 feet to 900 feet (231 m to 274 m) below the spring's site. Wells more than three miles (4.8 km) away have encountered warm water (115°F), 40 feet (12 m) above bedrock.

The valley fault was postulated as a result of drill hole data and regional aeromagnetic anomalies. Resistivity and soil temperature surveys of the site show well defined high temperature and conducting zones. Hammer seismic survey techniques suggest that the hot springs lie at the apex of a circular outward dipping cone of calcareous cementation about 500 feet (152 m) in diameter within the upper gravels.

The surface temperature of the springs is 130.3°F (54.6°C). The flow was 30 gallons per minute (2 l/s), but additional well drilling increased the flow to as much as 75 gallons per minute (5 l/s) without pumping. The geothermometers show a range of 169°F to 239°F (76°C to 115°C) for reservoir temperatures. The water is fairly clean with only 436 mg/ℓ total dissolved solids.

The reservoir potential is unknown, but a well was drilled to the 450-foot (137-m) level with hot water encountered at 48 feet (14.6 m), and 127 feet to 130 feet (39 m). The area of the reservoir is thought to be extensive in nature, with a possibility of reaching some point between the spring and Bozeman. The reservoir should be able to supply significant amounts of water should adequate temperatures by found.

Potential for Geothermal Development

The possible uses for a temperature of 130.3°F (54.6°C) are shown in figure 2 on page 27. Of these, the applicable uses for the spring area include aquaculture, soil warming, animal husbandry, individual space heating, and limited greenhouse facilities. The list is expanded by considering the projected reservoir temperature of 239°F (115°C) to include district space heat, larger greenhouse facilities, and commercial processing of agricultural and timber products. A variety of crops, primarily animal feed, are grown in the Bozeman area. The timber industry uses timber from the national forest nearby.

The possible uses which appear economically feasible for the study area are space heat oriented. Subdivisions could be heated near the site. This is attractive since housing expansion is already directed toward the spring area and winter heating bills, even using natural gas, are very high.

If the reservoir can be shown to underlie areas nearer the city of Bozeman with a usable temperature and quantity, space heating of a major part of the population of Bozeman is possible in the state at this time.

Greenhouse installations are more versatile in placement of the facility and can be constructed near known reservoirs. The Bozeman area would be an ideal market for any locally-grown food products. The freshwater supplies, located nearby, would allow cultivation of many fish farming operations. The Montana market for fresh fish and prawns is very lucrative. Most of the fish purchased in Montana today is frozen and flown into the state. There is a fish processing plant located in Livingston with a marketing system already established.

The valley is mostly private land with large, flat, open areas. There are no severe development restrictions which would affect direct-use projects.

Interest in Development

The major interest in development in the Bozeman area has been limited to that of the hot spring owner to further develop his resources. The Montana State University Earth Sciences Department has conducted measurement surveys to characterize the reservoir and the U.S. Geological Survey has shown interest in finding out more about the resource. The owner is working with the U.S. Geological Survey to evaluate the spring sources through a sampling program. There have been inquiries into the possibility of using the resource for greenhouse production. The student population of the Bozeman area is interested in pursuing alternative energy sources and would provide positive influence to development of the geothermal resource as an alternative to consuming petroleum energy resources.

The spring owner has a proposal submitted to Montana's Renewable Energy Grant Program to drill a deep well at the spring site. This well would be a significant step in characterizing the valley geothermal resource. It has a good possibility of being funded in the oncoming fiscal year.

The area is within a region designated "Potential Geothermal Resources Area" (PGRA) by the U.S. Geological Survey. This classification for federal land allows leasing on a noncompetitive basis unless overlapping lease applications are received.

There are no known leases of geothermal resources in this area. Private land is available for leasing by interested parties. There is only a small amount of state land in the area. There is one parcel to the southwest of Bozeman in line with the spring area which may have potential as a space heating reservoir.

Scenario Discussion

The factors which are important to rapid development of geothermal resources are quite positive for the Bozeman area compared to many other sites. The resource has a good possibility of being area wide instead of just site

oriented. The land is flat and privately owned and there appears to be a large demand for heat resources inherent in the local population. The economic base of the area is varied enough to allow a number of alternatives for heat use. The leasing of land is much simplified due to its private ownership, and development procedure is not restricted by federal or state guidelines.

The scenario which was constructed to characterize the development process at the Bozeman site is indicative of a large-scale project which would deal with numbers of people, such as a space heating district for a subdivision.

The assumptions used to formulate a realistic time line development plan are as follows:

1. Community interest is present.
2. Leasing of private land is necessary.
3. Location of a suitable resource is found.

It shows only a small part of the potential development since the nature of the resource, and thus the total potential is still completely unknown. Additional events of the same nature would follow with staggered development after a trial period of testing for the first development event. The beginning of the event is projected for 1982. It should take approximately nine years with complete power-on-line by 1991. Total energy production would be 124×10^6 Btu/hr. Should the resource prove to be extensive, additional events would begin sooner than the end of the first development event.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 39' 38" (31)

..Longitude: 111 11' 10" (31)

..Rectilinear: T. 2 S., R. 4 E., sec. 14, DAD (31)

..County: Gallatin

..Adjacent Counties: Park, Broadwater, Beaverhead-Montana, Fremont-Idaho

..Topography: The site is located near the Gallatin River which flows from the northwest corner of Yellowstone National Park, north through the Gallatin Canyon. This river joins two others to form the headwaters of the Missouri River. Bozeman and the hot spring site are situated in a wide valley which marks the intersection of six mountain ranges. The mountain range to the south is the Gallatin Range and has elevations from 6,000 feet to 11,000 feet (1829 m to 3353 m). The elevation of the valley floor at Bozeman is 4,600 feet (1,402 m). The valley is approximately 18 miles (29 km) wide to the north and south and 15 miles (24 km) long to the east and west. The highway does follow a continuous valley floor which extends much further than 15 miles. The valley floor in this direction extends for about 34 miles (54.4 km) in the west-northwest direction.

..Present Land Use: The surrounding area is rural in nature with ranching and farming as the main occupation. Bozeman Hot Springs is a commercial campground serving those tourists going east-west or entering the Gallatin Canyon on the way to Yellowstone Park. There are some homesites on Highway 191 which goes west out of Bozeman.

..Future Land Use Plans: The present land use will remain much the same with increases in housing for people working in Bozeman.

..Aesthetics: The area is rather flat so any construction would have to adhere to acceptable visual aesthetic standards. This area will continue to grow with additional housing for Bozeman workers. A semi-residential atmosphere will be required in the future.

..Historical/Archaeological Significance: The Gallatin Valley was not the home of any one tribe of Indians, but was crossed often by hunting and war parties. The first recorded account of the area is that of Lewis and Clark in July 1805. Fur companies attempted to trade and trap in the area, but Indian opposition proved too formidable. The first real settlements were not mining oriented, but agricultural communities. Mining was a significant factor in growth.

Nineteen kilometers east of Bozeman is Bozeman Pass which separates the Gallatin and Bridger Mountains. This was a key thoroughfare for Indians and whites from prehistoric times to the present. Coal and coke were mined 16 kilometers east of Bozeman in 1864. Fort Ellis, 4.8 kilometers east of Bozeman (1867-1886), was established for protection against Crow and Sioux raids. It later served as a base from which government expeditions explored the mountain regions, including those around Yellowstone Park.

Historical/Archaeological cont.

To date, 117 archaeological sites of different types have been identified in Gallatin County. The county had a medium rating for future archaeological potential. (20, 43)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The Madison and Gallatin Ranges occupy the southeastern end of the northern Rocky Mountain Physiographic Province. Structurally, they could be grouped with the ranges of the central Rocky Mountain Tectonic Province. In general, these ranges are broadly uplifted asymmetric anticlinal folds, bounded on their margins by prominent faults. The thin mantles of shallow Paleozoic and Mesozoic marine sediment have for the most part been eroded away exposing Precambrian crystalline basement rocks. The Madison-Gallatin area has a similar structure.

The Madison and Gallatin Ranges are a single structural entity. Generally, the Madison-Gallatin block is a broad area of sedimentary rocks compressed between Precambrian crystalline buttresses at the northeast and southwest. The study area has been dissected by the Gallatin River which currently exists in a stage of early maturity.

Bozeman Hot Springs issue from a thick sequence of loosely consolidated Tertiary and Quaternary ash and sediment. These layers were produced by erosion and transport of sediment into the basin of the Gallatin Valley. Volcanic ash falls added to these sediments. The top layers of sediment were deposited by the present West Gallatin River.

The sediments are underlain by Precambrian-age crystalline gneiss at unknown depths. A fault trending N. 85° W., is predicted to cross the valley floor at the northern edge of the occurrence of Precambrian outcrops, dropping the valley floor down on the north. (10, 11)

..Geophysical Summary: Area wells indicate that Precambrian rock occurs about 700 feet to 900 feet below the surface at the spring's site. Some wells, more than three miles away have encountered warm temperatures, 115°F (46°C) about 40 feet above the bedrock.

The fault postulated for the valley is based on a vertical offset in a drill hole, geomorphic evidence to the west, and regional aeromagnetic anomalies.

Resistivity and soil temperature surveys were conducted by Dr. Robert Chadwick of Montana State University. Well-defined high temperature and conducting zones were delineated.

Hammer seismic survey techniques were conducted by Montana State University personnel suggests that the hot springs lie at the apex of a roughly circular 63-foot outward-dipping cone of calcareous cementation about 500 feet in diameter within the upper gravel unit. (8, 10, 11)

..Geologic Hazards: The Gallatin area is described as being in a high potential zone of earthquake activity. Although none of the known faults are active, the area has most recently received seismic shocks of modified Mercalli scale intensity of VI (scale I - XII). The effects of the Hebgen Earthquake of August 17, 1959, in the Hebgen-like area south of the Gallatin Canyon can serve to illustrate the problem potential. The potential for landslides or other mass-gravity movement is present throughout the entire area. (20, 21)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 130.3°F (54.6°C) (31)

..Subsurface:

..Geochemical

SiO_2:	Chalcedony	169°F	(76°C)	Quartz	239°F	(115°C)	
Na-K-Ca:	Na-K-1/3 Ca	237°F	(114°C)	Na-K-4/3 Ca	169°F	(76°C)	(80)

..Flow Rates: 75 gpm 285 l/m (31)

..pH: 9.5 (31)

..Total Dissolved Solids: 436 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	819
Hardness (Ca, Mg)	28 mg/ℓ
Ca	8.6 mg/ℓ
Mg	2.4 mg/ℓ
Na	130 mg/ℓ
Bicarbonate	83 mg/ℓ
SO_4	130 mg/ℓ
Cl	50 mg/ℓ
F	10 mg/ℓ
SiO_2	63 mg/ℓ
B	220 mg/ℓ

(31)

..Comments and Critical Issues: This is an excellent site with which to promote geothermal development. Bozeman's population pressure is in the direction of this reservoir. There is plenty of private land for development. The environment is excellent for greenhouse facilities. There is the availability of technical assistance from M.S.U.

..Subsurface Area of Reservoir: Unknown at depth.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	100%	0%	0%	100%	0%
..Land Leased:	0				
..Highest Priced Leases (Dollars/Acre):	N/A				
..Tentative Lease Sale Dates:	N/A				
..Number of Sales Offered But No Bids:	N/A				
..Number of Bids Rejected Resulting In No Lease:	N/A				

..Summary of Leasing Status and Needs: The entire area is privately owned. The lack of surface manisfestation other than the spring site has discouraged landowners or other interested parties from actively pursuing development of any kind. Reservoir assessment with demonstration projects will undoubtedly spur further activity. There appears to be no institutional factors which presently hinder development.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The hot water from three flowing wells and seepage around well casing is collected in a 15-foot deep concrete tank from which it is pumped for use in a swimming pool and laundry, and for space heating of a skating rink and warehouse.

The owner erected scaffolding and standpipe over the deep well to facilitate temperature logging by the U.S. Geological Survey under static conditions. A settling pond about one-half mile north of the springs was constructed and has partially constructed channels leading from the springs to the pond.

Previous to drilling the wells, the flow rate was about 30 gpm; after completion of three flowing wells, the flow rose to 50 gpm. Two of the wells are about 66 feet deep. The third well was drilled adjacent to the tank to a depth of 457 feet. The wells encountered hot water at about 48 feet and again at 127 feet to 130 feet. A 60-gpm flow was encountered at the 127-foot level, but was cased off due to sand infiltration. (8, 30)

..Projected or Planned Development: The hot spring owner has submitted a proposal to the Montana Renewable Energy program for funding to drill a 1,000-foot well. The purpose is to assess the hot water resources at Bozeman Hot Springs. The objective of this project is to supply a large quantity of hot water for local uses such as space heating, aquaculture, and greenhouses.

No other development is currently planned.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The only institutional requirements known at this time are concerned with water rights (no foreseeable problem) and wastewater disposal (should be able to dispose of by injection).

..Agency and Public Attitudes: There are no apparent negative attitudes in the public sector. The Montana State University Earth Sciences Department is very supportive and can be relied on to assist with any development project. The State Governing Departments are also supportive.

..Status of Requirements (i.e., EIA/EIS Requirements): An Environmental Impact Statement for the State Major Facility Hiring Act will be required if a large-scale project should be initiated. This should not hinder development other than some time delays.

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds: The prevailing flow is westerly. (21)
Sometimes at 50-60 mph in the winter and spring. (21)

..Precipitation (Annual): 17.38 inches (44.15 cm) (20)

..Days of Sunshine (Annual): 228 days of clear or partly cloudy skys. (20)

..Average Temperature:

Minimum:	January 10.3°F	July 51.3°F	
Maximum:	January 30.2°F	July 81.5°F	(67)

..Degree Days (Annual): 8,165 (67)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: Air quality is generally good with a minimum amount of man-made contaminants. Local winds scour the area periodically sweeping any pollution produced out of the area. Temperature inversions occur sporadically, collecting smoke and other pollutants locally released. These episodes are generally very short-lived and dissipate with sunlight in the mornings. (38)

..Geologic Factors:

..Water Quality: The major drainage is the Gallatin River which flows to the north. It joins the Madison and Jefferson Rivers to form the headwaters of the Missouri River. The snowpack which feeds the Gallatin accumulates up to 100 inches/year. The Gallatin River is classified as B-D_1 by the Montana Water Quality Bureau. This is a high quality designation requiring a dissolved oxygen of 7.0 mg/ℓ. It is suitable for bathing, swimming, recreation fishing, drinking, and food processing after pretreatment. (39)

..Noise: The site is subjected to vehicular noise from the adjacent highways. It experiences much human activity and could be classified as rural-suburban.

ENVIRONMENTAL FACTORS
(continued)

..Biological:

..Dominant Flora: The valley flora consists mostly of forage including sagebrush and many types of bunchgrass. The cultivated areas have varying crops of alfalfa, timothy, rye, some cereal grains, and other graze type of grass.

The higher elevations in the mountains have extensive lodgepole pine and some Engelmann spruce.

..Dominant Fauna: The wildlife includes elk, mule deer, bear, bighorn sheep, moose, and waterfowl. The river has very good fishing.

..Endangered Species:

Flora: None

Fauna: None

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

Electric Transmission Lines:

50 KV Adjacent (42)

Natural gas is piped to Bozeman and surrounding areas. Fuel oil and propane is shipped in via truck and railroad from the east and west.

..Transportation Corridors or Facilities:

Highways:

U.S. Highway I-90	8 miles
U.S. 10	8 miles
U.S. 191	Adjacent

POPULATION

..General Description of Population: Bozeman (population 18,670) is the site of Montana State University and supports a large service population. It is a trade center for the surrounding ranching activities. A major east-west highway is located adjacent to the town to the north. This brings in a lot of tourist trade.

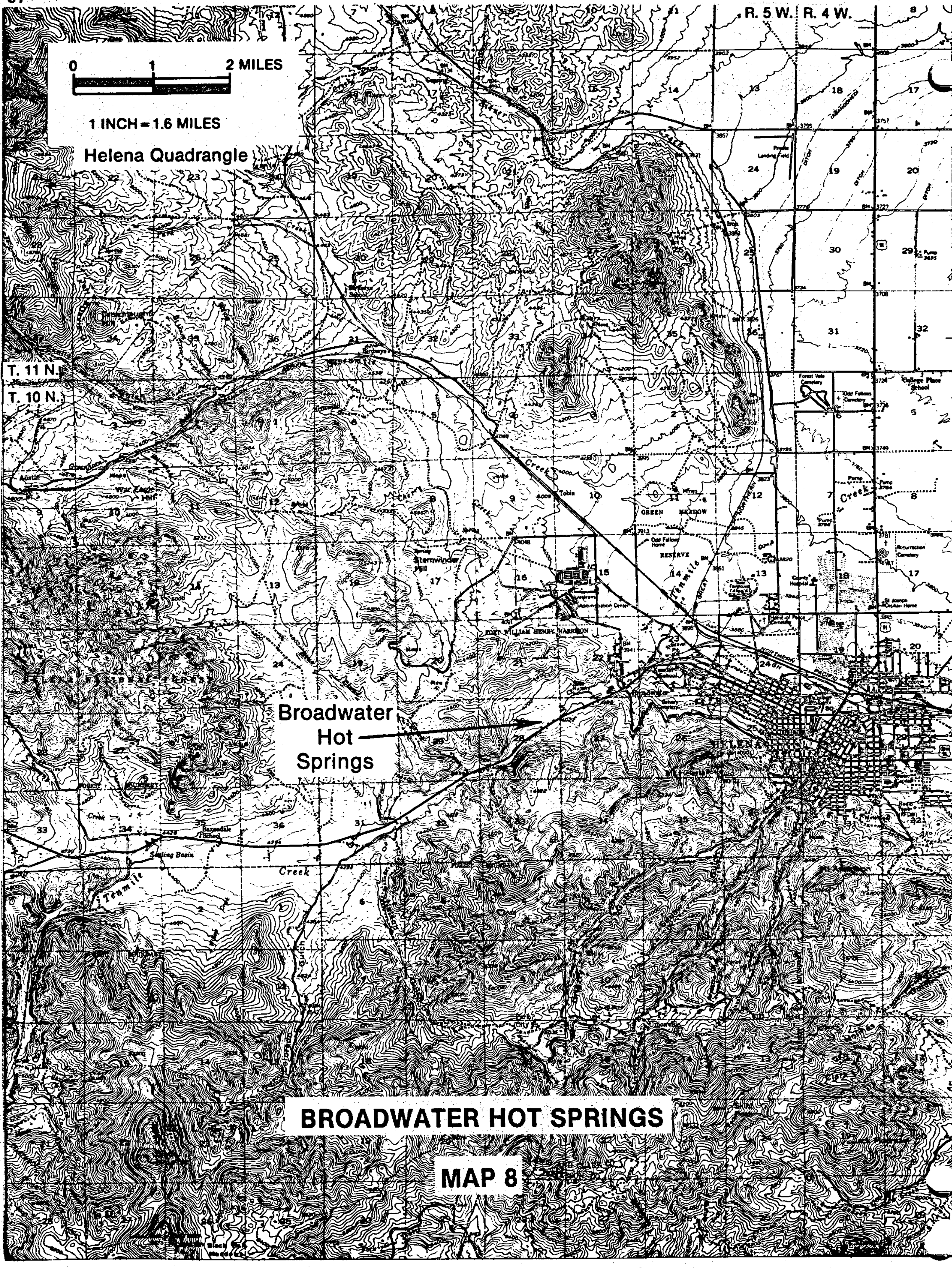
The nearest population centers to the resource site are:

Bozeman (population 18,670)--7 miles to the east
Ennis (population 500)--45 miles to the southwest
Manhatten (population 816)--18 miles to the northwest

..Economics:

..Present Land Use: The site is presently used to support a commercial camping facility. It is located near the so-called "Four Corners" intersection of U.S. 191 and State Highway 289 and 291. There is little in the way of a local economy at the present. Tourism is greatly depended on by the service businesses. The surrounding land is used for ranching and the complementary agricultural activity.

..Future Land Use: The area surrounding the "Four Corners" intersection is one of the fastest growing communities in the greater Bozeman region. Recent estimates by the city-county planning board predict a population of over 50,000 for Bozeman and the surrounding rural area by 1990. Housing and commercial developments are already extending between Bozeman and the "Four Corners." There is a great need in the Bozeman area for low-cost housing, such as apartments and multi-family dwellings.


0
1
2 MILES
1 INCH = 1.6 MILES
Helena Quadrangle
R. 5 W.
R. 4 W.
T. 11 N.
T. 10 N.
Broadwater Hot Springs
BROADWATER HOT SPRINGS
MAP 8

Western Region

Subchapter D

BROADWATER HOT SPRINGS

The Broadwater Hot Springs, located two miles (3.2 km) west of Helena, Lewis and Clark County, Montana, provided hot water to the Broadwater Hotel and Spa from the early 1900's until it closed its door in 1941.

The hot springs, ranking among the 10 hottest in the state, have a very high potential for use due to their geographic location. Broadwater is one of the very few geothermal resource areas which is located near a major Montana city. It is also one of the few with a significant natural spring flow, yet previous drilling has already demonstrated that the flow of hot water could be increased. The hot water that this resource can provide could be used for heating buildings, including greenhouses, as well as for aquaculture, ice and snow melting.

Site Description

The hot springs are located in section 28, T. 10 N., R. 4 W., immediately adjacent to Ten Mile Creek, a small perennial stream. Highway 12, a major travel route, ascends the steep-walled creek valley west toward Missoula. Nearby is Helena with a population of 25,000 and East Helena with a population of 1,700. The spring site is sparsely populated but is subject to steady surburban growth from Helena. Housing is already located close to the spring site. Helena is located near the mouth of the Ten Mile Creek Valley on a bench above the Helena valley floor.

The site is unused at the present except for one house which, as an experiment, uses some of the spring water for heat. Another hot water-heated house and swimming pool is adjacent to the site and uses spring discharge water. A recreational spa and racket club is under construction at the site which will also use the hot water.

The surrounding area is only marginal for grazing with slopes too steep for building and too rocky to grow commercially useful crops. The better parcels of land near the mouth of the Ten Mile Creek Valley are used for residential dwellings. Farther out toward the Continental Divide, the valley widens and ranching is carried on to some extent, although population pressure is felt in this area also. A commercial greenhouse facility, covering about four acres, is located one mile (1.6 km) downstream from the spring site.

Helena is the capitol of the state of Montana and government is the economic base of the area. East Helena, located five miles (8 km) east of Helena, is the site of the ASARCO smelter which processes ore for lead, zinc, gold, and silver. (Most of its ore comes from Peru and Tasmania.) The land around these population centers is subdivided into parcels from one acre (.41 hec) to twenty acres (8 hec) which is used as suburban living space. The land further away from these cities is used for ranching and farming activities.

Of the land within 6 kilometers radius of the springs, 75 percent is privately owned while 25 percent is owned by the state. Much of the higher elevations are administered by the U.S. Forest Service.

Energy for the area is supplied by natural gas and electricity. Many homeowners are installing wood stoves to provide domestic heat. Natural gas is the cheapest form of commercially available energy but, even so, many homeowners using it pay $80 to $100 per month for heat during the cold winter months. Because of this, the local population may be very interested in geothermal energy. Hot water from this source could be used directly to heat buildings in the area. Electrical production would, however, be less feasible and the possible environmental damage would draw some objections.

Geothermal Resource Description

Broadwater Hot Springs is situated on a satellite of the Boulder batholith. Numerous granitic intrusions are found in the surrounding areas. The springs issue near the center of a nearly circular igneous body. This intrusion is exposed except where it is capped by recent alluvium.

The surface temperature is 151°F (66.2°C) and wells tap the subsurface supply at a depth of about 200 feet (61 meters) with a temperature of 154°F (67.8°C). The geothermometry indicates a possible temperature range of 204°F to 277°F (96°C to 136°C) could be located with drilling. The spring area is the site of six wells which were drilled by the developer. The proximity of the wells to each other allow that only a maximum of two may be continuously pumped. Quantities are estimated from 500 gpm to 2,000 gpm (32 l/s to 127 l/s) while maintaining a sufficiently hot temperature. The present spring flow is 207 gallons per minute (32.1 l/m).

Surface resistivity at the 100-foot level has been performed by Montana State University. Hydrogeologic modeling has also been done. Of the six holes drilled at the spring site, four encountered hot water, one supplied warm water, and one came up with cold water.

Potential for Geothermal Development

The range of applications using the known surface temperatures of 151°F (66.2°C) are shown in figure 2 on page 27.

These uses are possible, but not all are economically feasible. As mentioned earlier, the topography limits the uses which can be made of the spring site. The land surrounding the spring is best suited for homesites for people working in the Helena area. There are ample sites where housing units could be built without eliminating land from other useful purposes. The developer has access to a parcel of land near the spring area, which could be used to build a 300-unit subdivision. The subdivision could be heated with a district hot water supply system.

Another use which would be ideally suited for the resource would be to heat the commercial greenhouse facility located less than 1 mile (1.6 km) downstream from the hot spring site. The present heating bill for the major part of the complex of slightly less than 4 acres approaches $15,000 per month during the peak heating periods. A part or all of this heat requirement could be met with geothermal heat.

A less feasible, but much needed, alternative would involve piping the hot water down to Helena and constructing a heating district with retrofit of existing structures to use the hot water.

Interest in Development

The Broadwater Hot Springs area is a part of the U.S. Geological Survey classification, PGRA. This classification does not require that federal leases be let on a competitive basis, as does the KGRA classification, unless overlapping lease applications are received. The leasing of federal land in this area does not appear probable because much of the federal land is very steep and inaccessible. There is enough private and state land to supply reservoirs for heat extraction close by.

The site is surrounded by private and state land. The private land is available for leasing the geothermal resource if sufficient interest should arise. The state land is subjected to the Department of State Lands geothermal regulations which, at this point in time, do not allow individual leasing.

Developmental Restrictions

Leasing interest in the Broadwater Hot Springs area is nonexistent at this time. If and when the interest is generated, the only problems in leasing one is likely to encounter, will concern leases on state-owned land. This area has little in the way of environmental concerns beyond the ever-present water quality and water rights concerns to be found anywhere in Montana, which would restrict development of direct-use geothermal energy. The state land will be hard to obtain a lease on, due to procedural problems discussed elsewhere.

The functional difficulties being experienced now are concerned with disposal of domestic wastes. Any new housing project to be located on steep-sloped, thin soil over bedrock-type terrain will require central collection and treatment of domestic wastewater. Since this area is about 2 miles (3 km) from the city limits, the city of Helena will be very reluctant to extend a trunk line out to Broadwater without annexation of the intervening area to the city. The residents of this area are vehemently opposed both to annexation and to the greatly increased taxes annexation would bring. A lesser problem concerns the disposal of the spent geothermal water. It may not be discharged to the Ten Mile Creek since it is still too hot for the state water quality standards. Two options are presently open. The first is an injection system which would place the water back into the ground. The second option would involve some means of cooling and storing the water which could then be used for irrigation. The winter load, however, could not be used in this manner. A study of possible disposal alternatives and their related environmental impacts would be required before this problem could be solved.

Scenario Discussion

A developmental scenario was constructed using the resource characteristics, local environment, and population consideration. The time lines describe a single space heating district and a greenhouse facility near the spring area. These are not the only developments which could occur, but it will illustrate the various timed development phases which would be required of any development.

The assumptions are as follows:

1. Private land would be leased.
2. The construction of a completely new housing development will occur.
3. Water chemistry will allow direct use of hot water without heat exchangers.
4. All necessary disposal permits are obtained.
5. Adequate financing for buildings and heating system exists.

The beginning date is estimated at 1981 and the complete process should require eight years. The total energy use would be 54 x 10^6 Btu per hour.

If state land is used for the hot water supply, the development would take a similar amount of time with an additonal factor for obtaining a state lease. This process cannot begin until the state changes its leasing policies.

If the resource proves to be wider spread in nature, then as currently anticipated, many additional projects could occur. A primary event would be the heating of the commercial greenhouse complex located one mile downstream from the spring site. Another would call for piping that water closer to the residential area of Helena for district space heat of existing houses.

The realistic probablity of a new subdivision being built with district heating is very good. It is likely that it will not be initiated within five years for a variety of factors, the most important of which have been mentioned. The greenhouse use is a better prospect for immediate development if a resource could be located on the owner's land. Piping of water to Helena is very far (10 years) into the future and depends wholly on the quantity and quality of additional resources.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 35' 44" (31)

..Longitude: 112 06' 55" (31)

..Rectilinear: T10N, R4W, S28 NE 1/4 (80)

..County: Lewis and Clark

..Adjacent Counties: Broadwater, Cascade, Flathead, Jefferson, Powell, Teton

..Topography: Helena is located on the south side of an intermountain valley. It is bounded on the north and east by the Big Belt Mountains and on the west and south by the main chain of the Continental Divide. The valley is approximately 25 miles (40 km) in width from north to south and 35 miles (67 km) long east to west. The average height of the mountains above the valley floor is 3,000 feet (914 m). (65)

..Present Land Use: The area is used for urban living with associated activities. The surrounding land is used for some ranching and farming activities. Much of the mountainous land is used for recreation and silviculture. (65)

..Future Land Use Plans: The future land use will follow the present directions with increased population as a result of relocation activity. This will require more services including recreation and living space.

..Aesthetics: The central valley oriented areas are readily visible from the Helena Valley and Highway 12 west. There is much scenic travel through this area. (65)

..Historical/Archaeological Significance: Extensive gold mining activity in the past has left much evidence. An 1864 gold discovery touched off a boom era which saw Helena become "Queen City of the West" and Montana's capitol. The Broadwater Hotel and Spa was owned and financed by C. A. Broadwater, a Helena businessman. This spa, one of the "Seven Wonders of the West," was built by Frederick Whiteside over a natural hot springs. The ornate hotel closed in 1941 and deteriorated slowly. It was then auctioned off piecemeal by its owner in 1974.

Archaeologists have briefly investigated the Avon Valley with estimates of as many as 50 to 75 sites being present. Forty-five sites of archaeological significance have been found in other parts of Lewis and Clark County. The county is rated as having high future archaeological potential. (43, 65)

..Geologic Description: Broadwater Hot Springs, located in a satellite of Boulder batholith, is within 4 miles (6 km) of the northern margin of the batholith. There are numerous granitic bodies which are intruded into country rock and are exposed in the Broadwater area. Compositions vary from gabbro to diorite. Many of these are intruded along or near faults in the country rock.

The satellite body intrudes Precambrian and Paleozoic shelf sedimentary rocks. These rocks dip away from the intrusive at 10 to 30. The shallow dips suggest that only recently has the satellite been exposed and erosion has not removed much of the rock.

The fault trends are northeast, northwest, and east-west and have both dip and strike-slip displacement. Northwest of the springs lie northwest-trending thrust faults. Much folding of the Paleozoic rocks occur in this area with northwest trends.

The hot springs issue near the center of a nearly circular igneous body, entirely composed of biotite adamellite. The biotite adamellite is a coarse-grained dark gray rock, with almost equal amounts of plagioclase and potassium feldspar, quartz, and biotite. The intrusion is exposed at the surface except where it is capped by Quaternary gravels, some colluvium, and recent alluvium. Quaternary gravels are exposed along a narrow northeast-trending ridge north of the site. Zones of colluvium and weathered biotite adamellite up to a meter thick overlie portions of the intrusive. Drill holes near the springs have encountered up to 4 meters of sand and gravel in the Ten Mile Creek alluvium.

The intruded country rock includes the Precambrian Empire and Helena Formations. The Empire Formation consists mostly of argillaceous shales and argillite, with some quartzite. The Helena Formation is a buff-weathering, siliceous dolomite. Metamorphism is minor near the site of intrusive contact. (22)

..Geophysical Summary: Isoresistivity maps, constructed at depths of 10 and 30 meters, show northwest elongated zones of low apparent resistivity in the area of the springs and to the northwest. This resistivity configuration could represent thermal water rising along the N. 50° E., fractures and moving down gradient southeasterly in the near surface weathered rock and alluvium.

Vents at the spring's site appear to be localized at a relatively low elevation along an intense N. 50° E., fracture zone. There is possibly a relationship with the west-northwest-trending Lewis and Clark lineament which trends through this area. Deep-seated fracture zones of this lineament could provide sufficient permeability for deep circulation.

Hydrogeologic modeling was done for this site by Michael John Galloway as a master's thesis for Montana State University in August 1977.

Hydrogeologic modeling was also done by Michael Kaczmarek with a master's thesis for Montana State University in August 1974. (22, 28)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 151°F (66.2°C) (31)

..Subsurface: 154°F (67.8°C) (31)

..Geochemical:

SiO_2: Chalcedony 204°F (96°C) Quartz 277° F (136° C)

Na-K-Ca: Na-K-1/3 Ca 275°F (135°C) Na-K-4/3 Ca 212° F (100° C) (80)

..Flow Rates: 30 gpm (114 l/m) (28) 207 gpm (787 l/m) (31)

..pH: 8.2 (31)

..Total Dissolved Solids: 581 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	872
Hardness (Ca, Mg)	29 mg/ℓ
Ca	11 mg/ℓ
Mg	0.8 mg/ℓ
Na	170 mg/ℓ
Bicarbonate	152 mg/ℓ
SO_4	180 mg/ℓ
Cl	34 mg/ℓ
F	9.6 mg/ℓ
SiO_2	93 mg/ℓ
B	800 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Immediate area of springs is identified by drilling. Peripheral boundaries not known.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	2560	0	640	1920	0
	1036 (hec)	0	259 (hec)	777 (hec)	0
..Land Leased:	0	0	0	0	0
..Highest Priced Leases (Dollars/Acre):	N/A				
..Tentative Lease Sale Dates:	N/A				
..Number of Sales Offered But No Bids:	N/A				
..Number of Bids Rejected (Resulting in No Lease):	N/A				

..Summary of Leasing Status and Needs: No leases let. State land could be leased through established channels.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The Broadwater Hot Springs and the surrounding land was purchased by a developer (Frank Gruber) for the purpose of building dwellings. He has drilled six wells on, and adjacent to, the springs to increase the hot water supply. There were four hot wells, one warm well and one cold well. The total supply varies from 500 gpm to 2,000 gpm of hot water.

An experimental house was funded in part by the State's Alternative Energy program to be heated by the hot water. The hot water supply for household use is also heated geothermally.

No further work is being done. A developer wants a 150-unit subdivision okayed, but sewage restrictions are preventing further development. The city of Helena must supply a trunk line to the area before building can begin. They are not willing to do this at the present.

..Projected or Planned Development: It is assumed that eventually population growth in this area will create a demand for the housing presently proposed by the developer and construction will result.

There is a commercial greenhouse operation located about one mile downstream from the hot springs which is interested in converting the heating system to geothermal heat. The potential for this use is very good. Conversion is anticipated if a suitable quantity can be located by drilling or supplied by contract from the hot springs owner.

The proximity of this resource to urban dwelling areas predicts future use of hot water in district heating.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: Water quality is of prime concern. The adjacent Ten Mile Creek has temperature increase limitations of 1°F.

A subdivision must have adequate domestic waste disposal. This will require the extension of a trunk line for sewage from the city of Helena.

..Agency and Public Attitudes: The county is in favor of utilizing geothermal energy and for the proposed location.

..Status of Requirements (i.e., EIA/EIS Requirements): No state or federal requirement other than water quality and water rights is present.

ENVIRONMENTAL FACTORS

..Climate: Can be described as modified continental. (65)

..Prevailing Winds: From the west with an average speed of 7.9 mph (12.6 km/h). (65)

..Precipitation (Annual): 12.2 inches (31 cm) (65)

..Days of Sunshine (Annual): 189

..Average Temperature:

Minimum: 20°F (-6.8°C) (67, 69 Helena)

Maximum: 68°F (20°C)

..Degree Days (Annual): 8,373--Six-year average (67)

..Relative Humidity (Seasonal Peaks):

Summer: 28%

Winter: 74%

..Air Quality: Air quality is generally very good. Presence of vehicular traffic and construction provide particulate and exhaust emission contaminents. Temperature inversions which dissipate with morning sunlight are common. (65)

..Geologic Factors:

..Water Quality: The high mountain peaks catch and store water which supply the surface streams. Quality of surface and subsurface water is good with turbidity increases during spring runoff. Ten Mile Creek, which is rated as B-D_1 by the State Water Quality Bureau, drains the study area. (39, 65)

..Noise: Noise associated with a centralized urban environment, surrounding suburban areas, outlying ranching activity and some remote forest, is found in different sections of the area. The immediate study area is subject to vehicular traffic from Highway 12.

Some of the modifying factors are invasion by Pacific Ocean air masses, drainage of cool air into valleys from mountains, and mountain shield in all directions. (37)

..Biological:

..Dominant Flora: The immediate area above the creek is rather dry with rocky soils. Some species of bunchgrass and sagebrush dominate the flora. The creek bottom has willow, cottonwood, and lush grasses along its boundaries. (65)

ENVIRONMENTAL FACTORS
(Continued)

..Dominant Fauna: The study area is subject to continuous human presence so animal life is limited. The more remote mountain area surrounding this study area contains mule deer, elk, and a good trout population in the lower streams. (65)

..Endangered Species:

Flora: None

Fauna: None (65)

TRANSPORTATION AND UTILITIES

..Transportation Corridors or Facilities: Highway 12 runs adjacent to the site and provides access to the interstate system, running north and south, next to Helena (5 miles).

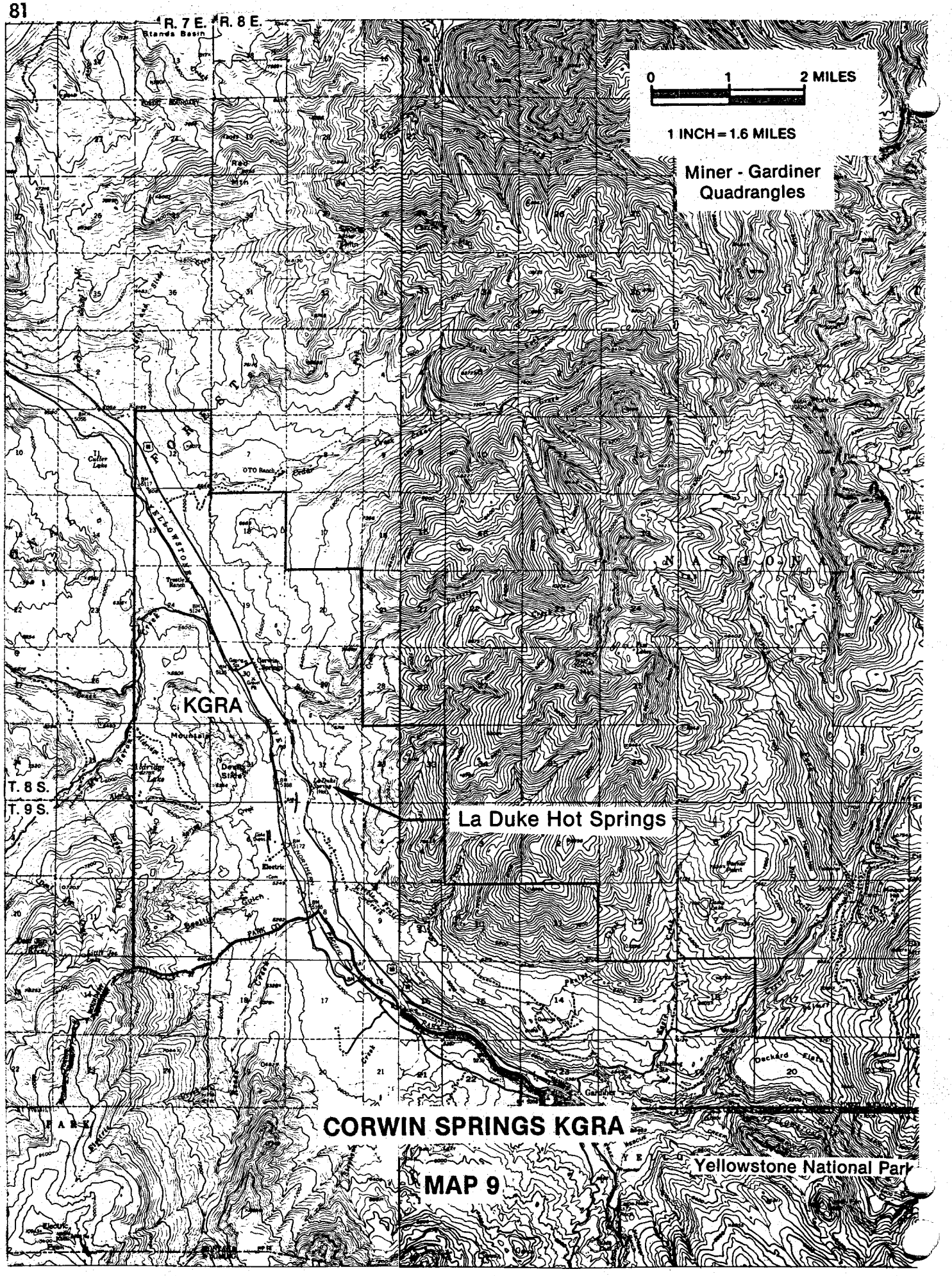
POPULATION

..General Description of Population: The site is located about 4 miles from urban Helena in a narrow valley. The present land use of the area is very restricted due to steep terrain which limits useful land availability. Some ranching activities are carried on. Suburban dwellings are progressing up the valley towards this area. The nearest concentration is about 2 miles from Broadwater. There is a small concentration of dwellings past the site in Colorado Gulch. A commercial greenhouse is located about a mile downstream from the springs.

