Geothermal Energy

a brief assessment

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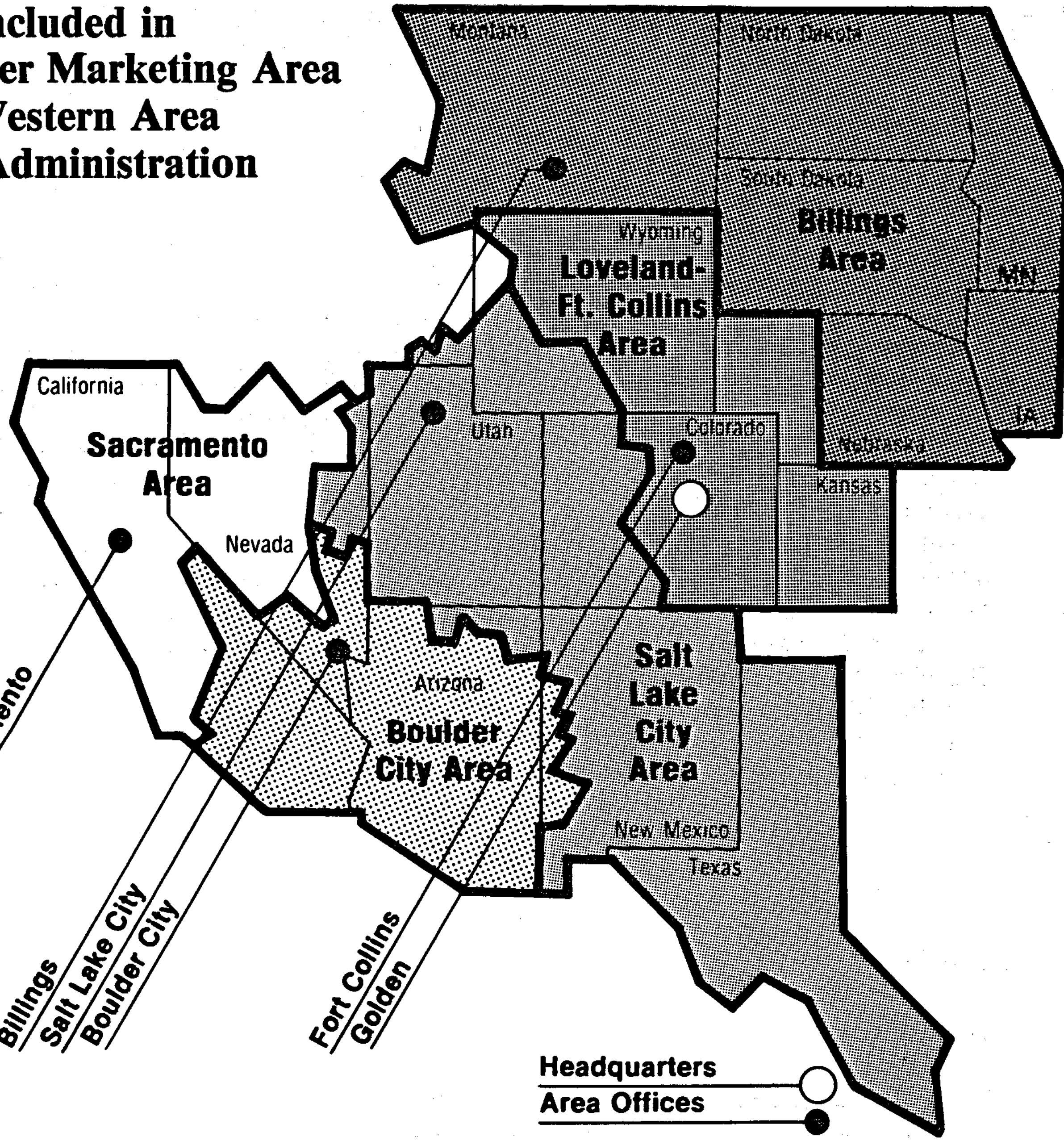
States Included in the Power Marketing Area of the Western Area Power Administration



Preface

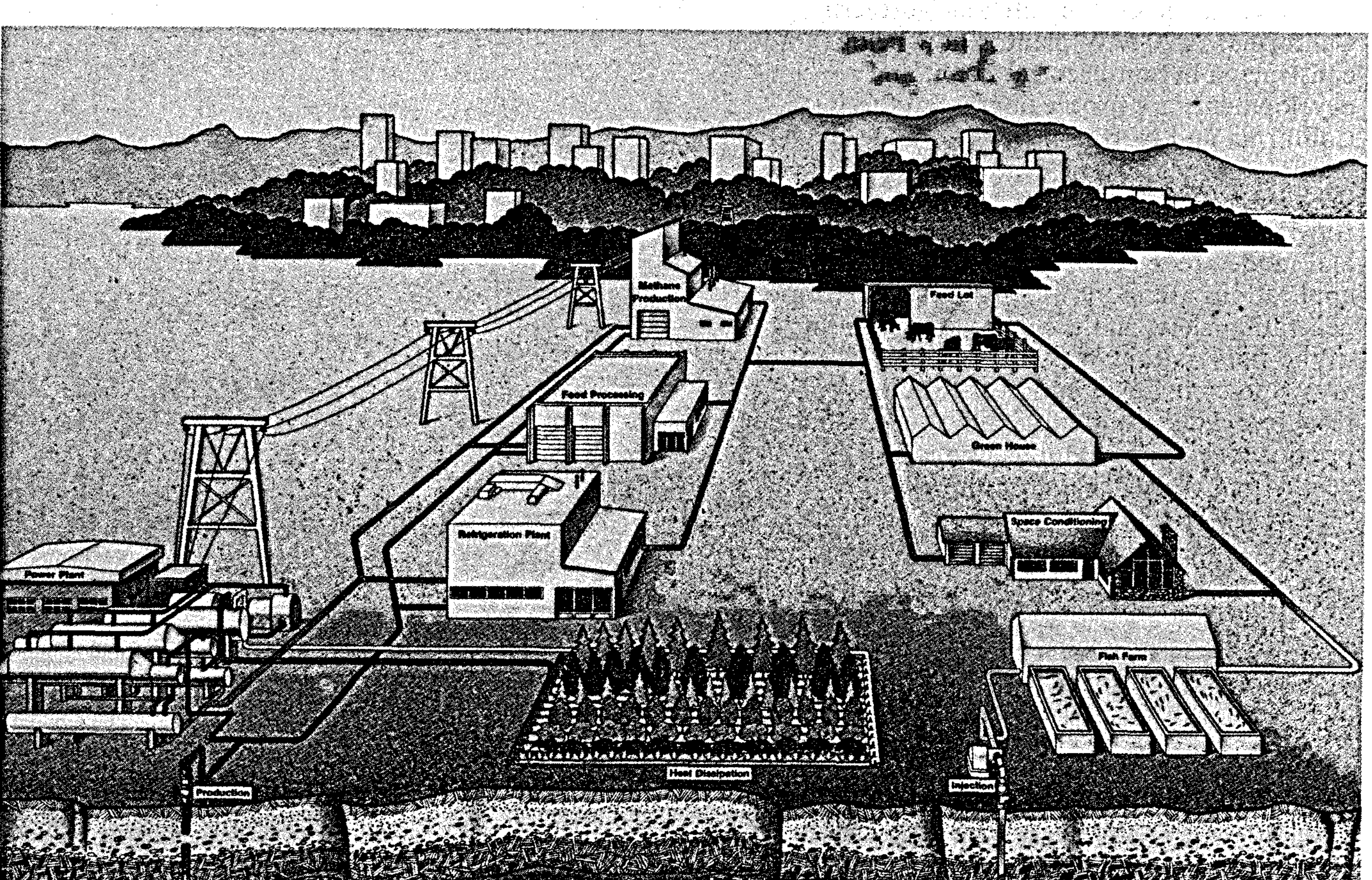
This document is primarily intended for small utility organizations, i.e., REA cooperatives, municipalities, and others who are wholesale power customers of the Western Area Power Administration (Western). It is designed to provide a short, easy-to-understand assessment of geothermal energy resources within Western's 15-state power marketing area. If the reader develops an interest in obtaining further technical and/or economic details regarding geothermal resource development, several sources for obtaining additional information are identified throughout the report and in Appendix A.

Section I

Foreword

Geothermal energy, the earth's interior heat, is generated by natural processes beneath the earth's surface. It occurs at great depths everywhere, but surface activity appears in places such as active volcanos, hot springs, fumaroles, and geysers. This energy has been used for centuries—for religious and therapeutic uses, heating, and in more recent times to generate electricity, process foods and other consumer goods, and to heat and cool buildings. This renewable form of energy is steadily increasing in use throughout the world, and it is proving to be both economical and beneficial.

Where renewable energy resources are located in close proximity to Western's utility customers, and there are indications of economic benefits to be derived from the development of such resources, Western encourages its customers to actively explore possibilities for using these alternatives to nonrenewable energy. The development and use of renewable energy resources such as geothermal energy lessens America's dependence on limited fossil energy sources, thereby benefiting the entire Nation. Where economic benefits exist, Western supports the development and continued use of geothermal energy.



Summary

Geothermal Energy—A Brief Assessment has been prepared to acquaint the reader with the geothermal resource that is increasing in use and complementing other available energy resources. This assessment is one of a series being prepared by Western for energy suppliers and users. It is Western's desire that the information provided herein will serve as a catalyst to interest their customers in another form of renewable energy that is increasing in use and popularity, and to indicate where and how this energy may be applied within their power marketing areas.

This document includes discussions about geothermal energy, its applications, and how it is found and developed. It identifies known geothermal resources located in Western's power marketing area, and covers the use of geothermal energy for both electric power generation and direct applications. Economic, institutional, environmental, and other factors are discussed, and the benefits of the geothermal energy resource are described.

Geothermal resources with enough heat to generate electricity are located throughout the world. About 1,000 megawatts (MW) of electricity, which is enough power to meet the needs of a city the size of San Francisco, is being generated at the Geysers area in Northern California. A 20-MW plant is now being constructed in Southcentral Utah, and developments are proceeding in Southern California and Northern Nevada. Other high-temperature resources, located primarily in the Western United States, are under consideration for development. Geothermal resources with low and moderate temperatures suitable for direct applications are more widespread than electric generation sites, and they are being used in many of the states within Western's power marketing area. Increasing exploration for geothermal resources and heat pump applications will expand opportunities for development and use of geothermal energy in the future.

Geothermal energy can be cost competitive under certain circumstances. In some cases, the payback period may be only several years. Recognizing that geothermal resources vary widely in quality, temperature, and quantity; the methods of developing geothermal energy are also quite varied, requiring evaluation by qualified personnel to properly estimate their costs. An indicator of geothermal power generation costs compared with conventional power plants can be obtained from the curve on page 3. The economics of geothermally produced power are very strongly influenced by resource size and quality (i.e. temperature, pressure, salinity, productivity, etc.), thereby affecting capital costs and utilization efficiency.

It is noteworthy that geothermal energy projects for electric generation applications are capital intensive, and these projects are usually only economical when built on a megawatt (MW), rather than kilowatt (kW) scale. Direct heat applications, however, are less capital intensive and can be developed on a relatively smaller scale.

The geothermal industry has grown in the past few years, and many advances have been made in the technologies required specifically for developing this type of energy. Exploration, drilling, plant design, and construction technologies are either proven or past the pure demonstration stage, increasing the economic attractiveness of geothermal energy. The future usability of this energy form is being enhanced by state-of-the-art improvements that are currently underway in geophysical exploration, drilling, and utilization technologies. Environmental impacts are relatively less than for some other resources, making geothermal energy more desirable regarding this developmental aspect.

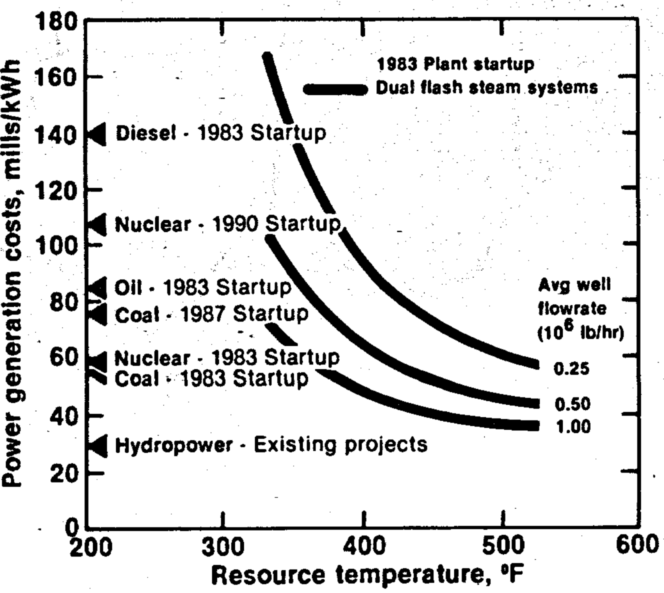
The use of geothermal energy provides an alternative for future power generating needs and direct-use applications. Adequate resources will reduce energy costs and complement other energy sources. The use of geothermal energy can also defer expenditures for other energy systems.

Geothermal power plants are relatively small in comparison with conventional systems, and they require a relatively short period from start of design to power production. These factors allow a closer match of utility capacity growth with load growth, and they reduce the magnitude and duration of construction financing as compared with conventional fossil/nuclear power plants.

The National Energy Act of 1978 and Crude-Oil Windfall Profits Tax Act of 1980 currently provide favorable Federal tax treatment for geothermal development through investment tax credits, depreciation, and depletion allowances.

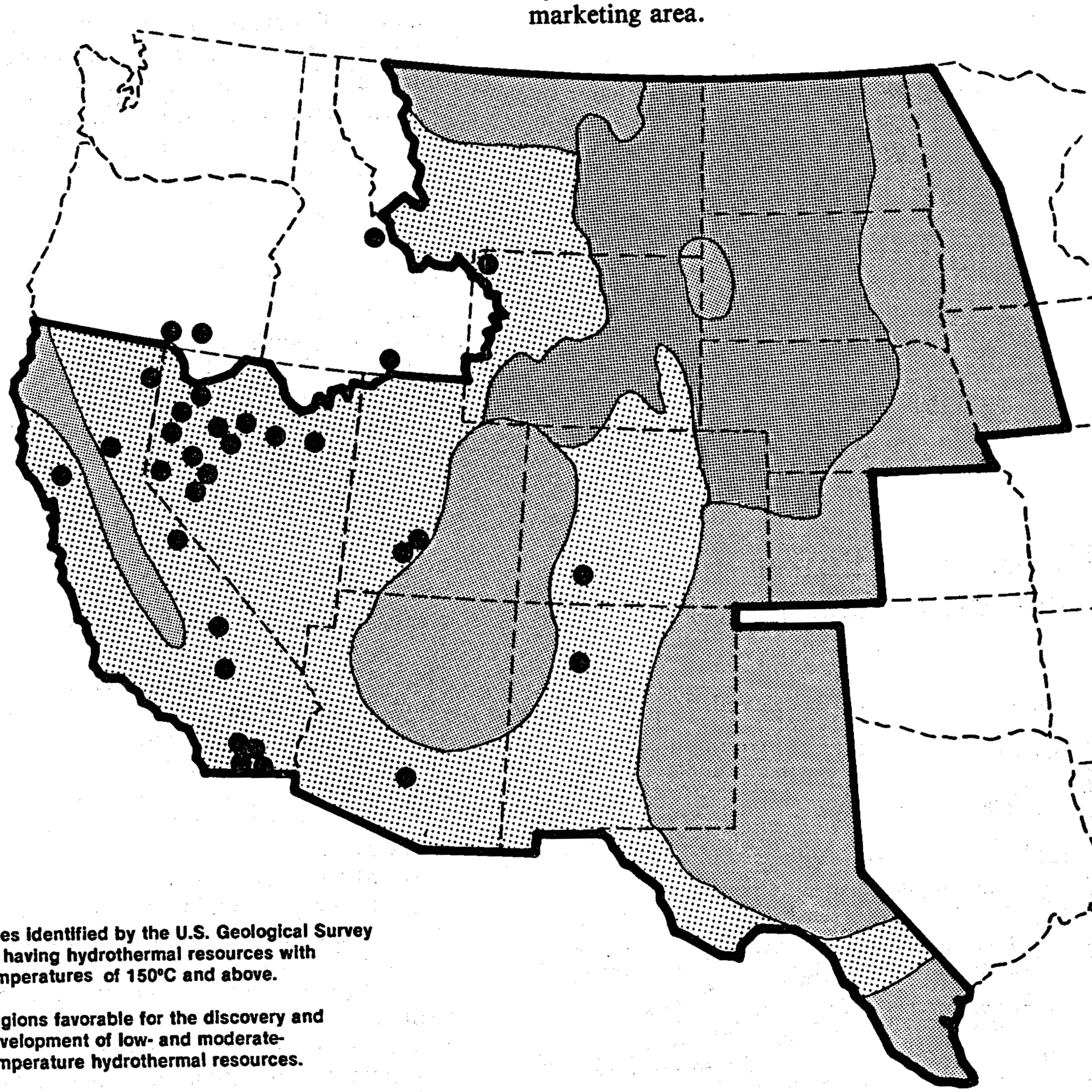
The development of geothermal energy has resulted in the formation of geothermal trade associations and professional organizations. A principal organization is the Geothermal Resources Council located at Davis, California. The Council is active in promoting the development of geothermal energy and has prepared numerous documents for the industry. A good reference handbook is its Special Report No. 7, Direct Use of Geothermal Energy, A Technical Handbook. This document discusses at length the nature and distribution of geothermal resources, resource exploration, confirmation and evaluation, reservoir development and management, utilization, economics, financing, and legal, institutional, and environmental aspects of geothermal resource development.

Geothermal Power Generation Costs



The Occurrence of Geothermal Resources

Geothermal resources can be divided into three major catagories: **hydrothermal** systems, or those with naturally occuring hot water; **geopressured** systems, or highly pressured hot brines containing natural gas; and **hot dry rock** systems, where water must be injected. The discussion below focuses on **hydrothermal** systems, as geopressured and hot dry rock systems are still too experimental to contribute significantly to energy production before the turn of the century. The following map is a general depiction of the nature and location of hydrothermal resources in Western's power marketing area.



Sites identified by the U.S. Geological Survey as having hydrothermal resources with temperatures of 150°C and above.

Regions favorable for the discovery and development of low- and moderate-temperature hydrothermal resources.

Region favorable for the discovery and development of hydrothermal resources from deep sedimentary basins.

Region most favorable for the development of ground water heat pumps.

Hydrothermal Systems

In order for a usable hydrothermal system to exist, three conditions must be met. First, there must be an unusual concentration of a heat source. Although it is true that the ground temperature increases with increasing depth everywhere, heat must be concentrated nearer the surface in order to become a useful resource. This heat source can be magma or molten rock, such as occurs at volcanos, or the natural heat of the earth. Second, there must be a mechanism to transfer the heat from its natural depth to the ground surface. In nature, this mechanism is usually water or steam. Third, there must be faults, fractures, or other permeable channels through which the heated water or steam can rise to shallow depths or the ground surface.

Hydrothermal resources have been divided by the U.S. Geological Survey into three categories: high-temperature resources above 300°F; moderate-temperature resources between 195-300°F; and low-temperature resources less than 195°F. High-temperature resources are generally suitable for development of electric power, and moderate- and low-temperature resources may be used for industrial, agricultural, and space heating and cooling applications. High-temperature resources are further subdivided into those that have just steam (vapor-dominated systems), and those with steam and water (liquid-dominated systems).

Hydrothermal resources occur in a variety of geologic environments. The most attractive resources for the generation of electricity occur in young volcanic or fault-dominated geologic terrains. Recent volcanic activity may mean that ground water could circulate in the vicinity of magma, become heated, and develop hydrothermal circulation systems. In fault-dominated geologic terrains, ground water may circulate to depth, be heated by the thermal gradient of the earth, and rise before cooling along permeable channels produced by faults.

Young volcanoes are found in Western's power marketing area in the Cascade Volcanoes of Northern California, the Clear Lake Volcanic Field at the Geysers, the Imperial Valley of Southern California, along the western and eastern margins of the Great Basin, such as at Coso, California, and Roosevelt Hot Springs, Utah, in isolated areas of Arizona, and along the Rio Grande Rift of Central New Mexico. Fault and fracture terrains dominate wherever mountains occur, which is almost all of Western's power marketing area west of the Great Plains.

One other major type of geothermal resource also occurs in Western's power marketing area. In the Great Plains, ground water circulates to depth in aquifers where it is heated by the natural thermal flux of the earth. This water may then either rise along geologic folds or basin margins, or it may be reached by deep drilling. The thermal brines found in oil fields fall into this catagory. In some areas of the Great Plains, thick layers of thermally insulating rocks, such as shale, may help increase brine temperatures.

Exploration for Hydrothermal Resources

Geothermal resource exploration, testing, and confirmation programs draw upon the skills of geologists, geochemists, geophysicists, hydrologists, and reservoir engineers. Geoscientists are involved in all phases of the program, while hydrologists and reservoir engineers are involved in the testing and confirmation of particular resources.

As a very simplified and condensed explanation, geothermal exploration programs for electrical-generation quality resources are usually phased, beginning with a large area. A study of such a region, typically more than a thousand square miles, will lead to the identification of some favorable and some unfavorable geologic environments. The exploration process selects progressively smaller areas of favorability, until a few specific targets have been defined. These targets are then drilled and tested, with development drilling proceeding once a resource has been confirmed.

Exploration programs for direct heat application resources are typically much more confined in nature, and are largely dependent on the willingness of an industry to relocate near a resource, or to develop a colocated resource. Direct heat applications are lower cost, and they generally have a much higher degree of success as compared with electrical generation applications.

The geological, geochemical, and geophysical tools used in an exploration program will vary, depending on the nature of the resource being sought, the funding available for exploration, and the legal, cultural, and institutional constraints of the chosen exploration and development area. Successful exploration programs involve selection of appropriate techniques and data integration from all geoscientific disciplines.

Obvious geological indications of the presence of a hydrothermal resource include hot springs and wells, geysers, and fumaroles. Hot springs and wells, and their deposits, are by far the most common of these features. All exploration programs should include early identification of existing geothermal sites in the area of interest. Indirect geological indications of hydrothermal potential may include volcanic activity, existence of faults, and the presence of hydrothermally altered rocks. Geological investigations usually begin with preparation of a geological map and interpretation of aerial and satellite photography. More detailed studies include determination of the time sequence and spatial relationships of individual rock units in the study area. These detailed studies allow identification of the most likely channels for fluid-flow at depth, and, once these data are integrated with geochemical and geophysical studies, the selection of potential drilling targets is made.

