GEOTHERMAL DISTRICT HEATING SYSTEM CITY OF KLAMATH FALLS

Paul J. Lienau
Kevin Rafferty, P.E.
Geo-Heat Center

INTRODUCTION

The city of Klamath Falls became interested in the possibility of a establishing geothermal district heating system for downtown government buildings in January 1977. Since that time, the project has undergone some controversial and interesting developments that may be of educational value to other communities contemplating such a project. The purpose and content of this article is to identify the historical development of the project; including the design of the system, well owner objections to the project, aquifer testing, piping failure, and future expansion and marketing incentives.

The shallow geothermal reservoir in Klamath falls extends for at least 6.8 miles in a northwest-southeast direction, as shown on Figure 1, with a width of about 2 miles. More than 550 thermal wells ranging in depth from about 10 to 2,000 ft, and obtaining or contacting water from 70 to 230°F, have been drilled into the reservoir. The system is not geologically homogeneous. Great variations in horizontal permeability and many vertical discontinuities exist because of stratigraphy and structure of the area. Basalt flows, eruptive centers, fluvial and lacustrine deposits, diatomite and pyroclastic materials alternate in the rock column. Normal faults with large throw (estimated up to 1,700 ft) are spaced less than 3,300 ft apart and appear to be the main avenue of vertical movement of hot fluids.

In order to more effectively utilize this resource, the city of Klamath Falls decided in 1978 to apply for a federal grant (Program Opportunity Notice to cost share field experiment projects) to construct a geothermal district heating system that would deliver geothermal fluids to areas not located on the resource.

In 1977, several Geo-Heat Center staff members visited Reykjavik, Iceland, to study the design of their geothermal district heating systems. This was in part the basis for the conceptual design and feasibility study (Lund, 1979) of a downtown commercial district. The main difference between the Icelandic systems and the Klamath Falls design was that the Icelanders used an open-type system delivering geothermal fluids directly to the customers; whereas, the Klamath Falls type was a closed-system design employing a central heat exchanger.

SYSTEM DESIGN

The conceptual design involved determining production field locations and characteristics, identifying boundaries of market areas and determining the heat load of the commercial district, development of the commercial district distribution design for geothermal fluid delivery and disposal, evaluation of potential economic impacts and costs. During the design process, a three-phase approach was developed. The first phase (Phase I: 12.1 x 10^6 Btu/hr) consisted of supplying heat to 14 government buildings. Subsequent phases would expand the customer base to commercial buildings adjacent to the main pipeline (Phase II: 34.8 x 10^6 Btu/hr) and finally, the entire downtown commercial area (Phase III: 143 x 10^6 Btu/hr). To date, only Phase I has been completed.

The engineer of record for the project was James K. Balzhiser, Balzhiser/Hubbard & Associates, 860 McKinley Street, Eugene, OR 97402. In 1989, the Geo-Heat Center reviewed the materials and equipment (Rafferty, 1989) for the completed system. Description of the design was primarily taken from that report.

Production

The first of two production wells for the district heating project was spudded on August 21, 1979, in the area of Old Fort Road and Laguna Street, Figure 2. Figure 3 shows the temperature gradient for City Well-1 (CW-1) production well. This is a classic example of a temperature reversal after drilling through the shallow geothermal aquifer. The well was originally drilled to 90 ft and cased to 334 ft. during the first pump test, produced 60 gal/min of 190°F water with a drawdown of 170 ft or specific capacity of 0.35 gpm/ft. after perforating between 190 and 245 ft, the well produced 720 gpm of 212°F water with a specific capacity of 100 gpm/ft. This isolated example may not be typical; but, simple logic tells us the difference in transmissivity between the geothermal aquifer and zones above and below must be significant else those zones would be part of the geothermal aquifer. The second well, CW-2, was drilled to 367 ft and produced 770 gpm at 219°F with 77 ft drawdown (specific capacity of 10 gpm/ft).

After completion of the wells, tests were conducted on September 29 and 30, 1981, and preliminary indications were that the water level decline in the area of the production wells would be small, 2 to 3 ft when pumping large volumes of water. However, long-term testing was proposed to determine whether or not the two production wells could be used without causing negative impacts on the nearby private wells for Phase I or the project.

The production well pumps are vertical lineshaft turbines with variable-speed fluid drives. The variable-speed drive provides continuous operation of the pumps for constant

