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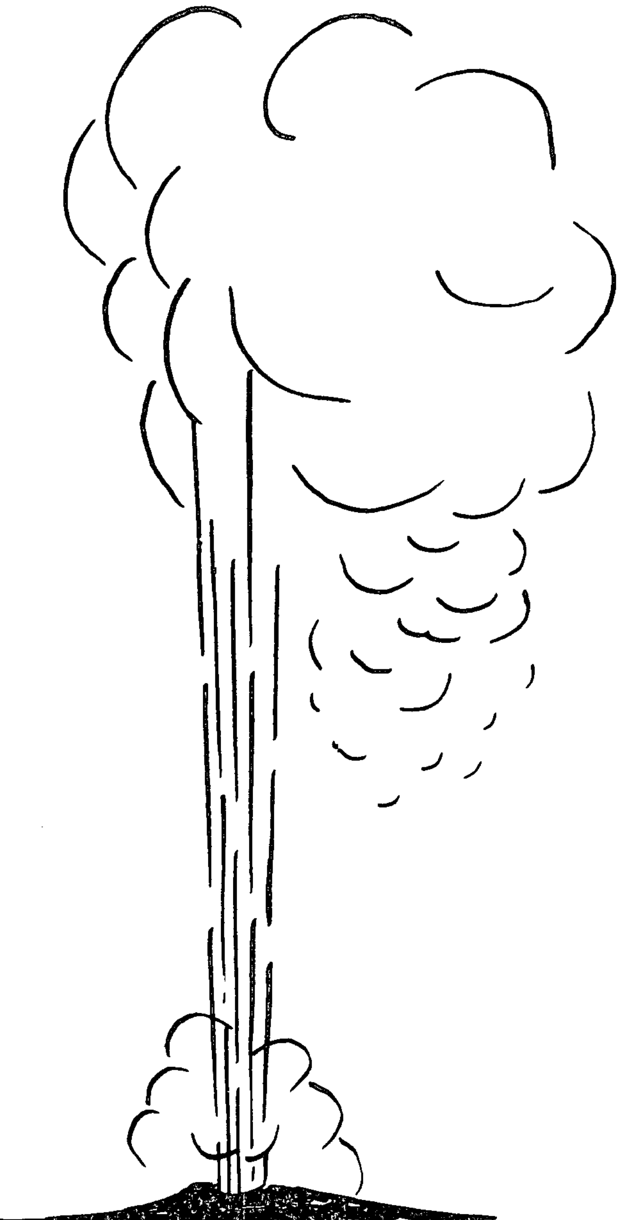

A FEASIBILITY ANALYSIS OF GEOTHERMAL DISTRICT HEATING FOR LAKEVIEW, OREGON

Final Report

DOE/ET/27229--T1

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December 23, 1980

Work Performed Under Contract No. AC51-79ET27229

Coury and Associates, Inc.
Denver, Colorado

U. S. DEPARTMENT OF ENERGY

Geothermal Energy

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A FEASIBILITY ANALYSIS OF GEOTHERMAL DISTRICT HEATING FOR LAKEVIEW, OREGON

FINAL REPORT

December 23, 1980

By

Coury and Associates, Inc.

For

Northwest Geothermal Corporation

Sponsored by the U.S. Department of Energy, Geothermal Division
Seattle, Washington, Regional Office

U.S. DOE Contract No. DE-AC06-79ET27229

ABSTRACT

An analysis of the geothermal resource at Lakeview, Oregon, indicates that a substantial resource exists in the area capable of supporting extensive residential, commercial and industrial heat loads. Good resource productivity is expected with water temperatures of 200°F at depths of 600 to 3,000 feet in the immediate vicinity of the town. Preliminary district heating system designs were developed for a Base Case serving 1,170 homes, 119 commercial and municipal buildings, and a new alcohol fuel production facility; a second design was prepared for a downtown Mini-district case with 50 commercial users and the alcohol plant. Capital and operating costs were determined for both cases.

Initial development of the Lakeview system has involved conducting user surveys, well tests, determinations of institutional requirements, system designs, and project feasibility analyses. A preferred approach for development will be to establish the downtown Mini-district and, as experience and acceptance are obtained, to expand the system to other areas of town. Projected energy costs for the Mini-district are $10.30 per million Btu while those for the larger Base Case design are $8.20 per million Btu. These costs are competitive with costs for existing sources of energy in the Lakeview area.

ACKNOWLEDGMENTS

There are numerous individuals who have made significant contributions to the development of this study. We wish to express our appreciation for their assistance.

First, Northwest Geothermal Corporation has provided excellent cooperation and input to several aspects of the analysis. Specific acknowledgment is made to Messrs. Paul H. Howe, Carl N. Petterson, H. Jack Meyer, Wilford F. Covert, and Edward D. Rowan.

Ms. Debra L. Justus conducted the in-depth analysis of institutional factors. Dr. David A. Sommers of Hydrosciences, Inc. assembled and evaluated information concerning the area's hydrothermal potential. Mr. Jay Hook contributed to the geologic and hydrologic analysis.

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I. SUMMARY

Lakeview, Oregon, is located in the Warner Valley region of south-central Oregon. The population of the Lakeview general service area is about 3,200 people. Historically, the regional economy has been closely tied to the utilization of its natural resources; lumber and wood products, mining, livestock raising, and farming have all been major regional economic factors. Hot water utilization in the region dates back to the decade of the 1920's. Currently, a substantial interest is being expressed to develop a geothermal district heating system to serve the Lakeview area. Northwest Geothermal Corporation, a subsidiary of Northwest Natural Gas Corporation, has obtained a geothermal utility franchise to develop a district heating system to serve the town. The purpose of this study is to determine the technical, economic, and institutional feasibility of constructing and operating a district heating system to serve the residential, commercial, and industrial sectors in Lakeview.

A review and analysis of existing geologic and hydrologic data and literature indicate that a geothermal water resource likely exists in the region capable of supporting substantial development. Water temperatures at 200°F are estimated at depths ranging from 600 to 3,000 feet, depending on the well location chosen. The water quality for district heating application is good.

Two feasibility-level geothermal designs are presented as alternates for the Lakeview area. First, the Base Case design includes generally the same service area as does the current municipal water system. A second design, designated as the Mini-district case, serves the downtown core business area and represents service to a more concentrated block of energy users. This minimizes distribution costs relative to the energy load served.

A significant energy user base is important to the economic soundness of a district energy supply system. Domestic, small commercial, municipal, and larger industrial users were sought as prospective energy customers in the systems. A favorable mix of these different types of users helps to insure the necessary revenues on a year-round basis; this tends to level out what can be extensive seasonal fluctuations of peak energy to average energy demands.

The analysis of potential industrial users indicates an attractive possibility for design adaptations to supply process heat energy to a proposed ethanol motor fuel plant. The plant is planned to use locally grown grain as its feedstock. The anticipated energy demand of this facility, which is to be supplied by the proposed geothermal system, is 1 million Btu per hour, 330 days per year. Geothermal applications to lumber kilns were not economically viable. The potentials for conversion of wood wastes to alcohol fuels were also reviewed; these processes are either technically and commercially not proven, or the processes do not match effectively with the Lakeview geothermal resource supply temperatures. Additional light industrial applications such as the greenhouse operation, aquaculture, and commercial mushroom production may be economic but require additional product market analysis.

The preferred heating district design is based on indirect geothermal heat supply. The geothermal system design presented includes production wells and injection wells, gathering lines, heat exchanger units, and a closed-loop system of delivery and return lines necessary to serve the potential customers. The proposed disposal of the cooled geothermal waters is by injection back into the groundwater aquifers; therefore, existing water-use patterns will be maintained. The analysis of piping materials for the system indicated either insulated thin-walled steel pipe or alternately insulated fiberglass pipe would be acceptable for the proposed use at competitive costs. Standard space heating and hot water heating systems capable of utilizing the geothermal water in individual homes and businesses are available at reasonable cost. Federal and State tax credits are available to owners and could cover up to 70% of the initial cost of the conversion. The closed-loop system of delivery and return lines will carry high quality city water; therefore, public health and safety risk, and corrosion or scaling risk are nil.

The Base Case design is sized to serve 1,170 residences, 119 businesses, and the proposed alcohol facility. The peak design meets a demand of 118 million Btu per hour at geothermal production rates of 4,800 gpm. The system's estimated annual energy consumption is 183,000 million Btu per year. Total system costs are estimated at $11.3 million; a cost analysis conforming with standard utility accounting practices was performed and indicates delivered energy costs of $8.20 per million Btu. This is based on a required 10% return on investment on equity capital.

The Mini-district design serves a peak load requirement of 16 million Btu per hour with an estimated average annual use of 17,000 million Btu per year. Total costs of this system are estimated at $1.23 million. Projected delivered energy costs for this case are $10.30/million Btu. Current costs of alternate conventional energy supplies range from a low of $8.76 per million Btu for electricity to a high of $13.62 for residential propane use. This latter figure is corrected for combustion inefficiencies at the 4,700-foot Lakeview altitude.

The geothermal cost presented must be evaluated in the perspective of a national shortage of fossil fuel resources. The cost of these resources is expected to rise in ranges of 7-10% per year which presently would account mainly for inflationary price increases and allows little room for supply-and-demand forces raising fossil fuel prices. Geothermal systems should not experience increasing costs to the same extent as fossil fuels, since geothermal costs are more exclusively associated with capital goods and labor. Current estimates suggest a geothermal increase of only one-fourth to one-third of the rate of expected conventional fuel increases.

In addition to the technical effort, a broad ranging institutional analysis of the Lakeview region was completed and indicates a favorable potential for this type of geothermal development. Environmental and socioeconomic factors do not suggest that significant impediments to such development exist. Socioeconomic considerations, in fact, are cited as reasons for pursuing municipal geothermal resource utilization. The general populace, including government and business leaders, appear to support the proposed action; most civic leaders view the development as an avenue to improve lagging economic conditions in the area. To insure a continued progress toward the final construction and operation of the system, permitting and regulatory requirements will need to be addressed in a well planned and timely manner.

The recommended plan for implementing geothermal energy supply in Lakeview is to initially proceed with the installation of the Mini-district system. This should prove out the technical feasibility and the economic advantages of the geothermal alternate, and act as a catalyst to the installation of the larger Base Case system in subsequent years. The schedule for permitting, final engineering design, construction, and startup is estimated for 10-19 months for the Mini-district use.

II. LAKEVIEW PROJECT BACKGROUND

A. Introduction

1. Physical Setting--The town of Lakeview, Oregon, is located in the Warner Valley region of south-central Oregon. Lakeview is situated approximately 335 miles southeast of Portland, 96 miles east of Klamath Falls, about 15 miles north of the California border, and at an elevation of 4,860 feet. Figure 1 illustrates the geographic location of Lakeview relative to the States of Oregon and Washington. Lake County, for which Lakeview is the County seat, is the third largest county in the State, covering over 8,300 square miles. The topography within the county varies substantially. Lower elevations in the plains regions are about 4,300 feet above sea level; the terrain rises to over 8,400 feet in the Warner Mountains. Lakeview is in the more moderate climatic zone of the region.

The population of the incorporated town is about 2,800; the population of the Lakeview general service area is close to 3,200 people. Lake County exhibits a total population of between 6,500 and 7,000 people.

The general climate in this high eastern region of Oregon is cool and dry. The winters are fairly severe; Lakeview's all-time recorded low temperature is -22°F, and it averages 7,079 degree-days per year. The frost-free growing season is short, averaging about 100 days; historically, frost has occurred in every month of the year. Summers are moderate and sunny. Precipitation averages 14.1 inches annually, most of which occurs during late fall, winter, and early spring.

The Lakeview area is served by a branch line of the South Pacific Railroad, one motor carrier, and a stage line. An airport located approximately 5 miles west of the town is utilized for both charter air service and commuter flights.

2. Review of Economic Base and Principal Industries--Historically, the economy of the Lake County region has been closely tied to the effective utilization of its varied and considerable natural resources. Significant examples are the production of lumber and wood products, livestock raising, farming, and mining, especially of uranium; these have played important roles in supporting the local economic base. More recently, government employment, tourism, and recreational activities have also come to contribute substantially to the economy. Currently, a variety of new industries are actively being sought to establish operations in Lakeview, in order to diversify and strengthen the area's economy.

3. Brief History of Local Geothermal Resource Use--Records of hot water springs in the Lakeview area date back to the turn of the century. Hunter Hot Springs, located about 2 miles north of the town, was the object of commercial activity as early as 1923. Dr. H. A. Kelty and several associates undertook construction of a sanatorium with the intent of using the reputedly therapeutic waters of the hot springs for the treatment of patients. Exploratory well-drilling activities initially resulted in the creation of one geyser. A fourth well was successfully drilled approximately

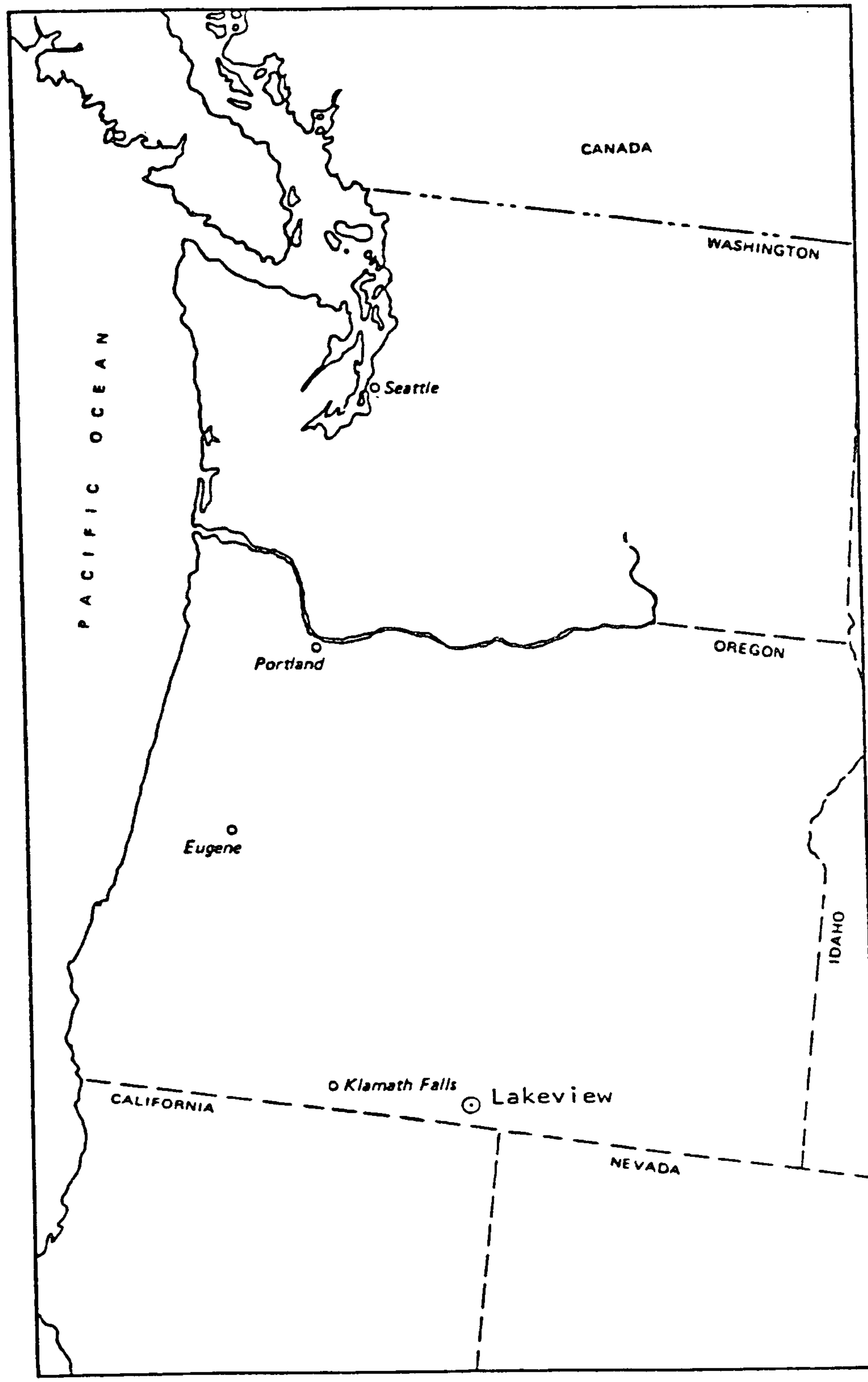

Figure 1. Lakeview Location Map

1/4-mile to the northeast and has satisfactorily supplied hot water for heating Hunter's Lodge for 57 years. Currently, six residences located near the Lodge, and the Oregon Desert Farms' greenhouse located approximately 1/2 mile east of the hot spring, are also successfully heated via geothermal energy using individual, private wells. These users obtain water temperatures ranging from 170°F to 205°F, and cumulative flows of about 600 gpm. The used water is discharged to the surface in ditches draining to nearby fields.

A group of 15 large homes, referred to collectively as the Goldmohr Terrace district, were at one time heated by a small geothermal heating system. However, the majority of these homes have since been switched to conventional heating systems due to pipeline scaling problems and associated frequent interruptions in water supply flows.

In Lakeview, itself, a 42-year-old well has supplied warm water for use in heating the municipal swimming pool. The well was drilled in 1938 to a total depth of approximately 2,300 feet; downhole temperatures of nearly 200°F have been logged. Other geothermal resources south of Lakeview include the Rockford Ranch and Barry Ranch Hot Springs. The Rockford Ranch, which is located 12 miles south of Lakeview on Highway 395, is irrigating with 170°F water at pumped flows of 400 to 600 gallons per minute. The Barry Ranch Hot Springs, located only about 1 mile south of Lakeview, has a 193°F maximum water temperature, poorer quality waters, and it is not extensively utilized.

To summarize, previous uses of the geothermal resource in Lakeview are documented for many years; these uses are principally for space heating and, except for the municipal swimming pool, the users are localized in the northern regions near Hunter Hot Springs. No significant operating industrial applications have been identified.

B. Program Objectives

The current interest for developing new systems to extensively utilize this important resource is substantial. In 1978, the Northwest Geothermal Corporation, a subsidiary of Northwest Natural Gas Corporation, applied for and received a geothermal utility franchise to serve the town of Lakeview. Public acceptance of the potential development is high. The purpose of the current study is to determine the technical, economic, and institutional feasibilities of establishing a geothermal district heating system to serve the residential, commercial, and industrial sectors in Lakeview.

III. GEOTHERMAL RESOURCE ASSESSMENT

Chapter III discusses the geologic and hydrologic information that serve as the basis for an evaluation of the Lakeview geothermal resource for use for district heating. The geologic information in this chapter is drawn largely from a report by Hook and Myer (12) for the Northwest Geothermal Corporation (NGC) and from a preliminary analysis by NGC (27). Hydrosciences, Inc. of Lakewood, Colorado, also analyzed well performance and geologic data to evaluate the resource hydrology. Section A, as follows, is a summary description of regional geology; Section B focuses on local geologic detail, temperatures and distribution of hydrothermal resources, and the hydrology of Lakeview's underlying geologic structures. Section C discusses the conclusions and assumptions which form the design basis for the proposed district heating system.

A. Regional Geologic Summary

The predominant structural feature of the Lakeview vicinity and surrounding mountains is extensive normal faulting. Two major types of faulting are apparent. A series of northwesterly-trending faults (Denio-Eugene Fault zone) is the older of the two and resulted in vertical displacements of the order of 500 feet. A much more recent occurrence of faulting (Basin and Range) is northerly-trending. This latter activity resulted in vertical displacements of up to 5,000 feet, and gave rise to the horst and graben features of which the Goose Lake depression is typical. It is possible that some intermittent movement of the faults may still be occurring. For reference purposes, the topographic setting of Lakeview region is presented in Figure 2.

The Warner Valley, wherein Lakeview resides, is an alluvial basin with alternating, interfingered sediment beds of silts, sands, and conglomerates extending at least to depths of the order of 5,000 feet.

The town of Lakeview sits on a down-dropped block oriented along the northerly-trending Lakeview Fault, which rises toward the east at an angle of approximately 60° from the horizontal. East of the Lakeview Fault line is a bank of parallel faults within the Warner Mountain Range, so that the mountains resemble a series of blocks standing on edge that have been tipped to the side.

B. Resource Description

1. Geologic Detail--The manifestations of the Lakeview geothermal resource are closely associated with the Lakeview Fault, which constitutes the western baseline of the Warner Mountains. Lakeview is also distributed along this fault line, placing it in close proximity to the hot water resources. The geographic association of hot water springs and wells with the fault line is widespread. A considerable fraction of wells drilled in the lake sediments near the west side, and more generally on the lower mountain slopes on the east side, of the Lakeview fault line have produced warm to hot water.

These occurrences are not limited geographically to Lakeview. The Lakeview Fault is a small part of a major geologic feature extending tens of miles north and south of the town. Hot water manifestations occur along much of the fault line's total length.