..Economics

..Present Land Use: The surrounding land has very little productive use now. The parts of the valley which have bottom land are used for hay production. Isolated parts are subdivided for dwellings.

..Future Land Use: This area will be used for housing for people working in Helena. The potential for any other use is small.


R. 7 E.
R. 8 E.
0
1
2 MILES
1 INCH = 1.6 MILES
Miner - Gardiner Quadrangles
KGRA
T. 8 S.
T. 9 S.
La Duke Hot Springs
CORWIN SPRINGS KGRA
Yellowstone National Park
MAP 9

Western Region

Subchapter E

CORWIN SPRINGS KGRA

The Corwin Springs site is located just north of, and adjacent to, Yellowstone National Park in southern Montana. This area has the potential of being one of the very few Montana sites capable of supplying high enough heat for the generation of electrical energy. The full potential of this reservoir for direct use will probably never be realized due to the remoteness and rugged terrain. The resource can be used for space heating, fish rearing, and limited greenhouse applications in Gardner and the upper Yellowstone Valley.

There has been interest shown in developing the hydrothermal resources at Corwin Springs in the form of geothermal lease applications for federal lands. These have been aimed at electrical generation development and have not considered direct-heat uses. Local interest has been minimal. Development in locations other than on private lands will be subject to strict environmental controls. Visual aesthetics, slope erosion, wildlife habitat, and water quality will be of prime importance.

Site Description

The Corwin Springs KGRA is contiguous to Yellowstone National Park along a part of the northern boundary near Gardiner, Park County, Montana. The surface manifestations of the geothermal resource are several hot and warm springs in the area. The main spring for which Corwin Springs is noted is not located in Corwin but about 1-1/2 miles (2.4 km) to the south, along the Yellowstone River. The spring is known as LaDuke Hot Spring and water was piped from here to Corwin Springs in the past for resort purposes. Another warm spring, known as Bear Creek Spring, is located east of Gardiner. In addition to LaDuke Spring, a section of adjacent riverbank about 1 mile (1.6 km) long has various warm water discharges and the town of Gardiner has some seeps and heat anomalies.

The nearest population center is the unincorporated town of Gardiner with a resident population of 600, 7 miles (11.2 km) to the south; Livingston, about 53 miles (85 km) to the north, has a population of about 7,000.

The Corwin area is located in a narrow river valley about 1 mile (1.6 km) wide at this point. The valley is narrow from Gardiner, 5-1/2 miles (8.8 km) to the south to a point 9-1/2 miles (15 km) to the north. Mountains rise on both sides to heights of over 10,440 feet (3182 m) above the river level of 5,115 feet (1559 m). Slopes are generally very steep with little topsoil and outcropping of rock. The Corwin Springs/Gardiner area holds a transitional position between the Middle Rocky Mountain and the Northern Rocky Mountain physiographic provinces.

The present land use of the Corwin area includes hunting, fishing, rock hounding, timber production, wildlife habitat, permanent and seasonal homesites, and scenic thoroughfare. Future land use should be similar to that

of the present, with increased tourism due to the new designation of the nearby Beartooth Wilderness Area. This additional use would increase demand for overnight facilities and permanent and seasonal dwellings.

Economic pursuits of the Corwin Springs area are limited to a small amount of agricultural activities such as ranching. The Gardiner area, 7 miles (11.2 km) to the south has a full-time population of 600, but supports a much larger seasonal population which uses the motel facilities at Gardiner as a base for touring Yellowstone National Park. The economy of Gardiner is based primarily on tourism, with some support of employment with the Park Service and U.S. Forest Service. There are no industrial activities within the Gardiner area. The largest energy use here is space heating and lighting of homes and tourist facilities.

An area with a radius of 3-8/10 miles (6 km) was centered around the hot spring area to be used in obtaining a breakdown of land ownership in the immediate vicinity. The results were indicated that 39 percent is private, Forest Service controls 51 percent, and National Park has 10 percent. The KGRA is exclusively U.S. Forest Service lands except for a narrow strip in the Yellowstone River Valley.

The present energy sources include electricity, fuel oil, propane, and wood. The electricity is supplied via transmission line from the Livingston area. A wood supply is located in nearby forested areas. Fuel oil and propane must be trucked in from Livingston.

The local attitude toward the geothermal resource is one of dubious concern to electrical generation with the majority of the inhabitants unconvinced of the potential for direct use in their town. Some of the townspeople concerned with the local school system would like a geothermally-heated swimming pool for the school system.

Geothermal Resource Description

The surface temperature of LaDuke Hot Springs is 149°F (65°C) at the main springs. The geothermometry indicates reservoir base temperatures in the range of 160°F to 324°F (71°C to 162°C). Some geophysical measurements have been done by private industry, but the results are unavailable to the public at this time. The structural controls were investigated in a master's thesis by Eric Struthsacker of Montana State University in 1976. The flow from LaDuke Hot Springs has been estimated at 132 to 500 gallons per minute (8.3 l/sec to 31.1 l/sec) with dissolved solids of 2290 mg/ℓ.

No drilling for the hydrothermal resource has occurred in this area. The structural controls indicate a major fault intersection strata. This could allow the production of relatively large volumes of hot water which could be tapped by drilling.

Potential for Geothermal Development

The range of applications that are possible using the surface temperature of 149°F (65°C) are shown in figure 2 on page 27. Many of these will not be useful in the Corwin area since the population is low.

The possible direct uses which are economically feasible for the study area include a space heating district for Gardiner to heat homes, motels and the school building, a recreational spa facility with baths and swimming pool in the Corwin area, and a small greenhouse operation located somewhere between Gardiner and Corwin. If water allocation is available from the Yellowstone River, a trout raising facility is a possible use.

Electrical generation is a definite possibility for the PGRA area to the west of Corwin Springs. Commercial interest is large and if a resource is located after leasing is accomplished, electrical development is sure to occur.

Interest in Development

The Corwin Springs area has utilized the hot water in the past. The first commercial use was a hot water bathing facility which has since been discontinued. There is no present use of the hot water from LaDuke Hot Springs.

Federal lands, including the Corwin Springs area, were opened for geothermal lease applications in January 1974. Applications were received from at least seven individuals and companies. Several of the applications were overlapping, indicating competitive interest, with numerous other non-overlapping lease applications filled in the area in subsequent months. As a result of this display of competitive interest and known geologic criteria, the area was considered for KGRA designation status. The Corwin Springs area was delineated a KGRA by the Central Region of the U.S. Geological Survey in July of 1975. The KGRA includes 20,349 acres of federal and private land.

The KGRA designation allows only competitive lease bids so all applications within the KGRA were invalidated. Lease applications for parcels outside of the KGRA are still in effect.

The present noncompetitive lease applications are submitted by companies who are interested in possible electrical production. To date, there are five companies with applications on file. These are Utah International, Earth Power, Burlington Northern, Thermal Resources, and Charles J. Herringer.

The KGRA area will not be opened for competitive bidding until an Environmental Impact Statement (EIS) has been completed. This process will not begin until the Forest Service finishes a similar study for the West Yellowstone Island Park KGRA. This should occur sometime at the end of 1979 or the beginning of 1980.

There has been no further interest shown in this area. The reasons are obvious with the delay of the required Environmental Impact Study. This lack of interest pressure may also be a result of the availability of other higher potential sites in the western United States.

Restrictions to Development

The Corwin Springs KGRA is located very closely to the new Beartooth Wilderness Area. This fact could influence lease stipulations and impose strict controls on development, perhaps to the extent of specifying "no surface occupancy." The area is very mountainous with steep, easily erodable slopes. In addition, the aesthetic factor is important since the Yellowstone River Valley is a major entrance to the National Park.

Scenario Discussion

The social and economic environment of the Corwin/Gardiner area combined with the known quality of the local geothermal potential has been analyzed to obtain a realistic time frame for direct-use resource development. The small population base and limited private land available restricts the level of direct use. The development event which was projected describes a district space heat for Gardiner with a potential for 7×10^6 Btu/hr capacity. This use could tap hot water reservoirs on private land thereby eliminating the federal permitting requirements.

There appears to be ample private land available for lease which could be used to supply all the heat energy that the Corwin Springs/Gardiner area can use. Municipal interest and location of a suitable reservoir are additional assumptions. The starting date is 1982 with 5 years required for completed development.

An electrical production scenario was also constructed to illustrate development times for on-line operation of a 100-MW generation facility. Since the interest is already evident, the only assumptions necessary are that the EIS does not restrict development to a discouraging level and that adequate reserves of heat energy are located.

The starting date is expected to be 1986 which includes a lag time before EIS is started. The first event should take 9 years. Subsequent events would depend on the resource extent and are virtually the same with a reduced permitting time lag.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 05' 35" (31)

..Longitude: 110 46' 25" (31)

..Rectilinear: 8S *E 32 CDBA (55)

..County: Park

..Adjacent Counties: Gallatin, Stillwater, Sweetgrass, Carbon

..Topography: LaDuke Hot Springs issues across the road (Highway 89) from the Yellowstone River. The valley is fairly narrow here (1 mile or 1.6 km). It remains narrow for about 9 miles (15 km) to the northwest. The valley widens slightly approaching Gardiner 5.5 miles (8.8 km) to the southeast. Mountains rise on both sides to heights of over 10,440 feet (3182 m) above the river level of 5,115 feet (1559 m). Slopes are generally very steep with little topsoil. There is much outcropping of rock on the slopes. Terrain is broken.

..Present Land Use: The present land uses are timber production, wildlife habitat, recreation (nonvehicular in forest areas) including hunting, fishing, rock hounding. There are permanent and seasonal dwellings. The highway is a major scenic thoroughfare. (61)

..Future Land Use Plans: Increased use of the area is probable with the establishment of the Beartooth Wilderness. This would be limited to back-country recreation with increased support services and possibly further local subdividing for recreational and permanent housing. (15, 61)

..Aesthetics: Visual resources are very important in this area, particularly for the area adjacent to the highway. The highway is the northern entrance-way to Yellowstone Park and is open year-round. Touring aesthetics are quite noticeable and thus important. (61)

..Historical/Archaeological Significance: The Yellowstone Park area was first visited by John Colter back in the 1800's. He brought back many stories of the strange landforms in this area. Very little activity, other than uses established by the Indians, occurred until gold was discovered in 1866 at the head of Bear Gulch. It was hand-mined until 1884 when hydraulically-operated mining was practiced until 1886. The mining town of Jardine located about 6 miles south of Gardiner was established during this period.

Fifty-six archaeological sites have been located in Park County. The future archaeological potential is rated as "medium." (43)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The surface manisfestation of the geothermal resource is a flowing spring along the Yellowstone River called LaDuke Hot Springs, which issues in a long concrete tank beside the highway. There are additional springs issuing along about a mile of river bank. In addition, there are warm water discharges in Bear Creek about 1.5 miles (2.4 km) north of Gardiner. The town of Gardiner has a few warm spots where snowfall melts very rapidly.

..Geophysical Summary: Studies of the geologic record of the Gardiner area suggest that seismic activity has been present since the late Cretaceous period. The Laramide compressional stress subsided and was replaced with a tensional stress system during the middle Eocene time. These stresses were most active during the Pliocene and have continued into the Holocene. The Gardiner area is a part of the Intermountain Seismic Belt. This area extends from southern Utah to northern Montana. (57)

Many earthquakes have occurred in the last 5,000 years. There is evidence of fault movement and associated earthquakes within the last 200 years. Future activity is expected and continuous monitoring of the area is conducted. (61)

Specific geologic mapping of the area has been done by Montana State University through a master's thesis by Eric Struthsacker (1976).

..Geologic Hazards:

Corwin Geology

The Corwin Springs-Gardiner area is in a transitional position between the Middle Rocky Mountains and the Northern Rocky Mountain physiographic provinces. An uplift of Precambrian crystalline rock (the Beartooth block), bounded on the southwest by the Gardiner reverse fault, borders the thermal area on the north and east. To the west and south of Corwin Springs-Gardiner area lies the southern Gallatin Range, a horst block structure. Sedimentary rocks of the Paleozoic and Mesozoic periods accumulated to a depth of over 10,000 feet on the Precambrian crystalline basement before Tertiary times. The lithology includes limestone, dolomite, and lesser amounts of clastic rock. Andesite and dacitic flows, mudflows, and volcanic breccias of the Eocene Absaroka-Gallatin volcanic field underly large areas of both uplifted blocks. The region is quite mountainous, with as much as 5,000 feet of relief above the Yellowstone River valley floor. A layer of glacial till and alluvium covers the valley floor and walls.

The upper drainage of the Yellowstone River system had been subjected to high-level tectonic activity and volcanism from the Late Cretaceous to the present. The Gardiner Fault which runs through the study area is a steeply northeast-dipping imbricate reverse fault zone. This fault zone is one-quarter to one mile in width. (57)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 65°C at the main spring. (80) 67.5°C (31)

..Subsurface:

..Geochemical:

SiO_2:	Chalcedony 71°C	Quartz 101°C
Na-K-Ca:	Na-K-1/3 Ca 162°C	Na-K-4/3 Ca 75°C (80)

..Flow Rates: 500 l/m (80) 836 l/m (31) 1900 l/m (55)

..pH: 6.5

..Total Dissolved Solids: 2290 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	2600
Hardness (Ca, Mg)	1100 mg/ℓ
Ca	330 mg/ℓ
Mg	61 mg/ℓ
Na	240 mg/ℓ
Bicarbonate	281 mg/ℓ
SO_4	1400 mg/ℓ
Cl	42 mg/ℓ
F	3.5 mg/ℓ
SiO_2	45 mg/ℓ
B	480 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Completely unknown.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership:	20,349 (8235 hec)	17,149 (6940 hec)	0	3,200* (1295 hec)	
..Land Leased:					
..Highest Priced Leases (Dollars/Acre)					
Leases applied for:		9,379 (3796 hec)			

..Tentative Lease Sale Dates: 1980?

..Number of Sales Offered But No Bids:

..Number of Bids Rejected Resulting in No Lease:

..Summary of Leasing Status and Needs: An EIS will be initiated after the the West Yellowstone KGRA EIS is completed. This should occur sometime in late 1979 or early 1980. (54)

*Approximately (KB)

LEASE DATA FOR CORWIN-CHICO KGRA

Burlington Northern, Inc.

Leases Applied for:

Sec 13	T6S	R8E	1497.27 acres	M27455
Sec 24	T6S	R8E		
Sec 10	T6S	R9E	640	
S1/2, Sec 9	T6S	R9E	320	M27456
Sec 8	T6S	R9E	640	
S1/2, Sec 7	T6S	R9E	320	
Sec 15	T6S	R9E	640	
Sec 16	T6S	R9E	640	M27457
Sec 17	T6S	R9E	640	
Sec 18	T6S	R9E	640	
Sec 26	T6S	R8E	640	
Sec 34	T6S	R8E	640	M27457
Sec 35	T6S	R8E	640	
Sec 3	T7S	R8E	640	
Sec 4	T7S	R8E	640	M27459
Sec 9	T7S	R8E	540	
Sec 14 (Partial)	T6S	R8E	281.41	
Sec 23 (Partial)	T6S	R8E	523.43	M29278
Sec 27	T6S	R8E	648.56	
Sec 33	T6S	R8E	638.38	
Sec 11	T6S	R9E	640	M29279
Sec 12	T6S	R8E	640	
Sec 3	T9S	R8E	664	M27462

LEASE DATA FOR CORWIN-CHICO KGRA
(Continued)

Earth Power Corp.

Leases Applied For:

Sec 35		T8S	R8E	640	
Sec 36		T8S	R8E	640	M27878
Sec 2	(Partial)	T8S	R8E	1274	
Sec 1	(Partial)	T9S	R8E		
Sec 22		T8S	R8E	640 Corwin	M27879
Sec 27		T8S	R8E	640	
Sec 26		T8S	R8E	640 Corwin	M27885

Charles J. Herringer, Jr.

Lease Applied For:

Sec 26	(Partial)	T8S	R7E	400	M27887

Thermal Resources, Inc.

Lease Applied For:

Sec 34		T8S	R8E	640	M27880

Utah International, Inc.

Leases Applied For:

Sec 21		T8S	R8E	(Partial)	M27881
Sec 13		T8S	R8E	640	
Sec 23		T8S	R8E	640 Corwin	M27883
Sec 25		T8S	R8E	640	

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The hot water from LaDuke Hot Springs was originally piped to Corwin Springs for use in spa type facilities. The hot water is presently unused.

A study of the structural controls was done by Eric Struthsacker (MSU, 1976).

..Projected or Planned Development: There is no activity presently occurring or planned for the future. The community of Gardiner is located nearby and some of its citizens have expressed interest in a geothermally-heated pool and school building complex. In addition, there is a land owner near Gardiner who is interested in building a greenhouse to supply fresh vegetables for that community. He is presently considering solar power but warm springs are located on his property.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The EIS will undoubtedly consider aesthetic values of this area. The terrain is steeply sloped which will prohibit some development avenues. The Beartooth Wilderness area recently designated will have some effect on possible development sites. The water quality of the Yellowstone River and its tributaries is considered prime fishing waters and will have to be carefully watched.

..Agency and Public Attitudes: A generally low interest in electrical generation is present. Nonelectrical use would be well received on private land.

..Status of Requirements (i.e., EIA/EIS Requirements): An Environmental Impact Statement will have to be written for the Corwin Springs KGRA before any leasing activity can occur. This process should be very near completion in the 1980s.

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds: Highly variable, showing mixture of easterly, southwesterly and northwesterly flow. Wind speed increases in the winter season. (68)

..Precipitation (Annual): The precipitation varies from 8 inches (20.3 cm) at the Yellowstone River valley to 40 inches (102 cm) on Sheep Mountain. (68)

..Days of Sunshine (Annual): July and August average about 75 percent sunny days while June and September get close to 65 percent of the days sunny. The rest of the year averages only 40 percent sunny days.

..Average Temperature:

Minimum: January minimum average temperature is 9.0°F.

Maximum: June maximum average temperature is 88.3°F. (68)

..Degree Days (Annual): 10,986 (68)

..Relative Humidity (Seasonal Peaks):

Summer: Between 12% and 100%. (68)

Winter:

..Air Quality:

..Geologic Factors:

..Water Quality: The entire area drains into the Yellowstone River which is classified as a "Blue Ribbon" trout stream. The water use of the Yellowstone is irrigation, domestic water supply, and recreation. Most of the water rights have been claimed and ownership is presently being adjudicated. The state water quality classification is B-D1 which requires a minimum of 7.0 mg/ℓ dissolved oxygen and is suitable for swimming, fishing, drinking, and food processing after pretreatment. (39)

Noise: No data is available other than field impressions which indicate typical road traffic and river noise near the highway. The remoter areas have very little man-made noise and wind sounds are the prominent source.

..Biological

..Dominant Flora: Lodgepole pine is the major species in forested areas. The nonforested areas support mainly sagebrush and several varieties of bunchgrass.

..Dominant Fauna: The study area supports substantial populations of elk, mule deer, moose, bighorn sheep, pronghorn antelope, golden and bald eagles, and trout.

ENVIRONMENTAL FACTORS
(continued)

..Endangered Species:

Flora: None

Fauna: There are no endangered species but the grizzly bear is a threatened species.

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities

Power Transmission Lines: 50-KV line from Livingston down the Yellowstone Valley, past Gardiner to Jardine.

..Transportation Corridors or Facilities

Roads: US Highway #89 Adjacent to study area.

Short private road systems in the study area.

POPULATION

..General Description of Population: The Corwin Springs area has a few scattered permanent residences. There are very few agricultural operations because of the scarcity of private land (limited to a strip along the river) and poor quality of surrounding terrain for feed purposes.

The unincorporated town of Gardiner is located about eight miles (12.8 km) to the south. It has permanent population of about 600 and a much larger seasonal population of tourists visitng Yellowstone Park from this base area.

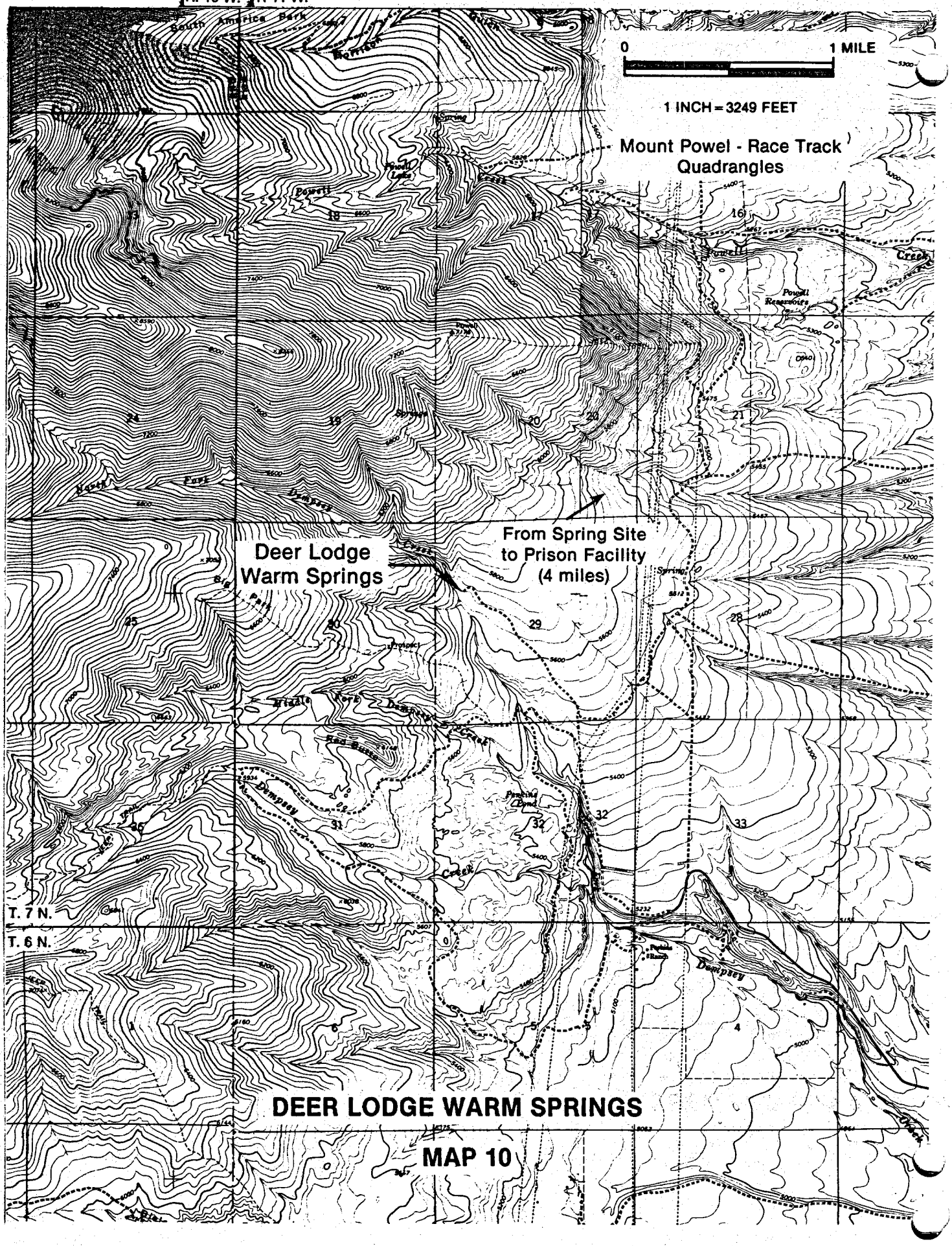
The economy of Gardiner is based on seasonal tourism with a number of motel units available. Some employment is available with the Park Service and the U.S. Forest Service.

..Economics

..Present Land Use: The present land use is limited to the town of Gardiner and a private strip of land along the Yellowstone River. The valley is not rich enough nor wide enough to support much agricultural activity. The mountains surrounding the Yellowstone Valley are rugged and can only be used for recreation. Past recreation use has been limited but with the advent of the Beartooth Wilderness to the west, increased area use is anticipated.

..Future Land Use: The increased recreational use to be associated with the Beartooth Wilderness will create demand for additional permanent and seasonal dwellings. This should increase the subdividing of real estate along the river.

Snowmobiling has created a demand for winter tourist facilities in West Yellowstone a few miles away. It is conceivable that a similar interest will arise for the Gardiner area.



DEER LODGE WARM SPRINGS

MAP 10

Western Region

Subchapter F

DEER LODGE WARM SPRINGS

Deer Lodge is the location of the Montana State Prison and prison ranch. It is 26 miles (42 km) north of Anaconda in western Montana. The prison and prison ranch are located a few miles west of the town.

The warm springs of interest in this section are located on an old homestead settled in the late 1800's. The springs were used at that time to heat a small piece of land on which potatoes were grown.

The relative potential of heat production of these springs compared to others in the state is low. The spring temperature and flow are now adequate for many uses, however, the prison ranch is extremely interested in using this warm water and/or locating a better supply by drilling to be used in an agricultural growing facility. This results in a rather high-use potential for the site.

The prison ranch has submitted a Program Opportunity Notice proposal to the U.S. Department of Energy to obtain funding for developing the spring resources. The Montana Bureau of Mines and Geology is providing support with geophysical surveys.

There are concerns about how drilling and subsequent water withdrawal will effect the area water supply and downstream uses. Another restriction would involve the extent to which the prison ranch is allowed to provide various food-stuffs produced to other state institutions without competing with area retailers.

Site Description

The warm springs on the prison ranch are located at the base of the Flint Creek Range with coordinators of T. 7 N., R. 10 W., sec. 29. This is about 5 miles (8 km) west of the city of Deer Lodge in Powell County. Deer Lodge is adjacent to the major east-west Interstate 90. Missoula is 79 miles (126 km) to the northwest and Butte is 40 miles (64 km) to the southeast. The nearest population concentrations are Deer Lodge (population 4,360), Anaconda (population, 9,771), Butte (population 23,368), and Helena (population 22,730).

The site location is within a north-south trending basin in west-central Montana near the center of the Northern Rocky Mountains physiographic province. There is a group of low, rounded mountains to the east and a higher, more rugged range to the west. The Clark Fork River drains the entire area toward the north. The springs are located on the western edge of the valley about 6,000 feet (1758 m) on both sides of a tributary of the Clark Fork River.

The immediate area is used for grazing land for the prison ranch's cattle operation. Farther down into the valley some fields are irrigated to produce

hay for winter cattle feeding and other agricultural products. A prison facility and ranch buildings are about 4 miles (6 km) from the spring site. The land in the regional area is also ranch and agriculture oriented. The city of Deer Lodge has some state governmental agencies which contribute to the economic base. The regional economics includes ore production in the copper mine at Butte and ore processing in the smelter at Anaconda. The economic picture seems stable with no anticipated future changes. The land ownership within a 6-kilometer radius is 44 percent federal, 40 percent state, 16 percent privately owned. A greater portion of the valley area is privately owned.

The town of Deer Lodge is supplied with natural gas via pipeline and electricity. The prison complex uses natural gas and electricity both for heating purposes. The high cost of heating in this area using the commercial forms of energy is of concern to the local population. In addition, the state of Montana had mandated a 10 percent reduction in energy consumption for its facilities. These factors should serve to provide an awareness of geothermal energy for direct use.

Resource Description

There are three warm springs supplying warm water at this site. The combined flow exceeds 70 gallons per minute (4.4 l/s). The temperature range is 72°F to 82°F (22°C to 28°C), with geothermometry predictions of reservoir temperatures in the 162°F to 205°F (72°C to 96°C) range. The total dissolved solids is low at 193 mg/ℓ.

The reservoir location and depth is being investigated through geophysical means at this time. The reservoir is believed to be within 500 feet (152 m) of the surface at the spring site. No drilling has occurred in the area to support this projection. The potential of the reservoir to supply hot water is completely unknown.

Potential for Geothermal Development

The possible application of the resource using the present surface temperature is very limited. Heat pumps and aquaculture are possible. Very limited space heating capability exists.

The geothermometry estimates are for more than adequate heat extraction temperatures to be available at depth. The upper limit of 250°F (121°C) is very satisfactory for any type of space heating application. It is ideally suited to the desired uses of greenhouses, domestic space heat, animal housing, crop season extension, and accelerated methane production.

Interest in Development

The spring water is unused at present. It has been used recently for bathing purposes for work crews which used to stay at the site for extended periods. The Department of Institutions owns the land and should encounter no problems in using the resource from a minerals ownership standpoint. The prison ranch management is interested in building a greenhouse facility capable of supplying vegetables to the state-owned institutions, which could reduce food costs. The prison ranch currently supplies beef and milk to state

institutions. The distribution network could remain the same while supplying a wider range of foods. Along with the agriculture, additional development stages would include heated animal husbandry facilities to take advantage of the fact that animals which do not have to produce heat for survival gain weight much faster. There is interest from various entities in funding methane production unit using thermophilic microorganisms to convert manure to methane gas. This site would be easily adaptable to this use. All of the above uses could be cascaded to extract the maximum amount of heat.

The Program Opportunity Notice (PON) submitted by the prison ranch is presently being considered for sufficient merit by the U.S.D.O.E. The Bureau of Mines and Geology operating under the D.O.E. State Coupled Program for resource definition is performing seismic, gravity, and resistivity measurements to further identify the geology and structure of the site. A regional approach to geophysics in the area between Deer Lodge and Warm Springs is being financed by the Montana Alternative Energy Program.

Restrictions to Development

This site is closed to public mineral exploration except by specific license due to state institutional ownership. The only restrictions which would affect this project is concerned with water rights definition. While the state owns a majority of the water in the creek, downstream users are very concerned about any project which could affect their portion of the resources. The surrounding federal, state, or private area is available for exploration. There are no known environmental factors which would prohibit geothermal development.

Scenario Discussion

A scenario was constructed for this site using a geothermally-heated greenhouse as the prime event. The assumptions are as follows:

1. Financing would be available.
2. A suitable resource would be located within the exploration budget.
3. The water right concern could be settled with the prison ranch being allowed to use the hot water.

The process is postulated to begin in 1980 with the sequence of development requiring 5 years to obtain power-on-line. Maximum power usage in this event would be 24×10^6 Btu/m.

The realistic prospects for this event to occur are gaged to be low. The resource is as of yet an unknown quality and surface use of the spring is not feasible.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 20' 03" (36)

..Longitude: 112 53' 11" (36)

..Rectilinear: 7 N., 10 W., 29 BC (36)

..County: Powell

..Adjacent Counties: Deer Lodge, Granite, Missoula, Flathead, Lewis and Clark, Jefferson.

..Topography: The Deer Lodge Valley is a basin trending north-south in west-central Montana near the center of the Northern Rocky Mountains physiographic province. It trends northward between a group of relatively low, rounded mountains to the east, and the higher, more rugged Flint Creek Range to the west. The South Clark Fork River and its tributaries drain the valley in a northerly direction.

The main topographic features are a broad lowland, the Clark Fork flood plain bordered by low-fringing terraces that are, in truth, bordered by broad, high terraces which slope gently upward to the mountains. The high terraces have been mostly obscured in the south end of the valley by erosion and by recent deposition of great coalescent fans radiating outward from the mouths of various tributary canyons.

The warm springs are located on the western edge of the valley at the 5,768-feet (1758-m) level on both sides of a tributary of the Clark Fork River. (64, 78)

..Present Land Use: The site is located on the state prison ranch. It is used for animal grazing and some hay production. The surrounding area is used for timber harvest, mining, grazing, and recreation. The foothill slope is all prison ranch with the higher elevations belonging to the U.S. Forest Service. Below the prison ranch land is used for agricultural support of ranching. (64)

..Future Land Use Plans: The site will remain property of the prison ranch. It is planned to use the site for greenhouse production and confined animal feeding operation. No change is anticipated for the surrounding area.

..Aesthetics: Most of the mountain area is timber covered, typical of forested mountian areas in the state. All of the area bordering the valley is subject to scenic use. The higher ridges and peaks can also be seen from the valley highways. Although this area is not specifically known for it scenic beauty, any change must consider the altered appearance.

SITE LOCATION AND PHYSICAL DESCRIPTION
(continued)

..Historical/Archaeological Significance: The Upper Clark Fork River Valley served as a main travel route for several Indian tribes on their way to and from buffalo country to the east. Early day trappers and fur traders followed this same route. In 1852, gold was discovered which led to settlement of the area. It has been populated continuously since. (64)

No archaeological sites have been discovered in Deer Lodge County although the area is rated as high for future discovery potential. (45)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The mountains east of the Deer Lodge Valley are formed primarily of Cretaceous sedimentary and volcanic rocks, and lower Tertiary granitics. Those mountains to the west of the valley are formed of Precambrian to Cretaceous sedimentary rocks and a core of lower tertiary granitic rocks. Geophysical data indicated that the valley is a deep graben which formed in early Tertiary time after emplacement of the Boulder and Philipsburg batholiths. During the Tertiary period, the valley was partly filled to a maximum depth of more than 5,500 feet (1650 m) with erosional detritus that came from the surrounding mountains and was interbedded with minor amounts of volcanic pyroclastics. This material was deposited in a large variety of local environments resulting in extremely variable lithology. The deposits grade from unconsolidated to well-cemented and from clay to boulder-sized aggregates. The strata dips gently towards the valley axis in most of the area but along the western margins of the valley they dip steeply into the mountains.

The main source of ground water in the Deer Lodge Valley is the upper few hundred feet of unconsolidated valley fill. Most of the existing wells drawing from these deposits range in depth from a few feet to 250 feet (75 m). Water levels range from somewhat above land surface (in flowing wells) to about 150 feet (45 m) below. (78)

..Geophysical Summary: The USGS performed a gravimetric survey in 1961. Results are contained in the Water Supply Paper 1862, along with geologic mapping from aerial photographs.

The geology of part of the area was mapped in a Doctorial thesis by Thomas A. Mutch of Princeton University in 1960.

There are several geophysical data collection projects ongoing at this time. The spring's site is being assessed using several methods including seismic for the purpose of locating hot water wells. The main investigative agency is the Montana Bureau of Mines and Geology which is the Department of Energy (US) state-coupled program for reservoir definition.

The Warm Springs Hospital is also being assessed for similar purposes. It is anticipated that some regional work will be done in connection with this effort.

There are four springs issuing from rock on the west side of a tributary to the Clark Fork River.

These springs have been analyzed for fluid chemistry and geothermometry. Seismicity, gravity, and resistivity should be done on site by the Montana Bureau of Mines and Geology.

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 72°F to 82°F (22°C to 28°C) (54)

..Subsurface:

..Geochemical:

SiO_2: Chalcedony 162°F (72°C) Quartz 205°F (96°C) (54)

Na-K-Ca:

..Flow Rates: Approximately 70 gpm (260 l/m) for a total combined flow (3 springs) (54)

..pH: 9.3 (36)

..Total Dissolved Solids: 193 mg/ℓ (36)

..Fluid Chemistry:

Conductivity	228
Hardness (Ca, Mg)	10 mg/ℓ
Ca	3.9 mg/ℓ
Mg	.1 mg/ℓ
Na	45.8 mg/ℓ
Bicarbonate	40.9 mg/ℓ
SO_4	33 mg/ℓ
Cl	2.55 mg/ℓ
F	7.5 mg/ℓ
SiO_2	45.8 mg/ℓ
B	

Additional analyses of various parameters are available. (36)

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	100%	44%	40%	16%	0%
..Land Leased:	None				
..Highest Priced Leases (Dollars/Acre):	N/A				
..Tentative Lease Sale Dates:	N/A				
..Number of Sales Offered But No Bids:	N/A				
..Number of Bids Rejected (Resulting in No Lease):	N/A				

..Summary of Leasing Status and Needs: The present interest in development is restricted to land owned and operated by a state institution. There is state-controlled land and federally-controlled land which may be suitable for direct-use development located in the area. If and when interest for development is evidenced by the private sector, the land will have to be considered for lease bids. This will require that an EAR be done for both state and federal lands.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The warm springs are not being used at this time. Some geophysical work is being done in anticipation of drilling a well.

..Projected or Planned Development: The state prison ranch is submitting a PON to the U.S. Department of Energy for grant money to erect and geothermally heat a greenhouse and confined animal feeding operation. The State Bureau of Mines is assisting with the survey work needed to define the reservoir and optimum drilling sites.

It is anticipated that future projects will include a geothermally heated methane digester and space-heated residences.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The present project is supported by the Montana Department of Institutions and is strictly dependent on the U.S. Department of Energy funding. The economic viability is also a major concern for continuing with construction of the planned facilities.

..Agency and Public Attitudes: All feedback on the project has been positive to date. The only problem which may arise is the question of whether or not drilling will affect the water supply system which downstream users have rights to.

..Status of Requirements (i.e., EIA/EIS Requirements): There are no institutional requirements for this project foreseen.

ENVIRONMENTAL FACTORS

..Climate: The Deer Lodge Valley has a semi-arid climate characterized by long cold winters, short cool summers, low precipitation, and moderate winds.

..Prevailing Winds:

..Precipitation (Annual): 10.51 inches (26.7 cm) (67)

..Days of Sunshine (Annual): Approximately 190 days. (69)

..Average Temperature:

Minimum: 24.8° F (-4° C)

Maximum: 59° F (15° C) (67)

..Degree Days (Annual): 8,407 (67)

..Relative Humidity (Seasonal Peaks):

Summer: 31% to 80%

Winter: 38% to 70% (67)

..Air Quality: Air quality is considered to be excellent except during times of slash burning or large wildfires in the west which cause pollutants to enter the area. Air quality requirements are high. (64)

..Geologic Factors:

..Water Quality: Most of the streams flow through glacial till and Tertiary sediments into the Clark Fork River, a tributary of the Columbia River. This stream is rated as B-D_1, which is clean enough to allow almost all uses without pretreatment. Private water rights cover most surface supplies. (39)

..Noise: Noise at the site is limited to naturally occuring wind and water sounds. The valley noise varies from agricultural based noise to urban population center sounds.

..Biological

..Dominant Flora: The higher elevations have quantities of lodgepole pine and Douglas fir. The terraces and valleys have various varieties of bunchgrass and sagebrush. The cultivated areas have primarily grass hay with some cereal grains. (64)

ENVIRONMENTAL FACTORS
(continued)

..Dominant Fauna: The mountain areas support populations of elk, mule deer, whitetail deer, black bear, goats, and moose. Trout is present in lakes and streams. (64)

..Endangered Species:

Flora: None

Fauna: None

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities: Natural gas is piped directly to the town of Deer Lodge.

