GROUNDWATER AND GEOTHERMAL: Urban District Heating Applications

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INTRODUCTION

This report describes how several cities use groundwater and geothermal energy in district heating systems. It begins with groundwater, introducing the basic technology and techniques of development, and describing two case studies of cities with groundwater-based district heating systems. The second half of the report consists of three case studies of cities with district heating systems using higher temperature geothermal resources.

While only a handful of cities have drawn on these resources, government and university studies indicate a much larger potential. Part of the reason for the discrepancy between potential and application may be that most geothermal exploration has gone on in rather remote parts of the West, and has been focused on very high temperature sources suitable for electric generation. Much less attention has been given to so-called "direct uses", i.e., industrial processes, or hot water and space heating. The result has been a popular misconception that geothermal is a limited resource, located in wilderness areas, and applicable only to electric generation.

Yet much broader applications are likely to be in direct uses. One survey of 8 western states found that, of cities with populations above 10,000, 94 were within five miles of a known geothermal site. Another study of 12 midwestern and southern states found 211 counties with geothermal potential. Nationally, the U.S. Geological Survey concluded in a 1978 assessment of geothermal resources that they "...represent a significant resource of great importance to the energy economy of the United States."

The purpose of this report is to show mayors and city officials how this potential can literally be tapped. One of the basic assumptions of the report is that cities should look at the full range of district heating applications from subsurface waters. Thus, the scope of discussion extends from cases using ground water at about 55° F, all the way up to cases involving geothermal water that, at 218° F, is virtually steam. While important differences exist in these cases, they are all united in similar issues of locating and drilling for the resource, distributing it through a piping network, connecting it to end uses (primarily hot water and space heating), and managing resource use.

For the past three years the U.S. Conference of Mayors has conducted a program of research and technical assistance aimed at showing cities how municipal waste can be turned into an energy resource through district heating networks. As that program has emphasized throughout, municipal waste is only one of several heat sources that can be used for district heating. With this report USCM highlights two others--ground water and geothermal

resources. We hope these materials are successful in illustrating one more way in which cities can meet the challenge of providing stable supplies of energy for local businesses and households.

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PART I

LOW-TEMPERATURE AND GROUNDWATER APPLICATIONS

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DEVELOPMENT OF LOW-TEMPERATURE GEOTHERMAL ENERGY AND GROUNDWATER RESOURCES IN THE UNITED STATES

I. INTRODUCTION

The city of St. Paul is presently developing an "Energy Park" -- a major urban revitalization project designed to boost the local economy by attracting new energy related and other light industry. One of the project's most attractive features is its unique heating and cooling system. Five 400-ton York heat pumps located in a central energy plant will provide all heat, air conditioning and hot water for the nearly 900,000 square feet of residential, commercial, and light industrial space included in Phase I of the project. The heat pump system -- which will use groundwater at a year-round temperature of 53°F supplied by a 550-foot well -- was identified as the least-cost heating and cooling system among nine alternatives studied for the 245-acre park.

In Bellows Falls, Vermont, the city is working with a private developer to rehabilitate and expand an historic downtown hotel for elderly housing with HUD Section 8 assistance. All heat and hot water for the 42,000 square foot housing project will be supplied by two Westinghouse Templier heat pumps, which have already been installed. The heat pumps will use about 180 gallons of water per day at a year-round temperature of 53-54°F to supply heat and hot water to the building.

Most people think of geothermal energy as a western resource; however, these examples show it can be tapped by cities nationwide. The high-temperature resources west of the Rocky Mountains typified by geysers and hot springs are often located in remote wilderness (e.g., Yellowstone and The Geysers). Western communities far from known high-temperature resources, as well as all cities east of the Rocky Mountains, may find lower temperature groundwater to be a promising resource. This paper will refer to groundwater resources east of the Rocky Mountains as "eastern" resources in order to focus attention on an area where geothermal energy use has not been widely exploited; however, the applications discussed here are possible throughout the United States. This study will describe the potential for using low-temperature geothermal resources in district heating systems.

This introduction includes discussion of the location, temperatures and accessibility of low temperature geothermal resources; recent public and private development efforts; and some of the major barriers preventing greater use of the resource. Section II will discuss the technology for tapping the

heat energy of groundwater. Next, in Section III, economic, environmental and legal barriers preventing wider use of this developing technology will be identified. Finally, case studies of St. Paul and Bellows Falls will be presented in Section IV to illustrate how city governments can overcome these barriers and put geothermal energy to work.

1. National Geothermal Resources

Below 50-100 feet, all groundwater is heated more by the earth than by the sun. The earth above and around the groundwater acts as an insulator, keeping it at an almost constant temperature throughout the year. Because the heat source providing this year-round temperature is the radioactive decay of the earth's core, groundwater at depths of 50 feet or more may properly be termed a "geothermal" resource regardless of its temperature. However, most people use the term "geothermal" only to refer to water with temperatures much higher than ambient air temperatures (typically 100° - 400°F). For the sake of clarity, we will follow this definition, referring to "groundwater" when temperatures are at or below about 80°F and to "geothermal" when water temperatures are higher than about 80°F.

As shown in Figure 1, the constant year-round temperature of groundwater at 50-150 feet below the earth's surface is much warmer than average winter air temperatures and cooler than summer air temperatures throughout the continental U.S. Groundwater heat pumps now on the market can tap this heat source to provide heating, cooling, and hot water. Because the groundwater temperature is almost constant, these water-source heat pumps operate much more efficiently than air-source heat pumps which require extra electricity (or may not operate at all) in extremely hot or cold weather.

In addition to St. Paul and Bellows Falls, other cities around the United States are considering the use of groundwater heat pumps. Richmond, Indiana, considered their use for heating and cooling of commercial buildings as part of a downtown rehabilitation project. As part of the HUD/DOE District Heating Assessment Program, the city of Campbellsville, Kentucky, is examining the feasibility of a residential district heating system using groundwater heat pumps for industrial and residential use. In Easton, Maryland, the municipal utility has been monitoring a slightly different technology -- a heat pump connected to the municipal water supply -- since 1976, and is considering alternative approaches to developing a citywide system. Large groundwater heat pumps of the size needed for district heating are also in increasing use in private developments. Many large commercial buildings in Portland, Oregon, use them, and two large hotels in Louisville, Kentucky, have recently installed groundwater heat pumps.

As discussed above, the distinction between "groundwater" and "geothermal" energy resources in the U.S. is difficult to draw.

Figure 1: Ground Water Temperatures in Wells Ranging from 50 Feet to 150 Feet in Depth

Source: Brookhaven National Laboratory Department of Energy and Environment, Economic Impact of Using Nonmetallic Materials in Low to Intermediate Temperature Geothermal Well Construction, V. II, 1979.

Until recently, most interest in geothermal energy was focused on high-temperature resources above 300°F which can be used for electric power generation. Geothermal resources in the 200-300°F range are generally termed "moderate-temperature," and anything lower than about 200°F is viewed as a "low-temperature" resource. All known geothermal resources east of the Rockies fall into the last category. However, for district heating systems supplying residential and commercial buildings and low-temperature industrial processes, temperatures of 100-200°F are more than adequate. Additionally, groundwater heat pumps may be used to boost water temperatures, either at a central heating plant or at the point of end use, if required.

In general, the availability of geothermal resources has been associated with areas of recent volcanic or earthquake (tectonic) activity. The eastern U.S. is more geologically stable than the west and has experienced little activity in the most recent geologic time period (the Cenozoic period). As a result, eastern geothermal resources are generally associated with earlier periods of tectonic activity, and are more localized and of lower temperatures than western reserves. Figure 2 shows eastern areas with geothermal potential.

Geologists have classified eastern geothermal reserves into four different types. First, folding and faulting throughout the Appalachians and the geologically similar Ouachita Mountains sometimes allows warmer waters from deep within the earth to reach the surface, as at Hot Springs, Arkansas; Lebanon Springs, New York; and Berkeley Springs, West Virginia. These areas have easy access to geothermal resources. A second type of geothermal resource is found in Atlantic coastal plain, where radioactive granite plutons (which give off heat) are overlain by thick, low-conductivity sediments. The thick sediments prevent the heat given off by the granites from being dispersed, trapping it at accessible depths. Test wells at Crisfield and Cambridge, Maryland, have confirmed geothermal resources of this type, with water temperatures of 133°F at 4,000 feet and 107° at 2,274 feet respectively.

The third category of eastern geothermal energy is found in deep sedimentary basins (areas in Figure 2 shown as having basement depths greater than 4,000 feet below the surface). These thick sediments in Illinois, Michigan and the Appalachian and Ouachita basins can produce high water flow rates, and their great depth indicates elevated temperatures. A final resource type is described simply as "abnormally warm aquifers," associated with folding and faulting and found in both the Gulf coastal regions and South Dakota.

In many cases, it is difficult to determine the source of warm geothermal waters in the eastern U.S. For example, a recently-drilled well at Auburn, in west-central New York, is producing geothermal water at temperatures of about 122°F at 5,300 feet. The exact cause of the elevated temperatures is not

Figure 2: Potential Geothermal Resource Areas in the Eastern United States Showing Reservoir Confirmation Areas

Basement depth greater than 4000 ft below surface

Approximate areas of investigation

Limit of coastal plains sediments.

* Contours adapted by APL from basement map of North America

** From Gruy Federal report

Source: Johns Hopkins University, Geothermal Energy Development in the Eastern United States: Final Report, Oct. 1981.

known, although warm springs are found further east at Levitton Springs and Saratoga Springs. The higher-than-normal water temperatures may be due to Appalachian folding and faulting or to the presence of thick, insulating sediments trapping heat from deeper sedimentary layers.

Whatever the geologic origin of their geothermal reserves, city officials must consider their markets as well as the accessibility and temperature of the reserves in examining the overall feasibility of developing geothermal district heating. Scientists at Johns Hopkins University have developed a methodology to evaluate the feasibility of geothermal energy development in many of the areas with resource potential outlined in Figure 2 (due to lack of data, Minnesota, Wisconsin, Upper Michigan, most of Missouri, and New England were excluded from the evaluation). The methodology considers geothermal resource characteristics, cost and market factors. Depending on the desired application of the district heating system, greater weight can be given to residential, commercial or industrial heat demand in the overall feasibility calculation. The results of their analysis, using alternative weights for each of these factors, are shown in Table 1. Of 260 eastern counties with geothermal potential, each of the 39 counties listed in Table 1 ranked in the top 25 in district heating development potential for at least one primary application (overall, residential, commercial or industrial).

Table 1: Eastern Counties with High Potential for
Geothermal Development*

<u>State/County</u>	<u>Type of Potential</u>
Illinois	
Champaign	Overall
Sangamon	Overall
Vermillion	Overall
Indiana	
Knox	Industrial
Tippecanoe	Industrial
Michigan	
Tuscola	Residential
Mississippi	
Harrison	Industrial
Hinds	Industrial
Jackson	Industrial
Madison	Industrial
Montgomery	Industrial
Washington	Industrial
New York	
Allegany	Commercial
Cattaraugus	Commercial
Cayuga	Commercial
Chemung	Residential/Commercial
Steuben	Residential/Commercial
Tioga	Commercial
Wyoming	Commercial
Ohio	
Belmont	Residential

<continued on next page>

Pennsylvania

Blair	Overall
Butler	Overall
Cambria	Overall
Carbon	Residential/Commercial
Centre	Overall
Clearfield	Commercial
Columbia	Industrial
Crawford	Residential/Commercial
Jefferson	Residential
Lackawana	Overall
Lawrence	Overall
Luzerne	Overall
Lycoming	Overall
McKean	Residential
Northampton	Residential/Commercial
Northumberland	Industrial
Schuykill	Overall
Washington	Overall
Westmoreland	Overall

*Counties in the top 25 among 260 considered for each type of development (overall, residential, commercial, industrial). Counties in the upper Midwest and New England were excluded due to lack of data.

[Source: Johns Hopkins University, Evaluation of Potential Geothermal Resource Areas, July 1980.]

A number of eastern cities are beginning to consider developing nearby geothermal reserves. The City of Auburn was an active participant in the drilling of the well discussed above. Mayor Paul Lattimore worked with the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Agency (ERDA) (which jointly financed the well drilling), to initiate the project and find a site for the well on the property of a local middle school adjacent to Cayuga County Community College. Geologists are presently testing the mineral content, flow rate, temperature and other characteristics of the resource. Preliminary assessments indicate a very good flow rate and temperature. If the geologic tests are positive, the City of Auburn plans to sponsor an economic and engineering feasibility study of a district heating system for the middle school and community college.

Under the DOE/HUD district heating assessment program, the City of Berlin, Maryland, is studying the feasibility of a geothermal heating district that would serve the local poultry industry as well as residences and downtown businesses. The city is located near DOE's test wells at Cambridge and Crisfield, Maryland, and consultants expect to find 140-150° F water at about 6,000 feet. In addition, New York ERDA is conducting

resource assessments in the Albany area. Two 500 foot test wells have been drilled, and a 2,000 foot well will be drilled in the near future. Depending on the results of the 2,000 foot well, city and state agencies may begin to assess the feasibility of district heating for state office buildings and downtown businesses in the city.

2. Barriers to Geothermal Development

Despite this increasing interest, there are very few actual applications of geothermal or groundwater heat pump district heating systems in the eastern states. The St. Paul energy park will be the first example of a community-scale heat pump system in the east, although private homeowners in some cities such as Virginia Beach, Virginia, have installed many residential heat pumps. Most larger-scale groundwater heat pump systems, such as that installed at Battelle Memorial Institute in Columbus, Ohio, in 1958, have been experimental. The Battelle system, which provides all heating and cooling for a 317,000 sq. ft. section of the Battelle complex, was developed largely out of the interest of a few resident scientists and engineers. Commercial-sized heat pumps for large buildings are being used increasingly, especially in Portland, Oregon; Virginia Beach, Virginia; and other areas with high water tables. However, these systems are generally for a single large building rather than a community-scale district heating system.

Geothermal district heating is even less developed than central groundwater heat pump systems in the eastern states. One of the few demonstrations of geothermal space heating is found at the Hot Springs, Arkansas, National Park headquarters building. If this system is extended to serve additional buildings as planned, it would be the first geothermal heating district in the east. A private developer is expected to drill an 8,000 foot well near Lewes, Delaware to supply hot mineral water to the Barcroft Corporation, an antacid manufacturer. If an adequate flow of 150° F water is found, other users may be added to the geothermal supply. This, too, might be the first geothermal district heating system in the eastern states. Like the efforts in Auburn, New York, and Berlin, Maryland, the Lewes system is just getting underway. The status of eastern geothermal district heating stands in sharp contrast to the completed systems in Susanville, California; Boise, Idaho; Klamath Falls, Oregon and other western cities.

Several barriers contribute to the slower development of eastern water resources. First, both temperatures and flow rates must be adequate for development of geothermal or groundwater heat pump district heating. A second, environmental constraint to wider use of eastern groundwater as an energy source is the problem of disposing of fluids withdrawn for heat extraction. Potential problems include thermal pollution, subsidence and chemical pollution from geothermal fluids.

Perhaps the major constraint to wider use of eastern geothermal reserves is simple economics. Exploration and drilling costs for eastern resources, which are generally deeper than western high-temperature resources, are very high. These costs, along with pumping costs, make geothermal district heating only slightly economically competitive with conventional fuels at today's prices. The lack of demonstration projects makes it less likely that private developers will invest in a marginally economic technology.

The final important barriers to eastern geothermal development are legal and institutional. State laws in the east (with a few exceptions discussed below) do not provide an adequate legal framework for ownership, allocation, and disposal of water resources for energy purposes. Western states have begun to adopt water-rights laws to accommodate use of their high-temperature geothermal reserves as development activity in the far west increases. Institutionally, there is an overall lack of information about low-temperature groundwater resources, and the technology required for tapping them.

The purpose of this paper is to attempt to overcome the lack of knowledge about low-temperature geothermal energy. While further explanation and experimentation can expand the horizons for future use, the technology for putting low-temperature geothermal resources to work is well-known and widely available. Many areas of high potential are described in preceding pages, indicating that the aquifers are much more widespread than once thought. Low-temperature geothermal reserves offer an alternate energy source readily available today.

II. GEOTHERMAL AND HEAT PUMP TECHNOLOGY

This section will discuss the technology of both low-temperature geothermal and groundwater district heating, looking at the hardware needed to drill, pump, distribute, and extract the heat from underground water reserves. While the two types of systems will be discussed separately, city officials should consider them together for economic reasons. It may be more cost effective to drill shallow geothermal wells and boost the temperatures with central or distributed water heat pumps than to drill deeper for higher-temperature reserves. Or, a complete analysis may indicate that groundwater heat pumps are more economic than drilling to reach even shallow geothermal resources.

1. Geothermal Technology

The few geothermal wells completed in the east to date have used drilling technology similar to that used for oil and gas. For example, Halliburton and Christiansen oil well crews participated in a DOE-funded program to drill 50 heat flow wells of 1,000-2,000 feet in the Atlantic coastal plain in 1978. These test wells and the 4,000 foot well at Crisfield were drilled by

oil rigs and completed using oil well completion techniques. The basement rock was hydraulically fractured and the bottom of the well plugged with cement. Then the crews blasted a hole every three inches in the cement well casing in zones of interest to allow waters from selected geologic strata to flow in.

An alternative drilling and well completion technique, commonly used for wells of less than 500 feet in depth, is that used for water wells. Because there are water well contractors throughout the east, this technology may be more readily available. After a water well is completed, it is lined with steel or plastic casing. The bottom portion of the well, rather than being plugged and then perforated, is left open. Well screens are placed in the water-bearing aquifer as an extension of the well casing. These screens allow free entry of water without allowing sediments to enter the well. This completion technique, which is less costly and more appropriate for geothermal drilling than oil and gas well completion techniques, can be adopted for eastern geothermal wells. For example, developers of the geothermal well at Lewes, Delaware, plan well casing to about 2,700 feet. The bottom 5,000 feet of the planned well will be filled with up to 2,000 feet of screen sections. If necessary, the bottom portion of the hole will be opened to 21 inches using an underreamer and packed with gravel before installing the screens. Drilling of the Lewes well may involve both water well and oil well contractors. A water well contractor may be engaged to prepare the site and drill the first 150 feet if it is less expensive than using an oil rig throughout. In time, water well drilling techniques may be used even for deep eastern geothermal wells. In the west today, water wells are often drilled to 1,000-2,000 feet in depth. Adoption of water well technology to eastern geothermal drilling would bring costs down and speed geothermal development.