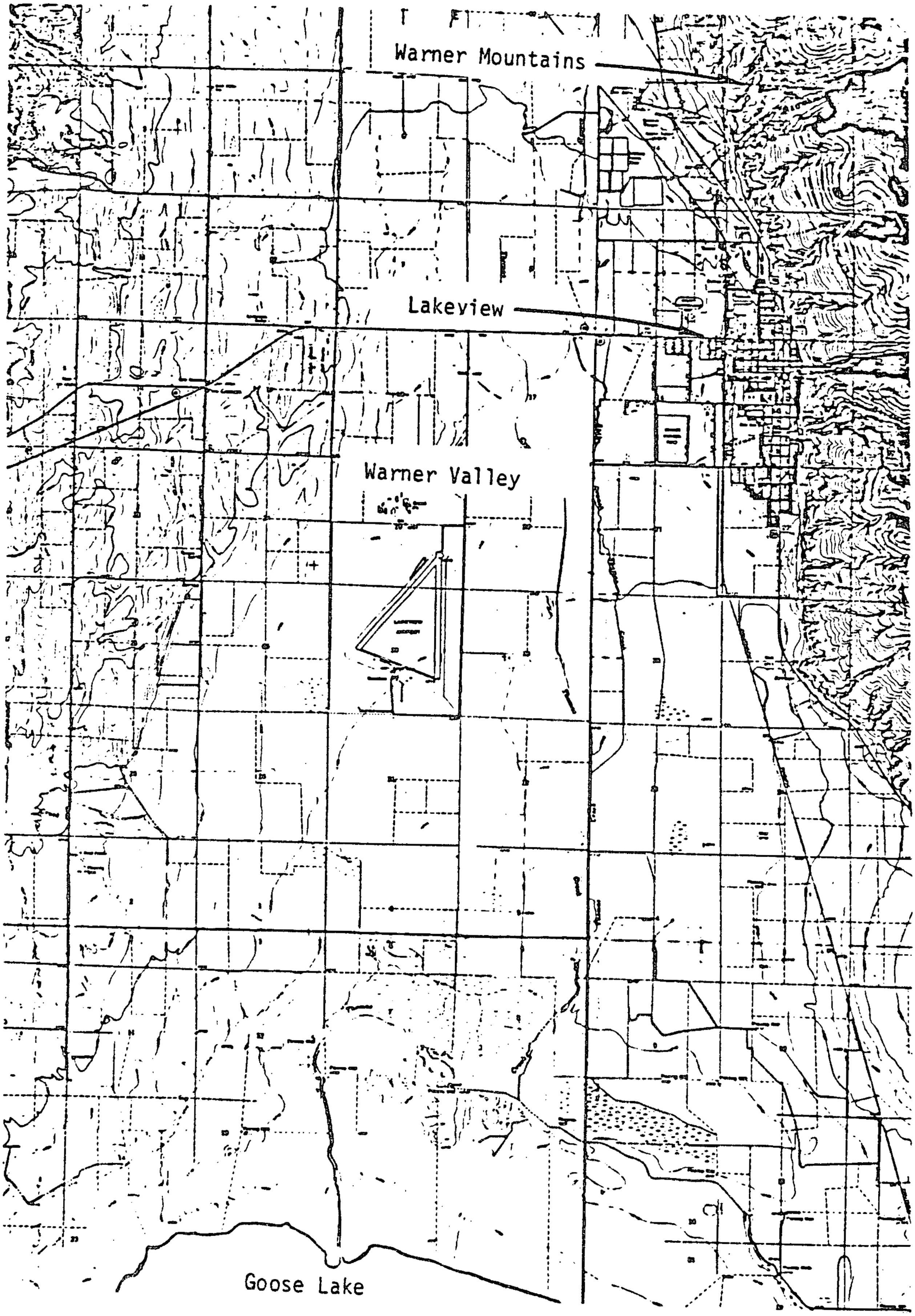

Figure 2. Topographic Setting of Lakeview, Oregon

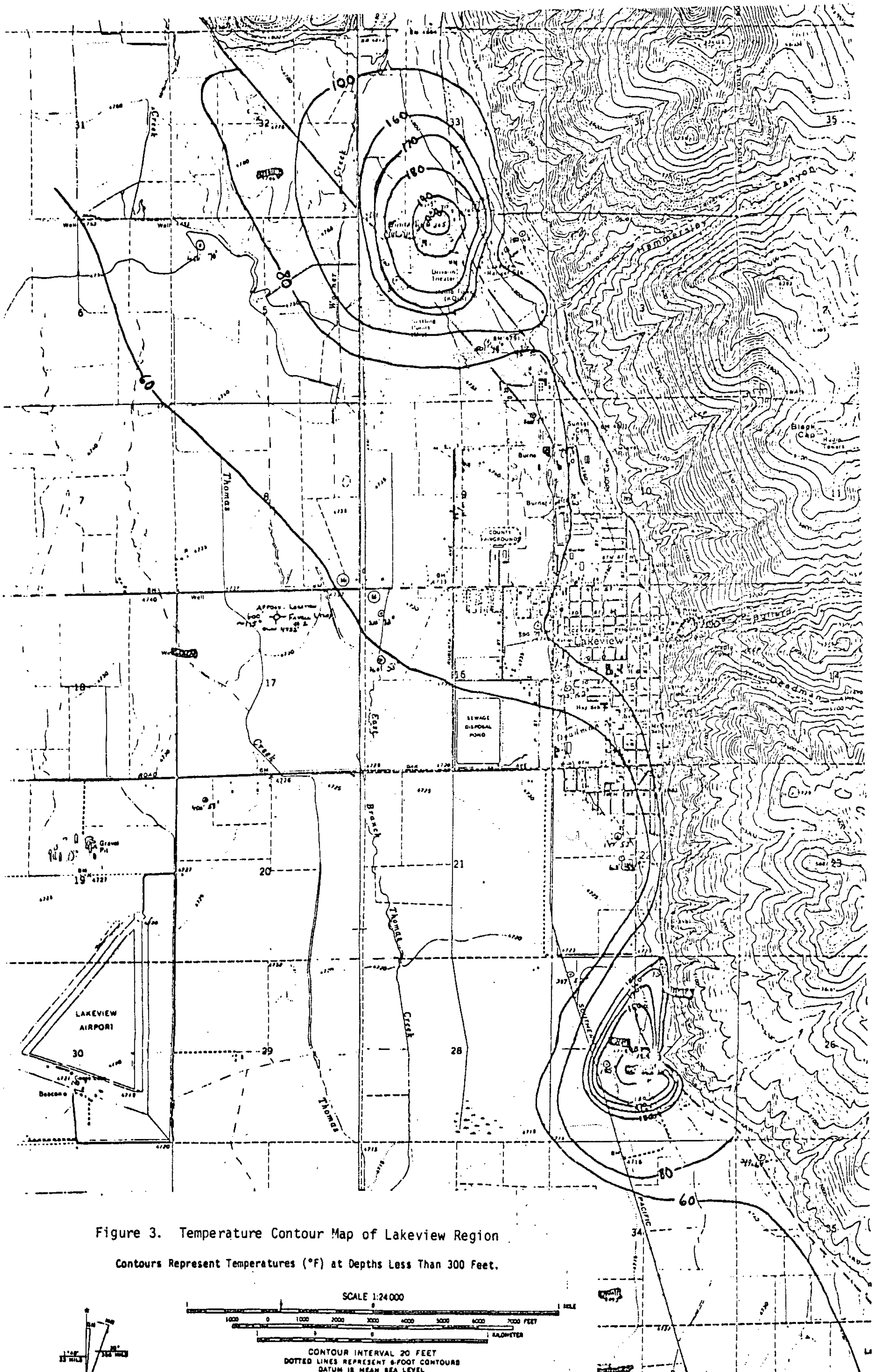

Figure 3. Temperature Contour Map of Lakeview Region

Contours Represent Temperatures (°F) at Depths Less Than 300 Feet.

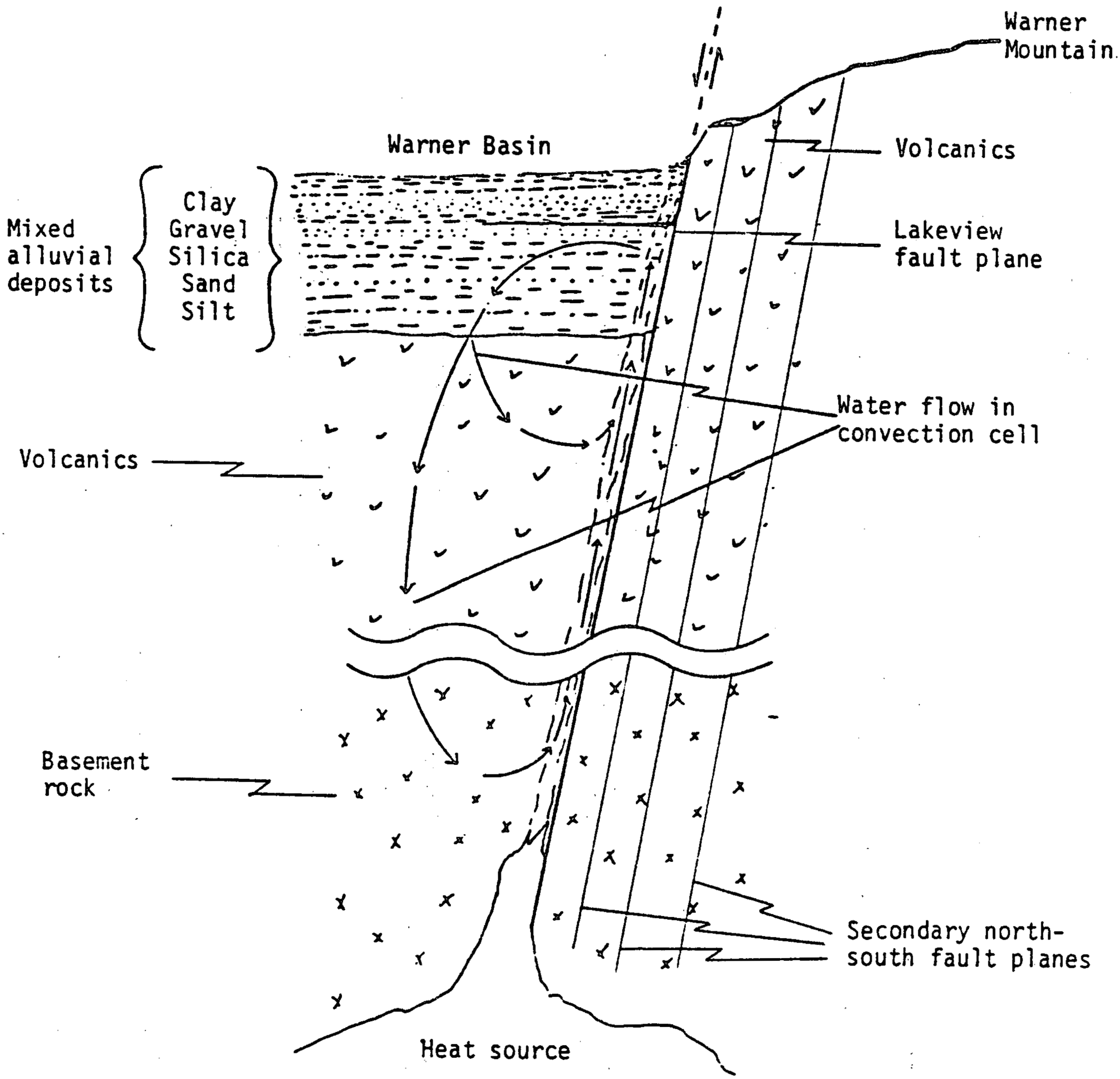

Figure 4. Conceptual Thermal Convective System

Numerous complex cross-faulting features exist along the north-south fault line. These features follow a northwest-southeast orientation. They are secondary in magnitude compared to the monolithic structure containing the Lakeview Fault, and are also thought to be older than the Lakeview Fault in most cases.

The specific Lakeview resource manifestations are associated with this cross-faulting. Figure 3 is a temperature contour map of the hydrothermal resource in the Lakeview vicinity. Two localized high-temperature sources on the Lakeview Fault line straddle Lakeview, separated by a distance of nearly five miles. The hot spots correspond nominally to Hunter Hot Springs and Barry Ranch Springs, north and south respectively, which flow at temperatures of about 205°F and 190°F. Surface features in the vicinity of the northern hot spot suggest a geologic structural block that was isolated and particularly affected by the combined effects of the two systems of faults described above.

The fault block is interpreted as the pronounced response to the nearly perpendicular shearing in the two sets of fault planes. This has locally produced significant geologic conduits for deep, heated water to enter the near-surface fractures of the mountain rock masses, which also supply the lake basin alluvial beds close to the plane of the Lakeview Fault. Figure 4 depicts an east-west cross section through a conceptual model of the geologic structures near Lakeview. The extensive faulting conduits as illustrated have facilitated the migration of water heated at great depths toward the surface where hot springs appear. Well drilling has also opened up pathways for heated water to move rapidly to the surface.

2. Depths and Temperatures--Wells in the vicinity of the two hot spots produce water at about 220°F from depths of 200 to 650 feet from the surface. Static temperatures have also been logged as high as 240°F at depths less than 650 feet. This variability of temperature-depth occurs within a radius of as little as 1/8-mile near the the Oregon Desert Farms well near Hunter Hot Springs, here the greatest number of hot wells have been drilled. Many of the hot wells are unlined bores into hard rock. It may be inferred from static temperature logs and flow data that there are multiple or extended production zones producing varied water temperatures in some wells.

Sources found in literature surveys (12) cite prediction of resource temperatures up to 315°F based on geothermometric analyses. Such prospects, although unsubstantiated, are attractive for future consideration.

Between the two hot spots, lesser temperatures have been encountered in wells near the Lakeview Fault line. At the entrance to Bullard Canyon, about the midway point between the hot spots, the town has a 2,400-foot warm-water well used for the municipal swimming pool. The well has been tested and logged following repairs in 1979. Tests indicated downhole temperatures of 196°F at 1,800 feet. After 10 hours of pumping and after the well reached static conditions, the downhole temperature was found to be only 146°F. Additionally, the reported wellhead temperature while flowing was of the order of only 100°F. These observations lead to two conclusions. First, a resource water temperature of 196°F is accessible. Second, the well is drilled into rock and not sediment. Therefore, the post-flow downhole temperature and flowing wellhead temperature indicate that hot water is entering the lower portion of the well probably from deeper depths via a fault, while cooler water is entering the upper portion of the well via separate fault fractures intersected by the well.

To summarize this and the preceding section, within the 5-mile span of the Lakeview Fault centered on the town of Lakeview, hot water is available at up to 240°F. At the north and south ends of the span, respectively, water of 220°F can be pumped from depths of 200 to 650 feet, and 190°F water issues naturally from springs. In the northern area, 240°F static temperatures have been logged at depths less than 650 feet. At the midpoint between the two hotter sites, water temperatures of 196°F have been documented at depths of 1,800 to 2,200 feet. Minimum resource temperatures predicted using geothermometry methods (Fournier, et al.) indicate a range of 180°F to 315°F. The lower of these two values would seem to be either overly conservative, or results from analyzing water produced by the mixing of thermally different waters, as exemplified by the swimming pool well.

The surface proximity of apparent rock-fracture conduits of hot water is very encouraging in terms of minimizing well costs to produce such water. However, due to the importance of the faulting and fracturing, and recognizing the lack of specific information on subsurface rock structures, further resource exploration will be necessary to identify the preferred well locations for meeting system design water temperatures, and for minimizing well costs and collection system pipeline costs.

3. Hydrology--This section discusses the results of a review and analysis of data and experience relating to groundwater availability and physical aquifer properties. The work includes estimates of attainable production capacities, injection capacities, and natural groundwater recharge mechanisms.

Currently, groundwater is produced from numerous wells in the lake basin. A 480-foot irrigation well drilled about 1-1/2 miles west of Hunter Hot Springs produces at rates of up to 4,000 gpm. Another irrigation well nearby produces up to 2,500 gpm. Also the Oregon Desert Farms greenhouse well has been pumped at 900 gpm at water temperatures of 222°F. These wells are north of Lakeview in the Hunter Hot Springs area. Volumes of this magnitude are not surprising because of the clastic nature of the Pleistocene lake sediments that underlie the surface. A test well drilled by Gulf Oil Company logged a sand body extending from at least 140 to 300 feet, and two 20-foot-thick gravel beds at 520 and 490 feet. The Lakeview swimming pool well differs from the preceding three wells in that the former are drilled in sediments, and the Lakeview well is in hard rock. The hard-rock wells produce from fractures and their productivity can be unpredictable. Well-stimulation techniques have not been applied, but may be considered to improve flow in hot but marginally productive wells.

Recharging of the aquifers occurs both vertically and horizontally. Vertical downward migration of water is related to the surface runoff from the mountains to the east and the west of the valley. Horizontal recharge is also expected from the mountains because of observations of interaction of the thermal and nonthermal water bodies. In total, this implies that the thermal waters may be adequately recharged by the combined supply of water from the lake basin sediments and the mountains.

C. Conclusions

The hydrothermal resources near Lakeview show good potential of having the volume and productivity needed to supply a district heating system and to permit disposal and partial aquifer recharge via injection of spent geothermal fluids.

Design water temperatures of 200°F at production rates of 870 gpm per well are estimated for 600-foot wells in the basin sediments at the Hunter Hot Springs and Barry Ranch Spring locations. To maintain similar temperatures, the required drilling depth may increase to 3,000 feet in hard rock at the mid-point between the two spring areas, corresponding to the eastern side of Lakeview near the central business district. The assumed design basis water temperatures, water chemistry, well production rates, and well depths are based on the combined data from the Hunter Hot Springs, the Barry Ranch Springs, and the Lakeview swimming pool well coupled with additional projections of increased water temperature with depth in the hard-rock drilling area for well sites located nearer the center of town. In hard-rock wells, production rate uncertainties exist; stimulation may be necessary to obtain the required flow rates. Recharge by natural means and by injection of spent fluid will preserve the integrity of all groundwater aquifers and current water uses; if properly designed, injection will not lead to production temperature declines due to short-circuiting of cooled water back into production wells.

Based on present knowledge of the thermal and nonthermal groundwater aquifers, and the complex faulting of the region, it should be noted that a substantive risk exists that any given well to be drilled may fail to meet one or more of the above qualifications. The extent of this risk will be quantified during resource exploration phases of the program.

IV. SPACE AND HOT WATER HEATING ENERGY DEMANDS

The design and sizing of the district heating system proposed for Lakeview is principally dependent on two factors: (1) the demand for energy for space heating and hot water heating applications; and (2) the demand associated specifically with industrial process uses. Chapter IV discusses the first of these two loads; industrial demands are discussed further in Chapter V.

The following analysis documents the market of potential geothermal heat users in Lakeview - the geographic distribution of potential customers, the seasonal fluctuation of heat demands, and current energy costs by source and user category. The projected energy demands are reviewed both for the Base Case system proposed to serve the entire community, also for the Mini-district heating system which is being proposed to serve the larger users located in the downtown region.

A. Projected Energy Loads

1. Estimated User Count--Base Case--The procedure for estimating the peak design capacity for the Base Case Lakeview system was twofold. First, the total number of residential and commercial users was identified. Second, loadings for each individual user were established and summed to provide the total system needs. Considerable effort was expended to establish a sound, fundamental basis for estimating the number of residential and commercial entities comprising the customer base for the proposed system. All existing studies pertaining to energy uses were reviewed. Principal to these are studies by Northwest Geothermal Corporation (28) conducted in 1978, a 1978 postal count , and a 1979 study conducted by Barry F. Norris which focused primarily on the commercial loadings of the downtown area. Coury and Associates, Inc. also independently conducted a review to confirm and complement the findings of the above studies. In this analysis, a block-by-block structure count of the town and fringe areas was performed. These were then compared to the results of the previous studies, and conclusions were developed based on sound engineering judgment.

The original Northwest Geothermal Corporation marketing study indicated a residential structure count of between 1,116 and 1,498. The lower figure is for Lakeview proper; the higher figure includes nearby fringe areas. That structure count included residences, multiple family dwellings, and mobile homes. Some of the structures identified as being in fringe areas are thought to be outside the normal service area of the proposed geothermal system. The postal count also conducted in 1978 indicated service to 1,516 units. This count is thought to be high in terms of the number of structures to be served, since more than one postal service unit can be at the same location. The Coury and Associates block-by-block structure count indicated 1,170 residential-type units. The 1,170 figure is consistent with the range of the Northwest study and somewhat lower than the postal count as one might expect. It was, therefore, adopted as the design basis number for residences to be served in the proposed district heating system.

With respect to commercial users, the Northwest study indicated a count of 209 commercial entities potentially to be served. The Norris study focused on 70 entities specifically located in the downtown region. Finally, the block-by-block structure count by Coury and Associates indicated a commercial structure number close to the original Northwest figure. Therefore, the estimated commercial users to be serviced was based on the 209 figure plus a projected additional loading of 20 warehouse units for the industrial park and one strong user in the form of a 1-million-gallon per year alcohol plant. This gave a total number of 230 commercial customers.

The Norris report provided data for 70 commercial users within the town. With an additional 29 users discussed in the Northwest report plus the projected warehouses and alcohol plant, 120 major commercial users for Lakeview have been identified. These 120 users provide the design bases for the Base Case commercial sector which represent about 85 percent of the total commercial requirement. The remaining commercial users will be of the small shop variety similar to residential units. The Base Case design will have the flexibility to service most of these other users if they so desire.

To summarize, the proposed Base Case geothermal district heating system is designed to fully supply the domestic hot water heating and the space heating needs for 1,170 residences, and 120 commercial users; this latter figure assumes a high percentage hookup of the major users in both the downtown area and the region immediately southwest of the downtown area. The results of the studies as discussed above are shown in Table 1.

TABLE 1. SUMMARY--SURVEYS, OF POTENTIAL GEOTHERMAL ENERGY USERS, LAKEVIEW, OREGON

Study	Date	Residential Count	Commercial Count
Northwest Geothermal	1978	1,116[1]-1,498[2]	209
Postal count	1978	1,516	--
Norris	1979	--	70[3]
Coury and Associates	1980	1,170[4]	120[4]

[1]Includes only Lakeview proper
[2]Includes fringe areas
[3]Addressed downtown commercial users only
[4]Chosen for design basis, includes projected warehouse units and alcohol plant

2. User Count--Mini-District--A second design basis was developed for a Mini-district to serve the concentrated commercial-municipal users

in downtown Lakeview along with the proposed alcohol plant. Based on the Norris report (25) and on additional work, the Mini-district is set up to serve 50 of the 70 commercial-municipal entities in the downtown region. No residential areas are to be served by this system. The purpose of this smaller system is twofold. First, it establishes the design and cost of the nucleus of a heating district for the most concentrated users. This minimizes fixed ditribution system costs. Second, it also provides the opportunity to "prove" the system on a smaller scale and to then act as a catalyst for pursuing the larger longer-term proposal to serve the entire city.

3. Residential and Commercial Peak Load Calculations

a. Climatic investigation and design temperatures--The methodology used for determining heating, ventilating, and air conditioning (HVAC) system design requirements and the overall economic feasibility of a proposed system requires the determination of two important system parameters. First, the design temperature and associated wind conditions, together with such factors as exposed surface area, insulation, and materials of construction, set the peak energy demands for each individual home. Design temperature levels are application dependent in that the appropriate levels can be different for industrial processes, as compared to residential systems or other space heating systems. This parameter is a most important input since it determines the physical size of the heating plant and, thus, the capital cost requirements for an energy supply system.

The second important factor of evaluating the rate of return on investment and, hence, the economic feasibility of a project is the calculation of the average annual energy consumption for a system. In the current study, the annual energy demand was determined using energy consumption data of existing homeowners and businesses.

For purposes of determining valid design temperature levels, the ASHRAE Handbook of Fundamentals data is accepted throughout the HVAC industry. For numerous selected communities throughout the United States, ASHRAE has determined winter design temperatures based on historical frequency of occurrence data; for buildings of normal heat capacity characteristics, ASHRAE recommends utilizing a 99 percent design level; i.e., that temperature level such that 99 percent of all winter temperature minimums would be above that level. A -3°F temperature represents the 99 percent design level for the town of Lakeview; that is the design value used in this study.

b. Residential Space Heat Peak Load Calculations--The initial step in establishing individual home and business geothermal heating system requirements is to document the space heating and hot water heating demands of the respective users. To do this, peak space heating and hot water heating requirements were estimated for an "average" or "typical" home; the Lakeview residential sector is fairly homogeneous and, therefore, the example system as discussed here should be applicable, with small modifications to most homes in the area. Most of the homes in Lakeview are older than 30 years. They typically are partially insulated. The average structure was assumed to be a one-story frame home with approximately 1,300 square feet of floor space. The floor surface area, dimensions, height, insulation, window area, and construction materials are important since the heat load analysis uses the basic heat transfer relationship as given in Equation 1 to calculate the heat losses.

The overall heat loss equation is:

$$Q = U \times A \times T \tag{1}$$

where

Q = peak residential heat loss in Btu/hr
U = heat transfer coefficient in Btu/hr-°F-ft
A = exposed surface area, ft
T = temperature difference between inside and outside conditions, °F

A -3°F design temperature was adopted based on documented weather data for the area. Assuming a 70°F inside temperature level, the ΔT would equal 73°F.