..Transportation Corridors or Facilities:

U.S. Interstate 90	Adjacent to the town of Deer Lodge (8 km from site)

Private roads access the area but these are not open year-round.

POPULATION

..General Description of Population:

The closest towns of any size are as follows:

	Miles	Population
Helena	56	22,730
Butte	40	23,368
Anaconda	26	9,771

Deer Lodge has a population of 4,306. The economy is supported by the presence of state offices and the presence of the state prison facility which includes a confining structure for inmates and a prison ranch facility. The rest of the local economy depends on farming of the valley in support of the ranch industry.

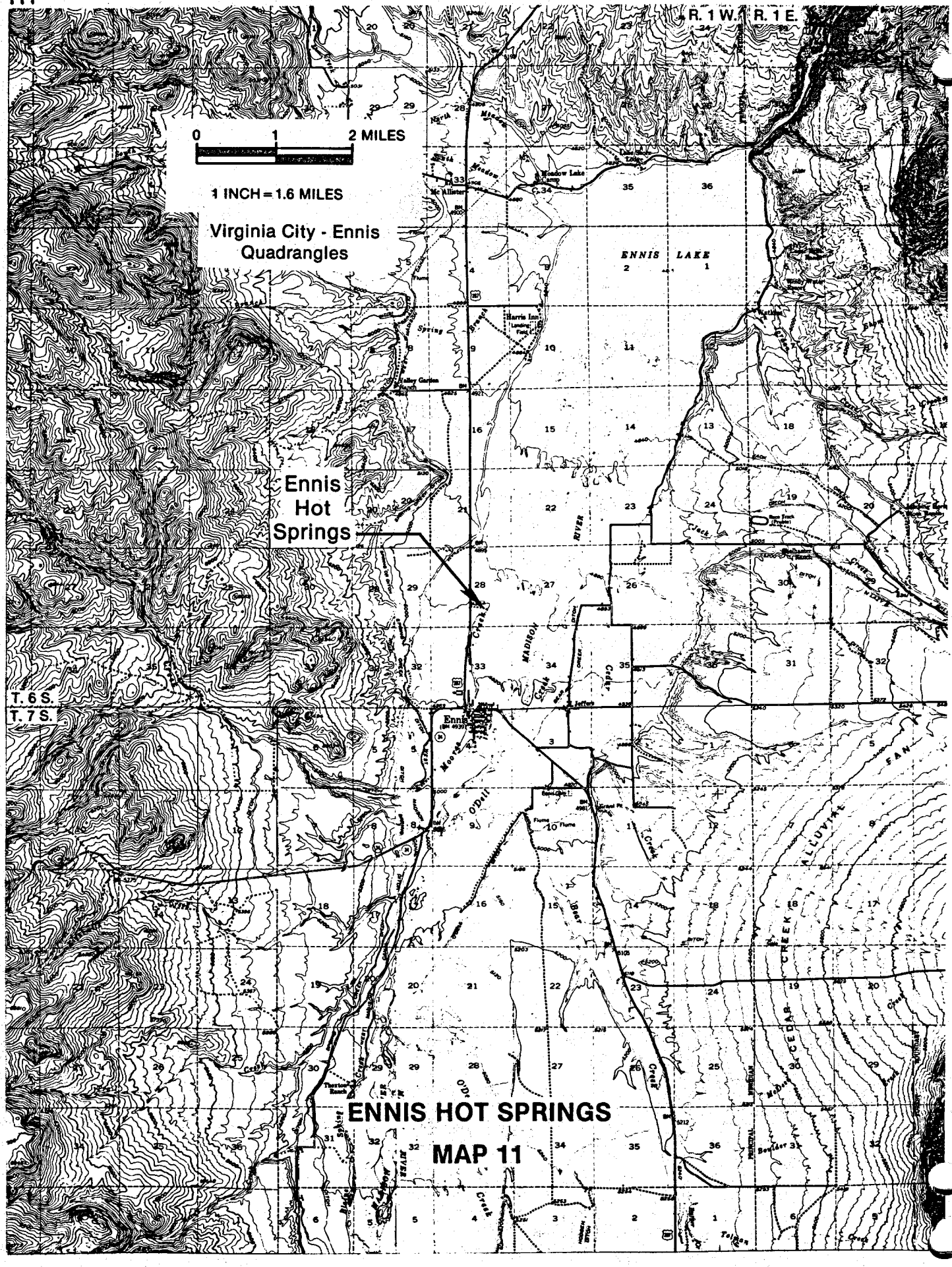
The population density is less than 1/2.5 kilometers. There are not residences on the site or nearby. There are a few scattered residences to the south.

..Economics:

..Present Land Use: Most of the valley land is used for farming with hay as the major irrigated crop which is used locally to support the livestock industry. Potatoes are the largest cash crop in the valley, this area being one of the largest producers of potato seed in Montana. Wheat, barley, and corn are also grown.

Mineral processing at Anaconda is a major contributor of the economic base. The state has hospitals in Warm Springs and Galen which also support the valley economy.

..Future Land Use: No change is anticipated for the future economy in this area.


R. 1 W.
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0 1 2 MILES
1 INCH = 1.6 MILES
Virginia City - Ennis Quadrangles
ENNIS LAKE
Ennis Hot Springs
T. 6 S.
T. 7 S.
Ennis
MADISON RIVER
CEDAR CREEK ALLUVIAL FAN
ENNIS HOT SPRINGS
MAP 11

Western Region

Subchapter G

ENNIS HOT SPRINGS

Ennis Hot Springs (sometimes known as Thexton's Hot Springs) is 1-1/2 miles (2.4 km) north of the community of Ennis, adjacent to the Madison River in southwest Montana. The springs issue from the foot of a bench above a thick layer of valley sediments. The hot water from the springs is unused, but a well drilled to a depth of 100 feet (30 m) supplies hot water for use in a laundry facility.

This site has the hottest surfacing geothermal fluids of any known spring in the state. The flow is good with excellent chances of increasing production by pumped wells. Ennis Hot Springs also has very good potential for being used since the flood valley has good solar exposure and few restrictions which would limit direct use of the heat resource.

The community of Ennis contains only 500 people so space heating potential is limited for domestic use. Greenhouse and manufacturing facilities would be most suited for development at this site. The recreation potential is good due to the proximity of the site to tourist traffic.

The valley is privately owned except for a small amount of state land. The reservoir is thought to extend throughout a wide area within the valley. The area would permit multiple withdrawal sites.

Site Description

The location coordinates of the spring site are section 28 of township 5 south, range 1 west in Madison County. This is 71 miles north and west of the west entrance to Yellowstone Park. This route is heavily traveled by tourists from Yellowstone Park. The spring site includes the valley floor and high bench on which the owner has a very small trailer park. The owner operates a laundry room with hot water provided by a well.

The area economy is based on ranching and associated agriculture, with seasonal tourism in the summer and fall. The population is sparse. The spring site and surrounding land is privately owned, although there are a couple of state-owned parcels to the northwest which may or may not be within the reservoir perimeter. The mountain ranges to the west are known as the Tobacco Root Range and the eastern mountains are the Madison Range. This mountainous land is federally controlled.

The nearest cities are Ennis, population 500, 1-1/2 miles (2.4 km) to the south; Bozeman, population 25,000, 53 miles (85 km) to the northeast; and West Yellowstone, population 1,000, 71 miles (114 km) to the south. Ennis does not have a natural gas pipeline and relies on fuel oil for 85 percent of the heating requirements, with electricity supplying the remainder. Fuel oil and propane are trucked in from the north.

Inhabitants would be receptive to direct use of geothermal energy, particularly if economic feasibility can be demonstrated. This area seems somewhat economically depressed and could be benefited by geothermal development activities, particularly those which involve labor intensive industries.

Geothermal Resource Description

The hot springs surface at the foot of the lowest bench on the valley floor. The strata is alluvium with Precambrian metamorphic rock surfacing at the edge of the valley which lies to an unknown depth below the valley floor. Wells to 400 feet (22 m) have not encountered bedrock. The main igneous event is the intrusion of the Tobacco Root Range with outcrop exposure near the site to the north.

The area of hot water upwelling is identified in the spring area by a circular area of radius 75 feet (23 m) which melts snow very quickly in winter. A small storage building built against the side of the bench has no heating system but the temperature in it never goes below freezing.

The spring temperature is 181°F (83°C). The artesian flow is more than 20 gallons per minute (1.3 l/s). Wells in the 100-foot (30-m) depth with 6-inch casing are thought to supply 50 to 100 gallons per minute (3.2 to 6.3 l/s) of hot water. The total dissolved solids content is not excessive at 1030 milligrams per liter. Water quality analysis has been done by the U.S. Geological Survey. Geothermometry has been done but is as yet unpublished. The predicted range of reservoir temperatures are 266°F to 338°F (130°C to 170°C).

Little resource definition work has been done until recently. Therefore, little information about the water supply potential is available. The ability of the aquifer to supply water should be very good as indicated by the pumping of cold water wells in the area.

Potential for Geothermal Development

The possible uses for the surface temperature of 181°F (83°C) are shown in figure 2 on page 27. The uses which would be applicable to the site are aquaculture, soil warming, recreation, animal husbandry, individual and small district space heats, and extensive greenhouse facilities. The possible uses for the projected temperature of 300°F (150°C) are almost unlimited. Many agriculture process industries would be adaptable to this range of heat. Timber products could also be processed such as kiln drying of green lumber and veneer. The local agriculture and access to timber may provide an economic base for developing these uses of the resource.

The uses which appear presently feasible to the study area are space heat oriented. Primary use would be in greenhouse heating with a minor use of heating residences in the Ennis community. Since natural gas is not available here, no cheap form of fuel is available. The long winters require large amounts of fuel use and economics of geothermal development may be much better in this area than in others.

The Ennis site has many natural resources such as an abundance of sunshine, fresh water, and privately-owned flat land. Future industrial or manufacturing installations in Montana should consider sites such as this to shift population emphasis and thus pair up population with heat resources.

Interest in Development

The owner of the spring has been trying to generate capital for the construction of recreational facilities for the last 30 years, but has been unable to do so. He is interested in leasing the resource development. There has been little outside interest shown in this area in the past but with present day energy costs, recent inquiries into the possibility of leasing the resource for greenhouse production have been received.

The Montana State University Earth Sciences Department has done some geophysical work to identify the resource. More recently, the U.S. Geological Survey has been provided with funds for shallow temperature grading holes to characterize the reservoir in this area. About four holes have been drilled thus far, but the data have not been published. The results of these tests have prompted further geophysical work to be done by the Montana Bureau of Mines and Geology in cooperation with the U.S. Geological Survey. Gravity, magnetic, seismic, and infrared methods will be used to map the anomaly in the Ennis area. The results of these studies will be available in early 1980.

Scenario Discussion

The known resource potential, together with the local environmental factors, has been considered in a possible development scenario for the Ennis Hot Springs site. The resource has good possibility of existing outside of the specific spring site. This could allow multiple development projects to be initiated.

This scenario event was postulated to be a 5-acre commercial greenhouse facility to be constructed in one phase requiring 40 x 10^6 Btu per hour. The springs site is the location of these greenhouse units. The assumptions used to model the development were:

1. Commerical interest will be available.
2. Financing would be present.
3. Leasing of private land would be required.
4. Suitable quantities of hot water will be located.

The starting date is 1981 with 3 years required for completion. This scenario shows only one event for the purpose of illustrating the development process. In reality, the project may incorporate staged events. The unknown potential of this resource, together with the scarcity of economic data for this type of greenhouse industry, limited the number of assumptions that could be realistically made.

Development of a district heating system for the community of Ennis would be economic at some point in the future. A scenario was considered for this event. Time sequence is approximately the same as the greenhouse event with a starting date of 1984 and requiring 5 years. The heat output would be 8 x 10^6 Btu/hr.

The amount of heat used in the proposed greenhouse would total 40 x 10^6 Btu/hr. This could be expanded if economics justified the increased production. The total possible production of heat using an end temperature of 90°F is predicted to be 225 x 10^6 Btu per hour indefinitely for this reservoir.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 22' 02" (31)

..Longitude: 111 44' 51" (31)

..Rectilinear: T. 5 S., R. 1 W., sec. 28, DCAD (55)

..County: Madison

..Adjacent Counties: Beaverhead, Gallatin, Jefferson, Silver Bow

..Topography: The Madison River Valley at Ennis forms part of the Northern Rocky Mountain physiographic province. It also has some features characteristic of the basin and range province of the southwestern United States. The topography is that of a rugged, mountainous region dissected by stream erosion and modified by glaciation. The elevations are 4,080 feet (1483 m) at the valley floor to 10,267 feet (3129 m) for some mountain peaks. The Madison Valley varies from 9.25 miles (14.8 kilometers) to 11.5 miles (18.4 kilometers) in width at Ennis. It is broken by low benches extending out from the foothills. The valley floor is relatively flat and subirrigated. The valley extends south from Ennis Lake with a length of 14 miles (22.4 kilometers) in the study area. Mountain slopes have been locally steepened by glaciation, and cirques at the heads of some valleys present precipitous walls for several hundred feet. Alluvial fans moderate the slopes and form gently concave profiles from the valley floor to varying distances up the mountain sides. The mountains may be likened to a block hinged on one side and thrust up on the other producing a long, gentle cast slope and a steep westward facing scarp.

The region is east of the Continental Divide and the drainage is to the Gulf of Mexico via the Missouri River. Though many streams dissect the range, only those occupied in the valleys which stretch far into the mountains are permanent and even these are subject to marked seasonal variation. The streams have steep gradients, sometimes as much as 700 feet per mile except where accumulations of debris flatten them, and occasionally they produce lakes.

..Present Land Use: The valley is used primarily for cattle grazing. A large percentage of people in the valley live in the town of Ennis. The Madison River is a "Blue Ribbon" fishing stream and attracts many sportsmen.

..Future Land Use Plans: The future land use should not change drastically in the foreseeable future.

..Aesthetics: State Highway 287 is a north-south transportation line which connects with the west entrance to Yellowstone National Park. The valley is flat and any installations would be easily seen. The only geothermal use which would prompt concern would be electrical production. This use could develop nuisance conditions to the local people.

SITE LOCATION AND PHYSICAL DESCRIPTION
(continued)

..Historical/Archaeological Significance: The Nevada City Historic District is located 3 miles (4.8 km) west of Virginia City (1860s). This was the site of the first vigilante execution. It is one of the mining camps which lined Alder Gulch. The summit Union City Historic District located near Virginia City was a minor gold producing district in 1863. Virginia City itself was the site of Montana's second major gold discovery at Alder Gulch in 1863. Fifty-two archaeological sites have been identified in Madison County. The future potential for archaeological finds is high. (43)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 181°F (83°C) (31)

..Subsurface:

..Geochemical:

SiO_2:

Na-K-Ca:

..Flow Rates: 20 gpm (76 l/m) (31)

..pH: 7.7 (31)

..Total Dissolved Solids: 1030 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	1510
Hardness (Ca, Mg)	17 mg/ℓ
Ca	5.6 mg/ℓ
Mg	.6 mg/ℓ
Na	340 mg/ℓ
Bicarbonate	442 mg/ℓ
SO_4	220 mg/ℓ
Cl	120 mg/ℓ
F	11 mg/ℓ
SiO_2	91 mg/ℓ
B	610 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: The boundaries are being defined through a project done by the U.S. Geological Survey. The present depth to hot water at the spring site is about 100 feet or 30 meters.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	100%	5%	6%*	89%	0%
..Land Leased:	0				
..Highest Priced Leases (Dollars/Acre):	N/A				
..Tentative Lease Sale Dates:	N/A				
..Number of Sales Offered But no Bids:	N/A				
Number of Bids Rejected Resulting In No Lease:	N/A				

..Summary of Leasing Status and Needs: There is no demand for additional land to be made available for geothermal development. Increased demand will require that state land be evaluated for lease.

*Part of the state land is tied up in the Mt. Haggan Game Preserve and would be difficult to use.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The only present use of this resource is a shallow well that was drilled to provide hot water for a laundry facility which the owner provides for the inhabitants of trailers using his trailer park.

The owner would like to develop a spa resort but cannot get financial backing. There has been interest shown in leasing land and the resource for a greenhouse operation.

..Projected or Planned Development: There are no planned projects for the future. Some use of this resource is projected for the near future.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The only requirements of note would be water quality considerations involved in increased use of hot water and discharged to surface supplies. Water rights which may be affected will have to be considered. These are thought to be relatively mild.

..Agency and Public Attitudes: Public attitudes are for the most part apathetic but no against development for nonelectric applications. The state would like to see utilization of this resource.

..Status of Requirements (i.e., EIA/EIS Requirements): No federal or state requirements.

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds:

..Precipitation (Annual): 17 inches (43.5 cm) (67)

..Days of Sunshine (Annual):

..Average Temperature:

Minimum: 27°F (-3°C)
Maximum: 65°F (18.4°C) (67)

..Degree Days (Annual): 8020 (69)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: This area has very good air quality due to the lack of industry, commercial operations, or large populations. Occasional particulate pollutants are present from agricultural practices. (38)

..Geological Factors:

..Water Quality: Quality is very good in surface supplies which are numerous. Subsurface hot water is high in alkali. Water rights are available in some areas. The adjacent Madison River is billed as a "Blue Ribbon" fishing stream. It is classed as B-D_1 by the State Water Quality Bureau which indicates its high quality. (39)

..Noise: Noise at the site is limited to traffic origin on Highway 287 and normal ranching activities. The population in this area is sparse outside of Ennis. The close proximity to Ennis increases occasional construction and urban noise.

..Biological:

..Dominant Flora: The valley floor has planted grasses for grazing with little flora supported on the benches. Some sagebrush is present. Bunchgrass of various varieties is found on the hillsides where the benchland ends.

..Dominant Fauna: The presence of fauna in the valley is inhibited by the constant human activity. Prairie dogs are the main animal life.

..Endangered Species:

..Flora: None

..Fauna: None

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities: Ennis is not served by natural gas lines.

..Electical Lines:

50 KV	Adjacent

..Transportation Corridors or Facilities:

Highway 287 is located adjacent to the site. Access is year-round.

Interstate 15	70 miles (112 km)
Interstate 90	46 miles (74 km)

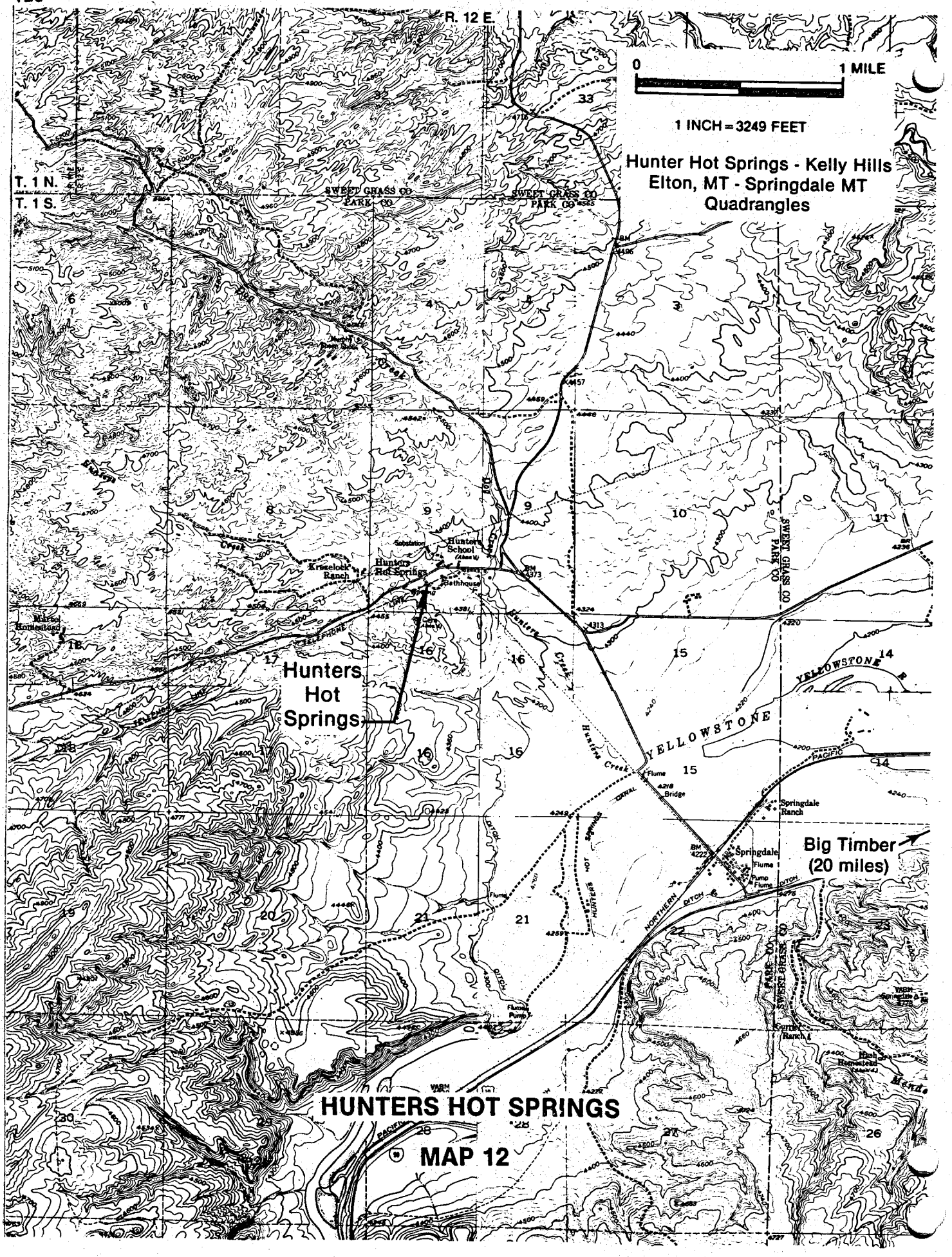
POPULATION

..General Description of Population: The spring area and surrounding land is owned by William Thexton. He has a very small trailer park (six trailers). The nearest neighbor is located about one-quarter of a mile away. Ennis, a small town of about 500 persons, is located about 1.5 miles (2.4 km) to the south. The population density outside of the town is sparse.

..Economics:

..Present Land Use: The economy of the area is very restricted. It depends on tourism, in part, during the summer and fall. The surrounding area is used mainly for ranching and associated agriculture.

..Future Land Use: There are no large changes anticipated for the future.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1 MILE
1 INCH = 3249 FEET
Hunter Hot Springs - Kelly Hills
Elton, MT - Springdale MT
Quadrangles
T. 1 N.
T. 1 S.
SWEET GRASS CO
PARK CO
Hunters
Hot
Springs
Hunter's School
Hunters Hot Springs
Bathhouse
Krzelock Ranch
Martel Homestead
YELLOWSTONE
Springdale Ranch
Springdale
Big Timber
(20 miles)
Gurney Ranch
HUNTERS HOT SPRINGS
MAP 12

Western Region

Subchapter H

HUNTER'S HOT SPRINGS

Hunter's Hot Springs is the easternmost site in Montana's Western Region. It lies between Livingston and Big Timber in south-central Montana. The springs first became known during the period of 1864-1968 when the Bozeman Trail served as an immigration route from the Oregon Trail to Bozeman. In 1864, Dr. Andrew Jackson Hunter came through to discover and stake claim to the hot springs area. The Indians had used the springs for many years previously for bathing. A large resort was built after 1885 and was used until 1933 when it was destroyed by fire.

These springs flow at over 1,000 gallons per minute (64 l/s) and have the largest flow of any hot spring in Montana. The use potential of this site is very high for agriculture and aquaculture, and rates very high as compared to other sites in Montana. The probability of locating additional reserves of hot water is excellent.

The interest in developing the resource at this site has been very high. The owner is quite interested in utilizing the existing flow in some manner but lacks the necessary capital. Commercial interest for exploring the electrical potential was present a few years ago but institutional barriers prevented the project from getting off the ground.

The BLM land in this area has been processed for noncompetitive leasing, and applications can be submitted at any time. There are presently no restrictions of note other than the original problem of state leasing policy, which remains a major obstacle.

Site Description

Hunter's Hot Springs is about 1-1/2 miles (2.4 km) north of the community of Springdale in south-central Montana. The rectilinear coordinates are section 90 F., township 1 south, range 12 east, adjacent to Interstate 90. Interstate 90 is the major east-west thoroughfare in the state.

The spring produces the largest hot water flow in Montana and originates from sedimentary formations. The undiscovered potential appears to be very high, perhaps to the extent of electrical production. The geology is not self-limiting as it is in some fault-fracture controlled crystalline rock systems.

The site topography consists of broad plateaus and low, rolling hills which descend gradually to the Yellowstone River valley. Elevations range from 4,183 feet (1303 m) on the valley floor to over 4,863 feet (1515 m) near the ridge tops. The vegetation consists of foothill grasslands with some sagebrush and bunchgrass.

The immediate site is a working cattle ranch which produces alfalfa and grain. The surrounding area is also agriculture and ranching oriented with no major concentration of people nearer than 20 miles (32 km).

The isolated position and limited production capability of the land predicts no change in land use for the future. The communities of Livingston and Big Timber are minor trade centers depending on ranching, ranching-needs supply, and transportation stop-over for continued existence.

The land ownership for a 6-kilometer radius was evaluated and consists of 3 percent federal, 5 percent state, and 92 percent private. The spring site is surrounded on three sides by privately owned land. Four hundred and forty acres of state land borders the south side. The energy supply is primarily electric with bottled gas and fuel oil available in the neighboring towns.

The sparseness of population in this area and the rather nonscenic nature of the landscape would contribute to little opposition to any form of geothermal development. The spring owner is very interested in leasing for many uses. This area does not draw tourists and a major installation would probably be welcomed as a change for the better.

Geothermal Resource Description

The spring area was analyzed by resistivity measurements and showed a resistivity low centered in the northwestern group of orifices. The anomaly is circular in design at 20 meters depth. The pattern suggests that the thermal water may be rising along two sets of fractures trending northwest and northeast respectively.

The surface temperature is 139°F (59°C) and flow has been measured at 1,315 gallons per minute (83 l/lec). The geothermometry indicates a reservoir base temperature range of 140° to 237°F (60° to 114°C). The total dissolved solid content is relatively low at 268 m/l and with a pH of 8.6. The geothermal gradient for this area is 29.5° C/km. The temperature of the discharge has been explained as a result of deep circulation groundwater being affected by the local geothermal gradient in the Crazy Mountain Basin.

No drilling to depth has been conducted in the Hunter area, although the reservoir is thought to have a very large capacity to supply water at higher-than-surface temperature.

Potential for Geothermal Development

The range of geothermal applications possible using the surface temperature of 139°F (60°C) are shown in figure 2 on page 27. Many of these uses are population-oriented and would not apply at this site. The suggested uses would include aquaculture, individual space heat, animal husbandry, and commercial greenhouse production. If predicted reservoir base temperatures can be located, commercial heat-oriented agriculture processing plants are possible. Some products would be alfalfa pellets, dried grain, and dehydrated vegetables. Malted barley is another possibility.

The initial suggested uses with the highest apparent economic feasibility are aquaculture and greenhouse production. These two uses have near to ideal conditions for operation.

Interest in Development

The hot springs were used for commercial recreational purposes for years by the owner. A swimming pool and hot baths exist but are in a state of dispair. The spring water is now used for some irrigation after cooling.

The Hunter's Hot Springs area is part of the U.S. Geological Survey classification known as PGRA. This classification allows for leasing on a noncompetitive basis. A developer applied to the area BLM office for a lease in the Hunter area. An EAR was prepared which took 2-1/2 years. The lease sale was scheduled for January, 1976, but all applications were withdrawn. No further interest or official action has taken place although leases can be let at any time in this area.

This same developer leased the Hunter spring area and attempted to lease state land which adjoined the spring site. This request was denied by the state on policy grounds. He is still interested in the area but no change in state leasing policy has occurred.

The spring owner has received various inquiries concerning leasing for greenhouse heating. No firm offers have resulted at the time of this writing. He is quite interested in pursuing some use of the resource for financial remuneration.

Restrictions to Development

There are few restrictions to geothermal development of any kind in this area. The one restriction which needs changing is the state leasing policy. This problem will be addressed under the Development Factors section of this report. To quickly recap the problem, according to present Department of State Land's policy (not regulation or law), the Commissioner will not hold a lease sale until "sufficient interest" is shown. His definition of sufficient interest is not one or two applications, but ten's of applications. The newness of geothermal energy in Montana seems to project that development will take place via singular projects, not mass development. These singular projects cannot begin under the state leasing policy.

Scenario Discussion

Two scenarios were constructed addressing electrical production and direct use for the Hunter site. The timed phases were tailored to the local conditions and land ownership. The first is an electrical scenario for a 50-MW generating facility. The assumptions for this event to develop are:

1. Private land is to be used for site.
2. State land will be leased.
3. A high potential resource will be discovered.

The starting date was projected for 1985. The development process for the first event requires 7-1/2 years. Subsequent installations would occur if resource potential warrants.

The second scenario describes direct use of the heat energy to supply a 5-acre commercial greenhouse installation. The assumptions for this use are quite probable with:

1. Private land is to be used.
2. Commercial interest will be present.
3. Financing will be available.

The projected starting date is 1980 with a development time to power-on-line of 3 years. This scenario has a very high probability of occurrence. The power which can be extracted with no drilling is 40 x 10^6 Btu/hr. Drilling could provide energy to a facility which would be only limited by production sales. This is postulated to be 15 acres requiring a power of 120 x 10^6 Btu/hr.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 45' 26" (32)

..Longitude: 110 15' 26" (32)

..Rectilinear: T. 1 S., R. 12 E., sec. 9, SW 1/4 (10)

..County: Park

..Adjacent Counties: Gallatin, Meagher, Stillwater, Sweet Grass, Wheatland

..Topography: The topography of the study area consists mainly of broad plateau and low, rolling hills which gradually descend to the Yellowstone River Valley floor. In places, these lands have been incised by minor tributaries to the Yellowstone River, forming rather shallow, but steep-walled canyons. Elevations range from 4,183 feet (1303 meters) along the valley floor to over 4,863 feet (1515 meters) near the ridge tops. (74)

..Present Land Use: The major land uses are livestock grazing, wildlife habitat, and recreation. Although data are not available, the area has good hunting potential for antelope, deer, and birds. The Yellowstone River is a "Blue Ribbon" fishing stream at this point. The site itself is a working ranch with no public access to the hot springs. (74)

..Future Land Use Plans: There are no major changes planned for this area. A few years ago, interest was shown for investigating the geothermal potential but institutional barriers discouraged further offers. (18)

..Aesthetics: Visual consideration will be important in some sites. Although this site is not on a major tourist route, local people do use the area for recreation. Most points are visible in the area. Nonelectrical uses would be compatible and possibly even electrical generation would be acceptable. (74)

..Historical/Archaeological Significance: Written history of the area began with the Lewis and Clark expedition in 1806 as they passed through Springdale on the Yellowstone River. From 1864-1868, the Bozeman Trail served as an immigrant route from the Oregon Trail in Wyoming to Bozeman and the mining country. In 1864, Dr. Andrew Jackson Hunter came through to discover and stake claim to the hot springs area. He developed the area slightly and had a pond for bathing, which was used by Whites and Indians both. Bath houses were built in 1873. In 1885, Dr. Hunter sold his rights to Murray interests in Butte. A large resort was built and used until 1933 when it burned. The plunge is not presently used.

Hunter's Hot Springs is on the state inventory of historic places by virtue of the historic events. A number of significant archaeological sites have been found within a 30-mile (48-km) radius. The potential for valuable archaeological sites in the study area is high. (74)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The study area is in the southwestern edge of the Crazy Mountains Basin. This basin is elongated northwest and is about 40-75 miles (64 km to 124 km) wide and 100-130 miles (160 km to 208 km) long. The basin is bordered by the Beartooth Range to the west, the Big Belt, and Little Belt Mountains to the north, and Lake Basin and Pryor Uplift to the east. The Crazy Mountains Basin is of late Cretaceous and Paleocene age.

The Crazy Mountains to the north consist of Tertiary intrusives. The Beartooth Mountains to the south are composed of an uplifted block of Precambrian metamorphic rocks and Tertiary intrusives.

Rock exposed in the area of Hunter's Hot Springs consists of the Livingston Formation and the Fort Union Formation. It is by far the greatest portion of bedrock in northern Park County. This formation has a thickness of at least 14,000 feet (4267 meters) and consists of andesitic sediments which were deposited in late Cretaceous and Tertiary time. The thickness in the study area is considerably less.

The Livingston Formation has been divided into five parts:

1. A lower 4,500-foot (1372-meter) unit of dark gray-green, medium- to thick-bedded, coarse-grained andesitic sandstone and conglomerates with minor shaly beds and a few modular horizons. The basal beds are conformable and gradational with the underlying Eagle Formation sandstone.

2. A finer grained valley-forming unit about 3,500 feet (1067 meters) thick consisting of fine-grained andesitic sandstone, micaceous shales, and bentonitic clays with some interbedded coarser-grained andesitic sandstone. Colors range from purple to gray-green and pale greenish-gray.

3. A conglomerate and andesitic sandstone about 3,500 feet (1067 meters) thick with coarse andesitic sandstones predominating in the lower 1,500 feet (457 meters).

4. An andesitic sandstone about 2,000 feet (610 meters) thick with sporadic conglomerate beds.

5. An upper congomerate unit about 1,000 feet (305 meters) thick.

..Geophysical Summary: The Department of Earth Sciences at Montana State University conducted D.C. resistivity and hammer seismic surveys at the Hunter's Site.

The results for these surveys delineate an apparent resistivity low centered on the northwestern group of orifices. The anomaly is circular in design at 20 meters depth. With increasing depth, the shape of the anomaly becomes more elongated in the northwest and northeast directions. At the limits of observation (100 meters), two favorable zones, one trending N. 60° W. and the

GEOLOGICAL/GEOPHYSICAL DESCRIPTION
(continued)

other N. 50 to 70° E. can be identified. The pattern suggests that thermal water may be rising along two sets of fractures trending northwest and northeast, respectively. Hot water may be channeled to the surface through the conduit formed at the intersection of these two zones. (9)

The thermal waters at Hunter's Hot Springs flow from nine primary and at least 10 smaller openings.

The geothermal gradient for this area is 29.5°C/km (AAPG geothermal gradient maps of the U.S., Map 21, Montana). The temperature of the discharge has been explained as the result of circulating deep ground waters being affected by the local geothermal gradient in the Crazy Mountains Basin. (10)

The three principal springs are located within 150 meters of one another. (80)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 139°F (59°C) (55)

..Subsurface:

..Geochemical:

SiO_2:	Chalcedony 140°F (60°C)	Quartz 237°F (114°C)
Na-K-Ca:	Na-K-1/3 Ca 178°F (81°C)	Na-K-4/3 Ca 163°F (73°C) (80)

..Flow Rates: 1315 gpm (5000 l/m) (80)

..pH: 8.6 (31)

..Total Dissolved Solids: 268 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	430
Hardness (Ca, Mg)	3 mg/ℓ
Ca	1 mg/ℓ
Mg	0
Na	85 mg/ℓ
Bicarbonate	150 mg/ℓ
SO_4	19 mg/ℓ
Cl	14 mg/ℓ
F	5.8 mg/ℓ
SiO_2	63 mg/ℓ
B	720 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Unknown.

Land Ownership

The springs and surrounding land are privately owned.

An important feature is the presence of state-owned land located immediately adjacent to the south. This amounts to about 440 acres which appear to be critically located from a geologic standpoint.

The land on the remaining three sides is privately owned. The fourth side is state owned.

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	28,250 (11,433 hec)	3%	5%	92%	0%
..Land Leased:	0				
..Highest Priced Leases (Dollars/Acre):	N/A				

..Tentative Lease Sale Dates: A federal lease sale was ready to be held by January, 1976, but no bid applications were received. (19)

..Number of Sales Offered But No Bids: 2 tracts; 440 Federal Acres (178 hec). (74)

..Number of Bids Rejected Resulting in No Lease: The BLM rejected 2 tracts totalling 320 acres (130 hec). (74)

..Summary of Leasing Status and Needs: W. C. Kaufman filed with the BLM for a lease on April 5, 1974. It took almost two years until January, 1976, to complete the EAR. At this point the lease application was withdrawn. No further action has been taken. (19)

Concurrently with the above action, Kaufman applied for a state lease on May 15, 1975. The state replied that a lease sale was not scheduled and is holding the application until one is held. To date, no lease sale has ever been held for geothermal leases. (51)

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The hot spring site was used in the past as a resort. The grounds still contain a swimming pool which stands empty. The spring water is presently used for irrigation after cooling.

A private business group is interested in pursuing development of the Hunter's area for electrical generation. Institutional factors are halting further work at this time. The main problem occurs under the administration of the State Lands Geothermal Leasing Laws. (18)

According to present operating procedure, the commissioner of the Department of State Lands won't hold a lease sale until "sufficient interest" in geothermal leasing is shown. Most investors are now aware of the effect this policy has on the Hunter's project and are unwilling to risk future roadblocks. Therefore, the Department of State Lands will get no lease applications until the policy or regulations change. (5)

..Projected or Planned Development: There is no planned development of any kind for the Hunter's site. The owner, Harold Johnson, would like to use the resource in some manner to bring a financial return. A number of possibilities have been discussed but nothing definite has come out of this. (27)

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: BLM lease stipulations are normal for any operation which may upset environmental balances. Normal development plan approvals are required. In general, the requirement set forth in the Hunter's EAR are development oriented and should not retard development.

The Department of State Lands has leasing procedures considered unreasonable by developers. The risk involved in tying up capital for very long periods is too great.

..Agency and Public Attitudes: Public attitudes are good with some private land available for leasing.

..Status of Requirements (i.e., EIA/EIS Requirements): A part of the land originally requested for lease was tied up until the question of geothermal rights classification on private land is settled. That is, federal mineral rights on private land. The outcome of a legal opinion on the federal level will determine whether these mineral rights extend to geothermal waters.

ENVIRONMENTAL FACTORS

..Climate: The climate is typical of eastern Montana with hot dry summers and cold wet winters. Temperatures range from -20°F to 100°F (-29°C to -38°C). (5)

..Prevailing Winds: From the west. This area receives much wind with gusts often reaching over 100 mph (160 km/h). (74, 5)

..Precipitation (Annual): 14 to 18 inches (36 to 46 cm). (74)

..Days of Sunshine (Annual):

..Average Temperature:

Minimum: 15°F (-9.5°C)

Maximum: 86°F (30.2°C) (67)

..Degree Days (Annual): 6,766 (69)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: Air quality over the entire area is very good due to the remoteness and the lack of human activity. Soil particulates may be raised by high winds in the dryer parts of the summer. (74)

..Geologic Factors:

..Water Quality: Water quality in the site vicinity is very good. As mentioned, the Yellowstone River is an excellent fishing stream at this point. Ground water is generally accessible and of good quality. All perennial streams have privately owned water rights. (74, 39)

..Noise: Generally, noise in this area is of natural origin--birds, wind, and river sounds. Occasional noise from Highway U.S. I-90 can be heard. Ranching activities also contribute some noise. (74)

..Biological:

..Dominant Flora: The foothill grassland has wheatgrass and fescue. The canyons are covered with shrubs and trees. Some sagebrush and varieties of bunchgrass are present. (74)

..Dominant Fauna: The principal animal inhabitatants are mule deer, elk, and antelope. (74)

ENVIRONMENTAL FACTORS
(continued)

..Endangered Species:

Flora: None

Fauna: Bald eagle. (74)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities

Electric:	50 KV lines	Adjacent	
	161 KV lines	5 miles (8 km)	
	230 KV lines	15 miles (24 km)	(42)
	Telephone	Adjacent	

..Transportation Corridors or Facilities

Highway:	I-90	2 miles (3.2 km)

Year-round paved road to the spring site from the Interstate.