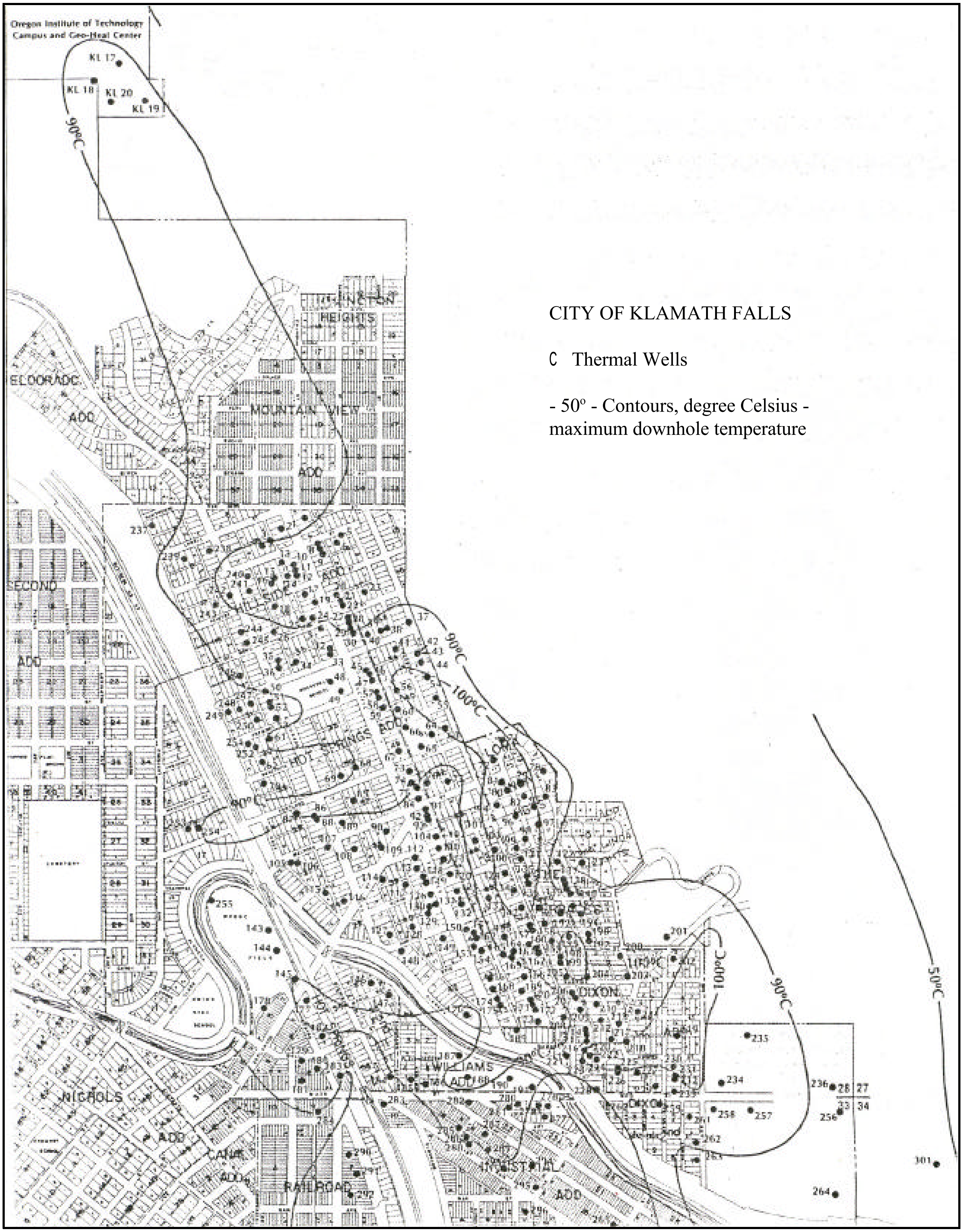


Figure 1. Temperature contours of the Klamath Falls urban area.

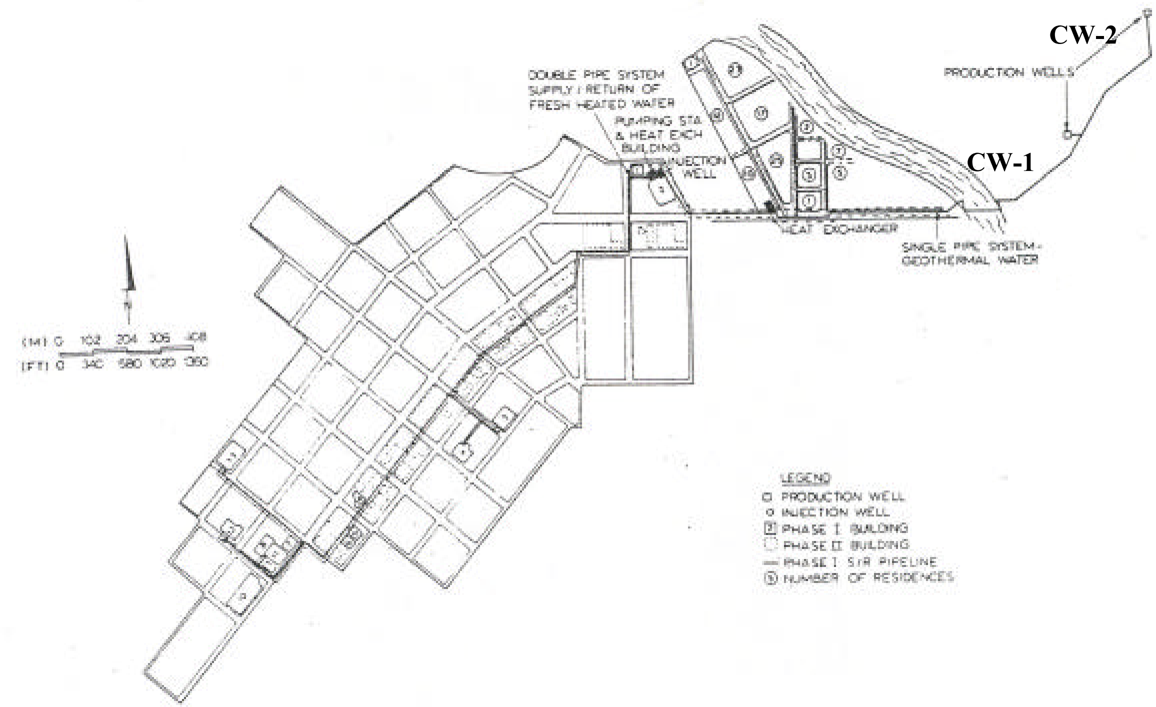


Figure 2. City commercial and residential district heating system.

pressure at the wellhead and in the supply line under varying flow requirements. The design of the production pumps took into account the pressure required for return of fluid into the aquifer via the injection well located adjacent to the heat exchanger/pumping building, Figure 2. Table 1 presents a summary of the production facilities employed by the city district heating system.

Table 1. City of Klamath Falls Production Facilities Summary (Rafferty, 1989)

	Well CW-1	Well CW-2
Well depth	900	367
Well diameter (in.)	12	12
Temperature (ºF)	212	219
Static water level (ft)	60	76
Specific capacity (gpm/ft)	100	10
Setting depth (ft)	300	300
Bowl sizes (in.)	10	10
Number of stages	8	8
Horsepower (hp)	50	50
Manufacturer	Aurora	Aurora
Variable-speed drive	Yes	Yes
Drive type	Fluid coupling	Fluid coupling
Manufacturer	Nelson	Nelson
Lubrication (shaft)	Oil	Oil

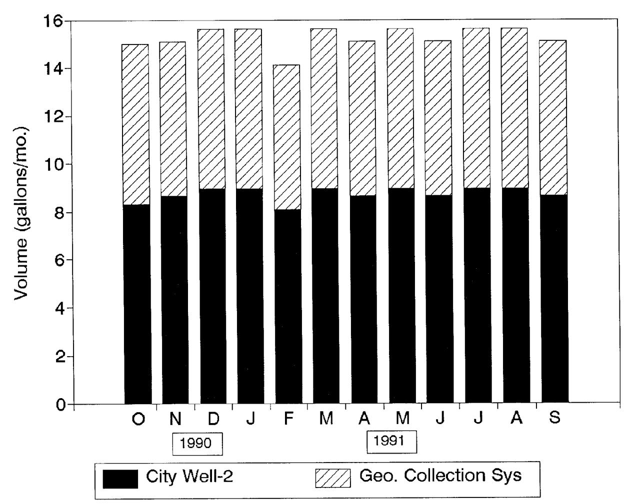


Figure 4. Volumes of geothermal fluid pumped from City Well-2 and produced from the Mills Addition geothermal collection system.

During the 1991 heating season, volumes of geothermal fluids pumped on a monthly basis are shown in Figure 4. As can be seen from the graph, there is not much change in pumped fluid volumes from month to month. This is due to the fact that the system is not loaded; i.e., the production pumps are adjusted to their lowest flowrate for the 11 government buildings and 12 homes currently on the system.