The individual heat loss calculations for all exposed surfaces are similar, with the value of U changing for each type of material. For example, the U value for a typical wall is calculated below. The heat loss must be calculated for the total surface area of walls, ceilings, roofs, windows, etc., individually. The results are then summed to evaluate total heat losses.

The total outside exposed wall surface area of the home is 980 square feet. The wall construction is framed of 2x4's supporting 1/2-inch sheettock on the interior, 3-1/2-inch dead air space in the walls, and 5/8-inch plywood outside covered with a wood siding. Table 2 gives the R-values of each layer of the building materials and the inside and outside air films. The sum of the R-values, for each distinct layer through which heat transfer occurs, is the inverse of the heat transfer coefficient, U. For this example, the overall heat transfer coefficient is 0.26 Btu/hr- F-ft . The resistance of the 2x4's was not counted, but the wood studding occupies up to 20 percent of the interior wall space; therefore, the value of U should be increased by about 10 percent, giving a U value of 0.28. The total peak heat flux through the walls thus calculated from Equation 1 is 20,000 Btu/hr.

TABLE 2. WALL CONSTRUCTION AND RESISTANCES
(R = hr- F-ft /Btu)

Outside film coefficient	R = 0.17
Outside wall siding	R = 0.81
5/8-inch plywood	R = 0.78
Air space	R = 0.97
1/2-inch sheetrock	R = 0.45
Inside film coefficient	R = 0.68
Total	3.86

Similar computational procedures were used for the doors, windows, ceiling, and floor. Ten percent of the wall area was assumed to be windows. Windows were all designated as single pane; ceilings were assumed to be insulated to R-11 values. Roofs were assumed to comprise composition shingles over plywood sheet. Finally, outside air infiltration was assumed to equal 9.6 Btu/hr per square foot of floor surface, based on ASHRAE standards.

The total home peak heat loss was then found by adding the six heat loss components as summarized in Table 3. The total calculated loading is to 55,000 Btu/hr. Using a 20,000 Btu/hr maximum hot water heating demand, the design energy demand for each 1,300 foot typical residence was calculated at 75,000 Btu/hr.

TABLE 3. PROJECTED RESIDENTIAL PEAK HEATING LOADS

Component	Heat Loss (Btu/hr)
Walls	20,000
Doors	1,000
Windows	5,000
Floor	10,000
Ceiling, roof	7,000
Infiltration	12,000
Total	55,000

The peak residential heating value is used as the basis for the design of the district heating distribution system. Based on 1,170 residences, the peak design figure for the non-commercial sector is 88 million Btu/hr. Residential sectors are not served by the Mini-District as currently outlined and, therefore, they do not contribute to the peak demand of that system.

c. Non-Residential Space Heat Peak Loads--The commercial establishments and municipal buildings in Lakeview exhibit a much broader range of space heat demands than do residences; building construction characteristics are variable. All of the buildings in the central business district were surveyed by Norris (25) and additional buildings were surveyed by Northwest Geothermal Corporation under the present contract. Therefore, a large amount of actual energy consumption data are documented. Based on these data, a peak design basis of 30 million Btu/hr was adopted. This includes a 1 million Btu/hr demand projected for the proposed alcohol facility. For the Mini-District case, the peak design energy demand was calculated at 16 million Btu/hr as compared to the 30 million Btu/hr for the larger Base Case system. Because of the variability of heat loads within this group, the peak-to-average space heating ratio was estimated to be 8 based upon standard engineering practices.

4. Average Annual Energy Use--To develop a good basis for the projected annual energy consumption for the residential and commercial-municipal sectors, energy data were collected in interviews with homeowners and commercial-municipal facilities operators. Data was gathered for 99 commercial-municipal entities and for 129 single-family homes in Lakeview. The data obtained from these users include energy consumption, either in the form of utility costs or in units such as gallons of oil or cords of wood. Wherever possible, the data were organized to segregate the amount of heat required for hot water production. The space heating systems were described by type, and the energy source was identified in each case for both the space heating system and the water heater.

The survey results indicates total annual domestic hot water heating load of 3,350 million Btu's for 89 of the homes for which hot water data were available and a total annual space heating load of 9,520 million Btu's for the 112 homes for which space heating data were available. Thus, the average hot water heating load is 31 percent of the combined space and water heating load.

The portion of the energy market made up of commercial-municipal facilities is much less homogeneous than the residential sector in its energy-use patterns. Therefore, annual energy loads were assigned on the basis of explicit survey data (32). The Base Case average annual energy was documented as 37,500 Btu/hr including industrial users.

To summarize, both total peak design values and total annual energy consumption estimates have been developed for both the Base Case and for the Mini-District. These design values are presented in tabular form below.

TABLE 4. SUMMARY OF ESTIMATED ENERGY REQUIREMENTS FOR BASE CASE AND MINI-DISTRICT SYSTEMS

	Heat Loads	
	Peak (10^6 Btu/hr)	Annual (10^6 Btu/yr)
Base Case	118	183,000
Mini District	16	17,000

B. Geographic Distribution of Users

The routing of the distribution piping network was developed from user information obtained from previous surveys and from additional work conducted as part of the current study. The users were plotted on a detailed map of Lakeview. Routing of major trunklines was established to service the overall user areas. Branch lines were then located so as to serve the various segments of these areas. Detailed layout maps identifying major trunklines and branch lines are shown in Figures 7 and 8, Chapter VIII, for the Base Case and for the Mini-district respectively.

C. Seasonal Heat Load Fluctuation

The effect of seasonal temperature changes on the geothermal system was also evaluated. The seasonal demand for space heat is proportional to the seasonal distribution of heating degree-days. Experience has shown that for buildings requiring an inside air temperature of approximately 70°F, the amount of fuel or heat energy input required per day is proportional to the number of degrees the average outside temperature falls below 65°F. Thus, by definition the number of degree days per day, 65°F base, is the difference between 65°F and the daily mean temperature when the latter is less than 65°F. Likewise, the number of degree days for longer periods, such as for 1 year, is the summation of the daily degree days for as many days as the period covers. Data were obtained from the National Weather Service giving the average occurrence of degree days on a monthly basis for a 30-year period. These data and the distribution of space heating demand are shown in Table 5 .

TABLE 5. DISTRIBUTION OF HEAT LOADS BASED ON DEGREE-DAY OCCURRENCE

	Degree Days[a]	Demand (Quantity Energy)[b]
December	1,100	-
January	1,200	-
February	900	43
March	900	-
April	600	-
May	400	17
June	200	-
July	100	-
August	100	6
September	200	-
October	500	-
November	800	34
TOTAL	7,000	100

[a] 30-year average values for Lakeview; National Oceanic and Atmospheric Administration.
[b] Percent of annual average heat load consumed quarterly.

D. Alternative Energy Costs

The June 1980 costs for the various available energy sources in Lakeview are given in Table 6 . Costs for conventional space heating fuels range from $8.76 to $13.62 per million Btu. The energy costs for combustion levels represent actual heat delivered per unit, accounting for a net combustion efficiency of 60 percent. This efficiency rating is appropriate to correct for a normal 80 percent furnace efficiency and the subsequent loss of 4 percent efficiency for each 1,000 feet of elevation above sea level.

TABLE 6. CURRENT CONVENTIONAL ENERGY COSTS

Fuel (Unit)	Commercial		Municipal (Schools-Hospital)		Residential	
	$/Unit	$/$10^6$ Btu	$/Unit	$/$10^6$ Btu	$/Unit	$/$10^6$ Btu
Propane (gal)	0.72	12.90	0.70	12.57	0.76	13.62
Oil (gal)	0.98	11.72	0.75	8.92	1.03	12.30
Electricity (kWh)	0.03	8.76		--	0.03	9.11
Wood (cord)					50.00	5.55

Heating values: 1 cord wood (pine) = 15 10^6 Btu; 1 gal oil = 140,000 Btu
1 gal propane = 93,000 Btu; 1 kWh = 3,410 Btu

E. Replacement of Present Fuels by Geothermal Heat

The estimated total heat loads for Lakeview presented in the chapter are obtained from the principal sources; oil, propane, electricity, and wood. The results of a survey of part of the domestic sector showed, in particular, that 53 percent of that sector's space heat load is supplied by wood. The distribution of annual heat consumption by sources is listed in Table 7 for both the Base Case system and the Mini-District. The Mini-District estimates are based on a full survey of potential users. The distribution of oil and propane use, overall, in the Base Case was assumed to be 75 percent oil and 25 percent propane.

Accumulated over a 30-year period, the use of geothermal heat in Lakeview would replace the equivalent of 39 million gallons of oil for the Base Case, and 4 million gallons of oil for the Mini-District case.

TABLE 7. ANNUAL ENERGY CONSUMPTION DISTRIBUTIONS

Base Case

Source	10^6 Btu/year	Equivalent Source Units
Oil/Propane*	51,000	398,000 gal
Electricity	79,000	23,000,000 kWh
Wood	53,000	3,500 cords
TOTAL	183,000	

Mini-District

Source	10^6 Btu/year	Equivalent Source Units
Oil	16,600	104,000 gal
Propane	200	4,000
Electricity	500	140,000 kWh
Wood	100	9 cords
TOTAL	17,400	

*Assuming 75 percent is oil, 25 percent is propane.

F. Interpretation of User Interest

The results of the survey of potential customers for a geothermal district heating system show that 28 percent of potential commercial-municipal users are interested in using geothermal energy; 75 percent of the homeowners surveyed expressed positive interest. These results are encouraging because they suggest a good likelihood for acquiring a large percentage of the domestic heating market. It is acknowledged that response from the commercial market is low. However, the opinions received were issued without the benefit of sufficient economic data necessary for a potential user to determine whether a geothermal district heating system will be cost effective. The encouraging costs of geothermal heating, as projected in this study, are grounds to anticipate a large commitment of potential clients to participation. Therefore, it is important to disseminate and explain to Lakeview's residents the essential economic conclusions of the study.

A. Introduction

The difficult economic conditions in Lakeview, Oregon, and the basic economics of geothermal energy utilization both contribute to a need for incorporating industrial users into the proposed geothermal system. Substantive industrial users are attractive to any geothermal system since an industrial base can make year-round use of this type of energy at substantial levels compared to seasonal space heat uses.

The current work effort, therefore, pursued a systematic analysis of potential industrial customers. Both industries, currently existing in Lakeview, and also proposed industries were included in the review. The Lakeview economy is heavily agricultural; therefore, good logic suggested that many of the industries considered should be of an agricultural orientation. Industries considered included lumber milling, chemical production from wood wastes, fuel alcohol production from grains, greenhousing, aquaculture, commercial mushroom production, feed lot operations, and dairy products.

With respect to proposed industries, the locating of industries in any specific geographic region is based on the favorable evaluation of numerous factors affecting the profitability of the particular enterprise. Energy costs and availability are certainly two of these factors, and with recent rapidly increasing conventional fuel costs, these factors are continuously gaining importance in the overall decision-making process. Nonetheless, other business factors remain important and will materially affect the final decision to locate at any one specific site. These other factors include labor availability, financing, raw material supplies, and product markets to name a few. Therefore, the process of systematically evaluating geothermal industrial park sites necessarily requires a broader review than to simply identify a site exhibiting an excellent geothermal resource.

A first cut review of these various energy and nonenergy factors indicated that geothermal applications to lumber milling, alcohol production from small grains, and alcohol production from wood wastes currently represent the strongest potentials for utilizing the Lakeview system. Each of these three potential applications are discussed with respect to their economic feasibility of converting to or hooking up the proposed geothermal energy supply system at Lakeview. The remaining industries which are judged to have lesser potentials for the Lakeview marketing area have been discussed previously in references (4, 5).

B. Lumber Kilning

Lumber milling has long been an important base of the Lakeview economy; there are currently four operating mills in the town. Of the various energy requirements in the milling operation, the only application for hot water at the present design temperature at 200°F is to provide heat for the lumber drying kilns.

1. Estimation of Heat Demand--The operators of the Lakeview mills were contacted to discuss the technical requirements for the kiln operations. The cumulative peak heat load for all the mills is about 30 million Btu's per hour. At an energy recovery rate of 50 Btu's per pound of geothermal water, this load would require a peak geothermal water supply of 1,200 gallons per minute.

2. Heating System Conversion Benefits--There are two parts to the determination of potential costs and savings for the lumber kiln owners, if the kilns were to be converted to a geothermal water heat source. First, the equipment to provide the needed geothermal heat must be designed and the capital and operating costs of that equipment estimated. Second, these costs considered together must then be compared to existing energy costs to judge the potential cost benefits in switching heat sources.

3. Conversion Costs--The conversion costs depend on the type of equipment needed to replace or augment what is now in place for heating the kilns. The kilns now are heated by 320°F - 410°F steam. This steam is used to heat air blown over coils or finned tubes. The conversion cost was determined by deriving the cost of additional heat transfer surface necessary to enable direct substitution of geothermal water for the steam. This assumes the required heat transfer tubing can be installed without significant modification to the kilns. It is also assumed that existing tubing can be used without replacement. When comparing the steam to geothermal water as heating media, these calculations indicate the hot water system requires a total additional heat transfer area of the order of 200,000 square feet to handle the cumulative duty of Btu's per hour. Cost data was obtained from manufacturers. Finned tubes could be obtained with 5 square feet of transfer surface per lineal tube foot, at a cost of about $2.40 per lineal foot. Therefore, the added heat transfer area would cost $140,000.

4. Current Operating Costs--The mills have effectively no fuel cost, as they burn their own waste wood, with excess left over to sell. Since wood wastes are combusted for fuel, the present costs of operation of the lumber kilns are limited to boiler maintenance costs, and electrical costs for operating a hogging machine to reduce the size of waste wood chips to meet the boiler feed requirements. Based on information from the operators in Lakeview, these costs are estimated at about $146,000 per year.

To estimate the net operating costs for a geothermally heated kiln, the cost is estimated as the total charge for the energy by the district heating system operator, assuming a cost of $8.20 per million Btu's. The total annual expense for the delivered geothermal energy, not including retrofitting costs, is approximately $2,150,000. Using geothermal heat, the mills will incur some net credit, because the wood waste formerly burned may be sold at a value of $30 per oven-dry ton. The wood waste used for firing the boilers to provide the total annual heat load amounts to 17,000 oven-dry tons. The annual credit for sale of the unburned wood waste is $513,000.

5. Comparison of Costs--We have calculated three costs: the cost for conversion to geothermal kiln heating, the present conventional kiln operating cost, and the net cost of geothermal heat, giving due credit for sale of the unused wood waste boiler fuel for alternate use. In summary, the kiln owners would have to pay $140,000 to convert to a geothermal kiln heating system, and thenceforth they would pay more than $1,496,000 per year in net energy costs for the geothermal heat. On this basis, geothermal heating of lumber kilns is judged to be uneconomic. Therefore, this application was eliminated from further consideration and was not included in the proposed system designs.

C. Fuel Ethanol Production from Small Grains

A 1-million-gallon per day fuel alcohol plant is currently being proposed for the Lakeview region. The plant is proposed by a local farm equipment supplier, Ag Center, Inc. Mr. Don Liddycoat is the project manager. The plant will use locally produced grain as a feedstock to make transportation fuels. A 1-million-Btu/hr energy demand from this plant is designed into the Base Case design and the Mini-district design of the proposed geothermal system. The 1-million-Btu/hr figure does not constitute the complete energy requirement for the plant, but rather comprises moderate temperature inputs in temperature ranges of 180°F to 200°F. For purposes of providing further insite into ethanol production requirements, a brief discussion of the process and its associated energy requirements is provided below. The discussion first described a conventionally fueled plant; following that review, the basic considerations for adapting a design to geothermal energy are presented.

The production of ethanol from agricultural commodities is currently receiving numerous notices as a potential energy source capable of helping to alleviate the oft-predicted shortage of convenient hydrocarbon fuels such as gasoline. Ethanol could, for example, supplement gasoline in a 10% ethanol-90% gasoline mixture commonly called gasohol. This utilization could also simultaneously create a continuing, stable market for grains such as wheat or barley. This is especially important for an area such as Lakeview where the plant feedstock supplies would come from local sources.

However, a major limitation of the production of ethanol from agricultural products is that the ratio of energy produced to energy consumed, both as concentrated hydrocarbon fuels, is conventionally low for plants deriving process energy from the combustion of coal, oil, or gas. In other words, it is desirable to minimize the consumption of the fossil fuels in the production of the alternative hydrocarbon fuel, ethanol. Geothermal energy can provide substantial portions of the energy requirements of the ethanol production process, thereby greatly improving the net ratio of production to consumption of hydrocarbon fuels. For purposes of evaluating Lakeview potentials, the ethanol production process was first analyzed to determine the magnitude and distribution of its energy requirements and the means by which geothermal energy could supply these needs.

There are four basic steps in the standard process for production of alcohol via fermentation-distillation. Figure 5 illustrates these steps, which are described briefly here. The process steps consist of saccharification, wherein the starch of a grain feedstock is taken into aqueous solution and is converted to a simpler carbohydrate, sugar; fermentation in which the sugar is biologically converted to ethyl alcohol and carbon dioxide; distillation, wherein most of the water added in the earlier steps is removed; and dehydration, in which the remaining water is removed.

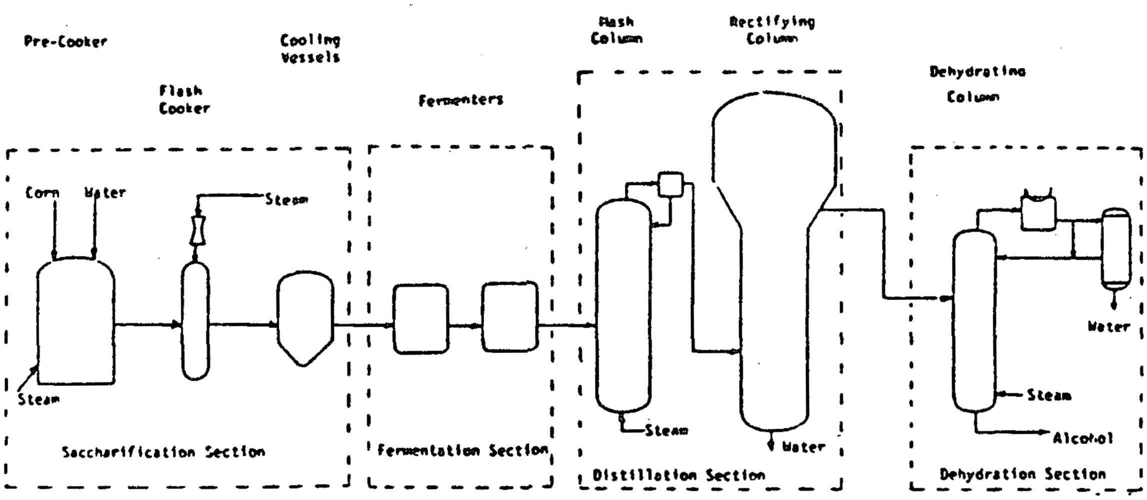

Figure 5. Schematic Diagram of Ethanol Process

1. Saccharification--The saccharification step involves cooking the grain in a water solution to high temperatures. This is necessary to extract the starch material from the cell of the grain. Once removed from the grain cell, the starch is converted to sugar by the addition of yeast and a suitable enzyme. This process requires temperatures of 320°F for a 30-second cooking time. The cooking temperature can be lowered to about 220°F; however, the cooking time increases to several hours and this could increase equipment costs. In the conventional process, the 320°F temperature is provided by pumping the grain slurry through an ejector, where it is instantaneously heated to its cooking temperature by addition of 320°F steam. Subsequent to the cooking step, the slurry is flash cooled to 90°F-100°F temperature levels in two stages prior to fermentation. The 230°F flashed steam collected during this cooling is reused later in the distillation and dehydration processing steps.

2. Fermentation--The fermentation step consists of adding a yeast to the sugar solution produced from the saccharification step and providing enough residence time for the yeast to convert the sugar to alcohol according to the following reaction:

$$C_6H_{12}O_6 \xrightarrow{\text{yeast}} 2C_2H_5OH + 2CO_2$$

The solution entering the fermentation tanks is cooled to 90°F and additional cooling water is used during fermentation to remove some of the heat of reaction evolved, in order to maintain an optimal temperature for fermentation to occur. No thermal energy is added to this step from any outside heat source.

The product from the fermentation step is called beer and consists of a solution of 5-12 percent alcohol in water.

3. Distillation--The distillation step consists of separating the water from the alcohol and other minor products produced during fermentation. The distillation takes place in two main columns called the mash column and the rectifying column. The mash column is operated at atmospheric pressure and produces approximately 40-percent alcohol vapor steam overhead as feed to the rectifying column. The bottoms from the mash column is water which contains some suspended solids. The suspended solids are removed by a centrifuge, and the wet cake produced can be used as animal feed.

The heat input required in conventional systems is usually supplied by the injection of 230°F steam directly into the bottom of the mash column.

The rectifying column operates under a vacuum. The overhead consists of the lighter boiling components and the bottoms consist of water. The main ethanol stream is removed as a sidestream draw near the top of the tower and higher boiling components called fusel oil and consisting primarily of other alcohols are removed as another sidestream draw further down the column.

The heat input to this column is supplied by condensing the vapors from the mash column prior to feeding them to the tower.

Ethanol and water form a constant boiling azeotrope so that the ethanol withdrawn from the rectifying column is restricted to 96-percent ethanol and, in actual practice, is normally about 95 percent.

4. Dehydration--The dehydration step removes the remaining water from the ethanol. This is usually accomplished by adding a component such as benzene, cyclohexane, or gasoline, which forms a minimum boiling ternary system. This allows absolute ethanol to be removed as a bottoms product in a distillation column. The overhead containing the benzene or other additive, water, and ethanol is condensed, and decanted. The organic layer is returned to the distillation column and the water layer is further distilled to remove the small amount of organics present. The source of heat for the distillation columns in the dehydration step is usually 230°F steam, which is condensed in conventional reboilers.

5. Adaptations to Moderate Temperature Geothermal Resources--The modifications which must be made to the standard process so that it can be adapted to geothermal resources are usually not major ones, and depend on the temperature of the geothermal heat source. In the cooking section, which is that portion of the process requiring the highest temperature inputs, a countercurrent heat exchanger replaces the steam ejector of the conventional facilities. The heat exchanger is used to extract sensible heat from the liquid brine. For moderate temperature geothermal waters in Lakeview, the cooking water temperatures may need to be boosted through the use of conventional heating equipment. This type of geothermal-fossil fueled combined system has the potential for providing the necessary energy at attractive rates as compared to standard off-the-shelf systems.

As in the conventional case, the cooked slurry is flash-cooled prior to fermentation. Again, this is important in that the flashed steam from this cooling step, as well as flashed steam from geothermal waters, are then utilized later in the distillation and dehydration processing sections. If the 180°F-200°F geothermal waters are not boosted fully to the 320°F-350°F level, the cooker would have to be increased in size to accommodate the longer cooking time associated with the use of lower temperatures. This would constitute an economic trade-off between operating energy costs and capital equipment costs.