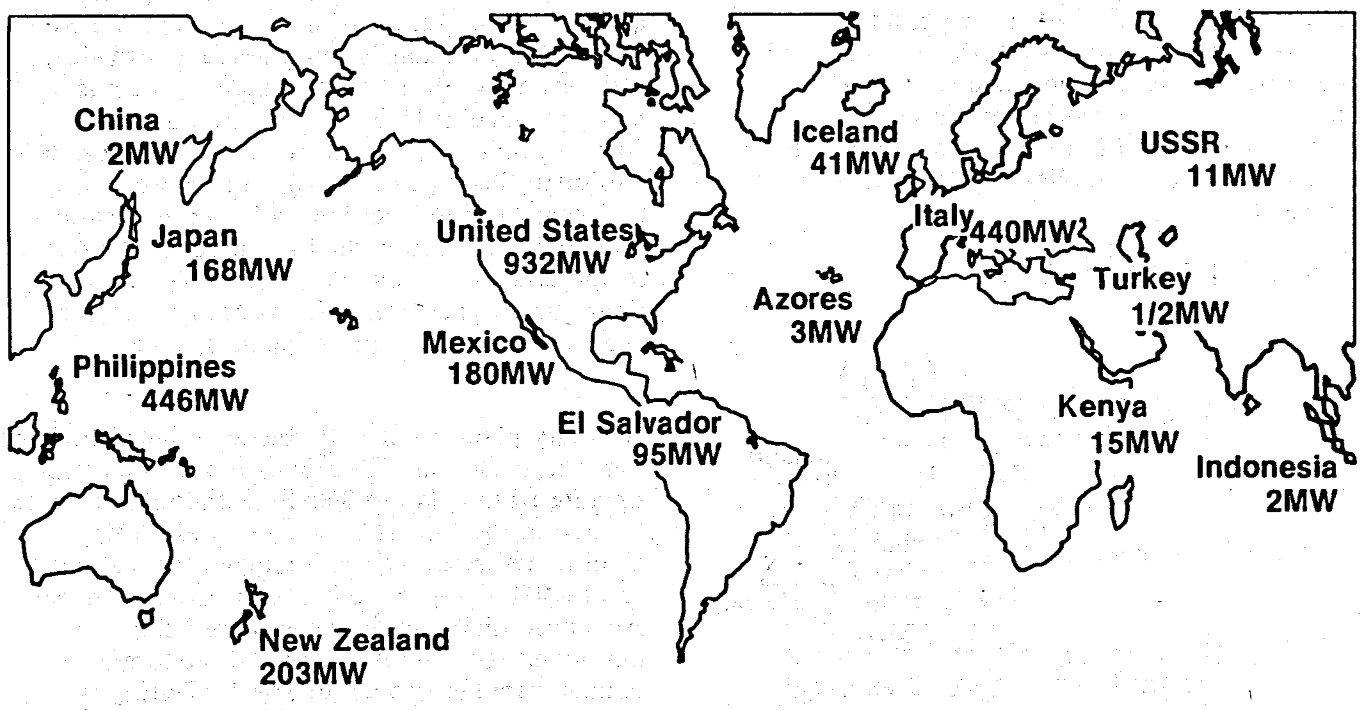
Geochemical indications of hydrothermal systems can include hot spring and well-water chemistry, and changes in the chemical signatures of rocks and soils. These are all indirect, but valuable, signs of thermal activity at depth. The water chemistry may indicate the existence of hotter waters at depth. The silica concentration, or the relative abundances of sodium, potassium, and calcium, can be interpreted to indicate the existence of hydrothermal systems. An example of a chemical signature is the element mercury, which has been concentrated in soils above faults near many high-temperature systems. Studies of water chemistry should be an early reconnaissance step in an exploration program, with other techniques being employed as the areas of interest become smaller.

Physical changes in the earth's thermal and electrical fields may be brought about by hot water circulation. Changes in the earth's gravity and magnetic patterns may indicate geological conditions favorable to the existence of hydrothermal systems. Detection of these changes is the basis of geophysical exploration. Drilling test holes to measure thermal gradients and to provide data for the calculation of heat flow is a major part of all geothermal exploration efforts. Without an unusual heat concentration an attractive thermal system will not exist. Electrical fields may change in response to the presence of magma, altered rock, circulation of hot water, or geologic structures. Gravity and magnetic fields may be interpreted to indicate the presence of faults, or in special cases, existing shallow heat sources.

Other geophysical studies such as seismic exploration which is widely used in petroleum exploration programs, have been applied with mixed success in geothermal environments. Reconnaissance geophysical studies include the development of regional models; detailed models may be integrated with geological and geochemical data to help identify drill-hole sites.

Resource target models evolve during geothermal resource exploration programs as more data becomes available. Optimum data collection, integration, and interpretation aid in the identification of specific, successful targets. These targets are then tested by drilling a discovery well. After a resource has been discovered, it is necessary to confirm it by further drilling and testing. Reservoir engineers and hydrologists can then analyze the data from well tests to demonstrate the existence of a viable resource.

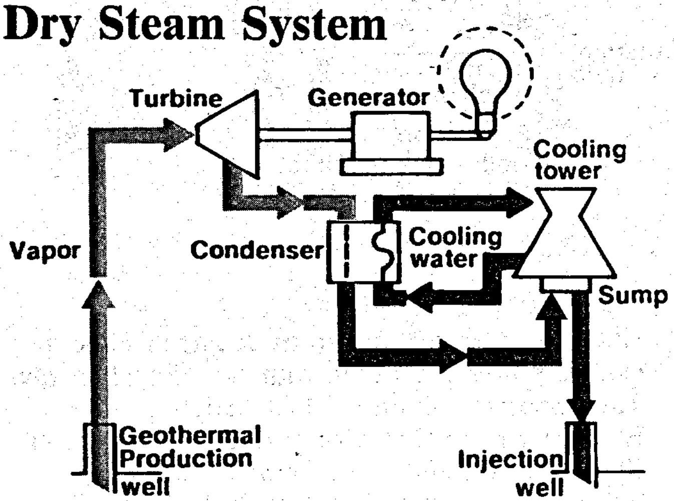
Geothermal Powerplants in the World



Electric Power Generation Systems

Hydrothermal resources, the only type of geothermal energy presently being used commercially, range in temperature from slightly over normal ground water temperatures to over 500°F, and are generally located within 8,000 feet of the earth's surface. In a few places, such as at the Geysers and China Lake (both in California), super-heated steam can be extracted directly from the ground.

Dry Steam System

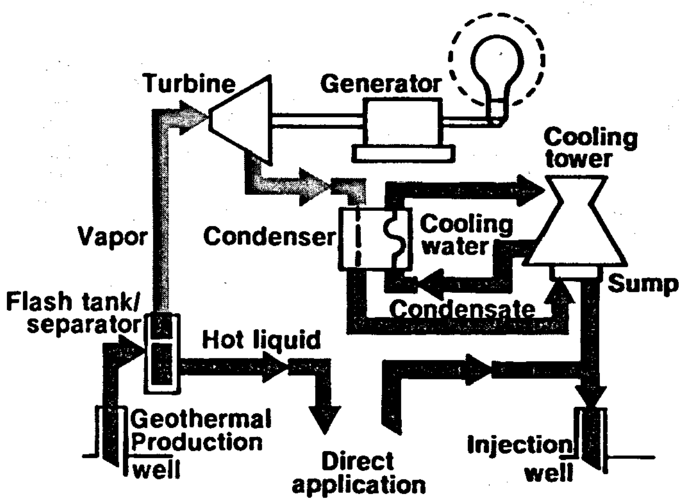


Pressurized geothermal fluids are flashed to steam at other sites, such as at Roosevelt Hot Springs in Utah, or are used to heat a secondary fluid in a binary system as at Heber, California, and Raft River, Idaho. It is estimated that within Western's power marketing area, resources over 300°F could supply between 2,600 and 6,000 MWe for 30 years. The above figure shows the locations and sizes of existing geothermal power plants in the world.

Three basic systems are used to convert geothermal energy into electricity; dry steam, flash steam, and binary heat exchange systems. The dry steam system, which has the highest quality and lowest cost, uses steam directly from a production well to drive a standard turbine generator and produce electricity. Most of the condensate can be used for cooling tower makeup.

The flash steam system is similar to the dry steam application, and next in steam quality or desirability for development. The hot pressurized geothermal fluid is flashed to steam, and the steam is then sent through a turbine to drive a generator. The figure below is a schematic diagram of a typical geothermal flash steam system. The residual hot water can be used in numerous direct-use applications and/or reinjected.

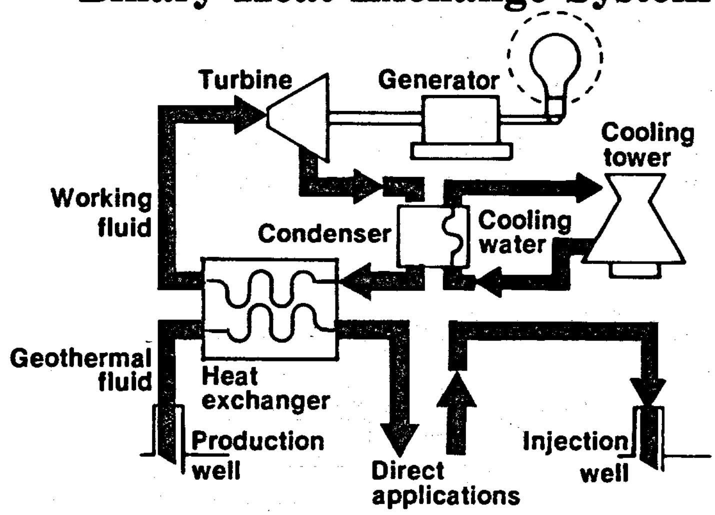
Flash Steam System



Another method of producing electric power is with a binary heat exchange system. A secondary working fluid, such as isobutane, is vaporized and used to power a turbine generator. A 5 MWe demonstration plant is being tested at Brawley, California. A 50 MWe powerplant project is being planned at Heber, California, and a 10 MWe unit is scheduled for Northern Nevada. Although this type of system can be used for high temperature resources, a larger application potential is for geothermal resources that have temperatures between about 320 to 400°F. The figure below is a schematic diagram of a typical geothermal binary heat exchange system.

A binary plant is currently being designed for San Diego Gas and Electric Company that will operate from a 340 to 360°F geothermal resource located in the Imperial Valley of California. Geothermal resources with temperatures about 350 to 400°F appear to be relatively economical. Advanced binary cycle systems are being developed, and should lower the economic temperature limit to about 340°F. Testing is underway on the Raft River demonstration binary system where resource temperatures are about 290°F, but resources at or below this temperature appear to be uneconomical, although technically feasible, for electricity generation.

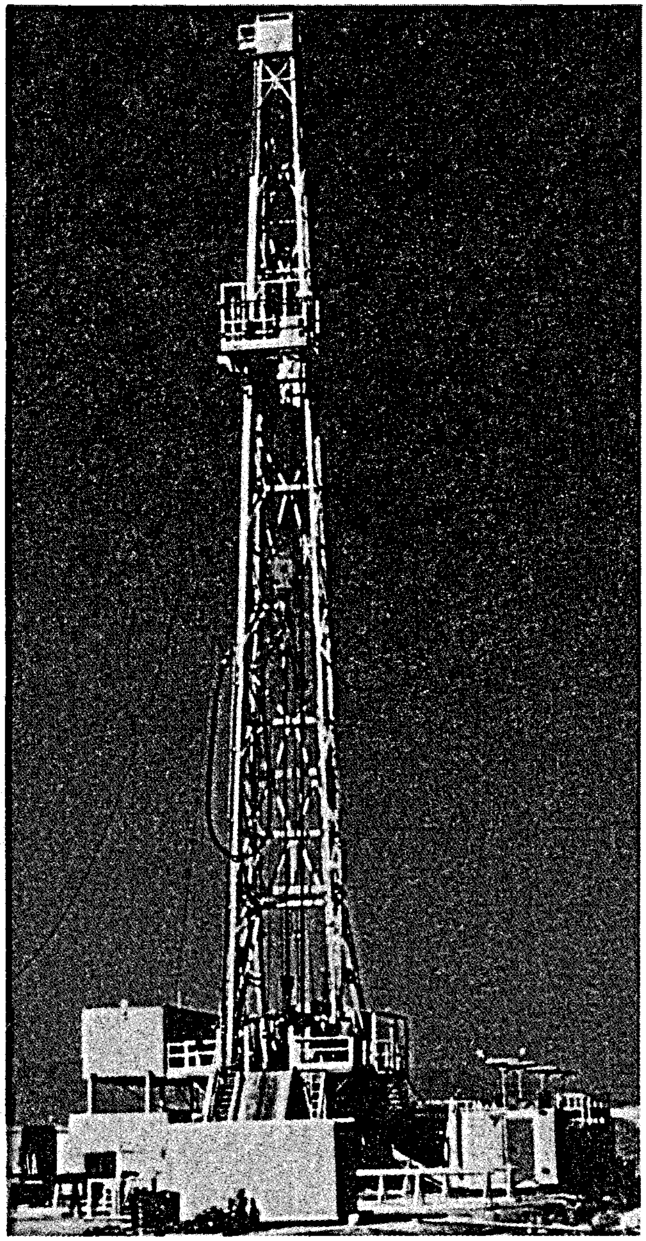
Binary Heat Exchange System



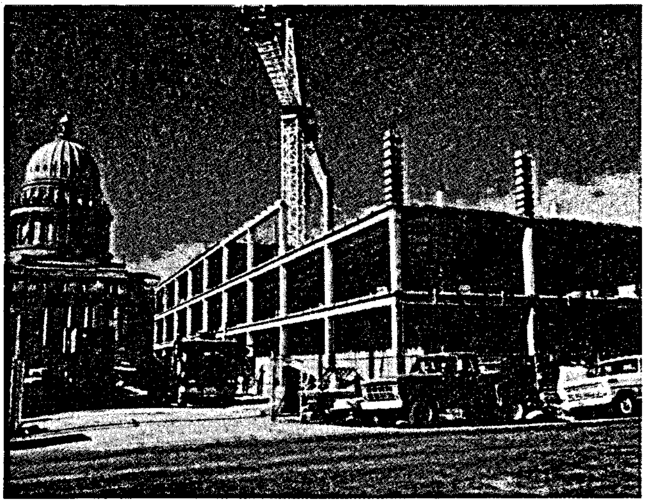
DOE has prepared numerous documents about electric power generation with geothermal energy. The "Sourcebook on the Production of Electricity from Geothermal Energy" by Joseph Kestin, et. al., and "Geothermal Energy as a Source of Electricity" by Ronald DiPippo, provide extensive technical data about this subject.

Direct Applications

It is often more efficient and economical to use geothermal energy as a direct source of heat, either as a cascaded (i.e., multiple use) application from an electric generating facility, or directly from a well. The Italians used geothermal energy in the early 1800's for evaporative chemical refining. Boise, Idaho is still using, and expanding, a district space heating system that was started in 1894. Current uses also include applications in the wood and paper industry, mining, chemical production, alcohol distillation, food processing, plant production, and building space conditioning.



Hybrid Wood Drying/Power Generation, Susansville, California



State District Heating Project, Boise, Idaho

Building space heating can be provided even with low-temperature resources (i.e., 55°F), especially when heat pumps are used. Cooling of buildings requires geothermal water temperatures above 200°F, but the best economics are experienced when the refrigeration systems are driven by geothermal steam.

A big advantage for Western's customers in using geothermal energy for direct applications is in the substitution of this energy for applications that would otherwise be served as electric loads, which can delay the acquisition of new conventional electric generating systems.

Development Factors

Geothermal utilization requires a unique blending of skills to locate and assess a resource, and to concurrently match the varied needs of the user in order to develop a successful project on an economic basis. Since each resource development project is unique, this discussion is limited to a generic overview. A summarization of the development process is shown in the diagram below.

Long-range planning is essential, and commercial development organizations exist in many locations within Western's power marketing area who can provide the necessary services to determine the relative advantages and disadvantages of geothermal energy. In some instances, the entire development process is performed by a developer who sells electricity, steam, or hot water to the user. The development of a project should be approached in phases so as to minimize risk and costs. The first phase generally involves an evaluation of the proposed project to determine if exploration work should be performed. This phase involves data searches, reconnaissance geologic work, geochemical modeling, site energy determinations, interface definitions, and preliminary systems concept preparation.

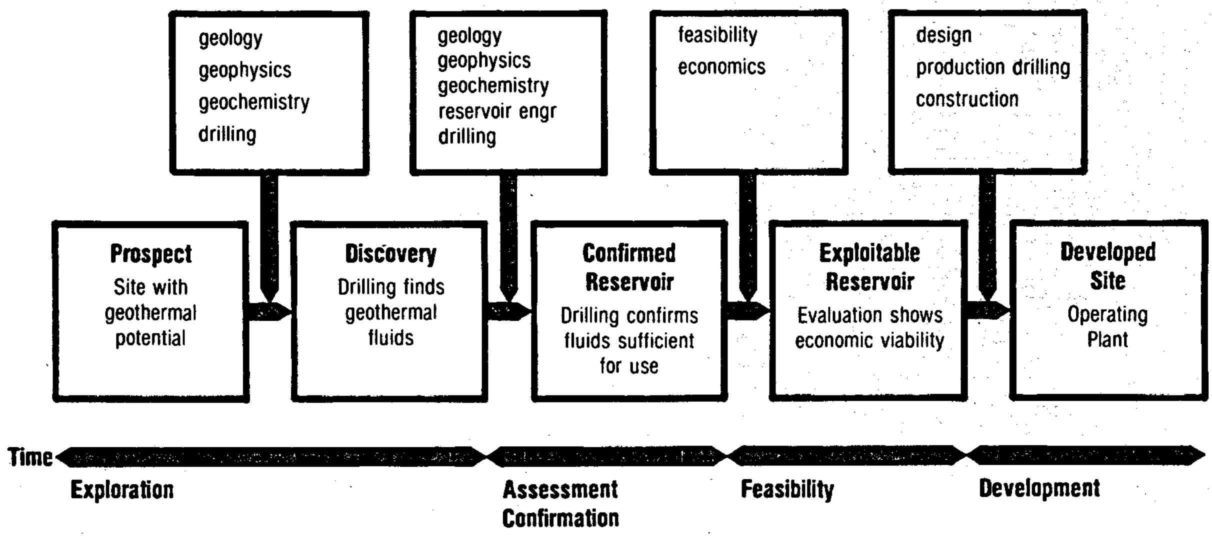
If these activities produce positive results, exploration work takes place. This includes performing geochemical, electrical resistivity, and aeromagnetic surveys; drilling thermal gradient holes; complying with environmental and permitting requirements; performing well-logging; flow-testing and reservoir engineering analyses; and selecting a well site(s) and the optimum energy conversion system. If this phase gives positive results, then detailed design is performed, production/injection wells are drilled and tested, the well-field is developed, and the application facility is constructed and tested. Depending on the resource and its utilization, these activities can take several years. Actual experience has ranged from 3 to 10 years for electric generation applications. Direct applications, which are less capital intensive, have a time frame which is much shorter.

Legal, Institutional, and Environmental Factors

There are many other factors to be considered in developing a geothermal project. Early planning to determine local environmental regulations and permits is a must. Surface ownership determination is needed to have access to a development site. Sometimes surface ownership is separate from the resource rights, the resolution of which is necessary for project development. The developer will identify and obtain all resource rights, which vary because the rights to develop geothermal resources are classified differently between states (i.e., water rights versus mineral rights).

Whether access is gained by purchase, lease, option, permit, or otherwise; accurate ownership determinations are needed to ensure cooperation among the parties involved in resource development projects.

Geothermal Development



Access to state lands is also governed by statutes and regulations, which vary from state to state. Generally, state water laws will govern the production and use of geothermal fluids. Appropriate state agencies should be contacted for specific requirements. The National Conference of State Legislators located in Denver, Colorado has prepared a comprehensive document, "State Policies for Geothermal Development" by Douglas M. Sacarto, which reviews the various technical, economic, and institutional aspects of geothermal development.

Federal lands are controlled by the Bureau of Land Management (except for Department of Defense and Indian lands). BLM leases are obtained by competitive bidding in Known Geothermal Resource Areas (KGRAs). However common, this is a complex process. Other areas can be used on a noncompetitive basis, with procedures providing for phased development of geothermal projects.

Permit requirements vary for exploration and field development. The types of permits needed, and the times and timing required to process them, are factors to be considered in developing a resource, as are the distribution and use of the resource.

Disposal of fluids, relationships with existing utility systems, and environmental issues are a part of the development scenario. Land use requirements, the disturbance of natural habitats, and threats to endangered species are considerations, as are air and water quality needs. Subsidence may be a concern if withdrawal of geothermal fluids exceeds natural recharge or injection. Socioeconomic impacts have been quite small to date, even on large-scale projects, while archeological/cultural resources may impact facility siting.

Taxes

Taxes, tax credits, incentives, depletion allowances, and intangible drilling cost deductions vary from state to state, and state to Federal. State corporate and personal income tax structures may or may not follow the Federal system. The Energy Tax Act of 1978 and the Crude-Oil Windfall Tax Act of 1980, have eliminated some of the uncertainties of Federal tax treatment of geothermal exploration and development. The new provisions of these Acts can be used to promote capital investment and to generate tax savings to reduce investment risks. The Acts cover three basic subjects; intangible drilling costs, depletion allowances, and tax credits. These features allow the investor the option to deduct as expenses the intangible drilling costs, provide two methods (cost and percentage) of computing depletion allowances, provide for a nonrefundable tax credit for certain expenditures incurred for equipment which uses geothermal energy in a taxpayer's principal residence, and make available a 15% energy tax credit in addition to the existing investment tax credit for qualifying geothermal equipment. It should be noted, however, that: 1) the provisions of the current Acts expire at the end of 1985; and 2) the possibility exists that the current tax incentives may be repealed prior to their 1985 expiration date.

An extensive analysis of state tax systems has been prepared by (and can be obtained from) the Geothermal Resources Council at Davis, California. It is entitled "State Taxation of Geothermal Resources Compared with State Taxation of other Energy Minerals," by Sharon C. Wagner.

Utility Acceptance

Utility acceptance of geothermally produced power is increasing in favorability. At the Geysers, where over 900 MW are generated, acceptance is highly favorable. This is evidenced by the Pacific Gas and Electric Company et al future expansion plans for these very successful projects. The Utah Power and Light Company is optimistic about the geothermal project presently under construction at Roosevelt Hot Springs, Utah, and Idaho Power Company is also evaluating the prospects of geothermal energy use.

Western's Development Assistance

In assisting Western's customers in the renewable resource aspects of development and implementation of their conservation and renewable energy (C&RE) programs, Western can work with its customers in providing the following services:

- Purchase of energy from renewable resource generating facilities consistent with Western's approved power marketing plans and economic conditions. The exact purchase arrangements and power rates would vary within Western's 15-state power marketing area and would be negotiated on an individual basis.

- Standby energy storage and other loadshaping services, as appropriate, to those generating electricity from renewable resources.