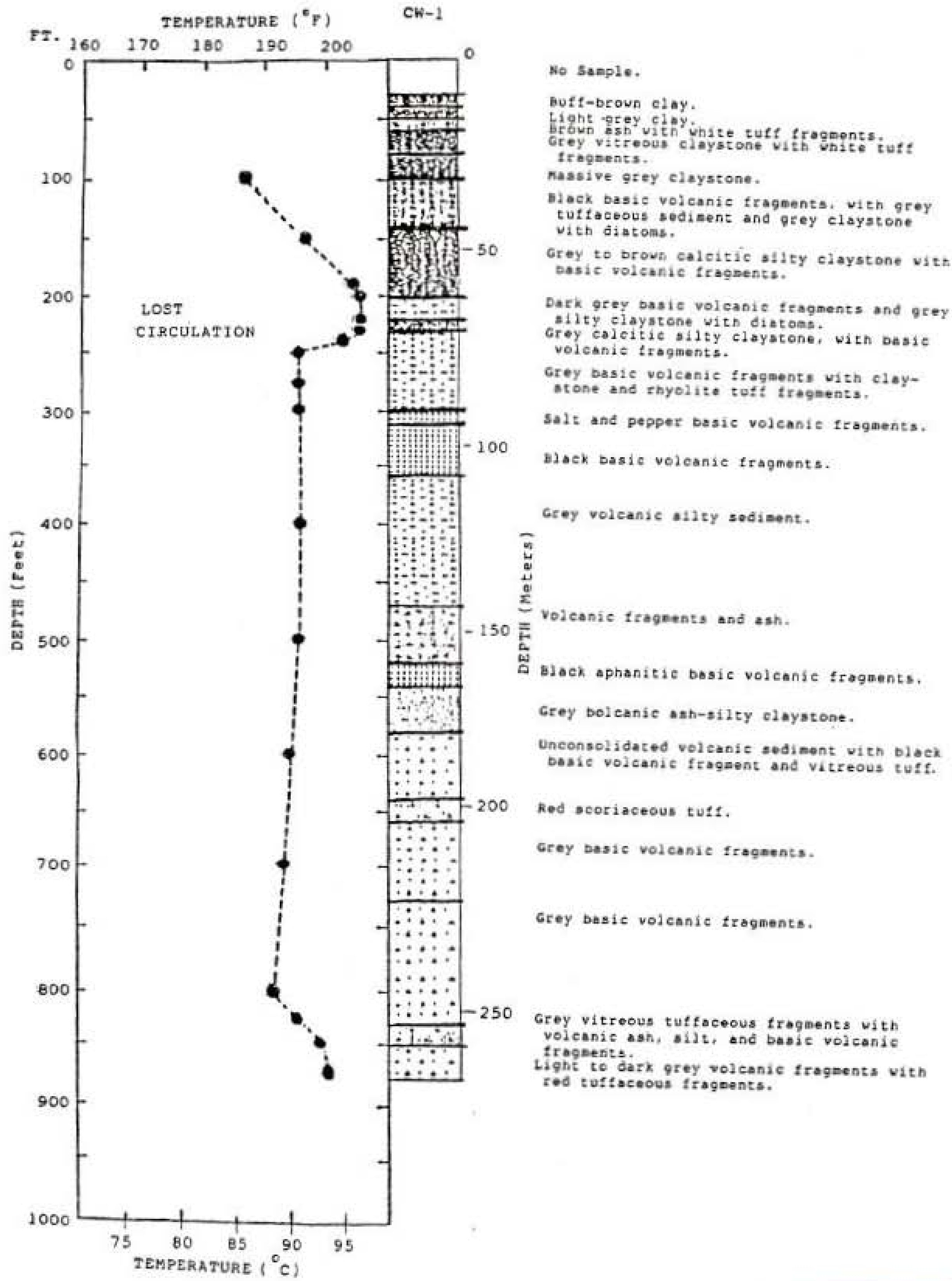


Figure 3. Temperature profile and lithology of Klamath Falls City Well-1 (Benson, 1980).

Distribution

A layout of the distribution system appears in Figure 2. The system consists of two major portions:

1. Transmission line.
2. Distribution loop.

The transmission line employs two types of installation methods: direct buried and concrete tunnel. The entire 4,040 ft length is composed of 8-in. Preinsulated Schedule 40 steel piping with a fiberglass jacket. From the production wells to Point A (Figure 2), this line is direct buried. Expansion joints are located in vaults along the route. The expansion joints are of the controlled flexing type with 304 SS carrier. At Point A, the line passes under a state highway and across a canal bridge. The road bore was installed with a 20-in. steel casing in which the 12-in. OD pre-insulated line was located.

For the bridge crossing, the pre-insulated line was hung from the bridge structure with spring loaded, roller-type hangers.

Concrete tunnel above ground for railroad underpass.

At the west side of the bridge, the line enters the concrete tunnel. The concrete tunnel has a high cost when compared to other systems; however, the advantages to this type of system are: (1) access to the pipe for installation of future primary supply pipes as the system expands; (2) access to the pipe for future connection of geothermal wells located along its route; (3) access for maintenance and repair and better assurance that groundwater will not contact the pipe and thus, cause corrosion; and (4) the lid may be used for a sidewalk, with heat radiating from the pipe providing snow removal. It proceeds for a distance of 2,290 ft to the system mechanical room. The same type of expansion joints are used in the tunnel as were used in the direct buried portion of the line.

All of the secondary loop is direct buried piping. Approximately 4,400 feet of the total is ten inch preinsulated Schedule 40 steel similar to the transmission line. Sizes less than ten inch (8.280 feet) were preinsulated FRP piping of the key-lock type mechanical joining system. In 1985, after approximately 12 months of operation, the FRP piping failed. The failure of the system was the result of the lock ring portion of the joint becoming detached from the piping. The lock rings were attached, by the manufacturer, with an epoxy adhesive. This adhesive was evidently improperly manufactured or applied. In any case, failure of the epoxy permitted axial movement in the joint. Eventually, this resulted in leaks at these locations and the system had to be shut down on February 1986. The fiberglass material was replaced entirely with ductile iron in the fall of 1990, after litigation and the city had secured funding for construction. The system was brought back online in January of 1991.

Lock ring portion of joint detached from fiberglass piping.

Central Mechanical Plant

The central mechanical building contains the main place heat exchangers, circulating pumps, expansion tank and control system for the district. A flow scheme for this portion of the system appears in Figure 5.

The system employs two heat exchangers, each capable of transferring 10 x 10^6 Btu/hr. Automatic, two position valves interlock these heat exchangers with the main circulating pumps so that only one heat exchanger is on when only one pump is on-line. Both heat exchangers operate when both pumps are on-line.

Plate heat exchanger capable of transferring 10 x 10^6 Btu/r.