The adaptation of geothermal energy to the distillation and dehydration processing steps can be made with only minor modifications, again the only difference being the origin of the heating steam. In the conventional process, steam is supplied from the boiler; in the geothermal case, steam is supplied by flashing 300°F-310°F geothermal brine from the saccharification section in a flash vessel. Thus, the only additional piece of equipment specifically required because of the geothermal heat source is the flash tank. If lower cooking temperatures are used, it is not practical to flash the brine because not enough 230°F steam can be produced per pound of geothermal water. In this case, liquid-liquid heat exchangers could be used.

One final energy demand, not previously discussed, is the drying of the distiller's dried grain (DDG) by-products. These DDG by-products are normally used as a cattle feed supplement. Conventional drying temperatures are usually high--often in the range of 1,000°F-1,200°F. Geothermal waters could be used for preheating or more directly as the actual drying heat source. In the latter case, an additional economic analysis would have to be performed in the final engineering design to justify the additional capital cost associated with the substantial additional heat exchanger areas reouired.

The ethanol production process in a well-designed plant usually requires between 60,000 and 90,000 Btu per gallon of alcohol produced. Assuming a 90-percent plant availability, i.e., 330 days of operation per year, a 1-million gallon per year plant would produce 126.2 gallons per hour of product alcohol. Thus, a total energy demand ranging between 7.6-11.4 million Btu per hour could be expected. Since geothermal energy represents only a partial heat source to the facility, a 1-million Btu per hour demand was designed into the proposed district supply system. In summary, the proposed fuel alcohol plant represents an attractive example in which the proposed geothermal energy district can play an important role in bolstering the local economy by providing a long-term cost-effective energy supply.

D. Industrial Chemical Production from Wood

A third industrial process considered for the Lakeview region is for using wood waste feedstock for conversion to chemicals, particularly to organic liquid fuels such as ethyl alcohol, which could replace some oil and gas fuels currently imported to Lakeview. A literature survey was conducted to determine what processes should be considered for commercial conversion of wood to chemicals. Although there are several sources of information on this subject, the major study was done by Raphael Katzen Associates (11), and most other studies use the findings developed by Katzen.

This Chapter gives a brief discussion of the various wood-conversion processes and then focuses on the hydrolysis and fermentation technology because it is most adaptable to using geothermal energy. The review also identifies some of the numerous research and development programs which are currently being conducted in the field of cellulose hydrolysis. Most of these programs are only developed at the laboratory or bench-scale level, which does not facilitate scale-up of the processes' designs to a commercial size.

1. Wood Chemical Conversion Processes

a. Gasification--Production of methanol from wood using a gasifier is a complex process involving high temperatures and pressures and costly process equipment. The basic steps of the process consist of the following:

1) Gasification of the wood at 2000-3000°F to produce a Syngas which consists of CO, H_2, CO_2, N_2, and some organic species.
2) Removal of the CO_2, N_2, and organics with several scrubbing steps and a cryogenic separation step.
3) Reaction of some CO with water to produce additional H_2 to achieve proper CO to H_2 ratio needed for methanol reaction.
4) Removal of CO_2 formed in water shift reaction.
5) Reaction of CO and H_2 over a zinc catalyst at 600°F and from 1500 to 5000 psig to produce methanol.

The process is not presently economically competitive with other sources of producing methanol, and because of the temperatures and pressures involved it is not suited to the application of geothermal energy.

b. Hydrogenation--Hydrogenation of wood to produce phenols was mentioned by Katzen, but no process information was given. The process is still in the development stages. Most hydrogenation reactions, however, require high temperatures and pressures. This factor, along with the requirement of a source of hydrogen, make this process unsuitable to the application of moderate-temperature geothermal energy in Lakeview.

c. Hydrolysis and Fermentation--Hydrolysis reactions break down the cellulose portion of wood into sugars which can be fermented to produce ethanol. However, the yields of the fermentable sugar are relatively low without significant pretreatment, and the overall economics of this process are dependent on developing markets for the other chemical components which are produced. Some by-products, such as furfural and methanol, have established market values; other materials, such as lignin and pentose, have been much evaluated in regard to their potential for use as a boiler fuel and livestock feed supplements, respectively.

Hydrolysis and fermentation use fairly large amounts of energy, and since the operating temperatures and pressures are predominantly in the low to medium range, there is a definite potential for using geothermal energy. For this reason, this technology will be considered in greater detail.

2. Ethanol from Cellulose via Hydrolysis and Fermentation

a. Process Chemistry Summary--Wood consists principally of cellulose, hemicellulose, and lignin. Only the cellulose portion may be converted to ethanol by conventional fermentation. In order to accomplish the conversion step, it is necessary to break down the cellulose portion, and usually to separate it from the other wood components.

The addition of an acid will hydrolyze both the hemicellulose and cellulose portions of the wood. They are converted to simpler carbohydrate forms, which are soluble sugars known as pentose and hexose, respectively. This step is called saccharification. The lignin remains as a solid. The hemicellulose is more easily hydrolyzed by the acid than the cellulose, and the conditions which are necessary to hydrolyze the cellulose will also cause some further degradation of the pentoses to furfural and methanol. The extent to which these simultaneous reactions occur can be varied by changing the acid strength, the temperature, or the residence time of the reaction step.

Hydrolysis is also possible using recently developed enzymes; however, it is necessary to break the bond between the hemicellulose and cellulose portions of the wood before the enzyme will work on the cellulose. This requires an additional treatment step which could involve weak acid hydrolysis, solvent pulping, or physical grinding of the wood.

After the cellulose has been converted to hexose, the solid lignin removed, and the solution pH adjusted if necessary, the resulting sugar solution is ready for fermentation. The addition of the yeast, saccharomyces cerevessie, to the solution causes the hexose to be converted to ethanol and carbon dioxide. The product stream from the fermentation step is a dilute weak alcohol solution, from which the alcohol is recovered by distillation.

b. State-of-the-Art Technology

1) Madison-Scholler Process--The Madison-Scholler Process is currently the process considered closest to being commercial. It is the most completely developed process and the one for which sufficient process information is available to make an economic analysis of its various applications. This process is based on a sulfuric acid hydrolysis step which was developed during the 1940's and 1950's. It has not been used because in a conventional form it could not economically compete with other methods of producing ethanol, particularly the reaction of ethylene with water.

Technical process details of the Madison-Scholler process are discussed further in Section 3 of this Chapter.

2) Gulf Process--Gulf has developed an enzyme hydrolysis process which will hydrolyze cellulose in the presence of lignin. There is a pre-treatment step necessary to isolate the hemicullulose, but details are not available as to what the pretreatment entails. The process also combines the saccharification and fermentation steps into one step.

The major advantages of the Gulf enzyme system are (1) no acids or solvents are present to create major corrosion problems, and (2) reaction times are shorter than for most enzyme processes. As its key disadvantages, however, the process entails large capital and operating costs. Gulf has operated a one-dry-ton-per-day pilot plant, ans has recently announced plans to work with the University of Arkansas to further develop the process to the point of commercialization.

3) Purdue (Tsao) Process--Purdue is investigating different forms of hydrolysis. One system developed is the use of a weak acid hydrolysis step followed by a strong acid hydrolysis step to most efficiently separate the hydrolyzed cellulose. The use of a strong acid, however, requires that the acid be substantially recovered in order for the overall process to remain economical. A review of the literature showed that preliminary cost estimates on the process assumed the use of conventional equipment and materials which are not suited to handle the corrosive process streams involved. In relation to these problems, there still are significant technical and economic questions which require further evaluation.

4) Other processes--Other organizations are currently doing research and development on cellulose-alcohol conversion processes. The Solar Energy Research Institute (SERI) is constructing a 3-ton-per-day acid hydrolysis pretreatment demonstration unit at Georgia Tech. They are also supporting efforts concerning different alcohol-water separation techniques.

The U.S. Army-Natick Laboratories and the University of California at Berkeley are both investigating pretreatment technology in conjunction with enzyme hydrolysis procedures.

The University of Pennsylvania and the General Electric Company are conducting a joint research project. Among the techniques being studied are solvent pretreatment to yield cellulose for enzyme hydrolysis, and new fermentation processes, including one to convert pentoses to alcohol.

None of the processes referenced above are currently to the point of actual commercialization.

3. Madison-Scholler Process

a. Description--A simplified process flow diagram for the conventional Madison-Scholler process is given in Figure 6. The hydrolyzer vessel is charged with wood, and live steam is injected until the temperature in the vessel reaches 275°F. Then dilute hydrolysis solution from the previous

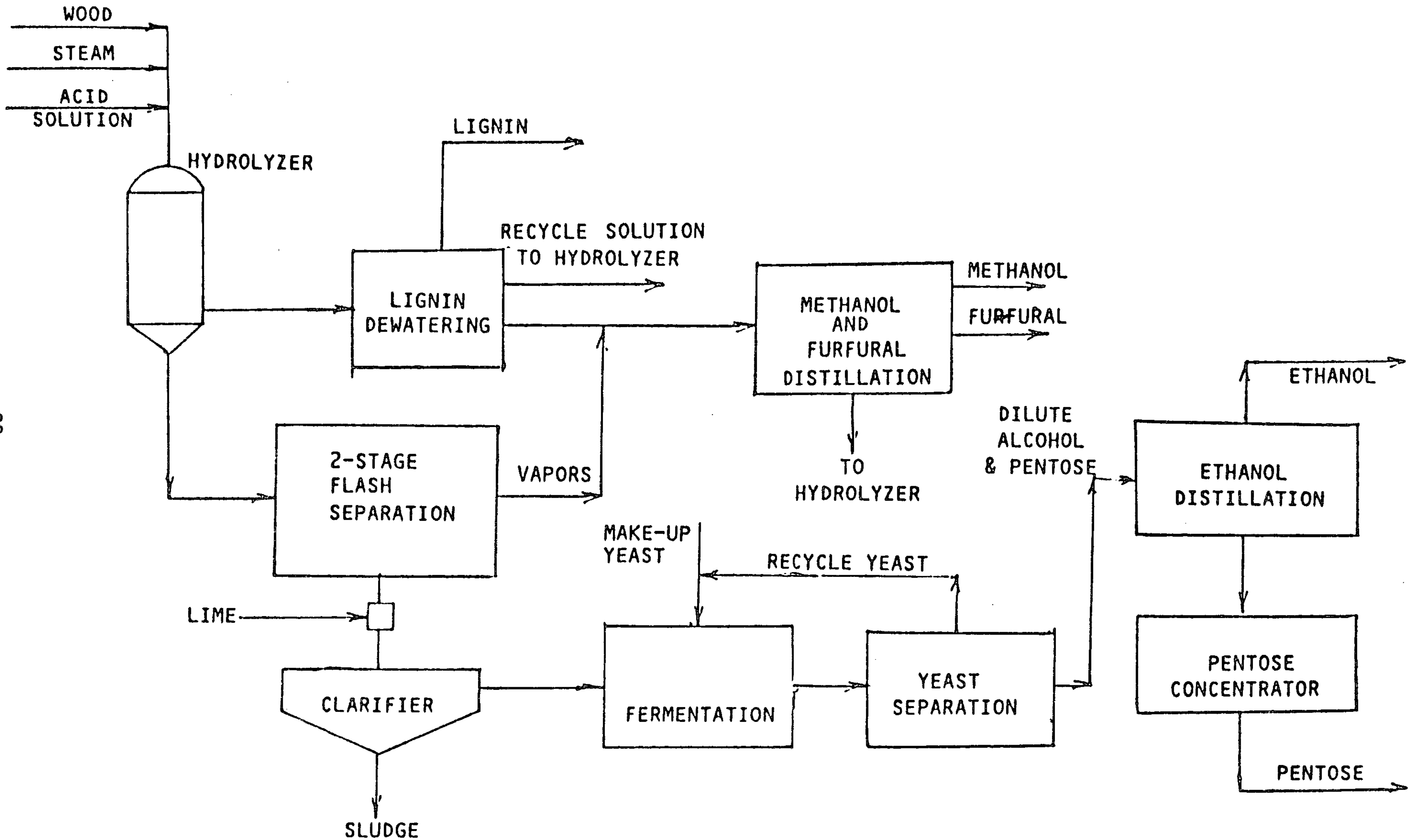

FIGURE 6.
PRELIMINARY PROCESS FLOW DIAGRAM
CONVENTIONAL MADISON-SCHOLLER PROCESS

batch is re-heated, mixed with sulfuric acid to form a 2-percent acid solution, and charged to the hydrolyzer; and hot water is percolated through the hydrolyzer at a constant rate. As the water percolates through, the acid concentration and the temperature vary. The average acid concentration is 0.53 percent and the maximum temperature is 385°F, corresponding to a steam pressure of approximately 200 psig. At the completion of hydrolysis, the hydrolyzate solution undergoes a two-stage flash step in which the pressure is reduced to 50 psig and then to atmospheric pressure. The vapors from the flash drums are condensed to recover some heat and then sent to distillation columns for the recovery of methanol and furfural.

The liquid portion from the flash drums is mixed with lime to bring the pH up to 4.5 prior to fermentation. The addition of the lime also causes the precipitation of calcium sulfate, which is settled in a clarifier, further dewatered in a centrifuge, and is discharged as sludge which must be disposed of, mostly simply in a landfill, for example.

The neutralized and clarified sugar solution is then sent to a fermentation tank where the sugar is converted to ethanol and CO_2 by the action of a yeast. After separation of the yeast for recycle, the weak fermentation solution goes through a series of distillation steps to recover the ethanol. The bottoms stream from the distillation process consists principally of a weak pentose solution. This can be concentrated by evaporation for possible use as a feed supplement for livestock.

The solid lignin which remains in the hydrolyzer after the percolation step is first fed to a cyclone separator and then to a dewatering press, from which it discharges as a 40-percent to 60-percent solid material suitable for use as boiler fuel.

b. Summary--As can be seen in the previous discussions, the Madison-Scholler process, although technically proven, is still a comparatively complex process requiring temperatures up to 385°F and steam pressures up to 200 psig. Although longer term potentials for geothermal applications to this process exist, especially for cases with high water temperatures (~400°F) the fuel alcohol plant facility discussed in section B of this Chapter is considered more viable for initial application at the Lakeview site. Energy loadings from a wood chemicals facility were, therefore, not integrated into the current geothermal district supply designs of this study.

VI. GEOTHERMAL WATER QUALITY AND TREATMENT NEEDS

The purpose of this chapter is to review the water quality of the Lakeview geothermal resource and determine if special treatment is necessary either for preventing corrosion and scaling within the proposed system or alternately for other health and safety reasons. The first step in such a review is to ascertain and document the water qualities of existing wells.

Water samples from the Oregon Desert Farms' geothermal well in Lakeview were analyzed under this project to determine the composition with respect to selected elements. The results of those analyses were then compared with literature values for previous geologic studies (21). Table 8 summarizes these data.

For purposes of district heating applications, the Lakeview geothermal resource is a good quality water. Only a few dissolved species are of sufficient concentration to provide scale or corrosion risk or raise health questions. Values for total dissolved solids concentrations in well and spring waters range from about 530 to 900 parts per million (ppm); the municipal drinking water supply contains only 150 ppm of dissolved solids. Values for the pH of geothermal waters in the Lakeview region range from 7.8 to 8.5. Some of the reported pH values were for samples taken from springs or open well flow. Based on these factors, and on the one chemical analysis made under this project, it is likely the actual pH range is 7 to 8. Some privately owned geothermal wells are used directly for potable water.

A. Scaling

Potential scaling species at Lakeview include calcium carbonate, calcium sulfate, barium sulfate, and silica. Water chemistry analyses show good consistency among the several geothermal water sources tested. Prior to the detailed discussion of scaling potentials, it is instructive to first document the assumptions which form the basis for the analysis. These analyses indicate the scaling potentials to piping or process equipment is minimal, as long as certain design features are incorporated to suppress a limited tendency for precipitation of solids. This is discussed below with respect to each of four scaling species.

First, it is assumed that each of the species is present in dissolved form at the saturation level corresponding to the source water temperature and overall water composition. As the waters have relatively low dissolved solid levels, ionic interactions were neglected, and the pure water solubility limits were used.

Calcium sulfate should not form scale. Its solubility in water is inversely proportional to temperature. No other factor in the operation of the proposed heating district would play a role in the potential precipitation of the species.

Calcium carbonate is subject to two factors that may cause it to scale. First to be considered is temperature. The solubility product

TABLE 8. LAKEVIEW GEOTHERMAL WATER ANALYSES

Source	C&A a	NGC b	LAKEVIEW c	EPA LIMITS d	
Species	(All values are mg/l) except gross ∝ and β)				
				Potable	Irrigation
Alkalinity($CaCO_3$)		66			
As	0.20	0.19	0.06-0.07	0.05	1.0
Ba		0.02		1.0	1.0
Cd		0.14		0.01	0.005
Ca	16	16	8.8-16		
Cl	114	112	99-170	(250)	
Cr		<0.002		0.05	5.0
Cu		<0.01		(1.0)	1.0
F	14	1.9	3.1-6.9	1.4-2.4	0.7-1.2
Hardness ($CaCO_3$)		39			
Fe	0.27	0.3	<0.02-0.07	(0.3)	0.3
Pb		0.017		0.05	5.0
Mg	0.2	0.8	0.1-4.4		
Mn		0.009		(0.05)	2.0
Hg	0.0002	<0.0005	0.0004-0.0017	0.002	
pH	7.1	8.0	7.8-8.5	6.0-8.5	6.0-8.5
K	7.9		2.2-9.0		
Se	0.002	<0.005	0.008	0.01	0.05
SiO_2	182	114	66-145		
Ag		<0.002		0.05	0.05
Na	224	85	152-280		
TDS	774	797	531-905	(500)	500
SO_4	252	252	152-289		
Zn		0.07		(5.0)	5.0
B	5.0	5.37	6.9-11.2		0.75
$S^=$	1.0			(0.05)	
HCO_3	<10				
CO_3	172				
Gross β(ρCi/l)	0.0±9.8			15	
Gross ∝(ρCi/l)	0.0±1.0				

a. Analyses for Coury and Associates, Oregon Desert Farms well, 9/80.
b. Analyses for Northwest Geothermal Corp., Oregon Desert Farms well, 9/80.
c. Range of analyses by USGS, Peterson & McIntyre; various geothermal wells and springs
d. EPA drinking water and secondary standards. Values in parentheses are recommended limits, only.

of calcium carbonate is essentially unaffected by temperature in the range of 100°F to 200°F which would encompass the range of heating system operating temperatures. However, the dissociation constants for dissolved CO_2 species and for water undergo changes with respect to temperature, such that the net effect of decreased temperature is increased $CaCO_3$ solubility. Therefore, as the saturated geothermal water is cooled, the water chemistry will change from that of precipitation conditions at the source formation temperature, to a condition of undersaturation. Other factors being held constant, cooling the water will reduce the tendency for calcium carbonate precipitation.

The second factor affecting calcium carbonate scale potential is the pH. In the pH range of 7 to 8 for the Lakeview resources, dissolved CO_2 exists as carbonic acid and carbonate and bicarbonate ions. A shift of pH from 7 to 9 will cause scaling to occur by the conversion of bicarbonate ions to carbonate ions. Such an increase of pH can result from the release of dissolved CO_2 from the original geothermal water. As evidence of this phenomenon, wellhead parts removed earlier from a freely flashing well that serves Hunter Lodge are clogged with massive scale buildup. The pipe beneath the flash level was relatively clean, and piping downstream of the wellhead sump is also clean. Thus, carbonate precipitation from the Lakeview geothermal resources will occur, in the absence of chemical treatment, unless the water is maintained pressurized to prevent degassing.

Amorphous silica scale is a third species of interest: silica is important since its solubility is directly proportional to temperature. Also, silica scale is difficult to remove from process equipment and piping. Solubility data (21) indicate that the highest dissolved silica concentrations found in Lakeview would be below the saturation level until temperatures of about 120°F. At lower temperatures the saturation limit would be exceeded. However, silica precipitation is subject to very slow rates at low levels of supersaturation. For the lower temperature levels expected in the Lakeview system, silica scaling is not expected to be a problem.

Finally, barium sulfate is only present at a 0.02 ppm level, which is not high enough to represent a significant scaling concern.

B. Corrosion

The corrosivity of Lakeview geothermal waters is predominantly due to two species--dissolved CO_2 and H_2S gases. The following qualitative evaluation is related to experience with Lakeview geothermal waters.

The effect of dissolved carbon dioxide should be negligible for copper piping. However, it could have a damaging effect on carbon steel pipe. The potential for corrosion of steel is favored by acidic pH levels and by elevated temperatures; it is minimized by high levels of $CaCO_3$ in solution. Based on the measured pH values at ambient temperatures, the geothermal water should not be aggressive toward steel. This is confirmed by past experience in the Lakeview area. Piping visually inspected at Hunter Lodge was clean and free of internal corrosion.

Hydrogen sulfide is more obviously a source of corrosion. The analyses of geothermal water showed sulfide present at 1 ppm, approximately. The analytical accuracy is about 0.3 ppm, implying that the actual sulfide concentration is between 0 and 2 ppm. Sulfide does exist at some low concentrations as evidenced by the sulfide odor evident at certain well sites. Corrosion damage in steel piping and equipment, due to H_2S, will occur only when frequently exposed to oxygen, as through the admission of air. In a district heating system such occurrences are infrequent, and should not lead to substantial sulfide corrosion of steel. Copper, on the other hand, is highly susceptible to attack by sulfide in almost any environment. Copper tubing was blackened and corroded through piping walls in one inactive home heating system where geothermal water was used directly over a period of 10 to 15 years.

The sulfide level has been analyzed in this project for only one water sample, the Oregon Desert Farms well. No other analyses for $S^=$ are present in the literature. As stated above, the analytical accuracy means the sulfide level could be higher or lower by about 1 ppm, and the odor of hydrogen sulfide and damage to copper pipe confirm its presence. At design flow rates, a level of 1 ppm of $S^=$ could result in the removal of 4,000 to 8,000 pounds of copper per year from users' heat recovery facilities. Lesser sulfide levels would result in proportionally reduced copper losses. The design case in Chapter VIII assumes the need for a treatment method, and approximate treatment costs are given. However, because of the high uncertainty about the precise sulfide concentration, more extensive water analyses are warranted before the need for, or cost of, a treatment to remove H_2S are considered necessary.

C. Health and Safety Considerations

Several dissolved species in the geothermal water of Lakeview could preclude its use for drinking, and in some cases for irrigation. The concentrations of such species varied with the source analyzed. Fluoride exceeds both the EPA standards for drinking water and irrigation, based on both USGS data and the analyses performed in this study. Arsenic exceeds drinking water limits in the most recent analyses. Boron levels are in excess of levels that are safe for irrigation without crop damage. Sulfate and total dissolved solids are present at levels above those recommended by the EPA for drinking water, but those recommendations are based broadly on taste and aesthetic preferences. Finally, cadmium was recently analyzed at levels 14 times potable water limits.