A. Pumping Systems

Because eastern geothermal resources are typically found at depths of 3,000 feet or more, submersible pumps will generally be required to bring the water to the surface. Vertical turbine pumps, another alternative, are generally limited to shallower lifts of 800 feet or less. The metal required for the submersible pump depends on the quality of the geothermal water. Hydrogen sulfide, a highly corrosive chemical found in high-temperature western geothermal waters, is not common in eastern waters. However, the high brine content of eastern waters at Crisfield, Maryland, and Auburn, New York, indicates a need for corrosion-resistant metals (usually nickel alloys) in the pumps. Even high-quality submersible pumps, however, will require periodic maintenance. Pumps in common use today which are quite small and are stacked on top of each other, must be removed at least every two years and cleaned of corrosion. Better pumps are needed if geothermal resources are to be used widely in the east.

Variable speed pumps, which can be adjusted to changing heat demands, are the most economical choice for district heating systems. However, the speed of submersible pumps can only be varied by a costly electronic system. In some cases, it may be preferable to construct two separate production wells with two pumping systems to allow for staging of pumping according to heat demand.

Because eastern geothermal waters have relatively low temperatures, a large water volume is needed to meet residential, commercial and industrial demands. Thus, eastern geothermal heating systems will tend to bring as much fluid to the surface as possible through effective use of pumps and to build larger distribution systems to serve more customers. The larger applications required for cost-effective systems in the east should work in favor of community-scale systems. It is very unlikely that a single homeowner or even a commercial building owner would drill a mile or more to tap geothermal resources. If individual industries--such as the Barcroft Corporation near Lewes, Delaware--drill for geothermal fluids, they may find it economically attractive to sell excess fluids to other industries or residential users, thus creating a district heating system.

B. Distribution and Heat Exchange

Obtaining insulated pipe of 3 to 12 inches in diameter for distribution of the geothermal resources should not be difficult. It is readily available in most parts of the country, and competition between manufacturers, both foreign and domestic, has brought prices down in the west. Uninsulated pipe is normally used for the return lines. Depending on the quality of the geothermal resources, a central heat exchanger may be needed for the district heating system. If the geothermal water is relatively free of corrosive minerals, as in Susanville, California, it can be distributed directly to the buildings for heat extraction on-site. However, where the geothermal fluids are more corrosive and potentially damaging to pumps and building heat exchangers, a centralized heat exchanger is required. For example, Klamath Falls uses a stainless steel plate-type heat exchanger to transfer the geothermal heat to pure water which is then circulated to buildings in the heating district. The high salinity of geothermal waters in the Atlantic Coastal plain (the Crisfield well produces fluids twice as saline as seawater) indicate that centralized heat exchangers will probably be required for geothermal district heating systems in this part of the east.

Building retrofit requirements for space heating depend on a building's existing heating system and the temperature and flow rate of the water in the district heating loop. As shown in Table 2, some on-site heat extraction systems can make use of rather low-temperature waters if there is a high flow rate. In some cases, buildings may require heat pumps, either at one central location or in individual rooms, to bring district heating

distribution system temperatures up to space heating requirements. Because none of the geothermal resources discovered to date in the eastern states is warmer than 133°F, it seems unlikely that natural air flow room convectors or room radiators would be used for eastern district heating systems.

Table 2
Methods and Flow Requirements for On-site Heat Exchange

<u>Heating Method</u>	<u>Water Temperature (°F)</u>		<u>Flow Rate (gpm)</u>
	<u>In</u>	<u>Out</u>	
Bare tubes in masonry floor, ceiling	85	81	14
Finned tubes in forced air ducts	105	75	1.87
Forced air flow room convectors	120	85	1.60
Natural air flow room convectors	140	110	1.87
Room radiators	160	140	2.80

[Source: Gene P. Ryan (Geo-Heat Center, Oregon Institute of Technology), "Direct Utilization Technology: State of the Art," paper presented at Geothermal Energy: Opportunities for California Business, September 28-29, 1981, San Diego, CA.]

Heat exchangers and hot water coils are supposedly available "off-the-shelf." However, the City of Susanville encountered delivery delays of 6 to 10 weeks in ordering retrofit packages. Valves, metering devices, and special fittings had to be special-ordered, adding delays of 8 to 12 weeks. Like the central heat exchange system, the on-site retrofits may require special metals if the geothermal fluids are especially corrosive.

C. Peak Load Back-up

In order to make the best use of their capital investment, city officials designing geothermal district heating systems primarily for residential users may decide to include a fossil-fired peaking unit as part of the system. In contrast to industries, which have constant year-round heating requirements, residences only require space heating for part of the year. Thus it is difficult to recapture the high capital costs of the geothermal district heating system through sales to residential customers. However, if a large number of residences can be included in the heating loop, the system's load factor will be

improved. By designing the geothermal portion of the heating systems for only moderately cold winters (rather than extremes) and using a fossil-fired peaking unit when required, a much larger number of residences can be served. For example, a geothermal district heating system designed to maintain indoor temperatures in Boise, Idaho, down to an extreme outdoor temperature of -10°F would only be in use 22 percent of the time. If the system were designed instead to provide comfortable indoor temperatures when outdoor temperatures were no lower than 28°F (which would supply 94 percent of actual total needs in Boise's climate), it could serve twice as many buildings, bringing the overall utilization factor to 45 percent. It is much more economical to supply six or even eight percent of actual heating loads through a fossil-fired boiler than to let half of the geothermal system sit idle 94 percent of the time.

2. Heat Pump Technology

Groundwater heat pumps may be used either to boost the temperature of geothermal fluids or as the prime source of heat from groundwater in district heating systems. If they are used to boost the temperature of geothermal water, no additional drilling will be required; but if they are used alone, a water well must be drilled. Plastic or steel casing is generally installed in the well to keep rock from caving in and to keep undesired water out. The well is usually completed using well screens as discussed above. Depending on local well construction regulations, the area around the casing may be filled in with cement to prevent seepage from the surface to the screened area. More than 700,000 water wells are drilled each year, so this technology is well developed.

Pumping requirements and equipment for groundwater heat pump wells, like those for geothermal heating systems, vary with well depth. In areas like Virginia Beach, Virginia, where the water is near the surface, surface pumps can be used; but submersible pumps are necessary in most parts of the country.

Several types of water-source heat pumps are now on the market. Closed-loop systems have the least impact on the environment, but, depending on their design, may be the least efficient. The most common type of closed loop system, often found in large commercial buildings, uses electricity or fossil fuels to maintain a temperature of $60-90^{\circ}\text{F}$ in a circulating water loop. Heat pumps in different zones of the building extract heat or cooling as needed from the main loop; a typical building could have as many as 40 heat pumps along the water loop. While this type of closed loop system offers significant energy savings for commercial buildings which may require both cooling of convention rooms and core areas and heating of perimeter rooms on a winter day, it does not take advantage of the natural heating and cooling offered by the earth's insulation. An alternative approach--the earth coupled system--uses the earth as a heat

source by burying the closed loop in plastic tubing underground. This system is still under development. Finally, individual buildings (but not heating districts) can make use of a down hole heat exchanger, consisting of vertical closed pipes placed down the well, with the heat exchanger located in the well.

When people discuss water-source heat pumps, they are most often referring to open loop systems which use groundwater as the heat source. While use of groundwater heat pumps in both residential and commercial applications is growing, the majority of sales are to single-family homeowners. Through 1978, annual sales averaged 5,000-10,000 units; but in 1979, more than 75,000 groundwater heat pumps were sold and 1981 sales are estimated to be 300,000 units. About 30 manufacturers now produce these heat pumps, and residential-sized units are available off-the-shelf (although district heating-sized units will probably have to be specially ordered).

According to the American Water Well Association, 75 percent of the U.S. is underlain by aquifers less than 250 feet deep which could supply the 10 gallon-per-minute flow rate required for a single-family heat pump. Newer heat pumps can extract heat from low-temperature groundwater in even the most northern states, although a greater flow rate is required if water temperatures are lower.

A. Operation

The groundwater source heat pump operates like a giant reversible refrigerator. As shown in Figure 3, its components are those of all heat pumps--a condenser, compressor, and an evaporator. Figure 4a shows the operation of a residential heat pump in more detail. In the heating mode, a liquid refrigerant (such as freon) circulates through the water-to-refrigerant heat exchanger, absorbing heat energy from the groundwater. As it absorbs heat, the refrigerant gasifies. Then it travels to the compressor which makes it still denser and hotter. From the compressor, the gaseous refrigerant travels to the air-to-refrigerant heat exchanger, where air from the home's heating system flows across the coils absorbing the heat and circulating it throughout the house. Because air from the blowers is only heated to about 105° F, as opposed to the 140° F temperature provided by the typical home furnace, larger air ducts and a slower fan are needed.

In most parts of the country, groundwater heat pumps are reversible, providing summer cooling as well as winter heating. However, in the most northern states, "heat-only" groundwater heat pump systems, which extract heat energy from groundwater in the winter and circulate the cool groundwater directly to the building's heat exchange system in summer, are being used. In its cooling mode, the reversible heat pump operates as shown in Figure 4b. In the air-to-refrigerant heat exchanger, liquid refrigerant absorbs heat from the building's air and evaporates.

It then travels to the compressor where its temperature is raised further. In the water-to-refrigerant heat exchanger, the refrigerant gives off its heat to the groundwater, which is then reinjected in the ground or disposed of in storm sewers, drainage ditches or ponds. Finally, the cooled, condensed refrigerant returns to the air-to-refrigerant heat exchanger to extract more heat from the air.

B. Large Scale Systems

Larger-scale water-to-water heat pumps of the size needed for commercial buildings or district heating systems are less widely used than residential systems. Many commercial buildings in Portland, Oregon, use these systems, but most manufacturers of commercial-sized heat pumps produce air-source rather than groundwater-source systems. The technology for these larger groundwater heat pumps is adopted from industrial water-to-water heat exchangers which are used to capture industrial waste heat for domestic hot water or other low-temperature hot water needs. They are highly efficient.

A number of different configurations are possible in designing a large-scale groundwater heat pump system. In the Bellows Falls hotel restoration, two central Westinghouse Templier 800,000 BTU/hr. heat pumps boost the temperature of the groundwater from 55° to 160° F in the winter months. This hot water is circulated to the apartments, where fan coils controlled by the tenants are used to extract and circulate the heat.

District heating systems offer a number of advantages to users of groundwater heat pumps. They allow end-users to share the costs of well drilling, pumping, water distribution and disposal. They are the most appropriate type of system in dense urban areas, since they avoid conflicts over withdrawals of limited groundwater supplies. If properly designed, they can optimize loads (and thus maximize return on equipment investment) by including both residential and commercial customers. They allow the use of innovative systems such as thermal storage and use of industrial waste heat. And finally, they require a smaller volume of groundwater and total size of pumps and pipes because the water is heated centrally.

Figure 3
Elements of a Heat Pump System

UNIT HEATING MODE

Schematic diagram courtesy of the National Water Well Assoc.

Figure 4: Operation of a Groundwater Heat Pump

4a: Unit Heating Mode

UNIT COOLING MODE

4b: Unit Cooling Mode

Source: A Groundwater Heat Pump Anthology, National Water Well Assoc., No date.

The technology of groundwater district heating systems is similar to that used for commercial buildings, except that the hot water loop extends beyond a single building. Current heat pumps can boost groundwater temperatures to as much as 230°F, allowing commercial and low-temperature industries such as food processing to be included in the heating district. The St. Paul Energy Park provides one example of this type of system. Five York 400-ton heat pumps have been ordered. Four centrally located heat pumps (the fifth is a back-up) will raise 53°F groundwater to 90-116°F in the winter and cool it to 44-46°F in the summer. The heated or cooled groundwater will be circulated via a supply line to about five buildings initially. Buildings lower than four stories will use fan coil systems to extract heat directly from the groundwater loop; taller buildings, such as an apartment complex, will use heat exchangers to extract the heat for distribution via the building's forced air-handling system. The temperature of the water in the loop may be changed up to 20 times per year depending on the ambient air temperature. However, at the change of seasons (for example on a cool spring day when the temperature of the water loop has been lowered to 45°F) the building may need some additional on-site resistance heating. The amount of on-site heating will be strictly limited. In addition, the buildings will use economizers for extra summer cooling.

In addition to their use as the primary heat source for district heating systems, heat pumps can also be used for auxiliary heating in geothermal district heating systems. As discussed above, it may be most economical to drill relatively shallow geothermal wells bringing lower temperature geothermal resources to the surface and to boost the geothermal temperatures with groundwater heat pumps. Eastern geothermal wells less than 3,000 feet deep can produce groundwater of 60-120°F. Current commercial-scale water-to-water heat pumps can be used to bring these temperatures up to between 140 and 210°F prior to circulation to residential, commercial, and industrial users.

C. Efficiency

Because energy enters the groundwater heat pump from two sources -- groundwater and electricity -- the heat pump delivers more energy than it consumes in electricity. The ratio of heat supplied to electric energy consumed under certain design conditions is called the "Coefficient of Performance" (COP). Because the COP is based on theoretical design temperatures, it is not the most accurate measure of energy efficiency. The "Seasonal Performance Factor" (SPF), which adjusts the COP over a full heating season in a particular climate, is more accurate. However, neither measure includes the energy needed to pump the groundwater from the well, which can account for up to 16 percent of the total energy used by the system.

Overall, groundwater heat pumps are much more efficient than air-source heat pumps because of the constant temperature of the water source. Air-source COP's range from 1.5 to 2.5, while water-source heat pumps have COP's of 2.5 to 3.5 assuming a 60°F water source. Table 3 shows Seasonal Performance Factors for groundwater heat pumps in several cities around the U.S.

While residential groundwater heat pumps are more efficient than air-to-air heat pumps, commercial-sized groundwater heat pumps of the type used for district heating are even more efficient than the residential systems. Westinghouse claims its Templifier operates at COP's of 3-6, depending on the water source temperature and desired output temperature. With a geothermal water source these heat pumps are even more efficient. The Westinghouse Templifier is claimed to be capable of using 95°F geothermal water to produce 150°F industrial process water. The York Company heat pumps sold to the St. Paul Energy Park are said to have an average COP of 5.

Table 3
Comparison of Seasonal Performance Factors

Location	Degree Days	Water Temp. (F)	GWHP*	Air-Air Heat Pump	Oil Furnace	Gas Furnace	Electric Baseboa
Houston	1,290	70	3.12	2.14	.61	.59	1
Birmingham	2,844	65	3.06	1.93	.61	.59	1
Atlanta	2,821	65	3.06	1.97	.61	.59	1
Tulsa	3,504	62	3.02	1.68	.63	.60	1
Philadelphia	4,508	55	2.94	1.87	.62	.61	1
Seattle	4,407	52	2.90	1.84	.62	.61	1
Columbus	5,467	55	2.94	1.69	.63	.62	1
Cleveland	6,097	55	2.94	1.68	.64	.63	1
Concord	7,377	45	2.82	1.41	.64	.62	1

*Groundwater heat pump

Gerstman, 1980

[Source: Guidebook to Water Source Heat Pumps, National Conference of State Legislatures, October 1981.]

One of the few commercial-sized groundwater heat pumps that has been monitored is at Battelle Memorial Institute in Columbus, Ohio. Staff scientists engineered the system themselves by installing valves on Trane air conditioning chillers. The Battelle system uses 54°F water from five 50 foot wells to heat and cool a 317,000 square foot area. Supplementary heating and cooling are used in the spring and fall, while the system operates at full capacity in the summer and winter. Scientists there report that the system operates at an average COP of 4.9 and the winter Seasonal Performance Factor for one building is said to be 5.4. More research is needed to verify the efficiency of this and other commercial systems.

D. Water Disposal

A number of alternative water disposal systems may be used for a groundwater district heating system, depending on local environmental characteristics and state laws and regulations. If a nearby river directly recharges the aquifer from which the water is withdrawn, the water can be safely returned to the river without fear of groundwater depletion or subsidence. For example, Battelle Memorial Institute discharges its water to the Olentangy River which supplies the aquifer, and the St. Paul Energy Park will discharge its return water to the river through the city's storm sewer system. Other disposal methods include surface discharge to ponds and irrigation ditches and construction of a second "recharge" well.

E. Aquifer Seasonal Storage

Although only a few aquifer seasonal storage systems are in use today, they appear to hold great promise for increasing the energy efficiency of groundwater heat pumps. They are particularly suited to large-scale heat pumps of the type used for district heating.

The Equitable Life Insurance Building in Portland, Oregon, completed in 1947, was probably the first to use aquifer heat storage in the U.S. It uses three wells. Two wells, drilled in the same aquifer to 158 feet and 165 feet respectively, supply water to the heat pump during the heating phase and discharge the slightly heated water produced by the cooling phase. A third well, drilled to 508 feet, supplies cooling water to the heat pump in the summer months and discharges water cooled by the heat pump system in the heating cycle. Thus, the heated or cooled water returning from the heat pump system is stored to allow the system to operate more efficiently in the following season. Several other buildings in Portland use similar aquifer storage systems.

While the Portland experience indicates that underground aquifers are capable of storing slightly heated or cooled water

for up to six months, the first research to scientifically test aquifer storage is now underway. During the spring of 1982, researchers at the University of Minnesota's St. Paul campus began to heat groundwater by circulating it through a heat exchanger connected to the campus' central heating plant. After being heated to 100-150°F, the water will be injected into a deep bedrock aquifer (about 700 feet below the surface) which is well-confined and separated from other aquifers. This cycle will continue for eight days and then be reversed. Records will be kept on how well heat is maintained and drawdown of the aquifer. Further tests will inject water at higher temperatures (up to 300°F) over longer periods. If test results are positive, the University of Minnesota researchers hope to construct a 20-megawatt thermal energy storage demonstration facility.