- Transmission and interconnection services, as appropriate, to integrate energy from renewable resource generating facilities into regional grid systems.

- Marketing of the power output, as appropriate, from renewable energy resources in order to lessen the use of nonrenewable energy resources such as oil and natural gas.

- Cooperative efforts with Western's customers, as appropriate, to develop renewable energy resources and promote state-of-the-art renewable energy technologies.

- Technical information to customer utilities regarding the development of renewable energy resources; including presentation of renewable energy workshops to stimulate the exchange of current information/data on developmental technologies.

- Technical assistance to customers in their preparation of various renewable energy resource feasibility studies.

Western is interested, within its limitations, in providing the above-stated types of services where such supportive efforts result in reducing the use of nonrenewable oil and gas or increasing energy production from renewable resources. Customer-initiated renewable energy projects which could be integrated into Western's power marketing program will be considered on a case-by-case basis. Direct contact with Western should be made to the Area Office(s) from which customers receive their regular power billings.

Benefits of Geothermal Energy Projects

General

- Cost competitive in certain situations.
- Defers expenditures for other energy systems when economically competitive.
- Federal tax benefits are currently provided by the National Energy Act.
- Environmental impacts are relatively less than for other nonrenewable energy sources.
- An experienced community of developers is available to perform services needed for the development of geothermal energy projects.
- Potential long-term use (i.e., geothermal reservoirs generally have a long life).
- Relatively high thermodynamic efficiency.

Electric Applications

- Potential electric power generation sites exist in Arizona, California, Colorado, Nevada, New Mexico, and Utah.
- Load-leveling techniques for utilities are enhanced by the ability to construct smaller size plants (i.e., 50 MW) using geothermal energy, rather than the usual larger facilities that use non-renewable energy sources.
- The relatively smaller geothermal plants are accordingly less capital intensive, and they require smaller financing than larger power plants using other energy sources.

Direct Applications

- Potential direct-use application sites exist in all of the states comprising Western's power marketing area.
- Projects require a relatively short time from start to operation.
- Multiple uses are possible from a single resource.
- Geothermal energy can be used to meet many needs, from space heating to agricultural uses, processing, etc.

Considerations for Geothermal Energy Projects

- Electric power generation projects are capital intensive.
- Detailed identification is needed to properly locate a specific geothermal resource and to define its quality and magnitude—these activities require time and money.
- Projects are limited to certain geographic locations.
- Good planning and technical knowledge are needed for proper development of geothermal energy projects.

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General

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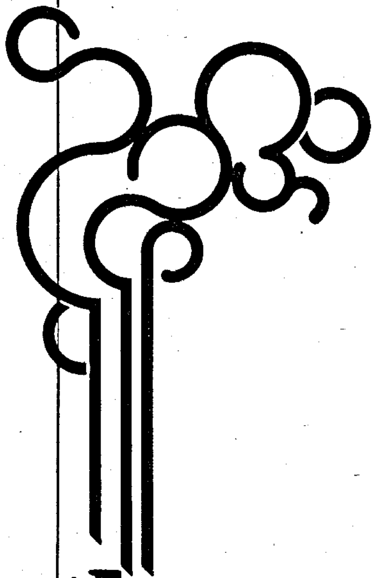
Section II-Appendices



Geothermal Energy

a brief assessment

Western Area
Power Administration

Western Area Power Administration
Power Marketing Area

State Geothermal Resources

Appendix A

Introduction to State Resource Maps

Geothermal resource maps with accompanying explanations, references, and places for further contacts for the fifteen states within Western's Power marketing area are included in this appendix. These resource maps represent a compilation of data from various state and Federal sources and, along with the explanations, are presented to give a general overview of hydrothermal resources within a given state. It has been left to the reader to seek additional details concerning specific areas of interest. Distribution of resources may not be consistent across state lines due to different data sources that were used and differences in resource classifications from state to state. Areas where ground water temperatures are such that ground water heat pumps could be used have not been designated separately on the resource maps, but virtually all areas should be considered as having potential for heat pump applications.

The United States Department of Interior, Geological Survey, is currently working on updating its data base for low-temperature (195°F) hydrothermal resources. The information will be published as a U.S. Geological Survey Circular sometime during 1982 and will be entitled "Assessment of Low-Temperature Geothermal Resources of the United States—1981" by Marshall J. Reed (editor).

Geothermal Resources

In

Arizona

Western Area
Power Administration

July 1982

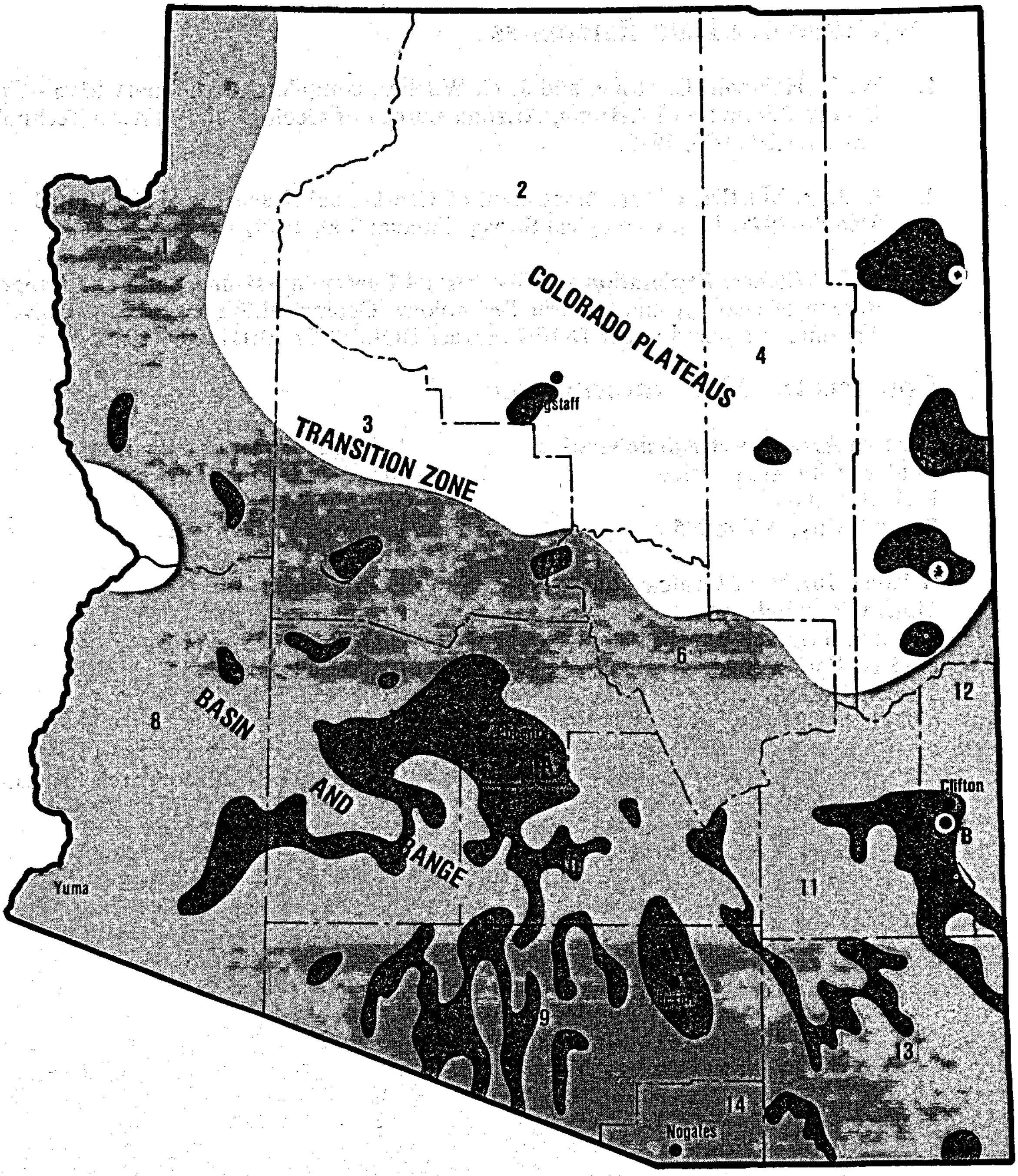
Geothermal Resources in Arizona

Geothermal resources in Arizona occur predominantly within the Basin and Range physiographic provinces. They are the products of the deep circulation of groundwater in a region of high heat flow; a thermally insulating blanket of young sediments helps increase the geothermal gradient. Resources are most often associated with the deeper sedimentary basins of southern Arizona. A temperature of 365°F was encountered at a depth of 10,450 ft in a well drilled by Power Ranches, Inc., located approximately 20 miles southeast of Phoenix. Detailed studies by the Arizona Bureau of Geology and Mineral Technology have been performed in the Safford and San Simon valleys of southeast Arizona near the Gillard Hot Springs KGRA where intermediate-temperature resources occur.

Direct-use applications for space conditioning, swimming pools and spas, and others are developing in this state. Geothermal energy use is occurring in locations such as Tucson, Safford, the San Bernardino valley, Kingman, Scottsdale, and at numerous other places. The Navopache Electric Company is developing plans for two 25 MW electric generating units near Springerville, Arizona.

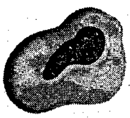
Number County

1 Mohave
2 Coconino
3 Yavapai
4 Navajo
5 Apache
6 Gila
7 Maricopa
8 Yuma
9 Pima
10 Pinal
11 Graham
12 Greenlee
13 Cochise
14 Santa Cruz



ARIZONA

0 10 20 30 40
Scale in Miles



Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources. Light areas indicate geologic favorability, but where data are inconclusive or lacking.

A Power Ranches, Inc. Wells
● B Gillard Hot Springs Known Geothermal Resource Area

Map/Resource Data References

1. W. R. Hahman, C. Stone, and J. C. Witcher, compilers, **Preliminary Map—Geothermal Energy Resources of Arizona**, Arizona Bureau of Geology and Mineral Technology, Map Scale 1:1,000,000, 1978.

2. L. J. P. Muffler, editor, **Assessment of Geothermal Resources of the United Stated—1978**, U.S. Geological Survey Circular 790, 1979, 163 p.

3. J. C. Witcher, **Exploration for Geothermal Energy in Arizona Basin and Range**, Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, University of Arizona: Prepared under DOE Contract DOE/FC07-79ID12009, 1982, 27 p.

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Geothermal Resources

In

California

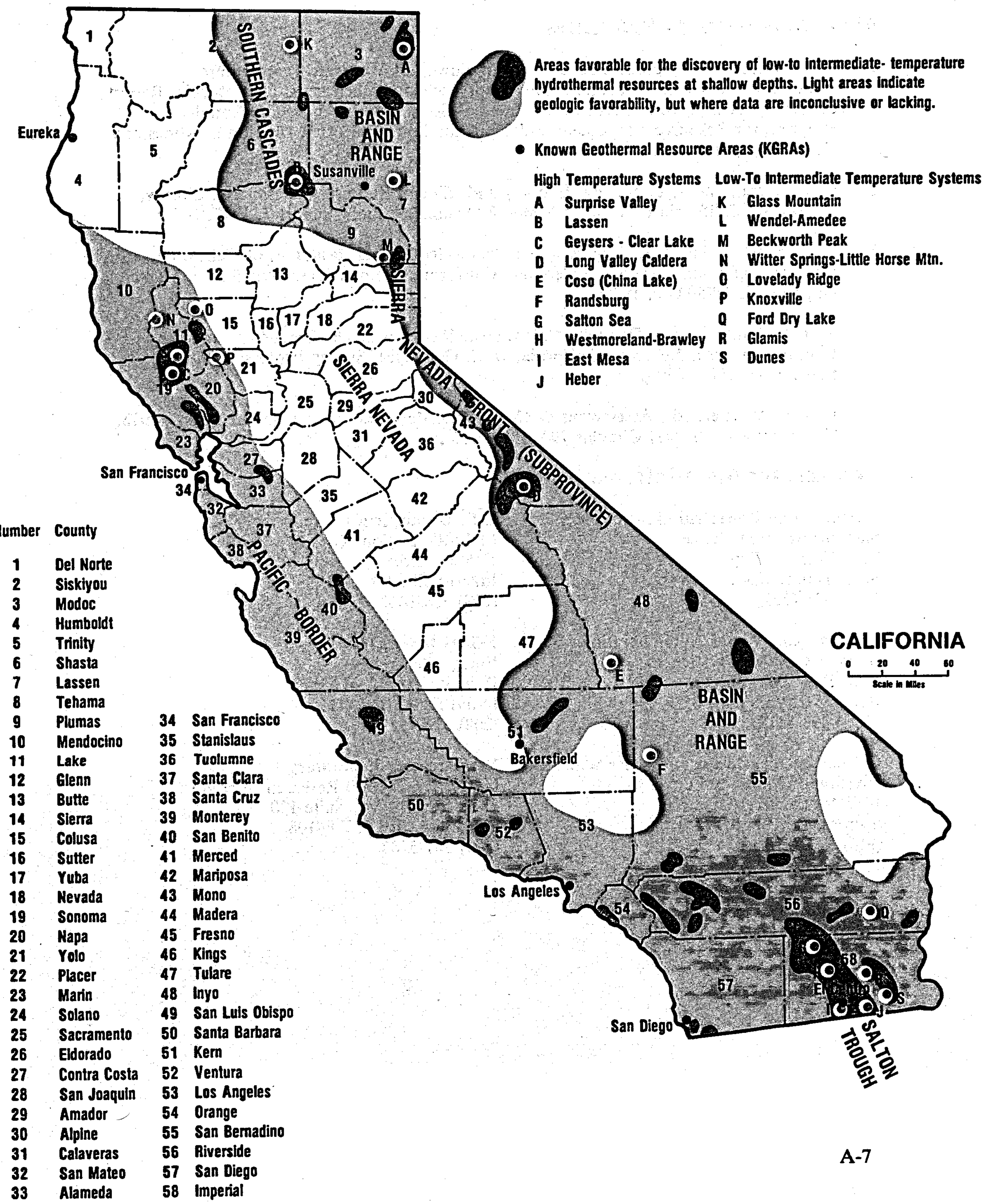
Western Area
Power Administration

July 1982

Geothermal Resources in California

California's geothermal resources occur in widely diverse gelogical settings. The state is divided into five separate physiographic provinces, four of which host major occurrences of convective hydrothermal resources. The Geysers geothermal field, the Clear Lake high temperature system, and Calistoga areas located within the "Pacific Border" are considered unique occurrences that probably will not be found elsewhere within the province. The Geysers geothermal field is one of the few known "dry steam" fields in the world. The field currently produces over 900 MW and is estimated to have a capacity to produce 2,000 to 2,500 MW. The Mono-Long Valley and Coso high-temperature areas situated along the eastern Sierra Nevada front are associated with large young volcanic features. Other high-, intermediate-, and low-temperature systems present in this part of the Basin and Range Province, including resources in northeastern California, are attributed to deep circulation in a region of bove normal geothermal gradient. A recent project partially funded by DOE involves the use of intermediate temperature geothermal water in the Susanville area to dry wood chips for use in electrical generation. High temperature resources are also known to exist adjacent to Lassen Volcanic National Park within the southern Cascades Province. Five major geothermal fields are currently under development in the Salton Trough of the Imperial Valley, an active crustal spreading center with associated high heat-flow. Geothermal fluids with temperatures ranging from 250° to 680°F have been encountered in nearly 100 geothermal wells drilled within the Salton Trough. Direct application and electrical generation projects have been hindered due to the high salinity, (i.e., up to about 23% of the fluids).

Direct-use applications for district heating, space conditioning, swimming pools and spas, agriculture, greenhousing, industrial and food processing, and others are developing in this state. Geothermal energy use is occurring in such locations as the Geysers area, Niland, Wendell-Amedee, Susanville, Lake County, Paso Robles, East Mesa, El Centro, the Imperial Valley, and numerous others. Electric power generation is taking place at the Geysers area, in the Imperial Valley, at East Mesa, the Salton Sea, Brawley, West Moreland, Coso, Mono-Long Valley, and Wendell-Amedee.


CALIFORNIA
0 20 40 60
Scale in Miles
Areas favorable for the discovery of low-to intermediate- temperature hydrothermal resources at shallow depths. Light areas indicate geologic favorability, but where data are inconclusive or lacking.
Known Geothermal Resource Areas (KGRAs)
High Temperature Systems
A Surprise Valley
B Lassen
C Geysers - Clear Lake
D Long Valley Caldera
E Coso (China Lake)
F Randsburg
G Salton Sea
H Westmoreland-Brawley
I East Mesa
J Heber
Low-To Intermediate Temperature Systems
K Glass Mountain
L Wendel-Amedee
M Beckworth Peak
N Witter Springs-Little Horse Mtn.
O Lovelady Ridge
P Knoxville
Q Ford Dry Lake
R Glamis
S Dunes
SOUTHERN CASCADES
BASIN AND RANGE
SIERRA NEVADA
SIERRA NEVADA FRONT (SUBPROVINCE)
PACIFIC BORDER
SALTON TROUGH
Eureka
Susanville
San Francisco
Bakersfield
Los Angeles
San Diego
umber County
1 Del Norte
2 Siskiyou
3 Modoc
4 Humboldt
5 Trinity
6 Shasta
7 Lassen
8 Tehama
9 Plumas
10 Mendocino
11 Lake
12 Glenn
13 Butte
14 Sierra
15 Colusa
16 Sutter
17 Yuba
18 Nevada
19 Sonoma
20 Napa
21 Yolo
22 Placer
23 Marin
24 Solano
25 Sacramento
26 Eldorado
27 Contra Costa
28 San Joaquin
29 Amador
30 Alpine
31 Calaveras
32 San Mateo
33 Alameda
34 San Francisco
35 Stanislaus
36 Tuolumne
37 Santa Clara
38 Santa Cruz
39 Monterey
40 San Benito
41 Merced
42 Mariposa
43 Mono
44 Madera
45 Fresno
46 Kings
47 Tulare
48 Inyo
49 San Luis Obispo
50 Santa Barbara
51 Kern
52 Ventura
53 Los Angeles
54 Orange
55 San Bernadino
56 Riverside
57 San Diego
58 Imperial

Map/Resource Data References

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5. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States - 1978,** U.S. Geological Survey Circular 790, 1979, 163 p.

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Geothermal Resources

In

Colorado

Western Area
Power Administration

July 1982

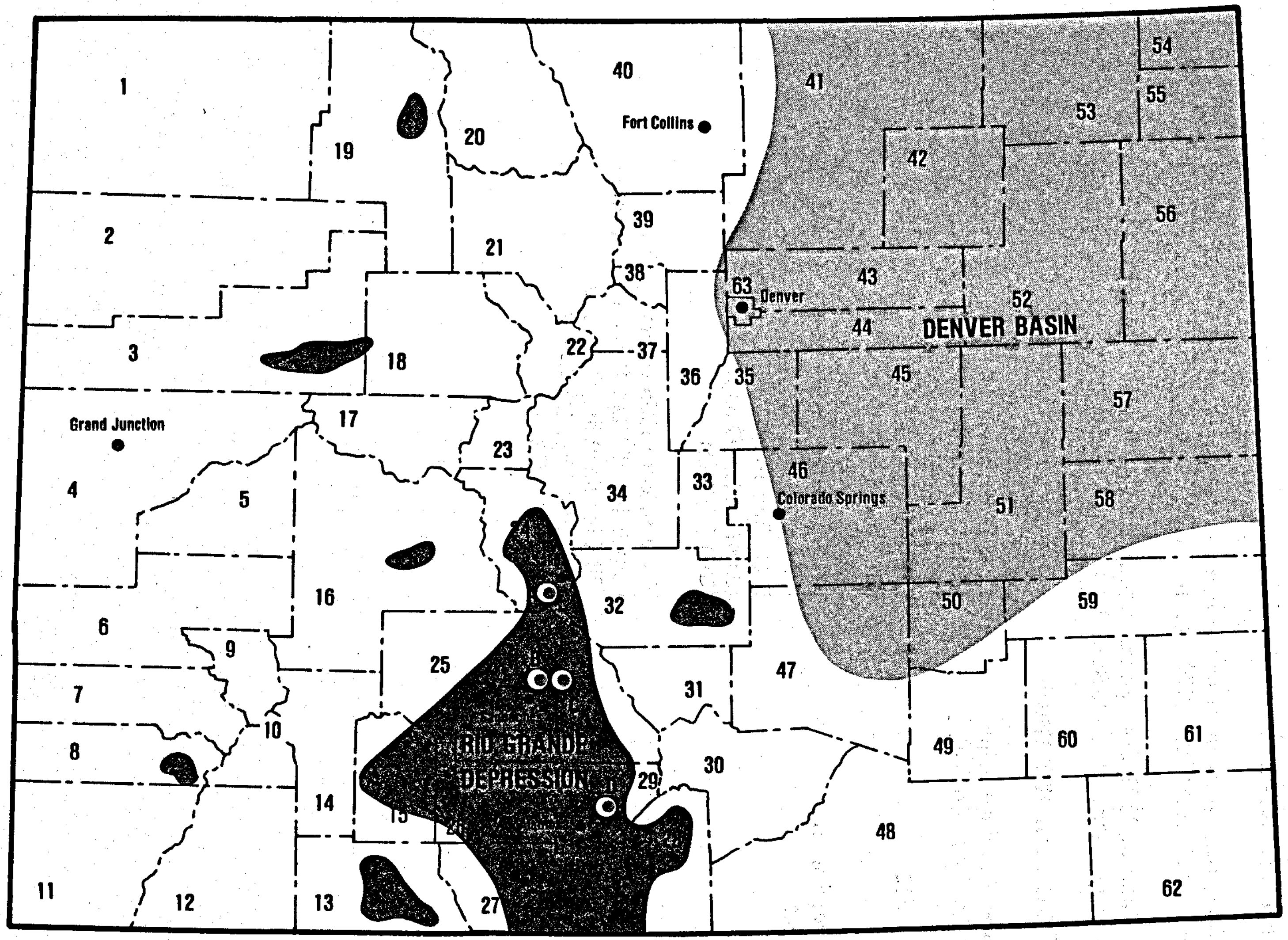
Geothermal Resources in Colorado

Geophysical data suggest that the Rio Grande Rift, a large north-south trending geological depression defined by geophysical anomalies, hydrothermal activity, and recent volcanism, extends northward from New Mexico into Colorado. The San Luis Valley and upper Arkansas Valley of southcentral Colorado are thought to be surface expressions of the Rio Grande Rift system. Low- to intermediate-temperature hydrothermal convection systems within the San Luis Valley comprise most of Colorado's known hydrothermal resources. The Poncha, Mineral Hot Springs, Valley View, and Alamosa County KGRAs are all located within the San Luis Valley. Thermal water occurrences are thought to result from deep fluid circulation along high-angle normal faults, and permeable stratigraphic horizons.