Dissolved radon and hydrogen sulfide gases have been tentatively identified in chemical analyses of Lakeview geothermal water. However, the accuracy of the analytical results is such that the presence of both gases is questionable based on the analyses alone. A priority is emphasized on the need for further analyses of the H_2S and radon presence to properly assess any need for treatment.

The presence of H_2S is evident by its odor and in corrosion of copper tubing. Hydrogen sulfide is toxic and potentially explosive at higher levels than found at Lakeview. Radon is radioactive, but there are no standards for its presence, alone. Limitations on its presence depend on gross radioactivity levels. These two gases pose potential health hazards only if they are allowed to build up to high concentrations.

D. Treatment Options

The acceptability for using geothermal waters in Lakeview for drinking or irrigation depends on specific analytical findings for each source. As shown in Table 8, the suitability of the different source waters for consumption varies from acceptable to unacceptable. Consideration of treatment techniques to remove the species necessary for producing potable quality or irrigation water was not in the scope of this project.

Treatment to prevent scaling is not necessary as long as the geothermal water is maintained at sufficient pressure to prevent degassing. The practical threat of scaling in the event of degassing results from calcium carbonate.

Corrosion of copper piping may occur due to the presence of H_2S. The options for dealing with this problem are to chemically treat the geothermal water to remove sulfur in a form that can be easily disposed of or to use a two-loop system where users are exposed only to clean water. Treatment options which are considered here include degassification and contact with iron oxide.

Degassification is commonly employed in water treatment systems for CO_2-related scale control. It is accomplished by acidification of the water, to remove H_2S. The acid treatment shifts the equilibrium of dissolved H_2S gas to favor a high partial pressure. A slight pressure reduction then produces a relatively large enough volume of steam such that most of the H_2S must evolve to the vapor phase to satisfy its vapor-liquid equilibrium. Subsequent neutralization of the water with caustic is required to prevent serious corrosion in downstream pipe and equipment. This approach to H_2S control has two other notable effects. Dissolved CO_2 will behave as the H_2S does. Its relatively high concentration will increase the overall demand for acid but the reduction of CO_2 will also eliminate carbonate scale as a hazard to the heating system. Secondly, degassing will remove almost all radon as it is only slightly soluble. This treatment option is considered to be very expensive and requires close operator attention. In the iron oxide process, sponge iron is used to contact the water reacting with H_2S to form iron sulfide. A process similar to this has been used to remove H_2S from sour gas and oil. The reacted sponge iron can be discarded or partially regenerated to the oxide form by blowing air through the iron bed to produce sulfur dioxide gas and elemental sulfur. Even with regeneration, periodic replacement of the sponge iron reactant is still necessary. The iron oxide system has not been used to treat water nor has it been used to remove H_2S at the low concentrations expected at Lakeview. As a result, it cannot be considered commercially available without further pilot testing.

Both treatment options discussed above are considered inappropriate for Lakeview. As a result, the preferred alternative is to use a two-loop heating system where clean water is heated by the geothermal fluid in a heat exchanger. The clean water is circulated throughout a closed-loop distribution system to the users and the spent geothermal water flows directly to injection wells. Not only will this system provide a greater degree of reliability, but it will also substantially eliminate any potential health effects related to public exposure to the geothermal fluid.

VII. RESIDENTIAL AND COMMERCIAL HEATING AND COOLING EQUIPMENT

The successful transition to a district heating system approach for supplying the energy needs for a community such as Lakeview is dependent on the various individual residences and businesses converting to the new energy supply. This Chapter reviews the retrofit equipment required for this conversion. Heating equipment specifications are discussed and cost estimates are presented for typical domestic and commercial systems. It is important to recognize that the heating systems used for the geothermal case are proven commercial units and are essentially identical in operation to standard hot water heating systems except that the heat is supplied by the geothermal source as compared to a propane or fuel-oil boiler. Finally, it is noteworthy that the costs given in this Chapter are greater than what the actual out-of-pocket conversion expenses would be for individual users. State and Federal tax-incentive measures may relieve the buyer of up to 65 percent of the initial cost for conversion.

A. Retrofit Space Heating Systems for Residential and Commercial Applications

A number of alternatives are available for modifying existing building heating sytems to use geothermal fluids. The selection of a retrofit alternative for any given building will be strongly influenced by the type of heating equipment presently in use. The designs of several types of retrofit systems discussed below are available to residential or commercial users over a broad range of sizes.

1. Conversion-Existing Hot Water Systems--These systems typically burn oil or propane to heat a circulating water stream. The high operating water temperatures range between 180°F and 215°F, and the systems are designed for temperature drops of 40°F to 60°F. As such, the retrofitting needs for conversion of conventional hot water systems to geothermal water would be minimal, requiring only that the municipal geothermal heating fluid be supplied to heat the building's circulating water system. About 65 percent of the downtown commercial area would require this type of modification.

2. Conversion-Existing Forced-Air System--Retrofit conversion of forced-air systems is also fairly straightforward. It requires replacing the burner element in the furnace with an air-heat coil for the geothermal water. This type of conversion is suitable to users who have either oil or propane-fueled forced-air systems, which includes about 20 percent of the commercial users.

3. New Baseboard Radiators--This retrofit essentially requires the installation of a standard hot water heating system minus a boiler. Small baseboard radiators are located in each area to be heated, as well as piping to distribute the warm water to the various independent radiators. This type of heating conversion would be applicable to users who do not already have either a standard hot water system or a forced-air system. Air is heated by natural convection over finned-tubes.

4. New Fan-Assisted Connection--This type of conversion is similar to the baseboard radiator conversion; the same water supply piping would be run to areas to be heated. The convector fan-assisted unit is more compact, however, since a greater heating capacity can be obtained from standard radiator sizes.

5. New Forced-Air System--An alternative to the new baseboard radiators and new fan-assisted convector units is a new, central forced-air system. This type of conversion tends to be the most expensive. It is most suitable for users who have either a crawl space or attic areas which facilitate ease of installation.

B. Size and Cost Data for Space Heat Conversion

The cost and size comparisons for equipment for residential conversion to geothermal are presented below and tabulated in Table 9. All information presented is based on inlet water temperatures of 180°F and a temperature drop of 50°F in the water before it exits the unit.

1. Heating Coil in Existing Forced-Air System--The required heating coils will be either two or three row coils; their costs range from \$5-\$6 per 1,000 Btu's of capacity. Where conversion space is limited, a six-row coil can be obtained at a cost of about \$7 per 1,000 Btu.

These types of heating coils are commercially available in a variety of sizes and shapes. A typical home heating coil would have a cross-section of several square feet and would be several inches deep.

2. Baseboard Radiators--With the 180°F supply temperature and required 50°F temperature drop, baseboard radiators will supply about 1,000 Btu per linear foot. Thus, for the typical home, 55 linear feet of baseboard will be needed.

The cost for baseboard heaters ranges from \$10-\$15 per foot. The variability in price is due primarily to the range of costs of the outer covering for aesthetic considerations. This type of radiator is about 10 inches tall, 3 inches wide, and is elevated 1 foot off the floor.

3. Cabinet Convectors--This type of heater is appropriate in areas where space is a primary concern. In homes, these heaters are usually mounted on the floor or walls. In large buildings or warehouses, these heaters are usually hung from the ceiling. An estimated price is about \$17 per 1,000 Btu for small units of a capacity less than 80,000 Btu per hour. A price of \$7.5 per 1,000 Btu can be used for estimating costs of units larger than 500,000 Btu.

Units that would be used in homes are several feet square and 8 inches deep. The larger commercial units are typically several feet square and 3 feet deep.

TABLE 9. ESTIMATED RETROFITTING COST*

Heating Coil in Existing Forced-Air System	
Coil cost	$ 300
Piping	100
Thermostatic control	100
Labor	300
Total	$ 750
Baseboard Radiators	
Radiator cost	$ 700
Piping	100
Thermostatic control	100
Labor	700
Total	$1,600
Cabinet Convector	
Heating units	$ 400
Piping	200
Thermostatic control	100
Labor	800
Total	$1,500
Intallation of New Forced-Air Heating System	
Heating system	
Materials and labor	$1,600
Piping	100
Thermostatic controls	100
Heating coil	300
Total	$2,100

*Based on equipment which gives a 50°F temperature drop of the fluid across the heating unit, and a peak space heating demand of 55,000 Btu/hr for residential users.

4. Installation of New Forced-Air Heating System--For installation of a new central-air heating system, a fan, a heating coil, and a duct system would be installed. The coil costs would be as outlined previously. The installation and materials for the duct system can be estimated at $1.20 per square foot of floor area. This $1.20 figure assumes there is easy access for ductwork in a crawl space, attic, or overhead area.

Table 9 lists comparative costs for materials and installation for a space heating conversion in an average home in Lakeview.

C. Water Heating Systems

1. Domestic Units--Based on the results of surveys of domestic, commercial, and municipal buildings in Lakeview, about 20 percent of the potential total annual heat demand is associated with hot water heating. This load is more nearly constant over the year, as compared to space heat demand which is seasonally dependent. The most direct method for retrofitting domestic hot water supplies is the use of commercially available equipment developed for the solar industry. The retrofitting would involve the purchase and installation of a special hot water tank and the plumbing required to get the geothermal fluid to the tank. The capacity of the new tank would be about twice that of a conventional hot water heater. Costs of such a tank range 25 percent to 50 percent higher than new conventional hot water heaters, or approximately $225. The typical domestic water heater is designed to provide a peak heating rate of 20,000 Btu/hr. Installation piping and labor costs to hook up these units are estimated at $100.

2. Commercial Units--The design of units for hot heating water in commercial establishments, including municipal buildings, is the same principal as for a domestic unit except that larger capacities are required. In some cases it may prove economical to buy small, prefabricated shell and tube heat exchangers to supply this increased capacity. This will have to be determined on a case-by-case basis.

D. Space-Cooling Potentials

In the Lakeview area the temperature seldom rises above 90°F. Although several of the commercial establishments have air conditioning, the overall demand for space cooling was considered too small to have a major effect on the design of the district heating system. Nevertheless, space cooling can be provided from the hot circulating water to those users who purchase the necessary equipment.

Commercial equipment is available to provide air conditioning. Minimum sizes for these cooling units are rated at 3 tons. For these units to operate properly a supply temperature of 195°F must be provided. A flow of about 3 gpm is needed for each ton refrigeration capacity.

Space cooling for these applications would be provided through absorption type air conditioning equipment. For temperatures in the range of 195°F, the working fluid system would be lithium-bromide-water ($LiBr-H_2O$) solution. The system would operate in a manner similar to a standard ammonia absorption refrigeration system.

VIII. DISTRICT HEATING SYSTEM DESIGN

This chapter presents the Base Case and Mini-district design for heating systems in Lakeview. Chapter IV developed a detailed discussion of the peak and annual estimated energy consumption for service to the entire town and the downtown Mini-district. The heating system is a two-loop system where geothermal water is used to heat a secondary circulating fluid which in turn provides heat to the individual user.

Section A presents a system description for the Base Case design. Section B reviews the major system components. Section C discusses the system operation and control. Section D reviews the Mini-district design for the downtown area of Lakeview.

A. Base Case System Description

A schematic diagram of the district heating system is shown in Figure 7. Geothermal fluid is pumped from production wells to a bank of heat exchangers where it heats a secondary fluid consisting of municipal water. The heated municipal water is then circulated in a closed loop through distribution piping system by means of one to six pumps, depending on user demand, and returned to the heat exchangers. Municipal water provides makeup to the circulating water system. The geothermal fluid leaving the heat exchanger is piped directly to injection wells for disposal.

A plot plan showing the arrangement for the Base Case system is depicted in Figure 8. The production wells will be located at quarter-mile increments along the Lakeview Fault line on the east side of Lakeview. A gathering line connecting the wells will converge at the control building located near the east end of Center Street. This building will house the heat exchangers necessary to transfer heat from the geothermal fluid to the secondary fluid which is circulated to the users. The geothermal fluid exiting the heat exchangers is piped to reinjection wells. The reinjection wells have been located to minimize effects on geothermal water withdrawn from the production zones.

The secondary circulating fluid will be pumped by circulating water pumps, also located in the control house, to users through various supply and return trunklines, branch lines, and feeder pipes. The main trunkline supply and return lines run along Center Street, which passes through the center of the main business district and bisects the Lakeview area. Two secondary trunklines branch to the north and south of the main trunkline. The routings for the trunklines were chosen based on the distribution of the total heating load and location of available street and alley rights-of-way. The trunklines service both individual users and the 40 smaller branch lines. Feeder pipes carry water from the trunklines and branch lines to the users. There will be 1,170 residential and 120 commercial users on the distribution system when used to design capacity. The total peak circulating flow requirement to heat all of these users is 4,839 gpm. This flow is based on a 75,000-Btu/hr load for residential users with a 50°F temperature drop and a 60°F temperature drop for the commercial users. The flow requirements for each of the branch systems is listed in Table 10.

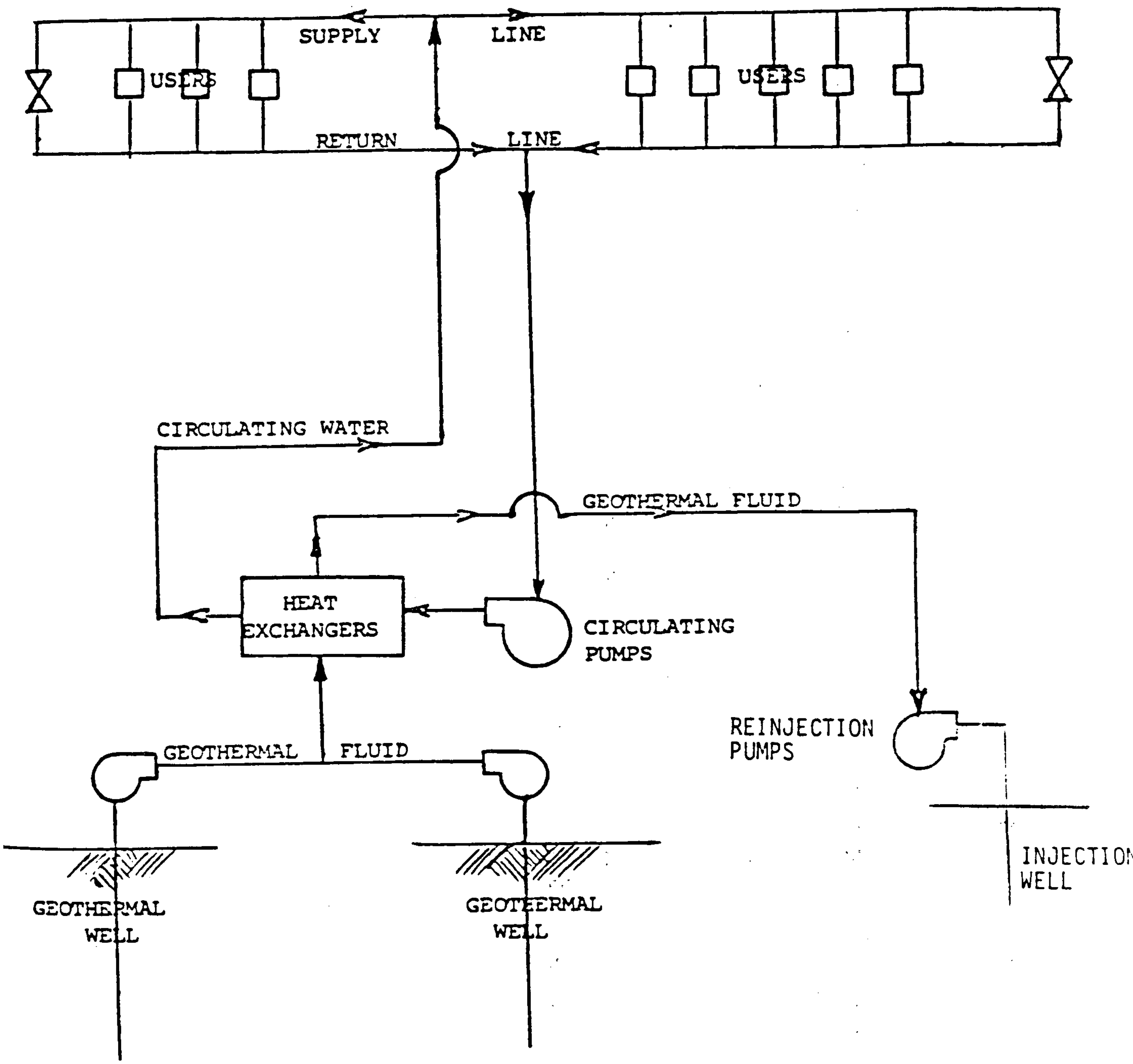

Figure 7. Schematic Diagram of Heating System

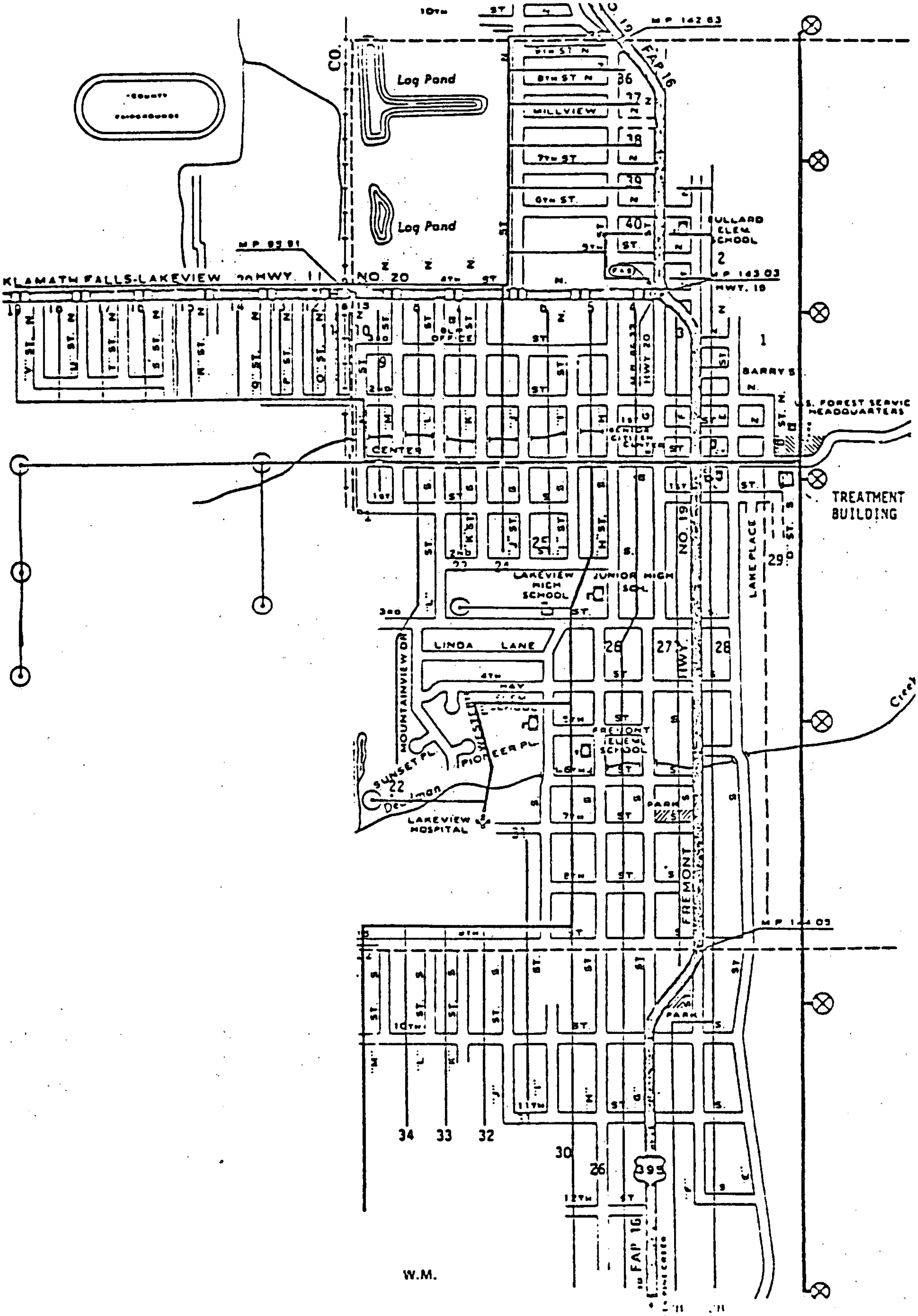

Figure 8. Base Case Plot Plan

B. Major System Components

The major system components for the district heating system are the wells, pumps, heat exchangers, and distribution piping. The major size and performance requirements for these components are shown in Figure 9.

1. Wells--Eight production wells are required for the Base Case--seven operating and one spare. Each well is to produce a maximum of 870 gpm at expected temperatures of 200°F; however temperatures of 240°F may be encountered. The design temperature is 200°F. The wells are assumed to be drilled in hard rock or sediment to an average depth of 2,000 feet. The wells will have 12-inch ID casing to the 200-foot depth and 9-inch ID casing from there to the well bottom.

Eight reinjection wells will be required--seven operating and one spare. Each well will handle up to 870 gpm at temperatures ranging from 120°F to 160°F. These wells are assumed to be drilled in fractured hard rock to a depth of 800 feet. The wells are cased their full depth with nominal 9-inch ID casing.

2. Pumps--The production pumps will be vertical centrifugal downhole pumps with surface-mounted motors. There will be one pump per well with the impeller set at 200 feet below furface. The pumps will be sized to handle 870 gpm at at 350-foot head and at temperatures of up to 240°F. Each pump will have a 100-hp motor. The pumps will be constructed of carbon steel.

The injection pumps will be horizontal centrifugal pumps located at the injection pump wellhead. There will be one pump per well sized to handle 870 gpm at at a 450-foot head. Each pump will have a 125-hp motor. The pumps will be constructed of carbon steel.

Six recirculating pumps will be required to circulate hot water to individual users. The pump will be horizontal centrifugal pumps sized to provide 800 gpm at a 180-foot discharge head. Each pump will have a 40-hp motor. The pump will utilize bronze or carbon steel wetted parts and be rated for temperatures of up to 240°F.

3. Heat Exchangers--Four heat exchangers will be required for the Base Case. These heat exchangers will be plate exchangers designed for the conditions shown in Table 11. The exchanger internals will be constructed of stainless steel.

4. Piping--The piping network provides for: (1) routing geothermal fluid from the production wells to the heat exchanger and out to the injection wells; and (2) circulating the closed secondary fluid to and from individual users. The important design parameters considered in specifying piping network requirements are line velocities, materials of construction, insulation, installation and special provisions.