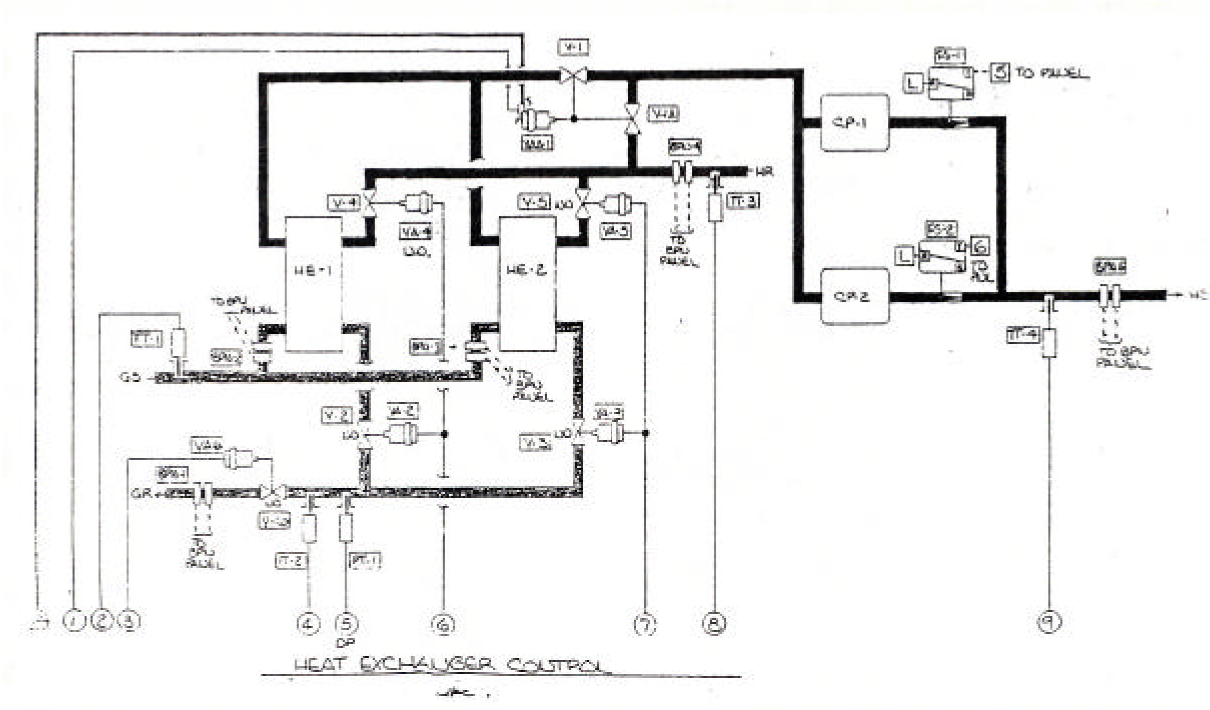
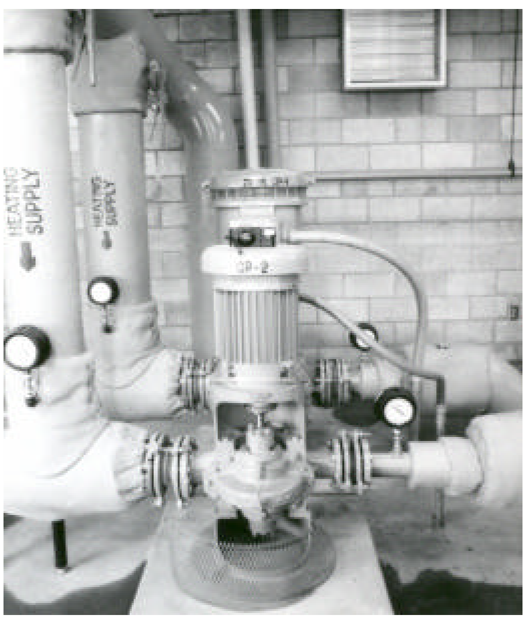


Figure 5. Flow scheme of the city district heating system.



Circulating pumps.

In summary, as shown in Figure 5, a pair of valves (V-1 and V-1A) on the loop side of the exchangers modulate to maintain a supply water temperature of 180ºF. The pneumatic signal to these valves is also delivered to a pressure transducer. This transducer sends a signal, via telephone lines, to an actuator located at the production wells. This actuator then varies the speed of the production pumps, thus conserving the resource and electricity.

Metering

Energy metering is employed on all buildings connected to the system. The existing eleven government buildings and twelve homes are charged on a price per Therm basis. The government buildings are currently charged $0.59 per therm ($0.02/kWh) based on the cost to payback the loan to replace the fiberglass piping. Homes on the system are charged $0.32 per Therm ($0.01/kWh).

Disposal

Disposal for the spent geothermal fluids is by means of a single injection well. This well is located (see Figure 2) adjacent to the central mechanical room. In fact, the system was laid out to take advantage of this well (which was already in existence at the time of construction) for injection purposes.

The museum well, as it was previously known, was drilled in 1975, and was used only as a downhole heat exchanger well (to heat the county museum) until construction of the district heating system. Figure 6 presents key data on the well. The temperature profile was taken during a "no load" injection test.

Originally, 1,235 feet deep, the well has filled in to approximately 1,180 feet. At completion, it was slightly artesian (2 psi shut in) and was capable of producing 188 gpm of 188ºF water at full artesian flow (Sammel, 1984). The artesian head in recent years had dropped below the surface. A maximum temperature of 199ºF has been measured in the well.

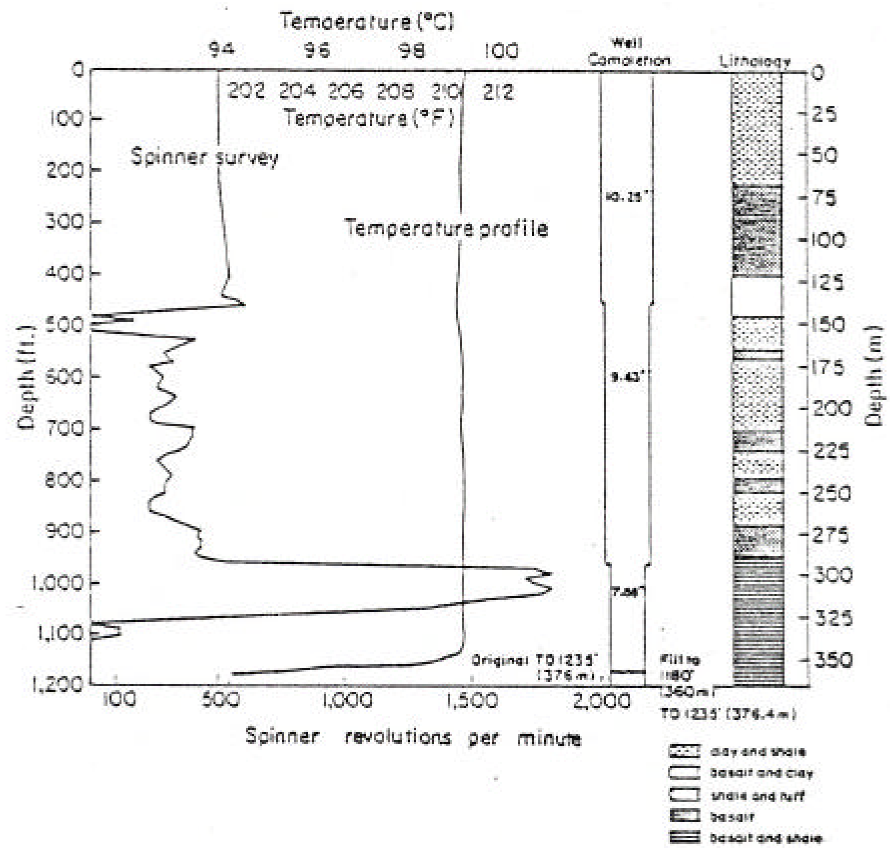


Figure 6. Temperature profile and spinner survey obtained during injection into County Museum well (Sammel, 1984).