The St. Paul Energy Park overlies the same confined aquifer being tested by the University, and park developers hope to use a similar thermal storage system in conjunction with their heat pump system. Depending on the university's test results and state regulations, the Energy Park may use aquifer storage ponds, tanks, or some type of semi-constructed heat storage.

III. BARRIERS TO DEVELOPMENT

1. Economic Barriers

The high costs of developing low-temperature geothermal and groundwater energy present a major barrier at present, but these economics may change as prices for conventional energy supplies increase.

Exploration and test drilling to provide the basis for geothermal and groundwater development are very expensive. In the east, where there has been less oil and gas drilling and mining than the west, less is known about underground water temperatures and permeability of various geologic formations. In the past few years, almost all of the western states have mapped their geothermal resources with DOE funding and used background data from oil and gas drilling. In the east, in contrast, only a few contractors have been funded to do the same mapping over a much larger area. As a result, only a few areas of the east, such as the Atlantic coastal plain and portions of New York State, have been explored. Even in these areas, only three deep wells have been drilled to confirm the temperature and flow rates of the geothermal fluids.

Groundwater development, too, requires extensive and costly hydrologic studies before it can go ahead. The city of Louisville has considered development of its underlying aquifer for downtown district heating for several years, but has not yet begun the system, in part due to concern about the effects of extensive pumping on the watertable.

The costs of drilling for geothermal resources in the east are very high now due to a lack of experience. The DOE test wells at Crisfield and Cambridge, Maryland, cost three times as much as oil and gas wells of the same depth in Appalachia. The high costs may be due in part to the oil well service companies' view of the Atlantic coastal plain as a "frontier operation." These costs must be brought down, and lower-cost water well drilling techniques must be adapted to geothermal drilling if development is to go ahead.

Groundwater drilling can be economically risky, too. Owners of a large (3,000 sq. ft.) new home outside Charlotte, North Carolina, drilled a 247-foot heat pump well and found 61°F water with a flow rate inadequate to meet their heating and cooling needs. A second well had to be drilled to 600 feet to provide an adequate flow rate of 60 gallons per minute. A well 600 feet deep can cost as much as \$3,000.

Like drilling costs, pumping and distribution costs are higher in the east than the west. To oversimplify somewhat, pumping costs are greater because well depths are greater (e.g., Susanville's geothermal reservoir is at 925 feet, while the Crisfield test well is 5,000 feet deep). And distribution costs are higher because lower-temperature eastern geothermal fluids average 170°F, while the Crisfield well produces 133°F water and the Bellows Falls hotel heat pump system uses water at about 54°F).

Overall, the economic attractiveness of low-temperature geothermal district heating is only marginal in comparison to conventional heat sources. A 1980 study by Johns Hopkins University (Geothermal Energy Development in the Eastern United States: Final Report, October 1981) found that the discounted average space heating cost for a district heating system in Salisbury, Maryland, would be \$13.69 per million BTU delivered. By July 1981, electricity prices in the Washington, D.C., area had reached \$19.04/MMBTU, making the geothermal district heating system an attractive alternative. However, District of Columbia oil prices of \$8.80/MMBTU and natural gas prices at \$4.60/MMBTU were still much lower. The Johns Hopkins report found that the variable load for space heating was the biggest constraint to overall system economics. If industrial users with constant year-round heat demand were included in the heating district, the discounted average cost dropped dramatically.

The overall economics of heat pumps varies with the depth to the aquifer and the type of system. For a single-family home, well construction can cost as little as \$500 in areas where the water table is high or as much as \$3,000 at greater depths. In 1978, the average cost of two wells (for production and reinjection) and a heat pump system for a single-family home was about \$3,600-\$5,700. These costs, at today's fuel prices, result in an overall system payback of 6-10 years. For most homeowners in the present period of high inflation and economic uncertainty, paybacks greater than

one or two years are not economically attractive. However, homeowners in Virginia Beach, where paybacks average 10 years, are installing an increasing number of heat pumps.

The economics of district heating with groundwater heat pumps, particularly where new construction is involved, are more favorable for two reasons. First, municipal or private investors in large-scale energy systems have a much longer time horizon when viewing the economics of their investment. While a homeowner may require a payback of three years or less, a city government, with access to tax-free financing and a long-term view of public costs and benefits, may find paybacks of up to 30 years acceptable. For example, the heat pump and aquifer thermal storage system planned for the St. Paul Energy Park is estimated to have a discounted life-cycle payback of 14 years. The second reason heat pump district heating systems are economically attractive is their lower cost relative to conventional heating and cooling systems. The Honeywell Technology Strategy Center compared nine alternative heating and cooling systems, ranging from conventional in-building heating to cogeneration to central district heating, for St. Paul's Energy Park. All of these alternatives had paybacks greater than 25 years, making the heat pump storage system the most attractive candidate.

Financial barriers also prevent the wider development of geothermal and groundwater energy. The marginal economics of geothermal energy makes private investors wary. One of the first examples of private investment in an eastern geothermal well is now underway. A private company, Delmarva Energy Resources Incorporated, has raised about \$170,000 or one-fifth of the cost of drilling a geothermal well for the Barcroft Corporation near Lewes, Delaware. Investors in the company, which is leasing the well site from the state for 10 years, expect payback in less than five years. If this demonstration is successful, more private capital may become available to cities wishing to develop geothermal energy.

The Lewes project illustrates another constraint to eastern geothermal and groundwater development: the tax code. At present, the Internal Revenue Service definition of geothermal energy requires the energy system to have a wellhead temperature of at least 122°F and to rely completely on geothermal energy in order to qualify for business and residential tax credits, drilling cost deductions, and depletion allowances. The Barcroft Corporation, which will purchase the geothermal fluids from the Lewes well, requires temperatures of only about 110° at the wellhead. Delmarva Energy Resources Corporation could reach these temperatures with a well of less than 4,000 feet. However, in order to insure that tax credits are obtained, the drilling plan calls for a well of 7,000 - 8,000 feet which will produce water at 130-140°F. Thus, developers may be required to incur additional drilling costs in order to obtain tax incentives. In addition, the IRS requirement that the heating system rely completely on geothermal energy excludes not only all heat pump systems, but other economically

attractive district heating options: geothermal district heating assisted by central heat pumps or fossil-fired boilers.

2. Environmental Barriers

A number of environmental barriers could slow geothermal and groundwater development in some eastern cities. The most obvious constraint is the availability and quality of water resources. As discussed above, little is known about the permeability and temperature of eastern geothermal reserves. Groundwater flows, too, must be adequate and of good quality if this technology is to be used. The National Water Well Association estimates that 15-20 percent of the groundwater in the U.S. has inadequate flows or is too corrosive for residential groundwater heat pumps.

Permeability and recharge of the aquifer geothermal resource must be considered prior to withdrawal of large amounts of fluid. Rapid drawdown of an aquifer, particularly if uncontrolled, could cause land subsidence or conflicts with other water users. The city of Virginia Beach, after careful study, decided that its underlying aquifer was inadequate to provide municipal water supplies. However, private homeowners in the city are tapping the aquifer for both heat pumps and domestic use. The city estimated that if one out of five homes installs a heat pump, withdrawals will total 2 million gallons per day; therefore an ordinance was enacted requiring reinjection wells as part of residential heat pump systems. In Portland, Oregon, the increasing number of heat pumps in large commercial buildings on the west side of the city has drawn down the aquifer. As a result, groundwater heat pumps are no longer being included in the design of new buildings.

Problems of water quality as well as quantity can result from disposal of geothermal and groundwater fluids. Geothermal fluids, with their high brine content, must be handled carefully. In the Lewes project, well developers plan to dispose of the geothermal fluids along with other effluents from the Barcroft chemical plant through discharge into the Delaware Bay. The addition of the geothermal fluids will increase the total dissolved solids of Barcroft's effluent now being discharged to the bay. Both geothermal and heat pump systems, particularly thermal storage systems, have the potential for causing thermal pollution. And heat pump systems near septic fields or other pollutants can draw up pollutants, and then spread them farther through reinjection wells. Problems of pollution spreading through groundwater heat pump reinjection wells are particularly serious in areas such as Virginia Beach, where domestic waterwells and heat pump wells are located in the same vicinity.

A final environmental problem that can result from disposal of groundwater is overloading of sewage treatment plants. In Louisville, Kentucky, groundwater was widely used for summer cooling of commercial and industrial buildings. However, disposal of large amounts of this water through the city's combined sewers

caused overloading of the local sewage treatment plant. To reduce this overload, the sewer district began to charge a high fee to commercial buildings using groundwater cooling. As a result, almost all of the buildings converted to electric air conditioning or other cooling sources.

3. Legal/Institutional Barriers

In general, city authority to use or regulate resources such as water or energy relies on state law. Unfortunately, in the area of geothermal and groundwater energy, state laws in the eastern U.S. are often unclear and contradictory. Many western states now have laws and regulations governing the use of geothermal energy, but, until 1978, none of the eastern states had this type of legislation. In 1978, Maryland passed a geothermal law, followed by Virginia in 1981. Delaware is expected to approve legislation in 1982, and other states are beginning to draft geothermal and groundwater legislation. However, the lack of experience with actual geothermal and groundwater heating systems in the east makes judicial interpretation of these laws uncertain.

In general, eastern water law follows the riparian doctrine that ownership of water resources rests with the owner of the adjacent land. There is little concept of severance of "mineral" or "geothermal" rights from land ownership, which would allow for leasing arrangements for geothermal developers. This lack of legal clarity can slow both public and private groundwater energy development. For example, the City of Bellows Falls has legal access to the underlying aquifer through its ownership of the well site, but it has no legal guarantee of exclusive control over the aquifer resource. Individual homeowners or businesses could, at least in theory, install their own heat pumps, causing conflicts with the city's planned district heating system.

In addition to a lack of clarity regarding ownership and access to underground water, states and municipalities in both the east and west often have contradictory laws regarding disposal of withdrawn fluids. Some states treat surface discharges of any fluids, including pure groundwater, as potential pollutants and require an National Pollutant Discharge Elimination System (NPDES) permit. Regulations regarding underground discharge via recharge wells are often even more stringent. For example, developers of the Lewes well decided that the costs of constructing a reinjection well and the time delays required for an underground disposal permit from the state were too great to pursue this option, and chose surface disposal to the Delaware Bay instead. Several states, such as Maine, Missouri, and Minnesota, do not allow any type of underground disposal at present. A special variance from the State of Minnesota was required even for the University of Minnesota's very small test aquifer storage facility. Under a special program, the Minnesota State Health Department is now granting special reinjection permits to 200 small and 10 larger groundwater heat pumps. This program, with its monitoring requirements, indicates the state's generally cautious

attitude toward recharge wells.

Prohibition or stringent regulation of recharge wells can have adverse effects on local water tables. As the result of experience with large withdrawals for groundwater heat pumps, some governments such as the State of Oregon and City of Virginia Beach now require use of recharge wells. These regulations generally require that that groundwater be returned to the same aquifer from which it was withdrawn.

4. City Role in Overcoming Barriers

While many obstacles remain before large-scale development of eastern water resources can occur, these same barriers can act as an incentive for thoughtful city officials. The uncertain economics of geothermal or heat pump district heating from the perspective of the private homeowner provides city governments with a unique opportunity to develop these resources for long-term public benefit. Economies of scale and increased efficiencies in centralized heat pump or geothermal systems make them much more economically attractive than individual systems. In the long term, energy prices will rise, hurting city residents, businesses, and industries. Cities can act now to provide a lower-cost alternative to their citizens and act as models to the private sector.

Secondly, problems of aquifer and geothermal fluid management suggest that these resources are best managed by city governments in community-scale systems. Careful planning and management is needed to withdraw and use these fluids and dispose of them without environmental damage or resource deletion. Local governments with responsibility for water supply and water quality control are in the best position to do this.

IV. CASE STUDIES: HOW BARRIERS HAVE BEEN OVERCOME

1. Bellows Falls

A. Background

Bellows Falls is a village of 3,300 located within the Town of Rockingham, Vermont (population 5,500). A former center for the paper industry, it is presently economically depressed, with very few jobs for its semi-skilled workers. Unemployment is estimated at 7.5 to 8 percent, and the town government is presently considering a variety of strategies to attract tourists and new light industry.

In 1977, as part of an investigation of springs and wells throughout New England, the Dunn Geoscience Corporation of Albany, New York, discovered groundwater in an abandoned municipal well with an unusually high temperature of 59°F. The company contacted Rockingham's town manager to discuss the possibilities for using this groundwater as a heat source. The following year, the town

contracted with Dunn to undertake a complete hydrologic investigation, including monitoring of nine test wells around the city.

In its recently completed study, Dunn confirmed the unusual warmth of the aquifer. The average temperature was found to be 53-54°F year-round, or 5° above normal groundwater temperatures. However, the cause of this unusual warmth has not been identified. One possibility is that a subterranean warm spring is bringing heat from radioactive Tumica granites in the bedrock up to the aquifer underlying the city. A second possibility is that the aquifer acts as a heat sink for water warmed by the sun. Connecticut River water warmed by the sun at a dam at the edge of town may be migrating through the aquifer. The time lag between peak temperatures of surface water and peak temperatures monitored in the aquifer indicate that surface water reaches the aquifer after 2-3 months. A final possibility for the unusually elevated groundwater temperatures is the location of the aquifer under downtown Bellows Falls. The large number of buildings on the surface there may protect the ground from freezing, keeping water temperatures higher than normal.

B. Development Activities

As a first step in development of the aquifer, Bellows Falls village and the Town of Rockingham decided to incorporate heat pumps in the restoration of the Rockingham Canal House, a Victorian building in downtown Bellows Falls that had been abandoned for 20 years. The city has worked closely with the private developer, and the project is near completion. About 19,000 square feet of the original hotel has been renovated and 23,000 square feet of new space added to provide 40 units of Section 8-assisted apartments for senior citizens and 4,000 square feet of commercial space. All heat and hot water are provided by two central heat pumps.

While working on the Canal House restoration, the town was also seeking federal funds to develop a larger downtown district heating system based on groundwater heat pumps. In January 1981, the town received a three-year grant from HUD under the Small Cities Block Grant program. With these funds, the town will provide energy audits, technical and financial assistance to encourage downtown property owners to upgrade the energy efficiency of their buildings in anticipation of a groundwater district heating system. In May 1981, Rockingham received funding for a district heating and cooling assessment under a DOE/HUD cooperative program.

The first step in Rockingham's district heating feasibility study has been taken with completion of the Dunn Geoscience study. Dunn has confirmed the temperature and permeability of the aquifer. Because the town is located in a river valley, recharge of the aquifer is quite rapid, and the city could withdraw 1,000-1,500 gallons per minute of water without depleting the

aquifer. Withdrawals at this rate could supply heat to 25 percent of the planned heating district without any recharge wells. However, to provide heat to the entire downtown area, recharge wells will be required.

In conjunction with its building energy conservation program, Rockingham is now taking the second step in the district heating assessment: determining heat demand in the central business district. The third step will be a detailed engineering and economic feasibility study. Among the alternatives to be considered in the study are: centralized heat pumps, individual heat pumps for each building, and distributed heat pumps in large commercial buildings. As discussed above, some type of recharge wells will be required to avoid subsidence and aquifer depletion.

If possible, the town will use a thermal storage system. Warm water from the Connecticut River would be pumped into the aquifer during the summer months and withdrawn the following winter for circulation through the heat pumps. In addition, the slightly warmer groundwater returning from the heat pump in the summer months would be stored for use during the winter.

C. How Barriers Were Overcome

A number of economic and financial barriers faced the city in development of the Rockingham Canal House groundwater heat pump system. The biggest problem, of course, was simply obtaining financing. The Canal House restoration was part of an overall restoration of the central business district begun in 1975. During that year, the city created a private nonprofit Townscape Improvement Corporation which purchased the hotel and planned the renovation. By 1978, the city had obtained EDA funding for architectural planning, applied for HUD Block Grant funding for the restoration, and selected a private development team.

In putting together the restoration financing package, Rockingham encountered a great deal of skepticism of the planned groundwater heat pump system. First, the private developers were concerned about the high costs of drilling both construction and reinjection wells in addition to the cost of the heat pump itself. To overcome this problem, the city allowed the developer to use the abandoned municipal well where the abnormally high water temperatures were first discovered. This well, located in the village municipal parking lot, was drilled in 1966 to determine the feasibility of providing municipal water supply from the aquifer. However, a change in Vermont water laws prevented domestic use of water withdrawn from built-up areas so the well was abandoned. The city and the developer also agreed that water returned from the heat pump would be discharged through the storm sewer system to the Connecticut River, thus avoiding the high cost of constructing a reinjection well.

Restoration of the Canal House was to be financed through a 30-year mortgage issued by the Vermont Housing Finance Agency.

This agency, too, was skeptical of the heat pump system and uncertain whether the bonds to finance the mortgage could be sold. Rockingham was able to overcome these fears by guaranteeing the private developer access to the municipal well over the lifetime of the mortgage. A legal contract signed by the village, the town, and the developers guarantees the developers all water needed for space and water heating and cooling for 30 years. This contract helped persuade the housing finance agency to issue the mortgage.

The town's first economic barrier in developing the district heating system was the high cost of assessing the aquifer. Through persistent fundraising efforts begun in 1977, the city was finally able to obtain HUD funding in 1981 for a complete hydrologic study. Now that the availability of the resource is confirmed, further studies are needed to determine the heat source and its future availability. These studies would be useful in obtaining financing for actual system construction. One alternative being considered to both confirm the temperature source and begin construction is a joint venture between the city and a private developer who would assume the financial risk of drilling. However, the uncertainty of tax benefits when drilling for low-temperature groundwater may preclude this option. Another alternative would be municipal bonding or a combination of public and private funding.

As discussed previously, a major barrier facing the town is lack of legal ownership or control over the aquifer. Under Vermont law, the town owns only that part of the aquifer underlying the municipal parking lot and municipal buildings. In the short term it seems unlikely that private individuals will install their own heat pump systems, and the Canal House developers were satisfied with the city's guarantee of access to the aquifer for 30 years. In the longer term, Rockingham is working with the state legislature to develop new legislation granting municipalities the authority to regulate aquifer use for energy purposes. For example, the town would like to require buildings wishing to hook up to the district heating system to meet certain conservation standards.