POPULATION

..General Description of Population:

The closest population centers are:

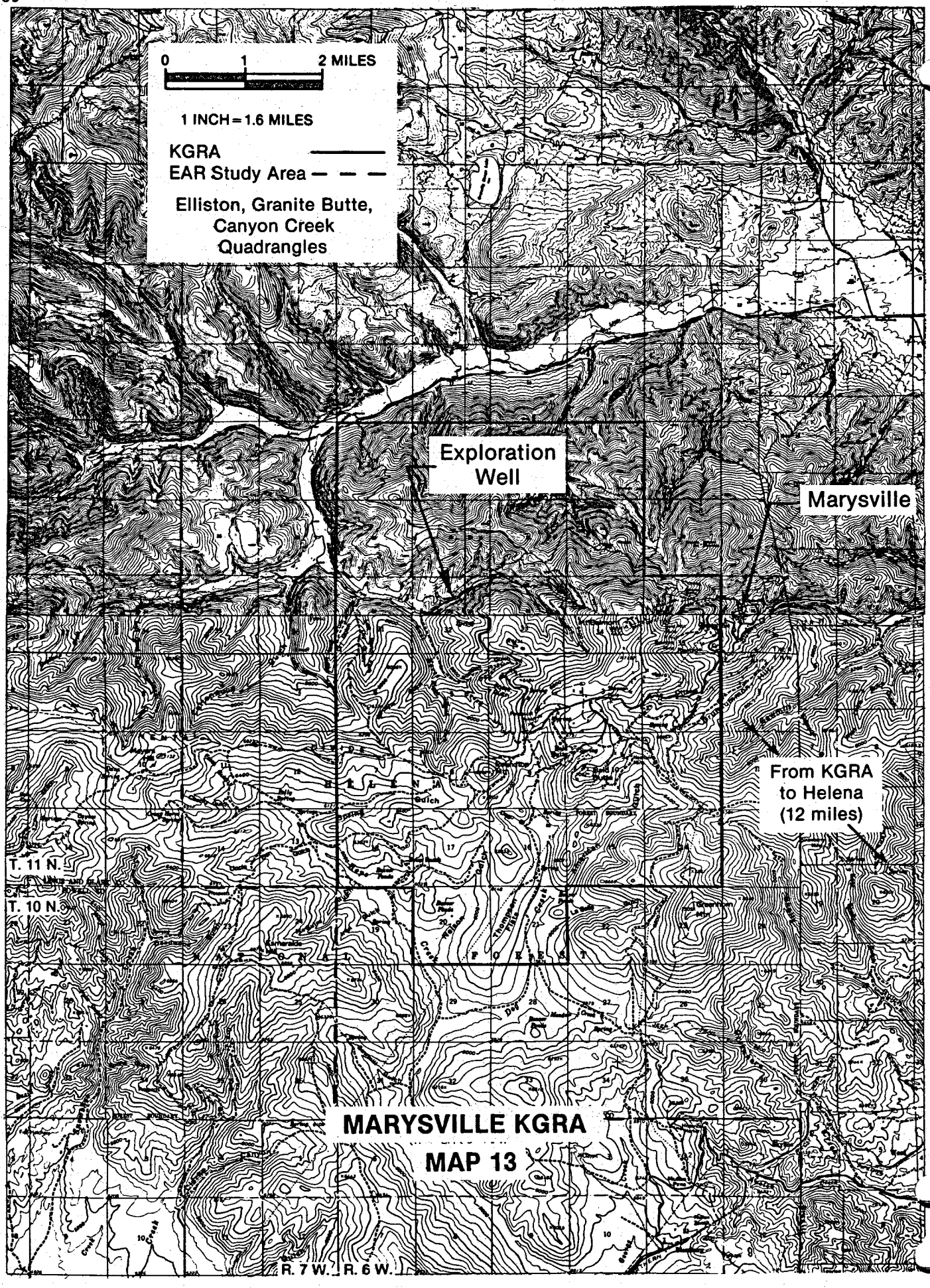
Springdale	1.5 miles (2.4 km)	Population 15	
Big Timber	15 miles (24 km)	Population 1,592	
Livingston	20 miles (32 km)	Population 6,883	(47)

The population at the study site consists of ranch families. Often these ranches are placed miles apart in this area. A higher concentration of homes is located in Springdale, 1.5 miles to the south which is adjacent to the Interstate.

..Economics

..Present Land Use: The economic base for this area is primarily ranching and some agriculture.

..Future Land Use: There should be no change from the present land use and economic base.



MARYSVILLE KGRA

MAP 13

Western Region

Subchapter I

MARYSVILLE KGRA

The Marysville KGRA is a 30-square-mile (76.8 km^2) area located about 17 miles (27 km) northwest of Helena in Lewis and Clark County. This area is a historical gold mining district with high-relief topography. The area geothermal potential was not realized until very recently since there are no hot water springs or other surface manifestations to alert the observer. The potential was recognized from heat flow measurements which are abnormally high. The land ownership is mostly federal.

Direct use is very limited since there is no population concentration closer than Helena. The terrain in the heat flow anomaly area is rugged with steep slopes and narrow valleys. There is a possibility of piping the water to the Little Prickly Pear Valley, which is 5 miles (8 km) to the east. Piping the water to Helena would be a minimum of about 20 miles (32 km). This alternative appears to be presently uneconomical. The range of applications for the known temperature includes individual and district space heat, greenhouse heating, aquaculture, growing season extension, and low temperature industrial and manufacturing uses.

There were a number of lease applications which showed enough overlap to assign the area a KGRA designation. An Environmental Analysis Record study was prepared as a prerequisite to leasing. No activity can be pursued until this is completed. The study is finished, but no lease sale has been held.

Site Description

A geothermal anomaly was discovered in this area in 1966 by David D. Blackwell during a regional heat-flow study. These studies led to the announcement in 1973 of plans for drilling a 6,000-ft. (1829-m) geothermal test well in the area. Federal lands were opened for the filing of lease applications in January 1974, and as a result of the publicity, the vicinity of the heat-flow anomaly was covered with overlapping, noncompetitive geothermal lease applications. This led to a KGRA designation.

The Continental Divide crosses the southern part of the study area, so the terrain is mountainous with a local relief of more than 3,200 feet (1000 meters). The area has well-dissected drainage patterns and a high occurrence of steep to fairly steep slopes. The topography can be described as a mature mountain system. The northern boundary is marked by the Little Prickly Pear Creek Valley. Empire Creek drains into the Little Prickly Pear Creek near the northwest corner of the KGRA.

The study area is used primarily for cattle grazing and recreation. The community of Marysville has 50 to 100 year-round inhabitants and is subject to intense tourist use in the summer and skier use in the winter. The KGRA is a popular hiking and exploration area due to its historic mining history. This

use is expected to increase along with the county population. Other uses should remain roughly the same.

The private land is owned primarily by ranchers with a scattering of private patented mining claims. Cattle grazing, with associated agriculture, is the economic base of the area fringe. The Belmont Ski area located in the KGRA brings up to 600 skiers a day through Marysville, which has some facilities for recreation support. The population areas near the KGRA are Marysville (population 50), Canyon Creek (population 50), Birdseye (population 100), and Helena (population 23,000). The land ownership for the KGRA is federally controlled 14,200 acres (5747 hectares) and private land, 5,000 acres (2024 hectares). The ownership for an area centered around Marysville with a radius of 6 kilometers is federal land 62 percent, and private, 37 percent.

The area uses electricity, bottled gas, and wood for heat energy. Bottled gas is available in Helena as is fuel oil. The only industrial energy use in the area is a sawmill located on the main road near the Marysville turnoff at Silver City.

The public attitude toward geothermal development is divided in respect to type of use. Electrical generation is looked at with suspicion since most information about this use has been negatively slanted, geysers being the only example to compare with. Direct use would most likely find acceptance with little concern if good environmental practices are followed.

Geothermal Resource Description

The 1966 heat flow study by Blackwell indicated very high values for a few specific sites (6.6 $\mu cal/cm^2sec$). Subsequent measurements at other sites showed even higher values (3.3 to 20 $\mu cal/cm^2sec$) over an area of several square kilometers. The average background for western Montana is approximately 2.0 $\mu cal/cm^2sec$, as compared to the world average of 1.5 $\mu cal/cm^2sec$. The heat flow in the Marysville area then is up to 10 times the already high background of western Montana.

A gravity study (Mazzella, 1974) indicated a negative residual gravity anomoly, and thus a region of mass deficiency which was associated with the higher value of heat flow. The correlation of the high heat flow and relatively low density in the same area was considered indication of a relatively shallow (less than 2 kilometers) cooling chamber of recent molten igneous rock. This prompted further extensive geological and geophysical investigations to detail the characteristics of this interesting anomolous area.

The intriguing aspect of the Marysville site is the complete lack of surface manifestations of the anomoly. The nearest hot spring is located 19 miles (30 km) away. The nearest recent volcanics are over 188 miles (300 km) away at Yellowstone.

The detailed geophysical data identified a probable site for a test hole. This test hole was drilled to a depth of 6,600 feet (2.4 km) in 1974. The results were quite different than those predicted from surface data. Hot water was encountered in granite rock at 1,900 feet (579 m). Water began entering the

hole at an estimated 1,000 gallons per minute (63 l/sec.) This negated the concept of a dry magma chamber. Drilling continued to 6,790 feet piercing numerous fracture zones. Water inflow seemed capable of maintaining a constant head at 600 feet (183 m) from the surface.

The expected temperature gradient was 96°F/100 feet (175°C/km). The temperature log indicates a steady rise of temperature of about 66°F/1,000 feet (100°C/km) to a depth of about a kilometer, wherein isothermal conditions prevailed to a depth of 6,600 feet (2.4 km). The maximum temperature has been increasing very slowly since the hole was drilled as indicated from continuous temperature logging by the U.S. Geological Survey. It has reached approximately 217°F or 103°C.

The results of the drill hole data indicate hydrothermally controlled heat flow in this area. The source driving this convection cell which utilizes the Empire granitic rock for a conduit is not identified but can be projected to lie at considerable depth.

The practical utilization considerations indicate a reservoir capable of supplying water at 200°F (94°C) with a flow of at least 1,000 gallons per minute (63 l/sec) from a well with an 8-inch casing. The reservoir boundaries have not been delineated so the choice of drill site is critical. The probable depth seems to be located at 1,900 feet (579 m) level.

Potential for Geothermal Development

The range of applications which are possible at the temperature encountered in the Empire Creek well of about 212°F (100°C) is shown in figure 2 on page 27. The area where the resource appears available is not suitable for many of the applications since it is quite remote. There are three main factors which restrict immediate use of this resource. The first is the absence of sufficient quantities of end users or people who could use the resource nearby. The second is the rugged terrain which is space limited for agricultural applications, and the third is the lack of reservoir definition for sites other than the present test hole.

The community of Marysville is much too sparsely populated to economically use a district heat system, and the resource is too deep as indicated by the drill hole to individually heat homes. The closest flat land for agricultural use of the water is at least 5 miles (8 km) away. This flat land receives restricted sunlight so that greenhouses may not receive enough light. The resource potential for direct use in the Marysville area must be considered marginal for present uses with known criteria. This is not to say that future investigations won't change the resource characterization to a point where the various uses noted are economically feasible.

There is a possibility of piping hot water to points of utilization if a sufficient reservoir is located. These uses could include greenhouses in the Birdseye area to the east, or piping water to the Helena Valley for domestic space heating. This distance could be as little as 12 miles (19 km). Industrial users could be supplied if water approaching 240°F (116°C) could be located. One use in the local area would be kiln drying of green lumber.

Electrical generation is still a possibility. The test well did not locate a hot enough reservoir or heat flow area. Subsequent wells may encounter better resources in other areas of the KGRA. This possibility is of little interest under the present economic circumstances. Commercial companies have much more lucrative prospects in Utah and Nevada. Future demand is almost certain to change the economic feasibility of geothermal exploration at Marysville.

Interest in Development

As discussed previously, the heat flow anomoly was unknown until 1966, and there are no surface hot springs which could be used directly. For these reasons, there is no use of the resource at this time.

All federal lands including the Marysville area were opened for geothermal lease applications in January, 1974. Applications from a number of commercial energy development companies were received for the Marysville area as a result of the academic exploration projects that were ongoing. These resulted in the KGRA designation as required by law. The area of the KGRA was set at 19,200 acres (7771 hectares) with an additional study area of 57,000 acres (23068 hectares) to be included in the EAR. The study was finished in late 1977, but lease stipulations were not decided upon at that time.

Development interest is still present in the form of lease applications for noncompetitive land on forest service and BLM land. It is unknown whether or not the present applications will be left in or withdrawn in the future.

Restrictions to Development

Development "stipulations" which will be attached to any federal lease granted are sure to contain important impacts for development in the Marysville area. Typically for this type of terrain, steep and erodible slopes will necessitate the "no-surface occupancy" restriction for some areas. Another requirement which may be levied concerns seismic monitoring of the area before a production well can be drilled.

Water and air pollution will be rigidly controlled for any development project in the Marysville area. There will be other development situations which are yet to be agreed upon within the U.S. Geological Survey, U.S. Forest Service, and BLM.

Scenario Discussion

Time lines for possible geothermal development using local social and economic data were prepared. There were two separate cases for consideration. The first deals with the possibility of a 50-megawatt electrical generation facility being developed by major energy-oriented companies. This development sequence will soon begin after the lease sale and continue steadily until

power-on-line is obtained. The assumptions which would allow the scenario to proceed are:

1. Federal land will be leased.
2. Commercial interest would be present.
3. A viable resource can be located.

This avenue was chosen as a result of the lease applications which remain on file by energy development corporations in spite of the negative data from one test well. It is anticipated that the generation event will take 9-1/2 years beginning 1985, and ending with an operation facility in 1994. Multiple events for generation were not outlined due to the completely unknown potential to support steam generation. Additional facilities would be considered after an initial trial phase of the first generating plant.

The second event describes direct use of hot water from the KGRA, via transportation by pipeline to the Helena Valley. The necessary supply would have to produce several thousand gallons per minute with a temperature of at least 180°F.

The assumptions for this scenario are:

1. Municipal interest will exist.
2. Financing would be available.
3. A suitable resource can be found.
4. Federal land will be leased.

This project would be expected to start no sooner than 5 years from the lease sale date. It would take approximately 8 years for a district heating system to partially supply the Helena Valley. The total energy production postulated for this event is 84×10^6 Btu/hr. Although multiple events are not shown, it is anticipated that uses other than domestic space heat would be found. The most obvious is greenhouse heating.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 45' 14" (31)

..Longitude: 112 22' 33" (31)

..Rectilinear: T. 12 N., R. 06 W., sec. 2, AAD (31)

..County: Lewis and Clark

..Adjacent Counties: Broadwater, Cascade, Flathead, Jefferson, Meagher, Powell, Teton

..Topography: The topography of the area is that of a mature mountain system. It is well dissected with a combination of dendritic and trellis drainage patterns and occurrence of steep to fairly steep slopes, rounded hill crests, and some cliff exposures. The Continental Divide runs an irregular course northward from the southern boundary of the area over Greenhorn Mountain. From there it turns westerly about 2 miles north of Greenhorn Mountain and passes through the western boundary of the study area near Meyers Hill. Only about 25 percent of the study area lies west of the Divide.

Elevations range from 4,214 feet (1280 m) near Birdseye on the east boundary to 7,505 feet (2275 m) on Greenhorn Montain.

The northern boundary of the area is marked by the Little Prickly Pear Creek Valley. This valley is less than a half-mile wide at the northwest corner of the area and widens to the east. Where Little Prickly Pear Creek meets Canyon Creek, the valley is about 3 miles wide along the northeast boundary of the study area. (75)

..Present Land Use: The site is owned by the U.S. Forest Service and is used for recreation and animal grazing. The Belmont Ski area is in the study area. Other recreational activities include snowmobiling, snowshoeing and cross-country skiing. Hiking, camping, fishing, and hunting are the spring, summer, and fall activities. (75)

..Future Land Use Plans: No changes are anticipated for future use. (75)

..Aesthetics: Evidence of man's activities is found throughout the study area. Disturbed earth contrasts sharply with forest and grass-covered slopes in most of the study area. Most roads are low standard. Numerous two-track trails run through the area but blend with surroundings. Sensitivity levels and visual quality objectives have been completed by the forest service. No highly sensitive areas were delineated. (75)

..Historical/Archaeological Significance: The Marysville Historic District lies about 18 miles (29 km) northwest of Helena. This was an important gold mining district from the 1870s through the early 1900s. Between 1880 and 1894, it was Montana's largest producer of gold. The population of Marysville at this time reached 3,000. The operation was a good example of the high

SITE LOCATION AND PHYSICAL DESCRIPTION
(continued)

state of development in hardrock gold mining. The primary mine was the Drumlummon mine whose owner also built a large mill to process the ore.

Other important mines were the Belmont, the Bald Butte, the Penobscot, the Shannon, and the Empire mine. Accompanying communities that appeared to support these mines were Bald Butte, Empire, and Gloster. The historical evidence is considered important at the national level. Portions of Marysville have been nominated for inclusion in the National Register of Historic Places.

There has been no systematic archaeological inventory for the study area. Four sites in the study area have been recorded in the Statewide Archaeological Survey files at the University of Montana. Other known archaeological sites are immediately outside the study area. Some sites to the east have been dated as old as 10,000 years. Forty-five archaeological sites of various types have been identified in the county. The future archaeological potential is rated as high. (43, 73, 75)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The Marysville EAR area lies in the northern Rocky Mountain structural and physiographic province. The thrust faults that mark the eastern margin of this province are about 25 miles (40 km) east of the study area.

The bedrock material in this area consists of Precambrian sedimentary rocks of the Belt Series. Empire Shale and Helena Limestone are the two formations which crop out most extensively in the study area. The shale is a dense, blocky fracturing argillite. The limestone is a very siliceous limestone or dolomite. In a large part of the area, the limestone has been transformed into a dense, low-porosity, calcsilicate hornfels. To the southwest, Paleozoic and Mesozoic sedimentary rocks cover the Belt rocks.

The sedimentary rocks are cut by several intrusive bodies. The only exposed body of any size is the Marysville stock which is thought to be of late Cretaceous age. The Radiometric age dating is 79 million years old.

The Marysville stock is surrounded by a broad belt of contact metamorphosed, sedimentary rocks, and thus the stock may have a much larger subsurface extent than its present exposure would indicate. The stock occupies the center of a structural and topographic high which may have been caused by doming associated with emplacement of the stock. Faults in the area are high angle faults and can be followed for several miles. The maximum displacement appears to be a few hundred feet. (75, 6)

..Seismicity: A zone of earthquake activity extends from Helena northwest to the Marysville heat flow anomaly. This is essentially the same as the study area. This trend follows the Intermountain Seismic Belt. The Marysville heat flow anomaly is characterized by a lack of earthquake activity. The seismic activity in the Helena area has been of the swarm type with a major sequence in 1935 of magnitudes of 6-1/4 and 6. Studies by the University of Montana in 1974-75 indicate that the swarm pattern is still occurring. The magnitude of these swarms is usually below 3.5 on the Richter scale. Helena is regarded as one of the more active seismic areas in Montana. (75, 6)

..Geophysical Summary: Magnetic Surveys. Magnetic surveys indicate anomalies associated with content variation of magnetic material. In the Marysville area, the only magnetic anomaly of note is associated with the Marysville stock. A model of the Marysville stock was developed from data using the numerical technique of Talwani (1965).

Electrical Surveys. A roving dipole resistivity survey was done by the U.S. Geological Survey in 1972. The results indicate rather high resistivity associated with the geothermal anomaly. Magnetotelluric surveys done in 1974 found high apparent resistivities associated with the heat flow anomaly. This contrasts with relatively low values of electrical resistivities usually found in geothermal areas.

GEOLOGICAL/GEOPHYSICAL DESCRIPTION
(continued)

Seismic Ground Noise. A ground noise background survey was run with negative results--in fact, contrary to the normal conditions usually encountered with the lowest values of ground noise associated with the highest heat flow.

Microearthquake Survey. A microearthquake survey of the general area indicates activity along a fault or faults extending from northwest of Helena to the southeastern boundary of the geothermal area. No activity was identified in the geothermal anomaly itself.

Infrared Survey. Airborne infrared survey techniques were conducted in order to test for indications of the geothermal anomaly. The detection limit of the system was not fine enough and no indications were found.

Gravity Survey. A gravity survey has been ongoing for 3 years. The results thus far show a negative residual gravity anomaly is associated with the geothermal anomaly, but the lowest values of gravity are located south of the geothermal anomaly.

Heat Flow Survey. A preliminary study of a large area (Blackwell and Baag, 1973) supplied 15 heat flow values in four different areas. During the course of the NSF study, 17 holes were drilled. The depth ranged from 50-130 meters. The results clearly outlined a heat source. (76)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: The source is a nonflowing well 6,600 feet with a water table to the 500-foot level.

..Subsurface: 217°F (103°C) (30)

..Geochemical:

SiO_2: 248°F (103°C) (33)

Na-K-Ca: 256°F (180°C) (33)

..Flow Rates: "Large quantities" (33)

..pH: 7.5 (33)

..Total Dissolved Solids: 782 mg/ℓ (30)

..Fluid Chemistry:

Conductivity	960
Hardness (Ca, Mg)	22 mg/ℓ
Ca	7.8 mg/ℓ
Mg	0.6 mg/ℓ
Na	200 mg/ℓ
Bicarbonate	242 mg/ℓ
SO_4	160 mg/ℓ
Cl	47 mg/ℓ
F	19 mg/ℓ
SiO_2	83 mg/ℓ
B	820 mg/ℓ

Additional analyses of various parameters are available. (31)

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership KGRA:	19,200	14,200	0	5,000	0
Additional Study Area:	57,000	20,680	1,200	35,275	0

..Land Leased Not Open:

..Highest Priced Leases (Dollars/Acre): N/A

..Tentative Lease Sale Dates: Late 1978 or Early 1979

..Number of Sales Offered But No Bids: N/A

..Number of Bids Rejected Resulting In No Lease: N/A

Twenty-three lease applications were received in 1974. All but four overlapped enough to cause rejection because of competitive interest. (75)

..Summary of Leasing Status and Needs: At the present, the Federal government cannot lease geothermal resources where it owns the mineral rights under private surface.

The EAR was completed but leasing stipulations have not been finalized. This must be done before a lease sale can be held.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: A study financed by the National Science Foundation to locate and drill for a hot, dry rock experimental power production project. The study team picked the Marysville area as a result of heat flow data collected by Blackwell of Southern Methodist University in 1973. Geophysical surveys were conducted to locate a site for drilling. A 6,600-foot (2000-m) deep hole was drilled. The anticipated temperature was not encountered, but hot water at about the boiling point was discovered. The hole is presently being monitored by the U.S. Geological Survey. No further geothermal activities are occurring in this area.

..Projected or Planned Development: There is no planned development for this area at this time. The resource is too deep and of a nature which prevents its use in an economical manner. It has been deemed unsuitable for power production on the basis of the project.

ENVIRONMENTAL FACTORS

..Climate

..Prevailing Winds: Westerly (highly variable speeds) (75)

..Precipitation (Annual): 20.9 inches (53 centimeters) (75)

..Days of Sunshine (Annual): 184 (69)

..Average Temperature:		Extremes:	
Minimum:	28.9°F (-1.7°C)	-33°F (-36°C)	
Maximum:	53.6°F (12°C)	97°F (36°C)	(75)

..Degree Days (Annual): 8,860 (69)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: Urban and industrial pollutants are not characteristic of Marysville. The closest urban center is Helena, 15 miles (24 km) southeast of the KGRA center. Much of the study area is above the level of temperature inversions that occur in the Helena Valley. Smoke from a sawmill at Silver City may occasionally become trapped in the valley around Silver City, Canyon Creek. Temperature inversions during fall and winter may intensify smoke accumulation in the Litte Prickly Pear Valley. Slash burning on timber sale areas in and around the KGRA produces wood smoke but has minimal impact on air quality. Dust from timber harvest mining and vehicular traffic may occur. (75)

..Water Quality: The surface water quality is good for most drainages except for some leaching of mine tailings in a few areas. Discharge from 44.4 square miles in the study area is 25.7 cfs. Most reaches of stream, including the Little Prickly Pear, are classified as B-D_1 by the state which sets requirements of direct uses for most purposes. Little Prickly Pear Creek was adjudicated in the early 1900s and claims essentially all the flow during an average period from July to September. (75, 39)

..Noise: Sounds in the study area are natural for the most part. Occasional road traffic and snowmobiles can be heard. The community of Marysville had associated suburban noises. Some noise is associated with operation of the Belmont Ski area. Recreational traffic is expected to increase.

ENVIRONMENTAL FACTORS
(continued)

..Biological:

..Dominant Flora: The study area is about 60 percent forest with the remaining area consisting of grassland or shrubland. Lodgepole pine and Douglas fir are the major seral species. Some other types include alpine fir and whitebark pine.

Grasses include beargrass, bluejoint, bluebunch, wheatgrass, and Idaho fescue. (75)

..Dominant Fauna: Elk, mule deer, whitetail deer, small amounts of antelope, black bear, cougar, upland game birds (blue grouse, Franklin grouse, and sharptail grouse). Some parts of the streams are excellent habitat for cutthroat trout and whitefish. (75)

..Endangered Species:

Flora: None (75)

Fauna: None (75)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

Electric: 100 KV 5 miles (8 km)

There are no natural gas lines in the vicinity.

Major heating source is wood and electricity.

..Transportation Corridors or Facilities:

Roads: County Road 279 5 miles (8 km) from Marysville

County maintained gravel road to within 5 miles (8 km) of the drill site.

There are many unimproved forest service or old mining roads which access the entire area.

POPULATION

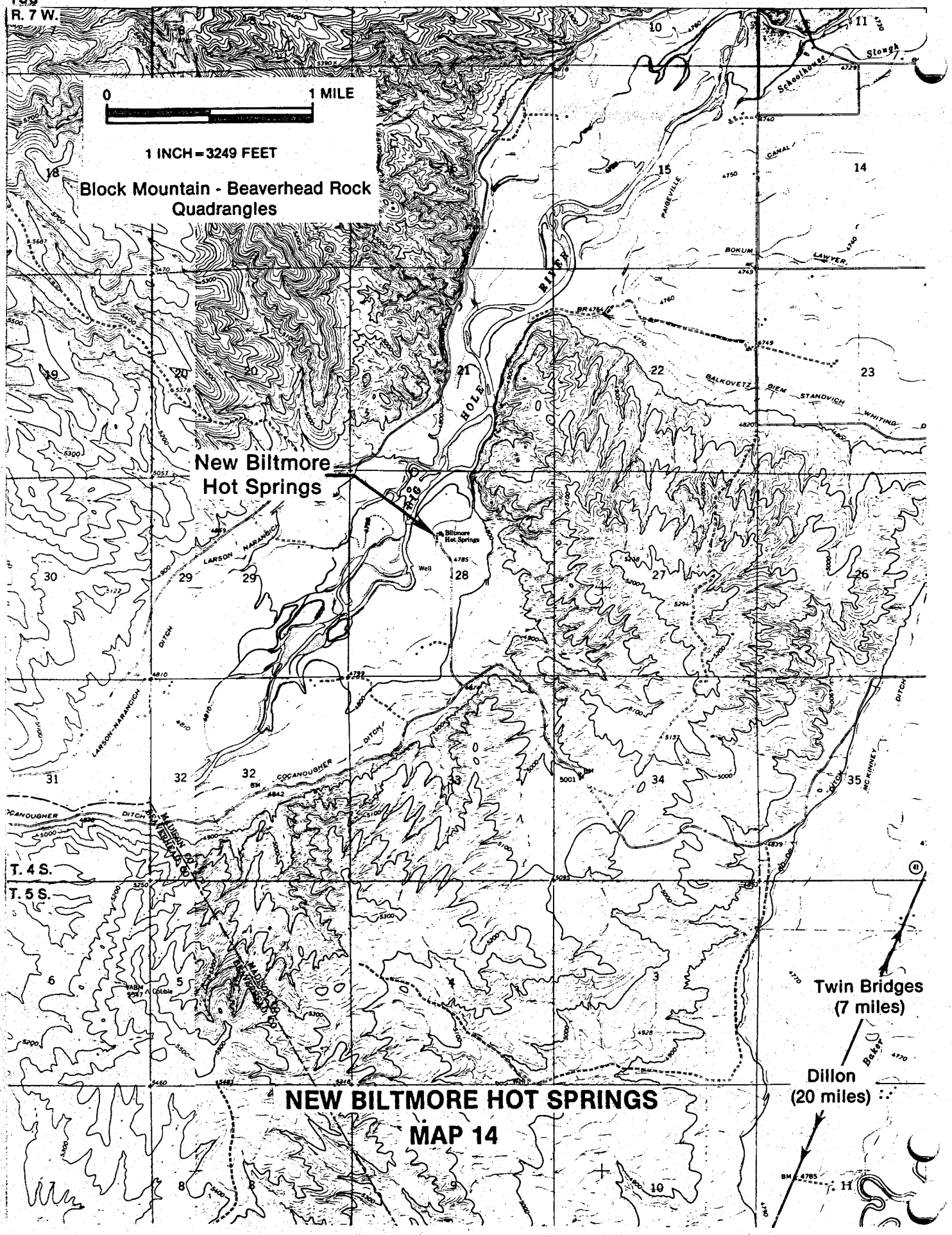
..General Description of Population: The site has no inhabitants and is snowbound for at least 6 months of the year. The community of Marysville is located over the mountain from the site and has about 50 residents. Tourists frequent the area in summer and the fall. Recreational skiers use the Belmont Ski area during the snowy season. Helena is the nearest population center and is 22 miles (35.5 km) by road, with a population of 22,730.

..Economics:

..Present Land Use: The area land use includes commercial timber sales, grazing, ranching with hay production. Recreation uses include fishing, hunting and hiking the area to explore the old mining sites.

Marysville supports a small amount of tourism and recreationists.

..Future Land Use: There should be increased recreational uses. The other land uses should show little change.


R. 7 W.
0
1 MILE
1 INCH = 3249 FEET
Block Mountain - Beaverhead Rock Quadrangles
New Biltmore Hot Springs
Biltmore Hot Springs
Well
HOLE
RIVER
LARSON-NARANCICH
DITCH
COCANOUGHER
MADISON CO.
BEAVERHEAD CO.
T. 4 S.
T. 5 S.
Twin Bridges (7 miles)
Dillon (20 miles)
Baker
NEW BILTMORE HOT SPRINGS
MAP 14

Western Region

Subchapter J

NEW BILTMORE HOT SPRINGS

New Biltmore Hot Springs is located about 12 miles (19 km) southwest of Twin Bridges in southwestern Montana. This site is 4 miles (6.4 km) off the main paved road, State Highway 41. Hot water issues from river gravels about 300 yards (275 m) from the scenic Big Hole River. The hot water is used in a recreational spa to fill a swimming pool and hot plunges.

The surface temperature is not particularly high, but the reservoir has a high production capacity. Restrictive topography would limit some uses of the resource and the rural environment does not lend itself to domestic space heating uses. Some appropriate uses of this site are heating of greenhouses and aquaculture.

The owner wishes to sell this site and hopes the resource will be developed. There has been little outside interest expressed in this geothermal resource.

There should be little in the way of development restrictions outside the physical constraints of the site environment.

Site Description

The rectilinear location of the spring's site is section 28 of township 4 south, range 7 west, about 20 miles (32 km) northeast of Dillon. New Biltmore is privately owned and is situated on about 50 acres (2.02 hectares) next to a working ranch. A combination bar, cafe, and spa are all on the property. Dillon, to the southwest, has a population of 4,548 while Twin Bridges, to the northeast, has 613 people.

The topography of the region is generally rolling hills with elevation changes of 500 feet (150 m) in the vicinity. The spring's site is a small meadow hollowed out of a steep-walled gorge. The meadow probably covers 300 acres (121 hectares). The Big Hole River is adjacent while the Jefferson River parallels to the east.

The present regional land uses include grazing, watershed, and recreation. The economic base is ranching with little future change in land use anticipated. Gold mining played an important role in the past history.

The local energy uses are small and limited to domestic heating and lighting. Fuel oil is trucked from Dillon via State Highway 41 and electricity is available from a 50 KV line adjacent to Twin Bridges. Twin Bridges could use hot water for space heating if a nearer reservoir could be found. New or expanded recreational facilities and a commercial greenhouse operation could be heated with the two hot wells already on the site.

Within 3-8/10 miles (6 km) of the hot springs, 89 percent of the land is private, 9 percent is state, and 2 percent is federally controlled.

Area residents are generally well disposed towards geothermal direct use. Utilization of the hydrothermal resource could be promoted successfully if economic cost benefits can be determined.

Geothermal Resource Description

The surface temperature of the hot springs is 127°F (53°C). The predicted reservoir temperature calculated using relative concentrations of specific dissolved elements gives a theoretical temperature range of 158°F to 352°F (70°C to 178°C). These temperatures may be obtainable through drilling to depth to tap a deeper reservoir than is currently producing the hot water.

The spring water is slightly radioactive and is claimed to have healing properties because of this. The total dissolved solids is 1970 mg/ℓ, which is rather high, although the radient heat system that has been operating in the owner's house for many years has no evidence or deposition or corrosion. The flow from a spring and a well is 100 gallons per minute (378 l/m).

This area is in the same regional geology structure as Barkell's site and it is subject to the same seismic activity. This is a good indication of deep faults and associated high potential for geothermal reservoir systems. Most of the faults which do exist in the area were established during and after the emplacement of the Boulder batholith. Zones of extensive hydrothermal alteration and mineralization are common. Little in the way of geophysical exploration has been done.

Potential for Geothermal Development

The range of applications using the known surface temperature of 127°F (53°C) are shown in figure 2 on page 27. Many of these would not be feasible in the New Biltmore area. The suggested uses would include aquaculture, soil warming, limited space heat, large greenhouses, and increased recreational uses. The predicted reservoir temperature of 158°F to 352°F (70°C to 178°C) is high enough on the upper end for commercial processing of agricultural products such as potato and onion drying. Animal feed processing is a likely use since animal feeds are locally produced. The most economically productive uses would be commercial greenhouses and increased recreational uses. There are populous areas within a marketable distance, good growing conditions, and an adequate heat supply.

Interest in Development

The New Biltmore Hot Springs is within the U.S. Geological Survey "Potential Geothermal Resource Area" (PGRA). In areas thus classified, federal leases need not be let on a competitive basis unless overlapping applications are received.

Federal lands including the area around the New Biltmore Hot Springs were opened for geothermal lease applications in January, 1974. Applications were received by the local BLM regional office from Phillips Petroleum Corporation for leases in an area between New Biltmore and Barkell's Hot Springs. An environmental analysis which covered much of the BLM land in this area was prepared. Federal land was certified for noncompetitive leasing and 6 leases were issued to Phillips Petroleum Corporation in 1975. No further leasing interest has developed.

According to local sources, Phillips Petroleum drilled one or more wells on their leases shortly after permission was given. The company has not released the results of that test drilling at this writing. It can be assumed that the resource doesn't appear to be outstanding for electrical generation compared to other areas of the west. Phillips Petroleum is exploring other sites and has done no further work in the Barkell's area, although leases have been kept current.

Scenario Discussion

A developmental scenario for an electrical generating plant of the 100-megawatt capacity was formulated on the Barkell's Hot Springs. This electrical generation plant would be located somewhere between the New Biltmore Hot Springs and Barkell's. It is felt that the area will only support one for planning purposes until further data supports higher development projections. Therefore, a separate electrical scenario under the New Biltmore site is omitted at this time. The electrical event in Barkell's scenario is equally applicable to the New Biltmore site.

A direct-use scenario involving a commercial greenhouse facility for producing foodstuffs was postulated. This development is illustrated by showing a single event; that is, a single construction phase in which all building is done at one time. It is assumed that:

1. Sufficient commercial interest for development exists.
2. Private land will be leased.
3. Necessary financing would be available.

The development could begin in 1985 and would require 2-1/2 years to become operable. The total energy potential of this single event would be
24 x 10

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 45 27' 41"

..Longitude: 112 28' 24" (31)

..Rectilinear: T. 4 S., R. 7 W., sec. 28, BDA (55)

..County: Madison

..Adjacent Counties: Beaverhead, Silver Bow, Jefferson, Gallatin

..Topography: The topography consists of rolling hills trending generally north-south. The elevations vary from 4,755 feet to 5,249 feet (1463 meters to 1615 meters) over approximately 1 mile (1.6 km). The Big Hole River runs adjacent to the site; the Jefferson River flows to the east. (71)

..Present Land Use: The site is used for a tourist spa. The surrounding area is used for grazing, watershed, recreation, and Blue Ribbon trout fishing. (71)

..Future Land Use Plans: No change from the present use.

..Aesthetics: Most of the land of interest is not widely exposed to visual scrutiny from traveled roads. The previous human impact is already quite severe in some areas. (71)

..Historical/Archaeological Significance: This area lies within the larger area that was generally heavily contested hunting grounds by many different tribes of Indians. The first known white men to enter the area were Lewis and Clark. Much mineral exploration and some mining occurred in the 1800s. (71)

No archaeological inventory has been made. There are several known archaeological sites in or adjacent to the study area. At least one pictograph site is present in the vicinity. (71)

Fifty-two archaeological sites have been identified in Madison County. The potential for future archaeological finds is high in the county.

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: Hot water issues from river gravel overlying the Meagher Limestone, and probably is circulated at depth where it is heated in Paleozoic sedimentary rocks. A probable northeast-trending fault displaces rocks near the site and could serve as the conduit for passage to the surface. (48)

..Geophysical Summary:

..Site Information: Shallow wells discharge hot water to covered concrete tanks from which it is piped to fill a swimming pool. (48)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature:

..Surface: 127°F (53°C) (80)

..Subsurface:

..Geochemical:

SiO_2: Chalcedony 158°F (70°C) Quartz 208°F (98°C)

Na-K-Ca: Na-K-1/3 Ca 352°F (178°C) Na-K-4/3 Ca 167°F (75°C) (80)

..Flow Rates: 100 gpm (378 l/m) (80)

..pH: 6.8 (31)

..Total Dissolved Solids: 1970 (31)

..Fluid Chemistry:

Conductivity	2240
Hardness (Ca, Mg)	1100 mg/ℓ
Ca	300 mg/ℓ
Mg	7272 mg/ℓ
Na	160 mg/ℓ
Bicarbonate	229 mg/ℓ
SO_4	1200 mg/ℓ
Cl	45 mg/ℓ
F	3.6 mg/ℓ
SiO_2	44 mg/ℓ
B	870 mg/ℓ

Additional analyses of various parameters are available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Unknown

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	28,250 11433 (hec)	2%	9%	89%	0%

..Land Leased: 10,687
4325 (hec)

..Highest Priced Leases (Dollars/Acre):

..$/Acre	Lessee
$1.00/acre	Phillips Pet.

..Tentative Lease Sale Dates: Leased in 1976

..Number of Sales Offered But No Bids: 0

..Number of Bids Rejected (Resulting in No Lease): None

The hot springs and surrounding land are privately owned. Parcels of state land are adjacent to the site.

..Summary of Leasing Status and Needs: Phillips Petroleum has 6 leases in the Barkell's/Biltmore area. Some resource definition drilling and geophysical work has been done, but no results are available.

Federal land is available for further leasing. The private land is available in some cases for leasing also. If further interest is demonstrated, the state lands in this area should be opened for leasing.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The federal land has been evaluated in an Environmental Assessment study with noncompetitive leasing now available.

The only work done in the area for resource definition was done by Phillips Petroleum. These results are unavailable.

The springs are presently used for a recreation spa facility.