This well currently accepts injection fluid from the main downtown district heating system and the Mills Addition collection/district heating system. In order to avoid problems which might arise due to the thermal affects on adjacent wells, the injection temperature for the city district system was selected to exceed that of the surrounding wells. In this manner, the only thermal effect which could occur would be one of increasing rather than decreasing temperature. It is primarily for this reason that a ΔT of only 40°F is achieved by the district system. If thermal impact on other wells was not a consideration, the system would likely have been designed for a much greater ΔT.

Michigan Street System

The Michigan Street System was constructed with funds from HUD in 1982. This system was an effort to extend the heating district into a low income residential area. Because many of the homes in this area are rental units (in which tenants pay the heating bills), only a small fraction of the total number of homes (12 out of approximately 120) have been connected. The system is connected to the primary transmission line for the downtown system. Fluid is pumped from the transmission line through the central plate heat exchanger and back into the transmission line by one of two geothermal circulating pumps.

The heat exchanger along with all other mechanical equipment, is located in an underground concrete vault. This type of installation was employed as a result of the lack of available surface space for a mechanical room. The vault is located under the sidewalk adjacent to the main transmission line. The heat exchanger was designed for the following duty:

Heating load	5.76 x 10^6 Btu/hr
Geothermal flow	160°F in, 120°F out
Loop flow	110°F in, 150°F out

The distribution system for the Michigan Street area consists of 6,258 feet of 2 to 4 in. buried fiberglass pipe with epoxy joints. Individual branch lines to homes (3/4 inch) were constructed of field insulated polybutylene piping.

Mills Addition System

The Mills Addition system, completed in 1987, is the latest addition to the Klamath Falls heating district. This system is connected to the main transmission line to provide geothermal fluid for emergency backup purposes. The primary source of heat is "waste" flow from seven existing private geothermal systems. The fluid is collected, delivered to a 2,000-gallon holding tank and passed through a heat exchanger to provide heat to a closed-loop distribution system. Effluent from the heat exchanger is delivered through an uninsulated line to the injection well. This system employs the same injection well as the main downtown loop and serves only as a disposal method for the private wells at this time.

WELL OWNER'S OBJECTION TO THE CITY SYSTEM

Well owner reaction to the building of the City district heating system caused serious delays in startup from 1981 to 1984. The well owners organized a citizen's committee, Citizens for Responsible Geothermal Development, who objected to the pumping of geothermal fluids from the area of many private residential wells utilizing downhole heat exchangers (DHE). The DHE consists of two strings of pipe connected at the bottom by a reverse bend. In most of these wells, no geothermal fluids is pumped out of the well and the static water level must remain above the upper perforations in the well casing to work properly. Lowering the water level in a well below these upper perforations by pumping wells in the reservoir was the main concern of the private well owners.

The citizen's group initiated an ordinance which was approved by the voters in June 1981. The ordinance essentially regulated the use of geothermal water by requiring that any water pumped from a well be returned to that same well. Since the city system would utilize two production wells, located in the residential area, and a third injection well, the ordinance stopped th city from utilizing its system.

Third-party mitigation by the Chamber of Commerce was responsible for the successful initiation and coordination of the Klamath Falls aquifer test. This mitigation resulted in many community groups and outside institutions working together to establish valuable baseline data which appeared to change the attitude of a majority of the citizens regarding the development of the resource and eventually allowed the city to operate the district heating system. A Geothermal Advisory Committee was also established consisting of a cross-section of representatives from all interested groups. The Committee's role is to recommend specific action with regard to development and management of the geothermal resource.

AQUIFER TEST

In 1983, the Klamath Aquifer Test consisted of a seven-week pressure interference test and doublet tracer testing involving the cooperation of many citizens, local organizations, USGS, Lawrence Berkeley Laboratories, Stanford University and the OIT Geo-Heat Center. An enormous quantity of hydrologic data was obtained from the Klamath Falls geothermal aquifer. It was an unprecedented achievement both for the extraordinary high quality data obtained and for the cooperation of the many individuals who provided data, interest, and participation in the aquifer test. Under well controlled conditions, the response of the aquifer and the individual wells to both pumping and injection were measured. The test was of sufficient duration and data of adequate quality so that conventional and non-conventional analysis techniques could be applied with a great deal of confidence.

Interference Test

The interference test of the aquifer covered a seven-week period from July through August 1983. The test consisted of monitoring water-level changes in 52 wells; while, pumping and injection operations were ongoing in tow other wells. An area of approximately 1.7 square miles of the geothermal aquifer was monitored during the test. For the first three weeks, the observation wells were monitored while City Well-1 (CW-1) was pumped. For the final four weeks, hot water was pumped for CW-1 and concurrently injected into the County Museum well. Locations of production, injection and monitored wells are shown in Figure 7.

The central focus of the research was the response of the shallow geothermal aquifer to stresses imposed by pumping and injection of thermal water. In order to properly interpret the data derived from the pumping and injection tests, a number of additional tests and studies were made. These included chemical analyses, tracer tests, temperature measurements, and the collection of lithologic, climatic, seismic, discharge and utilization data. As a result of these activities, some existing concepts of the geothermal aquifer were confirmed and several crucial new concepts were developed.

The plots of drawdown vs. time (Figures 8 and 9 as examples) obtained during the test fit theoretical curves that represent double-porosity conditions in the aquifer. Double-porosity describes an aquifer in which the initial flow in response to pumping occurs largely in more permeable strata or in fractures; whereas, flow at later times is sustained partly by contributions from less permeable masses of rock (the matrix). Examinations of drillers longs and well cuttings indicates that the aquifer contains both fractured rock and granular strata of high permeability as well as unfractured, massive rock and sedimentary strata of low permeability. For practical purposes of use and development, these two types of aquifers behave similarly and may have identical potential for development.

Pressure changes were transmitted rapidly at the start of the pumping test. This finding is in accord with results of the doublet-well tracer tests, which show that the thermal water moves rapidly in permeable strata or fractures. The rapid and uniform response of observation wells also indicates that the permeable strata and fracture zones are confined by rocks of low permeability so that they behave more like a network of pipes than an unconfined reservoir. This concept is supported by the isotopic data (tritium), which show that little recent meteoric water mixes with the thermal water in the shallow aquifer.