The Denver Basin located along the western Great Plains occupies much of eastern Colorado. Although comprehensive studies have not been performed to date, the Denver Basin may be host to potential low-temperature hydrothermal resources contained within deep regional stratigraphic aquifers.

Direct-use applications for district heating systems, fish farming, penwarming, irrigation, swimming pools and spas, greenhousing, and others are developing in this state. Geothermal energy use is occuring in locations such as Alamosa, Pagosa Springs, Idaho Springs, Glenwood, Gunnison, Ouray, Pueblo, the San Luis Valley, Canon City, and at numerous other places. Heat flow studies in the north and middle park areas indicate the possibility of temperatures hot enough for electric power generation.

Number	County	Number	County	Number	County
1	Moffat	45	Elbert	55	Phillips
2	Rio Blanco	46	El Paso	56	Yuma
3	Garfield	47	Pueblo	57	Kit Carson
4	Mesa	48	Las Animas	58	Cheyenne
5	Delta	49	Otero	59	Kiowa
6	Montrose	50	Crowley	60	Bent
7	San Miguel	51	Lincoln	61	Prowers
8	Dolores	52	Washington	62	Baca
9	Ouray	53	Logan	63	Denver
10	San Juan	54	Sedgwick		
11	Montezuma				
12	La Plata				
13	Archuletta				
14	Hinsdale				
15	Mineral				
16	Gunnison				
17	Pitkin				
18	Eagle				
19	Routt				
20	Jackson				
21	Grand				
22	Summit				
23	Lake				
24	Chaffee				
25	Saguache				
26	Rio Grande				
27	Conejos				
28	Costilla				
29	Alamosa				
30	Huerfano				
31	Custer				
32	Fremont				
33	Teller				
34	Park				
35	Douglas				
36	Jefferson				
37	Clear Creek				
38	Gilpin				
39	Boulder				
40	Larimer				
41	Weld				
42	Morgan				
43	Adams				
44	Arapahoe				



Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources.

Area underlain by regional aquifer system(s).

● Known Geothermal Resource Areas (KGRAs)

A Poncha
B Mineral Hot Springs
C Valley View
D Alamosa County

COLORADO

0 10 20 30 40
Scale in Miles

Map/Resource Data References

1. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States**, U.S. Geological Survey Circular 790, 1979, 163 p.

2. R. H. Pearl, **Colorado's Hydrothermal Resource Base—An Assessment**, Colorado Geological Survey, Map Series 14, Scale 1:500,000, 1979.

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Geothermal Resources

In

Iowa

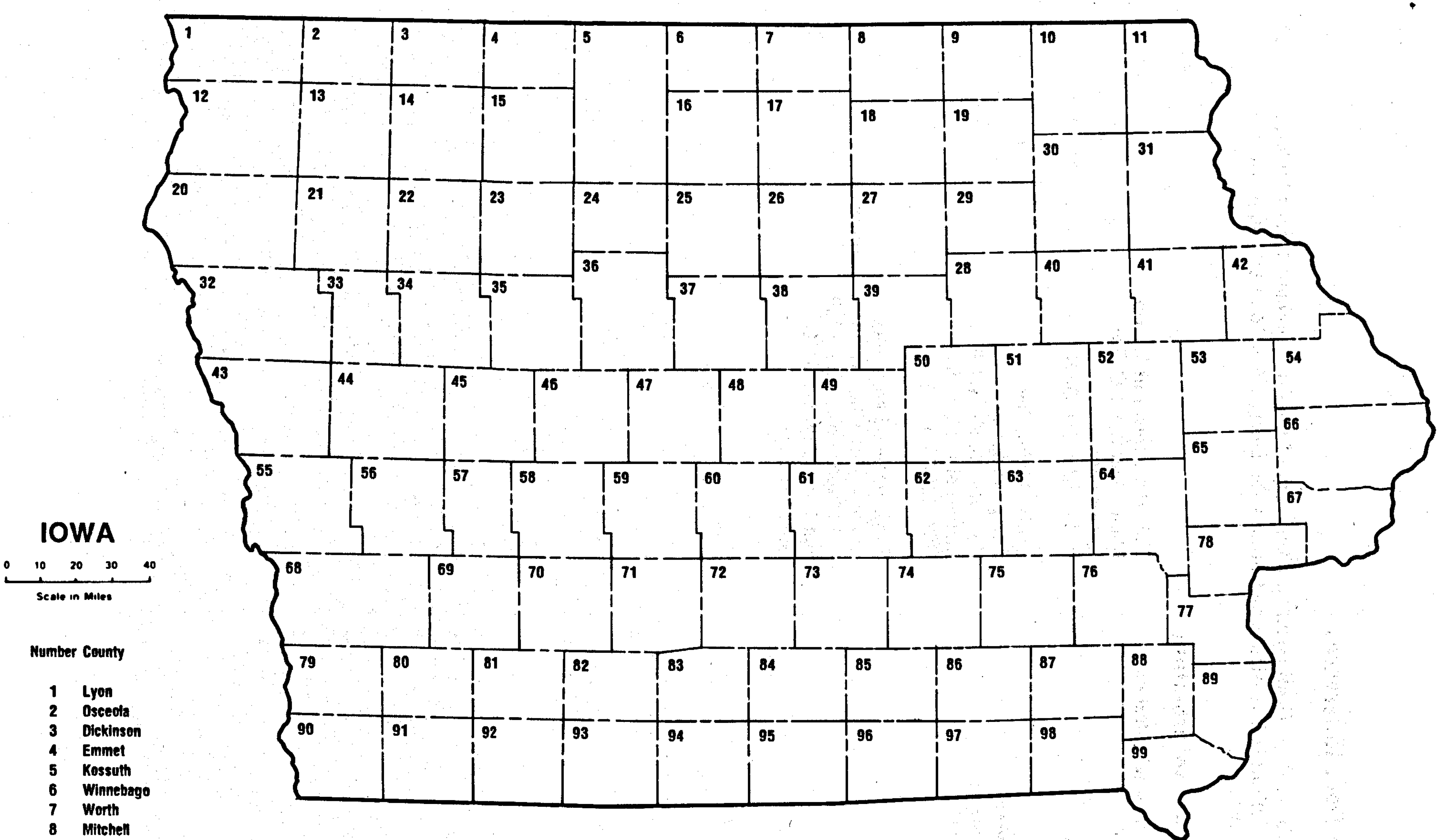
Western Area
Power Administration

July 1982

Geothermal Resources in Iowa

Hydrothermal systems have not been identified to date in Iowa. Geothermal gradients have been measured between 0.8 and 1.1°F/100 ft, which is below normal for the conterminous United States. Thermal energy contained in ground waters may be extracted through heat pump applications.

There are no identified applications of geothermal energy in this state, and geothermal power generating capabilities do not appear to exist. However, increasing use of ground water heat pumps is expected.



Number	County
1	Lyon
2	Osceola
3	Dickinson
4	Emmet
5	Kossuth
6	Winnebago
7	Worth
8	Mitchell
9	Howard
10	Winneshiek
11	Allamakee
12	Sioux
13	O'Brien
14	Clay
15	Palo Alto
16	Hancock
17	Cerro Gordo
18	Floyd
19	Chickasaw
20	Plymouth
21	Cherokee
22	Buena Vista
23	Pocahontas
24	Humboldt
25	Wright
26	Franklin
27	Butler
28	Black Hawk
29	Bremer
30	Fayette
31	Clayton
32	Woodbury
33	Ida
34	Sac
35	Calhoun
36	Webster
37	Hamilton
38	Hardin
39	Grundy
40	Buchanan
41	Delaware
42	Dubuque
43	Monona
44	Crawford
45	Carroll
46	Greene
47	Boone
48	Story
49	Marshall
50	Tama
51	Benton
52	Linn
53	Jones
54	Jackson
55	Harrison
56	Shelby
57	Audubon
58	Guthrie
59	Dallas
60	Polk
61	Jasper
62	Poweshiek
63	Iowa
64	Johnson
65	Cedar
66	Clinton
67	Scott
68	Pottawattamie
69	Cass
70	Adair
71	Madison
72	Warren
73	Marion
74	Mahaska
75	Keokuk
76	Washington
77	Louisa
78	Muscatine
79	Mills
80	Montgomery
81	Adams
82	Union
83	Clarke
84	Lucas
85	Monroe
86	Wapello
87	Jefferson
88	Henry
89	Des Moines
90	Fremont
91	Page
92	Taylor
93	Ringgold
94	Decatur
95	Wayne
96	Appanoose
97	Davis
98	Van Buren
99	Lee

Potential for ground water heat pump applications throughout Western's power marketing area.

Map/Resource Data References

1. A. Kron and G. Heiken, **Geothermal Gradient Map of the Conterminous United States**, University of California Los Alamos Scientific Laboratory, LA-8476-MAP, Map Scale 1:5,000,000, 1980.

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Geothermal Resources

In

Kansas

Western Area
Power Administration

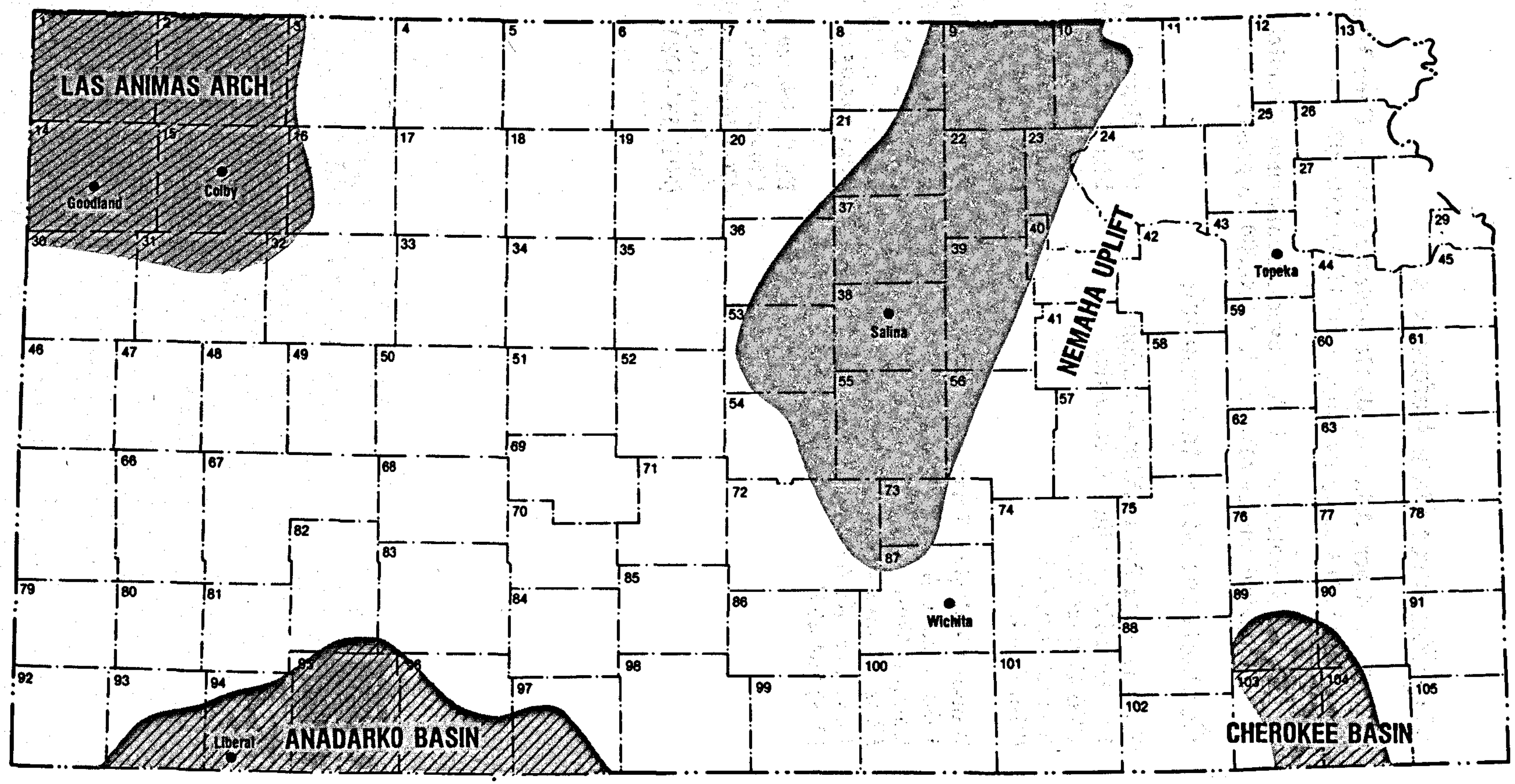
July 1982

Geothermal Resources in Kansas

Low-temperature geothermal resources in Kansas occur primarily within regional stratigraphic aquifers of northwest and southeast Kansas. In southeast Kansas low-temperature water occurs within aquifers of the Cherokee Basin. In northwest Kansas, low-temperature water occurs in aquifers adjacent to the Las Animas Arch. In central and southwestern Kansas, future studies may define additional low-temperature resource areas west of the Nemaha Uplift and along the northern extension of the Anadarko Basin.

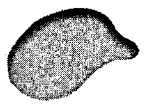
Kansas does not have operational geothermal systems at the present time, but initial resource assessment work may lead to developmental activities in the future.

No.	County										
		16	SHERIDAN	34	ELLIS	52	BARTON	70	EDWARDS	88	ELK
		17	GRAHAM	35	RUSSELL	53	ELLSWORTH	71	STAFFORD	89	WILSON
		18	ROOKS	36	LINCOLN	54	RICE	72	RENO	90	NEOSHO
1	CHEYENNE	19	OSBORNE	37	OTTAWA	55	McPHERSON	73	HARVEY	91	CRAWFORD
2	RAWLINS	20	MITCHELL	38	SALINE	56	MARION	74	BUTLER	92	MORTON
3	DECATUR	21	CLOUD	39	DICKINSON	57	CHASE	75	GREENWOOD	93	STEVENS
4	NORTON	22	CLAY	40	GEARY	58	LYON	76	WOODSON	94	SEWARD
5	PHILLIPS	23	RILEY	41	MORRIS	59	OSAGE	77	ALLEN	95	MEADE
6	SMITH	24	POTTAWATOMIE	42	WABAUNSEE	60	FRANKLIN	78	BOURBON	96	CLARK
7	JEWELL	25	JACKSON	43	SHAWNEE	61	MIAMI	79	STANTON	97	COMANCHE
8	REPUBLIC	26	ATCHISON	44	DOUGLAS	62	COFFEY	80	GRANT	98	BARBER
9	WASHINGTON	27	JEFFERSON	45	JOHNSON	63	ANDERSON	81	HASKELL	99	HARPER
10	MARSHALL	28	LEAVENWORTH	46	GREELEY	64	LINN	82	GRAY	100	SUMNER
11	NEMAHA	29	WYANDOTTE	47	WICHITA	65	HAMILTON	83	FORD	101	COWLEY
12	BROWN	30	WALLACE	48	SCOTT	66	KEARNY	84	KIOWA	102	CHATAUQUA
13	DONIPHAN	31	LOGAN	49	LANE	67	FINNEY	85	PRATT	103	MONTGOMERY
14	SHERMAN	32	GOVE	50	NESS	68	HODGEMAN	86	KINGMAN	104	LABETTE
15	THOMAS	33	TREGO	51	RUSH	69	PAWNEE	87	SEDGWICK	105	CHEROKEE



0 10 20 30 40
Scale in Miles

KANSAS



Areas favorable for the discovery of low temperature geothermal resources. Crosshatched areas in northwest and southeast depict resources contained primarily in regional stratigraphic aquifer system(s).

Map/Resource Data References

1. R. F. Meyer, **AAPG-CSD Geological Provinces Code Map**, American Association of Petroleum Geologists Map, Scale 1:500,000, 1974.

2. D. W. Steeples, and S. A. Stavnes, **Geothermal Resources Map of Kansas**, Kansas Geological Survey Map, Scale 1:500,000 (in press), 1982.

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Geothermal Resources

In

Minnesota

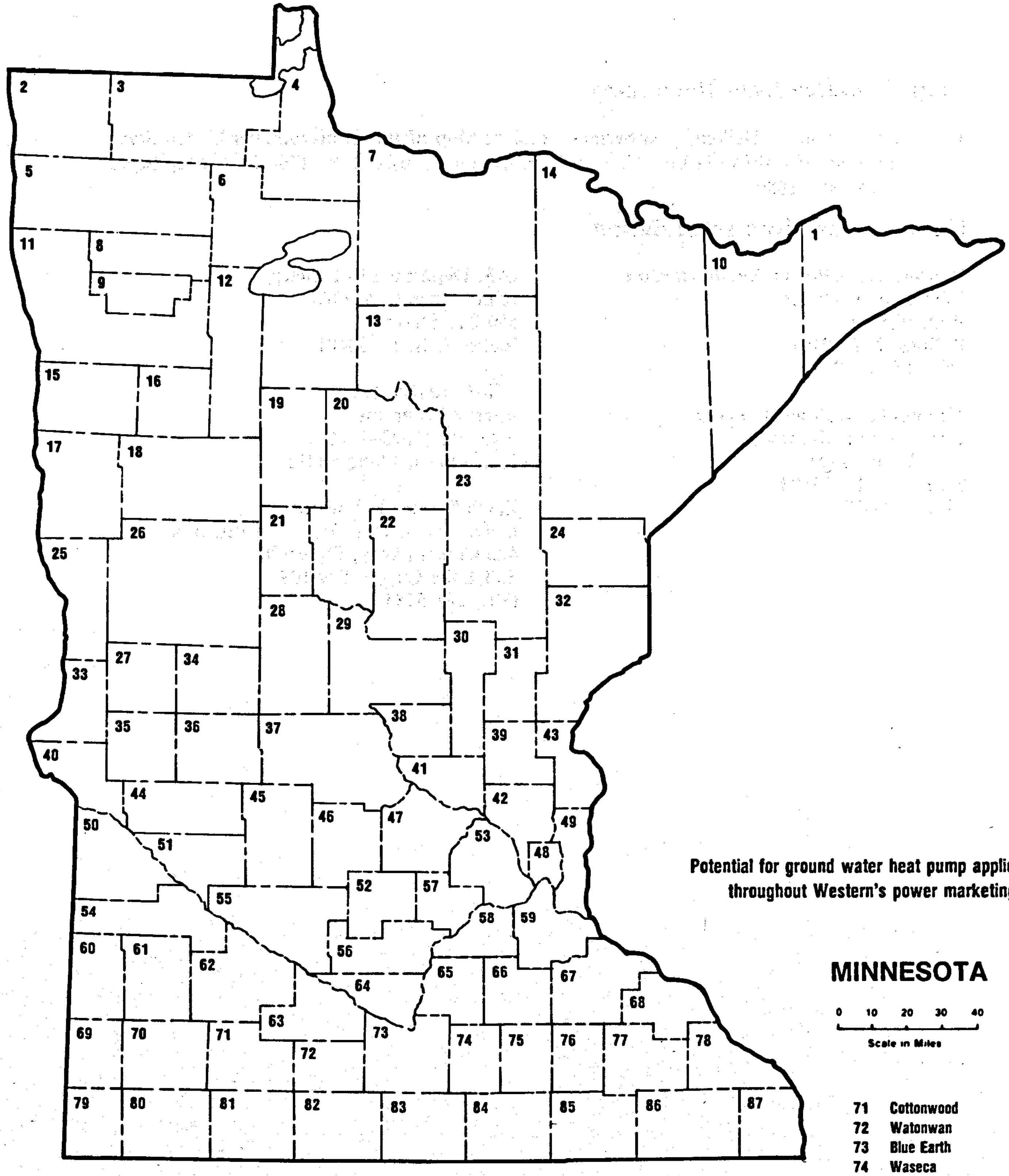
Western Area
Power Administration

July 1982

Geothermal Resources in Minnesota

Hydrothermal systems have not been identified to date in Minnesota. Geothermal gradients have been measured between 0.8 and 1.1°F/100 ft, which is below normal for the conterminous United States. Thermal energy contained in ground waters may be extracted through heat pump applications.

There are no identified applications of geothermal energy in this state, and geothermal power generating capabilities do not appear to exist. However, increasing use of ground water heat pumps is expected.



Potential for ground water heat pump applications throughout Western's power marketing area.

MINNESOTA

0 10 20 30 40

Scale in Miles

Number	County
1	Cook
2	Kittson
3	Roseau
4	Lake of the Woods
5	Marshall
6	Beltrami
7	Koochiching
8	Pennington
9	Red Lake
10	Lake
11	Polk
12	Clearwater
13	Itasca
14	St. Louis
15	Norman
16	Mahnomen
17	Clay
18	Becker
19	Hubbard
20	Cass
21	Wadena
22	Crow Wing
23	Aitkin
24	Carlton
25	Wilkin
26	Otter Tail
27	Grant
28	Todd
29	Morrison
30	Mille Lacs
31	Kanabec
32	Pine
33	Traverse
34	Douglas
35	Stevens
36	Pope
37	Stearns
38	Benton
39	Isanti
40	Big Stone
41	Sherburne
42	Anoka
43	Chisago
44	Swift
45	Kandiyohi
46	Meeker
47	Wright
48	Ramsey
49	Washington
50	Lacqui Parle
51	Chippewa
52	McLeod
53	Hennepin
54	Yellow Medicine
55	Renville
56	Sibley
57	Carver
58	Scott
59	Dakota
60	Lincoln
61	Lyon
62	Redwood
63	Brown
64	Nicollet
65	LeSueur
66	Rice
67	Goodhue
68	Wabasha
69	Pipestone
70	Murray
71	Cottonwood
72	Watonwan
73	Blue Earth
74	Waseca
75	Steele
76	Dodge
77	Olmsted
78	Winona
79	Rock
80	Nobles
81	Jackson
82	Martin
83	Faribault
84	Freeborn
85	Mower
86	Fillmore
87	Houston

Map/Resource Data References

1. A. Kron and G. Heiken, **Geothermal Gradient Map of the Conterminous United States,** University of California Los Alamos Scientific Laboratory, LA-8476-MAP, Map Scale 1:5,000,000, 1980.