..Projected or Planned Development: No planned or expected development is now known of.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The Environmental Assessment requirements are generally limited to enforcement of all regulations governing water and air quality, and protection of the basic environmental quality. (17)

..Agency and Public Attitudes:

..Status of Requirements (i.e., EIA/EIS Requirements): The Environmental Assessment Record is completed. There were no specific mitigating measures included. (17)

ENVIRONMENTAL FACTORS

..Climate:

..Prevailing Winds:

..Precipitation (Annual): 13 inches (33 centimeters) (67)

..Days of Sunshine (Annual):

..Average Temperature:

Minimum: 34°F (1°C) (67)

Maximum: 66°F (19°C) (67)

..Degree Days (Annual):

..Relative Humidity (Seasonal Peaks):

Summer: 35% (67)

Winter: 50% (67)

..Air Quality: Present air quality is generally excellent. Some land surfaces are susceptible to wind erosion. These dust storms are generally mild and infrequent. Smoke is sometimes generated from range fires and trash burning. (71)

..Water Quality: Water quality is excellent. Surface runoff is snowmelt supplied. Two excellent fishing rivers are present. Water is used extensively for irrigation. Almost all available water appropriation rights are private. The lower Big Hole River runs adjacent to the springs. (71, 39)

..Noise: No area industry is present other than occasional agrarian pursuits. The noise is representative of a fairly isolated woodland and prairie with the exception of areas near the highway and sparsely populated urban areas. (71)

..Biological:

..Dominant Flora: The primary plant life is big sagebrush and varieties of bunchgrass, with some forests of Lodgepole pine. (71)

..Dominant Fauna: The large animals present include mule deer, elk, antelope, and fish. (71)

..Endangered Species:

Flora: None (71)

Fauna: None (71)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

Electric:

50 KV lines	Adjacent to site
100 KV lines	10 miles (16 km)
230 KV lines	14 miles (23 km)

No natural gas lines are present.

Fuel oil and propane are hauled in via truck from the Dillon and Butte areas.

Telephone lines are adjacent.

..Transportation Corridors or Facilities:

State Highway 41	Adjacent to site
U.S. Highway 15	20 miles (3)

POPULATION

..General Description of Population:

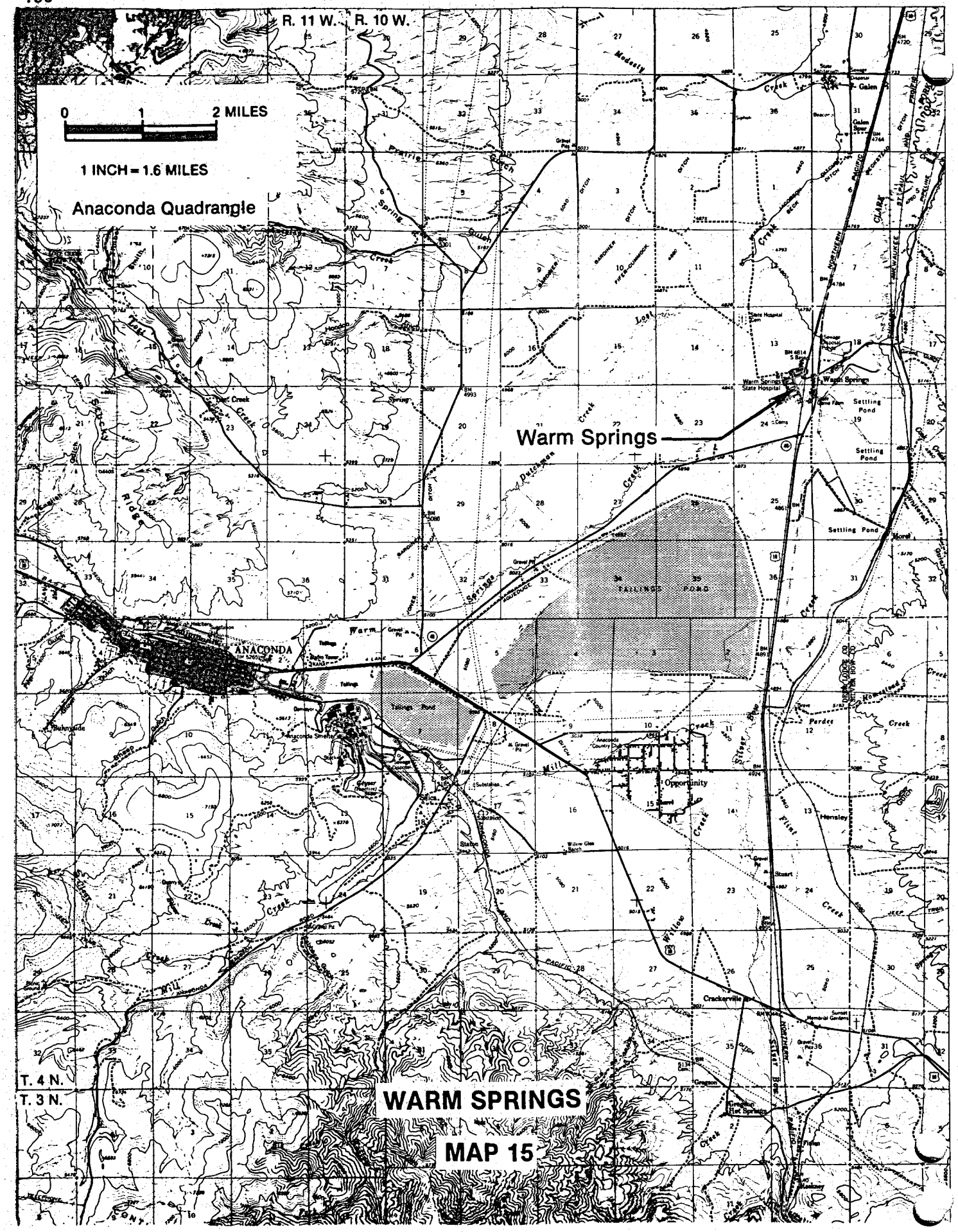
Closest Urban Centers:

Twin Bridges	9 miles (14 km)	613 population
Dillon	18 miles (29 km)	4,548 population

..Economics:

..Present Land Use: The majority of the area inhabitants earn their living from ranching and associated agriculture. The surrounding area is used for grazing and recreation. (71)

..Future Land Use: No change from the above is anticipated. (71)


R. 11 W.
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0 1 2 MILES
1 INCH = 1.6 MILES
Anaconda Quadrangle
Warm Springs
ANACONDA
Opportunity
Galen
Crackerville
Hensley
Tailings Pond
Settling Pond
T. 4 N.
T. 3 N.
WARM SPRINGS
MAP 15

Western Region

Subchapter K

WARM SPRINGS

Warm Springs is the site of the State Mental Hospital Complex. It is 11 miles (17.6 km) south of Deer Lodge in Deer Lodge County. The state of Montana purchased this site over 100 years ago as the location for the state mental hospital because of the therapeutic effects of the naturally occurring hot water. A facility was constructed which housed 1,900 patients. A number of the patients were able to participate in the operation of a greenhouse for supplying vegetables and a cattle operation. Hot water was used to heat the greenhouse and cow barn. The water was also used for showers and soak tubs for the patients. The declining patient population and remodeling of facilities finally shut down all uses of hot water by 1950. The present patient population is 380.

The hot springs are currently the second hottest surface springs in the state. The flow is moderate but can possibly be enhanced and the potential for heat production is moderate to good as compared to other sites in the state. The solids content and deposition problems require more costly equipment for heat extraction. The on-site use of this energy within the institutional complex to supply much of the presently required energy is a very good possibility. Other uses would be limited on-site, but adjacent land could be used for agriculture and aquaculture.

There has been some interest on the part of MERDI (Montana Energy Research and Development Institute) to heat the complex with the geothermal fluid. The problems associated with this proposal are sure to be economical rather than institutional in nature.

Resource Environment

Warm Springs is adjacent to U.S. Interstate 10 and 6 miles (9.6 km) from U.S. Interstate 90. Deer Lodge (population 4,306) is located 10 miles (16 km) to the north, and Anaconda (population 9,771) is 13 miles (21 km) to the south. Butte is located 24 miles (38.4 km) to the southwest and has a population of 24,000.

The site location is within a north-south trending basin in west-central Montana near the Northern Rocky Mountains physiographic province. There is a group of low mountains to the east and a higher, more rugged range to the west. The Clark Fork River drains the entire area in the northern direction. The springs are situated on the valley floor near the headwaters of the Clark Fork.

The spring surfaces in the top of a large carbonate mound. This water was valued in the late 1800s for its reputed therapeutic powers and was used to a large extent early in the 1900s. There is currently interest in again using the natural hot water for heating purposes within the state buildings.

The spring site is owned by the Montana Department of Institutions and used as a facility location for a state hospital. There are a number of buildings on this land. The surrounding land is mostly privately owned and the land use is primarily ranching and agriculture. No major economic base change or population density change is anticipated for the future. A land ownership breakdown for a radius of 6 kilometers shows 1 percent federal land, 10 percent state land, and 89 percent privately owned land.

The present energy is supplied in the form of natural gas and electricity. Fuel oil and propane are available from Deer Lodge and Anaconda via truck. The high cost of any conventional form of energy insures interest on the part of the local population for cheaper alternatives. Public attitudes should be good for direct-use implementation if it is economically desirable.

Geothermal Resource Description

The surface temperature of Warm Springs is 172°F (78°C). Geothermometry indicates a base or reservoir temperature range of 171°F to 383°F (78°C to 195°C). 176°F or 80°C seems to be the most probable available temperature. The total dissolved solids are low at 1250 mg/ℓ. The present flow has been measured recently at 50 gallons per minute (3 l/s) but past flows have been over 150 gallons per minute (9.5 l/s).

The spring issues form Tertiary valley fill sediments overlain by Quaternary alluvium. The underlying sequence is poorly known but the high calcium content of the water and the presence of a large travertine mound at the orifice suggest extensive contact of the water at depth with carbonate rock.

The capacity of the reservoir has not been investigated by drilling and pump tests. The strata from which the water is thought to originate is porous and known to be a good supplier of ground water. An extensive fault is thought to exist within a mile of the springs and may be the source of the heat transfer. The artesian nature of the surface manifestation shows significant hydraulic pressure at the reservoir depth.

Potential For Geothermal Development

The range of applications that are possible using surface temperature of 172°F (78°C) are illustrated in figure 2 on page 27.

Of the above uses only a few are economically feasible in this area. The most interesting use would be to heat the entire state facility including bathing and washing water. This could be easily done and would require heat exchangers to protect piping. This is the only promising use on the state land at the site. Good reservoir potential on some of the surrounding land would support space heating for domestic use. Although only sparsely populated at the present, cheap energy sources could draw more people.

Agricultural uses would benefit the most from this heat supply. Commercial processing of agricultural products for animal and human consumption would be possible with reservoir temperature approaching 240°F (116°C).

Greenhouses could be economically supported at this location. Aquaculture is also a possibility if a sufficient freshwater appropriation is available. The absence of a population center other than the state facility limits some direct uses.

Interest in Development

The springs are not being presently used for any heating purpose. A study is ongoing to define problems associated with, and economic feasibility of, converting the state complex to geothermal heat. This study is being conducted by a nonprofit energy institute (MERDI) with a grant from the Montana Alternative Energy Grant Program. An associated geophysical research project is also being conducted to define the reservoir and select likely spots to drill for increased flow of hot water. This project is also funded by the Alternative Energy Grant Program.

There is another data collection project which is studying nearby Deer Lodge Warm Springs. This work is being conducted by the Montana Bureau of Mines and Geology which is a part of the Department of Energy's state-coupled program for reservoir definition.

Private interest has not been in evidence at this time. A program of information transfer in geothermal use possibilities is scheduled for the next planning project year. This is sure to generate private interest in using the geothermal resource.

Restrictions to Development

There should be few functional restrictions associated with development of a geothermal resource in this area. Most of the land is private on which leases will be comparatively easy to arrange. State leases are controlled by the current Department of State Land's policy which discourages individual lease applications at the present.

The common environmental restrictions will apply to this site. These are related to disposal of the warm water effluent and concern for the effects of water withdrawal of previous water right holders in the same area.

Scenario Discussion

The presented scenario illustrates one possible development which is concerned with the heating of the state hospital facility. The beginning date is postulated as 1978 and the process should take approximately 2 years for an energy production of 4×10^6 Btu/hr.

The assumptions for this scenario are:

1. State land owned by the Department of Institutions is to be used for the well with no further legal complications.

2. Money will be available for the capitalization of the well drilling supply system and retrofit of the existing heating system.

3. A sufficient reservoir capacity to supply hot water will be encountered at a reasonable depth.

4. The Department of Institutions would be willing to change over to the alternative source of energy.

Development of a resource on private land or leased state land would entail much of the same concerns. The difference would occur at the beginning of the process in the time needed to acquire the lease. Private land can usually be leased in a few months while state land would take a minimum of 6 months. This could slow to years under the present policy.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 10' 40" (31)

..Longitude: 112 47' 40" (31)

..Rectilinear: T. 5 N., R. 10 W., sec. 24, NE 1/4 (80)

..County: Deer Lodge

..Adjacent Counties: Powell, Branite, Beaverhead, Jefferson, Silver Bow

..Topography: The Deer Lodge Valley is a basin trending north-south in west-central Montana near the center of the Northern Rocky Mountains. It trends northward between a group of relatively low, rounded mountains to the east and the higher, more rugged Flint Creek Range to the west. The Clark Fork and its tributaries drain the valley in a northerly direction.

The mountains in this area are locally known as the Deer Lodge Mountains and are mostly below 8,000 feet (2438 m), but a few attain altitudes of more than 8,500 feet (2590 m). The valley topography is dominated by great terraces, designated here as high terraces that slope gently downward from the mountians and end in abrupt scarps above low terraces bordering the broad flood plain of the Clark Fork. The flood plains of the tributary streams coalesce and merge with the low terrace along the Clark Fork River.

The Warm Springs are located on the valley floor near the headwaters of the Clark Fork drainage. The area is flat at approximately 4,813 feet (1467 m). (59, 64, 78)

..Present Land Use: The site is presently used as a location for the Warm Springs State Hospital and a state game farm. The surrounding area is used for agricultural activities or smelter process water treatment.

..Future Land Use Plans: No change is expected for the near future.

..Aesthetics: In early years, miners roamed at large, sinking shafts, digging and cutting trees. When a hole fizzled out, it was left open; consequently, a large amount of disturbed area is present. This area is not subject to intensive tourist use. Development in the valley would be open to visual scrutiny as the land is relatively flat with little cover. Direct-heat use should not pose any large aesthetic problems.

..Historical/Archaeological Significance: The Upper Clark Fork River Valley served as a main travel route for several Indian tribes on their way to and from buffalo country to the east. Early day trappers and traders followed this same route. In 1852, gold was discovered which led to settlement of the area. It has been populated continuously since.

SITE LOCATION AND PHYSICAL DESCRIPTION
(continued)

Deer Lodge County is the site of the famous Washoe Smelter which processes copper ore from Butte. This operation began in 1883 and is important for engineering and industrial advances. Nearby is the Georgetown-Southern Cross Historic District which was a minor gold mining area (1857).

No archaeological sites have been discovered in Deer Lodge County, although the area is rated as high for future discovery potential. (43, 64)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: The mountains east of the Deer Lodge Valley are formed primarily of Cretaceous sedimentary and volcanic rocks and lower Tertiary granitic rocks. Those mountains to the west of the valley are formed of Precambrian to Cretaceous sedimentary rocks and a core of lower Tertiary granitic rocks. Geophysical data indicates that the valley is a deep graben which formed in early Tertiary time after emplacement of the Boulder and Philipsburg batholiths. During the Tertiary Period, the valley was partly filled to a maximum depth of more than 5,500 feet (1676 m) with erosional detritus that came from the surrounding mountains and was interbedded with minor amounts of volcanic pyroclastics. This material was deposited in a large variety of local environments, resulting in extremely variable lithology. The deposits grade from unconsolidated to well-cemented, clay to boulder-sized aggregates. The strata dips gently towards the valley axis in most of the area, but along the western margins of the valley they dip steeply into the mountains.

The main source of ground water in the Deer Lodge Valley is the upper few hundred feet of unconsolidated valley fill. Most of the existing wells drawing from these deposits range in depth from a few feet to 250 feet (76 m). Water levels range from somewhat above land surface (in flowing wells) to about 150 feet (46 m) below. (78)

The hot water issues from a sequence of several thousand feet of Tertiary valley fill sediments overlain by thin quaternary alluvium. The Tertiary sediments include unconsolidated to well-consolidated siltstone, shale, arkosic sandstone, sand conglomerate, gravel, volcanic ash, bentonite, limestone, and dolomite. The underlying sequence is poorly known, but the high calcium content of the waters and the presence of a large travertine mound at the orifice suggest extensive contact of the water at depth with carbonate rocks.

A north-northeast trending fault is thought to exist 1/2 to 1 mile (402 m to 1609 m) east of the springs where gravity and magnetic values decrease rapidly westward. A reservoir located in the calcareous beds of the Tertiary sedimentary fill or deeper Paleozoic or Mesozoic carbonates may supply water through a fault plane migration to the discharge point. (10)

Geophysical Summary: The U.S. Geological Survey performed a gravimetric survey in 1961. Results are contained in the Water Supply Paper 1862, along with geologic mapping from aerial photographs.

The geology of part of the area was mapped in a Doctoral Thesis by Thomas A. Mutch of Princeton University in 1960.

There are several geophysical data collection projects occurring in the area at this time. A warm springs site on the Montana State Prison Ranch is being assessed using seismic, gravity, and resistivity to locate positioning of wells for hot water. A similar project for the area, including Warm Springs, is slated to begin soon. The main investigative agency is the Montana Bureau of Mines and Geology which is the U.S. Department of Energy's state-coupled program for reservoir definition.

GEOLOGICAL/GEOPHYSICAL DESCRIPTION
(continued)

The water from Warm Springs has been analyzed for fluid chemistry and geothermometry.

A preliminary resistivity study of the spring site was done by the Montana State University, Earth Sciences Department.

RESERVOIR CHARACTERISTICS

..Reservoir Temperature

..Surface: 172°F (78°C) (31)

..Subsurface:

..Geochemical:

SiO_2: Chalcedony 171°F (78°C) Quartz 225°F (107°C)

Na-K-Ca: Na-K-1/3 Ca 383°F (195°C) Na-K-4/3 Ca 176°F (80°C) (80)

..Flow Rates: 50 gpm (190 l/m) (31)

..pH: 6.6 (31)

..Total Dissolved Solids: 1250 mg/ℓ (31)

..Fluid Chemistry:

Conductivity	1465
Hardness (Ca, Mg)	570 mg/ℓ
Ca	190 mg/ℓ
Mg	22 mg/ℓ
Na	130 mg/ℓ
Bicarbonate	254 mg/ℓ
SO_4	680 mg/ℓ
Cl	5.7 mg/ℓ
F	2.4 mg/ℓ
SiO_2	53 mg/ℓ
B	300 mg/ℓ

Additional analyses of various parameters are available. (31)

The springs surface in the top of a large carbonate mound. Some gas is present. (80)

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership (6 km radius):	28,250 11433 (hec)	1%	10%	89%	0
..Land Leased:	None				
..Highest Priced Leases (Dollars/ Acre):	N/A				
..Tentative Lease Sale Dates:	N/A				
..Number of Sales Offered But No Bids:	N/A				
..Number of Bids Rejected (Resulting in No Lease):	N/A				

..Summary of Leasing Status and Needs: Most of the land in the study area is privately owned. A small amount of state land could be leased. Private land would be available for lease if interest should increase.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The springs are not being used at this time.

A study by the Montana Energy Research and Development Institute of Butte is ongoing with a grant from Montana's renewable energy grant program. The purpose of this study is to determine the feasibility and design of a space heating system for the state hospital nearby.

The Montana Bureau of Mines is conducting various geophysical exploratory methods to characterize the reservoir at the Warm Springs site.

..Projected or Planned Development: The projected development at this site is to heat the entire hospital complex with the hot water from the springs.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The State Department of Institutions owns much of the state controlled land which limits the potential for outside (private) use, unless private land is bought or leased from the owner.

..Agency and Public Attitudes: The attitudes of all concerned parties are very good.

..Status of Requirements (i.e., EIA/EIS Requirements): No special requirements are present. The state may have to have a ruling by the Department of State Lands on leasing applicability of state land owned by the Department of Institutions.

ENVIRONMENTAL FACTORS

..Climate:

..Prevailing Winds: Variable, average speed 6.3 mph (10 k/hr) (67)

..Precipitation (Annual): 10.5 inches (26.7 cm) (67)

..Days of Sunshine (Annual): Approximately 190 days (69)

..Average Temperature:

Minimum: 25.3°F Lowest: -22°F

Maximum: 62.5°F Highest: 89°F (67)

..Degree Days (Annual): 8407 (69)

..Relative Humidity (Seasonal Peaks):

Summer: 31% - 80%

Winter: 38% - 70% (67)

..Air Quality: Air quality is considered to be excellent except during times of slash burning or large wildfires in the west. Air quality requirements are high. (64)

..Water Quality: Most of the streams flow through glacial till and Tertiary sediments into the Clark Fork River, a tributary of the Columbia River. This stream is rated as B-D_1 by the State Water Quality Bureau which indicates high enough water quality requirements for most uses without pretreatment. Private water rights cover most surface supplies. (39)

..Noise: Noise at the site is characteristic of a community health institution. The Interstate Highway runs adjacent to the site, contributing road noise to most of the surrounding area.

..Biological: The following data applies to Deer Lodge National Forest, located about 5.6 miles (9 km) east and west of Warm Springs. The site area is institutional with surrounding land utilized in agricultural pursuits.

..Dominant Flora:

Lower Slope (Foothill Zone): Grassland types, Douglas fir, lodgepole pine, rabbitbrush, sagebrush, bitterbrush, and mountain mahogany.

General Forest: Lodgepole pine, some Douglas fir, englemann spruce, subalpine fir, and meadows have grasses, sedges and forbs.

High Area Zone: Scrubby alpine larch, whitebark pine subalpine fir, spruce, and lodgepole pine. Alpine meadows. (59)

ENVIRONMENTAL FACTORS
(continued)

..Dominant Fauna: Mule deer and elk are abundant with small populations of antelope, whitetailed deer, moose, goats, sheep, and black bear.

Rare species include arctic grayling and grizzly bear.

..Endangered Species:

Flora: None

Fauna: Montana West Slope cutthroat trout (59)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

Electric: 100 KV 5 miles (8 km)

Natural gas is available via pipeline adjacent to site.

..Transportation Corridors or Facilities:

U.S. 10	Adjacent to site
U.S. 90	6 miles (9.6 km)

POPULATION

..General Description of Population: The state hospital complex has 500 people full time. The nearest populations are:

Deer Lodge	10 miles (16 km)	4,306 population
Anaconda	13 miles (21 km)	9,771 population

The surrounding area consists mostly of rural families.

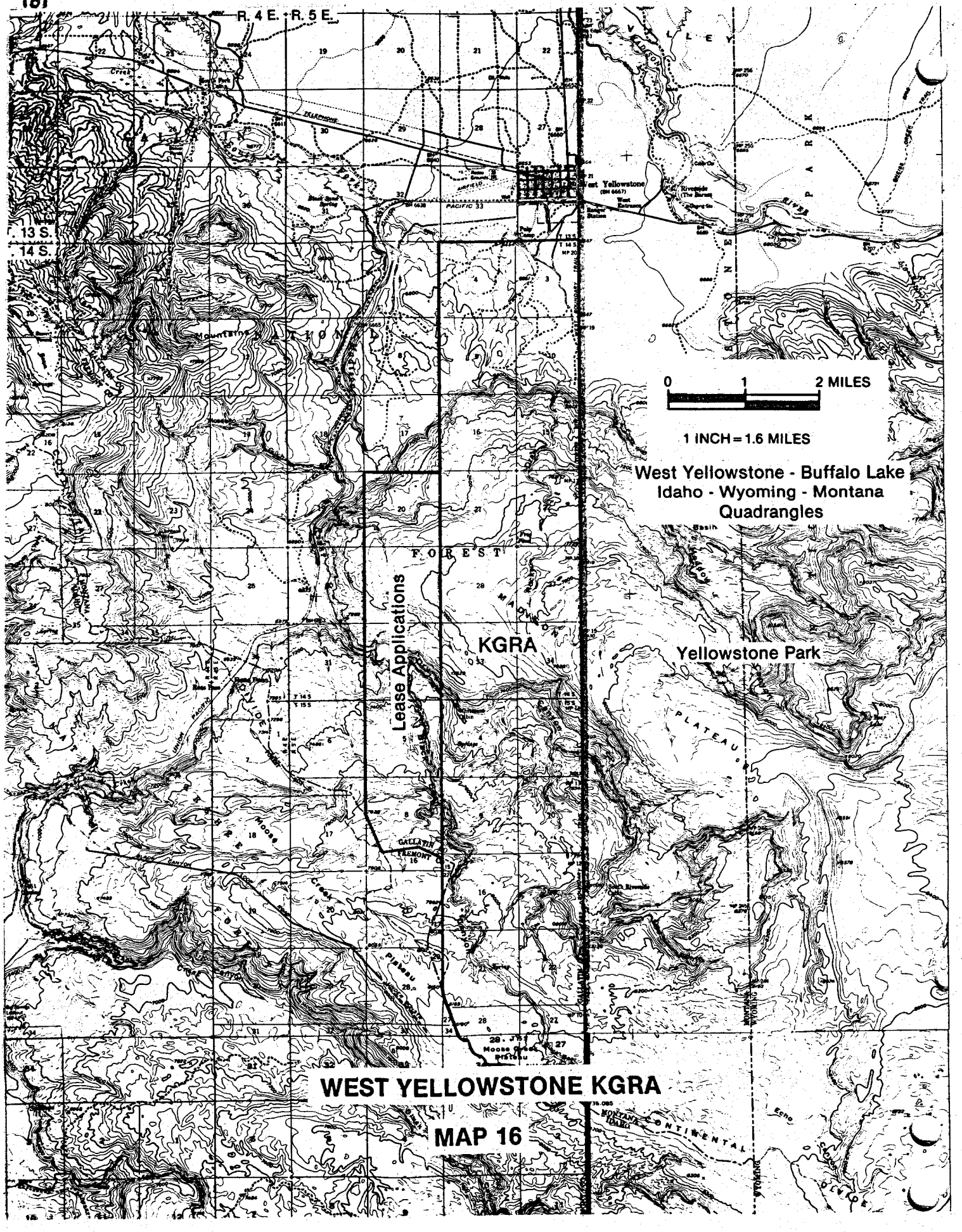
..Economics:

..Present Land Use: The area wide land uses include commercial forest production, livestock grazing, and recreation.

Agriculture and ranch activities use a majority of the valley area. Much of the land around Warm Springs is used for a settling pond for the Anaconda Copper Company. Ore smelting and copper mining are conducted in the near vicinity.

Potatoes are the largest cash crop in the valley; this area being one of the largest producers of potato seed in Montana. Wheat, barley, and corn are also grown.

..Future Land Use: The future should remain much the same as the present.


R. 4 E. R. 5 E.
T. 13 S.
T. 14 S.
West Yellowstone
Lease Applications
KGRA
Yellowstone Park
0 1 2 MILES
1 INCH = 1.6 MILES
West Yellowstone - Buffalo Lake
Idaho - Wyoming - Montana
Quadrangles
WEST YELLOWSTONE KGRA
MAP 16

Western Region

Subchapter L

WEST YELLOWSTONE KGRA

The West Yellowstone KGRA is a narrow strip of land located adjacent to the western boundary of Yellowstone Park, north of the Continental Divide. The city of West Yellowstone is on the northern edge of the KGRA. This area is among the southernmost areas of the state of Montana.

The study area has good potential for containing a high output geothermal resource due to its proximity to the surface indications of heat in Yellowstone Park. The highest potential would be for electrical production. The very young volcanic nature of the geology indicates a high probablity of finding sufficient temperatures for producing the desired quantities of steam.

The direct-use potential is somewhat lower. The only users of a hot water resource which are within piping distance is the town of West Yellowstone. This community has a low resident population but could use the energy for its large tourist trade. There is a total of 10,528 acres of private land excluding West Yellowstone or the airport in the West Yellowstone Basin. Little of this is near the KGRA. The town of West Yellowstone would very likely recieve the idea of a district heating system favorably if protection of the geysers in the park is assured.

There are geothermal resource lease applications on file in the study area submitted by energy development corporations who are hoping for sufficient temperatures for steam generation. An EIS is being prepared at this time for the entire West Yellowstone Park area and the Island Park area to the south. The nature of the area and its proximity to the park are sure to produce some limiting restrictions on development of the resource.

Site Description

The study area is located about 90 miles (144 km) south of Bozeman, Montana. West Yellowstone is the only western entrance of the park, and is located north of where the southern boundary of Montana is marked by the Continental Divide.

Yellowstone Park is the site of some of the most recent volcanic activity in the continental United States. The youngest volcanic deposits are the Yellowstone rhyolites, which were deposited 70,000 to 150,000 years ago. Recent volcanics are a sure indication of substantial heat sources relatively close to the surface of the earth. There are many active surface manifestations of geothermal heat in the park, with Norris Geyser Basin to the north and the system including Old Faithful to the south of West Yellowstone being vivid demonstrations of residual magmatic heat in this area. The Yellowstone KGRA along with its counterpart, the Island Park KGRA immediately across the border to the south in Idaho, are the closest section of land to surface springs and geysers in the park.

The whole region to the west of Yellowstone Park is primarily national forest lands, with sparse population distribution. Bozeman is the nearest large city, with a population of 19,000. There are several very small communities to the south in Idaho.

The West Yellowstone Basin is surrounded by mountains on all sides and covers 30 square miles (77 km^2). Basin elevations range from 6,496 feet (1980 m) to 6,696 feet (2,041 m) at the foot of the mountains. Peaks rise 2,000 to 5,000 feet (610 m to 1,524 m) above the basin floor. The basin is essentially a high plateau surrounded by rugged mountains.

The area, being U.S. Forest Service land, is used for summer and winter recreation, timber harvest, and a small amount of stock grazing. The whole plateau area outside of the area is subject to timber sales which is being harvested due to a mountain pine beetle infestation. This bug attacks mature timber which requires that the wood be harvested to salvage the resource before it dies and becomes unusable. In addition, the increasing popularity of winter sports will increase use of this area in the future.

The only significant number of year-round inhabitants reside in the town of West Yellowstone. This community depends on summer and winter tourism and recreation for existence. There is a nonoperating sawmill which has employed 33 people in the past. Tourist support facilities provide the primary source of income. There are 59 motels, 22 restaurants, 9 bars, and 14 service stations in the town. The approximate year-round population is 1,000 persons, with periodic influxes of tourists amount to thousands during the peak seasons. Last year the snowmobile races drew as many as 15,000 people.

The KGRA encloses about 12,763 acres (5165 hectares), all of which is U.S. Forest Service administered land. The study area is larger with 42,400 acres (17,163 hectares) and contains a small, idolated amound of land controlled by the BLM. There is also a small amount of private property and state owned lands.

West Yellowstone has an electric corridor which supplies energy to the community. Propane and fuel oil is trucked in from the south and north. Some of the domestic housing utilizes wood to supply part of the heat requirements. This source is quite plentiful.

The people of West Yellowstone depend on tourism for their economy. The tourists come because the land is beautiful and the air is clean. The attitude toward geothermal development is colored by the concern for keeping a continuous tourist trade. Direct use of hot water for space heating is considered as a novelty. This attitude, coupled with a concern for the effect of tapping the geothermal resource on the park's thermal manifestations, develops a negative attitude towards any kind of resource development. The area residents are very interested in maintaining a status quo in the present economy. Economic viability of a district heating system itself will have little effect on the acceptability of such a proposal.

Geothermal Resource Description

The study area is devoid of the usual indications of geothermal activity. This can be explained in part by the geology. Much of the surface rock is volcanic sands which is over 1,000 feet (305 m) thick. Since this layer is extremely porous, one can expect water to penetrate and move laterally with the gradient. This is, in fact, what happens since the area is a gound water recharge area for the Snake River Plain to the south. Hot water would not show up on the surface or even near the surface. There are numerous bare warm spots often surrounded by 10 feet (3 m) of snow.

Recent geophysical and geological data suggests that the Snake River plain is an area of crustal weakness that has opened northerly as a propagation fracture, with the tip of the fracture at Yellowstone. This model would explain the presence of active seismicity and crustal fracture accompanied by widespread volcanism. This area is a part of the Intermountain Seismic Belt, a north-trending zone of seismicity in the western United States. Shallow focal depth of less than 9 miles (15 km) characterizes the seismicity.

Potential for Geothermal Development

The utilization profile is very hazy at this time since very little is known about the temperatures, quantities, and precise locations of hot water springs which might be present. The theoretical reservoir temperature cannot be calculated since there aren't any known sources of hot spring water.

As an alternative to listing possible users, we will consider the range of temperatures needed to be usable in the West Yellowstone area. The limited privately owned land in West Yellowstone precludes many possible uses of hot water. There isn't room for aquaculture or greenhouse facilities and there is little manufacturing or industrial activity in the area. The lumber mill would possibly use heat for a dry kiln operation if it were to be reactivated. This occurrence could be enhanced by the cutting of large sections of mature lodgepole timber. The temperature needed for this use would be in the range of 250°F to 300°F (121°C to 149°C). Space heating of the whole town of West Yellowstone is the obvious direct use of the resource. This would require a temperature of at least 180°F (82°C) ideally. The water could be used to heat homes and businesses, melt ice on sidewalks and streets, and provide hot water for bathing, swimming, and cleaning purposes. Electrical production, using present economic models, requires temperatures over 400°F (204°C) for efficient use of capital resources.

All of the above-listed uses would be economically viable, providing that the reservoir is close enough to th surface. It is possible that the discharge waters from an electrical facility could be used in a cascade style to supply the community with heat. In all of the listed uses, piping distances from the well to the user is critical to the economics.

Interest in Development

The Yellowstone KGRA was designated in April of 1971 after the passage of the 1970 Geothermal Steam Act. From this time until 1975, only 4 lease applications were received for the area outside of the KGRA. More than 150 lease applications were received for the Island Park area to the south. As a result of these applications, the Island Park KGRA was designated. These 2 areas will be studied and leased as a unit. The lease applications for the Yellowstone KGRA are on record, indicating development interest is still present. The real test will result from completion of the EIS and subsequent lease sale covering competitive and noncompetitive lease lands.

The lease applications in the Yellowstone study area are held by Phillips Petroleum with 3,143 acres (1272 hectares) in 5 parcels which are located outside the KGRA.

Restrictions to Development

The EIS will be completed in late 1978, with a projected lease sale to be held sometime in late 1979 or 1980. The specific lease restrictions will not be available until the time of leasing. There are several important environmental problems involving various animal species which use the area as a habitat. The most important is the grizzly bear, which is a threatened species protected by a federal law. This will require withdrawal of a large section of land to be left undeveloped. This will most likely be the area on the Continental Divide.

A large part of the area is rather flat with little danger of disrupting critical animal habitats. Also, the visual aesthetics are minimal considerations since the installation of facilities will not be visible for long distances. This same area will be subjected to a massive logging operation which will further negate environmental impacts from site development.

A major concern of people interested in the future of the area is the possibility of affecting the workings of such landmarks as Old Faithful by withdrawing water and steam. Lease stipulations may or may not address this possibility, but it seems evident that the first hint of change seen in the thermal features inside the park, the development outside the park will be the target of the hue and cry.

Scenario Discussion

The scenario for the Yellowstone KGRA includes two different uses. The first time limit will describe electrical production. The assumptions used to construct the scenario are as follows:

1. Federal land is to be leased.
2. A resource of sufficient economic quality could be located.
3. EIS stipulations for leasing will not be unduly restrictive.

The minimum power generation facility likely to be developed is a 100-megawatt unit. A single event is traced from inception to power-on-line. Many more events would occur if the resource proves to be adequate. These are not postulated in deference to the scarcity of reservoir data. The starting date is 1980, with a total of 9 years for power-on-line for the first unit.

The second use describes the direct use of hot water by the local population. The estimated energy use for heat and hot water within the town of West Yellowstone is 20 x 10^6 Btu/hr. This amount, and a possible additional quantity for ice and snow melting would be replaced with geothermal heat. The economics and local environment were considered and incorporated in the single time line. The event outlined is the development of a complete district heating system for the town of West Yellowstone. This might also occur, incidentally, with the development of a power generation facility. The construction of a kiln for drying lumber is not specifically described in the direct-use scenario. This industry may be able to use either source above, or it may have to drill a single-use well of its own. The starting date is 1982, with 7 years required for completion.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 44 39' N (68)

..Longitude: 111 06' W

..Rectilinear:

..County: Gallatin

..Adjacent Counties: Beaverhead, Mt. Fremont, Idaho

..Topography: The West Yellowstone Basin is surrounded by mountain ranges on all sides and covers roughly 77 square kilometers, including a small area of Yellowstone National Park and Hebgen Lake. Basin elevations range from 1980 meters along the shoreline of Hebgen Lake to 2041 meters where the basin plateau starts sharply upward to mountain ranges 610 meters to 1524 meters above the basin floor. The Continental Divide lies within 16 kilometers to the west and southwest. The basin is essentially a high plateau surrounded by rugged mountains. (68)

..Present Land Use: Outside of the small area occupied by the town of West Yellowstone, the major land uses are as follows:

1. Summer and winter recreation.
2. Timber harvest.
3. Stock grazing. (62)

..Future Land Use Plans: Expected to remain essentially the same with increases in the timber harvest due to massive infestations of the mountain pine beetle. An increase in tourism is expected. (46, 62)

..Aesthetics: This area is subject to intensive tourist use. West Yellowstone is a major entrance to the park and a base for wide-ranging winter sports use. It has become a popular snowmobile and cross country skiing area. The visual qualities of the surrounding landscape are a large factor in the increasing popularity. Much of the land is flat and visual distances are short. This will permit development in much of the study area without damaging the existing aesthetic resources. Site development will have to consider the existing scenic visual and audio resources.

..Historical/Archaeological Significance: Relics indicate Indians used the valley as early as 10,000 B.C. A well-used Indian trail existed from the Henry's Lake area over Targhee Pass through Hebgen Lake Valley into Yellowstone Park and over to the Wyoming Plains. Bannock and Shoshone used this trail into the 1800s. The first known white visitor arrived in 1834. The park was created in 1872 and West Yellowstone opened for homesteading in 1873. West Yellowstone initially existed to serve the 100-day tourist season in Yellowstone Park. Now with the current snowmobile boom, the town is a year-round resort area.

SITE LOCATION AND PHYSICAL DESCRIPTION
(continued)

It is known for deep snows and long cold winters. The area was abandoned each winter until 1964 when the snowmobile became common. Now a winter demand for facilities has developed around snowmobile use out of West Yellowstone. The town has become a year-round resort. (62)

Fourteen sites, including the Bannock Trail, have been identified by Davis (1973). The potential for future archaeological finds is good. (62)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geological Description: The Yellowstone National Park region is located at the northeast end of the Snake River plain. This is a 300-mile (500 km) long northeast-trending basalt-filled depression which has been postulated as a rift formed by crustal extension. Evidence suggests that the adjacent mountain blocks may have been tilted down during subsidence and volcanic filling of the Snake River plain. Also, the basin and range normal fault systems that trend north-south parrallel to the Intermountain Seismic Belt terminate at Yellowstone and then push northwest into Montana, north of Yellowstone.

Dating of volcanic rocks from the Snake River plain indicates that the foci of volcanic inception along the plain have progressed northeasterly from southwestern Idaho to Yellowstone beginning 15 million years ago. The youngest major volcanic units of this progression are Yellowstone rhyolites that were deposited 70,000 to 150,000 years ago.

On the basis of recent geophysical and geological information, it has been suggested that the Snake River plain could be an indication of a lithospheric zone of weakness that have opened northeasterly as a propagating fracture. This hypothesis would place the tip of the fracture at Yellowstone with resultant stresses producing active seismicity and crustal fractures which would facilitate widespread volcanism.