The piping system was designed to provide an average velocity of 6 feet per second (fps) for both the geothermal and circulating fluids. This average velocity provides a good compromise between smaller pipe diameters which decrease capital costs and larger diamteres which reduce pressure losses and, hence, operating costs. Table 12 presents the lengths and diameters of pipe required for the Base Case system. The insulated pipe required to get the

TABLE 10. DISTRIBUTION PIPING REQUIREMENTS

Branch/ Trunkline	Length (ft)	Number of Users Residential	Number of Users Commercial	Peak Flow (gpm)	Average Flow (gpm)
1	1,250	6	19	134	16
2	2,600	54	33	499	66
3	1,000	12	33	164	22
4	1,200	24	4	79	13
5	1,200	38	--	114	20
6	1,200	41	--	123	22
7	1,200	35	1	106	19
8	1,200	26	3	89	16
9	1,200	23	1	70	13
10				71	31
11	800	--	2	--	
12	800	4	--	12	2
13	800	2	2	14	3
14	800	3	1	13	3
15		1	--	3	1
16	800	15	--	45	8
17	800	12	--	43	7
18	800	11	--	33	6
19	800	10	--	30	5
20	4,000	15	--	45	8
21	200	8	--	24	4
22	3,000	10	--	30	5
23	650	18	--	54	10
24	650	24	--	72	12
25	650	24	--	72	12
26	6,800	153	--	459	80
27	6,600	108	--	324	57
28	6,400	114	4	377	61
29	3,600	47	--	141	24
30	2,500	31	--	93	17
31	1,400	26	1	86	16
32	1,400	18	--	54	10
33	Future	--	--	--	--
34	Future	--	--	--	--
35	700	4	--	12	2
36	900	17	--	51	9
37	1,000	17	--	51	9
38	1,000	25	--	75	13
39	1,000	29	--	87	15
40	1,400	48	--	144	25
West trunk	6,000	Branches only			
North trunk	2,800	37	2	117	20
South trunk	7,800	80	24	800	99
TOTALS		1,170	120	4,839	774

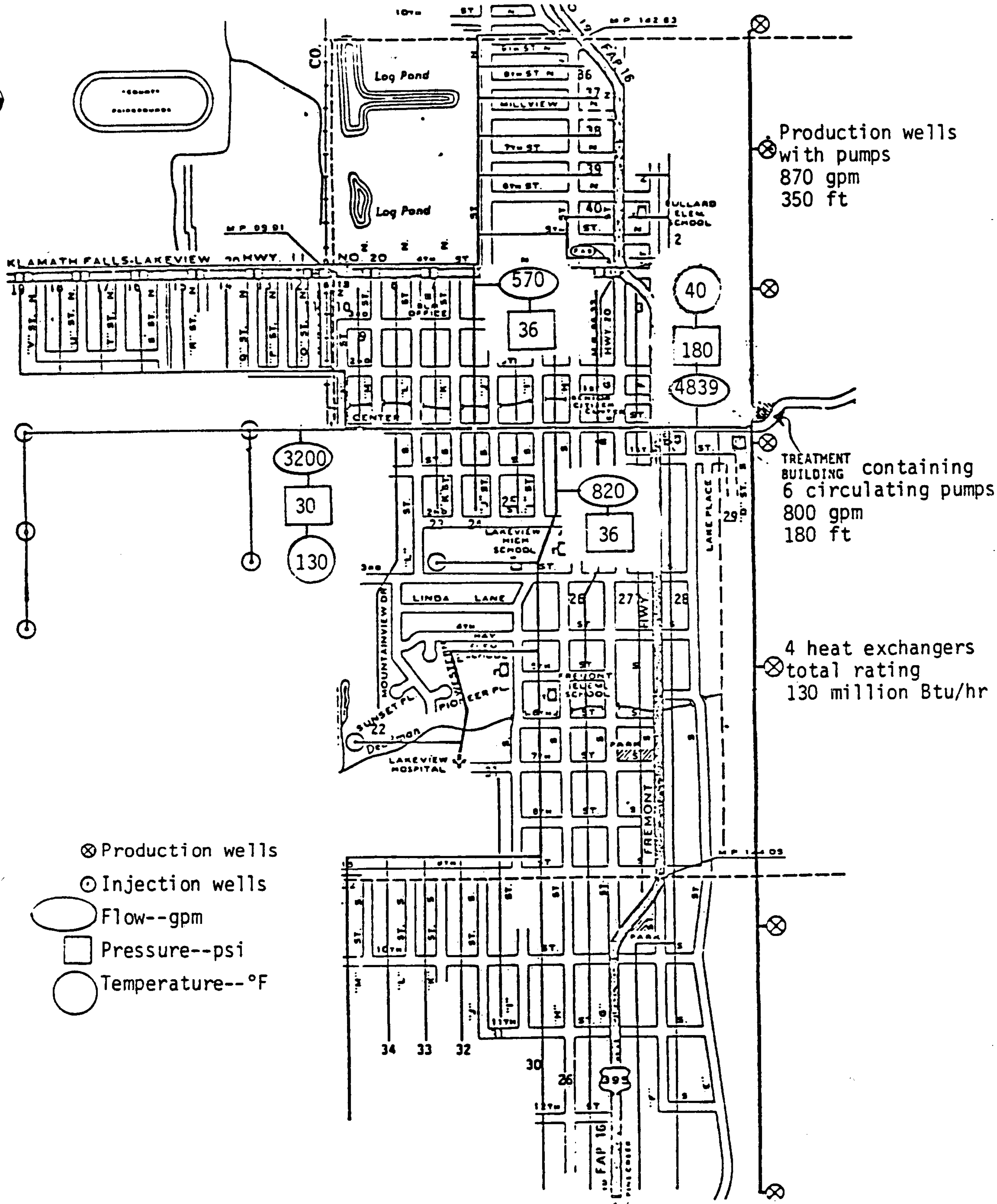

Figure 9. Major System Components

TABLE 11. HEAT EXCHANGER SPECIFICATION (PER EXCHANGER)

Fluids	
Hot side	Geothermal water
Cold side	Domestic water
Design heat load	36.6 million Btu/hr
Maximum pressure	150 psig
Approach temperature	10°F
Design flow rates	
Hot side	1,250 gpm @ 200°F
Cold side	1,200 gpm @ 190°F
Design pressure drops	
Geothermal side	14 psig
Circulating side	11 psig
Surface area	3,450 ft^2

geothermal fluid from the wells to the heat exchanger building is included in the delivery length column in Table 12. The bare pipe required to get the geothermal fluid to the disposal wells is included in the collection pipe column.

TABLE 12. PIPE REQUIREMENTS FOR FULL DEVELOPMENT OF LAKEVIEW

Pipe Diameter (inches)	Delivery Length (feet)	Collection Length (feet)
3	90,000	90,000*
3	28,700	28,700
4	24,850	24,850
6	15,100	15,100
8	9,300	12,000
10	6,640	5,320
12	2,640	1,320
14	1,600	1,600
16	800	4,400
	179,630	183,290

*User hookup lines

The maximum geothermal water and circulating water design requirements were set at 150 psig and 240°F. For these conditions, two piping materials are suitable--fiberglass reinforced polyester and carbon steel. The advantages and disadvantages of each are briefly reviewed below.

a. Fiberglass reinforced polyester (FRP)--There are numerous FRP products available; however, only a few are recommended for operating temperatures greater than 150°F. The main advantage of the fiberglass piping is its resistance to corrosion and scaling. Additionally, advantages to this pipe are that it is lightweight. This reduces the installation for this material. The major disadvantage to this material is that extra care must be taken when backfilling the pipeline trench to avoid damage to the outer epoxy coating of the pipe. If the outer protective epoxy coating is broken, water will quickly infiltrate the damaged fiberglass filaments, adversely affecting the structural integrity of the pipe. This same problem must be dealt with each time the pipe is broken into. Another disadvantage is that it is not recommended to mix types of fiberglass. Thus, when the choice of fiberglass is made, all fittings and any later addition should be of the same product.

b. Carbon steel--The major advantages of carbon steel are its availability, strength, and ability to operate at high pressures. It is also relatively easy to install. Another advantage includes the ease of ability to cut into the pipe to make new service line and repairs. This is a common piping material and the necessary labor is readily available. A thin wall steel pipe can be used effectively for this project due to the low pressure rating. Disadvantages of the steel pipe include its heavy weight and the need for extensive expansion joints.

Heat losses from the distribution lines and users feeder lines may result in increased capital costs, or higher operating costs, or both. If the supply lines are uninsulated, the delivered heating water temperature drops, forcing the users to install larger heat transfer units or to take a larger throughput of water to accomplish a given amount of heating. These design changes incur either higher retrofit costs for the user or higher operational costs for pumping power, and perhaps an added cost for larger pumps than would be necessary if the supply lines were insulated. If the return lines are not insulated, the central heat exchanger size increases only slightly. However, in this instance, the savings on insulation for the return lines is considerably greater than the cost of a larger set of heat exchangers. Table 13 summarizes the effects of insulating the pipe system, in terms of fluid heat and temperature losses.

TABLE 13. ESTIMATED TEMPERATURE (°F) LOSS PER 1,000 FEET PIPELINE

Basis	
Fluid temperature	200°F
Ground temperature	35°F
Burial depth	3 ft
Soil thermal conductivity	12 Btu-in/hr-ft^2-°F
Fluid velocity	6 fps

Material	4" (°F)	8" (°F)	12" (°F)	16" (°F)
Bare carbon steel	3.2	1.0	0.51	0.45
Insulated carbon steel	0.53	0.18	0.09	0.07
Uninsulated fiberglass	2.9	0.68	0.47	0.45
Insulated fiberglass	0.35	0.06	0.08	0.07

As seen in the table, the heat loss through either of the piping materials is similar. Of major significance is the result that a temperature loss in excess of 20°F could be realized if an uninsulated pipe is used, whereas an insulated pipe will reduce the temperature loss to less than 10°F. This indicates that the supply pipes for both the geothermal water and recirculating water must be insulated. The return piping from the users and the piping for geothermal fluid discharged from the heat exchangers need not be insulated since temperature loss in this portion of the piping is not nearly as significant.

The smaller feeder lines carrying a fluid to the individual user will range in size from 1 inch for the private residences to 2 inches for larger commercial users. Although the feeder branches average only 75 feet in length, the temperature loss through this section of pipe can be significant because these lines carry a small flow rate. The temperature loss at design conditions can reach 3°F when using a bare copper pipe, but is reduced to less than 0.5°F with an insulated copper pipe. A preinsulated copper or steel pipe is recommended.

All pipelines will be buried at a minimum depth of 3 feet to be under the frost line. Both the supply and return pipelines will be buried in the same trench with a separation of 1 foot. Figure 10 is a schematic of the typical trenching method for pipeline burial.

Special provisions required for the pipeline system include thrust blocks, breaker valves, check valves, isolation valves and drain lines. Thrust blocks will be placed at points where the opielines change direction. Air release and vacuum breaker valves are incorporated at least every 3,000 feet or at every local high point to permit the escape of any entrapped air and reduce the danger of cavitation of the pipe during cooldown. Check valves are incorporated on the discharge side of each user to prevent backflow during servicing and to prevent the unauthorized removal of water from the collection pipeline. Isolation valves are installed at strategic points to permit shutdown of portions of the system and still keep the remainder operational. Provisions to drain the lines in case of prolonged downtimes are included at system low points.

C. Operation

The district heating system is designed to operate over a wide range of conditions which may vary both daily and seasonally. It must automatically respond to heating changes in a manner to minimize operator attention, power consumption, equipment wear, and use of the geothermal resource. The following discussion reviews both the overall system control requirements and the controls necessary for individual users.

Figure 11 shows a piping and instrumentation schematic for the Base Case Lakeview heating system. The major elements in the control scheme are the minimum flow control bypass valves, the number of circulating pumps and heat exchangers in operation, the temperature of circulating water leaving the heat exchangers, and the flow rate from and number of the geothermal production wells in operation.

A flow control bypass valve will be provided in each of the 40 branch lines to maintain a minimum 5 gpm flow rate. This will insure adequate flows at the end of the branch line and minimize "dead-heading" the circulating fluid.

The circulating pumps and heat exchanger will be operated on user demand as indicated by the flowrate in the main supply trunkline. A minimum flow of 200 gpm (5 gpm per branch line) will be maintained at low heating loads by operating one circulating pump and one heat exchanger. As user demand and flow rate increase, additional pumps and heat exchangers will be brought on-line in accordance with the following sequence:

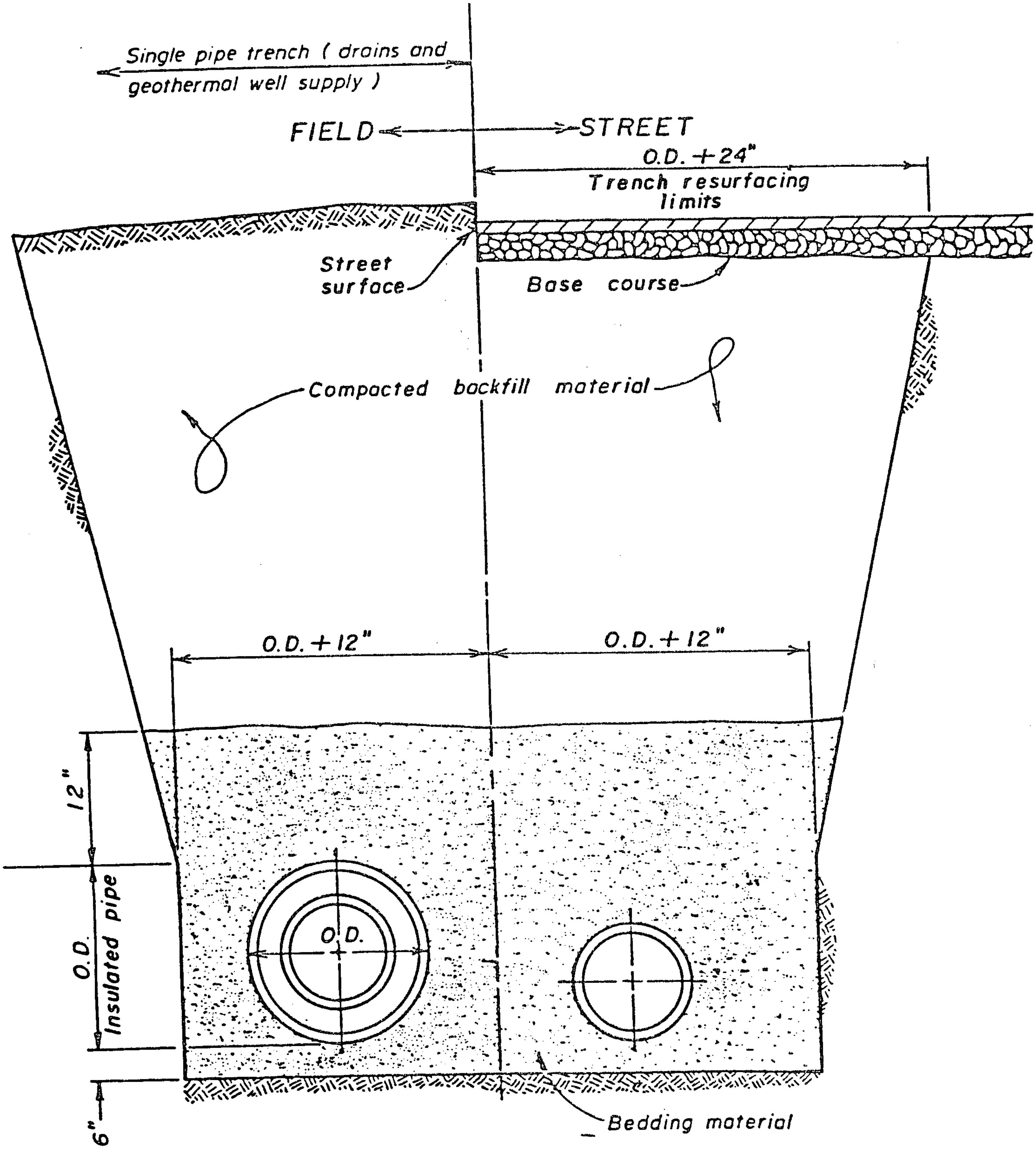

Figure 10. Typical Trench Section

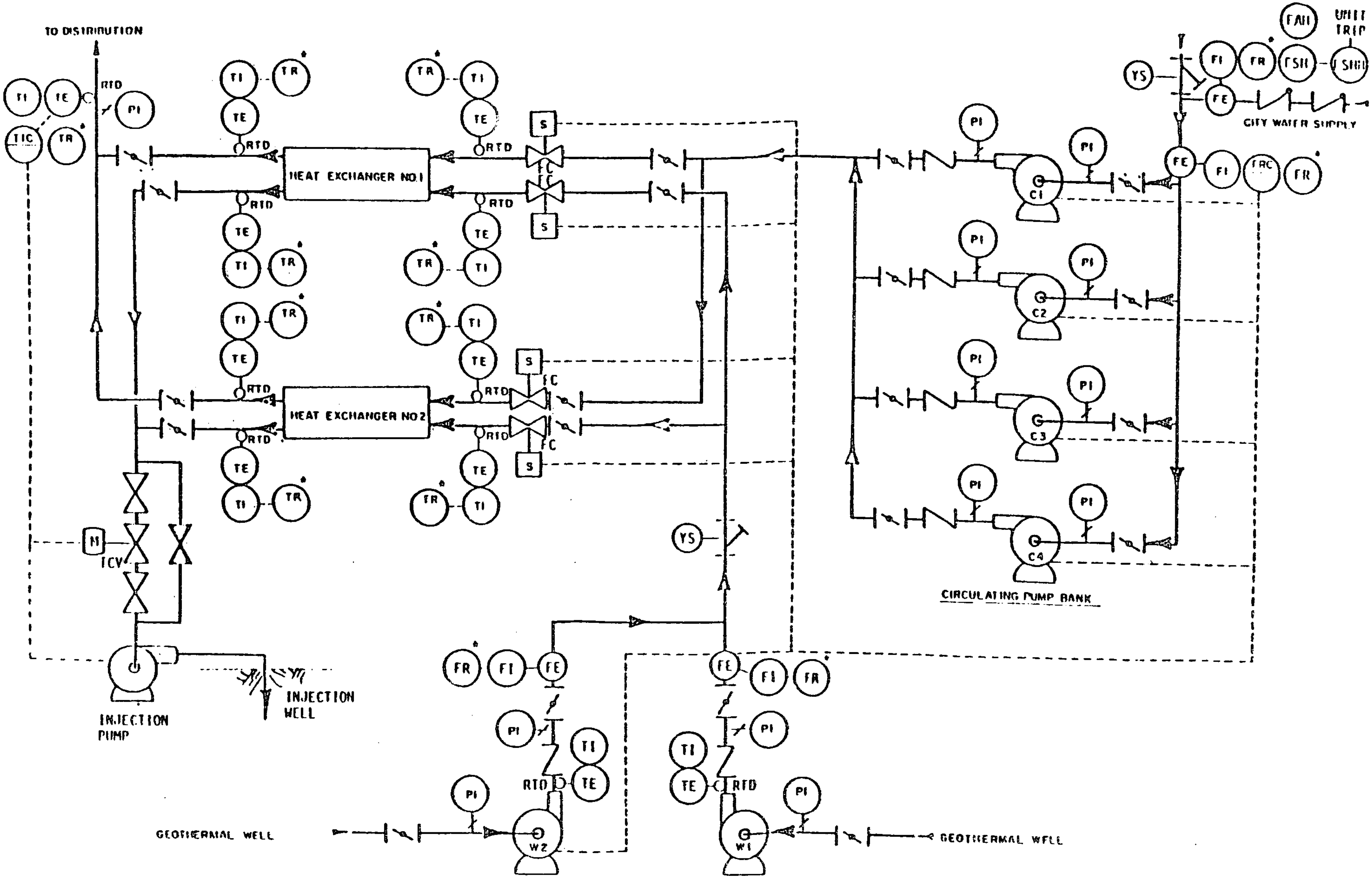

Figure 11. *INSTRUMENTATION AND CONTROL SCHEMATIC*

NO SCALE

Circulating Flow (gpm)	Operating Pumps	Operating Heat Exchangers
200- 800	1	1
800-1,200	2	1
1,200-1,600	2	2
1,600-2,000	3	2
2,000-2,400	3	2
2,400-2,800	4	3
2,800-3,200	5	3
3,200-3,600	5	3
3,600-4,000	5	4
4,000-4,400	6	4
4,400-4,800	6	4

The temperature of circulating water leaving the heat exchanger will be maintained at 190°F by controlling the flow rate from and the number of geothermal wells in operation. As the temperature falls below the lower control level, the flow rate of geothermal fluid will be increased. If the required flow rate exceeds the maximum flow rate available from the wells in operation, an additional well will automatically be placed on-line.

Instrumentation in addition to that needed for the major control elements is also shown in Figure 12. These variables are monitored to give an indication of how equipment is performing and whether maintenance or corrective action is necessary. They include parameters such as pump discharge pressures, heat exchanger inlet/outlet temperatures and flow rate of city makeup water.

A control scheme for an individual user is shown in Figure 13. The scheme consists of two block valves, one located on each of the supply and return pipelines. This allows isolation of home heating systmes for any routine maintenance or servicing. A constant flow valve assures a uniform flow of entering the home. A Btu meter will record the energy use. A thermostatic controller will operate a solenoid valve which controls the flow of hot water into the house. A check valve is positioned on the discharge line to prevent backflow into the home.

D. Mini-District Heating System

The Base Case system developed in this chapter serves the entire town of Lakeview. In actuality, it may be more attractive to develop the system in stages. In the early stages, emphasis could be given to the more concentrated heat load areas. As the initial development begins to generate income and the resource, design, and cost become more established and accepted, other service areas could then be added. The flow requirement for this system is 500 gpm.