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Geothermal Resources

In

Montana

Western Area
Power Administration

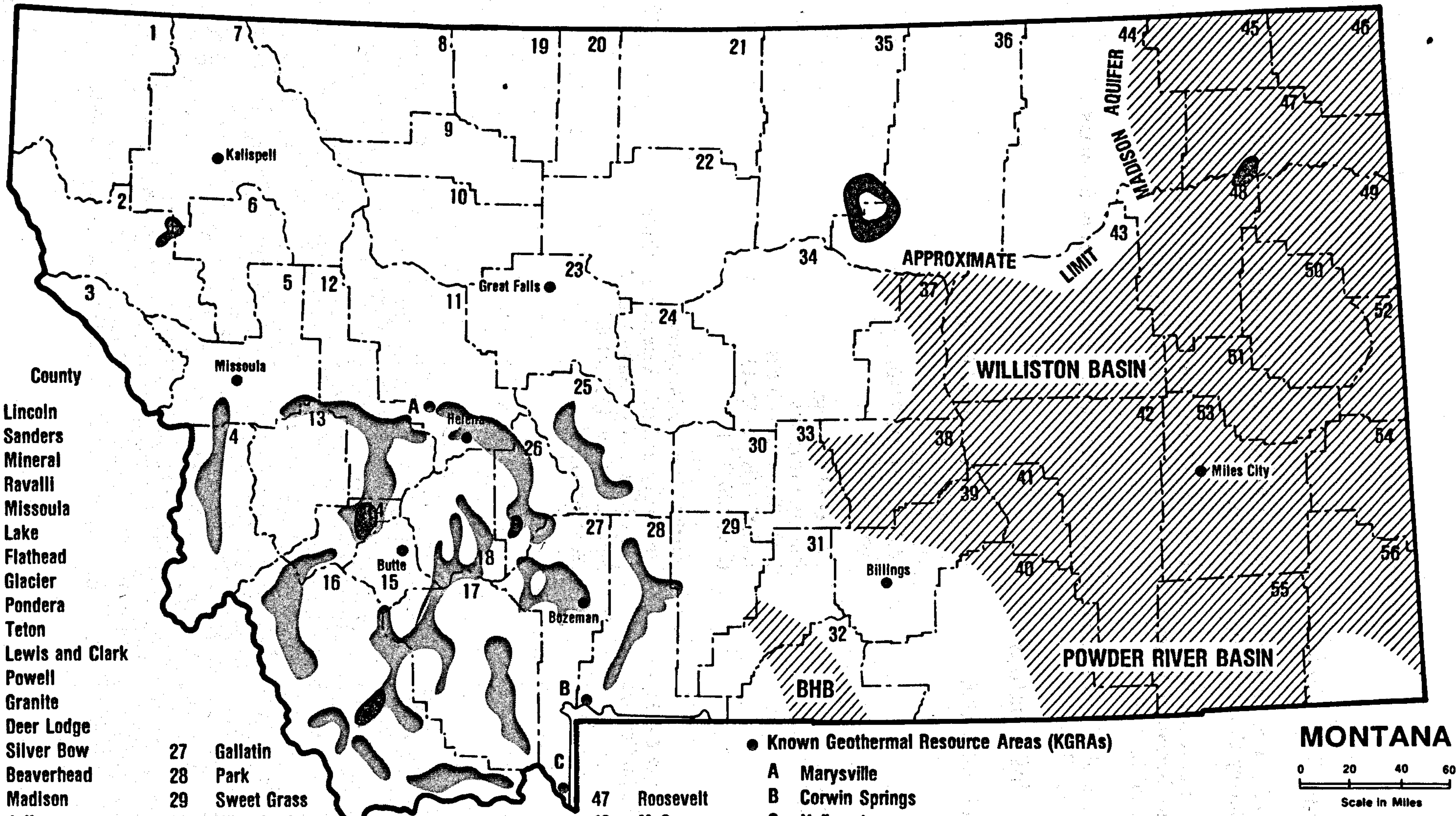
July 1982

Geothermal Resources in Montana

Convective hydrothermal systems in Montana are widely distributed throughout the northern Rocky Mountain region of the southwest quarter of the state. The Marysville KGRA near Helena, where a temperature of 217°F at a depth of 1.25 miles has been measured, is a possible high-temperature system with geothermometer estimates suggesting temperatures of up to 360°F. All other convective hydrothermal systems in southwest Montana are classified as low- to intermediate-temperature systems.

Geothermal resources in eastern Montana are contained within a deep regional stratigraphic aquifer commonly found in the Mississippian-Madison Group. Thermal fluids within this region are produced from depths ranging from 3280 to 8860 ft, with fluid temperatures of 108° to 260°F. The depth to the aquifer generally increases to the east.

Direct-use applications for hospitals and other building heating systems, swimming pools and spas, greenhousing, and others, are developing in this state. Geothermal energy use is occuring in locations such as Boulder, Bozeman, Jackson, White Sulphur Springs, Ennis, Marysville, and numerous other places. Resources adequate for electric power generation have not been located.



Number	County
1	Lincoln
2	Sanders
3	Mineral
4	Ravalli
5	Missoula
6	Lake
7	Flathead
8	Glacier
9	Pondera
10	Teton
11	Lewis and Clark
12	Powell
13	Granite
14	Deer Lodge
15	Silver Bow
16	Beaverhead
17	Madison
18	Jefferson
19	Toole
20	Liberty
21	Hill
22	Chouteau
23	Cascade
24	Judith Basin
25	Meagher
26	Broadwater
27	Gallatin
28	Park
29	Sweet Grass
30	Wheatland
31	Stillwater
32	Carbon
33	Golden Valley
34	Fergus
35	Blaine
36	Phillips
37	Petroleum
38	Musselshell
39	Yellowstone
40	Big Horn
41	Treasure
42	Rosebud
43	Garfield
44	Valley
45	Daniels
46	Sheridan
47	Roosevelt
48	McCone
49	Richland
50	Dawson
51	Prairie
52	Wibaux
53	Custer
54	Fallon
55	Powder River
56	Carter

● Known Geothermal Resource Areas (KGRAs)

A Marysville
B Corwin Springs
C Yellowstone

Area underlain by regional aquifer system(s).

Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources. Light areas indicate geologic favorability, but where data are inconclusive or lacking.

Map/Resource Data References

1. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978,** U.S. Geological Survey Circular 790, 1979, 163 p.

2. J. J. Sonderegger, and R. N. Bergantino, (compiler), **Geothermal Resources Map of Montana,** Montana Bureau of Mines and Geology, Hydrogeologic Map 4, Scale 1:1,000,000, 1981.

3. J. L. Sonderegger, et al., "Geothermal Resources in Montana," **Proceedings of Montana Academy of Science,** 1981.

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Geothermal Resources

In

Nebraska

Western Area
Power Administration

July 1982

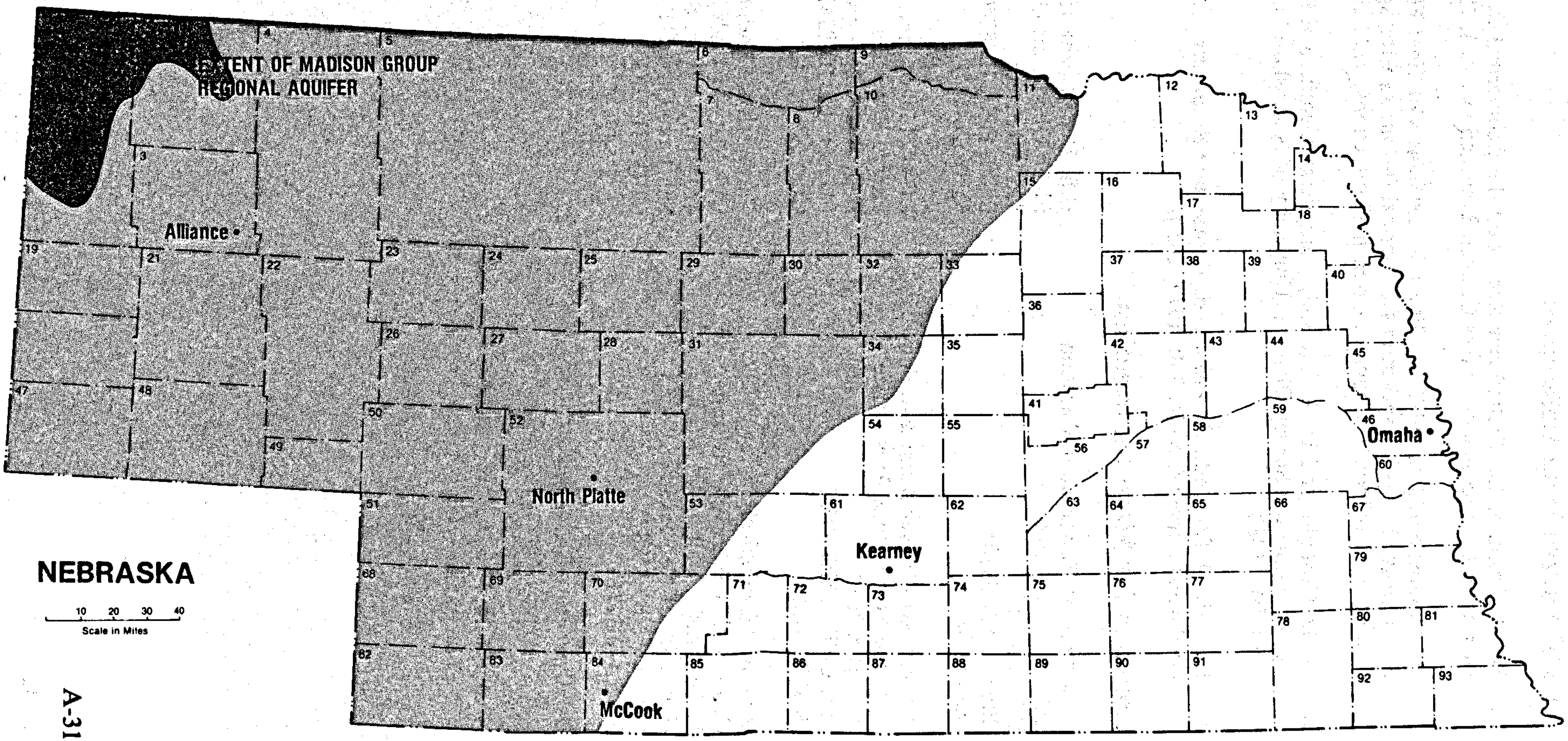
Geothermal Resources in Nebraska

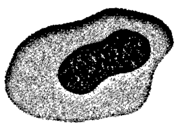
Low-temperature geothermal resources of Nebraska occur over broad regions underlian by the Cretaceous Dakota Sandstone. The Dakota Sandstone extends westward from eastern Nebraska beneath a cover of gradually thickening shale of low thermal conductivity. This general westward increase in overlying shale thickness, coupled with the low thermal conductivity of the shale and the increase in depth of the Dakota Sandstone, gives rise to higher thermal gradients to the west and a resulting high hydrothermal resource potential within the Dakota Sandstone of western Nebraska. Thermal water is thought to move "up dip" from the deeper portions of the Denver-Julesberg Basin.

The southern limit of the Mississippian-Madison Group regional aquifer extends into the northwest corner of Nebraska. Temperatures within the Madison Group in Nebraska are predicted to be between 140° and 160°F, although detailed geothermal characteristics of this aquifer system are presently unknown.

Direct-use applications are limited to livestock watering and other minor uses, but initial resource assessment may lead to development in the western part of this state. Geothermal bills have been introduced in the legislature, and bottomhole temperatures in oil and gas wells indicate that this state may have much higher than expected geothermal potential.

No.	County	No.	County	No.	County	No.	County	No.	County
1	SIOUX	23	GRANT	45	WASHINGTON	67	CASS	89	NUCKOLLS
2	DAWES	24	HOOKER	46	DOUGLAS	68	CHASE	90	THAYER
3	BOX BUTTE	25	THOMAS	47	KIMBALL	69	HAYES	91	JEFFERSON
4	SHERIDAN	26	ARTHUR	48	CHEYENNE	70	FRONTIER	92	PAWNEE
5	CHERRY	27	McPHERSON	49	DEUEL	71	GOSPER	93	RICHARDSON
6	KEYA PAHA	28	LOGAN	50	KEITH	72	PHELPS		
7	BROWN	29	BLAINE	51	PERKINS	73	KEARNEY		
8	ROCK	30	LOUP	52	LINCOLN	74	ADAMS		
9	BOYD	31	CUSTER	53	DAWSON	75	CLAY		
10	HOLT	32	GARFIELD	54	SHERMAN	76	FILLMORE		
11	KNOX	33	WHEELER	55	HOWARD	77	SALINE		
12	CEDAR	34	VALLEY	56	MERRICK	78	GAGE		
13	DIXON	35	GREELEY	57	POLK	79	OTOE		
14	DAKOTA	36	BOONE	58	BUTLER	80	JOHNSON		
15	ANTELOPE	37	MADISON	59	SAUNDERS	81	NEMAHA		
16	PIERCE	38	STANTON	60	SARPY	82	DUNDY		
17	WAYNE	39	CUMING	61	BUFFALO	83	HITCHCOCK		
18	THURSTON	40	BURT	62	HALL	84	REDWILLOW		
19	SCOTTS BLUFF	41	NANCE	63	HAMILTON	85	FURNAS		
20	BANNER	42	PLATTE	64	YORK	86	HARLAN		
21	MORRILL	43	COLFAX	65	SEWARD	87	FRANKLIN		
22	GARDEN	44	DODGE	66	LANCASTER	88	WEBSTER		





Area most favorable for discovery and development of low-temperature hydrothermal resources. Greatest potential is in the Dakota group (Cretaceous). The Madison group (Mississippian) extends into northwest Nebraska. Light area denotes areas underlain by regional aquifer system(s).

Map/Resource Data References

1. W. D. Gosnold, Jr., **Preliminary Report on the Geothermal Resource Potential of Nebraska**, Geothermal Resources Council Transactions, v. 4, 1980, p. 44-48.

2. W. D. Gosnold, Jr., and D. A. Eversoll, **Usefulness of Heat Flow Data in Regional Assessment of Low-Temperature Geothermal Resources with Special Reference to Nebraska**, Geothermal Resources Council Transactions, v. 5, 1981, p. 79-82.

3. W. D. Gosnold, and D. A. Eversoll, (compilers), **Geothermal Resources of Nebraska**, Conservation and Survey Division, University of Nebraska-Lincoln, Map Scale 1:500,000, 1982.

4. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States**, U.S. Geological Survey Circular 790, 1979, 163 p.

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Geothermal Resources
In
Nevada

Western Area
Power Administration

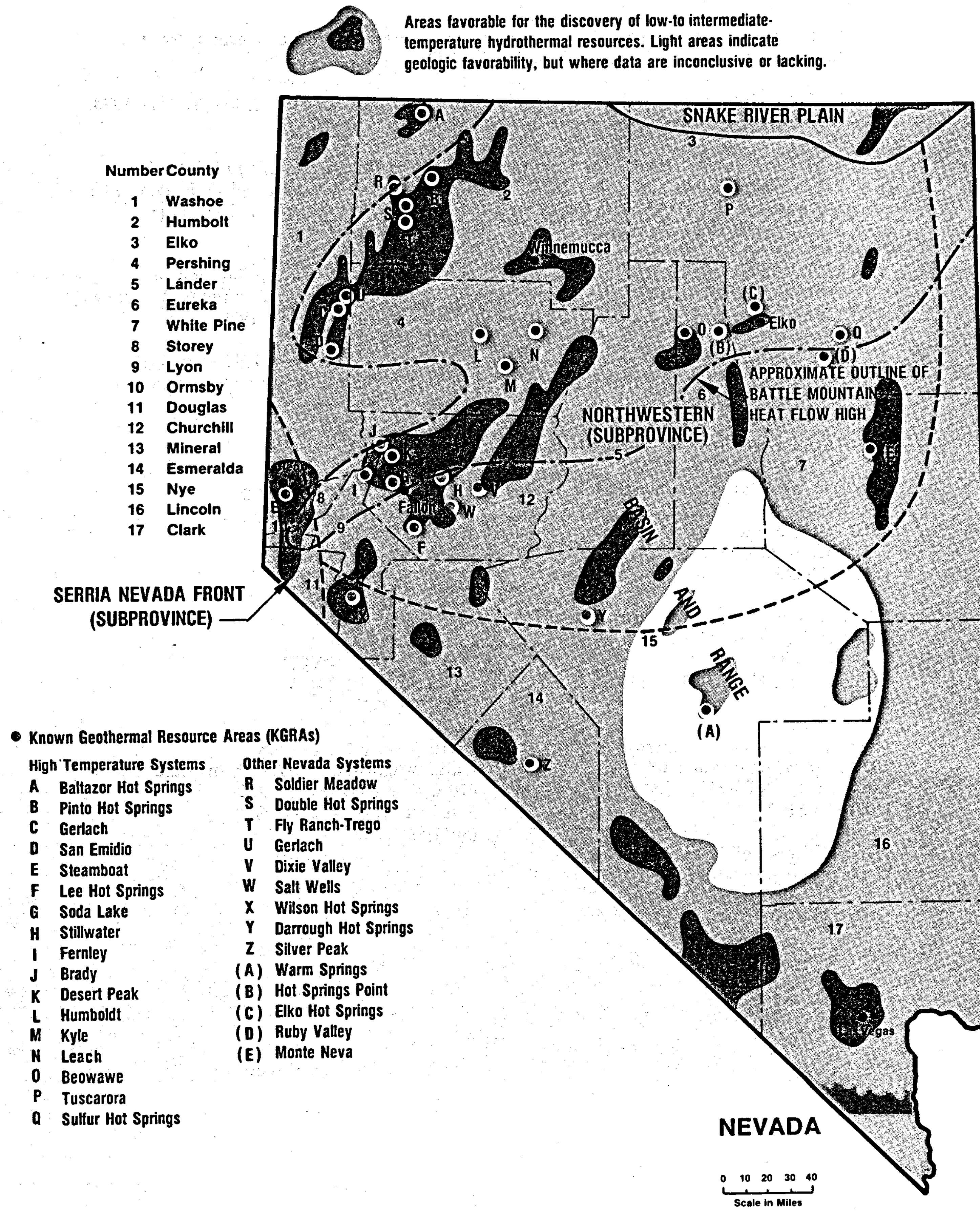
July 1982

Geothermal Resources in Nevada

Nevada's hydrothermal resources are manifested at numerous localities throughout the state, which is within the Basin and Range Province. High-temperature convective hydrothermal systems are present in northern and northwestern Nevada and are likely the result of a combination of a very high regional heat flow (Battle Mountain heat flow anomaly), insulating effect of young sediments, and numerous inactive and active Basin and Range faults that can provide channelways for deep circulation of thermal fluids. The Steamboat Hot Springs system near Reno is the only known high-temperature system in Nevada thought to relate to recent silicic volcanism.

Although the hydrothermal system within the Steamboat KGRA is the only high-temperature system in Nevada related to igneous activity, the remaining high-temperature systems in northern Nevada show good potential for electric and direct applications. Northern Nevada has the greatest concentration of high-temperature hydrothermal areas in the U.S.

Direct-use applications for district and heating systems, space heating, food processing, agriculture applications, swimming pools and spas, and others, are developing in this state. Geothermal energy use is occurring in locations such as Reno, Brady Hot Springs, Carson City, Caliente, Steamboat Hot Springs, Gerlach, Wabuska, Fallon, Hawthorne and numerous other places. Recent developments include a planned 10 MW geothermal demonstration power plant at Beowawe, and an expanded district heating system in Reno. Extensive exploratory activity has taken place in many parts of this state, and power development may also occur at Fallon. The U.S. Navy is soliciting formal proposals from private industry for development of geothermal resources at their Fallon, Nevada location.



Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources. Light areas indicate geologic favorability, but where data are inconclusive or lacking.
Number County
1 Washoe
2 Humbolt
3 Elko
4 Pershing
5 Lander
6 Eureka
7 White Pine
8 Storey
9 Lyon
10 Ormsby
11 Douglas
12 Churchill
13 Mineral
14 Esmeralda
15 Nye
16 Lincoln
17 Clark
SNAKE RIVER PLAIN
Winnemucca
Elko
Fallon
Las Vegas
APPROXIMATE OUTLINE OF BATTLE MOUNTAIN HEAT FLOW HIGH
NORTHWESTERN (SUBPROVINCE)
BASIN AND RANGE
SERRIA NEVADA FRONT (SUBPROVINCE)
Known Geothermal Resource Areas (KGRAs)
High Temperature Systems
A Baltazor Hot Springs
B Pinto Hot Springs
C Gerlach
D San Emidio
E Steamboat
F Lee Hot Springs
G Soda Lake
H Stillwater
I Fernley
J Brady
K Desert Peak
L Humboldt
M Kyle
N Leach
O Beowawe
P Tuscarora
Q Sulfur Hot Springs
Other Nevada Systems
R Soldier Meadow
S Double Hot Springs
T Fly Ranch-Trego
U Gerlach
V Dixie Valley
W Salt Wells
X Wilson Hot Springs
Y Darrough Hot Springs
Z Silver Peak
(A) Warm Springs
(B) Hot Springs Point
(C) Elko Hot Springs
(D) Ruby Valley
(E) Monte Neva
NEVADA
0 10 20 30 40
Scale in Miles

Map/Resource Data References

1. L. J. Garside and J. H. Schilling, **Inventory of Thermal Waters of Nevada**, Nevada Bureau of Mines and Geology, Bulletin 91, 1979, 159 p.

2. L. J. P. Muffler, ed., **Assessment of Geothermal Resources in the United States—1978**, U.S. Geological Survey Circular 790, 1979, 163 p.

3. J. H. Sass, et al., "Heat Flow from the Crust of the United States," in **Physical Properties of Rocks and Minerals**, Y. S. Touloukian, W. R. Judd, and R. F. Roy, eds. McGraw-Hill/CINDAS Data Series on Material Properties, vol. II-2: New York, McGraw-Hill Book Company, 1981, p. 503-547.

4. M. L. Silberman, D. E. White, T. E. C. Keith, and R. D. Dockter, **Duration of Hydrothermal Activity at Steamboat Springs, Nevada from Ages of Spatially Associated Volcanic Rocks**, U.S. Geological Survey Professional Paper 458-D, 1979, 14 p.

5. D. T. Trexler, B. A. Koenig, and T. Flynn, (compilers), **Geothermal Resources of Nevada and Their Potential for Direct Utilization**, Nevada Bureau of Mines and Geology, Map Scale 1:500,000, 1979.