Two factors should help Rockingham obtain the legal authority to manage its resource. First, under existing state statutes, the town can form a fire district with the power to distribute the energy (fire districts in Vermont have powers far beyond protecting property from fire). If a fire district were formed, the city could use some type of tax-exempt financing to construct the district heating system. Also, an entity for distributing the energy may qualify as a water company, with the status of a municipal corporation. Secondly, Vermont is a small state and the Town of Rockingham has good access to the state legislature through its State Representative who sits on the legislature's Energy Committee. Thus, town planners are confident that the legal clarification needed to go ahead with groundwater district heating development can be obtained. The town has already testified before the legislature and has contracted with the Energy Law Institute

in New Hampshire to research legislative changes further. Amendments to existing environmental and water resource law will be needed, along with new legislation.

2. Saint Paul

A. Background

The City of St. Paul, under the leadership of Mayor George Latimer, has been actively involved in energy conservation and alternative energy development since 1979. Throughout the spring and fall of 1979, more than 100 citizens participated in energy planning committees and in February of 1980, the Mayor organized a "mobilization" of city employees to conduct door-to-door energy audits. The city is also developing the first large-scale cogenerating district heating system in the U.S. Thus, the city's success in developing its Energy Park with an innovative groundwater heating system should come as no surprise.

B. Development Activities

Much of the infrastructure for Phase I of the St. Paul Energy Park has been completed, and ground has been broken for the central energy plant and 930 housing units. The first phase will include 249,000 square feet of residential space; 17,500 square feet of restaurants; 173,500 feet of commercial, retail, and office space; a 45,000 square foot health club; the 13,500 square foot central energy plant; and almost 300,000 square feet of light industrial space. Control Data Corporation is committed to building a 241,000 square foot "Energy Technology Center" as part of Phase I. Space in the Center will be leased to small businesses, with a particular emphasis on minority and women-owned businesses.

As discussed previously, nearly all heating and cooling for the total of almost 900,000 square feet will be supplied by four groundwater heat pumps located in the central energy plant. A 550 foot well to supply the heat pumps already has been drilled. The heat pump system is expected to save 25-30 percent of the cost of conventional in-building heating systems. At present, return water from the heating and cooling system will be discharged to the storm sewers. If the aquifer storage system is developed as planned, return water will be injected to the aquifer for storage and withdrawn during the following season. The aquifer storage system would bring energy cost savings for buildings in the park to 40-45 percent when compared with conventional building heating systems.

C. How Barriers Were Overcome

Financing the heat pump system along with the overall Energy Park was the result of careful planning and fundraising beginning in 1978. During 1979, St. Paul, along with representatives of

federal, state and regional governments, participated in an innovative intergovernmental process called the "Negotiated Investment Strategy" (NIS). Through the series of negotiations called for in the NIS, the city was able to obtain federal and state commitments of about \$40 million for the Energy Park. The public funds were to be used to "leverage" private investment.

In Phase I of the park, St. Paul received about \$12 million in Urban Development Action Grant funds from HUD and an additional \$2.3 million from the Economic Development Administration for initial infrastructure, including the heat pump systems. The city encountered no problems with federal agencies in including heat pumps in the infrastructure. All buildings located in the park will be required to hook up to the district heating system.

Private investment committed in Phase I includes Control Data's \$17.5 million "Energy Technology Center" and the Marfield Company's \$5.5 million "Energy Center Building." The AWH Corporation, a subsidiary of the local Wilder Foundation, is committed to building 950 housing units, including 50 Section 8-assisted apartments. The St. Paul Port Authority has assisted in this private development by issuing industrial revenue bonds. This successful track record in attracting private dollars was probably key in HUD's recent decision to grant the city another \$3.4 million "action grant." These funds will be used to expand the groundwater district heating system to serve more facilities.

The biggest barrier facing St. Paul's groundwater district heating system is disposal of return water, since Minnesota state laws prevent any recharge wells. In the short term, the Energy Park will dispose of return water through the storm sewer system. Because storm and municipal sewers are separate in the area around the Energy Park, this type of disposal will not overload city sewage treatment plants. A number of commercial buildings in St. Paul use groundwater for summer cooling and dispose of cooling water through the storm sewers.

In the long term, the Energy Park will need state approval for recharge wells if it is to develop the planned aquifer storage system. Under existing state law, the city might be able to obtain a special permit for a reinjection well, as the University of Minnesota did for its test storage facility. Another solution, depending on the reaction of the state Department of Natural Resources, the state Pollution Control Agency, and the state Health Department, would be able to use reservoir rather than aquifer storage. A reservoir could be used while testing of aquifer storage continues at the University. However, this alternative is 10 times more costly than aquifer storage. A medium-priced alternative, also under consideration, would be construction of an impermeable layer underground to prevent seepage to lower levels of groundwater. The final solution remains unclear. Ultimately, state laws and regulations will have to be changed if groundwater development is to take place in Minnesota.

V. CONCLUSIONS

We have seen that groundwater and geothermal energy hold great promise. Groundwater resources are widely available, while geothermal resources require further mapping and exploration east of the Rocky Mountains. The technology for geothermal district heating systems is available and has been proven in the western states. Groundwater heat pump technology is already well-developed and further improvements in efficiency can be expected.

However, cities wishing to develop geothermal and groundwater energy still face a number of obstacles. They will probably need to lobby their state legislatures to obtain legal clarification of their right to control the water resources. Financing, particularly from private sources, may be difficult to obtain. And local hydrology must be studied carefully before proceeding in order to avoid environmental problems. Cities willing to tackle these problems will find their efforts rewarded with a low-cost, dependable energy supply which can spur economic development and provide energy savings to private citizens, municipal operations and businesses alike.

APPENDIX A-ACKNOWLEDGEMENTS AND CONTACTS

Acknowledgements

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PART II

GEOHERMAL APPLICATIONS

Boise

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I. INTRODUCTION

On a dry, clear September day in 1981, Boise City Well #3 was pump tested before an audience of federal and local government staff involved in the development of geothermal resources across the country. Ira Fonshill, whose investment group funded the drilling of the well, looked on as the 170° F water gushed from the test pipe into an unused canal below the hillside.

The successful completion of this well represented the culmination of seven years of dedicated effort by Boise elected officials, city staff, and a mixed group of project participants. Many barriers were overcome to reach this point; but other important issues remain unresolved.

1. Background

The City of Boise, capital of Idaho, is one of the most rapidly growing cities in the U.S., both in population and in improved economic conditions. With a population of about 105,000, Boise is commercial, governmental, manufacturing and recreational center for southwest Idaho. Community growth is reflected in a surge of governmental, commercial and residential construction, and downtown redevelopment. The city is located on the broad, flat Boise River flood plain, with the Boise Foothills rising at the northern edge of the city.

Geothermal development in Boise began in 1890 when four young men began drilling for hot water in a perpetually snow-free area northeast of town. They encountered a good flow of water 400 feet down measuring a steady 172° F. On the strength of this discovery, a second well was dug, and the newly-formed Artesian Hot and Cold Water Company undertook building an extravagant Moorish-style Natatorium. In 1892, just prior to the opening of the Natatorium, two new homes on Warm Springs Avenue (one built by one of the four original entrepreneurs) were connected to the Natatorium supply well for space heating and hot water. This connecting pipe (later called the "Boise Water Corporation") soon was extended, eventually serving a downtown hotel and several commercial buildings as well as Warm Springs Avenue residences.

At its peak in the 1930's, the Boise Water Corporation's distribution system provided geothermal water from the two original wells for space heating to over 400 large homes and commercial customers. With the advent of low cost natural gas, and later, cheap electric power from the Bonneville dam system, however, this number dwindled to 170 customers -- all residential -- by 1974. At this point, the Corporation decided to discontinue services. The homeowners along Warm Springs Avenue who were still using the geothermal heat formed the Boise Warm Springs Water

District (BWSWD) to take over the district heating production and distribution facilities. BWSWD is an independent special district, formed by court order under state statutes providing for the establishment of water and sewer districts.

The geothermal resource which is so closely intertwined with the history of the City of Boise is commonly referred to as the Boise Front. It appears to be fault controlled, with the source of water being the annual runoff in the mountains immediately behind Boise. The two existing BWSWD wells provide a peak flow rate of approximately 1,700 gallons per minute (gpm) at 170° F (76° C). Studies of these wells and other wells in the area indicate the resource to be quite extensive, and to be recharging at a much higher rate than present withdrawals.

The Case Study description of the development of a downtown district heating system for the City of Boise and improvements in the existing BWSWD system which follows shows that the initial efforts were stimulated by the availability of outside financing (federal grants) but that the initiative, perseverance and flexibility of local officials were crucial to the project's success.

2. Impetus for Development

The energy shortages of 1974 triggered renewed national and local interest in Boise's hot-water resource. Exploratory drilling in the Boise area (completed in 1975) and geophysical mapping at Military Reserve Park were conducted by the Energy Research and Development Administration (ERDA) and Idaho National Engineering Laboratory (INEL). An associated study by Aerojet/Boise State University defined the surface geology denoting productive areas and other areas of high potential. Preliminary estimates of well productivity were established through these studies.

At the same time, the State of Idaho began looking at the resource's potential. In 1976, the State of Idaho Energy Office, with Pacific Northwest Regional Commission funding, undertook an experimental project to geothermally heat the state Health Laboratory. The 38,000 square foot laboratory building and two outbuildings were retrofitted to utilize geothermal heat and were connected to the existing BWSWD system. The state Agricultural Laboratory was later added to the demonstration project. The carefully monitored results indicate the geothermal system offers significant savings, both in the cost of fuel and maintenance expenses. For the first year of operation (1978), the geothermal system operated at slightly more than one-half the cost of the original gas-fired boiler, after adjustments for variations of heating degree days. This demonstration established the efficiency of the system design, defined new economic parameters, and explored the impacts of discharging spent geothermal water into the Boise River.

In 1976, Mayor Dick Eardley and the city council established the City of Boise Energy Office to explore possible community use of the resources. A 1977 DOE-funded feasibility study conducted by Boise Energy Office extensively examined the state and federal requirements for a geothermal energy utility. The report covered the engineering, geological, economic and institutional aspects of resource development. The Boise Energy Office proposed a district heating system which would serve downtown Boise and the state office buildings in the Capitol Mall. The study recommended that the city or a nonprofit corporation develop the system.

II. THE CITY AS DEVELOPER

At this point, it is important to note that there are three distinct governmental entities actively pursuing development of the Boise Front resource -- the State of Idaho, the Boise Warm Springs Water District, and the City of Boise. The potential for both cooperation and conflict inherent in this situation deeply affects ensuing events.

1. Institutional Factors

The institutional options available to insure development of geothermal energy cover a very wide range. The options chosen elsewhere include development under a private utility, by privately held corporations, by individuals, by special districts, by local governments, and by consortia of these groups. All of these options were equally possible in Boise, but, as it turned out, not equally probable.

In the 1970's, when interest in the development of the resource ran very high, a variety of groups expressed a desire to be involved in development efforts, including individuals using geothermal heat for their homes or commercial greenhouses; the local utility (Intermountain Gas); the State of Idaho; real estate developers; and several large manufacturing interests in the area as well as the city and Boise Warm Springs Water District.

Most of these players fell by the wayside during the lengthy negotiations and preparatory work. The final determination for active participation in the project ultimately came down to those entities willing to struggle through the delays and complications which will arise in any development project. Some, like Intermountain Gas, decided that exploration for geothermal reservoirs was too costly due to a bad heating season, while those with a secondary stake in the project (such as greenhouses or real estate development) did not have an overriding need to stay with the project.

Not all of the interested parties are out of the picture entirely. Many of them are potential customers for the district heating system. The State of Idaho considered building its own

system, using wells drilled on state property to heat the Capitol Mall Buildings. However, the state remained in contact with the Boise city system staff concerning the interrelationships between the two systems and ultimately chose to join the city system. Some of the parties, most notably large manufacturers, may develop their own resource systems rather than joining the city-run system. This raises the possibility of future problems of resource management, since the geothermal reserves are finite and can be drawn down by too many users. A new well can adversely affect the flows of existing nearby wells. The City of Boise has not been able to establish a clear legal right to manage the resource under state law. This issue will be discussed under section II.6, State Role, below.

2. Boise Geothermal

Boise Geothermal, the development corporation, is made up of the City of Boise and the Boise Warm Springs Water District (BWSWD). BWSWD is managed by an elected governing board chosen from district residents. The board is responsible for customer service and billing, and contracts out maintenance of the aging system components. All board members are volunteers, and there is no paid, full-time staff. The current BWSWD service area includes only those properties presently connected to the BWSWD system, within a five-block-wide corridor along 18 blocks of Warm Springs Avenue southeast of the Boise central business district. BWSWD presently has 250 customers, with another 250 on the waiting list for the refurbished system.

In 1978, the Department of Energy made funding for development of geothermal resources available under a Program Opportunity Notice (PON). Wishing to improve on their existing system and possibly expand, the Boise Warm Springs Water District joined with the City of Boise Energy Office in responding to the PON. BWSWD and the city entered into an "Agreement of Principle" creating "Boise Geothermal," a nonprofit entity which would administer the PON and would exist through the completion of the PON project, with the possibility of extension thereafter as the parties might agree. The two entities developed an agreement on definite ground rules for interaction between the governments. This agreement helped to clarify the relationships but has no legal force and effect.

Boise Geothermal includes all the members of the BWSWD board plus all of the city council. In order to make such a large group workable, an Executive Committee was established with four members, two each from BWSWD and the city. This committee reviews all activity and refers decisions, as appropriate, to the Boise city council or the BWSWD board. It has been a major help to the project that the membership of the Executive Committee has remained stable throughout the project period. Members for BWSWD are Warm Springs Avenue residents Dorothy Mott and Buck Jones. City council members are Ralph McAdams and Glenn Selander, both recently reelected to the city council.

Boise Geothermal has two full-time staff members. Phil Hanson, project director, came to Boise Geothermal in 1977 from the Urban Observatory at Boise State University, which participated in one of the early resource studies in Boise. Staff member Lee Post opened the Boise Energy Office in 1975, after working with the State of Idaho Energy Office. The resources of the Boise Energy Office were turned over to Boise Geothermal at its inception. Boise Geothermal has also been able to draw upon city staff for assistance in financial, legal, geological and property ownership research for the project.

CH2M Hill, a major engineering consulting company, is providing engineering work for the project. CH2M Hill's Boise office also worked on the early resource research and feasibility studies in Boise.

3. System Design

The continued interest of the BSWWD in the project stems from its already considerable investment in an existing system and the age of that system. Since its inception in 1892, the BSWWD system had not undergone major refurbishment. BSWWD entered the PON project planning to rejuvenate its deteriorating pipelines, restore the existing wells and drill two new ones.

For the city, the DOE PON offered an opportunity to spur new downtown economic development as well as provide present residents with a stable, reasonably-priced energy source. Throughout the complex process, Boise Geothermal has received full support from the members of the City Council (in their role as Boise Geothermal board members) and Mayor Dick Eardley.

The PON proposal submitted to DOE included upgrading and expansion of the existing BSWWD system, plus a separate district heating system for downtown Boise and the Capitol Mall area to be run by the city's Public Works Department. In this initial proposal, the city supply wells were to be drilled in Camelback Park, owned by the city and located some distance north of the central business district. Since then, a 1980 act of Congress turned the subsurface rights in the federally-owned Military Reserve Park (MRP), near downtown Boise, over to the city. The proposed site of the supply wells was then changed to the MRP, where proven reserves and a shorter pipeline to downtown customers improved the economic feasibility of the project.

Because of changes in funding levels, the on-and-off nature of the state's participation in the plan (see Section II.6, State Role), and the relocation of the proposed supply wells, the district heating pipeline routes have changed from the original proposal, although the downtown central business district (CBD) remains the focal point (See map).

The piping will now start at the supply wells drilled in Military Reserve Park, to the north and east of the CBD. Because

water must be transported from these wells, regardless of service area location, the service area is elongated toward the wells, with buildings located anywhere along the pipeline considered potential marketing locations. The main supply pipe will then skirt the CBD, running along Main Street where most of the larger buildings are located. The piping will be oversized to allow for future expansion into two potential service areas. One of these is along Broadway Avenue, south of Warm Springs Avenue; the other potential service area west of Capitol Boulevard along the Boise River includes the Eighth Street area, where considerable redevelopment is presently occurring and where developers have indicated an interest in using geothermal water.

An issue which is not completely settled is what to do with the spent geothermal water. This water is still quite warm (120° F) and several possibilities exist: 1) the water can be "cascaded" --reused for lower temperature purposes, such as cage heating at the Boise Zoo, greenhouse or other agricultural use, and some manufacturing processes -- prior to disposal; 2) the water can be cooled in a spray pond, as is the water from the state Health and Agriculture Laboratories, prior to disposal in the Boise River and/or a canal system feeding into the river; 3) the warm water can be discharged directly into the canals and river; and 4) the water can be reinjected through wells in city-owned Julia Davis Park. Reinjection wells are by far the most costly option, and the city plans to dispose of spent fluids directly in the river and canals. Geothermal water from the Boise Front is very nearly of potable quality; it is slightly higher in boron and fluoride than state water quality standards and contains levels of these chemicals similar to Boise River water. The results of the testing at the state Health Laboratory assisted in evaluating the environmental effects of direct river disposal. A Boise State University study of the river disposal concluded that there were minimal or no environmental effects. The individual residences presently dispose of the BWSWD system water in various ways, principally into Boise City Canal and into the city sewer system. This is satisfactory for the time being; however, if the BWSWD system expands, the city sewer system cannot handle significantly increased volumes, and another disposal option will have to be developed.

In order to keep all options open, the city piping system is planned to split, with one pipe ending just short of Julia Davis Park, close to the zoo and several potential industrial customers for the "cascaded" water. Julia Davis Park runs along the Boise River, so river disposal is possible as well as reinjection in the Park. The other leg of the city system ends at the abandoned canal system for direct disposal there. When the system begins operation, spent water will be discharged into the river and canals with the possibility of "cascading" to other customers still open. Disposal of the warm water into both the canal and the river has been approved by the State Department of Health and Welfare.