No hydrologic boundaries were detected during the test. On the basis of the above results, the radius of investigation (at 336 hours) was estimated to be 3.5 miles. The lack of boundaries to the system within this radius has several important consequences. First, it sheds an interesting light on the hydrologic properties of the fault zone that is the primary conduit for hydrothermal circulation (Sammel, 1984). Unlike the response predicted by classical models for constant-potential or constant-flow faults, this fault was invisible to

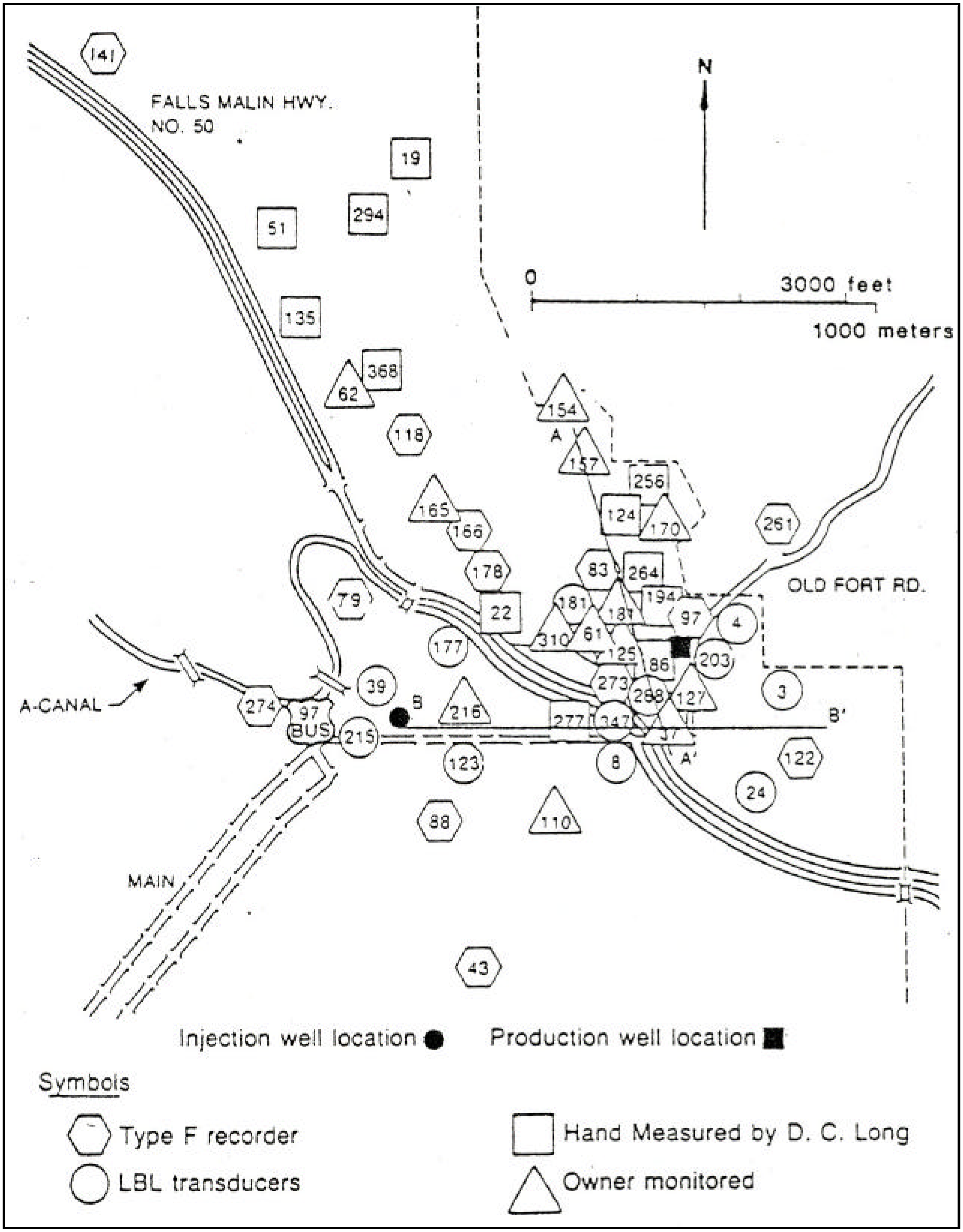


Figure 7. Observation-well location map.

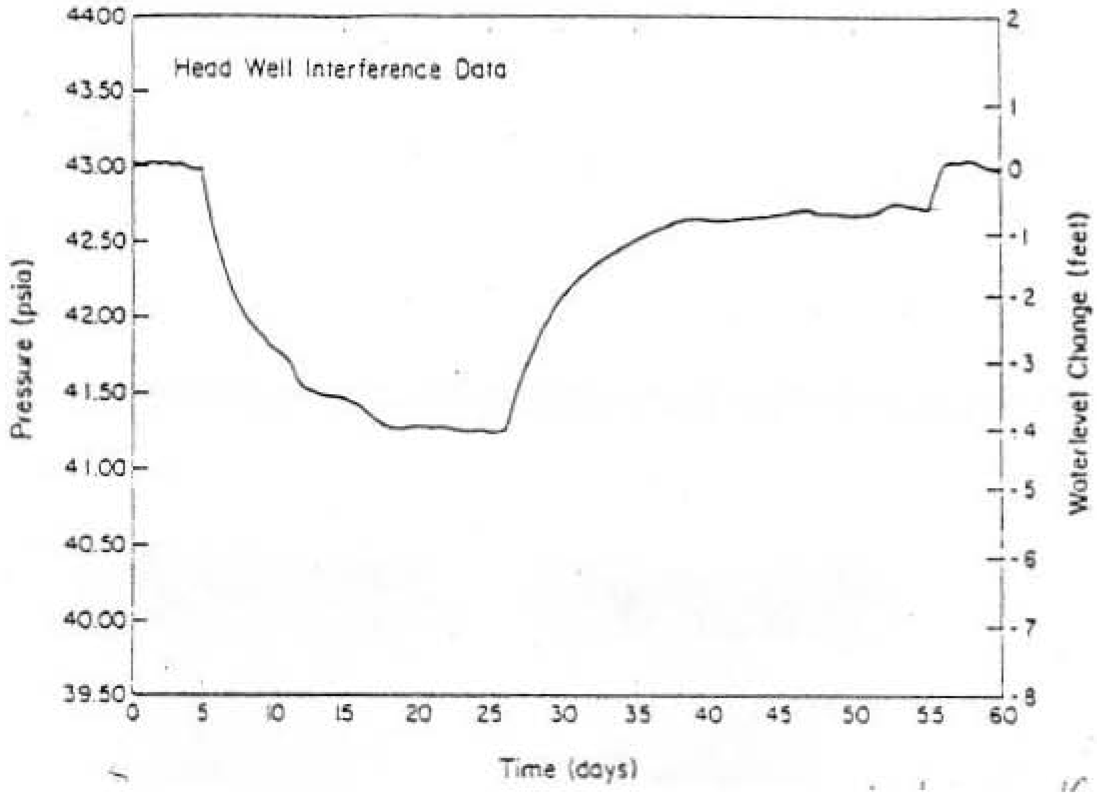


Figure 8. Interference data from the Head well (No. 101) near the production well CW-1, July 1 to August 29, 1983.