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Geothermal Resources

In

New Mexico

Western Area
Power Administration

July 1982

Geothermal Resources in New Mexico

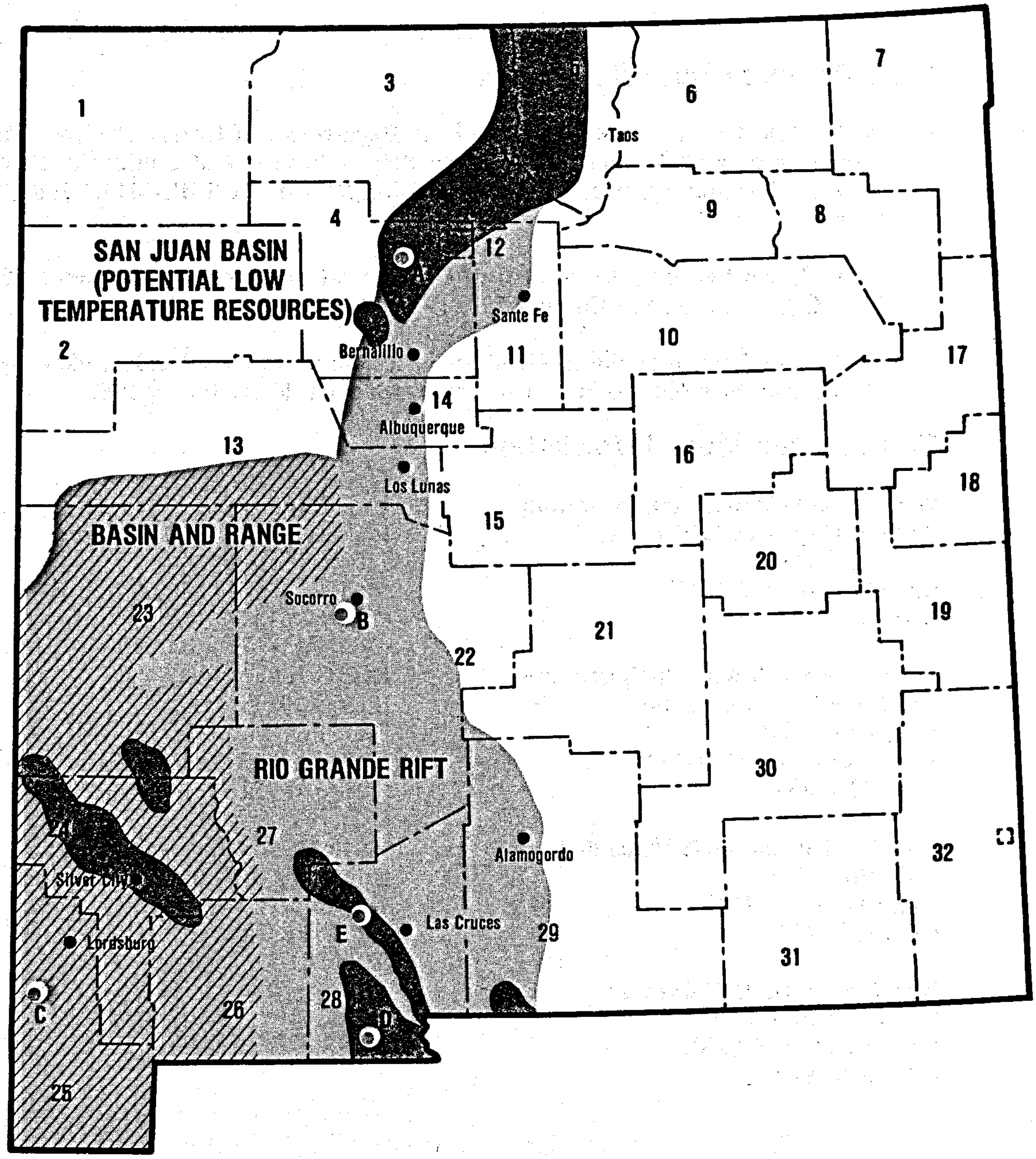
New Mexico's hydrothermal resources are contained predominantly within the Rio Grande Rift, a northward-trending structural depression characterized by Quaternary volcanism, high-heat flow and some surface hydrothermal manifestations. The Valles Caldera located within the Baca Location No. 1 KGRA is the dominant hydrothermal feature in New Mexico and is situated in the Jemez Mountains of north-central New Mexico along the western edge of the Rio Grande Rift. The Valles Caldera has been under intensive investigation for electric generation potential by both private industry and the U.S. Department of Energy. Elsewhere, most thermal water systems within the rift are attributed to deep circulation under above-normal geothermal gradient conditions. Geophysical evidence suggests the presence of several shallow magma chambers at a depth of 16,500 ft near Socorro, New Mexico that may be a driving mechanism for undiscovered hydrothermal resources.

Low- to intermediate-temperature resources are also located in the southeastward extension of the Basin and Range Province. Geothermal wells near Las Cruces and in the southern Tularosa Basin have encountered shallow (<1000 ft) water with temperatures greater than 140°F.

Geothermal development is very active in this state. Direct-use applications for district heating systems, space conditioning, agriculture, swimming pools and spas, greenhousing, and others, are developing in this state. Geothermal energy use is occuring in locations such as Las Cruces, Los Alturas, Truth or Consequences, Albuquerque, the Animas Valley, Socorro, Ojo Caliente, Radium Springs, Gila Hot Springs, Indian Reservations, and numerous other places.

Power generating potentials exist in the Valles Caldera area in the Jemez Mountains in the northern part of this state, but construction of a planned 50 MW demonstration unit at Baca Location No. 1 Known Geothermal Resource Area has been discontinued.

Number	County
1	San Juan
2	McKinley
3	Rio Arriba
4	Sandoval
5	Taos
6	Colfax
7	Union
8	Harding
9	Mora
10	San Miguel
11	Santa Fe
12	Los Alamos
13	Valencia
14	Bernalillo
15	Torrance
16	Guadalupe
17	Quay
18	Curry
19	Roosevelt
20	De Baca
21	Lincoln
22	Socorro
23	Catron
24	Grant
25	Hidalgo
26	Luna
27	Sierra
28	Dona Ana
29	Otero
30	Chaves
31	Eddy
32	Lea



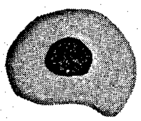
NEW MEXICO

0 10 20 30 40

Scale in Miles

● Known Geothermal Resource Areas (KGRAs)

- **A** Baca Location No. 1 (Valles Caldera)
- **B** Socorro Peak
- **C** Lightning Dock
- **D** Kilborn Hole
- **E** Radium Springs



Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources. Light areas indicate geologic favorability, but where data are inconclusive or lacking.

Map/Resource Data References

1. N. E. Goldstein, ed., **Final Report of the Department of Energy Review Team for the Baca Geothermal Demonstration Power Plant**, University of California, Lawrence Berkeley Laboratory, Earth Sciences Division Report No. LBL-14132, 1982, 51 p. (in prep.).

2. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States-1978**, U.S. Geological Survey Circular 790, 1979, 163 p.

3. C. A. Swanberg, (compiler), **Geothermal Resources of New Mexico**, New Mexico Energy Institute at New Mexico State University, Map, Scale 1:500,000, 1980.

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Geothermal Resources

In

North Dakota

Western Area
Power Administration

July 1982

Geothermal Resources in North Dakota

Hydrothermal resources of North Dakota occur within deep stratigraphic aquifers of the Williston Basin. The most prominent aquifer system is considered to be in the Mississippian-Madison Group, which is a thick (up to 2300 ft) sequence of permeable limestones, primarily noted for their oil production potential. Salinity within the Mississippian-Madison Group in North Dakota varies; locally it is as high as 350,000 parts per million. The center of the Williston Basin is located in eastern McKenzie County, where the depth to the top of the Mississippian-Madison Group is slightly greater than 8,500 ft.

Cretaceous and Upper Jurassic sandstones that overlie the Mississippian-Madison Group are also considered potential hydrothermal reservoirs. Plans to develop these resources have been formulated for the towns of Bismarck in Burleigh County, and Dickinson in Stark County.

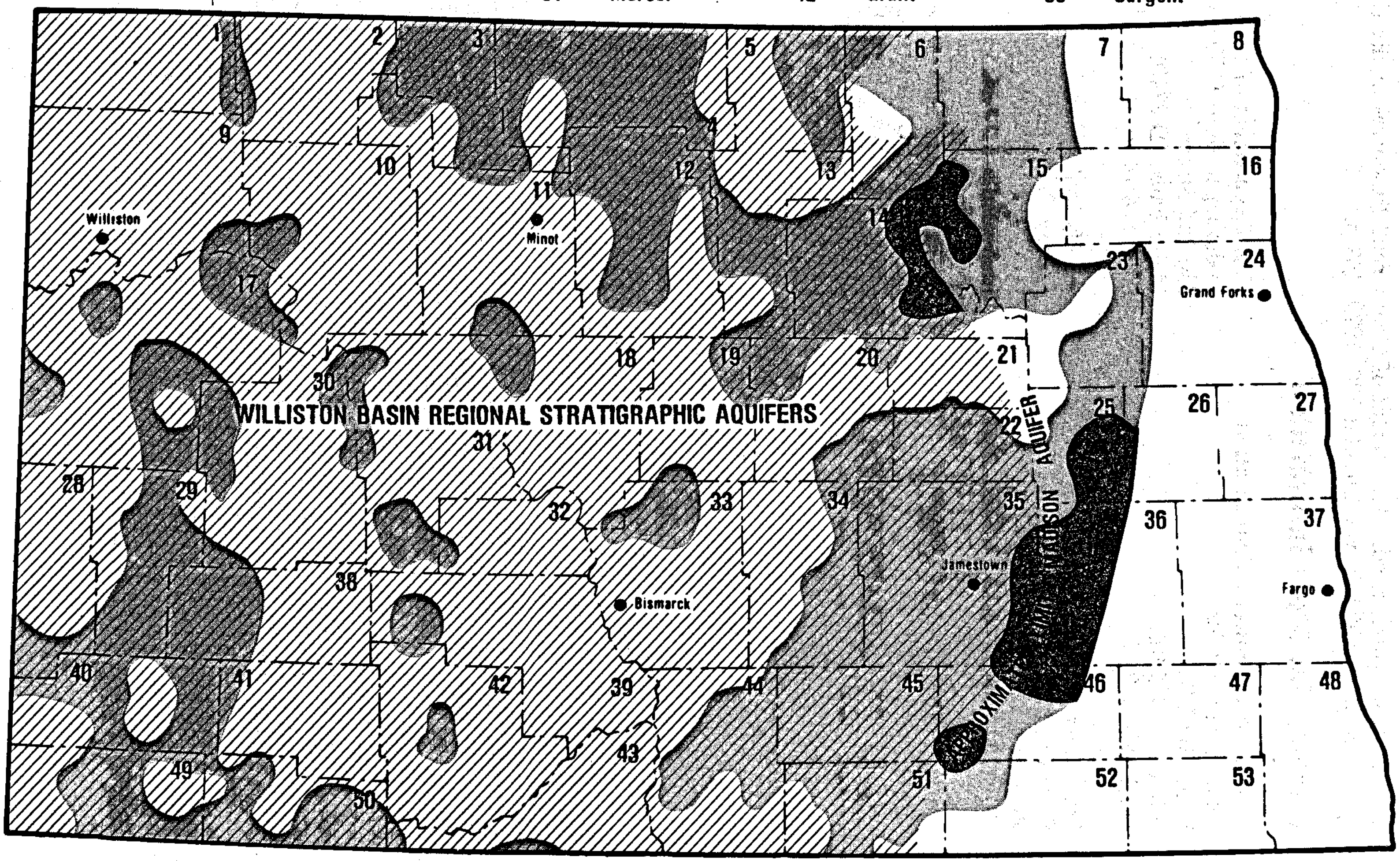
Variations in thermal gradients depicted on the statewide geothermal map may be due to areas of relatively higher heat flow, upward movement of thermal water from deeper sedimentary beds, or the presence of overlying shales of low-thermal conductivity.

Direct-use applications are primarily for space conditioning and agricultural use. Extensive interest is developing in the use of groundwater heat pumps. Geothermal energy use is occuring in locations such as Emmons, Burleigh and Stark Counties, Bismarck, Lamour, Horace, Oaks, Rolla, and other places. Resources adequate for power generation do not appear to exist.

NORTH DAKOTA

0 10 20 30 40
Scale in Miles

Number	County	Number	County	Number	County	Number	County	Number	County
1	Divide	11	Ward	21	Eddy	32	Oliver	43	Sioux
2	Burke	12	McHenry	22	Foster	33	Burleigh	44	Emmons
3	Renville	13	Pierce	23	Nelson	34	Kidder	45	Logan
4	Bottineau	14	Benson	24	Grand Forks	35	Stutsman	46	La Moure
5	Rolette	15	Ramsey	25	Griggs	36	Barnes	47	Ransom
6	Towner	16	Walsh	26	Steele	37	Cass	48	Richland
7	Cavalier	17	McKenzie	27	Traill	38	Stark	49	Bowman
8	Pembina	18	McLean	28	Golden Valley	39	Morton	50	Adams
9	Williams	19	Sheridan	29	Billings	40	Slope	51	McIntosh
10	Mountrail	20	Wells	30	Dunn	41	Hettinger	52	Dickey
				31	Mercer	42	Grant	53	Sargent



Areas where geothermal gradient is between 2.6 and 3.2°F/100 feet
Areas where geothermal gradient is greater than 3.2°F/100 feet
Area underlain by regional aquifer system(s)

Map/Resource Data References

1. K. L. Harris, (compiler), **Geothermal Resources of North Dakota**, North Dakota Geological Survey Map, Scale 1:500,000, 1981.

2. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978**, U.S. Geological Survey Circular 790, 1979, 163 p.

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Geothermal Resources

In

South Dakota

Western Area
Power Administration

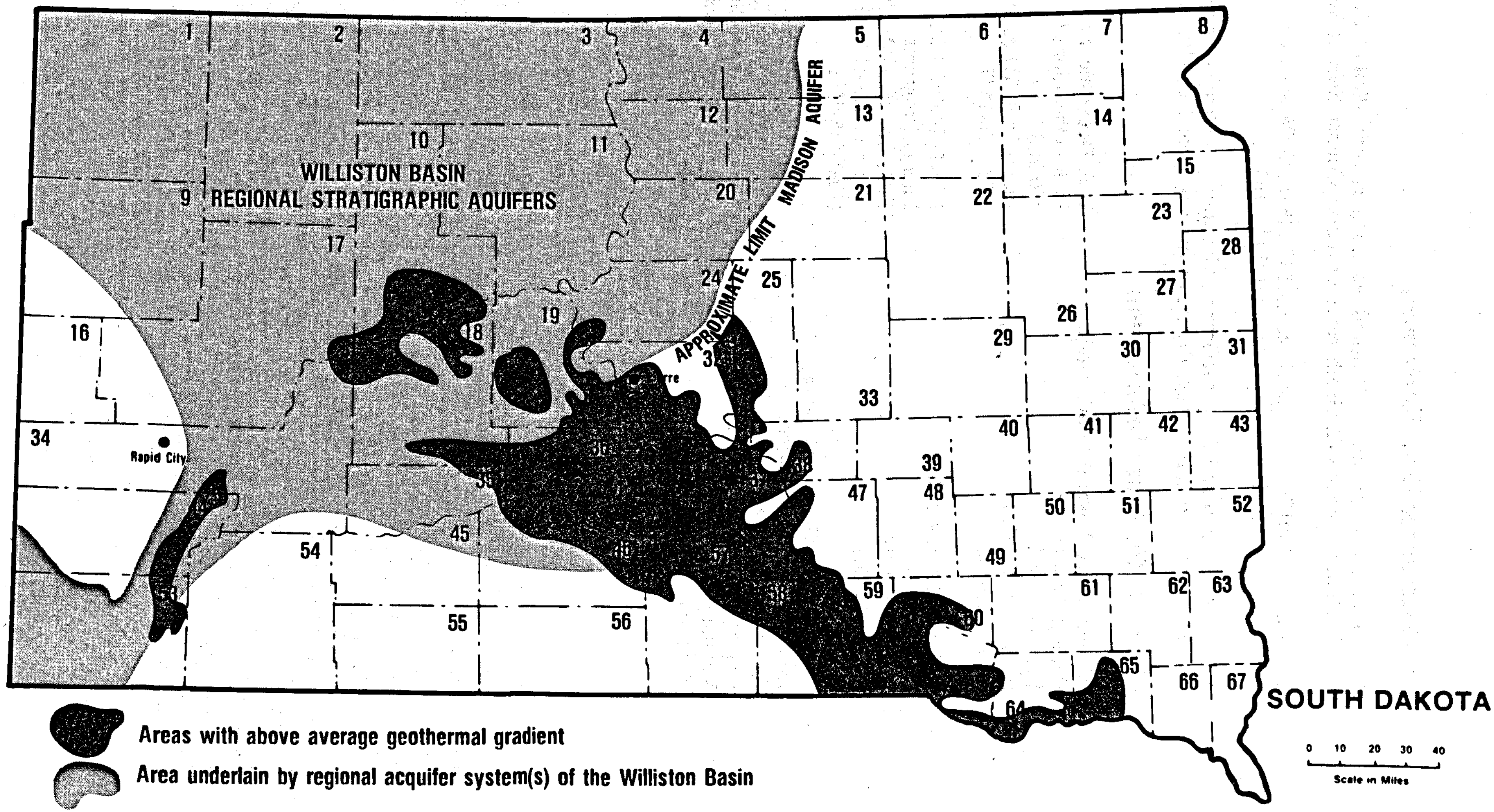
July 1982

Geothermal Resources in South Dakota

Hydrothermal resources in South Dakota are primarily the result of the deep circulation of thermal fluids within regional stratigraphic aquifers. The Mississippian-Madison Group may provide thermal water leakage to shallower sedimentary aquifers such as the overlying Cretaceous Dakota Sandstone. This situation may be partially responsible for certain areas of anomalously high-thermal gradients as seen in the central and southern portions of the state. In south-central and southeastern South Dakota, where the Mississippian-Madison Group is absent, temperatures ranging from 60° to 95°F have been encountered in shallow wells penetrating the Dakota Sandstone.

Direct-use applications for space heating, swimming pools and spas, agriculture, and others are developing in this state. Extensive interest is developing in the use of groundwater heat pumps. Geothermal energy use is occuring in locations such as Platte, Midland, Philip, Eagle Butte, Chamberlain, Box Elder, Pierre and other places. Resources adequate for power generation do not appear to exist.

Number	County
1	Harding
2	Perkins
3	Corson
4	Campbell
5	McPherson
6	Brown
7	Marshall
8	Roberts
9	Butte
10	Ziebach
11	Dewey
12	Walworth
13	Edmunds
14	Day
15	Grant
16	Lawrence
17	Meade
18	Haakon
19	Stanley
20	Potter
21	Faulk
22	Spink
23	Codington
24	Sully
25	Hyde
26	Clark
27	Hamlin
28	Deuel
29	Beadle
30	Kingsbury
31	Brookings
32	Hughes
33	Hand
34	Pennington
35	Jackson
36	Jones
37	Lyman
38	Buffalo
39	Jerauld
40	Sanborn
41	Miner
42	Lake
43	Moody
44	Custer
45	Washabaugh
46	Mellette
47	Brule
48	Aurora
49	Davison
50	Hanson
51	McCook
52	Minnehaha
53	Fall River
54	Shannon
55	Bennett
56	Todd
57	Tripp
58	Gregory
59	Charles Mix
60	Douglas
61	Hutchinson
62	Turner
63	Lincoln
64	Bon Homme
65	Yankton
66	Clay
67	Union



Map/Resource Data References

1. D. N. Anderson and J. W. Lund, eds., **Direct Utilization of Geothermal Energy A Technical Handbook,** Geothermal Resources Council Special Report No. 7, 1979, 241 p.

2. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978,** U.S. Geological Survey Circular 790, 1979, 163 p.

3. R. A. Schoon and D. J. McGregor, **Geothermal Potentials in South Dakota,** South Dakota Geological Survey, Report of Investigations No. 110, 1974, 76 p.

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Geothermal Resources

In

Texas

Western Area
Power Administration

July 1982

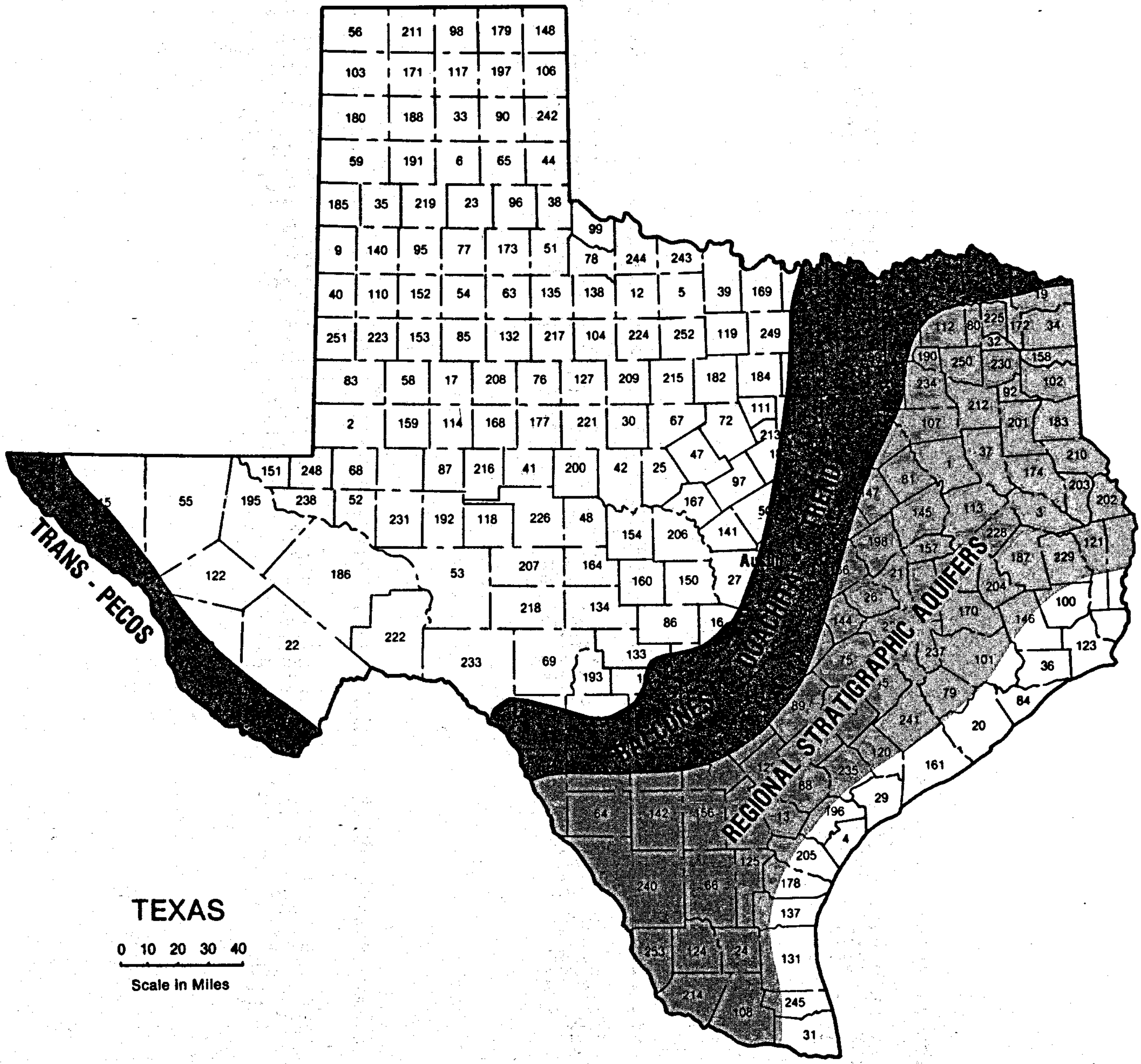
Geothermal Resources in Texas

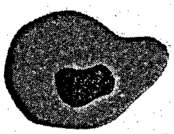
Hydrothermal resources along the western boundary of the state of Texas are located within what is termed the Trans-Pecos region where Basin and Range type faulting extends southward from New Mexico. Here, deep sediment-filled basins or bolsons trending north-south have high heat flow values and thermal gradients. Temperatures from thermal springs and wells in this region range from 90° to 117°F with estimated equilibration temperatures of near 140°F.