4. The Financing Package

The feasibility studies conducted in Boise were funded largely by ERDA/DOE. The 1975 Aerojet/Boise State University study and exploratory drilling cost ERDA \$250,000. The Boise Energy Office feasibility study began with an initial ERDA grant of \$71,502 and was completed in 1977 with additional ERDA/DOE funding of \$141,848 and a city contribution of HUD Block Grant funds of approximately \$98,000. The geothermal space heating demonstration at the state Health Laboratory was funded by a \$355,000 grant from the Pacific Northwest Regional Commission.

The 1978 Boise Geothermal PON application requested \$9.5 million for the drilling and construction project, to be divided equally between the two project participants -- BWSWD and the city. When awards were made in August 1979, however, DOE agreed to contribute only \$4.226 million -- less than half the requested amount. Consequently, it became necessary for Boise Geothermal to both cut back on the project plans and come up with substantial additional funding.

Meanwhile, because of delays in the city project, increased costs of service for the city system, and the highly promising results of their own feasibility study, the state chose not to participate in the Boise Geothermal project. This removed some of the most cost-effective potential customers from the proposed city pipeline route, plus the state funding for the Capitol Mall retrofit, at one time offered as part of the matching contribution to the PON. The state has since decided to rejoin the Boise city system.

The city council was unwilling to try raising the needed funds through bonds or other conventional municipal financing mechanisms because of a recently passed one percent initiative limiting property tax increases, a strong indication of voter sensitivity to city expenditures. Instead, the city allocated an Economic Development Administration grant of \$500,000, plus in-kind contributions valued at \$1.7 million in administrative duties. The remainder of the needed funds (approximately \$2 million) was raised through a private drilling fund.

The entry of the private sector into the Boise development project has important implications for future geothermal resource use. The risks of drilling for geothermal waters of the proper temperatures and flow rates are similar to those of drilling for oil and gas, without as broad a market base for spreading the costs of failure. In other words, in the fossil fuel world, "dry hole" costs can be spread among a very large number of customers, creating an imperceptible price rise. Because the number of users of geothermal water for space conditioning is limited, the cost of failure in a single well can create steep price increases, or must be absorbed over time, creating a lengthy pay-back period. Because of the high risks involved in drilling for geothermal resources, the cost of venture capital is very high.

The private development company participating in the Boise project is a limited partnership, consisting of a local investment company as general partner and outside investors as limited partners. None of the partners have geothermal experience or expect to remain in the geothermal business. The city has leased its water rights to the development company, which has committed to drill at the city well sites in Military Reserve Park, develop the geothermal production facilities, and bear all the risks associated with resource development.

The contract between the developers and the city gives the city the right of first refusal on all water produced at or about 170° F with a flow rate of 2,000 to 4,000 gallons per minute (gpm). The price of the hot water will be pegged to the price of natural gas. The city will have the option to buy out the production facilities after 15 years and can renegotiate the pricing formula at any time after the developers have recovered 300 percent on their original investment.

Bids for the pipeline construction phase of the project have come in under budget, so the Boise project is now firmly on a solid financial base. Until the bids were opened, however, the project ran the chance of financial difficulties, since the funding did not have a "deep pocket" to cover contingencies or serious cost over-runs. The bids, in fact, came in significantly under the engineers' estimates, and the Department of Energy has "de-allocated" \$600,000 of the remaining grant.

5. Marketing Strategy

In determining the piping route (with the best potential customers), Boise Geothermal made use of a 1976 Battelle Pacific Northwest Laboratories computerized simulation model called GEOCITY which can be used to calculate the total cost of geothermal energy for space heating. Not surprisingly, the model revealed that the best potential customers were those with the largest buildings -- they could most efficiently use the geothermal heat, thus getting the maximum amount of space heating per therm. The costs of piping and connection to the pipeline are generally lower for larger buildings per square foot of building space, depending on the type of existing space heating system.

The task of marketing to potential customers has been considerably complicated by the entry of the private sector into the Boise Geothermal project. The raising of venture capital is predicated on commitments by the city to purchase water at wholesale prices. These, in turn, are based on commitments by building owners to purchase water; but building owners will not make commitments until they know the delivered price of the water. These prices cannot be finally determined until firm bids, on which the price is based, are received for laying the pipeline and drilling the wells. Boise Geothermal, meanwhile, cannot drill wells until the drilling fund raises the money.

The solution worked out by Boise Geothermal was a three-step process. Boise Geothermal staff is currently working on steps two and three:

1. A preliminary connection agreement was prepared for signature by building owners. It provided the owners with a maximum price for the water -- about 30 percent lower than the cost of natural gas in the Boise area, and competitive with current electrical rates. (Many of the buildings in Boise are heated electrically, because of the very low cost of Bonneville hydroelectric power. The Bonneville dam system is presently at capacity, however, and the costs of increased electrical production will sharply increase costs to Bonneville customers in the near future.) The preliminary connection agreement gives the investment firm a commitment that can be used to raise funds for well drilling. The location and success of these wells does, to a certain extent, determine the pipeline route and cost.
2. After the wells are proven and bids for the pipeline received, a final connection agreement is signed by the building owners that specifies a definite price per therm. This will be backed up by a geothermal service ordinance.
3. In 1981, in an effort to speed up building owners' decision-making process, Boise Geothermal offered technical assistance in conducting a cursory review of in-building equipment and financial requirements for retrofit. This resulted in audits lasting no more than four hours per building to identify ballpark figures for retrofit costs and summary evaluations of financial feasibility. By June 1982, twenty-six audits had been conducted.

Marketing is currently underway in Boise. Of 140 building owners who have met with Boise geothermal staff, 30 have already signed up. Two-thirds of these buildings are large, commercial users, and the remainder are residences. Factors involved in the decision to join the city system include ease of retrofit, cost effectiveness, and the financial standing of the company or individuals involved. Two recent major customers are the state office buildings on Capitol Mall, and Boise State University campus.

6. State Role

The role of the State of Idaho in the Boise Geothermal development has two distinct parts; first, activities in regard to possible state use of the geothermal reserves for heating and hot water in state-owned buildings; and second, the state role as regulator and lawmaker.

The principal interest of the state in geothermal development in Boise is reduction of its own energy costs. The position of the state either as a developer or a distributor has not always been entirely clear. The state planned to become a customer of the city system; only after the PON was funded by DOE did the state pull out to develop its own system. One factor in the state's decision is that the cost of private investment in Boise Geothermal's system made it cheaper for the state to build and operate its own system. The state system would require an estimated \$1.7 million for piping (to run close to Boise Geothermal downtown pipelines), supply and reinjection well drilling and completion. The state kept the possibility of joining the Boise system open, however, and as the city system neared completion, the state decided to use the system.

The on-and-off nature of the state participation has caused some problems for Boise Geothermal. Removal of the state office buildings has caused no major changes in the proposed pipeline route, since the Capitol Mall is located at the edge of the CBD. Loss of the Capital Mall retrofit funds as local contribution to the PON has necessitated raising extra money on the part of Boise Geothermal. Also, the state would represent yet another governmental entity involved in direct use of the resource, further complicating resource management problems.

The state's role in resolving legal issues surrounding geothermal development in Idaho is still evolving. Geothermal resources in Idaho are defined as distinct from, but related to, mineral and water resources, and are regulated under a permitting regime established independently of the state's water rights regime. Subject to possible exceptions for certain low-temperature applications, anyone drilling a geothermal well for withdrawal or injection of fluids must obtain a geothermal well permit from the state Department of Water Resources (DWR). DWR has authority to protect existing groundwater rights from interference by geothermal use.

Under Idaho's water rights regime, the operating and proposed systems in Boise additionally require a water appropriation under the state's permit and licensing procedures. Generally speaking, in Idaho water rights are obtained by filing a claim for a specified amount of water to be applied to beneficial use within a specified time. If the permit is granted and the claimed amount of water is put to actual use within that time, a license is issued which protects the water right by giving priority over subsequent appropriations. This is a significant part of the background against which the various geothermal distributors in Boise must plan their resource development activities. To date, neither the Department of Water Resources, which has legal authority to manage geothermal reservoirs and groundwater, nor any of the developers in Boise have approached the issue systematically. Conflicts have occurred which have been resolved both formally and informally, but no single or joint overall management plan has emerged.

There is no serious opposition to the geothermal development within the community, probably in part because the city has not established any exclusive rights to resource use and thus does not impinge on any present or future private use. Also, Boise has had a long history of a large user (BWSWD) which makes the prospect of another large district heating system less threatening than it may be perceived to be in other communities.

Another resource management issue which has not yet been legally resolved is monitoring of the effects of geothermal use. The withdrawal of large volumes of water in other parts of the U.S. has resulted in problems of subsidence and interference. The geological engineering solution to this problem is to develop a monitoring program to track changes of ground or water levels. This solution is straightforward but costly. The institutional problem created is one of finding someone to assume technical and financial responsibility for monitoring. The city believes the state should assume responsibility, and vice versa. The state does not want to assume responsibility because of the cost, estimated at up to \$500,000. The city has proposed a joint effort, with each of the entities drilling for geothermal water (the state, BWSWD and the city) installing monitoring equipment at their wellheads, with the city providing a centralized monitoring point. This limited monitoring could be critical in the event of future litigation over interference or subsidence, when baseline data is needed.

Finally, the issue of what to do with the spent geothermal fluid has recently been resolved. Boise Geothermal will be producing and disposing of up to 2,000 gpm in the initial phase of the project. Options for disposal are variously under the regulatory authority of the state Department of Water Resources, the U. S. EPA, state Health and Welfare, the Corps of Engineers, and/or Bureau of Lands. The preferred disposal option is to return the waste water directly to the river and canals. In this case, Idaho Health and Welfare and EPA have principal responsibility. EPA usually requires the preparation of a National Pollutant Discharge Elimination System (NPDES) permit for surface water disposal, but, since the volume of water is small by its standards and the chemical content insignificant, EPA will not require a permit in this case. Idaho's Health and Welfare Department normally grants permission for disposal of a limited quantity of waste water for an indeterminate period of time. Boise Geothermal has worked out an agreement with Health and Welfare which will permit discharge into the river and canals for 20 years (a large fraction of the useful life of the system).

III. CURRENT STATUS

Bids for the pipeline construction were opened May 3, 1982. Bids came in under budget, and construction on the city-run system began July 6, 1982. Meanwhile, work on upgrading the BWSWD system was completed in June, just prior to beginning work on the city system.

IV. CONCLUSIONS

The development of the Boise Geothermal systems moved ahead as rapidly as was prudent throughout the process. If possible, difficulties were resolved as they arose, but many of the problems faced by the Boise Geothermal projects required lengthy negotiations. Continued progress was allowed through flexible planning; for example, designing the city distribution system to run close by the Capitol Mall which kept the option of connecting up the state buildings open while the state mulled over its decision on building its own system. Some issues remain unresolved but will not delay construction or marketing of the system:

- o Two related resource management issues:

- the problem of multiple users (including both governmental entities and private individuals and industries) possibly overdrawing the resource, and

- the lack of a centralized monitoring system to provide baseline data and forewarn of resource problems such as overdrawal or subsidence;

- o Development of a municipal utility. Boise Geothermal was formed to administer the PON project. Once the systems (the city system and the upgrading of the BSWSD system) are completed, Boise Geothermal will go out of existence. The Boise Public Works Department will operate the city system and it may not be necessary to develop a utility district.

Boise Geothermal has been notably successful, despite these remaining unresolved issues. The positive outcome of the Boise project is a tribute to the perseverance of the city council, who initiated the project in 1976, formed an alliance with BSWSD in response to the DOE PON, and has held the project together throughout the ups and downs of its history. The institutional relationships involved in the Boise project, while appearing tentative and fragile, have proved remarkably flexible. Each of the entities seeking to develop the Boise Front resource has carefully preserved its institutional integrity with an eye toward pursuing its own perceived best interests. This attitude has produced a series of ad hoc agreements and decisions which easily could have destroyed the project without the committed leadership of the Boise Geothermal Executive Committee and the full support of the city council.

The effects of the private sector financing on the Boise project have clear implications for future geothermal resource development elsewhere. Boise Geothermal found investment financing an efficient way to raise needed money, but has lost some key control over the project -- the price of the hot water at the wellhead. While the rise in water rates is significant enough to have stimulated the state to consider building its own

system rather than participate in the city project, the final cost of service to city customers is still well below the costs of traditional fuels in the Boise area. Together, this public/private venture has created a viable resource development project which is on the verge of becoming a reality.

APPENDIX A

Summary of Boise District Heating Projects

Resource Data

- A. Existing Boise Warm Springs Water District (BWSWD) Wells No. 1 and No. 2
Well Depth - 400 feet (122 m)
Date Completed - 1890's
Completion Technique - Open Hole
Wellhead Temperature - 170° F (76° C)
Flowrate - 1,700 gpm combined flow of wells No. 1 & No. 2
- B. New Boise Warm Springs Water District (BWSWD) Well No. 3
Well Depth - 600 feet
Date Complete - June 5, 1981
Completion Technique - Closed Hole
Wellhead Temperature - 134° F (56° C)
Flowrate - Inadequate
- C. New Boise Warm Springs Water District (BWSWD) Well No. 4
PROPOSED to DOE after failure of BWSWD well No. 3, but not accepted.
Well Depth - 600 feet (planned)
Date complete - planned for summer 1981
Completion Technique - Open Hole
Well Head Temperature - 170° F (76° C)-Goal
Flowrate - 1,000 gpm (planned)
- D. New Boise City Wells
- Well No. 1 -
Well Depth - 2,010 feet
Date Completed - April 17, 1981
Completion Technique - Slotted Casing and Open Hole
Wellhead Temperature - 155° F (68° C)
Flowrate - None artesian (not yet pump tested)

- Well No. 2 -

Well Depth - 800 feet

Date Complete - May 7, 1981

Completion Technique - Open Hole

Wellhead Temperature - 172° F (78° C)

Flowrate - 900 gpm artesian

- Well No. 3 -

Well Depth - 1,893 feet

Date Complete - June 4, 1981

Completion Technique - Slotted Casing and Open Hole

Wellhead Temperature - 165-170° F (73-76° C)

Flowrate - none artesian (not yet pump tested)

- Well No. 4 -

Well Depth - 1,103 feet

Date Complete - September 15, 1981

Completion Technique - Slotted liner/Screen

Wellhead Temperature - 172° F (76° C)

Flowrate - 900 - 1,000 gpm artesian

E. Summary:

Two wells presently serve the existing BWSWD system and provide a peak flow rate of approximately 1,700 gpm. A third well was completed under the current project and was expected to increase that flow by 1,000 gpm. Results from this well were poor and are being reviewed for further well drilling plans. Four new city wells have been completed. Flow testing of No. 2 and No. 4 was completed in April 1982. It was concluded that the Boise Geothermal Ltd. wells are capable of supplying a 2,000 gpm peak (7-20 days duration) system with an average demand (November through February) of 1,000 gpm.

SYSTEM FEATURES

Application - District heating
Heatload (Design) 1×10^8 BTU/hour (29.3 MW/year)
Yearly Utilization - 2×10^{11} BTU/hour (6.7 MW/year)
Energy Replaced - Natural Gas 2.92×10^8 cu. ft.
Facility Description - 500-1,000 residences and up to 2,000,000 square feet of office space.
Disposal Method - Disposal to Boise River and canal.

Summary - The proposed Boise City and BWSWD systems will utilize the local geothermal resource, as described above. Production wells for the City system will be located approximately 1.5 miles (2.4 km) from the primary load located in downtown Boise. The pipeline will be sized for 4,000 gpm to allow for further growth, although initial production capacity is expected to be approximately 2,000 gpm. The BWSWD pipeline will be sized for 3,000 gpm. The Boise system will require approximately 20,000 feet of transmission piping.

STATUS

Environmental Report	Completed
Geology Data Review	Completed
Well Siting Report	Completed
Preliminary System Design	Completed
Market & Rate Study	Completed*
Customer Confirmation	In Progress
BWSWD Well Specifications	Completed
Boise City Well Specifications	Completed
Waste Disposal Report	Completed
Drilling Fund and Lease	Completed
Drill BWSWD Well #3	Completed
Drill Boise City Well #1	Completed
Drill Boise City Well #2	Completed
Drill Boise City Well #3	Completed
Drill Boise City Well #4	Completed
Final Design of BWSWD Pipeline	Completed
Final Design of Boise City Pipeline	Completed
Construction of BWSWD Extended System	Completed
Construction of Boise City System	Due: October 1982 (Construction work began July 6, 1982)

*Additional reports are in production that will refine initial rate calculations. The final rate will be set at the time of customer connection.

PROJECT COSTS

Total - \$7,127,909

DOE Share - \$4,226,000 (less \$600,000 deallocated after
piping bids received for a final contribution of
\$3,626,000)

Participant Share - \$2,901,909

BWSWD Project Costs: \$1,623,705

Boise City Project Costs: \$5,504,204

APPENDIX B

References

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5. Anderson and Kelly, Flow Testing of Boise Geothermal, Ltd. Well Nos. 2 and 4, available from Boise Geothermal, Ltd, Boise, June, 1982.

APPENDIX C

Acknowledgements and Credits

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Dorothy Mott, Boise Warm Springs Water District
Nathan Little, formerly with CH2M Hill, now at Harvard Business School
IRA Fonshill III, Fonshill & Company/Investments

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Credits

Several key participants in the Boise project who are no longer involved in the project should be acknowledged here. They are: John Griffith and Michael K. Tucker, both formerly with the DOE Idaho Operations office; and Bob Schultz, who has left EG&G Idaho to join EG&G Services, and Nathan Little, P.E., formerly of CH2M Hill.

We would like to thank the Boise Geothermal project for permission to reprint the map and Appendix A material used in this publication.