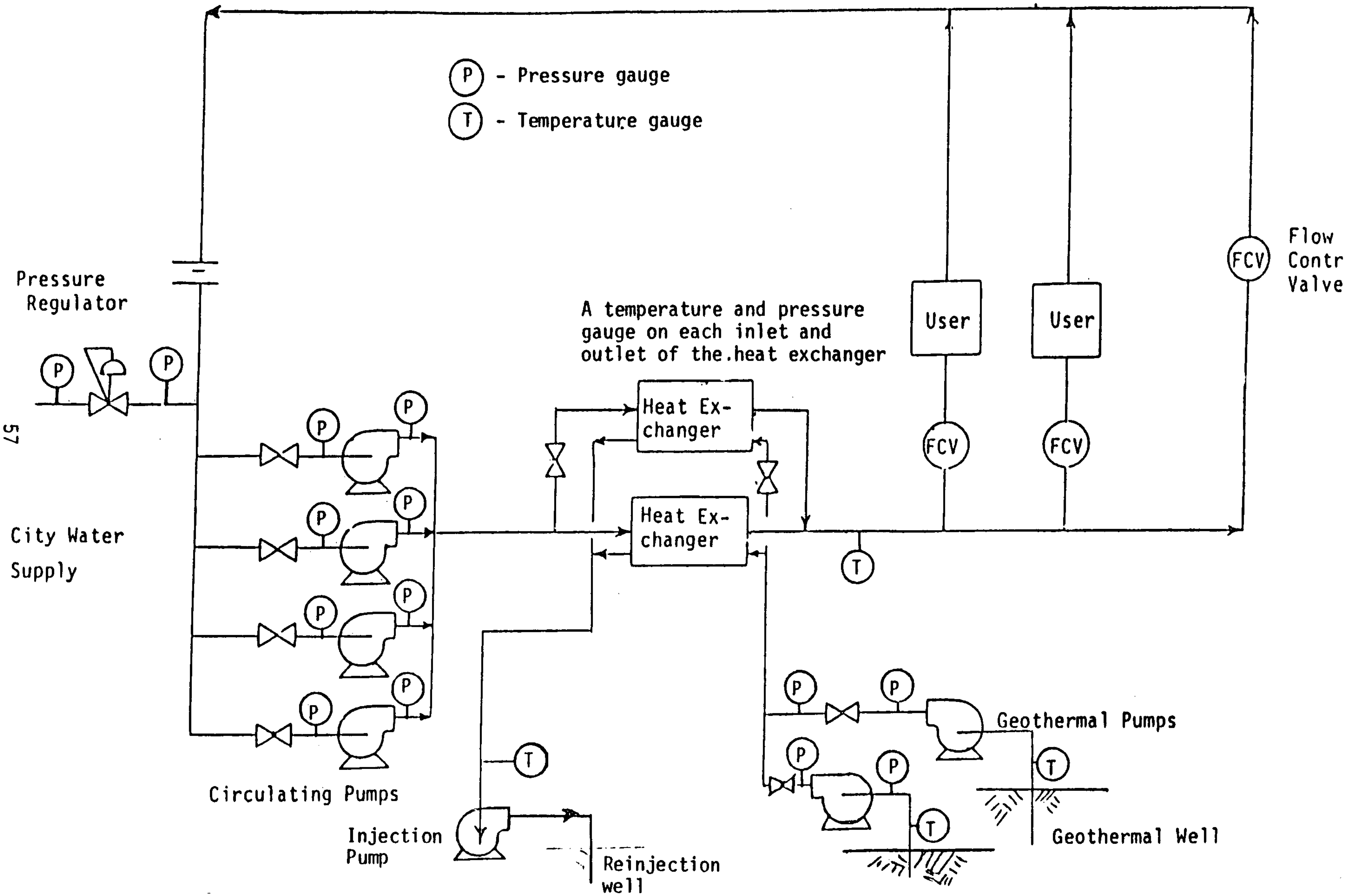

Figure 12. Schematic Diagram of Monitoring Points of System

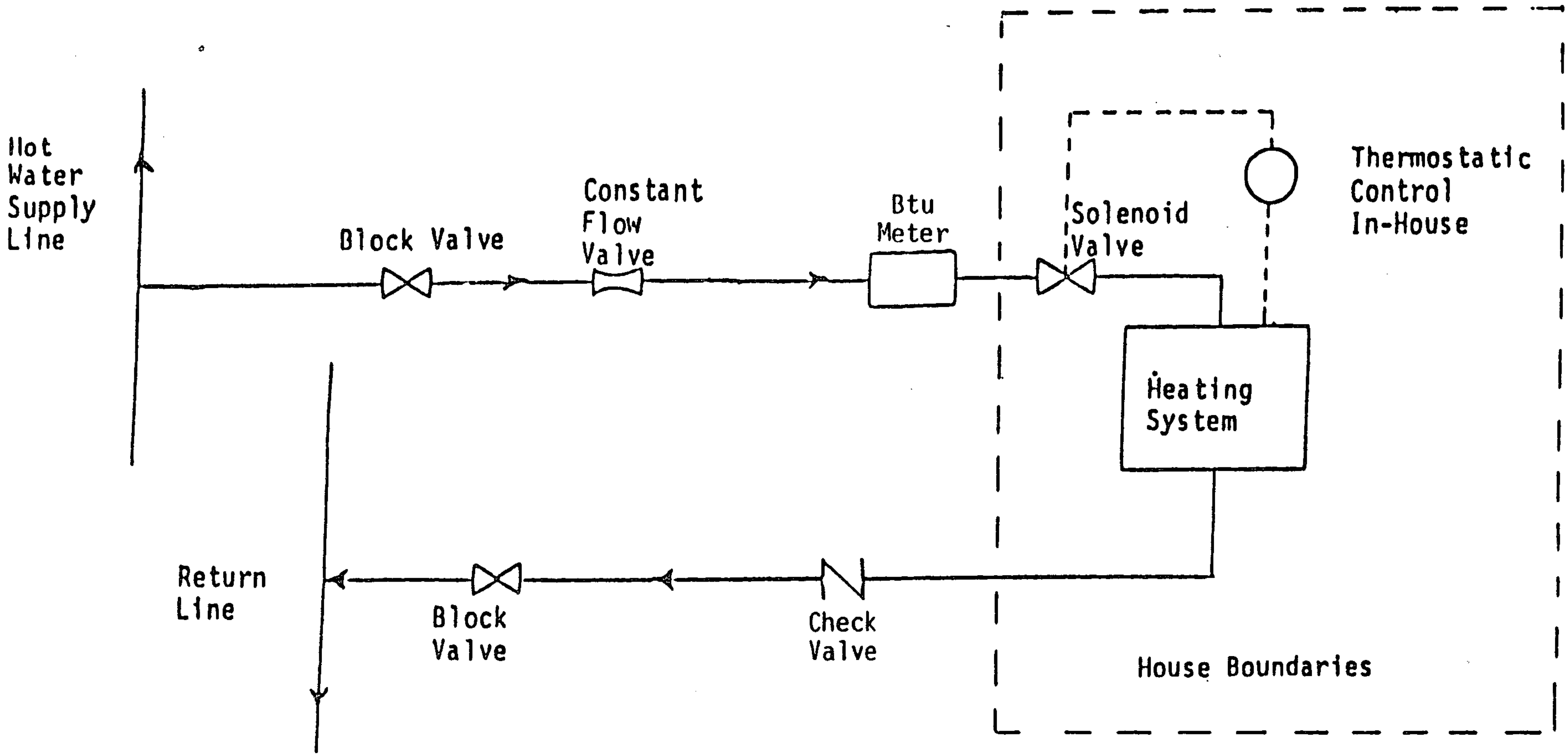

Figure 13. Schematic Diagram of Flow Metering System

This first segment of development has been termed the downtown mini-heating district. Figure 14 shows the location and piping network for this system. The Mini-district serves the downtown area and the ethanol facility west of downtown. For this system, the reinjection well has been near the high school property.

The type of equipment used for the Mini-district is the same as for the Base Case design. Differences in the two designs occur only in the sizing and number of certain major equipment items. Table 14 lists the major equipment components and specifications for the Mini-district. The control and instrumentation portion of the designs operate in similar manner to the Base Case.

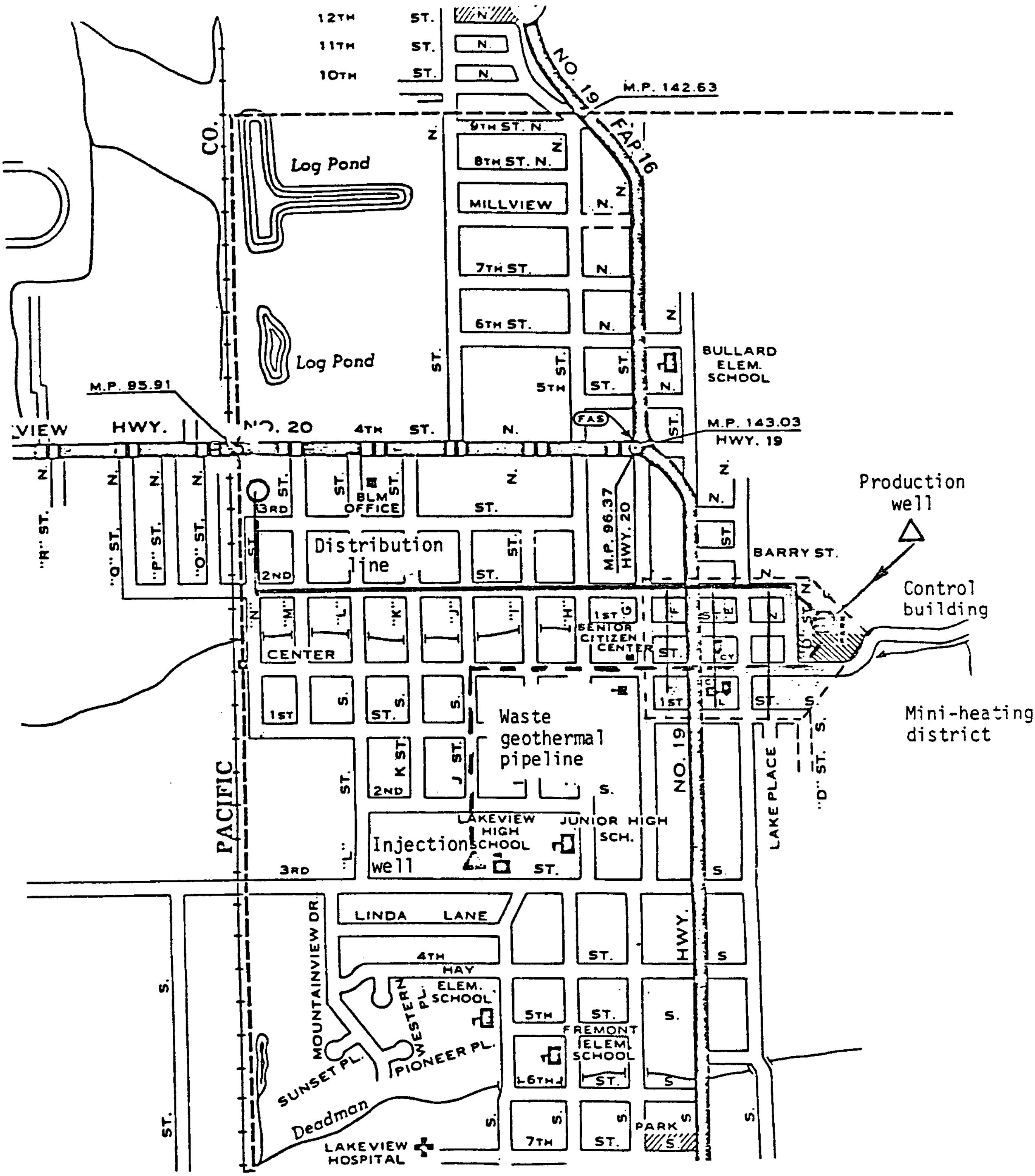

Figure 14. Location of Mini-District Piping

TABLE 14. EQUIPMENT SPECIFICATIONS FOR MINI-DISTRICT

Item	Quantity	Design Specifications
Production well	2 (one spare)	2,000', 9" casing 870 gpm, 200°F
Injection well	2 (one spare)	800', 9" casing 870 gpm, 160°F
Circulating pumps	3 (one spare)	300 gpm, 150' 40 hp
Well pumps		870 gpm, 200°F 350 ft head, 100 hp
Injection pumps		870 gpm 450 ft head, 125 hp
Heat exchanger		
Piping	6" bare, 3,950 ft 6" insulated, 750 ft 4" insulated, 2,500 ft 4" base, 2,500 ft	750°F, 150 psi 200°F, 150 psi 200°F, 150 psi 150°F, 150 psi

IX. ECONOMIC ANALYSES

Chapter IX presents the economic analyses for the district heating system designs discussed in the preceding chapters. The discussion is organized into two sections. Section A presents capital and operating cost estimates for the proposed systems together with projections of the delivered cost of energy. Section B discusses the bases and implications of these costs. Cost information presented in this chapter is based on standard evaluation methods used by the Northwest Natural Gas Company, the parent company of the Northwest Geothermal Corporation.

A. Cost Estimates

Feasibility level capital and operating costs were developed for the two alternative systems: the Base Case system and the Mini-district system. Tables 15 and 16 list the total installed and adjusted capital cost breakdowns for the two cases; Table 17 presents fifth year rate of return calculations and delivered cost of energy calculations for each case. For the Base Case system, the delivered cost of energy is calculated as \$8.20 per million Btu; the delivered energy cost is projected as \$10.30 per million Btu for the Mini-district case. This compares with current costs of \$8.76 - \$13.65 per million Btu for alternate energy sources in Lakeview.

B. Cost Bases and Implications

1. The estimated capital costs given in Tables 15 and 16 were developed from quotes from vendors and contractors, and also using documented cost experience in recent geothermal developments. An intangible drilling deduction amounting to 75 percent of the total production well and injection well cost was taken and subtracted from the total system costs giving the capital cost of the two systems. Then a 10 percent Federal and 10 percent Oregon State investment tax credit was used to calculate the effective adjusted capital cost for each case. A 25 percent equity position was used as the basis to determine interest charges and for the rate of return on equity capital calculations. The delivered price of energy was calculated using a 10 percent required rate of return. The adjusted estimated capital cost of the two systems figured in this manner is \$8.0 million for the Base Case system and \$790,000 for the Mini-district system. Northwest Geothermal has determined it is not able to take advantage of the Federal depletion allowance and the alternative energy capital investment tax credit; therefore, these two important tax incentives were not included in the calculations.

2. Annual Operating Costs--Preliminary estimates of annual operating costs were also developed and are presented in Table 17. Electrical costs are estimated on the basis of 3¢/kWh. Manpower requirements are estimated as one supervisor and one mechanic/operator at half-time for the Mini-district and at full-time for the Base Case. Maintenance is estimated at 1 percent of total installed cost; franchise taxes are 3 percent of gross revenues; and property taxes are calculated based on 2 percent of the assessed capital valuation.

Royalties are paid on revenues derived from all wells except the Mini-district primary source well, which is owned by the developer. The Mini-

TABLE 15. BASE CASE COST ESTIMATE

Cost Basis

1,170 Residences
119 Business and Municipal buildings
1 Alcohol Fuel Plant
System Capacity: 4,800 gpm

1.	Wells -- Production (8) 2,000 ft. @ $85/ft.	$ 1,360,000
	Injection (8) 800 ft. @ $60/ft.	384,000
2.	Gathering Lines	793,000
3.	Pumps -- Production (8) $31,950 each	256,000
	Injection (8) $20,700 each	166,000
	Circulating (6) $7,500 each	45,000
4.	Distribution Network	3,741,000
5.	Control System	200,000
6.	Heat Exchanger System and Structure	288,000
7.	Services -- 1,270 Domestic @ $600 20 Commercial @ $1,000	782,000
8.	Meters -- 1,270 Domestic @ $400 20 Industrial @ $2,500	558,000
9.	Subtotal	$ 8,573,000
10.	Engineering, and Resource Exploration and Confirmation	857,000
11.	Subtotal	$ 9,430,000
12.	Contingency @ 20%	1,886,000
13.	Total Installed Cost	$11,316,000
14.	Intangible Drilling Deduction	1,308,000
15.	Capital Cost of Proposed System	$10,008,000
16.	20% Federal and State Income Tax Credit	2,002,000
17.	Adjusted Capital Cost of System	$ 8,006,000

TABLE 16. MINI-DISTRICT COST ESTIMATE

Cost Basis

50 Business and Municipal Buildings
1 Alcohol Fuel Plant
System Capacity: 500 gpm

1.	Wells -- Production (2) average 2,000 ft @ $85/ft	$ 340,000
	Injection (2) 800 ft @ $60/ft	48,000
2.	Pumps -- Production (2) $24,000 each	48,000
	Injection (2) $15,500 each	31,000
	Circulating (3) $6,600 each	20,000
3.	Distribution network	287,000
4.	Control system	30,000
5.	Heat exchanger and structure	53,000
6.	Services -- 45 domestic size @ $600 5 industrial @ $1,000	32,000
7.	Meters -- 45 domestic @ $400 5 industrial @ $2,500	31,000
8.	Subtotal	$ 968,000
9.	Engineering, resource exploration and confirmation	97,000
10.	Subtotal	$1,065,000
11.	Contingency @ 20%	213,000
12.	Total installed cost	$1,230,000
13.	Intangible drilling deduction	291,000
14.	Capital cost of proposed system	$ 987,000
15.	20% Federal and State income tax credit	197,000
16.	Adjusted capital cost of system	$ 790,000

TABLE 17. RATE OF RETURN AND DELIVERED COST OF ENERGY--
FIFTH YEAR ANALYSIS

		Base Case	Mini-District
1.	Depreciated investment, end of fifth year	$7,480,000	$ 71,000
2.	Gross income	1,500,000	175,000
	Delivered energy cost	$8.20/10^6 Btu	$10.30/10^6 Btu
3.	Operation		
	Electricity	$ 61,000	$ 15,000
	Supervision	30,000	20,000
	Labor	20,000	10,000
	Maintenance	113,000	5,800
	Franchise (3% of gross revenues)	45,000	5,000
	Property tax (2%)	200,000	19,000
	Royalties	61,000	--
4.	Depreciation*	286,000	21,000
5.	Interest	645,000	49,000
6.	Net taxable income*	(127,000)	2,000
7.	Federal income tax	(64,000)	1,000
8.	Operating income	748,000	71,000
9.	Rate of return**	10%	10%
10.	Net earnings	39,000	22,000

*Depreciation is handled in two ways in this analysis. In computing income taxes, a double declining balance method is used for depreciation over the 35-year life. In computing the operating income, depreciation, as shown in Item 3, is straight-line based on a 35-year life.

**Rate of return is calculated as follows:

$$\text{Rate of return} = \frac{\text{Operating income}}{\text{Depreciated investment, end of 5th year}}$$

district, therefore, has no royalty cost. For the Base Case, the royalty rate is 16.25 percent of applicable gross revenues; on the basis that the exempt well (the Mini-district primary source well) would provide 75 percent of the average annual heat load. This predominance of the royalty-exempt as well as the heat supply source is an important factor in determining net earnings at a specified energy cost.

The Mini-district financing is based on an interest rate of 9 percent because Northwest Geothermal Corporation is eligible for State-based, low interest bonds. The Base Case interest rate of 11 percent is taken at a rate currently applicable for "A"-rated public utilities.

3. Cost Analysis--A comparison of the relative capacities and costs of the Base Case system and the Mini-district system shows that the economy of scale is significant in the Lakeview situation. The ratio of the annual loads between the Base Case and Mini-district is nearly 11-to-1, while the ratio of total installed costs is 10-to-1; this is the principal factor causing the increased energy cost of the Mini-district system.

One significant factor in the increased proportion of the cost of the Mini-district versus its capacity is the fact that while the Mini-district requires only one operating well, one spare must be provided adding $194,000 or 15 percent of the total cost. The inclusion of spare production and injection wells in the Base Case increases the total cost by only 2.5 percent.

A second important factor affecting the cost/energy use ratio is that for the large, more extensive Base Case design, it was assumed that essentially the entire commercial district is tied into the proposed system. Based on previous surveys (28) conducted by Northwest Geothermal, however, the Mini-district case design assumed a conversion of only 71 percent of the potential customers. This is a conservative assumption and again had the important effect of increasing distribution costs per unit of delivered energy. It is fair to assume that once the new system is installed and proven and when anticipated savings are confirmed, additional customers will desire to hook up to the Mini-district system; this will help decrease costs to other users.

There are other factors which do tend to offset the above somewhat. The cost of the closed-loop distribution grid is a major item in both cases. It amounts to 22 and 33 percent of the total system cost for the Mini-district and Base Case respectively. The increase in the proportional cost of the Base Case grid is due to the decreased geographic user density across the extensive system. The Mini-district service area encompasses nine continguous blocks plus the remote alcohol plant. The Base Case system covers of the order of 20 times more geographic area, while its cumulative heat load is only 11 times greater. The Base Case distribution branches were individually evaluated in terms of their installed pipeline cost per unit of average annual demand. This information is shown in Table 18, which lists the branches in increasing order of the cost-demand ratio. Note that this ratio is only for ranking the branches according to pipeline costs; it says nothing directly about total system costs.

TABLE 18. INDIVIDUAL BRANCH INSTALLED COSTS PER UNIT OF CAPACITY--BASE CASE

Branch Branch	Installed Pipeline Cost ($1,000)	Annual Heat Load (10^6 Btu)	Installed Pipeline Cost per Load ($/$10^6$Btu)
Main trunkline	483.4		
South trunk	377.4	25,670	14.70
North trunk	132.9	3,680	36.10
10 11	24.5	7,880	3.10
3	51.4	15,200	3.40
9	51.5	10,490	4.90
15	2.3	380	6.10
2	122.0	13,900	8.80
8	54.0	4,860	11.10
39	40.3	3,320	12.10
24	33.7	2,790	12.30
25	33.7	2,750	12.30
5	60.0	4,850	12.40
1	55.3	4,280	12.90
6	61.6	4,690	13.10
40	65.3	4,850	13.50
38	40.3	2,820	14.30
21	13.2	920	14.30
23	30.8	2,070	14.90
7	57.4	3,740	15.30
31	51.7	2,980	17.30
36	33.8	1,940	17.40
16	30.8	1,730	17.80
18	28.8	1,550	18.60
37	36.4	1,940	18.80
4	55.2	2,910	19.00
17	29.3	1,370	21.40
26	341.5	15,080	22.60
32	47.3	2,070	22.90
28	233.7	9,730	24.00
19	28.3	1,150	24.60
30	82.1	2,980	27.60
29	138.9	4,740	29.30
27	298.9	9,430	31.70
12	25.4	520	48.80
35	22.4	450	49.80
13	25.4	450	56.40
20	114.0	1,730	65.90
22	88.0	1,150	76.50
33	1.1	-0-	-
34	1.1	-0-	-

For the most cost-effective branches, each branch adds only a few dollars in cost per million Btu's of added capacity. However, about a third of the branches, serving only 26 percent of the total demand, are in the range of $20 to $67 of installed pipeline cost per million Btu's of capacity, and their total cumulative pipeline costs represent over 35 percent of the grid cost.

C. Summary

The $8.20 per million Btu and the $10.30 per million Btu costs are competitive with the currently available alternate fuel sources in Lakeview; these alternate fuel costs, adjusted where appropriate for combustion inefficiencies, range from $8.76 to $13.62 per million Btu for the electricity and residential propane, respectively. Therefore, for the Base Case system, the economic advantage lies with the geothermal alternative.

For the Mini-district case, the economic advantage is also to use geothermal heating. In spite of the $10.30 per million Btu cost, the business core area is predominantly dependent on fuel oil and propane which currently show an effective cost of $11.72 and $12.90 per million Btu of delivered energy. Based on an average annual consumption of 340 million Btu per establishment, the savings per fuel oil customer would average about $480 per year, which is attractive enough to justify the conversion to the new energy source. For propane users, the cost savings would be greater.

In addition, the geothermal cost presented must be evaluated in the perspective of a national shortage of fossil fuel resources. The cost of these resources is expected to rise in ranges of 7-10% per year which presently would account mainly for inflationary price increases and allows little room for supply-and-demand forces raising fossil fuel prices. Geothermal systems should not experience increasing costs to the same extent as fossil fuels, since geothermal costs are more exclusively associated with capital goods and labor. Current estimates suggest a geothermal increase of only one-fourth to one-third of the rate of expected conventional fuel increases.

X. INSTITUTIONAL FACTORS

Institutional factors, as defined in this report, are those factors which govern the development of the Lakeview geothermal district heating application. An analysis of these factors is summarized below; the full text of the institutional report is contained in reference (17).