In central Texas, hydrothermal resources occur along the Balcones-Ouachita trend, which may encompass as much as 75,000 square miles. Along this trend, thermal waters are produced from sandstone and limestone aquifers that are crosscut by a series of complex faults. Saline thermal fluids with temperatures up to 158°F are produced at places from relatively shallow depths (<600 ft) and have been used for a number of years in certain direct heat applications.

Regional stratigraphic aquifers situated between the Balcones-Ouachita trend and the Texas gulf coast may also contain potential low-temperature resources.

Direct-use applications for space and water heating systems, swimming pools and spas, and others are developing in this state. Geothermal energy use is occuring in locations such as Marlin, Corsicana, Ruidoso, Cotulla, and other places. Hydrothermal resources adequate for power generation do not appear to exist.





Areas favorable for the discovery of low temperature hydrothermal resources. Light areas indicate area underlain by potential regional aquifer system(s).

TEXAS

No.	County
1	ANDERSON
2	ANDREWS
3	ANGELINA
4	ARANSAS
5	ARCHER
6	ARMSTRONG
7	ATASCOSA
8	AUSTIN
9	BAILEY
10	BANDERA
11	BASTROP
12	BAYLOR
13	BEE
14	BELL
15	BEXAR
16	BLANCO
17	BORDEN
18	BOSQUE
19	BOWIE
20	BRAZORIA
21	BRAZOS
22	BREWSTER
23	BRISCOE
24	BROOKS
25	BROWN
26	BURLESON
27	BURNET
28	CALDWELL
29	CALHOUN
30	CALLAHAN
31	CAMERON
32	CAMP
33	CARSON
34	CASS
35	CASTRO
36	CHAMBERS
37	CHEROKEE
38	CHILDRESS
39	CLAY
40	COCHRAN
41	COKE
42	COLEMAN
43	COLLIN
44	COLLINGSWORTH
45	COLORADO
46	COMAL
47	COMANCHE
48	CONCHO
49	COOKE
50	CORYELL
51	COTTLE
52	CRANE
53	CROCKETT
54	CROSBY
55	CULBERSON
56	DALLAM
57	DALLAS
58	DAWSON
59	DEAF SMITH
60	DELTA
61	DENTON
62	DE WITT
63	DICKENS
64	DIMMIT
65	DONLEY
66	DUVAL
67	EASTLAND
68	ECTOR
69	EDWARDS
70	ELLIS
71	EL PASO
72	ERATH
73	FALLS
74	FANNIN
75	FAYETTE
76	FISHER
77	FLOYD
78	FOARD
79	FORT BEND
80	FRANKLIN
81	FREESTONE
82	FRIO
83	GAINES
84	GALVESTON
85	GARZA
86	GILLESPIE
87	GLASSCOCK
88	GOLIAD
89	GONZALES
90	GRAY
91	GRAYSON
92	GREGG
93	GRIMES
94	GUADALUPE
95	HALE
96	HALL
97	HAMILTON
98	HANSFORD
99	HARDEMAN
100	HARDIN
101	HARRIS
102	HARRISON
103	HARTLEY
104	HASKELL
105	HAYS
106	HEMPHILL
107	HENDERSON
108	HIDALGO
109	HILL
110	HOCKLEY
111	HOOD
112	HOPKINS
113	HOUSTON
114	HOWARD
115	HUDSPETH
116	HUNT
117	HUTCHINSON
118	IRION
119	JACK
120	JACKSON
121	JASPER
122	JEFF DAVIS
123	JEFFERSON
124	JIM HOGG
125	JIM WELLS
126	JOHNSON
127	JONES
128	KARNES
129	KAUFMAN
130	KENDALL
131	KENEDY
132	KENT
133	KERR
134	KIMBLE
135	KING
136	KINNEY
137	KLEBERG
138	KNOX
139	LAMAR
140	LAMB
141	LAMPASAS
142	LASALLE
143	LAVACA
144	LEE
145	LEON
146	LIBERTY
147	LIMESTONE
148	LIBSOMB
149	LIVE OAK
150	LLANO
151	LOVING
152	LUBBOCK
153	LYNN
154	MCCULLOCH
155	MCLENNAN
156	MCMULLEN
157	MADISON
158	MARION
159	MARTIN
160	MASON
161	MATAGORDA
162	MAVERICK
163	MEDINA
164	MENARD
165	MIDLAND
166	MILAM
167	MILLS
168	MITCHELL
169	MONTAGUE
170	MONTGOMERY
171	MOORE
172	MORRIS
173	MOTLEY
174	NACOGDOCHES
175	NAVARRO
176	NEWTON
177	NOLAN
178	NUECES
179	OCHILTREE
180	OLDHAM
181	ORANGE
182	PALO PINTO
183	PANOLA
184	PARKER
185	PARMER
186	PECOS
187	POLK
188	POTTER
189	PRESIDIO
190	RAINS
191	RANDALL
192	REAGAN
193	REAL
194	RED RIVER
195	REEVES
196	REFUGIO
197	ROBERTS
198	ROBERTSON
199	ROCKWALL
200	RUNNELS
201	RUSK
202	SABINE
203	SAN AUGUSTINE
204	SAN JACINTO
205	SAN PATRICIO
206	SAN SABA
207	SCHLEICHER
208	SCURRY
209	SHACKELFORD
210	SHELBY
211	SHERMAN
212	SMITH
213	SOMERVELL
214	STARR
215	STEPHENS
216	STERLING
217	STONEWALL
218	SUTTON
219	SWISHER
220	TARRANT
221	TAYLOR
222	TERRELL
223	TERRY
224	THROCKMORTON
225	TITUS
226	TOM GREEN
227	TRAVIS
228	TRINITY
229	TYLER
230	UPSHUR
231	UPTON
232	UVALDE
233	VAL VERDE
234	VAN ZANDT
235	VICTORIA
236	WALKER
237	WALLER
238	WARD
239	WASHINGTON
240	WEBB
241	WHARTON
242	WHEELER
243	WICHITA
244	WILBARGER
245	WILLACY
246	WILLIAMSON
247	WILSON
248	WINKLER
249	WISE
250	WOOD
251	YOAKUM
252	YOUNG
253	ZAPATA
254	ZAVALA

Map/Resource Data References

1. C. Henry and J. Gluck, **Preliminary Assessment of Geologic Setting, Geochemisty, and Hydrology of the Hueco Tanks Geothermal Area, Texas and New Mexico**, Texas Energy and Natural Resources Council Report, 1981.

2. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978**, U.S. Geological Survey Circular 790, 1979, 163 p.

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Geothermal Resources

In

Utah

Western Area
Power Administration

July 1982

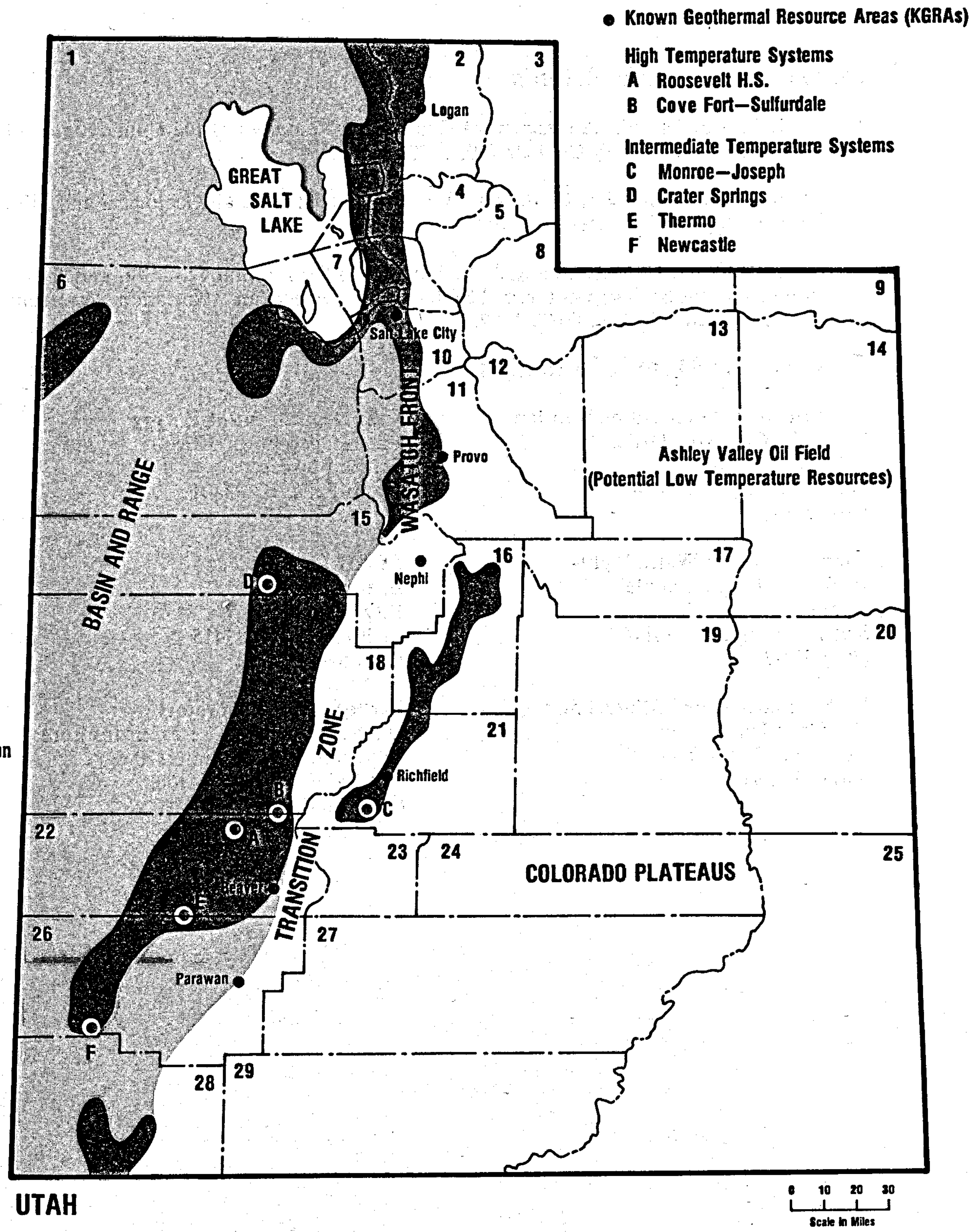
Geothermal Resources in Utah

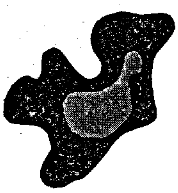
Hydrothermal resources in Utah are primarily located along the Wasatch Front where many thermal springs and wells are expressions of the deep circulation of meteoric water along high-angle fractured zones and faults. High temperature (<300°F) resources at Roosevelt Hot Springs and the Cove Fort-Sulphurdale area are thought to relate to shallow cooling intrusive bodies.

Although warmer waters occur along the southern Wasatch Front, a greater potential for direct heat application exists along the northern Wasatch Front, where low- to intermediate-temperature resources are located near the population centers. The Basin and Range Province of western Utah remains largely untested, but may prove to hold additional resources upon further investigation.

Direct-use applications for district heating systems, space conditioning, swimming pools and spas, greenhousing, and others, are developing in this state. Geothermal energy use is occuring in locations such as Salt Lake City, Monroe, Sandy, Honeyville, Midway, Utah Valley, Roosevelt Hot Springs, Cove Fort-Sulphurdale, Crystal Hot Springs (Utah State Prison), and numerous other places. A 20 MW geothermal power plant is being developed at Roosevelt Hot Springs by Utah Power and Light Company and Phillips Petroleum Company.

Number	County
1	Box Elder
2	Cache
3	Rich
4	Weber
5	Morgan
6	Tooele
7	Davis
8	Summit
9	Dagget
10	Salt Lake
11	Utah
12	Wasatch
13	Duchesne
14	Uintah
15	Juab
16	Sanpete
17	Carbon
18	Millard
19	Emery
20	Grand
21	Sevier
22	Beaver
23	Piute
24	Wayne
25	San Juan
26	Iron
27	Garfield
28	Washington
29	Kane





Areas favorable for the discovery of low-to intermediate-temperature hydrothermal resources. Light areas indicate geologic favorability, but where data are inconclusive or lacking.

Map/Resource Data References

1. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978,** U.S. Geological Survey Circular 790, 1979, 163 p.

2. P. J. Murphy, compiler, **Geothermal Resources of Utah,** Utah Geological and Mineral Survey Map, Scale—1:500,000, 1980.

3. H. P. Ross, D. L. Nielson, and J. N. Moore, **An Exploration Case Study of the Roosevelt Hot Springs Geothermal System, Utah,** American Association Petroleum Geologists Bulletin Vol. 66/7, 1982.

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Geothermal Resources

In

Wyoming

Western Area
Power Administration

July 1982

Geothermal Resources in Wyoming

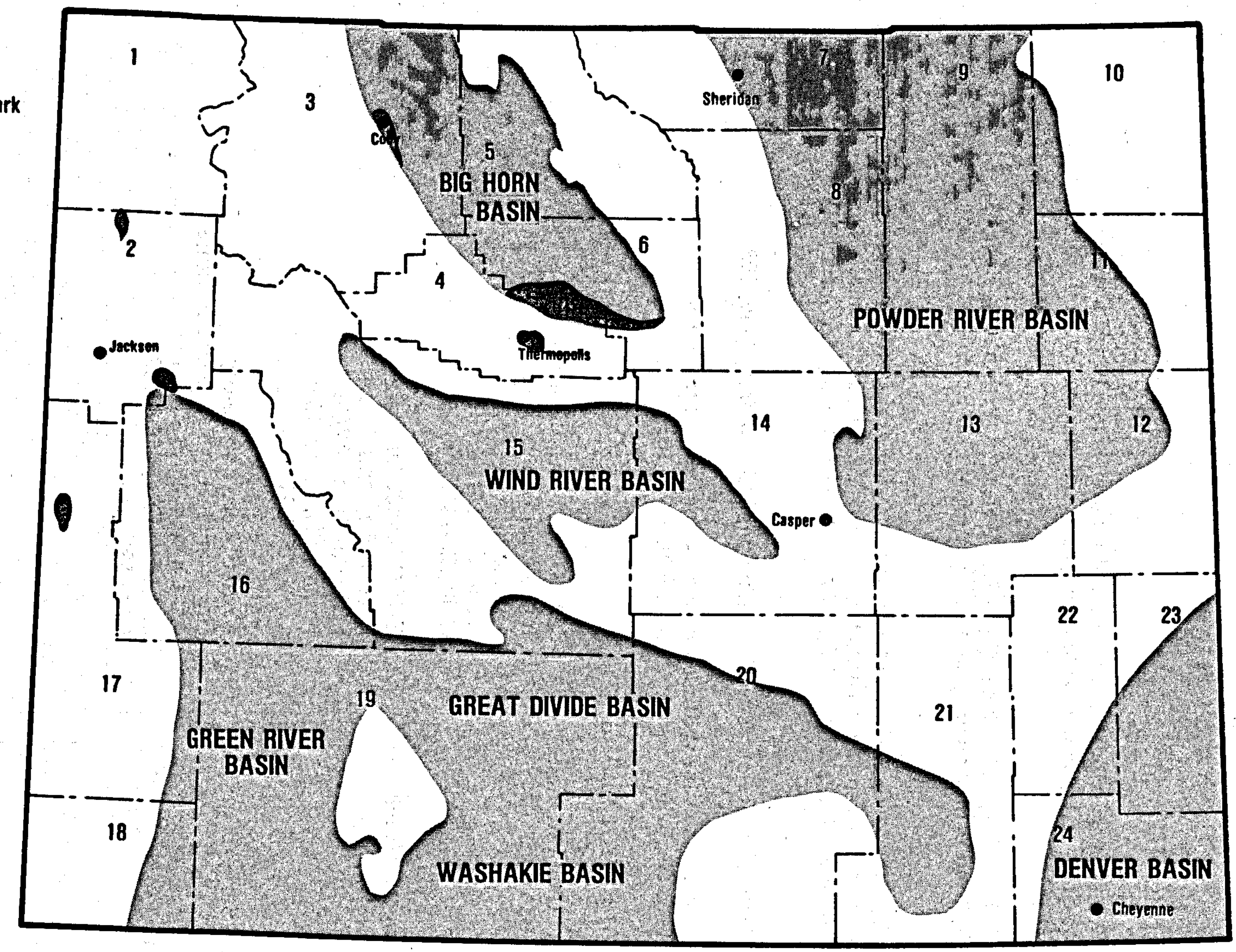
Hydrothermal resources in Wyoming outside of Yellowstone National Park have been classified as low- and intermediate-temperature (<300°F) systems. Surface manifestations and other indications of resources at depth are widely distributed throughout the state. Huckleberry, Granite, and Auburn hot springs located south of Yellowstone Park are all intermediate temperature systems that may have potential for direct use, although Huckleberry Hot Spring is located in a national parkway. The low-temperature system near Thermopolis is currently being evaluated as part of a feasibility study to establish a district heating system within the town. Low temperature resources may be developed in the future from deep stratigraphic aquifers contained within the Powder River Basin and Denver-Julesberg Basin of eastern Wyoming, and also the Big Horn, Wind River, Green River, and Great Divide-Wabhakie Basins of central and western Wyoming.

Yellowstone National Park contains over 10,000 hot springs, geysers, mud pots, and fumaroles. Because it is a National Park, it is not available for geothermal energy development.

Direct-use applications for space heating, agriculture, swimming pools and spas, greenhousing, and others, are developing in this state. Geothermal energy use is occuring in locations such as Saratoga, Lander, Thermopolis, Jackson, Cody, Midwest, and numerous other places. Resources adequate for economical power generation do not appear to exist.

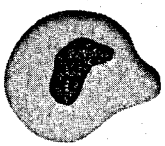
1 Yellowstone National Park

Number	County
2	Teton
3	Park
4	Hot Springs
5	Big Horn
6	Washakie
7	Sheridan
8	Johnson
9	Campbell
10	Crook
11	Weston
12	Niobrara
13	Converse
14	Natrona
15	Fremont
16	Sublette
17	Lincoln
18	Uinta
19	Sweetwater
20	Carbon
21	Albany
22	Platte
23	Goshen
24	Laramie



WYOMING

0 10 20 30 40
Scale in Miles



Areas favorable for the discovery of low-to intermediate temperature hydrothermal resources. Light areas are underlain by potential regional aquifer system(s) and indicate geologic favorability, but where data are inconclusive or lacking.

Map/Resource Data References

1. E. R. Decker, **Geothermal Resources, Present and Future Demand for Power and Legislation in the State of Wyoming,** Wyoming Geological Survey, Public Information Series-1, 1976, 21 p.

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5. L. J. P. Muffler, ed., **Assessment of Geothermal Resources of the United States—1978:** U.S. Geological Survey Circular 790, 1979, 163 p.

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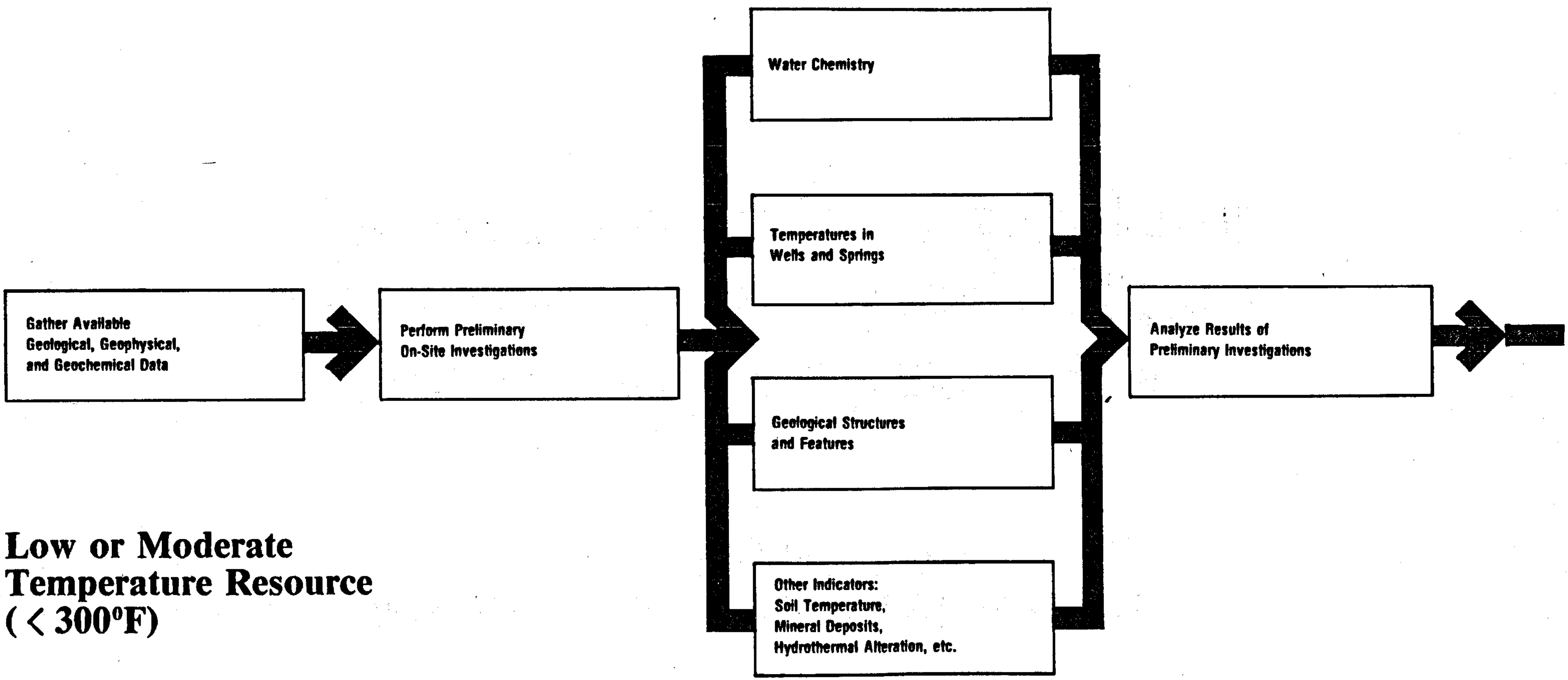
Western Area Power Administration
Power Marketing Area