City of Boise, ID
District Heating Pipeline
May 1982

Transmission Pipeline	Alternate B - Capitol Blvd
Laterals	Alternate C - Bannock/Sixth Street
Well Sites	Alternate D - Tenth Street
1 & 2 - Potential Interested Customers	Alternate E - Bannock Street
Alternate A - Third Street	Alternate F - Main Street

Klamath Falls

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I. INTRODUCTION

In the Fall of 1982 the City of Klamath Falls, Oregon, completed construction of a geothermal district heating system drawing hot water from two city-owned wells to provide hot water and space heating to 14 government building in the downtown area, and, within a few months, to homes in two low-income residential areas. The City has enough confidence in the technical and economic potential of the project that the system has been built large enough to accommodate expansion to all of the downtown commercial buildings and many nearby residences.

Yet the entire system, with several technical innovations, and the potential to lower city, county and state energy bills, is under a cloud of uncertainty. Serious questions about the future of the system have been raised as a result of a citizens' initiative passed in June 1981.

This report tells how the city came to develop a geothermal district heating system as part of a downtown revitalization and economic development program, and how a portion of the community came to oppose a key part of it.

1. Klamath Falls: The Setting

Klamath Falls is located in south central Oregon along the Link River running between Upper Klamath Lake and Lake Ewauna. The city is 18 miles from the northern California border. Crater Lake and the Oregon Cascades are just to the west. To the south and east is the Klamath basin, a large agricultural region producing potatoes, alfalfa, cattle and sheep. The first settlers in the area arrived in the 1850's, drawn by the agricultural and timber resources. Today the city's population is about 18,300, with a large unincorporated area directly to the south which brings the effective population closer to 45,000.

Use of geothermal heat in the Klamath Falls area has a long history. Eastern immigrants to the area found Klamath and Modoc Indians using natural hot springs. The new arrivals quickly adapted the resource to domestic uses, and for at least 80 years residents in the area have been using geothermal heat for hot water and space heating. Today much of the eastern portion of the city is heated geothermally. More than 500 wells supply homes, a college, a hospital, and several commercial buildings, including a local dairy which uses 181° F water as part of the pasteurization process. The city also uses the resource to heat schools and swimming pools and to keep ice off of some streets. All this leads the local economic development association to tout

Klamath Falls as "Oregon's Geothermal City."

The base of the Klamath Falls economy rests on three supports - agriculture, timber and tourism. In 1976 gross farm income in the Klamath basin was more than \$95 million, and Klamath County generally ranks near the top in the state for production of feed grain, hay, cattle, and potatoes. Timber is the dominant industry in the area. Commercial forests cover more than two-thirds of the 6,000 square miles in the county, and in 1976 the wood products industry employed 90 percent of the manufacturing labor force. Thus, an apparently agricultural county also ranks tenth among Oregon's 36 counties in the size of its manufacturing payroll. The third large source of income derives from tourists who come to view Crater Lake, to camp, and to hunt in the mountains.

In the past few years one of the legs of this base has weakened seriously as the timber industry has been hit hard by high interest rate and the prolonged slump in the housing industry. Weyerhaeuser Industries, the largest employer in the county, with 2,200 people at full capacity, has been working recently with only 1,600, a 27 percent reduction in work force. Unemployment in the county has been over 15 percent for almost a year.

II. DEVELOPMENT OF THE KLAMATH FALLS PROJECT

1. Origins of the Project

City officials had known they were sitting above a valuable resource that might make a significant contribution to the local economy. The U. S. Geologic Survey had designated the area has a "known geothermal resource area" or KGRA. Experts suspect that waters supplying the geothermal aquifer probably originate in the Cascades to the north and west of the city, and they speculate that the waters are heated as they seep deep into the earth before moving back closer to the surface near the city. Temperatures of up to 230° F have been recorded in existing wells. Well depths in the area vary from less than 100 feet, up to 2000 feet with most being under 1000 feet.

The origin of the district heating project dates back to 1976 when the Klamath Falls planning director and a group of faculty members at the Oregon Institute of Technology (OIT) discovered a common interest in the geothermal resource. Three men at OIT, located in Klamath Falls, had been researching geothermal heat for several years. The OIT campus itself is geothermally heated, and Paul Lienau, John Lund and Gene Culver had received frequent requests for assistance on geothermal projects both locally and outside Klamath Falls. In 1975, ministers from several churches in the downtown area requested help in assessing the feasibility of a system to serve their churches. A year later, though the project did appear feasible, the church leaders decided against

it. But this brief study left a few people thinking about a geothermal district heating system in the downtown area. Until the early 1970's, when deterioration and air pollution problems forced abandonment, the Modoc Lumber Company, through its subsidiary Consumers Heating System, had run a wood waste-fired steam district heating system in the downtown area. Perhaps a new version of that system could be built. A chance to continue the work begun with the churches occurred when the county allotted \$12,000 for a feasibility study and asked Lienau, Lund, and Culver to look into a possible district heating system for public buildings that would use an existing well serving the county museum.

That same year, 1976, was Eliot Allen's first in Klamath Falls as the newly appointed planning director. One of his objectives in the job was finding ways to move the city away from heavy dependence on the timber industry with its cyclical ups and downs connected to the national housing market. He was especially interested in using the geothermal resource to attract new businesses with process heat needs, and to support downtown businesses with low-cost heat. With lead responsibility for tracking down grant opportunities, Allen became the leader of a group of people within the city who played important roles at this and later stages. These included City Manager James Watson, Assistant City Manager Harold Derrah, Public Works Director Ray Bidegary and a technician in the Public Works Department, Kent Colahan.

But to get from ideas and discussion to actual construction the city needed to prepare a feasibility study of a potential system and then find means of financing it. The opportunity to do both appeared early in 1977 when the Department of Energy issued a Program Opportunity Notice (PON) under which it offered to fund demonstrations of direct uses of geothermal energy.

In the course of preparing its response to the PON, the city was offered an optional method of development, one involving partnership with a private gas utility. Northwest Natural Gas proposed that a joint bid be submitted under which the utility would operate the system as a franchise from the city. But believing that greater public benefit would come from public ownership and operation, and encouraged by results of a public opinion survey showing support for that approach, the council declined the proposal and the city made the bid on its own.

The PON announcement finally brought the city's interests in geothermal district heating together with those of OIT faculty members Lienau, Lund and Culver. The OIT study for the county was revised and submitted to DOE, and in the fall Klamath Falls was notified that it had been accepted. The initial award was for \$960,000, but revised estimates of cost and subsequent additions to the grant eventually brought DOE's share of financing to \$1.5 million.

The feasibility study was performed by Lienau, Lund and Culver, organized as the consulting firm of LLC for purposes of this project. City staff also provided considerable assistance. Three issues stood out in their effort to produce a workable design for the system.

Well site: First, they had to decide where the production wells should be drilled. In 1974 Lund and Culver had inventoried all existing well sites in the area, and thus knew of several areas with good potential. For this project, they looked for a site that minimized cost: it should be as close to downtown as possible; avoid topography that would be expensive to cross; make use of city-owned right of way whenever possible; and be available at a price the city could afford.

The two sites chosen were on city-owned land less than a mile from downtown, with easy access down a main street. When drilling was done later in 1979, both sites proved successful. The first well was drilled to 350 feet and when tested produced 680 gpm of 230° F almost potable water. The second, less than 1/4 mile away, was drilled to 1000 feet with similar test results. To bring the water to the surface, LLC proposed the same variable speed pumps in use on the OIT campus and at a local hospital. They felt that because the variable speed feature allows direct coupling of outside temperature and building heat demand to the pumping rate, it permits more efficient use of the resource.

Primary Line to Heat Exchanger: When well sites had been identified, the next step was to determine how the hot water should be transported from the wells to the large heat exchanger where the heat would be transferred to the secondary line and distributed in the downtown area. LLC had little trouble selecting the route for the primary line since it was an almost direct line from the production wells down a major city street to the County Museum where the heat exchanger building and reinjection wells would be located.

More time was spent selecting a pipe technology for the line. While LLC arrayed a total of 16 different options, the principal choice was between a line buried in the street and one enclosed in a concrete conduit with a removable lid doubling as a sidewalk. Eventually, they recommended, and the city accepted, a combined approach. As constructed, the 4,000 foot primary line consists of an eight-inch steel pipe surrounded by two inches of urethane insulation. The first stage of the line is buried directly in the ground. The rest of the line a little more than half the total length is housed in a 3x4.5-foot concrete conduit. Although initially more expensive than buried pipe, LLC and the city team felt it allowed greater flexibility for future expansion, and would be easier to maintain. As a small bonus, there is a long stretch of city sidewalk that remains snow-free during the winter.

Reinjection: Several options were discussed for disposal of the geothermal waters. The primary ones included discharge into the waste water system, reinjection near the production well, and reinjection at some point farther away. Despite the fact that present users already discharged over 3,000 gpm into storm sewers, LLC preferred to try to conserve the resource as much as possible and proposed to reinject the water back into the aquifer. However, reinjection back in the well field, they felt, ran the risk of "poisoning the well" if the cooler reinjected water came in contact with the well water. The option finally chosen was reinjection down the existing well at the County Museum, a distance of about 2,500 feet from the production well, and far enough away to eliminate the risk of cooling.

The other elements of the design were easier to resolve. The route of the secondary line through the downtown, for example, was largely dictated by the placement of the 14 buildings to be served and the arrangement of existing utility lines under the streets. Allen and LLC had hoped to use the same conduit design for the secondary loop as was used for the primary line; but cost ultimately dictated plastic pipe buried in the ground, running along alleys as it crossed the downtown area.

LLC completed the feasibility study in the fall of 1978. After receiving DOE's approval of the study and preliminary design, Balhizer and Hubbard, an engineering firm based in Eugene, Oregon, was hired to prepare the actual construction blueprints. These were ready in the fall of 1980, and construction was carried out in 1981 and early 1982.

Figure 1 shows the layout of the Klamath Falls district heating system, including the Michigan Avenue section which is being been constructed. The production wells are located just to the east of the downtown area, across an agricultural canal and on the edge of a residential area. As noted above, one well draws the resource from 350 feet and the other from 1000 feet. Both produce 218°-220° F water from eight-inch, 50 hp vertical turbine pumps with variable speed drives, each capable of producing up to 500 gpm. The pumps feed water into the primary pipeline. On the map, the "V-shaped" neighborhood just west of the canal is the Michigan Street neighborhood. The city has earmarked community development funds to serve this low-income area, and at the time of this writing bids have been received, and construction is expected to begin soon.

The primary and secondary lines are linked in the central heat exchanger building, located behind the County Museum (#2 on the list of the buildings on the system). The heat exchangers consists of a series of stainless steel plates stacked together vertically. As the first phase of the system expands, plates can be added easily to increase the distribution capacity. The building also houses the instruments monitoring the system, including those indicating temperature and flow requirements that are coupled to the variable speed drives on the pumps.

FIGURE 1. KLAMATH FALLS GEOTHERMAL DISTRICT HEATING PROJECT

The geothermal water arrives at the heat exchanger at 219° F, passes through the plates, and goes into the reinjection well at 176° F. The freshly heated water in the secondary loop leaves the heat exchanger at 200° F and returns at 160° F. The secondary loop consists of eight-inch fiberglass reinforced plastic pipe buried directly in the ground. Because of the relatively low distribution temperature, hookups to individual buildings can be made directly, without need for additional heat exchangers.

The cost of each of the major components of the system are as follows:

Production Wells (2)	\$ 63,965
Primary Pipeline	1,269,711
Secondary Pipeline	790,966
Engineering and Administration	<u>205,468</u>
	\$2,330,110

Generally, the cost of a geothermal district heating system will be a function of the factors which affect costs of production wells, primary pipeline and secondary pipeline. For production wells, these include the number and distribution of wells in a field, the depth and capacity of the field, and the temperature of the geothermal water. The cost of the primary pipeline is affected by the distance from the wells to the distribution station, the local soil conditions, and the type of pipe to be used. Finally, the cost of the distribution network is dictated by the area to be served, the density of heat demand, soil conditions, and the pipe to be used.

Virtually all of the financing for the project has come from public sources. The largest share, \$1.5 million, came from the federal government under the PON award. The rest, about 1/3 of the total, came from the state (\$50,000), the county (\$125,000) and the city (\$607,000).

Klamath Falls plans to use an additional \$450,000 of Community Development Block Grant funds to connect the Michigan Avenue neighborhood. Of this, \$200,000 will be used for pipeline construction, \$200,000 for a revolving retrofit loan fund to aid the 120 homeowners with hookup costs, and \$50,000 for administration. Extension into the Mill Street Addition will be financed with \$482,000 from HUD's housing rehabilitation program and will be divided up in a similar fashion.

The city also helped lobby passage of two bills in the Oregon legislature to allow tax credits for hookups. The bills offer taxpayers a 25 percent tax credit up to a maximum of \$1,000 for retrofit of heating systems necessary to accommodate connection to a geothermal district heating system, and another 25 percent tax credit up to \$1,000 for the expense of the connection itself.

The economics of geothermal district heating in Klamath Falls suggest that it should not be too difficult to arrange financing for future projects. Part of the feasibility study was an economic analysis of Phases I and II of the system, Phase I being service to the 14 government buildings, and Phase II being service to commercial buildings along 11 downtown blocks and to low-income residences in the Michigan Street and Mills Addition neighborhoods. Most of these commercial buildings are adjacent to the governmental buildings to be connected in Phase I. All of them currently use natural gas for space heating at a calculated efficiency (for purposes of the feasibility study) of 67 percent, and at a cost at that efficiency of \$5.67 per million Btu (\$5.85 per mcf). Some of the residential units use natural gas and others use electricity. Electricity cost for these customers was \$0.03/kWh, or \$8.79 per million Btu, at 67 percent efficiency. The analysis also assumed that the cost of natural gas and electricity would increase at about 16 percent a year for the next 20 years.

The study found that in its first year the geothermal heat could be delivered at a cost of \$5.84 per million Btu, assuming the cost of capital at eight percent and operation and maintenance cost of 6.2 percent of the unit cost. O & M costs were assumed to increase by seven percent a year. Since these are a relatively small part of the total, and since capital costs remain fixed, the price of service from the geothermal district heating system should change very little over its 20-year lifetime. In competition with natural gas, the geothermal system would operate at a loss for the first four years, but would recover its losses by the end of the eighth year. For the larger Phase II system, simple payback would be achieved in 10th year, and discounted payback in the 14th year.

2. Administration and Resource Management

Klamath Falls will divide administrative responsibilities between the existing Public Works and Public Service Departments. The city council will set policy, and the city manager's office will, as in other city functions, provide day-to-day coordination and direction.

The Public Service Department will handle meter reading, billings, and financial record keeping for the system. The city had considered using water flow as the basis for billing, but, encouraged by improvements in the technology, now plans to use Btu meters. At this stage the department does not expect administration of the district heating system to add much to its work load, since it should be able to read the Btu meters simultaneously with water meters and follow the same billing procedure. Rates will be set by the city council following the model of water rates. The Public Works Department will oversee operation and maintenance and any studies of possible expansion.

While the city found it relatively easy to set up an administrative system for the heating district, the larger problem of managing of the geothermal resource the district draws from has proven more difficult. Allen and others involved in the project are fairly certain the aquifer contains enough geothermal water to heat the entire city. But they have been concerned that uncoordinated development of new projects--some by the city, some by private developers, and some by individual homeowners--could result in misuse of the resource, diminishing its potential.

Under current Oregon law, use of geothermal waters above 2,000 feet and at less than 250° F is regulated by the state Department of Water Resources (DWR). DWR, with a very small staff, tends to confine itself to handling applications for water use. Generally, when the Department determines that an application meets state requirements for "beneficial use" and is not in conflict with any prior right, the application is granted. DWR is not, however, equipped to resolve competing uses and to oversee beneficial development of geothermal waters for an entire community such as Klamath Falls.

It was to overcome these limitations in DWR that Eliot Allen drafted the "Preliminary Model Ordinance for Municipal Geothermal District Heating and Reservoir Management." The document suggests a model according to which the state could delegate to a municipality authority to manage the resource locally. Allen located precedent for this in similar delegation of authority for land use planning. In addition to granting authority to regulate geothermal resource use, the ordinance would require creation of a central data file as a means of monitoring resource characteristics and aiding in minimizing conflicts between users. It would also give a city the right to franchise private systems, thus avoiding threat of antitrust challenges. Finally, the ordinance would recognize the rights of existing users, while simultaneously setting up a permitting system to control future expansion. Those interested in geothermal development in the state have made several unsuccessful attempts to convince both DWR and the state legislature that cities should be given authority to enact such statutes. (The document deserves wider attention. It is extremely well-researched and documented, and Allen drew on the experience of other several Western states, most of which have similar water laws.)

3. Citizen Response

The wells have been dug and pumps installed; lines have been laid; and the 14 governmental buildings are about to be hooked up with the promise of substantial savings to taxpayers. Presumably, citizens of Klamath Falls should be proud of the city's distinctive heating system and its potential to benefit the entire community. Yet the system was an issue in two different elections in the same year, and in the second Klamath Falls voters, a large proportion of whom were well-owners enacted

the citizen initiative referred to above. In doing so they set up a serious roadblock to any future expansion of the system.

The first vote was at the end of March 1981. In a very light turnout, voters rejected, by more than two to one, a charter amendment that would have authorized city formation of a geothermal heating district--the organizational vehicle by which the city had planned to administer and expand the system.

The second vote came three months later. This time voters faced a citizen initiative which had been filed with over 1,500 signatures gathered by Citizens for Responsible Geothermal Development (CRGD), a group organized in late 1980. The initiative, which passed in an even lighter turnout than the first election, 788 to 567, forbids "any person, corporation, organization, municipal corporation or any political subdivision of the State of Oregon from withdrawing geothermal water" from a well unless it is returned "undiminished in volume to the same well." The effect of the initiative is to prevent the City from using either of the two wells, and has forced it to consider alternative heat sources.

What is behind this reaction? It is risky to try to explain the basis for the opposition to the project, especially as an outsider relying on a handful of interviews and a survey of newspaper files. Still, one factor did emerge in conversations with several people including city officials, a leader of the CRGD, and independent observers. This was the failure of the city to appreciate the importance of sustaining an effective citizen participation process. The Planning Commission did get regular monthly briefings, but even this limited contact with the community was allowed to lapse at the end of 1979.