..Stratigraphy: Precambrian crystalline rocks are widely found in the Madison Range and near Hebgen Lake where they are exposed beneath the Paleozoic rocks or Tertiary volcanic rocks. These crystalline rocks are of pre-belt age and consist of various gneiss, schist, dolomites, amphibolites, and quartzites. Granitic rocks are also found in the Madison Range north of the Hebgen Dam.

The Precambrian crystalline rocks are overlain in the study area by about 8,000 feet (2438 m) of bedded sedimentary rocks that represent 5 of the 7 Paleozoic systems and all of the Mesozoic systems.

The southern part of the Madison Range is composed chiefly of a sequence of volcanic rocks to a depth of about 1,500 feet thick. Welded rhyolite tuff, olivine basalt, olivine trachyandesite, and leucite basalt are present. The age dating of a sample found low in the sequence dates it as of Oligocene age. The volcanic rocks have been raised several thousand feet and subjected to extensive erosion.

The Madison and central plateaus are formed mostly of enormous rhyolite flows of late Quaternary age. The youngest flow in the study area overlies moraines of both advances of the Bull Lake glaciation, but was subsequently eroded by a Pinedale Valley glacier.

..Seismicity: The Intermountain Seismic Belt, a north-trending zone of seismicity in the western United States, is thought to be a boundary between subplates of the North American crustal plate. This seismic activity closely

GEOLOGICAL/GEOPHYSICAL DESCRIPTION
(continued)

follows the boundary between the Great Basin and the Colorado Plateau-middle Rocky Mountains, and extends northwest into the northern Rocky Mountains. Shallow focal depths, less than 9 miles (15 km), characterize the seismicity. Earthquake swarms, which can be coincident with geothermal features and areas of high heat flow, also occur.

Earthquakes of both large and small intensity are concentrated within this seismic zone. In August 17, 1959, at Hebgen Lake, Montana, a major earthquake occurred and much surface phenomena was recorded. The magnitude was 7.1 on the Richter scale as measured in Pasadena, California. In Montana, 6 earthquakes with intensities of M.M. VIII (Modified Mercalli scale) or greater have occurred since 1868. (25, 50, 52, 53, 84)

..Geophysical Summary: Earthquake surveys, aeromagnetic surveys, and heatflow measurements have been completed. (53)

There has been no other resource definition for the area with the possible exception of private surveys by the oil companies or geothermal developers. This information is not available to the public.

A wildcat oil well is planned for the Hebgen Lake area for the fall of 1978. The Forest Service required that temperature measurements be logged as part of the permit stipulations. (46)

..Geologic Hazards: As was mentioned previously, the occurrence of earthquakes is frequent for this area. The last large quake was in 1959, and did a great deal of surface damage. The property damage was large but not catastrophic. The presence of unstable landforms is high in some areas and should be investigated as a prelude to any construction project.

RESERVOIR CHARACTERISTICS

..Reservoir Temperature:

..Surface: No flowing surface manifestations exist except for a few "warm" springs (20°C) and numerous bare, warm spots, often surrounded by 3 meters depth of snow.

No direct reservoir assessment work has been done to date. (46)

..Subsurface:

..Geochemical:

SiO_2:

Na-K-Ca:

..Flow Rates:

..pH:

..Total Dissolved Solids:

..Fluid Chemistry:

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Insufficient assessment data for competent guess. There is a possibility of ecnountering magma at a depth of 5 kilometers within the Yellowstone caldera. (53)

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership KGRA	12,763				
..Lease applied for:	3,143				
..Land Leased:	0				
..Highest Priced Leases (Dollars/Acre):	N/A				
..Tentative Lease Sale Dates:	5/79				
..Number of Sales Offered But No Bids:	N/A				
..Number of Bids Rejected (Resulting in No Lease):	N/A				

Phillips Petroleum has applied for 5 parcels outside the KGRA area totalling about 3,143 acres.

..Summary of Leasing Status and Needs: By 1975, more than 150 lease applications were received for Island Park and only about 4 were in Montana and West Yellowstone. (4)

All further leasing activity is curtailed until completion of the current Environmental Impact Statement study.

LEASE DATA FOR WEST YELLOWSTONE KGRA

Phillips Petroleum Company

Leases Applied For			Acres	Lease Applica II
Sec 5	T15S	R5E	640	M27443
Sec 8 (Partial)	T15S	R5E	583	
Sec 20	T14S	R5E	640	
Sec 29	T14S	R5E	640	M27454
Sec 32	T14S	R5E	640	

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The U.S. Forest Service is preparing an EIS for the West Yellowstone-Island Park KGRAs. This action was begun in September, 1976, and is projected for completion with a lease sale in late 1979. (4)

Earthquake surveys, aeromagnetic surveys, and heat flow measurements have been done for the West Yellowstone area. (53)

..Projected or Planned Development: Lease applications are on file with the USGS. A wildcat oil well is planned for the Hebgen Lake area during the summer of 1978. The Forest Service has written in requirements for temperature logging of the hole. (46)

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: The development requirements which will be dictated by the U.S. Forest Service and the U.S. Geological Survey will not be known until completion of the EIS.

..Agency and Public Attitudes: The public comments which are currently available show much concern for the aesthetics and environmental protection of the area. The presentation of the development of this resource has been rather one-sided in that the need for domestic, clean, and renewable energy sources is critical in the U.S. and has not been brought out in the evaluation process. If the public is made aware of the tradeoffs which will be made at some level at some point in the energy-starved future, a more meaningful development program would be sanctioned at this time.

..Status of Requirements (i.e., EIA/EIS Requirements): The Environmental Impact Statement is being written at this time. The draft was sent out for the review in August, 1978. The final statement should be available in 1979.

ENVIRONMENTAL FACTORS

..Climate: The chief characteristics of the climate are short, cool summers; the long, rigorous winters, with a tendency to linger late in the spring; and the usually pleasant open fall. The severity of the winters is not due so much to prolonged periods of extremely low temperatures, but rather to the persistence of comparatively low temperatures and cloudy, unsettled weather with frequent light snows. (14)

..Prevailing Winds: From the east, with a mean speed of 10 mph (4.5 m/s). (68)

..Precipitation (Annual): 22.7 inches (57.6 cm). Area is snowbound 8 months of the year. (77)

..Days of Sunshine (Annual):

..Average Temperature:

	January	July
Minimum:	-4°F (-18°C)	38°F (3.3°C)
Maximum:	25°F (-3.9°C)	79°F (26.1°C) (62)

..Degree Days (Annual): 10,879 Heating. (68)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: An air analysis by the U.S. Geological Survey in the fall of 1975 found good quality air with pollutants coming from slash burning, dust from road traffic, farming, and auto emissions. (50) Temperature inversions are common. (62)

..Comments and Critical Issues: The Madison Plateau is relatively well suited for geothermal development due to its flat nature, absence of surface water, and ability to mask the visual effects of development. The large timber sale covering this area will mitigate any construction effects to the environment. (46)

According to federal law, the grizzly bear habitat must be protected as it is an endangered species.

The area along the Divide and west will most likely be closed for the protection of the grizzly bear habitat. (46)

..Water Quality: The quality of the Madison at this point is good, being of sodium bicarbonate chloride type containing high concentrations of silica. Higher than normal potassium and flouride is also present. The sandy volcanic nature of the soils makes the occurrence of surface impoundments and streams rare.

ENVIRONMENTAL FACTORS
(continued)

There are a few tributaries of the Madison River present, and Hebgen Lake to the west is the only body of water of any size. The sandy soild may be the reason that no surface manisfestations of geothermal energy are present. This whole area is the source of ground water recharge for the area in Idaho to the southwest. (46, 62)

..Noise: Normal amounts of man-made noise associated with uses listed previously. There is an abnormal amount of noise from snowmobiles in winter time use.

..Biological:

..Dominant Flora: Douglas fir, alpine fir habitat, seral-lodgepole pine stage, 87 percent forest (lodgepole, Douglas fir), 13 percent nonforest (grasses, forbes, shrubs, sagebrush, meadows, riparian habitat). (77)

..Dominant Fauna: Elk use area for migration, calving, and summer range. Mule deer and moose use area for winter and summer range and calving. (50) Bighorn sheep, mountain goats, mountain lions, black bear, and game birds are also present. (4)

..Endangered Species:

Flora: None

Fauna: None

Threatened Species: Grizzly bears use some of the area for den area and summer and winter range. (77)

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

50 KV	17 meters (27 km)
46 KV	10 meters (16 km)

There are electric and natural gas corridors supplying the city of West Yellowstone as well as within the city itself. (20)

..Transportation Corridors or Facilities:

Highway U.S. 287 and Highway U.S. 20, 191 access the area.

Many logging roads throughout the area make easy access. Snow closes all of these roads for 8 months of the year.

POPULATION

..General Description of Population: The population of this area is in a somewhat unique situation, in that almost 100 percent of the surrounding land is owned by the U.S. Forest Service. There are a few isolated private parcels. The town of West Yellowstone is only a few hundred acres in size with no room for growth. It is rumored that the Forest Service is considering giving (selling?) an additional 160 acres to the town for strictly residential growth. The town's economy is dependent on tourism. It has about 22 restaurants, 14 service stations, and 59 motels and hotels. The population is about 1,000.

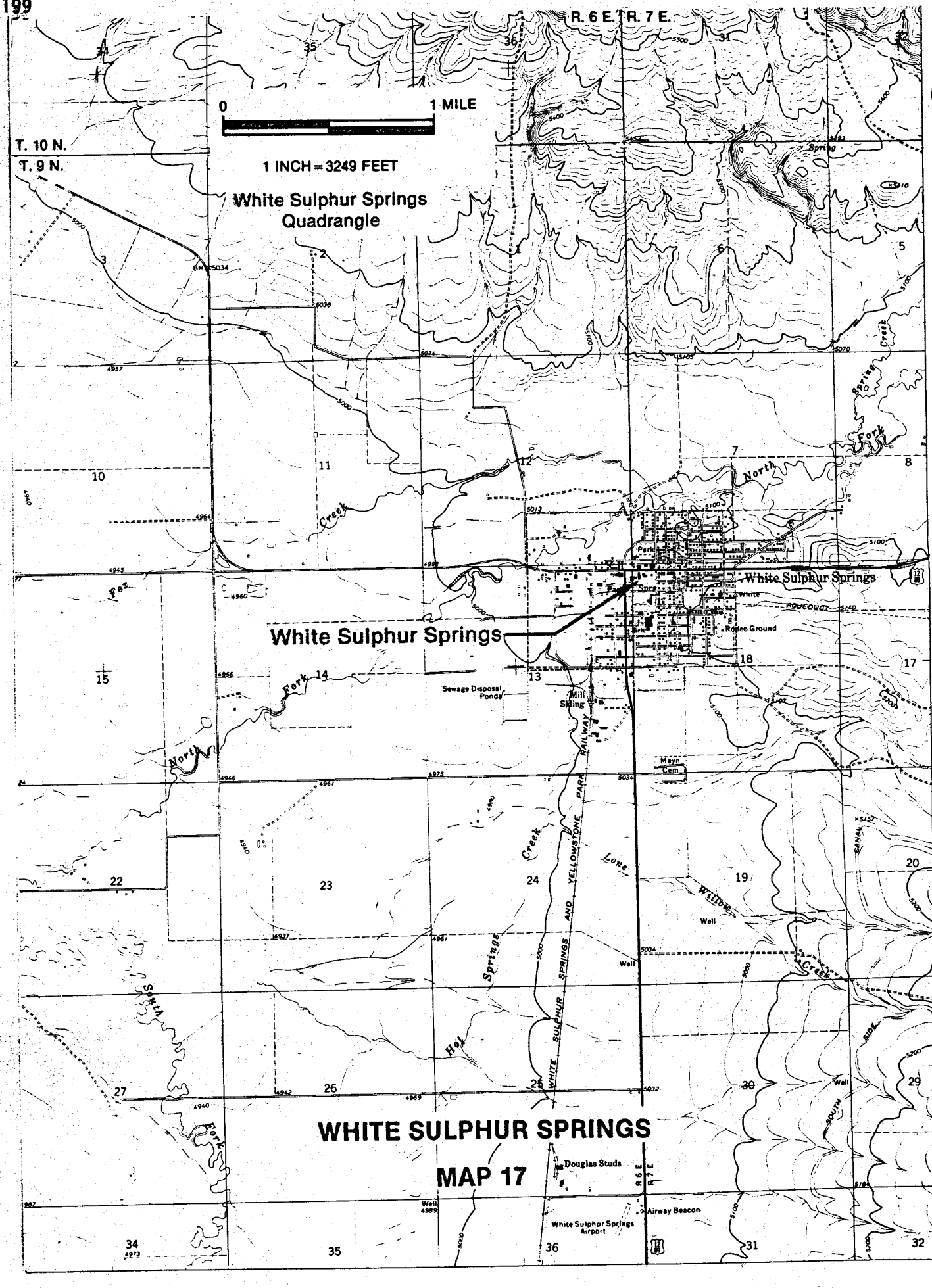
The nearest towns are:	Ennis	72 miles (115 km)	501 population
	Ashton, ID	55 miles (88 km)	population

There is a school with grades 1-12 and 270 students.

..Economics:

..Present Land Use: Most of the study area is U.S. Forest Service owned, with the town of West Yellowstone privately owned and the whole area adjacent to Yellowstone National Park. The economy was founded on seasonal tourism for the summer season. With the advent of the snowmobile, the winter demand for tourist facilities increased dramatically. Now there is a full-time population of about 1,000 which increases by thousands during the summer and by about an average of a thousand in the winter snowmobiling season. The motel accommodations have a total of about 4,000 beds. There is no farming, but a few livestock operations are present. The largest single timber sale ouside of Alaska was held in this area recently. It covered over 100 square miles and was necessitated by the infestation of the mountain pine beetle. There will be a great deal of wood available in this area for quite a few years. Employment outside of the town of West Yellowstone includes support facilities for recreation such as resorts, marinas, dude ranches, and real estate dealings in recreation home sites. (42, 46, 66)

..Future Land Use: If the Forest Service should decide to deed the extra parcel of land to West Yellowstone, the community would surely show a large growth. It is sure to increase in size and ability to accommodate tourists with increases in park use. Some population increases should be expected from the huge logging project to salvage the lodgepole pine resources. (42, 46)



WHITE SULPHUR SPRINGS

MAP 17

Western Region

Subchapter M

WHITE SULFUR SPRINGS

White Sulfur Springs is a town of about 1,200 people, located in west-central Montana, south of Great Falls, and east of Helena. An area near the center of the city was the site of a number of hot springs which were designated as neutral grounds for a number of conflicting Indian tribes. They would use the springs to bathe, the springs having religious significance common to these Indian groups. The hot water is presently used in a hotel swimming pool.

The geothermal use potential is rated as very high among the hot spring sites in the state. This rating is the result of the proximity to a nearby user in this case, the town of White Sulfur Springs. The community is an economic and trade center for this part of the state. Some lumber harvesting is done in the nearby mountains and the town is the only supply center for 70 miles for ranching and agriculture.

Interest in using the local resource has been very good. The motel spa owner has worked to increase his supply, and Montana State University has done some geophysical measurements to locate the heat anomaly. The First National Bank has been active in pursuing development of the natural resource to heat a new bank facility.

The site is a wide rolling valley situated on the north fork of the Smith River. The valley is bordered on two sides by rugged mountains. The elevations vary from 1295 meters at the north border of the Smith River, to over 2950 meters at Edith Mountain. Land ownership is mostly private with some state-owned parcels. There is a very good potential for extended use of the geothermal resource for space and water heating within the community of White Sulfur Springs.

Site Description

The rectilinear coordinants of White Sulfur Springs are section 18 of township 9 north, range 7 east. It is located in Meagher County about 92 miles (147 km) south of Great Falls, population 60,000, and 50 miles (80 km) east of Helena, population 23,000. This area is very sparsely populated and quite rural in nature outside the community.

The area economy is ranching whith associated agriculture. Tourism contributes on a seasonal basis. Lumbering is carried on in the surrounding mountains and the community has a sawmill located about one quarter of a mile (400 m) from the hot spring area. White Sulfur Springs is the home of the majority of the county population.

Land ownership is private with the municipal part being the previous site of the hot spring activity. Only 8 percent of the land in a 6-kilometer radius is state-owned, the rest being privately owned. The U.S. Forest Service controls the mountainous regions to the east and west.

The springs no longer flow from numerous vents, the major portion of spring area being covered over by asphalt or fill. The major spring orifice is enclosed within a wooden fence and is used by the Spa Motel. Another discharge seeps out of a fill bank across the highway.

The heating requirements are met with electricity, fuel oil, and bottled gas. Oil and bottle gas are trucked in from Great Falls, Livingston, or Helena

Geothermal Resource Description

The water issues from fractured, well-indurated Belt shales. Many individual seeps used to exist in the swampy areas south of Main Street which is now covered by fill. The soil temperature survey of shallow (0.6 meters depth) in this central area of town shows a high temperature anomaly (maximum 41°C) in an area previously filled with sawdust waste, southeast of the town hospital. Shallow resistivity coupled with a soil temperature survey (both done by Montana State University-Earth Sciences Department) defines an obvious area of about 32 acres (13 hectares). The actual size of the reservoir could be much larger.

Previous excavation found hot water seepage at the 2 meter depth across Main Street and this was thought to be a prime drilling spot. This prediction was not borne out as is described later in the text.

The temperature of the water used in the spa is 113.9°F (45.5°C). The flow has been measured at 10 liters per second. The geothermometry gives predicted reservoir temperatures of 158°F to 298°F (70°C to 148°C).

A test well was drilled to a thousand feet, across Main Street from the spa where hot water seepage has appeared before. Hot water almost exactly the same temperature as the spa was located in the 180 foot to 220 foot (55 m to 67 m) zone. The quantity was very good but continued drilling to the 1,000 foot (305 m) depth level found no other water-bearing strata. Well logs and temperature logs for this well, a much shallower well drilled at the spa motel, are available.

Potential for Geothermal Development

The possible uses within the surface temperature range of 113.9°F (45.5°C) is shown in figure 2 on page 27. The applicable uses for this area include all of those listed with the exception of aquaculture. The temperatures are too low for good heat exchanger operation and the water quality, if used directly, is poor for fish survival.

The possible uses, considering the predicted reservoir temperatures, are many. The community could use hot water for district space heating and also wood products processing. Agricultural processing for such crops as cattle feed and grain is also a possibility.

Uses which appear economically feasible at the present are space heat oriented. Heating of greenhouse facilities or district home heat would perform very well within the predicted reservoir temperatures.

This community is not served by natural gas lines. Other forms of available energy are expensive and will increase in the coming years. The people of White Sulfur Springs are in favor of geothermal heating and would support a heating project.

Interest in Development

Development interest is high in the community of White Sulfur Springs. The Spa Motel and the First National Bank were both granted money to explore the geothermal potential for space heating by the Montana Alternative Energy Grant Program. The Spa Motel wants to extend the present depth of its supply well and also encounter hotter water with a greater flow. The First National Bank proposed to drill a well to the thousand foot level to characterize the formation and heat the new bank building.

The bank project was initiated early in the summer of 1978. A well was drilled to 1,000 feet with well logging and temperature logging for the entire length. Water approaching 200°F (93°C) was expected. The results showed a fracture zone at about 200 feet (61 m) which is apparently the conduit for hot water generated elsewhere. The temperature was nearly the same as the resourse supply of the Spa Motel, 100 yards away. This result was somewhat disappointing but should not be interpreted as characterizing the entire area. It is possible that the major fault was missed and future drilling on other sites could locate a hotter resource.

The Federal Government has been interested in the results of this project in hopes that a demonstration district heating project could be established. EG&G Idaho Incorporated gave some assistance to the well logging.

The site is designated "potential geothermal resource area" (PGRA) by the U.S. Geological Survey. This classification for federal land allows leasing on a noncompetitive basis unless overlapping lease applications are received.

There are no known leases of the geothermal resources in this area. There is a small amount of state land available but it does not appear to be located favorably. Private land could be leased if desired.

Scenario Discussion

The known reservoir characteristics, together with the economic environment of White Sulfur Springs, were analyzed to provide a realistic base for preparation of a development scenario. Two events are postulated for the town of White Sulfur Springs. The first is a central space heating district for the urban area. The assumptions for this development are as follows:

1. Municipal interest will be present.
2. Funding can be arranged.
3. A suitable resource will be found.

The beginning date is 1982 with 6 years required for completion. The maximum power delivered would be 15 x 10^6 Btu/hr.

The second possible event is a wood processing industry. A green lumber kiln for drying is to be heated by the geothermal resource. The assumptions used to formulate the time-line development program are:

1. Industrial interest will be present.
2. Leasing of private land will be necessary.
3. Location of an economical resource will occur.

This is an extension of the above scenario. The beginning date is 1982 with a period of 8 years needed to provide power-on-line. Power used is postulated at 12 x 10^6 Btu/hr, and since little heat is extracted per pound of water, a cascade system with the district space heat may work.

If any one project met with success in locating a usable reservoir, other projects would be initiated. These are not shown with subsequent time lines because of the completely unknown quality of the local resource. These events could be expected to take less time in the exploration phase. A total estimated reservoir potential, using a 90°F end temperature and 200°F reservoir temperature, is 110 x 10^6 Btu/hr, assuming favorable conditions.

SITE LOCATION AND PHYSICAL DESCRIPTION

..Latitude: 46 32' 21" (31)

..Longitude: 110 53' 45"

..Rectilinear: T. 9 N., R. 7 E., sec. 18, BBB (31)

..County: Meagher

..Adjacent Counties: Broadwater, Cascade, Gallatin, Park, Judith Basin, Wheatland

..Topography: Meagher County's western border is the rugged Big Belt Mountains. Masses of jumbled topography mark the terrain. It is bounded on the east by the drainage divide extending north from the Crazy Mountains, through the Castle Mountains, and then northwest through the foothills of the Little Belt Range.

The Smith River is the major drainage of western Meagher County, flowing north and west where it empties into the Missouri near Ulm. White Sulfur Springs is situated on the North Fork of the Smith River, about 5 kilometers from its confluence with the South Fork. Here, the North Fork Valley is beginning to widen to a large flat area as it approaches the confluence with the South Fork.

The highest elevation is Edith Mountain (over 2950 m) in the Big Belt Range. The elevation of the Smith River at the north edge of the county is about 1295 meters. White Sulfur Springs is about 1539 meters. (34)

..Present Land Use: The county economy is based on ranching, farming, and lumbering. Some tourism is developing. White Sulfur Springs is the home of a majority of the county population. (34)

..Future Land Use Plans: No large change from the present is expected.

..Aesthetics:

..Historical/Archaeological Significance: The Castle Historic District (1880's) was located 19 kilometers southwest of White Sulfur Springs. Discovery of silver ore led to a number of mines and founding of the town of Castle. Copperopolis, located 24 kilometers east of White Sulfur, was the first major copper strike. Fort Logan, located 27 kilometers northwest of White Sulfur was established for protection of the freight route from Fort Benton to Helena and for defense.

Twenty-eight archaeological sites have been identified in Meagher County. The future archaeological potential is rated as high. (43)

RESERVOIR CHARACTERISTICS

..Reservoir Temperature:

..Surface: 45.5°C (31)

..Subsurface: 150°C (80)

..Geochemical:

SiO_2: Chalcedony 70°C Quartz 103°C

Na-K-Ca: 1/3 Ca 148°C 4/3 Ca 127°C (80)

..Flow Rates: 600 liters per minute (31)

..pH: 6.5 (31)

..Total Dissolved Solids: 1530 mg/ℓ (31)

..Fluid Chemistry:

H_2S	0.7 mg/ℓ
Hardness (Ca, Mg)	160 mg/ℓ
Noncarbonate hardness	0 mg/ℓ
Ca	44 mg/ℓ
Mg	12 mg/ℓ
Na	480 mg/ℓ
Alkalinity	591 mg/ℓ
CO_2	420 mg/ℓ
SO_4	320 mg/ℓ
F	6.5 mg/ℓ
SiO_2	44 mg/ℓ
B	9100 mg/ℓ
K	20 mg/ℓ
Specific conductance	2380 micro-mhos

Additional detailed data is available. (31)

..Estimated Nonelectric Energy Potential (MBtuh 30 years):

..Subsurface Area of Reservoir: Soil temperature and shallow resistivity surveys define an obvious area of about 13 hectares. The actual size of the reservoir should be much larger. (11)

GEOLOGICAL/GEOPHYSICAL DESCRIPTION

..Geologic Description: Exposed rock strata ranging in age from Precambrian to Tertiary are abundant. These strata are folded and extensively faulted. They are intruded by several types of igneous rocks.

The Smith River Valley lies in a structurally complex region between the Big Belt uplift, the Little Belt uplift, and the Castle Mountain dome. In addition, the valley is the apparent zone of the intersection of the huge central Montana arch comprising the Big Belt; Little Belt; Big Snowy and Porcupine uplift; and the famous southeast-trending zone of intricate thrust faulting, termed the Disturbed Belt. This belt extends from Canada to the Lombard-Three Forks area. Another major structural feature, as shown by the Livingston Formation, is the Crazy Mountain Basin which extends into western Meagher County. (34)

..Geophysical Summary: A soil temperature survey showed anomalies with temperatures as high as 41°C in the spring area. There was discovered a northwest-trending zone which may outline a major fracture conduit system. Resistivity was also used in this survey by Montana State University. (11)

Magnetometer survey was done for part of the county around the Fort Logan-Camas Creek area. (34)

Some spectography was done on formation material known as the "paint pots." This material is a significant example of hydrothermal alteration. (34)

LAND OWNERSHIP AND LEASING

	Total Area (Acres)	Federal (Acres)	State (Acres)	Private (Acres)	Other
..Land Ownership 113 km^2:	11300 (hec) 27922 (acre)	0%	8%	92%	

..Land Leased: (76) 0

..Highest Priced Leases (Dollars/Acre): N/A

..Tentative Lease Sale Dates: N/A

..Number of Sales Offered But No Bids: N/A

..Number of Bids Rejected (Resulting in No Lease): N/A

..Summary of Leasing Status and Needs: Most of the land is in private hands. Since geothermal development is in the beginning stages with no hard knowledge of the reservoir potential, no leasing activity is present.

GEOTHERMAL DEVELOPMENT STATUS

..Present Development Status: The Spa Motel uses water from a hot spring to heat a pool.

The First National Bank of White Sulfur Springs has grant money from the State of Montana totaling $43,500 for development and installation of geothermal space heat for a new bank building. Drilling was slated to begin in July, 1978.

Mountainview Memorial Hospital has a grant of $2,000 for test hole drilling to be used eventually for space heating.

Montana State University has done DC resistivity and soil temperature survey work in the spring area.

..Projected or Planned Development: If the bank space heating project well shows promise of a useful reservoir, planning will begin on a central space heating district for the entire town. Some industrial use may be developed.

INSTITUTIONAL CONSIDERATIONS

..Institutional Requirements: Exploratory drilling must be done to preclude the possibility of surface water contamination from temperature, dissolved solids, or suspended solids. The Water Quality Bureau has stipulated using mud for drilling.

Disposal of small quantities of discharge water can be handled by permit. Larger quantities will have to be either reinjected or treated before discharge to surface waters.

..Agency and Public Attitudes: State and local support is very good.

..Status of Requirements (i.e., EIA/EIS Requirements): Not applicable.

ENVIRONMENTAL FACTORS

..Climate: Vegetation of western Meagher County is indicative of a semiarid climate.

..Prevailing Winds: Southwesterly, average 8 mph (67)

..Precipitation (Annual): 17.5 inches (67)

..Days of Sunshine (Annual): 225 (69)

..Average Temperature:

Minimum:	January 25.5°F	Lowest -26°F
Maximum:	July 65.1°F	Highest -91°F (67)

..Degree Days (Annual): 8,792 (69)

..Relative Humidity (Seasonal Peaks):

Summer:

Winter:

..Air Quality: Air quality over the entire area is very good, due to the sparseness of population and minimum amount of commercial-industrial activity. Soil particulates may be raised by high winds in the dryer parts of the summer. (74)

..Geologic Factors:

..Water Quality: The Smith River is the major stream of western Meagher County flowing north to join the Missouri. The quality is excellent though the lower stretches have noted higher temperatures. The state classification is B-D_1 which indicates high standards. Ground water varies widely in quality. (39)

..Noise: Noise, associated with the urban part of the White Sulfur Springs area, comes from vehicular traffic, wood production near the edge of town, and occasional construction sounds. The outlining areas are subject to occasional agricultural activity noise, but the majority of the time the sounds are natural.

..Biological:

..Dominant Flora: The vegetation is characteristic of dry land environments. Sagebrush and many varieties of bunchgrass are present. The forest types vary from lodgepole pine in the dryer areas, to Engelmann spruce in the wettest areas. (63)

ENVIRONMENTAL FACTORS
(continued)

..Dominant Fauna: Antelope and mule deer inhabit the lower hills, with elk and mountain sheep in the higher elevations. Fishing is good in the stream system. (34)

..Endangered Species:

Flora: None

Fauna: None

TRANSPORTATION AND UTILITIES

..Utility or Energy Transmission Corridors and Facilities:

Electric Lines: There are no large electric transmission lines nearby.

..Transportation Corridors or Facilities:

Highways:

U.S. Highway 89	Adjacent
U.S. Highway 12	Adjacent
State Highway 360	Adjacent

POPULATION

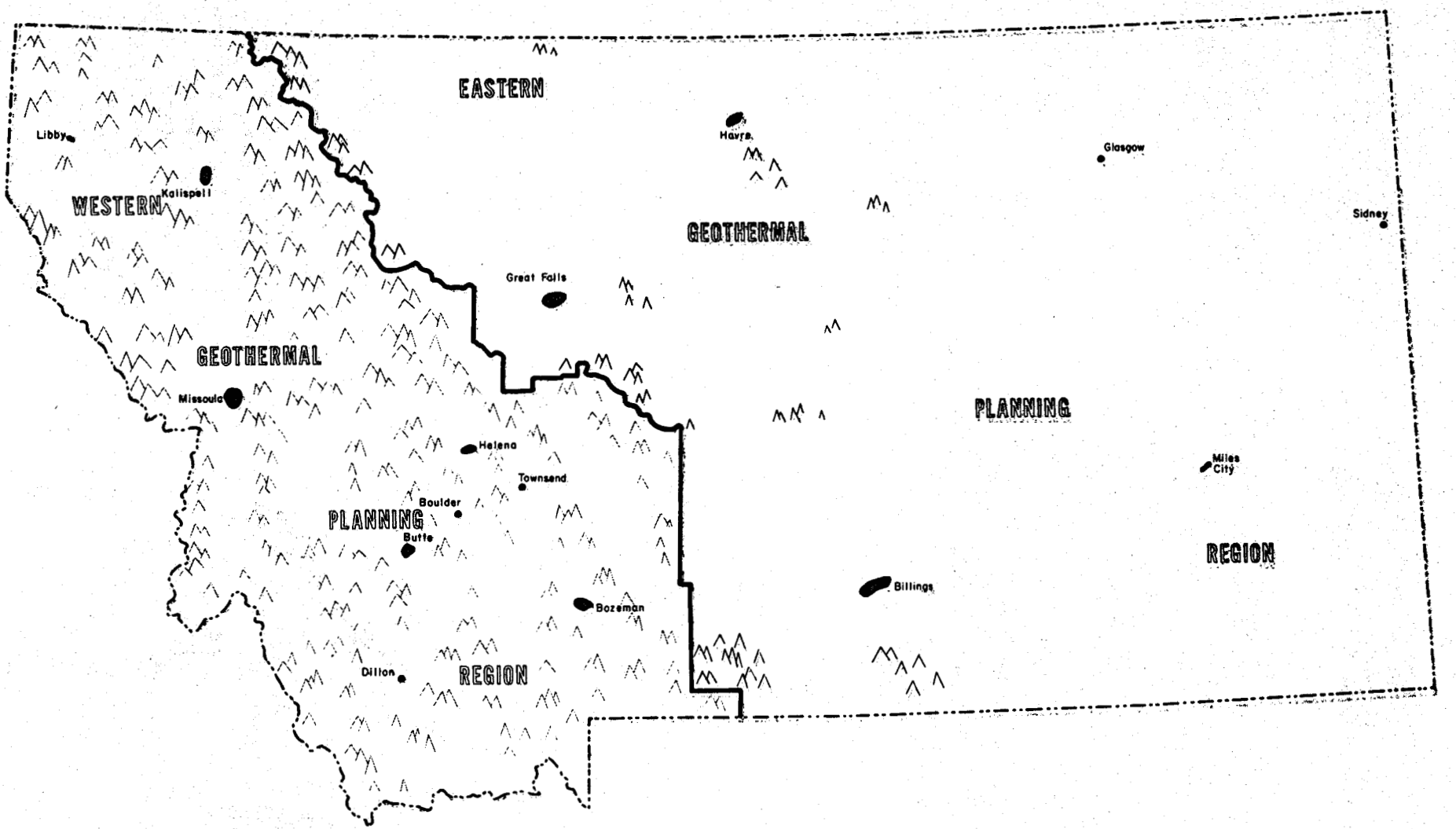
..General Description of Population: The bulk of the county's 2,000 inhabitants reside in the town of White Sulfur. The remaining portion occupy outlying agricultural operations. These are limited to the southern part of the county since the north is almost completely composed of mountains and forests.

The area was first populated by gold seekers in 1890. The population then was 4,749. Ten years later only 2,526 remained. The present population density is less than one person per square mile.

..Economics:

..Present Land Use: The economy is based on ranching, farming, and lumbering. White Sulfur Springs is the dominant economic and trade center of the county. Most of the county's towns are clustered in the southern half as is the bulk of the scattered ranches and farms. Tourism is increasing and makes a significant contribution to the present economy. (34)

..Future Land Use: No drastic changes are anticipated.



MONTANA GEOTHERMAL PLANNING REGIONS

MAP 18

EASTERN MONTANA GEOTHERMAL PLANNING REGION

REGIONAL INTRODUCTION

Montana's Eastern Geothermal Planning Region is shown on Map 18. This large area is essentially all of the land east of the western mountainous region and is twice as big as the western region, with 94,099 square miles. There are minor scattered mountain ranges in this region, as illustrated on Map 18.

The 1975 population of this region is estimated at 386,000 or about 53 percent of the state's whole. The population statistics through 2000 are shown by county in table 2. The two largest population centers are Great Falls with 60.091 and Billings with 61,581 people, located in this region. Although Great Falls is close to the western border of the planning area, it was included in the eastern region. Cascade and Yellowstone counties contain these two principal cities and account for 33 percent of the eastern region population. The remaining population is in sparsely located farms and ranches with very small communities--the majority of which have less than 1,000 persons.

If Cascade and Yellowstone Counties are subtracted from the population of the Eastern Planning Region, there are slightly over 200,000 people left. This is an overall population density of about 2.3/mi^2. Even with the two most populous counties, the density is only 4.0/mi^2.

The population growth projection by the Montana Department of Community Affairs for the 1970-80 period, not including the two most populous centers, is 0.7 percent/year. This is about one-half of the western total rate of growth. Many farming and ranching communities in the eastern region are experiencing population decreases as people leave to search for more lucrative employment opportunities. Great Falls and Billings are growing at a fast rate. One and nine tenths percent per year of growth is expected, increasing the present population of these two cities by 68,000 by the year 2000.

Physiography

Adjacent to the Rocky Mountain Region is central Montana in which variations of topography are less dramatic. Isolated, low mountain groups contrast greatly with the flat or rolling plains surrounding them. The plains themselves are sometimes broken by erosional river valleys. The eastern third of the state finds the plains becoming more featureless with elevation dropping gradually to the northeast. Some river valleys, 100 to 200 feet in depth, interrupt the rolling surface topography. These contain flood plains ranging in width from several hundred feet to a mile or more. In some places erosional activity of merging rivers has created shaped landscapes of considerable but low, local relief. These areas, called "badlands" have steep slopes, narrow divides, and closely spaced gullies. The northern plains have smoother surface features due to leveling of hills and filling in of valleys which leave depressions with no outlets.