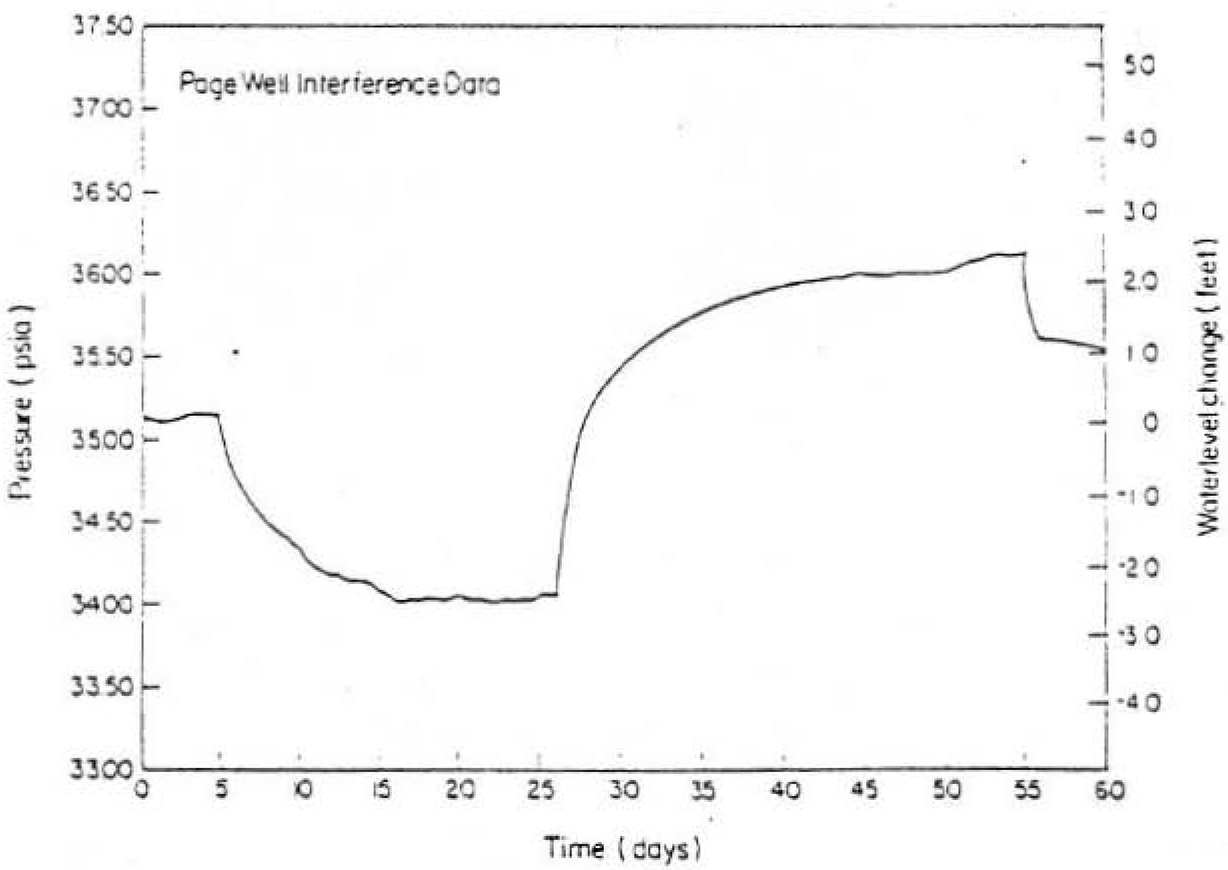


Figure 9. Interference data from the Page well (No. 177) near the injection well, July 1 to August 29, 1983.

hydrologic testing. Several hypotheses can explain this observation. First, the hot water may upwell over a broad region rather than along a single fault zone that could be detected hydrologically. Second, the fault permeability may be of the same order of magnitude as the permeability of the near surface aquifers and hence, indistinguishable. Third, a single fault may provide the conduit for upwelling from great depth, but as the fault approaches the surface, the width of the fractured zone increases and creates a diffuse permeable region in the near surface. Additional research in this area could provide further insight into the nature of the supply conduits. A second implication of the lack of hydrologic boundaries to this system is that the hydrothermal system is an integral part of the regional hydrologic system. As such, fluid recharge should be in abundant supply.

The start of injection produced a rise in water levels that was detected almost immediately in all monitor wells, see Figures 8 and 9. Aquifer characteristics observed during the injection phase of the test satisfactorily match those observed during the pumping-only phase.

The effectiveness of injection wells in supporting water levels and hydraulic pressures has been qualitatively known for many years in Klamath Falls. The analysis of the drawdown and injection data presented, show clearly that injection of thermal water is capable of offsetting the immediate and widespread drawdowns that occur during pumping. This conclusion could have been arrived at solely on the basis of the drawdown data, but the results of the injection test are doubly reassuring on this point.

Geochemistry

The chemical and isotopic compositions of the thermal and non-thermal waters of Klamath Falls show that the water in the shallow thermal aquifer is a mixture of a cold, dilute groundwater with a hot more saline component originally at a temperature between 300 and 375°F. The mixing produces waters at 203 to 266°F with a corresponding small range of salinity. The mixed thermal waters contain (in order of decreasing concentration) SO_4, Na, SiO_2, Cl, HCO_3, Ca and K, and have a total salinity of about 1,000 mg/Kg. This chemical composition is typical of waters that have equilibrated at high temperatures in a geothermal reservoir. Table 2 presents the fluid chemistry of CW-1 production well.

Sources of recharge were not identified in the study. Deuterium concentrations suggest that recharge may occur at higher altitudes than those in the immediate vicinity of Klamath Falls, and the low tritium concentrations show that the cold recharge water has had a long (>30 years) residence time in the ground. These indications imply that the water has traveled a significant distance from the points of recharge and that the flow may occur in a deep regional aquifer.

Tracer Tests

Information obtained from the tracer tests provided a preliminary basis for important decisions regarding the use and development of the resource. These decisions relate mainly to the possible consequences of injection when this method is employed as part of the development strategy. The analysis of the pumping and injection tests leaves little doubt that injection of the thermal water at almost any point in the aquifer could raise water levels over a larger area. However, this analysis must take into account the tracer-test results which related to the thermal effects of injection.