As a result, there were, at best, intermittent means of presenting the project to citizens, getting comments, and building support during the key periods when the feasibility study was being performed or when the study was being turned into working blueprints by the consulting engineers. As a result, the first detailed information average citizens received was at a public forum in September 1980, after the wells had been drilled, and close to the time construction was to begin on the primary pipeline. CRGD co-director I.H. Hart said that much earlier in the project, when he was chairman of the City Planning Commission, he had expressed concern to project leaders over the possible effects of pumping geothermal water out of the aquifer and reinjecting some distance away. He felt he had been assured that reinjection would be close to the production well, only to discover at the public forum that reinjection would be at the County Museum, 2,500 feet from the wells.

Hart--like more than a hundred other homeowners in the Hillside Area, an upper middle income section on the east side of the city--heats his house with a "downhole heat exchanger," a device using domestic water circulated down a well, through a

heat exchanger at the bottom of the well, and back up again. It is an extremely inexpensive source of heat, since once the cost of the well has been paid off the heat is essentially free.

The Hillside homeowners were concerned about the effect of city wells on their own wells, in particular the possibility that pumping from the city well could lower the water level in their wells, and thereby cut off their own energy supply.

The city responded with evidence from a preliminary pump test carried out by the Lawrence Berkeley Laboratories late in 1979. The pumps were run for 7 1/2 hours at a rate of 680 gpm to see what effect this would have on surrounding wells. In two wells monitored 1000 feet and 1,400 feet away the water level was drawn down only seven inches. In a well 180 feet away the drawdown was only 1.2 feet. The LBL report on the pump test extrapolated from the test data to predict that at a pumping rate of 680 gpm for 24 hours a day for 365 days a year the drawdown would only be two feet in a well 200 feet away. This compares with normal variation from rainy to dry seasons of 8-12 feet. The city has felt that this is strong evidence that the aquifer is quickly recharged and that the wells for the district heating system should not affect the residential wells using downhole heat exchangers. Moreover, they have pointed out, 3000 gpm is presently being pumped out, and this has been going on for several years without noticeable affect on the homeowners' systems.

The city realized that a 7 1/2 hour test could not provide conclusive evidence on the structure of the aquifer and the effects of additional pumping. For this reason, a full-scale pump test over six weeks had been planned since the beginning of the project. Monitoring surrounding wells while pumping for this length of time would give much more reliable data. The city council also sought to allay well-owners' fears by adopting a resolution stating its intention to complete the project and the six-week pump test, but at the same time promising to explore alternatives to pumping, and to halt the test if at any time there were signs of adverse effects on existing wells. None of this was sufficient to assuage the well-owners, who pointed to counter evidence of long-term lowering of water levels in some wells, and who worried about the lack of specificity in the city's pledge to halt the pumping if problems showed up. As one woman complained at a public meeting, "How much do we have to be hurt until you stop the project?" As a result, CRGD went ahead with its initiative petition and its ultimately successful campaign in favor of what it saw as a more conservationist approach to the geothermal resource.

But the initiative had scarcely been enacted into ordinance before it was challenged in court by the state. During the initiative campaign, the Oregon Department of Justice issued an advisory opinion stating that, if enacted, the ordinance would be in conflict with state jurisdiction over water resources. After

the election, the state petitioned to prevent enforcement of the ordinance, and in August 1981 the Jackson County Circuit Court granted a temporary restraining order.

III. CURRENT STATUS

As of this writing, a number of unresolved questions hang over the Klamath Falls geothermal district heating system. The largest concerns the outcome of the court case. A decision is still pending in Klamath County Circuit Court on a permanent injunction against enforcement of the citizens' initiative. The only significant action since the temporary injunction was issued in August 1981 was the judge's decision in March 1982 to grant CRGD intervernor status in the case.

Awaiting the outcome of the court's decision, the City is proceeding with plans for an alternative heat source for the district heating system. It has identified 500 gpm of 175° F water, part of the 3,000 gpm presently being dumped into the storm sewers, that could be used in place of the well water. This is not a perfect solution since nothing prevents those now dumping into the sewer from ceasing to do so, thereby denying the city some or all of its heat source. The city has no direct control over the resource under the alternative collection system. Nonetheless, this plan appears to be the best and most likely method of putting the system into operation.

The city is also proceeding with plans to hook up the 14 government buildings to the system to construct the Michigan Street extension. In May 1982 it announced acceptance of bids on construction to do the government building hookups. Below are approximate costs, according to the city manager's office to hook up each of the buildings:

State Office Building	\$24,000
State Office of Veterans Affairs	7,000
County Court House Annex	3,800
County Library	15,000
County Jail	50,000
County Court House	12,000
Veteran's Memorial (County Offices)	9,500
Old City Hall & Policy Department	15,000
City Hall Annex	16,000
U.S. Post Office	20,000
State Employment Office	5,000
City Fire Station	10,000
Total	\$192,300

A final question concerns how much support the project can obtain from the general community. The Klamath Falls Chamber of Commerce recently activated its Alternative Energy Task Force, which immediately began educating itself with a day-long seminar on local geothermal potential. The Task Force heard experts from

the Lawrence Berkeley Laboratory and Geothermex, a private engineering firm, argue that the city should complete the six-week pump test in order to establish the character of the reservoir. If the Chamber of Commerce and the business community decide to support the long-term pump test, and if the test proves successful, business could be an important element in the system's future growth.

IV. CONCLUSIONS

This examination of the Klamath Falls district heating project suggests several conclusions about the planning, design, and financing of similar projects.

1. In the early stages of a project, it is important to have people with a strong interest in and commitment to the project.

When work on the project began in 1976, it did not automatically become the most important city project. Several other problems were more pressing, including responding to the closing of a local military base and recovering the city's credibility following a real estate scandal involving a previous mayor. At the beginning, competing demands on time were greater obstacles to the project than were specific objections. In this situation, it was important to have people who had some technical understanding of the resource, who were critically placed in the city and community, and, above all, who were committed to moving the project ahead.

2. Luck can play an important part.

As important as the right people are, they can always use a few lucky breaks. In this case, fortune helped at least twice in the early stages. Perhaps most important was the county's early interest in a system that would serve government buildings. Coming after the interest of the ministers flagged, the \$12,000 contract gave the OIT group a chance to continue the work they had begun, and, even more importantly, it laid the groundwork for the proposal submitted to DOE when the PON was announced in 1977.

3. District heating projects can be feasible in rather low density areas.

It is often assumed that to be economically viable a district heating system has to serve an area of highly concentrated heat demand, the kind of demand found in an urban central business district or in a tightly clustered group of apartment buildings. Such, however, is not the case with the Klamath Falls system. The economic analysis for the project was based on service to the 14 government buildings, to commercial buildings on 11 of the 54 downtown blocks, and to 126 low-income single family residences. As Figure 1 indicates, these customers are not tightly clustered. Even though they are located in the central part of Klamath

Falls, the density is more typical of a neighborhood commercial strip area in a larger city than its central business district.

4. Citizens and citizen organizations should be included in project planning.

The citizen participation process begun as part of Klamath Falls's comprehensive plan development, was extended to planning for the geothermal project, but was discontinued at the end of 1979. The city held public meetings in the fall of 1980 to present the project to the community. But by then virtually all the important decisions about the project had been made, and the engineering firm was completing the blueprints for construction. The meetings may have presented valuable public information, but it was too late to gather citizen ideas that could contribute to the project, or to give people a sense of ownership in the project.

This last consideration is particularly important in a project that has as many implications for a community as does a geothermal district heating project. Cities in all parts of the country have discovered, often to their regret, how sensitive large-scale construction projects can be. Unless the broad range of interests affected by the project are included in the planning process from the beginning, there is a good chance one of them will raise objections that can severely constrain the project, or even kill it altogether.

APPENDIX A

Summary of Klamath Falls District Heating Project

Production Wells

Well Depth - No.1, 350 ft.; No.2, 1000 ft.

Date Completed - Fall 1978

Wellhead Temperature - 230°F

Flowrate - 680 gpm (Test rate)

Pumps - 50 hp, 8 in. verticle turbine pumps with variable speed drive and a maxium capacity of 500 gpm.

Distribution System

Primary Pipeline - 4,100 ft. of 8 in. steel pipe insulated with 2 in. of precast urethane insulation, about half of which is housed in a 3 x 4 1/2 ft. concrete conduit.

Heat Exchangers - Two stainless steel plate-type. Geothermal side - 219°F inlet, 176°F outlet
Secondary side - 200°F inlet, 160°F outlet.

Secondary Pipeline - 7,080 ft. loop of 10 in. direct buried, preinsulated pipe. Lines to buildings will be 3 in. fiberglass reinforced plastic pipe.

Capacity - 7.5×10^6 Btu/hr. capacity in Phase I with expansion possible up to 20.0×10^6 Btu/hr.

APPENDIX B

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APPENDIX C

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Susanville

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I. INTRODUCTION

On September 19, 1981, Mayor Harold Grayson of Susanville, California presided over the dedication of a geothermal district heating system which would soon provide heat and hot water to 14 buildings located in "Uptown" Susanville. Completion of the production well and piping system--which was designed to circulate 800 gallons of 170°F water each minute to the buildings -- was the culmination of years of citywide planning and management going back to 1974. Susanville's 6500 citizens surely had cause to celebrate.

However, completion of the Uptown district heating system was not the only reason for the ceremonies. September 19 also marked the beginning of construction of a second city-owned geothermal district heating system designed to serve the nearby state prison at Litchfield, California, and a planned industrial park. And construction of a third district heating loop to serve 110 low- and moderate-income homes in Susanville was also underway.

How was this small city able to develop not one, but three geothermal district heating systems? In part, Susanville succeeded because of the availability of federal funding for geothermal heating demonstration projects. However, the city's persistence and creativity in planning, financing, and building the systems also must be credited. An examination of Susanville's experience offers valuable lessons to other cities even in the present period of reduced federal funding.

II. BACKGROUND

Susanville, the county seat of Lassen County, is located in a very remote area of Northern California at the base of the Sierra Nevadas. The nearest large city--Reno, Nevada (population 100,756) -- is 90 miles away. The local economy is dominated by local, state and federal governments which together provide almost 50 percent of the jobs in Lassen County; other employment is in cattle and sheep ranching, farming and lumber industries.

Susanville's high unemployment rate was a key factor in developing its geothermal resources. In 1974 the threatened closure of the nearby Herlong military base triggered a state Commerce Department study which identified geothermal development as a tool for building up the area's economy. The need for an expanded job base was obvious. In that year, average annual unemployment in Lassen County was 16.7 percent. In December, when both private lumber mills and state and federal forest managers lay off seasonal workers, the rate was 20.4 percent.

The 1974 study described the potential for using geothermal energy to supply heat to greenhouse operations and other light industry which would be attracted by the cheap, reliable energy source. Produce from the greenhouse operations could be marketed both locally and outside the region.

Since that time, although construction of the geothermal system has created some jobs, Susanville's economy has not greatly improved. In 1981, average unemployment was 12.6 percent, with a December high of 18.1 percent. The current slump in the housing market continues to cause permanent and seasonal layoffs in the lumber mills. Incomes are also low in Lassen County. In 1981, Lassen county taxpayers filing joint returns had the 37th lowest combined incomes among the state's 58 counties. However, the military depot did not close down and government continues as a major employer. Geothermal industrial parks still in the planning stages could be a great boon to the area's economy.

Susanville's government structure also contributed to geothermal development. The city has neither a city manager nor a strong mayor system. The mayor is elected annually from among the five council members, who are elected every four years. As a result, council members became very involved in development of the project, helping to raise funds, plan, and build the district heating system. In addition, the lack of a strong central authority in the city administration allowed the geothermal project director, with the support of the council, to develop the project as he thought best.

Susanville area residents had always been aware of the presence of geothermal energy. Nearby Lassen Volcanic National Park is the site of geysers and hot springs, while boiling springs are found even closer to the city at Honey Lake. Since the 1930's, area lumber mills used geothermal heat for winter de-icing of mill ponds and the City of Susanville operated a geothermally heated municipal swimming pool. A greenhouse operation at the edge of town was also geothermally heated. However, it was not until 1974 that the city began to seriously consider tapping the resource on a large scale.

1. Impetus for Developing Geothermal Energy

In 1974 a number of actors who were to play key roles in the Susanville project began to come together. U.S. Congressman Harold T. ("Bizz") Johnson was instrumental in assuring Economic Development Administration funding of the State Commerce Department study which identified the economic development potential of Susanville's geothermal resource. At the same time, private developers at nearby Honey Lake hot springs began constructing 30 greenhouses to grow tomatoes and cucumbers using geothermal energy. This private development, along with the

state Commerce Department study, sparked the interest of Louie Templeton and Charlie Richardson, two city council members who have been involved from then until now in the Susanville district heating projects. Alfred Longyear, a consultant, became interested in Susanville's potential to provide a model of geothermal development to other cities.

In that same year, these actors helped get preliminary studies of the geothermal resource underway. Fred Longyear and council member Charlie Richardson approached the Western Federal Regional Coordinating Council with the results of the state Commerce Department study. Their good reception by the Council encouraged them to travel to Washington where they secured the support of Senator Alan Cranston in addition to that of Representative Johnson. As a result of their lobbying, the National Science Foundation, through the U.S. Energy Research and Development Administration (ERDA, now the Department of Energy) gave the city a grant in 1975 to study the resource; develop a planning model for combining economic with geothermal development; determine the replicability of Susanville's experiences; and conduct an environmental assessment. Longyear and other consultants worked closely with a "utilization panel" of nine cities with geothermal potential in conducting this study.

In 1976, Sen. Cranston and Rep. Johnson convinced Congress to approve a special appropriation (PL 94-156) for resource analysis in Susanville. The Federal Bureau of Reclamation began an extensive study including test drilling which later made the city's final selection of a production well site quite easy. In 1978, the Department of Energy contracted with Aerojet, Inc., to specifically study the feasibility of creating a geothermal district heating system in Susanville.

III. THE CITY AS DEVELOPER

While all of these early studies laid the groundwork for Susanville's district heating system, it took one key individual to put all the pieces together. In October 1978 Phil Edwardes, a local rancher, began helping the City of Susanville on a volunteer basis. By this time, the city had made a formal proposal to the Department of Energy to develop a district heating system to serve public buildings scattered across 12 city blocks. While originally planned to serve 17 public buildings, the proposed "Uptown" loop would cross residential and commercial areas that could hook into the system at a later date.

With Edwardes' help, the city modified and completed its proposal, originally submitted in July. Edwardes also went to Washington with Longyear to help promote the proposal. In February, the city received Phase I of a \$2 million grant for design and construction of the district heating system and in March Edwardes was hired as full-time project manager.

1. System Development and Design

Edwardes brought many years of experience in ranching, business management, and financing to his new position. He had moved to the Susanville area a short time before, after spending most of his life in southern Africa. Among his activities there were acting as president of the National Farm Bureau in Zambia and operating his own import-export business. Because of the much higher energy prices in that part of the world, Edwardes had a strong interest in renewable energy. In fact, he had used the geothermal resources on his own ranch in Kenya.

Hiring Edwardes as full-time manager of the city's "development team" greatly facilitated implementation of the DOE-funded district heating project. His presence relieved the volunteer council members, Charlie Richardson and Louie Templeton, who had put so much time into the project. Until Edwardes was hired, the one full-time city employee most involved in the project, James Jeskey -- who had been the city clerk and was then promoted to city finance director -- had many responsibilities besides the geothermal project.

Edwardes acted as a catalyst, unifying all actors into a single geothermal development "team." Because the Department of Energy project monitors felt a part of the team, they allowed Edwardes to make construction management decisions (including expenditure changes) in the field. This greatly speeded up the construction process. Cities developing privately-funded geothermal district heating systems should seek similar arrangements with the investors in order to avoid costly construction delays.

In design and construction of the Uptown system, Edwardes tried to use the simplest off-the-shelf technology possible, both to save money and to "demystify" the use of geothermal energy. As inflation drove projected costs up, he scaled back the proposed design from 17 to 14 buildings. Later, after the first 925-foot production well ("Susan I") proved to have adequate flow for the planned loop, he and the rest of the development team decided to cut back from two production wells to one. Edwardes also tried to facilitate the bidding process by holding a seminar for potential drillers, another seminar for pipelayers, and by using the local builders' newsletter to advertise the retrofit work. The city found that even "off-the-shelf" mechanical components took six to eight weeks for delivery; thus, careful and flexible management was needed to coordinate the various parts of the total construction.

As finally constructed, the Uptown district heating system includes a suction tank, a constant-volume line pump and an additional peak-load pump. Because Susanville's geothermal water

SUSANVILLE GEOTHERMAL ENERGY PROJECT

is not corrosive, a central heat exchanger is not required. Geothermal water is piped directly from the Susan I production well to the buildings included in the system through about 5000 feet of insulated eight-inch transmission line. Heat exchangers at the retrofitted buildings extract heat from the geothermal water. It is then returned via about 4000 feet of uninsulated six-inch pipe to two reinjection wells located along the piping route. System backup is provided by the two pumps at the wellhead. In addition, the retrofitted buildings can make use of their existing oil-fired heating systems in case of failure in the geothermal loop.

2. The Financing Package

Many different grants and studies were involved in the Susanville project. Groundwork was laid by the California Department of Commerce's 1974 economic development study. Through ERDA, the National Science Foundation allocated \$375,000 for feasibility studies beginning in 1975. The Bureau of Reclamation's resource evaluation, begun in 1976, was funded at \$1.3 million. According to consultant Fred Longyear, his corporation, (Lahontan, Inc.) invested at least \$150,000 of its own money in front-end costs. A HUD 701 planning grant of \$20,000 was awarded to the city to study geothermal-related economic development.

Actual design and construction of Susanville's "Uptown" public building district heating loop was primarily funded by the \$2,039,499 DOE demonstration grant awarded by the Geothermal & Hydropower Technologies Division under Project Opportunity Notice (PON) #79. In addition to the PON grant, Susanville received \$170,000 from DOE through the state Schools and Hospitals Energy Conservation grant program which was used to retrofit two schools for inclusion in the district heating loop. The city's share of total design and construction costs was only about four to five percent of the total. This was primarily in the form of in-kind contributions of land and staff, including Edwardes' salary. Finally, Lassen County made a small contribution to the Uptown project by paying for retrofit of the Veterans' Building, which it owns.