Table 2

EASTERN REGION POPULATION STATISTICS

County	Area Mi²	Population 1970	Est. 1975	Projected 1980	1990	2000	Pop. Den.	Change in Pop. % 1960-1970	Projected Change in Pop. % 1970-1980
Big Horn	5,023	10,057	10,900	11,400	13,400	14,900	2	.5	13.3
Blaine	4,275	6,727	6,800	6,700	6,500	6,400	2	-16.9	-.4
Carbon	1,193	7,080	7,700	8,900	9,700	11,000	6	-14.9	25.7
Carter	3,313	1,956	1,900	1,800	1,700	1,500	1	-21.5	-8.0
Cascade	2,661	81,804	84,700	85,600	93,000	101,400	32	11.4	4.6
Chouteau	3,927	6,473	6,200	6,300	6,100	5,800	2	-11.9	-2.7
Custer	3,756	12,174	12,000	13,100	13,500	13,900	3	-8.0	7.6
Daniels	1,443	3,083	3,000	3,100	3,700	3,400	2	-17.9	.6
Dawson	2,370	11,269	10,400	11,200	11,200	11,600	4	-8.5	-.6
Fallon	740	4,050	4,000	4,100	4,100	4,100	5	1.3	1.2
Fergus	4,242	12,611	12,900	13,300	13,300	13,600	3	-10.0	5.5
Garfield	4,455	1,796	1,600	1,800	1,800	1,600	1	9.3	.2
Glacier	2,964	10,783	11,600	11,200	11,600	12,100	4	-6.8	3.9
Golden Valley	1,176	931	900	1,000	900	900	1	-22.6	7.4
Hill	2,927	17,358	17,900	18,200	19,200	20,300	6	-6.9	4.9
Judith Basin	1,880	2,667	2,700	2,700	2,400	2,200	1	-13.5	1.2
Liberty	1,439	2,359	2,500	2,500	2,300	2,200	2	-10.1	6.0
McCone	2,607	2,875	2,700	2,600	2,500	2,300	1	-13.4	-9.6
Musselshell	1,887	3,734	4,100	4,400	4,600	4,600	2	-23.6	17.8
Petroleum	1,655	675	700	700	600	500	1	-24.5	3.7
Phillips	5,213	5,386	5,500	5,500	5,200	5,100	1	-10.6	2.1
Pondera	1,645	6,611	6,900	7,100	6,800	6,600	4	-13.6	7.4
Powder River	3,288	2,862	2,300	2,600	2,600	2,600	1	15.2	-9.2
Prairie	1,730	1,752	1,900	1,800	1,700	1,600	1	-24.4	2.7
Richland	2,079	9,837	9,700	10,400	10,200	10,000	5	-6.3	5.7

Table 2

EASTERN REGION POPULATION STATISTICS
(continued)

County	Area Mi²	Population 1970	Est. 1975	1980	Projected 1990	2000	Pop. Den.	Change in Pop. % 1960-1970	Projected Change in Pop. % 1970-1980
Roosevelt	2,385	10,365	10,000	10,700	11,100	11,500	4	-11.6	3.2
Rosebud	5,037	6,032	8,600	10,100	11,100	11,300	2	-2.5	67.4
Stillwater	1,794	4,632	5,300	5,500	6,800	6,200	3	-16.1	18.7
Sweet Grass	1,840	2,980	3,000	3,300	3,700	3,600	2	-9.4	10.7
Teton	2,294	6,116	6,500	6,300	6,200	6,100	3	-23.2	3.0
Toole	1,950	5,839	5,400	5,300	5,400	5,500	3	-26.1	-9.2
Treasure	985	1,069	1,200	1,200	1,000	800	1	-20.5	12.3
Valley	4,974	11,471	13,300	13,300	13,000	12,900	3	-32.8	15.9
Wheatland	1,420	2,529	2,300	2,500	2,500	2,400	2	-16.4	-1.2
Wilbaux	890	1,465	1,500	1,500	1,500	1,300	2	-13.7	2.4
Yellowstone	2,642	87,367	97,400	109,700	136,400	164,400	37	10.6	25.6
EASTERN REGION TOTAL	94,099	367,225	386,000	407,400	447,300	486,200	4	1.3	10.9
Major Cities									
Billings	-	61,581	-	77,350	96,150	115,900	-	-	25.6
Great Falls	-	60,091	-	62,500	67,900	74,050	-	-	4.0

Geothermal Resources

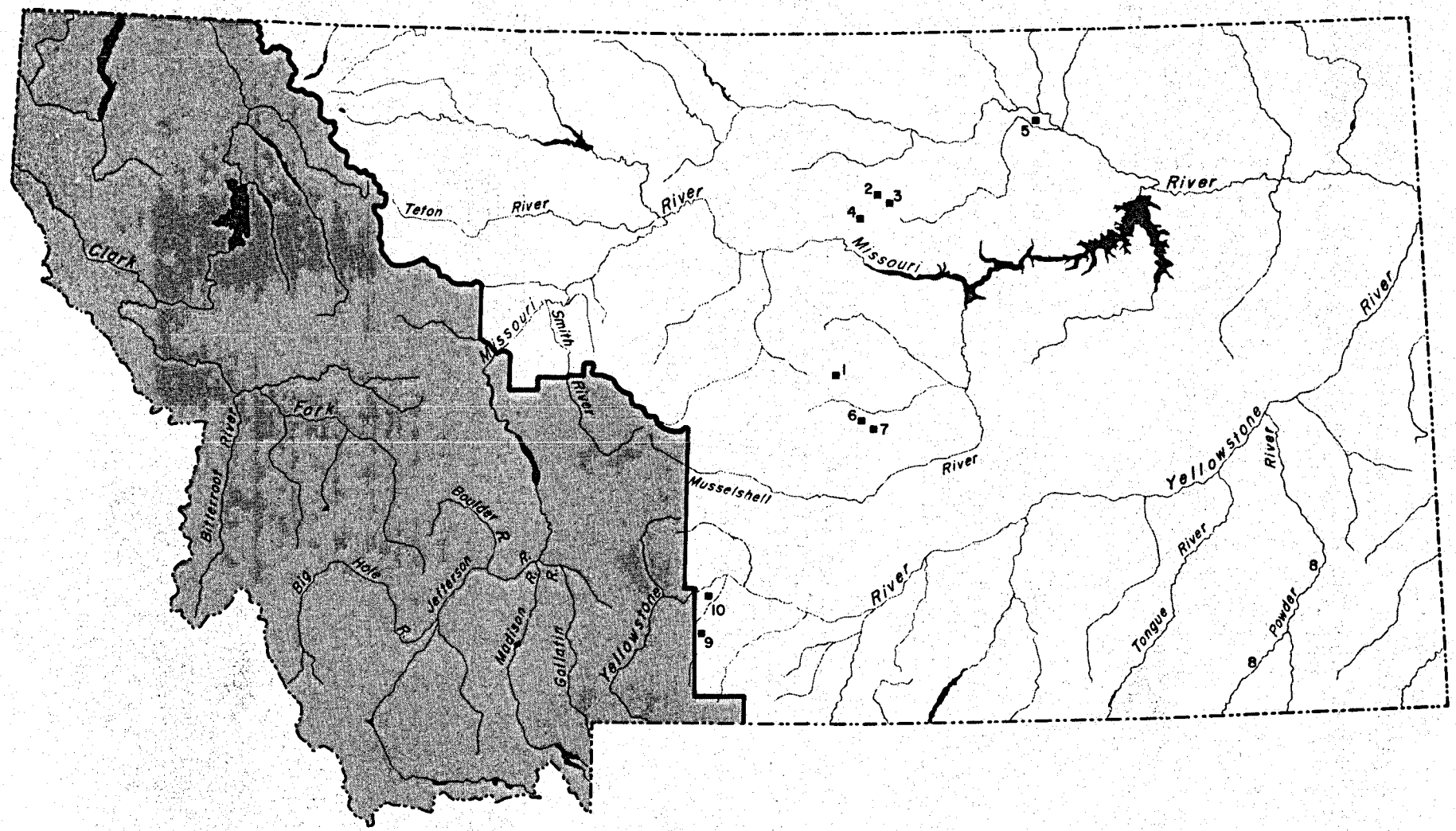
There are few hot springs located in the eastern region. A number of springs warmer than the normal for cold springs exist. The largest part of this region is underlain by a formation known as the Madison Aquifer of the Mississippian age. This formation is quite thick and extends below 10,000 feet in many areas. The regional geothermal gradient is such that 10,000 feet in Montana would produce temperatures on the order of 200°F. This indicates that the Madison Aquifer should be capable of supplying hot water in many places in eastern Montana. The wells that have been drilled to the Madison usually show artesian heads with the majority being flowing wells. The quantities pumped in some areas are enormous. For example, just below the Montana border in northern Wyoming, the Continental Oil Company pumped about a half-million barrels a day of 200°F water into the oil fields from the Madison to increase oil recovery.

The geology of the eastern region is not so complicated as that of western Montana. The specific depths at which the Madison can be encountered and the areal distribution of hot water reservoir areas of the Madison are not presently charted. The U.S. Geological Survey is working to identify regional parameters in Montana and Wyoming. This is primarily to identify the potential to produce water for a coal-slurry pipeline, but it will also show geothermal potential. Temperatures of over 280°F are thought to be commonly available in the Powder River Basin of northern Wyoming and possibly southern Montana. Higher temperatures are possible, but not identified at this time.

The principal use of geothermal waters in the eastern region outside of Cascade and Yellowstone Counties will be agricultural processing such as feed-pelleting, barley malting, and grain drying. The population is so sparsely distributed that space heating is not projected to account for significant energy production. It will certainly be possible to use the resource for space heat in the communities of sufficient size located in the eastern region.

Cascade and Yellowstone Counties could greatly benefit from residental space heating by geothermal hot water. Great Falls has no known geothermal indications, while Billings does have several rumored warm wells and springs. Both of these locations are within 20 miles of Madison Aquifer outcrops, the geology may be favorable in each area. This possibility should be sufficiently explored since the energy expended for space heating of these two areas is quite substantial.

A partial listing of warm to hot springs of the Eastern Planning Region is included for an overview of the region's resources. As can be seen by the small number and sparse information, much work remains in evaluating the geothermal resource in the Eastern Planning Region. The approximate locations of these springs are illustrated in Map 19.



EASTERN PLANNING REGION SITES

MAP 19

Lower Missouri River Valley

1. Flat Mountain, township 15 N., range 20 E., section 6. This is a warm springs which stopped flowing in the early 1900's.

2. Lodgepole, 1, 2, and 3. Discharge 95 liters per second from number 1. Flows from the other two unknown. The temperatures are about 32°C. These three springs issue from the Madison group. Total flow for all three springs is estimated at 190 liters per second. Other publications estimated the flow as high as 3167 liters per second. The specific conductance is 1,980. Total dissolved solids 1,669 mg/ℓ. Other mineral analyses are available.

3. Little Warm Springs, 1, 2, and 3, township 26 N., range 26 E., section 30 and 32. Flow varies, but number 2 has been measured as high as 317 liters per second. The temperatures averaged 26°C. The spring issues near the Madison-Jurassic strata contact and is currently used for domestic and livestock uses. The specific conductance is 2,082--pH 9.06--total dissolved solids 1,806 mg/ℓ. Additional mineral analyses are available.

4. Landusky 1, 2, and Plunge, township 25 N., range 24 E., section 32. Combined flow approaches 317 liters per second with a temperature between 20°C and 24°C. The spring issues near Madison-Jurassic contact. Waters presently for domestic and livestock watering. Specific conductance is 1,262--pH 8.09--total dissolved solids 1,008 mg/ℓ. Additional mineral analyses are available.

5. Saco abandoned well, township 31 N., range 34 E. Petroleum exploration well. No firm data.

Musselshell River Valley

6. Durfee Creek 1, township 12 N., range 22 E., section 13. The discharge is .06 liters per second at 23°C. This spring issues near the Madison and Pennsylvanian strata contact. The water is presently used for livestock watering. Specific conductance is 2,535--pH 8.08--total dissolved solids 2,655 mg/ℓ. Other analyses are available.

7. Durfee Creek 2, township 12 N., range 23 E., section 19. The discharge is 950 liters per second with a temperature of 23°C. This spring is also near the Madison and Pennsylvanian strata contact. Total dissolved solids is 558 mg/ℓ. Other mineral analyses are available.

Powder River Valley

8. Personal communications with USGS project director for the Madison Aquifer studies indicate that water of 140°C can be found in much of the Powder River Basin in northeast Wyoming, and that supplies of at least 100°C should be available in the Powder River Valley in Montana.

Yellowstone River Valley

9. Andersons, township 3 S., range 13 E., section 29. The temperature is 21°C to 25°C and the discharge is 2.9 liters per second. The source appears to be the Madison Aquifer.

10. McCloud. This spring is used for hot water baths. Little is known about its flow or temperature. Little additional information is available.

Eastern Region

Subchapter A

MADISON AQUIFER

..Location: The western boundary is defined by a diagonal line from Glacier Park to Carbon County. The study area is the area to the east of this line.

..Counties: Big Horn, Blaine, Carbon, Carter, Cascade, Chouteau, Custer, Daniels, Dawson, Fallon, Fergus, Garfield, Glacier, Golden, Hill, Judith Basin, Liberty, McCone, Musselshell, Petroleum, Phillips, Pondera, Powder River, Prairie, Richland, Roosevelt, Rosebud, Sheridan, Stillwater, Sweetgrass, Teton, Toole, Treasure, Valley, Wheatland, Wilbaux, Yellowstone.

..Topography: The northern Great Plains rise gradually westward from about 2,000 feet (609 m) above sea level on the Coteau du Missouri in North Dakota to 5,000 feet to 6,000 feet (1524 m to 1828 m) at the Rocky Mountain front. Though generally smooth featured, the plains are considerably dissected, sometimes have a relief of 500 feet to 1,500 feet (152 m to 457 m). There are several outlying mountain groups whose crests range from 6,300 feet to 9,000 feet (1920 m to 2742 m). At the boundaries of the study area, the Crazy Mountains attain 11,000 feet (3352 m) and the Big Horn Mountains in northern Wyoming, 13,000 feet (3961 m). (1)

..Geologic Description: The rocks of the plains in Montana and Wyoming are mostly shale and sandstone ranging in age from Early Cretaceous through Eocene. (1)

The carbonate rocks which occur in the Madison Group of Mississippian age are the most widely found and also the thickest Paleaoic rocks in eastern Montana.

Two structural features which allow surface exposure in the southern part of the study area are the Bighorn and Pryor Mountain uplifts. Madison rocks are exposed in the Little Rocky Mountains to the northwest, in the Judith uplift, Big Snowy uplift, and the Beartooth Mountains west of the area. (35)

Devonian rocks unconformably underlie the Madison in most of the study area, except where Ordovician and Silurian rocks underlie the Madison in the southwest, and Cambrian and Ordovician rocks underlie the Madison in the Porcupine Dome area.

Mississippian rocks underlie the Madison conformably to disconformably in most of the northern part of the area. Jurassic rocks overlie the Madison in the northwestern part and Pennsylvanian rocks overlie the Madison in the rest of the area.

The Madison is approximately 2,000 feet (610 m) thick in the northeast part of the study area. In central Montana, the Madison is 1,600 feet (490 m) thick. The Madison appears to thin northward and northwestward. It also thins toward the Montana-Wyoming border to about 800 feet (240 m) and to about 700 feet (210 m) in the Big Horn Mountains. (35)

..Hydrology: The Madison Aquifer holds water under high pressure in much of its area. The strata above and below the Madison have low permeability, but are not perfectly confining. Artesian pressure causes flowing wells in most of eastern Montana except in higher areas south of the Yellowstone River.

Water enters the Madison Aquifer at outcrops in mountain areas. The general movement is northeastward and is discharged through leakage in the east-central area of study. The recharge-discharge systems have equalized and present withdrawals from wells probably have little effect on this equilibrium. Recharge may depend on upward leakage so that increased withdrawal may result in increased recharge. (35) The Madison is noted for its ability to produce large artesian flows and also the accompanying drilling problems of lost circulation and well control. (23)

Well yields range from about 50 gallons per minute (3 liters per second) at several places. Two reports of 1,400 gallons per minute (88 liters per second) from the site of a flowing well on the north edge of the Porcupine Dome. Drill stem yield tests range from 1 to 157 gallons per minute (1 to 9.9 liters per second).

Water from the Madison contains generally less than 3,000 milligrams per liter dissolved solids south of township 1 N. The remaining areas have concentrations of from 3,000 to 10,000 milligrams per liter and in the Willison Basin, the concentration increases to more than 100,000 milligrams per liter.

..Institutional Considerations: There have been no tests of any institutional requirements for the development of geothermal energy in the eastern region. The most important consideration will be water withdrawal and water quality considerations. There should be no problem resolving these institutional requirements. The public will not be interested in utilizing geothermal resources until they can be convinced of its economic viability.

There are no lease applications on file for any federal lands in the Eastern Planning Region. There are no Known Geothermal Resource Areas designated within the eastern region, hence, no EIS nor EAR studies have been initiated. The region east-northeast of Malta near Saco, Montana, is designated as a PGRA.

..Madison Aquifer Present Development Status: Currently, there are very few uses of hot water in the eastern portion of Montana. There are a few occurrences of isolated ranchers using abandoned oil test wells which have flowing hot water from the Madison strata. These are usually used for stock watering and to keep stock watering holes open during winter periods. Very few attempts have been made to heat buildings with this hot water. A major use of the Madison, at this time, is by the Continental Oil Company near Sheridan, Wyoming, which pumps half a million barrels of 200°F Madison water into oil fields to stimulate production.

Two grants have been awarded to South Dakota counties by the USDOE to heat buildings with Madison Aquifer water. There is some ongoing future planning for use of this water in Wyoming. The results of the U.S. Geological Survey study of the geothermal potential of the Madison Aquifer with related depth and temperatures should provide baseline data which can be used to continue the planning effort for this region. Subsequent planning efforts in the state of Montana should make efforts to contact local potential end users of the geothermal resource providing information and technology transfer for possible applications. Greenhouse and agricultural processing applications will be emphasized.

..Madison Formation Area Climate: Two weather stations are considered to characterize the eastern region encompassing the highest area for geothermal potential from the Madison. The two sites are Billings and Miles City. Billings, Montana, lies in an elevation of 3,100 feet to 3,600 feet (945 m to 1097 m) above sea level. It is located on the borderline area between the Great Plains and the Rocky Mountains, and is affected by the climatic conditions of each. This climate can be classified as semiarid but irrigation and a favorable rainfall season in the spring and fall months allows a variety of crops to be cultivated.

The annual precipitation for the area is little over 14 inches (36 cm), with a third coming during May and June. June is the wettest month followed by May, April, September, and October. The winter months contribute less than 20 percent of the annual precipitation, but it is not uncommon to have snowfalls of 6 inches to 1 foot during this period. Snow seldom accumulates to great depth because of the occurrence of thawing.

Winter is usually cold but not extreme. Mild periods of a week or more occur occasionally. Cold periods are accompanied by snow and wind. These cold waves break suddenly with the onset of moderate to strong west to southwest winds. This condition is called a "chinook."

The summer season is characterized by warm days with much sunshine and low humidity, and cool evenings. Thunderstorms threaten the afternoons occasionally, but lengthy rainy spells are uncommon.

Average maximum temperatures in July are 85.6°F (30°C) with an average minimum temperature in January of 12.5°F (-10.8°C). There is an average of 72.65 degree heating days. Humidity varies from 28 percent to 71 percent. Resultant wind direction is west at an average of 12 mph (19.2 km/hr). This area received 65 percent of the possible sunshine.

Miles City, Montana, is situated on the western edge of the Northern Great Plains in the shallow part of the Yellowstone Valley. There are no nearby mountain ranges to complicate the climatic conditions. Temperatures range from very cold in the winter to hot in the summer, characteristically continental. Rainfall is normally about 13 inches per year (33 cm/yr), and the climate can be classified as semiarid.

The temperature has dipped to -65°F (-54°C) in January, 1958, to a high of 111°F (44°C) in July of 1901. Cold periods are usually accompanied by 0°F (-18°C) or below temperatures during the winter. Northerly winds and snow, lasting from 2 to 4 days, are typical.

Spring and fall are cool with high temperatures rarely reaching 90°F (30°C). Lows of 0°F (-18°C) have been reported as late as April 1, and as early as October 28. Maximums of 90°F (32°C) do occur in July and August as is normal for semiarid regions. Humidities are low.

Seventy percent of the precipitation occurs during the growing season--April through September. Spring and summer precipitation falls during thunderstorm activity. Measurable snowfall can occur as late as May and as early as September. The growing season averages 158 days. The sunny weather, with May and June rainfall, promotes rapid crop development. Crops grown in this area seldom have difficulty reaching maturity. The heating degree days average 78°F to 89°F (26°C to 32°C). The average high temperature during July is 88.9°F (31.6°C) and the low during January is 4.7°F (-15°C). The wind blows to the northwest at an average speed of 11.3 mph (18 km/hr). (69)

..Air Quality: Air quality in the eastern portion of Montana is generally very good, with exceptions being sites containing coal fire electrical generation plants. These sites are subject to constant supervision with an ongoing program of reducing pollutant admission. Subsequent coal fire generation plants will not be allowed unless air pollution can be suitably limited. Wind-generated dust particulates sometimes occur. Some pollution from oil refining is present in the Billings-Laurel area. Concentrations of pollutants drop quickly with distance from this area. (38)

..Water Quality: Streams and rivers in the eastern part of Montana are generally of less quality than those flowing directly out of the mountainous snow melt supply regions. The elevation gradient is usually much less, so rivers flow slower receiving less oxygen regeneration. The water has picked up a lot of suspended sediment at this point and irrigation return waters have contributed much dissolved constituents to the river system. (39)

..Noise: Noises, in general, in eastern Montana, are almost exclusively natural sounds. Urban areas can be expected to supply man-made noise in the immediate area. There is little traffic, and in the southern portions little mechanized framing occurs. The northern portions of the region are subjected to heavy machine cultivation for harvest of crops.

..Utility or Energy Transmission Corridor Facilities: A large coal-generating electrical plant is located at Coal Strip in the southeastern corner of the state. Transmission lines go west from here following the bottom of the state to the west. Transmission lines go from the southwest portion to the north-central part of the state. The central part of the Eastern Planning Region has transmission lines through part of it. Then the northern tier portion of the state has a couple of main lines running along the northern border. Much of the Eastern Planning Region does not have close access to major transmission lines.

..General Description of Population: The two largest counties are Yellowstone and Cascade. These counties contain Montana's biggest cities, each of which has approximately 60,000 people. The area covered by the Madison has only three other towns of approximately 10,000 people and four towns of approximately 5,000 people. The remaining communities, for the most part, contain less than 1,000 people. The employment picture for the two biggest cities have a large proportion of service-oriented employment. Another large portion is engaged in retailing. Manufacturing employs a number of people in both of these areas. The remaining portion of the entire area depends upon agriculture and forestry for continued existence.

The southeast portion of the Eastern Planning Region is almost exclusively devoted to livestock ranching. The northeast portion relies more on cash crop farming, mostly grain, and some mixed livestock and cash crop farming. The northwest part of the region also follows this trend with little livestock ranching. The southwest protion is mostly livestock ranching with some general farming and irrigation. The area with the largest cash income is the northwest area of the Eastern Planning Region. This area produces a great amount of income from wheat production.

Most of the population in the Madison Aquifer planning area is sparsely located in towns of less than 1,000 people. This population is usually engaged in some form of agriculture. A future study of the area should attempt to identify subregions within the Madison Aquifer study area, which can be grouped according to common pursuits. A study area might encompass a region where barley production is concentrated. This crop production might support development of a barley malting plant which could use geothermal heat resources. Another subregion might be a high wheat growing concentration area which could use drying facilities for the grain, utilizing geothermal resources. An alfalfa growing area might be able to support a feed-pelleting and drying plant. Both coal and petroleum production may be able to use local heat sources in the future for production of higher quality products. The coal resources in Montana show particular promise in this area.

MONTANA ENERGY

STATE ENERGY DEMAND

Montana produces large quantities of coal, oil, gasoline, natural gas, and electricity. Although Montana must import natural gas to meet its requirements for it, Montana produces more than enough energy to meet the state's needs.

The state's consumption of natural gas is approximately 93.7 x 10^{12} Btu/yr.

While much energy is exported to other states, 37.8 x 10^{12} Btu are annually imported. Of this, 18.5 x 10^{12} Btu are imported from Canada in the form of natural gas, and this supply cannot be guaranteed indefinitely. The price for the imported gas is also subject to increases. The county figures for energy production are given in table 3. The energy used by category, together with energy production, is shown on table 4.

The major energy consumer in this northern state is space heating, which requires approximately 29.5 x 10^{12} Btu per year. Of this, natural gas supplies 24.6 x 10^{12} Btu. Industry accounts for the use of 28.8 x 10^{12} Btu of natural gas per year. A table of major industrial categories and the Btu's required in 1974 is presented in table 5.

The present population in Montana is approximately 748,000. This is expected to increase at the rate of 1.0 percent per year. This will mean a 187,000-person increase by the year 2000. Energy consumption for Montana has not been projected at this writing. If we assume a proportionate increase in energy use with population increases, 116.9 x 10^{12} Btu per year of some form of heat energy will be required by the year 2000.

The most widely used heating fuel is natural gas and the increased population will create a greater demand for this fuel. Increased imports of this product are unlikely. In fact, decreases are expected as Canada increases its population. New development of domestic reserves is presently being pursued, but the increase is not expect to meet the project demand.

TABLE 3

FUEL AND HYDRO PRODUCTION

Place Name	Billions of Btu Production					Production less use 10^9 Btu
	Total	Coal	Oil	Natural Gas	Hydroelectric (thermal equivalent)	
Big Horn	24,046	11,889	467	29	3,887	20,605
Blaine	17,495	0	928	16,567	0	15,638
Carbon	1,106	0	90	1,016	0	-666
Carter	64	0	64	0	0	-665
Cascade	16,415	0	0	0	5,472	-8,093
Custer	496	0	0	496	0	-3,202
Daniels	38	0	38	0	0	-788
Dawson	9,009	0	8,838	171	0	5,547
Fallon	56,235	0	46,771	9,463	0	54,997
Flathead	9,239	0	0	0	3,080	-1,605
Garfield	512	0	512	0	0	-176
Glacier	17,634	0	15,834	1,801	0	15,075
Golden Val	619	0	0	619	0	319
Hill	16,022	0	0	16,022	0	11,297
Lake	12,648	0	0	0	4,216	8,561
Lewis and	10,136	0	0	0	3,379	1,069
Liberty	4,831	0	1,862	2,969	0	3,807
McCone	18,751	0	2,067	0	5,561	17,750
Musselshell	10,427	385	10,042	0	0	9,472
Petroleum	512	0	512	0	0	256
Phillips	2,915	0	0	2,915	0	1,295
Pondera	979	0	979	0	0	-1,093
Powder Riv	53,320	31	52,358	931	0	52,419
Prairie	4,785	0	4,614	171	0	4,190
Richland	14,752	4,928	9,824	0	0	6,775
Roosevelt	7,750	0	7,750	0	0	5,060
Rosebud	118,856	109,371	9,485	0	0	116,520
Sanders	19,644	0	0	0	6,548	18,129
Sheridan	13,555	0	13,555	0	0	11,312
Stillwater	1,290	0	0	751	179	21
Teton	32	0	32	0	0	-1,766
Toole	20,874	0	17,523	3,351	0	18,973
Valley	2,915	0	0	2,915	0	-678
Wilbaux	4,785	0	4,614	171	0	4,424
Yellowstone	179	0	179	0	0	-35,594
Montana TOTAL	492,866	126,603	208,941	60,356	32,322	275,314

Reference 17

Table 4

ENERGY BUDGETS

Name	Millions of Btu Use per Capita	Billions of Btu Fuel Use					Fuel Prod.	Electricity Thousands of MWH	
		Total	Coal	Oil	Natural Gas	Gasoline	Total	Generation	Use
Beaverhead	333	2,722	0	668	1,252	803	0	0	42
Big Horn	342	3,440	0	665	1,246	1,530	24,046	1,139	39
Blaine	276	1,858	0	466	874	517	17,495	0	27
Broadwater	357	901	0	196	368	338	0	0	11
Carbon	250	1,773	0	476	892	405	1,106	0	37
Carter	365	730	0	190	355	185	64	0	11
Cascade	300	24,509	0	5,705	10,694	8,110	16,415	1,603	1,286
Chouteau	339	2,195	0	643	1,206	346	0	0	48
Custer	304	3,700	0	886	1,661	1,153	496	0	67
Daniels	368	827	0	271	509	47	38	0	16
Dawson	307	3,462	0	814	1,525	1,123	9,009	0	63
Deer Lodge	199	3,116	0	703	1,318	1,094	0	0	46
Fallon	306	1,238	0	286	537	415	56,235	0	19
Fergus	349	4,407	0	1,002	1,878	1,526	0	0	89
Flathead	275	10,845	0	2,702	5,064	3,079	9,239	902	1,024
Gallatin	293	9,510	0	2,125	3,983	3,402	0	0	297
Garfield	454	689	0	193	361	136	512	0	11
Glacier	231	2,559	0	617	1,157	785	17,634	0	38
Golden Valley	379	300	0	90	169	40	619	0	5
Granite	204	586	0	176	330	80	0	0	23
Hill	272	4,724	0	1,212	2,271	1,241	16,022	0	122
Jefferson	386	2,023	0	220	412	1,392	0	0	14
Judith Basin	367	978	0	221	415	342	0	0	13
Lake	283	4,087	0	857	1,607	1,623	12,648	1,235	181

Table 4.

ENERGY BUDGETS
(continued)

Name	Millions of Btu Use per Capita	Billions of Btu Fuel Use					Fuel Prod.	Electricity Thousands of MWH	
		Total	Coal	Oil	Natural Gas	Gasoline	Total	Generation	Use
Lewis & Clark	272	9,067	0	2,325	4,358	2,384	10,136	990	428
Liberty	455	1,024	0	245	460	320	4,831	0	14
Lincoln	242	4,402	0	1,123	2,104	1,175	0	0	411
McCone	348	1,001	0	274	514	213	18,751	1,629	16
Madison	304	1,524	0	378	709	437	0	0	24
Meagher	450	902	0	183	344	375	0	0	33
Mineral	258	794	0	132	247	415	0	0	9
Missoula	315	18,345	0	4,196	7,865	6,284	0	0	1,344
Musselshell	256	954	0	229	430	295	10,427	0	18
Park	296	3,318	0	713	1,336	1,270	0	0	75
Petroleum	406	256	0	70	131	55	512	0	4
Phillips	298	1,620	0	426	798	396	2,915	0	25
Pondera	314	2,073	0	585	1,097	391	979	0	40
Powder River	315	901	0	238	447	216	53,320	0	14
Powell	300	2,000	0	406	761	833	0	0	71
Prairie	339	595	0	159	298	138	4,785	0	9
Ravalli	241	3,471	0	783	1,468	1,220	0	0	117
Richland	811	7,977	4,943	735	1,409	889	14,752	488	44

Table 5

CONSUMPTION OF NATURAL GAS AND ELECTRICITY
BY MINING AND MANUFACTURING IN MONTANA, 1974

SIC	Industry	Natural Gas (mmcf)	Percent of Total	Electricity (1000 kwhr)	Percent of Total	Percent of Combined Energy	Equivalent Btu's x 10^{12}
	Mining						
10	Metal Mining	NA		377,370	6.5%		
12	Bituminous Coal and Lignite	NA		8,336	0.1%		
13	Crude Petroleum, Natural Gas	NA		205,415	3.5%		
14	Nonmetallic Mineral Mining	NA		45,790	0.8%		
	Subtotal Mining	3,367	9.0%	636,911	11.0%	9.7%	4.73
	Manufacturing						
20	Food and Kindred Products	1,270	3.4%	69,577	1.2%	2.6%	1.21
24	Lumber and Wood Products	900	2.4%	235,176	4.0%	3.0%	1.48
25	Furniture and Fixtures	363	1.0%	3/		0.6%	.28
26	Paper and Allied Products	4,700	12.5%	151,047	2.6%	9.1%	4.09
27	Printing and Publishing	508	1.4%	6,414	0.1%	0.9%	.41
28	Chemicals and Allied Products	1,100	2.9%	489,802	8.4%	4.8%	2.51
29	Petroleum and Coal Products	6,195	16.5%	311,767	5.4%	12.7%	5.77
32	Stone, Clay, Glass & Concrete	4,400	11.7%	81,704	1.4%	8.2%	3.62
33	Primary Metals	13,100	34.9%	3,829,054	65.9%	45.6%	23.02
34	Fabricated Metals	436	1.2%	580	0.01%	0.8%	.34
35	Machinery (non-electrical)	0	0.0%	1,342	0.02%	0.0%	.01
36	Electrical Machinery	327	0.9%	0	0.0%	0.6%	.25
37	Transportation Equipment	300	0.8%	402	0.01%	0.5%	.24
39	Other Manufacturing	546	1.5%	0	0.0%	1.0%	.42
	Subtotal Manufacturing	34,145	91.0%	5,176,865	89.0%	90.3%	43.61
	Total Mining & Manufacturing	37,512	100.0%	5,813,777	100.0%	100.0%	48.35

CONVENTIONAL ENERGY REPLACEMENT

Geothermal resources can be used in place of electricity and natural gas in many instances, especially for providing low level heating. Table 6 shows the relative consumption of electricity and natural gas for the domestic and commercial energy uses. In the domestic community, space heating and hot water supply are the prime energy consumers. Total consumption for space heat and hot water is 19.1 x 10^{12} Btu per year. This energy use in particular could be easily adapted to a geothermal energy supply. Commercial consumers also heat much space and somewhat less hot water. The total demand for electric and natural gas energy is 10.4 x 10^{12} Btu per year. A large portion of this energy demand could also be replaced by geothermal sources.

The industrial sector uses energy in many different ways. Certain processes and many of the industries can be adapted to a geothermal heat supply. Of the industrial uses listed in table 5, the following could have major processes adapted to a geothermal heat supply.

SIC	Manufacturing	Natural Gas use Btu x 10^{12}	Electricity equiv. Btu x 10^{12}
20	Food and kindred products	.97	.24
24	Lumber and wood products	.68	.80
26	Paper and allied products	3.57	.52
28	Chemical and allied products	.84	1.67
29	Petroleum and coal products	4.71	1.06
32	Stone, clay, and concrete	3.34	.28

These industries use 49.4 percent of the natural gas and 23 percent of the electricity consumed by industry in Montana.

Table 6

ENERGY USE FOR SPACE HEAT AND HOT WATER

	Electricity			Natural Gas		
Category	Megawatt-Hours	% of Total Category Use	Equivalent Btu	Billion Cf	% of Total Category Use	Equivalent Btu
Domestic Space Heat	313,600	23.3	1.1×10^{12}	17.97	78.1	13.8×10^{12}
Hot Water	271,400	20.2	$.9 \times 10^{12}$	4.30	18.7	3.3×10^{12}
TOTAL	585,000	43.5	2.0×10^{12}	22.3	96.8	17.1×10^{12}
Commercial Space Heat	736,488	47.7	2.5×10^{12}	8.4	47.7	6.45×10^{12}
Hot Water	114,256	7.4	0.4×10^{12}	1.3	7.4	1.00×10^{12}
TOTAL	850,744	55.1	2.9×10^{12}	9.7	55.1	7.50×10^{12}
COMBINED	1,435,744	----	4.9×10^{12}	32.0	----	24.6×10^{12}

Source
Table 1 Consumption of Natural Gas and Electricity in Montana, 1976
Table 2 Consumption of Natural Gas and Electricity in Montana, 1976
Table 3 Consumption of Natural Gas and Electricity in Montana, 1976
Table 6 Consumption of Natural Gas and Electricity in Montana, 1976
Table 7 Consumption of Natural Gas and Electricity in Montana, 1976

POTENTIAL GEOTHERMAL USES IN MONTANA

Most of Montana's industry is concerned with extracting material from the earth with a small amount of secondary manufacturing using these materials. This applies to agriculture, mining, and the timber industry. For this reason, there isn't much demand for many of the possible uses of geothermal energy. There are a number of important areas of use which should be noted. Page 236 lists many of the uses which are suited to Montana. Many of these are energy intensive which allows very competitive marketing of products. A number of the listed uses are not currently practiced here. There would be excellent possibilities for new industry which would greatly benefit the Montana economy.

Energy is becoming a very important resource which is not limited to shipping of raw fuel resources. The near future will see manufacturers looking for energy rich areas in which to site new industry. Geothermal resource areas will be prime targets.

Some of the more ideally suited uses which could be usable now are crop drying and feed pelleting, greenhouse heating, sugar refining, aquaculture, individual and district space heat, pulp, paper and wood product drying. The above mentioned list should not construed as a complete listing. Any heat process which requires about 300°F or less is a candidate for adaption to geothermal heat. The majority of Montana's geothermal resources will be limited to the 200°F temperature range, however.

POTENTIAL GEOTHERMAL APPLICATIONS IN MONTANA

Agriculture

- Crop Drying (Wheat, Hay)
- Freeze Drying of Foods
- Fruit Dehydration (Cherries)
- Greenhouse Heating
- Mushroom Cultivation
- Seed Drying
- Soil Sterilization
- Soil Warming
- Sugar Refining
- Vegetable Dehydration (Onions and Potatoes)

Animal Production

- Aquaculture (Trout, Catfish, Prawns)
- Dairy Farming (Milk Cooling and Pasteurization)
- Feedlot Warming (Cows)
- Livestock Pen Warming (Poultry and Hogs)

Domestic and Commercial

- Accelerated Biomass Conversion (Methane Production)
- Electrical Power Generation
- Individual and District Space Heat
- Recreation
- Refrigeration
- Space Cooling
- Water Heating

Manufacturing

- Cement Curing
- Gasification of Coal and Other Carbonatious Materials
- Mineral Oil Processing
- Products of Fermentation (Ethyl Alcohol, Butenol Acetone, Citric Acid, etc.)
- Pulp and Paper
- Recovery of Salts and Minerals
- Recovery of Trace Elements
- Textile Processing (Wool)
- Wood Chemical Production
- Wood Drying (Curing Green Lumber and Veneer)

Page 238 lists example utilization areas for specific geothermal uses. This list, like the previous one, is not meant to show all uses of the energy in the world. It is included as a partial source for investigating the potential for a use in Montana.

Figure 2 shows the temperature range for a number of processes and uses of geothermal energy. The figure illustrates some of the commonly used ranges. This is not to show absolute limits but can be expected to give reasonable, tested temperatures for a specific use. Temperatures lower than are indicated for a use may be possible but detailed economic studies are required to insure feasibility.

Many variables enter into the economic feasibility question. Just a few are:

- How much expense is necessary to locate the resource?
- How deep must a production well be?
- Is the water production sufficient with one well?
- Is the resource hot enough?
- Are the pumping costs too high?
- How far will the water have to be pumped?
- How much heat will be used?

Each of these questions alone could make a product an economic disaster <u>if</u> it is not well considered.

UTILIZATION EXAMPLE AREAS

Aquaculture:	Freshwater prawns -	Klamath Falls, Oregon Japan
	Catfish -	Buhl, Idaho
	Trout -	Hot Creek, Bishop, California
	Alligators and eels -	Japan
	Tropical fish -	California Japan
Animal Husbandry:	Heated holding buildings -	Japan Hungary USSR
	Hog raising study -	Idaho
Animal Processing:	Butchering facility -	Vail, Oregon
De-icing:	Sidewalks - Roosevelt School,	Klamath Falls, Oregon
	Ponderosa School,	Klamath Falls, Oregon
	Roads -	Sapporo City, Japan
Greenhouses:	Oregon Desert Farms, Andy Parker, Lakeview, Oregon (3/4 acre) Liskey Farms, South of Klamath Falls, Oregon (1 acre) Hobo Hot Springs, Susanville, California (35 units) Millsted, Idaho Johnson, Idaho Garden Valley, Idaho Sun Valley, Idaho Bob Erkin, Buhl, Idaho	
Food Processing:	Alfalfa -	New Zealand
	Hay drying -	Iceland
	Onion dehydration -	Brady Hot Spring, Reno, Nevada
	Potato, onion, -	Ore-Ida--Ontario, Oregon
Manufacturing:	Diatomaceous earth -	Iceland
	Tasman Pulp and Paper -	New Zealand
	Laundry -	Klamath Falls, Oregon
	Car Wash -	Klamath Falls, Oregon
	Boric Acid -	Larderello, Italy
	Creamery -	Klamath Falls, Oregon
	Sulfur Processing -	New Zealand
Space Heating:	District heat -	Reykjavik, Iceland Akureyri, Iceland (planned) Sudernes, Iceland (Planned) Klamath Falls, Oregon Rotorua, New Zealand Boise, Idaho
	Individual -	Hungary Vale, Oregon Paris, France Larderello, Italy

REGIONAL ENERGY USE

Energy consumption and production, by category, for the Western and Eastern Geothermal Planning Regions is shown in table 7.

Western Regional Energy

The production in the western region is less than the use by 37.6 x 10^{12} Btu per year. This is roughly equal to the amount of natural gas imported for use in Montana.

The projected energy production possible from the 13 site-specific studies can be related to the energy picture. Table 8 illustrates possible geothermal heat energy production in the western geothermal planning region. The direct-use heat total of 2.5 x 10^{12} Btu per year is 7.0 percent of the region's present energy deficit. If the total electrical production is also included, the percentage is increased to 39 percent. The geothermal space heating energy supply from table 8 shows 1.2 x 10^{12} Btu per year or 7.0 percent of the residential heating demand for natural gas. While the amount of energy which could be supplied by the geothermal resource appear small, the contribution is supplied by only 13 sites. If the known sites are considered to be 10 percent of existing resource, the total future supply might have the capacity to supply 70 percent of the residential natural gas consumption.

The manufacturing energy available, as indicated in table 8, can provide a significant amount of energy for the processes listed on the previous page. The lumber and wood products require 0.68 x 10^{12} Btu per year. The small output from the 13 sites could supply 15 percent or more. If sites near the lumber industries are pursued with success, nearly all of the lumber products and paper product's energy consumption could be supplied. Thus, new industry should consider locating near geothermal reservoirs where possible. In many cases, the fuel savings will more than offset increased costs of doing business.

The present emphasis of the Federal Department on Energy is to replace existing conventional energy consumption with geothermal energy supplies. There are a number of uses for geothermal energy which are new (not presently existing), but which would displace energy requirements in other areas of energy demand. The principle uses are related to agriculture. For instance, commercial greenhouses would be new construction, but production of vegetables would eliminate transportation of produce from the southern and western United States. Another example would be feed pelleting which involves combining alfalfa and grains in a compressed pellet. This process requires heat energy for drying. Manufacture of this product in Montana would eliminate the energy required to bring in feed pellets from out of state. In addition, the inexpensive and virtually uninterruptible energy supply will allow more competitiveness in the market place.

Table 7
REGIONAL ENERGY BALANCE

	Use x 10^6 Btu									
	Per Capita	Btu of Fuel Use x 10^9					Production 10^9 Btu		Electricity Thousands of MWH	
		Total	Coal	Oil	Natural Gas	Gasoline	Total Prod.	Less Use	Generation	Use
Western Region	250	89,261	0	20,769	38,930	29,565	51,667	-37,573	5,045	4,670
Eastern Region	343	125,985	11,149	27,413	53,822	33,603	427,644	301,659	5,803	4,225

Table 8

POSSIBLE FUTURE GEOTHERMAL ENERGY PRODUCTION

	Heating Dist. x 10^6 Btuh	Greenhouse x 10^6 Btuh	Manufacturing x 10^6 Btuh	Electric x 10^6 hr	Electric Btu MWH
Barkell's		40		341	100
Bozeman	100				
Boulder	14	40			
Broadwater	35	32			
Corwin	7			341	100
Deer Lodge		24			
Ennis	8	40			
Hunter		40		171	50
Marysville	72		12	171	50
New Biltmore		24			
Warm Springs	4				
West Yellowstone	20				
White Sulfur Springs	15		12		
TOTAL RATE	275	264	24	1,365	400
Yearly energy production estimation 50% use	1.2 x 10^{12} Btu/yr	1.2 x 10^{12}	.1 x 10^{12}	12.0 x 10^{12} Btu/yr	3.5 x 10^6 MWHR
TOTAL	2.5 x 10^{12} Btu/yr				

The development of as many feasible sites as possible within this area will be needed to supply the additional energy sources. This region has a larger number of surface manifestations of geothermal activity than the eastern region, which should allow development to occur at a faster pace. The net energy demand for this area identifies a basic need to develop additional energy resources to help balance the energy budget.