Table 2. Fluid Chemistry of CW-1 Production Well

Key Species	mg/L
pH	8.60
TDS	795.00
Chloride, Cl	51.00
Sulfate, SO_4	330.00
Bicarbonate, HCO_3	20.00
Carbonate, CO_3	15.00
Hydrogen Sulfide, H_2S	1.50
Ammonium ion, NH_4	1.30
Oxygen, O_2	0-0.02
Silicon, Si	48.00
Sodium, Na	205.00
Calcium, Ca	26.00
Nitrate, NO_3	4.90
Potassium, K	4.30
Fluorine, F	1.50
Iron, Fe	0.30

The tracer tests tended to confirm the nature of the aquifer indicated by the pumping test. They showed the small volumes of fluid move rapidly through large fractures and permeable porous media. The transfer of large volumes of water is much slower, however, because most of the rock volume has low permeability. Most of the heat in the aquifer is stored in the massive rock material, and this storage has the effect of slowing the temperature decrease that occurs when cooler water is introduced into a hot aquifer.

Results of bot the tracer test and the pumping test suggested that injection wells should be carefully designed and located. In planning the locations ,the indications of anistrophy observed in the pumping test may be useful for guiding the placement of points of injection. For example, the probability of increased pressure support along the axis of anistrophy should be weighed against the increased likelihood of thermal breakthrough along this axis. The depth of injection is also an important consideration in relation to the depths of water entry in existing wells. Lithologic logs and drillers' reports can be consulted in making these determinations. Monitoring and tests of all injection activity is essential for increasing understanding of the aquifer behavior and for reducing uncertainties in predictive models.

Summary of Aquifer Test

The geothermal aquifer underlying the city of Klamath Falls is primarily a fault-and fracture-controlled system. The fault(s) and fractures provide highly permeable paths along which water moves easily. The sediments and tuffaceous rocks provide the bulk of the storage capacity of the aquifer as indicated by the double-porosity type pressure transients. Pressure-transient and steady-state analyses of the drawdown and buildup data from many wells were similar and the average values for the hydrologic properties of the system are as follows:

Transmissivity (kh) = 1.4×10^6 md-ft
Storativity $(\phi ch)_1$ = 5×10^{-3} ft/psi
$\phi = 10^{-7}$
$\varpi = 10^{-2}$

MARKETING AND THE FUTURE

The Klamath Falls system, as other small town systems, finds itself in a difficult marketing position. The availability of low-cost natural gas as a competing fuel, relatively small building sizes, past system reliability problems and a lack of marketing manpower have hampered efforts to add new customers. A new marketing plan, developed with input from the Geo-Heat Center and scheduled for implementation in early 1992, should successfully address many of these issues.

Natural gas rates locally as low as $.32 per therm offer a very competitive fuel source. The city has historically offered geothermal rates which were designed to provide a savings when compared to heating with natural gas. It is difficult to convince customers, however, that these rates although similar on a per therm basis do provide a savings as a result of the losses associated with the operation of natural gas heating systems. A further consideration is that the cost of the energy meter used to measure geothermal heat consumption has proven to be a substantial part of the retrofit in small buildings.

To address these issues, the new marketing approach will eliminate the use of energy meters and offer heat on a flat rate basis. The flat rate will be custom designed for each building and will be based upon the historic fuel use of their current heating system. The rate will offer the customer approximately a 50% savings compared to natural gas costs. To assure predictable savings in the future, the rate will be tied to a maximum allowable annual increase such as the natural gas inflation rate on the Consumer Price Index. This approach should clearly demonstrate to potential customers the savings associated with connecting to the geothermal system. It will eliminate the confusing discussion of natural gas system efficiency and its impact upon savings.

In addition to the elimination of the energy meter, the requirement for a customer heat exchanger will also be dropped for future accounts. Most potential customers in the downtown area are small buildings (<5,000 ft^2) and do not currently have hot water heating systems. As a result, this requirement of a customer heat exchanger also implies that a circulating pump, expansion tank, pressure reducing valve and water fill line be installed in order to operate a hot water system. Elimination of the heat exchanger greatly reduces the retrofit cots for small buildings, thus increasing the incentive to connect to the system.

To assist with retrofit costs, the State of Oregon Department of Energy offers the Small-Scale Energy Loan Program (SELP). This is a low-interest program available to any person, group or business in the state. Using the program, the business owner could retrofit his building using funds borrowed from the state. To further enhance this project, a 35% tax credit is available for connecting to a geothermal system. This tax credit must be taken over a 5-year period. These two programs should substantially increase the number of building owners to whom connection is economically attractive.

The Klamath Falls system has experienced extensive downtime in the past due to both political and mechanical issues. The political problems are discussed above have been resolved for some time. The mechanical problems, primarily pipeline failure, have been resolved with the replacement in 1990-91 of the defective portions of the distribution system. As a result, the system is able to offer potential customers a reliable source of heat not subject to the extended shutdowns of the past.

Due to a lack of available staff time on the part of the city, the Geo-Heat Center will be assisting in the marketing effort. Our input will be in the area of assisting individual building owners with their decision regarding connection to the system. Because funds are not currently available for major line extensions, the initial thrust of the marketing will be directed at building owners located adjacent to existing distribution lines.

The future is bright for the Klamath Falls system. The new marketing plan offers customers a reliable, competitively priced heating source. Retrofit equipment requirements and costs have been reduced, and financing and tax credits are available to enhance the overall economics of connecting to the system. These changes should result in an increasing customer base for the system and a shot in the arm for the local economy.

CONCLUSIONS

The development of the Klamath Falls geothermal district heating system has made geothermal energy available to government and commercial downtown buildings with a savings over the use of conventional fuels. The operation of the system requires minimum maintenance and with the exception of the join failures of the fiberglass piping, it has operated very satisfactorily.

Based on the Klamath Falls experience and problems encountered in establishing a geothermal district heating system, it is recommended that public awareness programs be conducted early in the planning process, organize a committee to represent a cross-section of all citizens on recommendations for specific action with regard to development and management of the resource, perform reservoir test programs early in order that a solid baseline of data may be obtained. It is essential to have a monitoring program throughout the life of the project and a marketing plan developed to attract new customers.

REFERENCES

Benson, S. M.; Goranson, C. and R. C. Schroder, 1980. "Evaluation of City Well-1, Klamath Falls, Oregon," Commercial Use of Geothermal Heat, Geothermal Resources Council, Davis, CA, pg. 17.

Lund, J. W.; Lienau, P. J.; Culver, G. and C. V. Higbee, 1979. "Klamath Falls Geothermal District Heating - The Commercial District Design," Report to City of Klamath Falls, LLC Geothermal Consultants, Klamath Falls, OR.

Rafferty, K., 1989. "A Materials and Equipment Review of Selected U.S. Geothermal District Heating Systems," Report to USDOE, Geo-Heat Center, Klamath Falls, OR, 124 p.

Sammel, E. A., editor, 1984. "Analysis and Interpretation of Data Obtained in Tests of the Geothermal Aquifer in Klamath Falls, Oregon," USGS Water Resources Investigation Report 84-4216, Menlo Park, CA.