A. Environmental and Socioeconomic Factors

There are no major conflicts to the development of geothermal energy resources in Lakeview due to socioeconomic or environmental considerations. Development of the geothermal resources to provide abundant, low-cost energy is viewed by government and local citizens as a potentially key factor for fostering economic growth in Lakeview. The area's economic output is lower than State and national averages; unemployment is above average; and the predominant sources of income are limited to lumber-related industry, government, and agriculture. The conclusions of recent economic studies of the area, as well as subsequent developmental planning, have both reflected a need for increased, diversified commercial and industrial activity. Therefore, both county and local government planning have promoted geothermal resource development and utilization. The general public has been convinced of the merits of this policy and overwhelmingly supports actions that would lead to geothermal heat utilization commercially and industrially. A high percentage of homeowners would readily convert to geothermal heating if it were competitively priced.

There is a need for careful selection of the types of industry to be introduced into the area economy. Attention is required to encourage industrial applications that will be viable in an area with a small skilled-labor force and limited market access. New industry must be compatible with available raw materials and the existing economy; yet it should also contribute to the area's economic diversification.

Evaluation of potential impacts on the natural environment points to one key concern, that being the effects of geothermal resource utilization on the collective groundwater and surface water resources in Lakeview. Limited knowledge is available describing potential interactions between thermal and nonthermal aquifers, rates and directions of aquifer recharge, the production and injection potentials, and the range of qualities of water in geothermal reservoirs. Hydrologic testing and evaluation are needed to quantify these factors as bases for resource development.

Other considerations for the environment do not pose as significant potential problems as do water resources. It is expected that effects of exploration and of construction and operation of facilities would have minimal and only temporary environmental impacts. There are some areas, notably Bullard Canyon and Hunter Hot Springs, which are identified as "potential natural areas." Care must be taken to insure that potential disturbances to such areas are not substantive.

B. Regulatory Requirements

Regulatory agencies having potential roles in the development and utilization of geothermal resources in Lakeview exist at the Federal, State, and local governmental levels. The statuatory considerations of the agencies pertain to water appropriations, well drilling for resource exploration and development, utility construction and operation, disposal of wastes, finances, and other factors.

The regulatory requirements discussed in this section are related to State and local agencies. Federal agencies may become involved in several ways. Construction or drilling on Federal land would require compliance with Federal standards. Funding of projects by the Federal government also may incur Federal involvement.

The EPA has overall responsibility for enforcement of minimum standards for discharges to the atmosphere and surface waters, and accumulation of residual solid wastes. Thus far, conceptual schemes for geothermal resource utilization in Lakeview have not incorporated water treatment, would not produce solid wastes, and would not involve significant gaseous releases to the atmosphere. The EPA has delegated authority for management of discharge to surface waters to the Oregon Department of Environmental Quality (ODEQ). Their role is discussed briefly later in the section. Finally, injection is presently under the authority of State offices. However, EPA is developing injection regulations, which will probably be administered by the EPA in Oregon.

State and local regulatory requirements are more obvious and direct in their potential impacts on the proposed program and are discussed below.

1. Water Appropriations--A State Water Resources Department (WRD) appropriations permit must be obtained prior to any proposed water use; this permit specifies a predetermined maximum volume of water to be consumed, and the location and nature of the proposed use. The permit authorizes the specified water use and requires substantial construction of the facilities within one year of issuance. This permit does not constitute or imply the awarding of a water right; that is addressed later in this chapter. Permit applications reviews may take up to 60 days.

2. Well Drilling--Permits are required for various types of wells that may be drilled, ranging from exploration and tests wells to production wells. Specific standards do not yet exist for injection wells, though they are under consideration for near future enactment. The Lake County Planning Commission, the State Water Resources Department (WRD), and the State Department of Geology and Mineral Industries (DOGAMI) will be involved in issuing well drilling permits. These latter two State agencies split the jurisdiction over wells depending on the depth and producing temperatures. Wells less than 2,000 feet deep with water below 250°F are considered simply water wells and are under the authority of WRD; they otherwise fall under DOGAMI's review. The State Department of Environmental Quality (DEQ) must approve of plans for surface disposal of drilling muds and geothermal effluents. Bonding ranging between $2,000 to $10,000 per

well, depending on the type of well, must be secured; a blanket bond of $25,000 covers up to 100 wells at a time. Permits are normally issued within 15 to 30 days of filing an application; however, production well permitting may take up to 45 days by statute.

With respect to obtaining permits for production wells, proposed disposal methods are evaluated by the permitting agencies, the Water Resources Department and the Department of Geology and Minerals Industries as part of the production well permitting process. Legislation passed in 1979 by the Oregon State Legislature specifically calls for injection of spent geothermal fluids back into the producing aquifer, with the exception that secondary uses without injection may be authorized. Acceptance of alternatives to injection is presently based on "public interest," which consists largely of ensuring the maintenance of groundwater quality and the conservation of the producing aquifer. As mentioned above, more definitive criteria for setting injection requirements are being developed by DOGAMI and WRD for their jurisdictional areas.

3. Utility Construction and Operation--The permitting agencies for construction and operation of a district heating system are also important to the implementation and timing of the project. Agencies involved include the Lake County Planning Commission, the Lakeview Town Council, the State Public Utilities Commission, and the State Energy Facility Siting Council (EFSC). These agencies function independently of one another. If the Energy Facility Siting Council becomes involved, as discussed below, it serves as a coordinating member for eliciting the evaluations of all other State and local regulatory bodies.

The Lake County Planning Commission and Lakeview Town Council must pass approval on construction of the physical facilities, such as piping and surface mechanical equipment. The Lakeview Town Council has responsibility for administering local construction statutes. The council has considered enactment of requirements specifically for geothermal development permits. Enactment of those measures may be completed in the latter half of 1980. Both the Town Council and County Planning Commission have been favorably oriented toward proposals for the utilization of geothermal resources.

The Oregon Energy Facility Siting Council is potentially the most important regulatory body to be dealt with. It is required to issue a site certificate before construction can begin for any geothermal pipeline of 6-inch or greater diameter and which is at least 5 miles in length. This size-length criterion cannot, incidentally, be circumvented by phased construction; the ultimate planned line size is the basis for deciding the EFSC's authority. The role of the EFSC is important because its approval must precede construction, and it may, by statute, take up to 12 months to complete its evaluation. It is, therefore, important that preliminary engineering designs be reviewed in the early planning stages to determine the likelihood of site certification requirements. The attention of the Council can also be expensive; an application fee of $15,000 is required.

The Council investigates each application to determine satisfaction of mandatory findings, and the Council may commission independent studies of any aspect of the facility. If the costs of these studies exceed the filing fee, additional expenses must be borne by the applicant. The siting process is, in effect, a one-stop regulatory procedure for the applicant. When an application is received, the Council distributes copies to 12 State agencies and affected local governments. The agencies must make provisions that they would normally make in their own permitting process. Any stipulations are included as site certificate conditions. Generally, once a certificate is granted, the various agency permits will be granted as a matter of course. Applications for permits do need to be filed directly with the relevant agency, however.

A site certificate authorizes the applicant to construct and operate the proposed facility under conditions set forth in the certificate. The Council maintains continuing authority over the site during the life of the facility. The holder of the site certificate is required to pay a fee each year during construction and operation of the facility.

From this brief overview of the siting process, it is obvious that imposition of these requirements on the Lakeview district heating project could have a major impact on the development of a first phase Mini-district heating system in the near term. To avoid these potential delays, it is essential that preliminary system design establish the length of pipeline 6 inches or greater in diameter that will be required. If this analysis determines that 5 miles or more of 6-inch or greater pipeline will ultimately be necessary, then the siting process should be instituted immediately by the applicant.

Two tactical considerations should be noted. The Council may be receptive to modifying siting procedures or waiving the requirement entirely. This view is based on the fact that the general standards were developed for energy facility siting primarily to protect public health and safety, and environmental concerns. The general standards apply to coal-fired and nuclear energy facilities. In the case of the proposed Lakeview project, the energy facility is akin to a municipal water system which will be constructed in an existing urban setting. In this context the potential impacts would be minimal. The Council might waive the requirement for a certificate or apply the criteria for certification less rigorously, based on the minimal disruption associated with district heating system construction in the small, urbanized setting.

Secondly, if it is determined that the Lakeview project will require a site certificate, the development will be evaluated based on EFSC regulations previously untested for a geothermal facility. Therefore, additional uncertainties might be encountered, and should be accounted for in contingency planning.

Through its economic oversight role, the State Public Utilities Commission (PUC) effectively plays a major role in the construction of any utility system. The PUC is formally responsible for approving rates, as well as for governing issuance of securities and other financial matters. In its role of approving rates to be charged to clients, the PUC takes into consideration the project and construction costs, thus indirectly taking a role in the design and construction phases of a project. The PUC's review and rate setting process may consume 6 months' time, and must be completed before initiation of services.

4. Miscellaneous Regulatory Factors--Once the geothermal district heating system has been constructed, end-users will need to obtain plumbing permits for waterline connections, and mechanical permits for new installations or retrofit of space conditioning systems.

New industries are likely to develop as a result of the availability of geothermal energy. If these industries will discharge emissions to the atmosphere, a permit from DEQ must be secured before construction.

The PUC will be the primary regulator during operation of the system, since the developer will be an investor-owned utility. The PUC's concern is to represent consumers in order to assure adequate service at fair and reasonable rates; this oversight responsibility is exercised through the rate-setting process. The PUC would approve the utility's budget annually and establish the allowable rate of return.

It can also be anticipated that specific standards for the siting of pipelines and criteria governing injection practices will be established in the next few years. The filing of applications to construct such systems may accelerate the development of these standards and practices. This may introduce additional requirements to be satisfied prior to future construction.

C. Water Rights

Oregon water law states that the right to use groundwater may be appropriated for beneficial uses, subject to the doctrine of prior appropriation--first in time is first in right. A water right is appurtenant to the place of use for which it was established and belongs to the property owner.

To establish a right to use water, it is first necessary to obtain a water appropriations permit from the Water Resources Department. An application for the permit must be filed, as discussed in Section B-1. However, an issued water appropriations right permit does not constitute nor imply an actual water right. The permit allows the appropriator to put previously unused water to beneficial use. Additionally, construction of the system to use the water must be substantially under way within one year from the date of permit issuance.

It is the use of water under the terms of the permit that establishes, or perfects, the water right. If water is available in sufficient quantity to satisfy existing water rights, while also maintaining minimum stream flows and groundwater aquifer volumes, then new appropriations may be allowed. In marginal instances there is a high degree of judgment involved in determining when a groundwater aquifer is not being adequately maintained even though maintenance of stream flow minima and existing water rights may be satisfied. It is significant that the Goose Lake basin is open to further water appropriations, indicating that groundwater supplies are not critical. Nevertheless, the approval of a water appropriations permit application gives no assurance that there is an adequate water supply. Once a permitted water appropriation has been put to use, then a certificate of water right is issued and the perfected water right is established.

When the supply of water is judged insufficient to meet the needs of all water rights holders, the available supply is distributed among the rights of record in order of individual priorities. Priorities are determined principally by the date of filing an application for a water appropriations permit; the appropriator having the oldest date of priority has first rights to demand available water.

It is an important consideration that the priority date becomes a secondary criterion to a water rights priority if water is being wasted. State policy stipulates the use of groundwater for maximum beneficial use in order to maintain a water right at a high priority. The distinction between "waste" and "beneficial use" could have significant impacts on water rights for geothermal projects, particularly in light of the fact that extraction of heat has not been declared a beneficial use of groundwater. By contrast, a system that extracts heat and then injects the fluid back into the reservoir maximizes use of the resource, according to WRD, and would be given a high priority. The criterion "beneficial" can also be ascribed to uses that do not reinject. Thus, a right to use water solely for heat extraction and subsequently waste the water would assume a low priority. If water from which heat had been extracted were put to an alternative beneficial use such as irrigation or domestic consumption, then that right would assume a high priority. However, if the WRD determines that any of the resource is wasted, then the right may become junior to future appropriations.

Indirectly related to the determination of beneficial use is the State policy that identifies injection of geothermal fluids into the producing reservoir as the preferred disposal method. This policy is the outcome of a Joint House Resolution passed in the 1977 Legislature which directed WRD, DOGAMI, DEQ, and DOE to address the question of geothermal fluid disposal. Recommendations from this group led the 1979 Legislative session to pass two measures stating that geothermal fluids shall be reinjected into the same reservoir from which withdrawn unless it is determined that policies and public interest indicate disposal by other means. Secondary uses as a method of disposal are specifically mentioned. The measures also direct DOGAMI and WRD to adopt rules governing reinjection for wells under their jurisdiction. Both agencies are presently drafting regulations which should be available by July 1980. It is expected that regulations developed by WRD will lend further support to the need for reinjection in order to establish a priority water right for wells permitted under the agency's authority.

The appropriation for the well that supplies the commercial geothermal greenhouses north of Lakeview is a case in point. The system extracts heat for space conditioning and wastes some of the geothermal water by discharging it into a ditch. The recorded water right gives heat extraction as the stated use of groundwater. Because the resource is not being put to maximum beneficial use, the water right could become secondary to future appropriations.

To summarize, in order to insure necessary water rights, the Lakeview district heating project should file an application for a water right permit as early as possible to establish a priority filing date. In order to file, the well location and maximum amount of water needed will have to be established; the application may be filed before wells are actually drilled. Because of the scale of development and costs associated with the development of geothermal energy utilization, it is important to conduct hydrologic investigations for potential geothermal development areas. If geothermal fluids are to be extracted from shallow depths and interference with existing wells is demonstrated, then water appropriations may be limited because of prior rights. On the other hand, if geothermal wells can extract sufficient fluids to meet system demands and not interfere with existing wells, water appropriations should not be a problem. Proper hydrologic evaluation will help in averting attempts to establish water rights in areas with inadequate water supply. Reinjection of spent fluids should be given serious consideration for system design to protect water rights.

D. Financial Incentives and Funding

The most direct method to fund geothermal projects is to secure private funding through lending institutions, investment companies, and individual investors. However, since most financial organizations have had little experience in dealing with geothermal energy development projects, and given the recent occurrence of high interest rates, obtaining private funding for geothermal energy development projects can be difficult. Federal, State, and regional programs exist to foster energy source development in general, and geothermal resource development in particular. These programs offer incentives in the forms of tax credits on certain investments and development-related expenses; funding programs are available to obtain money for both research and implementation activities.

1. Tax Incentives--State income tax credits are available to homeowners, renters, landlords, contract purchasers, and builders for the cost of residential geothermal systems. Applications for the credit must be approved by the Oregon Department of Energy (ODOE) before well drilling and construction. Residence-owning taxpayers can claim a 25 percent income tax credit on State taxes, up to a maximum of $1,000, for the cost of connection to a geothermal district heating system. The Federal residential energy credit for geothermal resource equipment expenditures is 40 percent of the first $10,000 of qualifying expenditures. Property equipped with a geothermal system is exempt from ad valorem taxation. Private geothermal developments may be able to deduct intangible drilling costs and make allowances for percentage depletion.

Business and industry income tax credits for the installation of equipment to use geothermal resources are available to facilities certified by the Oregon Department of Energy (ODOE) prior to construction or modifications. The credit is equal to 35 percent of the cost of the equipment and is claimed over a 5-year period. Utilities whose principal business activity is, directly or indirectly, the production, transportation, or distribution of electricity, petroleum, or natural gas are not eligible for the tax credit. Businesses and industries that use geothermal energy may be eligible for a 15 percent investment Federal tax credit, in addition to the standard 10 percent investment credit. The credit can be applied towards energy property and equipment. The tax credit was increased from the previously allowable 10 percent as a result of Windfall Profits Tax legislation passed in March 1980.

2. Funding Programs--Government funding and loan opportunities are limited, and competition for available funds is keen. Several of the sources listed in Table 1, below, are earmarked specifically for geothermal projects. Others are standard public works and economic development programs to support State and local governments and private entities in projects such as district heating systems development and development of local industry. Some of the funding programs for geothermal energy development focus on particular objectives, such as resource assessment, technology development, applications development, and institutional analysis.

Table 19 lists programs that may serve as sources of funnding for programs to develop geothermal resources and energy applications.

Table 19. FUNDING PROGRAMS FOR GEOTHERMAL ENERGY

Sponsor	Program Title
U.S. Department of Energy	Geothermal Loan Guarantee Program Program Research and Development Announcement (PRDA) Program Opportunity Notice (PON) User-Coupled Drilling Program Institutional Buildings Grants Program
Farmers' Home Administration	Community Facility Loans Business and Industrial Development Loans
Economic Development Administration	Public Works and Development Facilities Business Development Loans
Department of Housing and Urban Development	Community Development Block Grants Urban Development Action Grants Innovative Grants for Community Energy Conservation
Pacific Northwest Regional Commission	Geothermal Energy Studies District Heating System Studies
Oregon State Department of Energy	Small-Scale Local Energy Projects

XI. IMPLEMENTATION PLAN

The development of a district heating system in a timely and financially prudent manner requires the close coordination of a number of diverse activities such as resource exploration, user definition, and institutional activities. One approach to simplifying this requirement is to develop the heating system in phases. For Lakeview, this constitutes the development of the downtown Mini-district system, followed by expansion to other areas of town. This allows for the experience obtained in design, construction and operation of the Mini-district to be used in subsequent expansion.

For purposes of simplification, the development of the Mini-district system can be considered to consist of four phases. These phases are:

Phase I: Feasibility Analysis and Funding Determination

Phase II: Final Engineering and Specification

Phase III: Construction and Startup

Phase IV: Operation and Evaluation

Scheduling requirements for implementing these phases are shown in Table 20. The timing of future expansion to other areas in Lakeview would then depend on results of the Mini-district development. The remainder of this chapter reviews the activities required under each phase of the Mini-district development.

A. Phase I. Feasibility Analysis and Funding Availability

Phase I requires determining project feasibility and obtaining subsequent funding for the Mini-district system in Lakeview. Activities involved in this phase include user definition, resource characterization, permitting requirements, preliminary engineering, and economics and funding considerations. Many tasks in these areas have already been started or completed. It is expected that the remainder of the work necessary in this phase will require an additional 2 to 5 months to complete.

1. User Definition--A number of surveys conducted over the last 4 years have identified potential users, heat loads and prevailing attitudes toward geothermal energy development in the Lakeview area. Remaining work in Phase I should be to:

a. Complete research on requirements of users yet to be surveyed in the Mini-district service area.

b. Begin a program to inform Lakeview residents of the costs and benefits of geothermal heat. These information programs could include town meetings and information pamphlets.

c. Obtain service commitments from large space and water heating users in the Mini-district service area including the large, commercial buildings and the proposed alcohol plant.

TABLE 20. SCHEDULE REQUIREMENTS FOR IMPLEMENTATION OF A DISTRICT HEATING SYSTEM AT LAKEVIEW

Phases	Major Activities	Schedule Requirements
Phase I Feasibility Analysis and Funding Availability	User definition Resource characterization Permitting requirements Preliminary engineering Economics and funding considerations	2 to 5 months
Phase II Final Engineering and Specification	Permit applications User education Competion of well drilling and testing Engineering drawings and specifications	2 to 4 months
Phase III Construction and Startup	Construction contract awards Completion of system and user permit application Equipment installation	6 to 10 months
Phase IV Operation and Evaluation	Development of operating and maintenance experience Identification of user problems and experience	6 to 8 months

2. Resource Characterization--Existing well data and recent tests of the geothermal resources in Lakeview have been collected and analyzed. This data gives a strong indication that an excellent geothermal resource exists which could support a cost-effective district heating system. Additional Phase I work includes:

a. Determining specific locations for production and injection wells.

b. Drilling and testing production and injection wells to establish productivity, temperature profiles, and potential interactions.

3. Preliminary Engineering--The preliminary engineering design for the Mini-district system has been developed from heat loads and resource characteristics identified in previous studies. Although essentially complete, the preliminary design and related cost estimates may require further updating if significant differences are found in well tests or user surveys being conducted under continuing Phase I work.

4. Permitting Requirements--The Federal, State, and local agencies requiring permits are discussed in Chapter X. Contacts have been made with several of these agencies with respect to development of the geothermal resource in Lakeview. Activities which should be included in the remainder of Phase I are:

a. Preparing necessary well drilling permits for the exploratory production and injection wells.

b. Contacting the county regarding recent requirements being established for local geothermal development.

c. Contacting the State Energy Facility Siting Committee to determine the necessity of obtaining a State siting certificate.

5. Economics and Funding Considerations--Based upon current results, a geothermal heating system is a feasible energy alternative for the Lakeview area. Northwest Geothermal Corporation has obtained a district heating franchise from the town and has negotiated an agreement with Gulf Mineral Resources Company, the principal geothermal leaseholder in the area.

A major remaining task for Phase I is to acquire a commitment to finance the project. Funding has been applied for and received under DOE's User Coupled Drilling Program. This will cover partial financing of exploratory and reinjection wells. Additional funding will be applied for under various State and Federal programs for geothermal development and/or development of areas which are economically depressed.

B. Phase II. Final Engineering and Specification

After a funding commitment has been obtained for the Mini-district development, Phase II will start and is to include preparation of final specifications for the system. The major activities will include permitting, interfacing with users, drilling and casing wells, and conducting detailed engineering tasks. Phase II will take 2 to 4 months to complete.

The following summarizes tasks to be done in Phase II.

1. Permitting

a. Obtain water appropriation permits.

b. Obtain remaining drilling permits for exploration, testing, and production wells.

c. Complete review of requirements for the State Energy Facility Siting Committee. Submit necessary engin-ering plans and drawings for proper evaluation.

2. Interfacing with Users--Continue user education programs as defined in Phase I.

3. Well Drilling and Testing--Complete drilling, casing and testing of remaining production and reinjection wells.

4. Final Engineering

a. Complete engineering optimization studies.

b. Prepare detail arrangement, piping, wiring and layout drawings.

c. Prepare equipment and construction specifications.

d. Prepare system design, operation and maintenance manuals.

C. Phase III. Construction and Startup

During Phase III, construction and startup of the Mini-district heating system will occur. Phase III will require 6 to 10 months.

The major tasks during Phase III are:

a. Award of construction contracts.

b. Acquisition of remaining necessary construction and operation permits from the town council, County Planning Commission, the State PUC and the State Energy Facility Siting Council.

c. Installation of piping, equipment, controls, wiring and all other system appurtenances.

d. Acquisition of user permits for waterline connections and new installation of heating equipment.

e. Installation of user piping, space heating and water heating equipment.

f. Checkout and startup of Mini-district heating system.

D. Phase IV. Operation and Evaluation

After successful startup of the Mini-district heating system, Phase IV will begin. In this phase, experience will be obtained in operating the geothermal Mini-district heating system, and an analysis will be conducted to determine the desirability of further expansion. Phase IV will span one heating season, of approximately 6 to 8 months duration.

The major areas to be evaluated are:

a. Mini-district heating system operation, maintenance and design requirements.

b. Actual versus predicted energy consumption.

c. User retrofit and operation difficulties.

d. System costs and economics of future expansion.

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