Future increases in energy consumption will surely tax the state's energy supply. As mentioned before, a rough estimate is 116.9×10^{12} Btu per year may be needed by the year 2000. It is quite possible that 20 to 30×10^{12} Btu per year could be obtained from geothermal resources representing a substantial contribution to this energy supply.

Eastern Regional Energy

The energy consumption for the Eastern Geothermal Planning Region by Category is included in table 7. Since this area is the net energy exporter, the demand for additional supplies is less. However, the cost for providing the energy consumed will continue to rise regardless of the amount produced. The few surface occurrences of geothermal activity in the Eastern Planning Region are connected to the Madison Formation. The widespread nature of the Madison makes utilization of this geothermal resource a better prospect than the isolated springs of the western region.

The space-heat energy demand of isolated communities could be met with this resource in many places. Agricultural processing industry energy demand could also be partially met with this resource. A future use of the energy from the Madison could be utilized in coal gasification for the production of a substitute for natural gas. Production of a type of coal gasoline for vehicles is also a possibility. Hot water has been located in the large coal fields during exploratory drilling.

DEVELOPMENT FACTORS

The development of existing geothermal resources in Montana has been constrained by a variety of factors. These factors do not impact electrical production development with the same relative magnitude as they affect direct use of the geothermal resource. The following discussion considers each factor in decreasing order of impact upon direct-use development. The development factors for electrical production will not be addressed separately.

Economic Incentives

Perhaps the most obvious deterrent to geothermal resource development in Montana is the lack of economic incentive. This incentive must come in the form of demand for cheaper energy production alternatives. The present price structure for natural gas and other forms of key energy does not allow competitive use of geothermal energy. It is more expensive to provide space heat with geothermal energy and its higher preproduction cost than to install very cheap natural gas using existing supply lines. Even so, if a suitable 20-year energy inflation factor is considered in the feasibility evaluation--the desirability of using the geothermal resource in many cases can be justified. Unfortunately, the particular inflation rate which is to be used is not universally accepted. Inflation rates used in the past do not reflect the reality of a world population reaching critical proportions. These same rates are usually accepted by the public as indicative of future costs. Therefore, the public does not accept geothermal use as competitive on the energy market.

There are a few economic measures which would change present feasibility of geothermal development. They cannot change the cost picture of available fuel reserves, but by manipulation of other factors such as tax incentives and financing structures, can change relative importances of components which determine economic feasibility. An example of this would be a direct income tax credit, which could be applied in some manner to the individual. The existing tax incentives are included for information and completeness. This is not to suggest that these existing state tax laws are the primary restricting factor, but rather that the effect of the entire economic picture is an important restriction.

State Tax Incentive Programs

As encouragement for energy conservation, Montana has instituted some allowable deductions from adjusted gross individual income on state tax return portions of expenditures for capital investment in a building for energy conservation purposes. For a residential building it allows 100 percent of the first $1,000 expended, 50 percent of the next $1,000 expended, and 10 percent of the next $1,000 expended. If the installation is not a residence, the allowable deductions are doubled.

The state also has an energy system tax incentive for individuals which allows a tax credit against the state income tax owed. The amount allowed is 10 percent of the first $1,000, and 5 percent of the next $3,000 of the cost of such a system.

Tax credit is allowed to public utilities on capital loaned to occupants of a dwelling which is to be paid back in periodic installment payments added to the occupant's regular bill for electricity or natural gas.

The individual tax deductions or tax credit allowed by the state are so small that they barely enter into economic considerations involved in a decision to install a geothermal heat system. To induce use of alternative energy the state should be willing to let the user recap a major portion of the capital expenditures through tax credits. The small tax credit to the public utilities does not encourage them to loan money for less interest than their expected rate of return.

Financing

The present cost of borrowing money greatly affects capital intensive projects. Capital intensive means projects which require large sums of initial capital.

Conventional energy technology, such as natural gas heating, uses well-tested systems which can be installed by any number of local tradesmen. It usually requires little more than connecting the facility to existing gas lines. This also applies to electricity or fuel oil. Geothermal utilization requires geophysical exploration, resource development, a piping system, and specialized heat production equipment. Developers are not interested in investing large quantities of money in projects which have not been extensively tested in the United States. If money could be made available at cheaper interest rates for geothermal use systems, the capital factor would have lesser impact on the decision.

A second consideration in the financing factor is the uncertainty involved in geothermal resource development. As in oil well drilling, many exploration drill holes do not produce the resource. At $20 per foot for shallow wells and $100 per foot for deep wells, a developer cannot afford to gamble on too many holes. The method has been suggested whereby the risk in a development venture can be lessened. This would involve the federal Department of Energy loaning money for exploration holes to be paid back at a specified interest rate if a useful resource is encountered. If the hole ends up dry, the money would not be repaid. Naturally, much thought would be required to construct a working program such as this to prevent unrestricted speculation. Such a program would require a rather large funding base. Until some sort of guarantee program or greatly increased economic demand is evident, geothermal development will move at a snail's pace.

For information purposes, a partial listing of funding sources with brief descriptions is presented in Appendix B.

State Leasing

In Montana, as in other Rocky Mountain states, state land can be found in widely dispersed sections all over the state. Direct use of geothermal resources is effected more by state than federal land because of this spatial distribution. The communities are traditionally located in valleys and broad basins surrounded by private land. Federal land, Forest Service in particular, is located in mountain ranges some distance from these population centers, while state land can usually be found nearby. As it is essential to locate geothermal reservoirs near the use area, to avoid piping costs, access to these resources on state land is important.

As a good example of the problem presently plaguing leasing of state lands, we should consider the development project attempted in the Hunter's Hot Spring area. This project was aimed at finding a resource capable of supporting electrical generation. The developers decided that financial backing was adequate and began leasing land. The private lands surrounding Hunter's Hot Springs were leased. There were a few isolated parcels of Bureau of Land Management land which were applied for. These Bureau of Land Management parcels were cleared for leasing after two years of preparation. Finally, a parcel of land of less than a section was located directly adjacent to the Hunter's Hot Spring's site. This last piece has to be tied up to guarantee protection of the developer's investment. The lease was applied for but the controlling agency, the Montana Department of State Lands, had adopted a policy which effectively stated that if a number of applications were not received, then sufficient leasing interest was not present. This means no leasing activity will take place until such interest is noted. If the developer had gone ahead and begun his project investing the large sums of money required for geophysical exploration and drilling of exploratory test wells and located a reasonable resource, significant outside interest could have been generated for a state lease sale to be held. Other companies could afford to bid higher than this original developer for this state parcel since the exploration expense gamble had already been taken. Now, although the developer was interested in electrical production, the restrictive leasing policy of disallowing individual leases will apply to every applicant regardless of end use proposed. Geothermal development, especially in direct use will not proceed with a mass of individual products. It will begin with one developer as the experimenter and likely be followed by other tentative steps until enough public confidence has been built. The state leasing policy will have to be altered to allow that first small step.

Synopsis Of Current State Leasing Regulations

Any state land under the Board of Land Commissioners of the State of Montana may be leased. Each lease may be no more than 640 acres. The lease application may be made any time during the year and when sufficient applications have been received to warrant a sale, or at the Commissioner's discretion, the sale will be announced. Geothermal leasing will be let by competitive bidding with sealed bids submitted to the Department of State Lands within 40 days after the announcement of the leasing sale. The minimum bid is $1.00 per acre for the first year's rental. If at a lease sale no bid is made on the tract or tracts for which an application has been made, the applicant may negotiate with the board for the lease.

Each lease issued shall be for a primary term of 10 years and so long thereafter as geothermal resources in paying quantities are produced. A royalty of not less than 10 percent of the gross revenue, minus incurred production and transmission costs, will be paid to the state. The royalty of not less than 10 percent of the gross revenue received from the operation of geothermal resources for recreation and health purposes is also required by the state. Unitization of state-owned land for resource conservation is provided for. The lessee may not enter upon the leased land for casual exploration or inspection until there is in existence a fully executed lease. A person not holding the lease may not enter state land for casual exploration or inspection of geothermal resource potential. All state lands disturbed by exploration, development, and operation of geothermal resources must be reclaimed when the site is abandoned.

A minimum bond of $2,000 is required prior to the issuance of any geothermal resources lease. Prior to initiation of operations for drilling a well to 1,000 feet or deeper, the bond deposit must be increased to $10,000. The lease holder may not enter leased land for exploration involving earth moving equipment or otherwise engaging in operation which may lead to material disturbance without submitting a plan of operation to the Department of State Lands. The plan of operation must include the starting date and estimated completion date, the anticipated size of the operation including manpower equipment and extent of disturbance, and the general method of operation. The plan of operation is usually required when it is anticipated that a well of 1,000 feet or deeper is to be drilled. The plan of operations must be approved by the commissioners for projects of this extent. Projects which would not require a 1,000-foot hole would not require approval of the commissioners after submission of a plan of operations.

Federal Leasing and Permitting

Federal leasing of both Bureau of Land Management and U.S. Forest Service land is of primary interest to developers of electrical energy. The highest potential geothermal resources are usually located near mountainous terrain in Montana. Most of the mountainous areas lie within U.S. Forest Service or Bureau of Land Management boundaries. A developer of electrical energy in an area must hold production rights to all adjacent land in the area of interest to justify risking exploration capital. The risks involved in the pursuit of suitable reservoirs is so great that successful attempts must have the potential of complete use of that area for electrical production. This will guarantee that profits will be adequate to pay the rate of return on invested money that American corporations have come to expect.

Lease Procedure

The first step in the leasing procedure is determined by the area of interest. If the area has been previously classified as a "Known Geothermal Resource Area" (KGRA), then the developer must wait for a lease sale. If the area is classified as a "Potential Geothermal Resource Area" (PGRA) or not designated at all, he may submit a lease application to either the U.S. Forest Service or Bureau of Land Management. Upon receipt of a lease application, the appropriate agency must schedule to begin an evironmental assessment record or, if necessary because of sensitive issues, an evironmental impact statement for the area in question. This same study requirement is

is necessary before leasing can proceed in KGRA's also, the difference being that the study must be done for the KGRA's regardless of interest. The manpower requirement for Environmental Analysis Record or Environmental Impact Statement is very large, which limits the number of studies which can be carried out at any one time. Presently in Montana, one KGRA is in the process of being studied with estimated completion in early 1979, and remaining KGRA must wait until this previous study is completed before a new one can be begun.

Each study requires from one and one-half to as much as three years to complete. The study includes not only the Environmental Analysis Record or Environmental Impact Statement, but mitigating lease stipulations which are meant to lessen the environmental impact of geothermal development. It is sometimes difficult for the involved agencies to agree on specific stipulations as is the case with the Marysville KGRA. The net result of the Environmental Analysis Record or Environmental Impact Statement with mitigating stipulations is to seriously limit the extent to which a KGRA or PGRA can be developed. This was the case with the Boulder Environment Analysis Record. The most restrictive stipulation is the "no surface occupancy" requirement. This means that the company can lease the ground, but cannot use the ground in any manner for drilling or heavy surface exploration. Use of directional drilling, which involves boring a hole at an extreme angle from an adjacent parcel of land to tap the resource underneath that particular piece, is usually recommended. This is a very costly drilling method and the technology cannot guarantee drilling success. With the present economic incentives, this technique is not justified nor does it appear likely to be in the future.

Another difference between KGRA and PGRA is the leasing procedure. Leasing of a KGRA is required to be on a competitive basis. Many people are allowed to bid on the same parcel of land. In a PGRA, the original applicant is allowed to bid and if no one else is interested, he may have the lease. If a PGRA parcel is bid upon by two or more applicants, then it is automatically reclassified into a KGRA with competitive bidding, with the competitive bidding requirement. It has been demonstrated that a KGRA classification does not guarantee competitive or even singular interest. If lease sales have been held in a KGRA and little interest is evidence, the area should be returned to the noncompetitive classification. Procedures for doing this are not clear within the present federal laws.

Direct Use Technology

A very important factor which affects geothermal utilization in Montana involves unfamiliarity with transport mechanisms and heat-exchange technology. Present technology makes possible the transport of hot water over long distances with little loss of heat. Technology is available which allows transfer of the heat in the water to air to allow space heating, and into other mediums in which heat is required. This technology is currently not used to any extent in the United States, but foreign countries such as Iceland have proven its feasibility many times over. This lack of specific

utilization of the technology in this country makes financial consideration and equipment availability subject to much questioning. A developer who is interested in piping water a distance is faced with the difficult search to obtain necessary technical and cost parameters. The economic feasibility in the country has not been tested to any extent. Therefore, the developer has no guarantee that the system can be installed and operated with investigated cost and reliability figures.

There are very few occasions on which a geothermal developer can order "off-the-shelf" equipment designed specifically for geothermal applications. Much utilization equipment is available, but the present system of technology transfer to alert the developer of existing hardware is quite inadequate.

For commercial geothermal energy development to occur, entrepreneurs must be able to justify investment of monies into geothermally oriented systems. Few people can visualize the complete development picture required to be able to construct a profit picture model. While the geothermal energy supply technology is relatively little known, the importance of stimulating a direct-use economy to the nation has prompted the budgeting of funds for the purpose of initiating demonstration projects illustrating the technology available. Therefore, the first projects involved in geothermal direct use will be eligible for some subsidies from the government. These can be in the form of technical assistance, which is given by specific organizations, or it can be given in the form of financial assistance through grants and geothermal guaranteed loans. State government, in addition to federal government, is interested in promoting geothermal development. Technical assistance can be acquired through these channels also.

Water Quality Laws

The Montana Department of Water Quality is charged with the responsibility of maintaining water quality as set by the state water quality standards. All bodies of water, streams and river are given classifications. The classifications will apply to specific stream segments. One stream may be subjected to different water quality requirements for different points along its length. If the stream quality was high at the time of classification, the classification requirements were strict for the stream segment. Conversely, if the stream segment was subjected to some degradation, it was classified at a lower quality.

Many of Montana's streams have the BD-1 classification. The parameter of most concern to geothermal developers is the net temperature increase allowed for a stream. For the BD-1 classification, a maximum of a 1°F increase above naturally occurring water temperature is allowed within the range of 32°F to 66°F. For the range of 66°F to 66.5°F, no discharge is allowed, which would cause the water temperature to exceed 67°F. And, where the naturally occurring water temperature is 66.5°F or greater, the maximum allowable increase of water temperature is 0.5°F. A 2-degree per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55°F. And, at 2°F, the maximum decrease below naturally occurring water temperature is allowed within the range of 55°F to 32°F.

The concentration or levels of toxic or other deleterious substances, including heavy metal, are limited under each stream classification. The discharge itself is not addressed, but the maximum in-stream concentration of that substance is limited. There are very few instances in which a warm water discharge is allowed in state waters. In some cases, if a surface spring is already discharging water to a stream or river, the total temperature increase of the stream due to the discharge of the spring is considered. This would allow discharge of a greater volume of spring water if it could be cooled down some by efficient use. In some cases, geothermal fluid can be utilized in irrigation, via irrigation ditches with return to a stream if the discharging water is no higher than the normal ambient levels which irrigation water is discharged at. Any discharge to a surface body of water must be approved by issuance of a discharge permit. The discharger must apply for the permit before a discharge is allowed. The discharge permit would describe the nature of the discharge and insure compliance with the state's water quality standards. In Montana, the strict water quality standards would prohibit use of streams for warm waste water disposal.

Water Rights Laws

In Montana, goethermal waters are treated the same as standard water withdrawal applications at this time. This definition puts them under the state's water rights laws. Under these laws, any well which produces over 100 gallons per minute is required to have a permit. Interim permits for drilling and test pumping of a well are available. In the interest of investment protection, a provisional permit should be applied for if the withdrawal is anticipated to be over 100 gallons per minute. This permit should be applied for before drilling is started. It will notify surrounding landowners of the intended withdrawal permit application. If there are no objections from surrounding right holders, the permit is granted. If objections are received, the application request is investigated and a hearing may be held.

For domestic wells, a certificate of water right is issued for withdrawals of less than 100 gallons per minute upon completion of the well. This gives the landowner a domestic water right. Surface springs are also subject to water rights laws and would also require permits before any major changes can be initiated. This protects surface rights of downstream users.

The permit procedure is submitted in the field office which generally takes two weeks to review. Ownership of surrounding surface and well rights is reviewed. The second step of the process takes two weeks to two months and involves notification of the people involved with ownership and also newspaper notification. The third step takes two months, and is the public notice period when comments pertaining to the water right application are received. The fourth step, usually taking three weeks, is the alternative when no objections are received--the permit can be written. If objections from water rights owners are received, then the Water Rights Bureau must investigate any objection. This process takes one week to twelve months. If the objections are valid and it cannot be demonstrated that the proposed well will not affect those surrounding water rights, then the permit is

denied. If it can be shown that the use of this water right will not endanger other rights--the permit can be issued in spite of owner objections. If the withdrawal is equal to or more than 15 cubic feet per second, then the permit application must be subjected to an Environmental Impact Statement or clear and convincing evidence that no prior rights will be adversely affected. An interim permit cannot be issued under these circumstances. In areas of little development, some parts of the standard water rights permit process can be shortened. The Department of Natural Resources and Conservation can issue a waiver of public notice which speeds up the permitting process.

At this time, the question of whether the geothermal heat is protected by water rights remains unanswered. For instance, if a geothermal well is drilled in the vicinity of a hot spring area and the temperature of that hot spring goes down as water from the geothermal well is drawn, is the owner of the spring entitled to protection of that temperature? If, however, the spring level or quality that flows from it is decreased and he does own surface rights on the spring, then the well owner is required to decrease withdrawal to alleviate the situation. Resource definition questions concerning water will remain unanswered until specific tests of the laws are made.

Montana's Major Facility Siting Act

Under the present regulations, the Montana Major Facility Siting Act of 1973 prohibits construction of certain types of facilities in Montana without a certificate from the Board of Natural Resources and Conservation. One type of facility for which a certificate is required is "any use of geothermal resources, including the use of underground space in existence or to be created, for the creation, use of conversion of energy." Under these requirements an application to the Department of Natural Resources and Conservation is required. This application must contain certain types of information pertinent to the construction and operation of the desired facility. A filing fee, as set by a sliding scale rate schedule, is required with the application. This is decided on as a percentage of the construction costs of the facility. The Department of Natural Resources and Conservation then acts as the lead agency for preparation of an environmental impact statement. The department uses the information in the application, in addition to any information it deems necessary to collect on its own, for preparation of the statement. Public hearing procedures are followed for public input. The impact statement, application, and findings of fact by both the developer and the Department of Natural Resources and Conservation and Department of Health and Environmental Sciences are submitted to the Board of Natural Resources and Conservation. If there is controversy surrounding parts of the development, additional public hearings will be held. A decision is then made by the board whether the facility is environmentally sound and satisfies public needs. A section describing the requirements for geothermal facilities does not put a lower limit on size. Thus, any use of hot water must, by law, be considered in the Major Facility Siting Act. At this time, legislation setting a lower limit for inclusion on the Major Facility Siting Act of Geothermal Facilities is being prepared. It is anticipated that for projects involving the equivalent to about 7 megawatts electrical power or less, would be exempted from compliance with the act.

Geothermal Investigation Reports Required By The Montana Department Of Natural Resources

Any person or entity must submit a long-range plan for the purpose of describing anticipated exploration for geological data involving boring of test holes or other underground exploration, investigation, or experimentation, which is related to possible future development of a utility facility employing geothermal resources.

Initial field reports, periodic field reports, and final field reports are required of the exploration project. Geological reports are required after completion of the project. Confidentiality of pertinent technical data submitted will be recognized for a period of two years following commencement of the operations for the drilling of an actual well for testing of potential.

This requirement is designed to augment planning consideration under the Major Facility Siting Act.

COMPOSITE SCENARIO FOR 13 WESTERN REGION SITES

DEVELOPMENT PROJECTION SUMMARY

The scenario prepared for the 13 sites were combined in a graph form using starting dates and resulting finish dates with specific energy projections. The graph in figure 3 is a composite of possible nonelectric geothermal development as projected for the next 20 years. Figure 4 illustrates the possible electric geothermal development over this same period.

The nonelectric composite shows a start of the development on or before 1977. This process proceeds to the first power-on-line in 1982 with steady stepwise additions to a total of 567 x 10^6 Btu/hr by the year 1992. The total yearly energy production which could be expected if this development should occur is 2.5 x 10^{12} Btu/yr.

The electric scenario summary is the result of five different generating sites being developed with one unit each. The process would begin in 1980 with the first power-on-line by 1990. Subsequent development would raise the total energy production to 400 megawatts by 1995.

In both of the above development summaries we see primarily single events on each site. This condition would be expected to occur in reality. If a useful reservoir is discovered, then multiple energy uses could be expected at a single site area. The purpose of assuming single events is to illustrate possible development and to increase accuracy. Some sites may never be developed while others will have multiple development and it is hoped that this method of planning will result in an average energy development.

The validity of any one of the scenarios is very small, with a few exceptions. These projections were postulated to help in arriving at goals for development efforts. The underlying premise of this project is: Planning with an analysis of possible end results is necessary to most efficiently use capital resources in achieving specific goals.

COMPOSITE ELECTRIC GEOTHERMAL SCENARIO

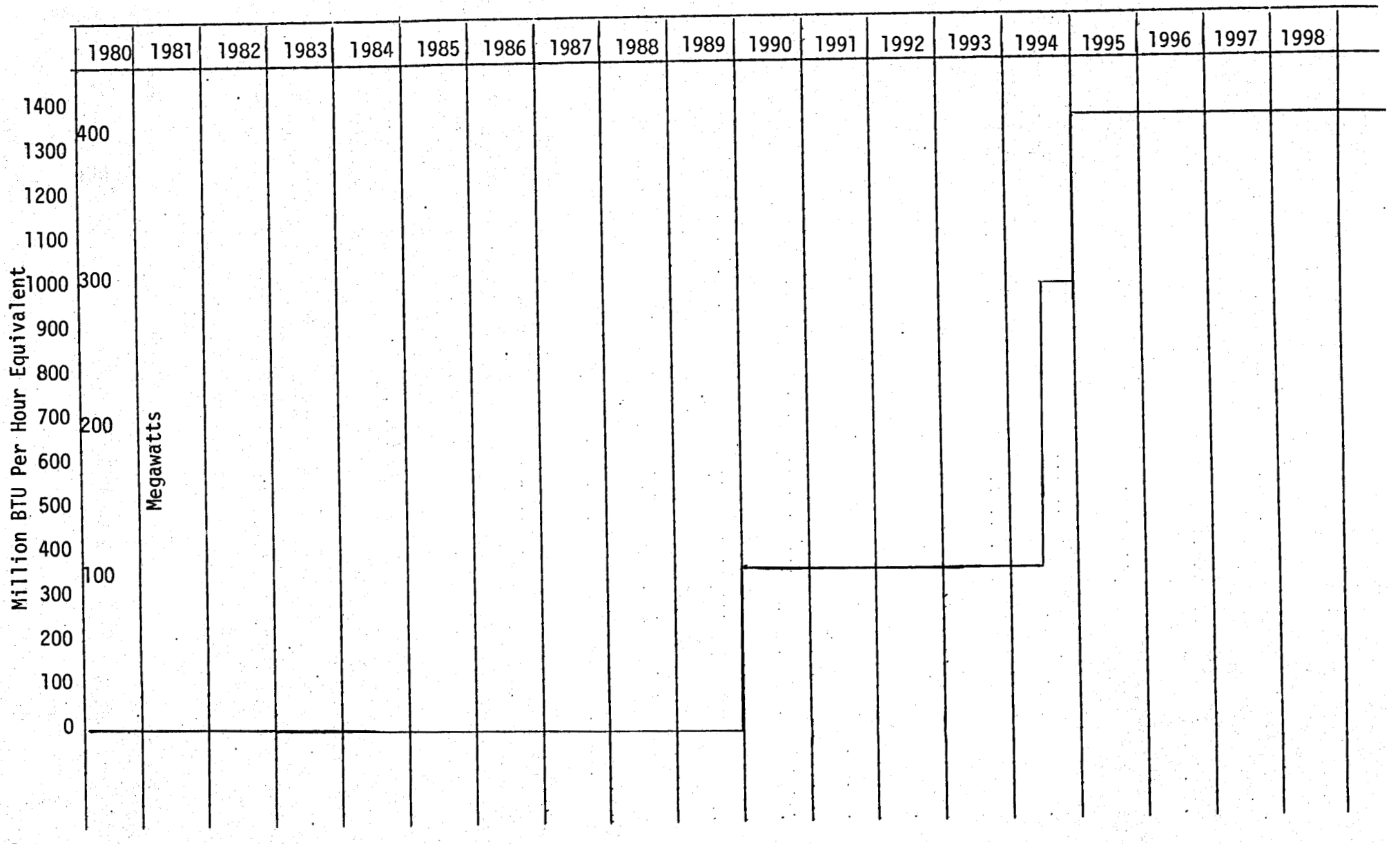


Figure 3

COMPOSITE DIRECT USE GEOTHERMAL DEVELOPMENT SCENARIO

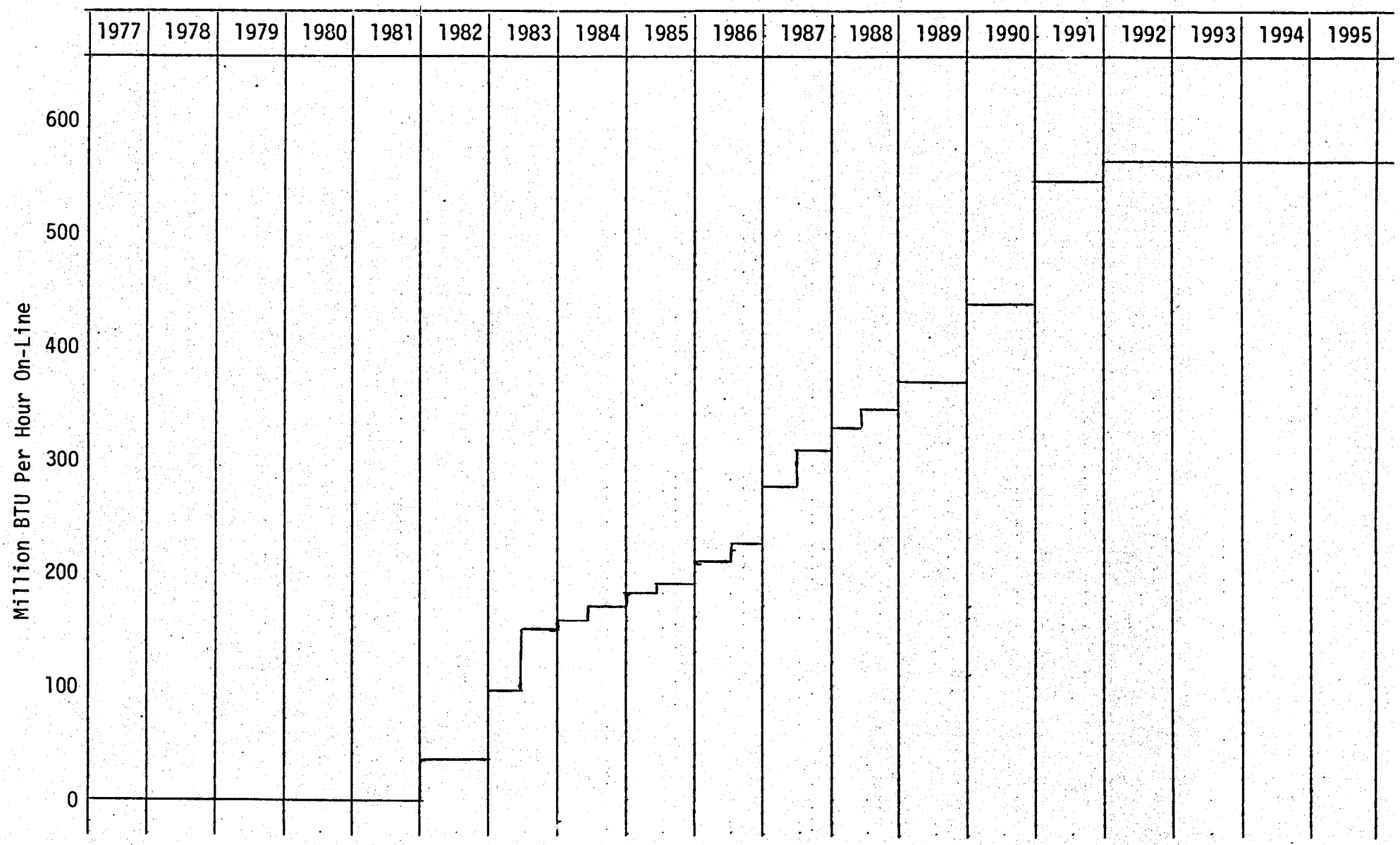


Figure 4

FUTURE PLANNING RECOMMENDATIONS

This planning effort pointed out some very important strategy needs. Specific sites with "known" potential were concentrated on during this study. The results illustrated that an end user of energy production is essential for maximum use. Most of Montana's known resources are not located near energy users. This condition allows three alternatives for future work. The first, which is undesirable and unacceptable, is to curtail all further work on geothermal development except those few near users. The second is to explore the possibility of relocating population and industry near the energy sources. The third, and best in this author's opinion, is to identify the areas of major present and projected future energy demand and study these areas for possible geothermal potential. It seems quite possible that many unidentified geothermal reservoirs exist in Montana. Directing emphasis to the energy demand areas would insure that fossil fuel use could be reduced significantly if geothermal reservoirs are found. This approach seems quite logical at this time since the state of resource assessment for the known sites is in a fledgling stage. Very little actual resource definition has been done in Montana on known or unknown sites.

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APPENDIX A

TIME FACTORS FOR SCENARIO PREPARATION

1.0 Private Land Owner.

1.1 Prospecting Permits--It was assumed from information gathered that little prospecting would occur without a cause. Therefore, this is usually not applicable.

1.2 Lease Land--This step should take from 3-6 months and is marked with a triangle. It was assumed that all leases would be obtained at once.

2.0 County/City--Montana has little in the way of organized city/county planning which would affect most of the possible projects. Usually not applicable, but could take 6 months for a construction permit if applicable.

2.1 Not applicable.

2.2 Not applicable. (Could be 6 months.)

2.3 Not applicable.

3.0 State.

3.1 Process EIA/EIS--Pre-Lease. A cursory EAR is required on state land which is to be leased. Should not take over 6 months prior to lease sale.

3.11 Issue exploration permit--The Department of State Lands will not allow exploration or access to an up-leased parcel. After permit is granted, it takes from 3-12 months to process.

3.2 Lease Land--Assume that a geothermal lease sale can occur at any one of four quarters during the year, 3 months after 3.1.

3.3 Water Rights Permit--Takes 9-18 months with an average of 12. Must begin process before production drilling to guarantee the right to use water.

3.4 Issue Drilling Permits and Permit issued 60 days after the development plan is submitted to the Department of State Lands.

3.41 Exploration--Permit will cover both 3.41 and 3.42.

3.42 Production--See above.

3.5 Certify Thermal Facility--This is controlled by Montana's Major Facility Siting Act. An average of 3 years is required for larger (750 MW) installations. Allow 1 year for smaller operations. Now legislation will try to exempt all installations of 75 WM or less.

3.6 Same as 3.5.

3.7 Issue Utility Charter--Most cases do not acquire state level participation other than for setting rate structure. The rate structure has to be approved by the Utility Commission. This could take 1-6 months. A utility charter is necessary within city limits and approval time varies but usually takes 3-6 months.

4.0 Developer.

4.1 Geophysical Exploration--Electrical requires 2-1/2 years on site. Direct use required 3-18 months.*

4.2 Exploratory Drilling--Electrical requires 2 years beginning 9 months after 4.1 begins; direct use requires 1-6 months.*

4.3 Commit to Develop--should occur at the end of 4.2.

4.4 Prepare plan of Operation--Begin 9 months before 4.3 and extend for 1-1/2 on electrical; begin as early as 9 months before end of 4.3 and extend 3-18 months for direct use.

4.5 Field Development Drilling--Begin 9 months after end of 4.4 or 3.5, whichever is later, and extend 1 year for electrical; extend from 1-12 months for direct use.*

5.0 Utility.

5.1 Commit to Develop--If user is different than the developer, then this will occur 3 months after 4.3. If user is the same, then 4.3 and 5.1 will occur together.

5.2 Prepare plan of Operation--Electrical will begin 9 months before 5.1 and extend 1-1/2 years. Direct use can vary since this is not always well defined in direct use. Usually begin before developer commits to develop for decision purposes, can extend 3-18 months.

5.3 Design--Electrical begins 6 months after 5.2 begins, extends 1-1/2 years. Direct use should also begin after 5.2 and can extend from 6-18 months.

5.4 Thermal Supply Facility--Electrical begins at end of 5.3 and extends 2 years. Direct use will start construction on this after the end of 4.5 (field development drilling), possibly after 5.3 and extend from 3-18 months.

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*All surface exploration and drilling has to occur during the summer season in Montana. Allows only 6 months work per year.

5.5 Install Distribution Lines--Electrical depends on 5.3. Direct use depends on type of facility and stages of construction. Space heating district will have continuous construction of distribution lines.

5.6 Utilization System Construction--Electrical should occur at the same time as 5.4. Direct use will usually occur after 5.3 ends. The extent of construction time varies with each project with a sample period being 12 months.

5.7 Direct Heat Application On-Line--This occurs at the end of 5.6 and Direct Use can have stages of additional power-on-line.

6.0 DOE/DGE.

6.1 Research and Development--Direct use is very hard to plan for without prior knowledge of technology available. This step does not enter any of the Montana scenarios.

6.2 Resource Exploration and Assessment--Scenarios were not postulated for imaginary sites. Future planning efforts could analyze the energy needed in an area and postulate a reservoir. DOE/DGE financed resource assessment did not enter into scenarios for Montana, nor are they likely to for the future. It is not a realistic mechanism for projecting geothermal potential.

6.3 Hydrothermal Technology Applications DOE/DGE--This activity does not affect overall planning efforts for Montana. Demonstration projects and other work which would benefit development will undoubtedly affect the rate at which resource use progresses. The timing or amount cannot be quantified and, consequently, was left out of Montana scenarios. Most projects will not need DOE/DGE help other than funding.

6.4 Advanced Technology--Not applicable.

7.0 DOE/AES--Environmental Baseline Study. Not applicable.

8.0 DOI/USGS.

8.1 Geologic Division.

8.11 Evaluate Land for Leasing--Varies with Site Interest. A completion date for all areas is projected for January, 1979. This does not seem realistic from past performance.

8.2 Conservation Division.

8.21 Issue Pre-Lease Surface Exploration Permit--Requires 3 weeks, can issue anytime.

8.22 Issue Exploration Drilling Permit--Requires 3 weeks, can issue anytime after lease.

8.23 Issue Production Drilling Permit--Requires up to 1 year after submission or application with plan of operation.

9.0 DOI/BLM.

9.1 Compile EIA/EIS Pre-Lease--Begins with applications for lease, requires 2-3 years.

9.2 Issue Lease--Can occur 3 months after end of 9.1.

9.3 Compile and/or Review--Thermal Supply Facility Drilling and Distribution Lines. This process begins with submission of plan or operation prescribing development. If all goes well with exploration and drilling, this step can be complete 4-1/2 years after lease is issued and applies to large projects. The actual time required can vary from 6 months or less, to a year. This is usually a milestone.

9.4 Certify Thermal Facility--A milestone which occurs at end of 9.3.

10.0 DOI/FWS.

10.1 EAR Review--This step takes 6 months and ends at the same time as 9.1.

11.0 USDA/FS.

11.1 Review EAR--This step ends the same time as 9.1.

12.0 EPR.

12.1 Review of EIS--This step ends the same time as 9.1.

12.12 Same as 8.22.

12.13 Same as 8.23.

13.0 DOE.

13.1 Review Pre-Lease EAR/EIS--This step ends the same time as 9.1.

APPENDIX B

FUNDING SOURCES

There are a variety of sources available for financing geothermal direct-use projects. Unfortunately, there is no established system under which a person can apply for a grant or a loan in the manner one might approach a bank for a car loan. The presently available funding sources are usually operated under a proposal approach. This involves drafting a description of the project in some detail, with submission to the appropriate entity for consideration, along with other proposals of similar nature. If the proposal has sufficient merit, over and above other proposals submitted at the same time, then this project could be funded. The funding is usually done on a cost-share basis.

Montana Alternative Energy Grant Program

One of the easier sources for which to apply under the proposal type approach is Montana's Alternative Energy Grant Program. This program is set up under law using a small percentage of the state's coal severance tax revenue. The purpose being that with the exhaustion of our coal resources, alternative energy will be needed in the future. This program is designed to prepare the technology necessary for the conversion. The budget for this program is small at the present, but is designed to increase over the years. The largest grant which will currently be considered is in the $100,000 range. There is no set matching fund requirement for this program. The grantee is expected to supply a certain amount of funding, services, or in-kind contributions. As mentioned above, the project must be documented with a written description, economics, design criteria, and overall approach. The funding periods are usually held twice a year and, at this point in time, an average of two grants in the geothermal area are approved per year. This is actually a healthy percentage since the application number are quite small.

Federal Geothermal Energy Grants

The U.S. Department of Energy-Division of Geothermal Energy has a grant program similar to Montana's. In the past, it has issued a Program Opportunity Notice or PON which asks for submission of grant proposals. This grant program is aimed at stimulating direct use of geothermal projects through demonstration facilities. The proposed project is described in detail using the application package supplied by the Department of Energy. The requirements are usually fairly restrictive in that professional technical assistance is required. A PON is issued usually once per year and grants as high as 2 million dollars have been approved. Total funding for this source is rather high, but competition is stiff.

Federal Geothermal Loans

A federal program establishing federally-backed geothermal guaranteed loans was established after the 1970 Geothermal Steam Act, which was passed by Congress. Its purpose was to stimulate the development of

electrical generation from geothermal sources. Under this program, an entity may apply, via much red tape, to a bank for a loan which will be federally guaranteed. It takes a long time period to set up the mechanism. Reports from applicants of this financing avenue have indicated that the process is very unwieldy. Conversations with officials in charge of this program have indicated that the minimum practical loan at this time is 1 million dollars. A request has been made to the Department of Energy for allowing funding of much smaller loans with a decrease in the paperwork required. If smaller, easier-to-obtain loans are available, the economic viability of direct-use projects in Montana will be greatly enhanced.

Indirect Loan Avenues

A possible state funding avenue may be available under a state program which can supply small low-cost loans for job creation in economically depressed areas. The loans are administrated through the Montana Department of Administration. The purpose of these loans is to help labor intensive industry in areas which have very little in the way of support for the local labor force. This program could be utilized by someone interested in constructing and operating some form of geothermally-heated manufacturing or industrial business. An ideal example would be a commercial greenhouse facility. By nature, greenhouse operations require very intensive manual care. A rural area which had little in the way of employment would offer reliable and inexpensive labor for a commercial greenhouse.

The Federal Economic Development Administration makes large cut-rate loans which can be used for economically desirable business ventures. Information on this program is available through a branch office of the EDA in Helena.

Other funding sources are sure to be instituted in the future. There is also a good possibility that other programs which have funding can be adapted to in use of geothermal direct use.