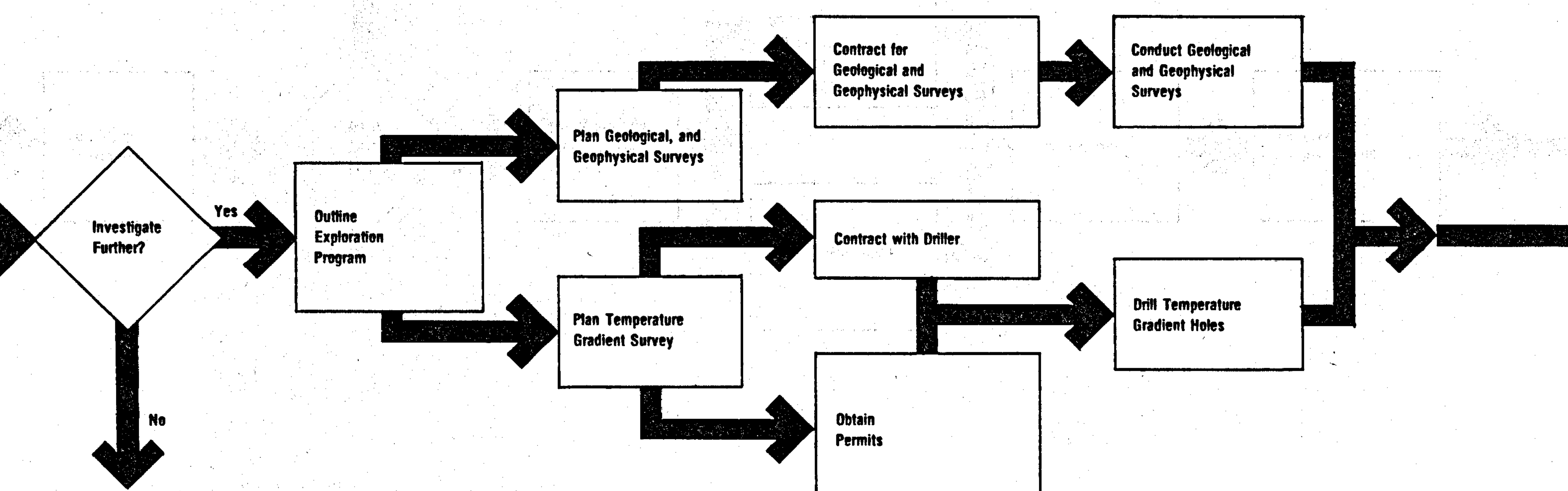
Typical Flow Chart for a Low-to-Moderate Temperature Resource Assessment Program

Appendix B

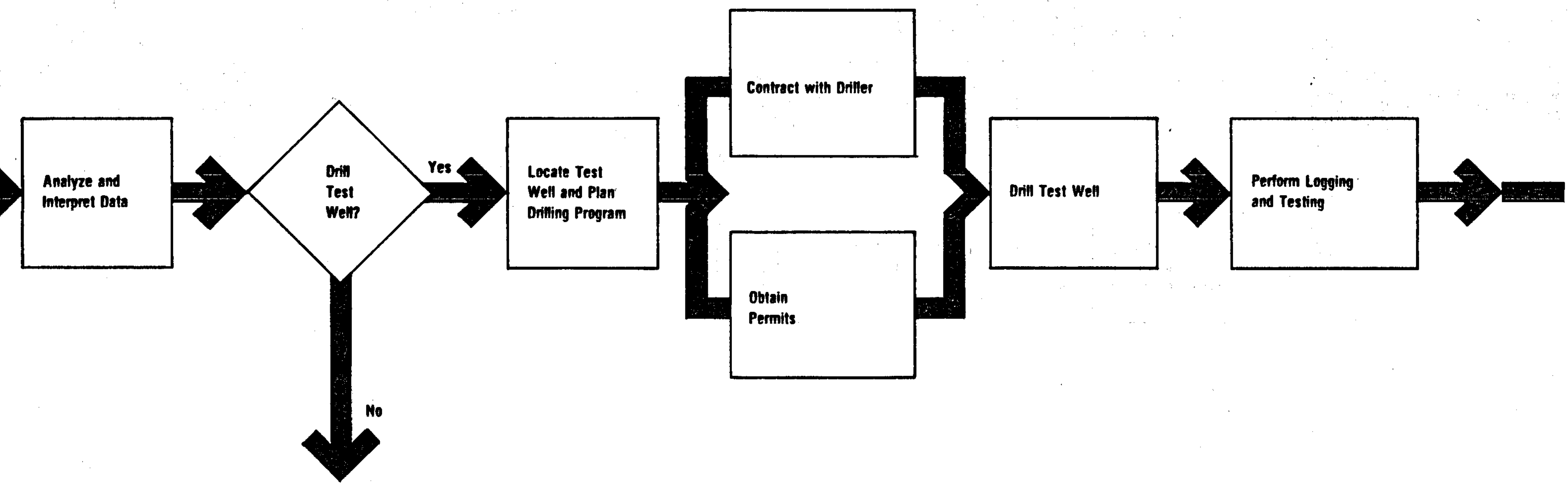


Low or Moderate Temperature Resource (< 300°F)

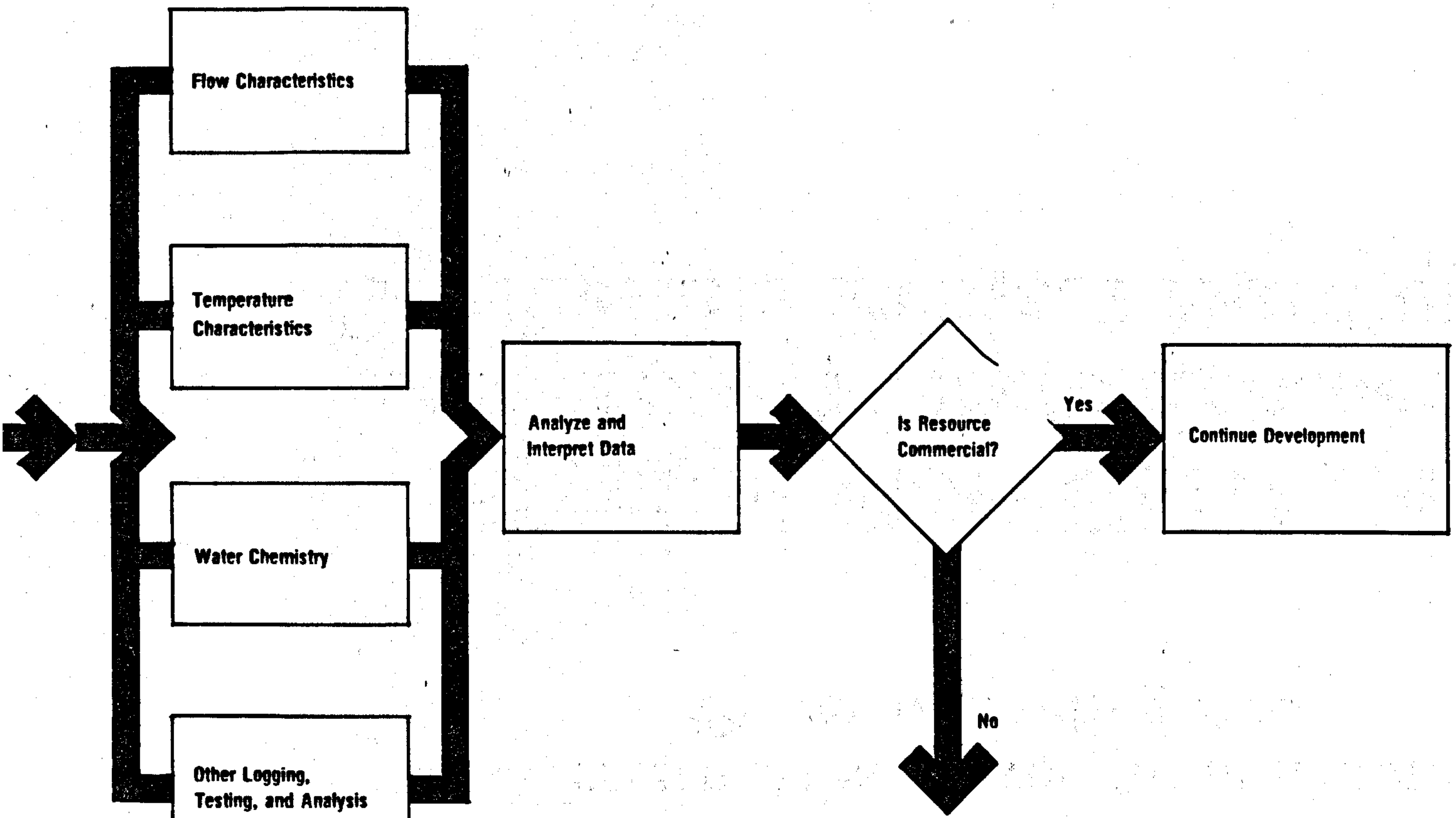
Typical Resource Assessment Program



Typical Resource Assessment Program *(continued)*



Typical Resource Assessment Program ***(continued)***

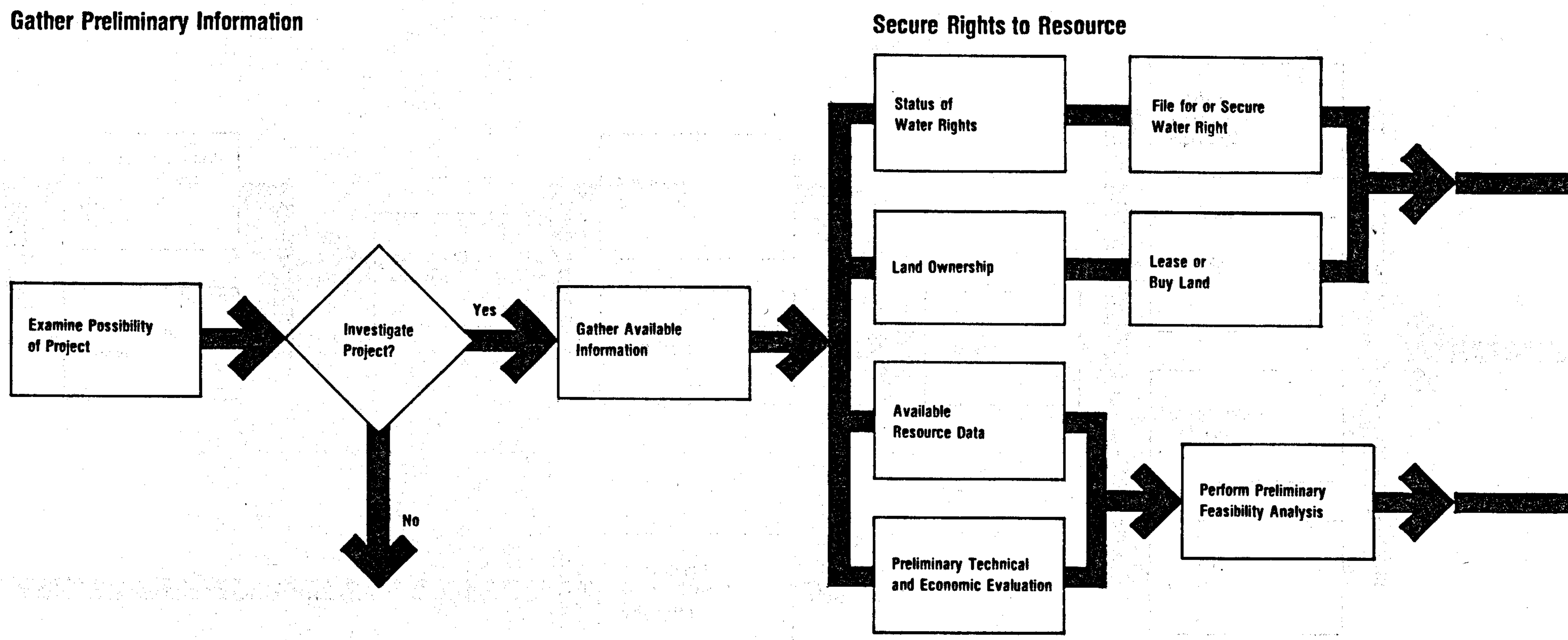


Typical Source Assessment Program ***(continued)***

Western Area Power Administration
Power Marketing Area

Typical Flow Chart for a Low-To-Moderate Temperature Geothermal Project Development

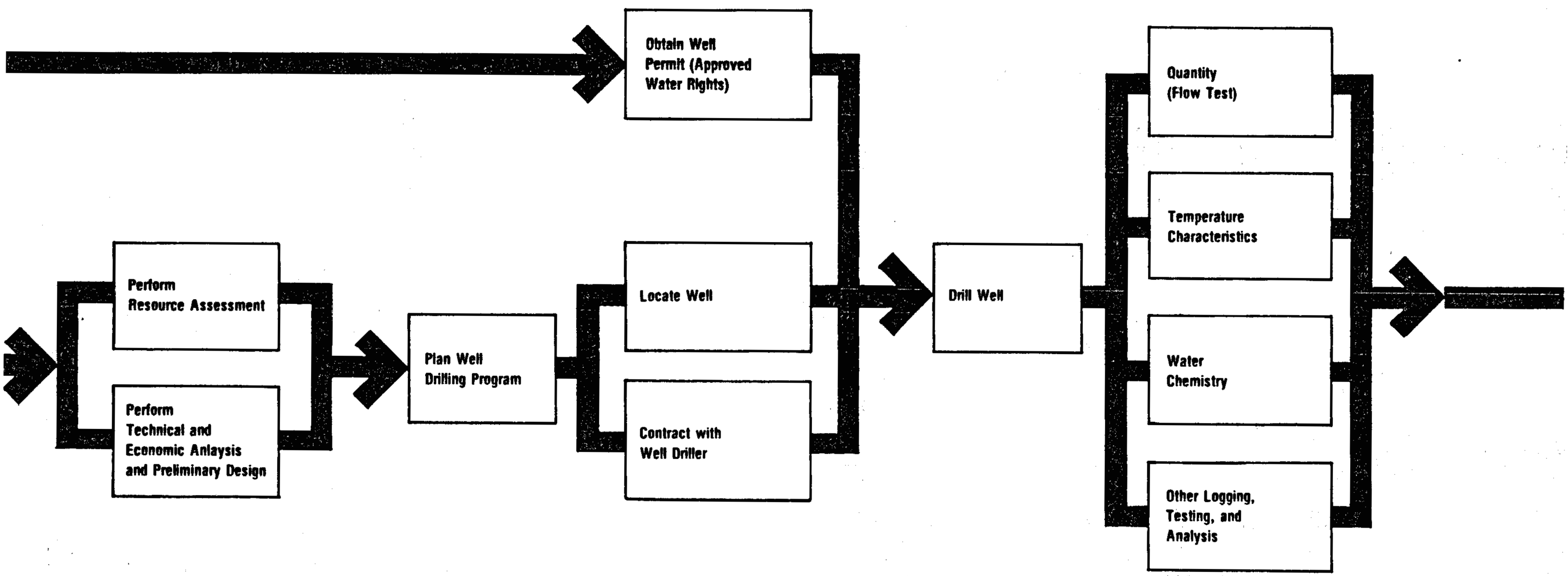
Appendix C



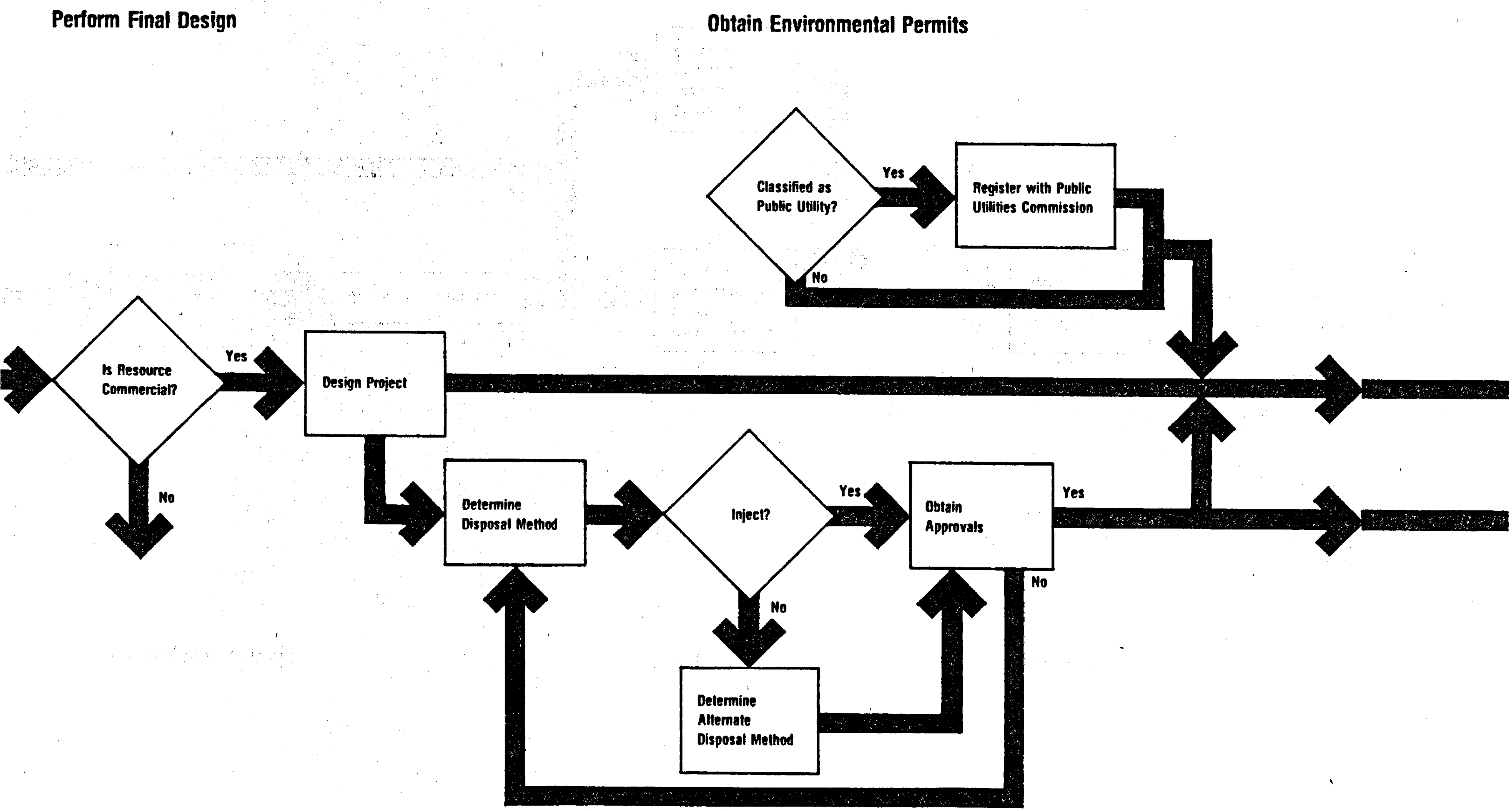
Typical Procedure for Development of Low or Moderate Temperature Resources (<300°F)

Plan Project

Analyze Drilling Results

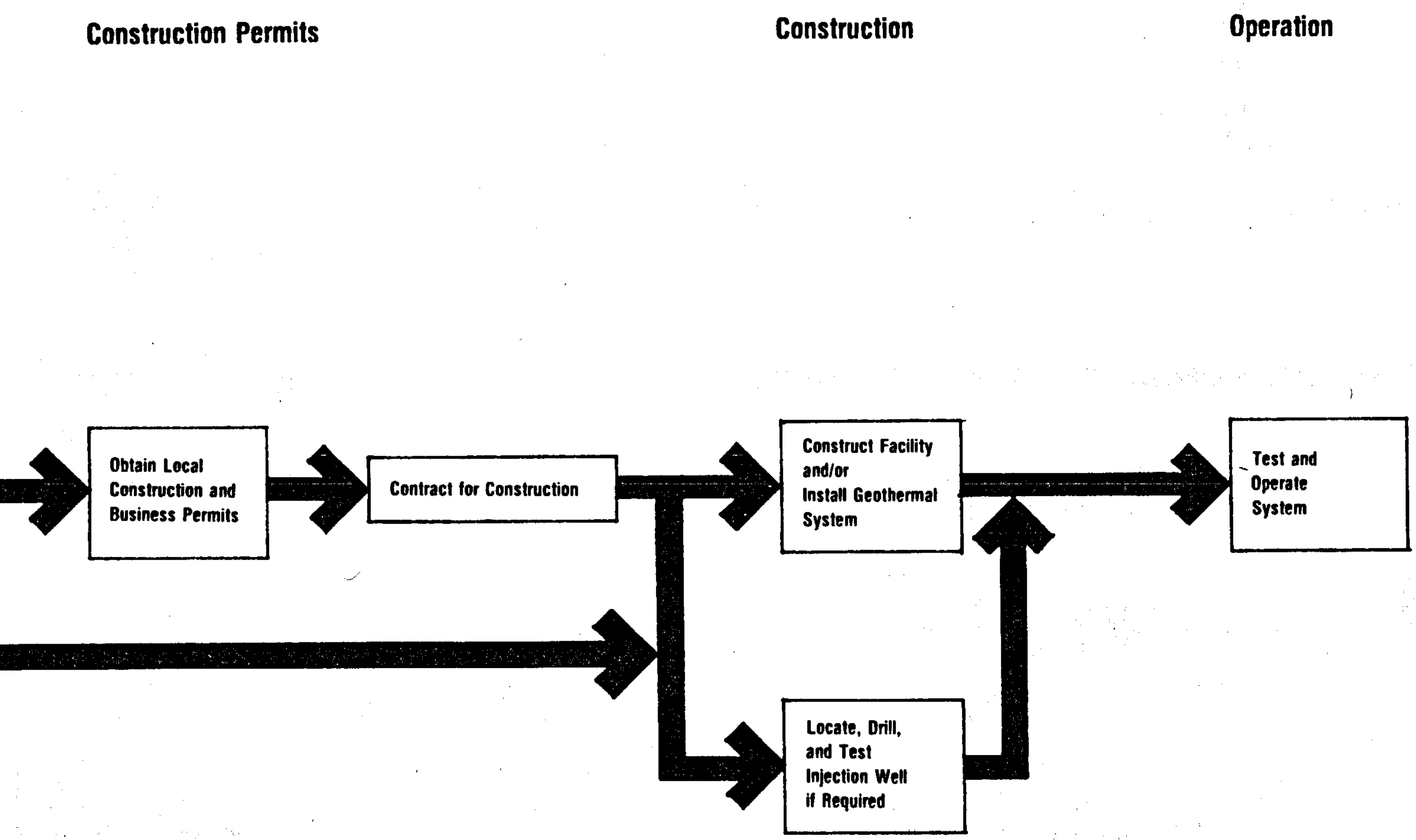


Development of Moderate Temperature Resources *(continued)*



Development of Moderate Temperature Resources *(continued)*

GPO 836-709



Development of Moderate Temperature Resources *(continued)*