Like the Uptown project, the residential district heating loop (the "South Mill" project) was almost entirely federally funded. Susanville received an \$800,000 grant from the U.S. Department of Housing and Urban Development's Innovative Community Energy Conservation Program for this field demonstration project. The funds are to be used for construction of the production well, pipeline, and retrofit of about 110 homes in a low and moderate-income neighborhood. Susanville also received a \$100,000 grant from the Farmers Home Administration to extend the South Mill geothermal loop to an greenhouse just south of the residential area, in order to encourage economic development at and around the greenhouse site. The city has reached an agreement with this Green House, the Susan River Nursery, to tie into the South Mill loop. The existing geothermal well at the nursery will provide backup to the South Mill project's production well.

The financial package for Susanville's third district heating loop, the Litchfield project, provides the most useful model for other cities in this time of shrinking DOE budgets. Phil Edwardes worked closely with a private developer, Carson Development, to raise the \$900,000 needed to construct two production wells and one mile of pipeline from the well site to the Litchfield correctional facility. By helping Carson sell tax-free industrial revenue bonds and working with Bank of America to assure purchase of the bonds, the city helped raise the needed funds. Carson obtained additional capital through a limited partnership from individual private investors seeking the tax advantages offered by the drilling project. The 10 percent federal investment tax credit, business energy tax credit, drilling credits and accelerated depreciation under the 1981 tax act offer these investors a very rapid return on their investment through tax savings within the first year. Overall return on investment in the Litchfield drilling project is estimated to be 15 percent.

Once Edwardes and the rest of the Susanville team had lined up private financing through Carson, they were able to leverage

state funding for the design and retrofit of the prison itself. First the city was awarded a \$90,000 engineering grant from the California Energy Commission for design of the pipeline and engineering of retrofits for prison buildings. Next, the California Department of General Services (which owns and operates the facility) obtained \$1.43 million from the state legislature for construction of the pipeline and building retrofits.

The City of Susanville has a long-term lease on the Litchfield geothermal well site. Carson has a sublease of approximately 10 years. After that time the production facilities will be turned over to the city. This "turnkey" model of private investment is being followed by Lassen Community College, located in Susanville, in a biomass cogeneration project. Lahontan, Inc., the consultants who worked with the city on the Uptown geothermal project, has set up a limited partnership to finance and build the waste-fired cogeneration system. The system will be turned over to the college after several years.

INSTITUTIONAL FACTORS

1. City Role and Community Support

The City of Susanville has taken the lead throughout all phases of geothermal development. Phil Edwardes describes the city's role as "leader, agitator, facilitator." In lining up financing, planning, and carrying out the various projects, the city benefited from its small size and found consensus on many issues. For example, the school district was actively involved in development of the Uptown project and has signed a letter of agreement with the city to buy geothermal heat for two schools. Seven different city councils have been involved in various phases of geothermal development and all seven have strongly supported it.

In addition to its small size, three factors contributed to the strong support for Susanville's district heating system. The first was the general concern about the area's high unemployment and the shared awareness that development of low-cost geothermal energy could be a means of attracting new industry. The state Commerce Department's 1974 study, a second state study in 1977 and Lahontan's planning study under the 1975 NSF grant all increased this awareness. A second factor was the availability of state and federal funding to support the projects, which minimized local disagreements about allocation of funds.

A third factor which helped the city develop consensus around the project was the outreach effort going back to 1974. In the early years, Alfred Longyear worked closely with then city clerk James Jeskey to unify council support for geothermal development. While some council members were concerned about the high costs, Longyear was able to show that outside funding would become available and thus secured their support. Longyear and council member Charlie Richardson also met regularly with the Rotary, Kiwanis and other civic clubs to update them on the results of Lahontan's planning study and the federal Bureau of Land Management's (BLM) ongoing geothermal resource assessment. Longyear also appeared on local television and radio call-in shows to answer questions about the planning effort. Through these efforts and with the support of the local newspaper, community residents became interested and enthusiastic about geothermal district heating.

While the high level of consensus within the city government and community could have allowed direct city ownership of the geothermal system, leaders of the Susanville project decided early on to own and operate the district heating system through a semi-autonomous utility. In order to gain experience in operating a city utility, Susanville planned to buy and operate the city's privately-owned water system. The voters approved a bond issue to finance the purchase; however, the bond sale was unsuccessful. Despite this setback, the city has gone ahead with creation of a geothermal district heating utility -- the Susanville Municipal Energy Corporation (SMEC).

SMEC is a wholly-owned subsidiary of the city, governed by a seven-member board of directors appointed by the city council. Its members include a leading area rancher, the owner of the local television station and other businessmen. A prominent local attorney will chair the new corporation board. The utility has bonding authority, but will probably raise funds through the state's Alternative Energy Financing Source Authority -- which has a proven record of successful bond sales -- rather than trying to sell its own bonds. Perhaps more important than its legal authority is the fact that the new district heating utility "depoliticizes" the system by removing it from direct city ownership and involving the local business community in its management. Because the future financial health of the district heating system depends largely on business customers hooking up, creation of SMEC will help ensure the system's viability.

2. State Role

The State of California influenced development of Susanville's district heating system in two major ways: legally and through technical and financial assistance.

California state law provides the basis for Susanville's geothermal resource development. For example, the city has

leased both the production well site and the underlying geothermal reservoir for the Litchfield project under California geothermal leasing laws and regulations. The land overlying the resource is privately held (it lies outside the city limits) and the city will pay the property owners a royalty based on the amount of geothermal water extracted. Thus, the city has the clear legal right to extract and sell that part of the resource underlying the leased land. Susanville is presently negotiating with the federal BLM to obtain protective agreements for the remainder of this reservoir.

The city's legal right to extract geothermal resources underlying the city for sale to the Uptown and South Mill heating districts is much less clear. The city owns the land on which the production well is located, and has leased two other pre-existing wells from private owners. However, ownership of the geothermal reservoir itself, which lies under private land, may legally rest with the landowners. The State of California has not made a clear statement on this issue, and the city continues to seek a legal decision. In order to protect itself, SMEC plans to set aside five percent of all revenues generated by geothermal heat sales in an escrow account. If private landowners are able to demonstrate legal ownership of sections of the reservoir, the escrow account will be used to pay royalty fees.

While California's lack of clarification on the legal status of the Susanville reservoir appears to be a major problem, it is unlikely to present serious obstacles to the new district heating system. Tapping into the city reservoir requires expensive hard-rock drilling and construction of costly production and reinjection wells which must meet state regulations. Most landowners in the city will find it easier and cheaper to hook up to the city's system than to drill and develop their own systems. This trend is already obvious in Susan River Nursery's decision to hook into the city's South Mill heating loop and incorporate its own production well as a back-up to the city system. The widespread support for the city system also makes it unlikely that private landowners would drill their own wells and claim rights to the reservoir.

State laws and regulations also affect Susanville's right to restrict drilling by private landowners. A city ordinance restricting drilling, approved in 1979, is carefully drafted to avoid conflicts with state geothermal exploration and extraction regulations. It allows drilling only by city permit and only at sites designated by the city council, but it is couched in terms of minimizing the nuisance and noise of drilling, rather than in terms of a city monopoly over use of the resource. SMEC will probably replace the ordinance soon with a detailed resource management plan. Again, the management plan will have to be carefully drafted to deal with the uncertain ownership of the resource and avoid conflicts with state law.

On one matter at least state law is clear: A general law city like Susanville has the authority to own and operate a heating utility. As a municipal utility, SMEC is exempt from regulation by the California Public Utilities Commission.

California's role in providing assistance to the Susanville geothermal projects should be a model to other states wishing to encourage development of this valuable resource. From the beginning, state studies aided in the local project. Both the state Commerce Department and the Energy Resources Conservation and Development Commission (the forerunner of the present California Energy Commission) participated in these early assessments of Susanville's potential for developing its geothermal resources and its local economy.

Susanville's U.S. Congressman Harold ("Bizz") Johnson worked closely with the city in both the Uptown and Litchfield projects. Working with Ray Johnson, the city's state senator, Rep. Johnson helped obtain the state legislature's approval of funding for design and construction of the Litchfield heating district. Design and engineering of both the heating loop and prison retrofit was funded under the California Energy Commission's geothermal demonstration program. The goals of this program -- "to assess and demonstrate the technical and economic feasibility of using geothermal resources in direct heat applications" -- are very similar to the goals of the DOE geothermal program that funded the Uptown heating district and several other geothermal district heating systems in the western U.S. As the DOE demonstration program winds down, state programs such as California's are increasingly important.

Finally, the California Energy Commission assisted Susanville with funding for geothermal retrofits of two schools included in the uptown heating district through its schools and hospitals grants program. Overall, the state's financial assistance, particularly its investment in initial feasibility studies that helped leverage federal funding, was crucial to Susanville's success.

3. Marketing Strategy

Susanville Municipal Energy Corporation is developing a five-year management, financing and marketing plan. The marketing plan is based on a pricing structure which keeps geothermal energy cheaper than oil. For example, the school district and SMEC are renegotiating their original letter of understanding which provided for the purchase of geothermal heat at two-thirds of 1978-79 fuel oil prices, because fuel oil prices have now dropped.

Most buildings in the Susanville area and all of the buildings included in the Uptown public building loop have relied primarily on oil for space heating until now. The city's present

agreement with Litchfield Prison calls for the facility to purchase geothermal heat at 70-75 percent of the initial year's fuel oil prices with a maximum 5% price increase each year thereafter.

Under this pricing plan, geothermal energy will cost much less than fuel oil within five years. As a result, SMEC will not require customers to sign long-term contracts but will simply offer the heat for sale at an attractive price. In fact, the public buildings that have been retrofitted for inclusion in the uptown project have all kept their existing heating systems intact, so they can purchase as much or as little geothermal energy as they choose. The pricing scheme is designed to cover operating and maintenance costs only; any major expansion beyond the three heating districts now underway would have to be financed through a bond issue, private capital, or state or federal funding.

Because of its strong support by the business community and its attractive pricing plan, SMEC already has a waiting list of businesses that would like to hook into the Uptown heating loop. However, business firms may be prevented from joining the system because of the high cost of borrowed capital to retrofit their buildings. To overcome this hurdle, the city is working with the California Alternative Energy Financing Source Authority and the Bank of America to negotiate an industrial revenue bond sale by 10 of the interested businesses. If the bond sale is successful, the businesses would set up a low-interest loan pool to finance their retrofits. SMEC is also considering a plan that would allow the businesses to finance their retrofits through energy cost savings. Partial geothermal heating retrofits also are being considered as a way to make hooking up more affordable.

In marketing geothermal heat to residential customers, SMEC is following a similar pricing and marketing scheme. By offering lower prices, SMEC will not have to require long-term contracts. For the initial customers of the South Mill heating district, hooking up to the geothermal heat and hot water system will be particularly attractive because their retrofit costs will be partially or completely funded by HUD. Retrofit costs are expected to be about \$2,500 per home. The city Community Development Office will follow HUD income guidelines in providing either direct grants or low-interest loans to about 110 homeowners in the target neighborhood. As the initial loans are repaid, loans will be made available to other homes in the target neighborhood and homes nearby. Most of the homes in this part of the city will be eligible for low-interest loans from the loan pool; however, market-rate loans may be made available to higher-income customers wishing to join the system.

To promote the residential heating project, the Susanville Community Development Office staff has held several community meetings in the target neighborhood. Media coverage of the project has been good. In addition, personnel visiting homes in

the area to identify retrofit needs have discussed the heating system with homeowners. As a result of these contacts, many homes are already on the city's waiting list for retrofits. Other homeowners are waiting to see how the district heating system actually would connect with their home before signing up. To demonstrate the system to both contractors and homeowners, the city is retrofitting two homes in the neighborhood; when these two model homes are retrofitted and the geothermal system is operational, homeowners are expected to sign up rapidly for retrofits.

Overall, Susanville's marketing strategy appears to be successful. With the base of customers provided by the already-retrofitted public buildings, and its good ties with potential business customers, SMEC should have little trouble keeping the Uptown system financially self-sustaining. HUD funding of initial retrofits in the South Mill loop should encourage residential customers to sign up, making this system economically viable as well.

V. CURRENT STATUS OF PROJECTS

Currently, the production well for Susanville's Uptown district heating project has been completed, two school complexes have been retrofitted and retrofit of two other buildings is underway. Construction of the pipeline and the reinjection well is almost complete. The distribution system has been operated for testing and appears to be functioning well. By the end of June 1982, the entire system should be operating.

The production well for the South Mill residential district heating loop has been completed and distribution piping will be laid this spring. Completion of the two demonstration home heating system retrofits has been delayed due to delays in getting materials. At the Litchfield site, one production well has been drilled. Carson Development recently completed its financing package and has begun construction of a second production well and piping. Engineering of the prison retrofit is completed, and actual retrofitting will take place this summer. All three district heating systems are summarized in Appendix A.

Various public and private economic development projects are underway in Susanville. Two private developers are constructing roads and sewers for an industrial park near the Susan River Nursery south of town. A light manufacturing plant recently located at this park. This and other plants locating in the park will have access to geothermal energy from the South Mill district heating loop through the FMHA-funded pipeline extension to the Susan River Nursery. In addition, Carson Development is planning an industrial park to use geothermal water returning from the Litchfield prison heating loop.

The City of Susanville is examining several alternative sites for another, city-sponsored geothermal industrial park. The city would try to annex whichever site it chooses and provide low-cost leases to industries wishing to locate there. Community Development Block Grant funding is being sought to finance the park development. One of the most promising sites is located east of the city near Lassen Community College. If that site were developed, industries would have access to low-cost electricity and steam from the community college's waste-fired cogeneration plant as well as geothermal energy from the Litchfield production well. All of these developments indicate that the city's original goal of combining geothermal development with economic development is being reached.

CONCLUSIONS

The most important lesson to be learned from Susanville's experience is that with creativity and flexibility, cities can obtain financing for geothermal energy development from sources other than federal agencies. The city's success in combining private and state financing in the Litchfield project is an important model for the 1980's. By using many different approaches, Susanville was able to assemble a \$5.4 million financial package that included funds from individual investors in a tax-sheltered limited partnership, purchasers of industrial revenue bonds, and two California agencies. The city's role in obtaining these funds ranged from working closely with Bank of America to ensure success of the bond sale to supporting its state and national representatives in shepherding a special appropriation through the California legislature.

Of course, Susanville might have had much greater difficulty financing the Litchfield district heating system if it had not first successfully completed the federally-funded Uptown heating loop. However, this does not negate the city's value as a model for other cities. From the beginning, Phil Edwardes treated the DOE grants as if they were Susanville's own limited funds. By designing and building the Uptown system to match the amount of funding and bringing potential customers into the project from the start, Edwardes was able to demonstrate the economic viability of geothermal district heating to the private sector. The city's success in marketing the Uptown and South Mill systems through SMEC and in financing the Litchfield system should encourage bankers and developers elsewhere in the country to work closely with city governments in building geothermal district heating systems.

A second lesson to be drawn from Susanville's experience is that even a small district heating system requires a long lead time to get off the ground. It took six years from the first studies in 1974 to actual construction of the Uptown project in

1980, and the system was not completed until 1982. Persistence was required throughout this period--from Fred Longyear and Charlie Richardson's refusal to take no for an answer in the early fund-raising to Phil Edwardes' juggling of construction timing when components took longer than expected for delivery. The extensive studies and analyses from 1974 through 1978 laid the groundwork for successful construction of the district heating loops in 1980 and 1981. And early community outreach efforts provided the basis for the successful marketing now underway.

The key to Susanville's success in moving from paper studies to actual hardware was having a full-time successful businessman as project manager. While not every city will have a local resident with Edwardes' experience available, cities wishing to develop their geothermal resources must be willing to invest in a full-time manager to pull the financial pieces together and unify the various actors involved. Susanville could not continue to rely on volunteer council members and outside consultants to manage the project once the DOE demonstration funding was received, and city staff with other responsibilities could not always be available to give the project the attention it deserved.

The final factor in Susanville's success at putting its geothermal resources to work was the city's energetic leadership in project development -- the "leader, agitator, facilitator" role. It was city government that initiated the resource assessments in 1975 and 1976 and district heating feasibility studies in 1978. In 1979, the city council's approval of an ordinance restricting geothermal drilling in the city helped ensure the city's leadership role in developing the resource. At the same time, Susanville's successful efforts at obtaining federal funds for well drilling allowed it to safely assume the financial risk of drilling through deep hard rock in the Uptown project. The success of this well demonstrated the feasibility of tapping the area's geothermal resources and encouraged the private sector to participate in the Litchfield well. Thus, Susanville has been able to work closely with the private sector to develop and supply low-cost geothermal energy to area residents.

APPENDIX A

Summary of Susanville District Heating Projects

<u>Project Name</u>	<u>Customers</u>	<u>Technical Scope</u>	<u>Financing</u>
Uptown	12 school bldgs. to date	925 ft. production well (Susan I)	\$2,039,499-DOE well & distribution system)
	Retrofit of other public buildings underway.	800 gpm pump below surface	\$170,00-DOE through State of California (school retrofits)
	Marketing to 10 private businesses	2 surface pumps	\$107,000-City of Susanville, County of Lassen
		13,000 gal. insulated surge tank	
		5000 ft. of 8 in. transmission pipe line	
		5500 ft. of 4-8 in. return pipeline	
South Mill	120 low-to-moderate income households in CDBG area initially	One production well (existing well or Susan I)	\$800,000-HUD \$100,000-FmHA
	Marketing to additional homes	Transmission and return pipe to 6 block area	
	Marketing return fluids to industrial park	Extension of distribution pipe 1 mi. to industrial park	
		Reinjection well at industrial park	

Project Name

Litchfield

CustomersState correctional
facilityMarketing return
fluids to indus-
trial parkTechnical
Scope2 production
wells planned1 1/2 mi. of
transmission
pipeline from
wells to faci-
lityFinancing\$1,430,000-
California
General Ser-
vices Admin-
istration\$900,000-City
of Susanville
and Carson
Development
Company\$90,000 -
California
Energy Commis-
sion.

APPENDIX B

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APPENDIX C

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Credits

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