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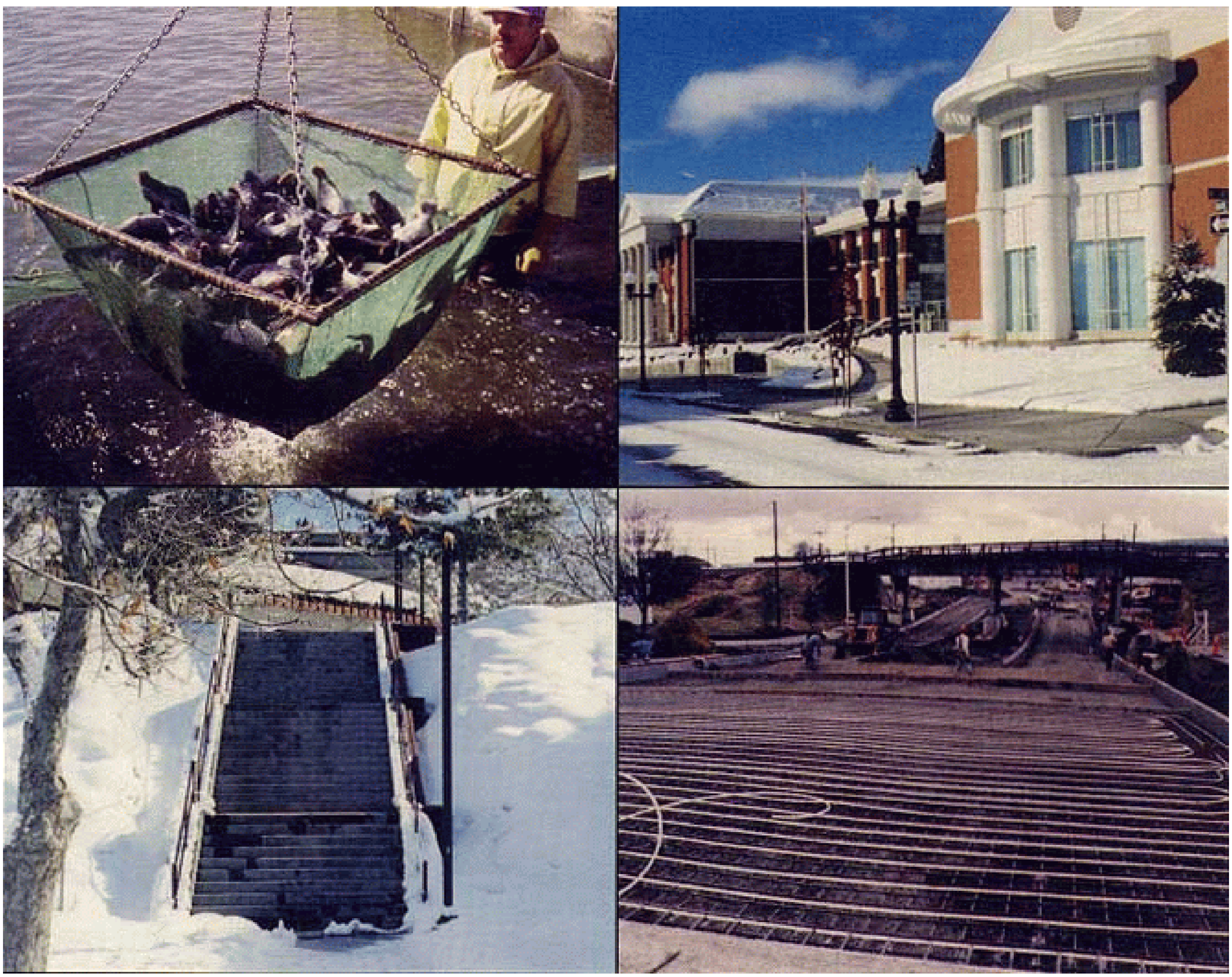

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GEO-HEAT CENTER QUARTERLY BULLETIN

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS

Cover Photos (left to right, top to bottm): Tilapia being loaded fro shipment at California Desert Fish Farm, Imperial Valley, CA; New Klamath County Government Center building with sidewalk snow melting system; Oregon Institute of Technology stair snow melting system; and Klamath Falls highway snow melting system installation (ODOT).

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AQUACULTURE IN THE IMPERIAL VALLEY
- A GEOTHERMAL SUCCESS STORY -

Kevin Rafferty
Geo-Heat Center

INTRODUCTION

The Salton Sea and Imperial Valley area of southern California has long been recognized as a "hot spot" of geothermal development. In the geothermal industry, this area has for some time been synonymous with electric power generation projects. Starting with the first plant in East Mesa in 1979, geothermal power has increased over the years to the present 400+ MW of installed capacity in the three primary areas of Salton Sea, Heber and East Mesa. Although most in the industry are aware of the millions of kilowatt-hours annually produced in this desert oasis of development, they remain surprisingly uninformed about the Valley's other geothermal industry—aquaculture.

At present, there are approximately 15 fish farming (or aquaculture) operations clustered, for the most part, around the Salton Sea. All of these farms use geothermal fluids to control the temperature of the fish culture facilities so as to produce larger fish in a shorter period of time and to permit winter production which would otherwise not be possible. In aggregate, these farms produce on the order of 10,000,000 lbs of fish per year most of which is sold into the California market. Principle species are catfish, striped bass and tilapia.

For the past several years, tilapia has been the fastest growing part of the aquaculture industry. In 1996, the total U.S. consumption of tilapia was 62,000,000 lbs. Of this, only 16,000,000 lbs (26%) was domestically produced and the balance imported. The primary market for the fish on the West Coast is among the Asian-American populations in the major cities. Fish are shipped and sold live at the retail level.

RESOURCES

The geothermal fluids used by the aquaculture operations are quite different from the those produced for electric power production. Table 1 presents a summary of water chemistry for typical Imperial Valley electric power and aquaculture wells.

Table 1. Typical Water Chemistry - Imperial Valley Wells[1] (Youngs, 1994)

	Electric Power Well	Aquaculture Well
Depth (ft)	2260	246
Temperature (°F)	509	145
pH	6.1	7.8
Na	47,300	980
K	7,960	46
Ca	23,600	132
Mg	110	33
SiO_2	435	65

1. All chemical species in ppm.

Temperatures of the wells used by the aquaculture operations vary from site to site with the highest in the area to the east of the Salton Sea. Pacific Aqua Farms and the California Desert Fish Farm, located on Hot Mineral Spring Rd (adjacent to the area's major hot spring resorts, see fig 2) at the foot of the Chocolate Mountains have the warmest water at approximately 165 °F. All of the wells in this area sustain some artesian flow though often it is not sufficient to meet the needs of the operators. In some cases, production is increased using air lifting. This method is not common in most conventional geothermal systems due to the corrosion resulting from the oxygen entrained in the water. In the aquaculture operations, however, all of the piping is of non- metallic (mostly PVC) construction so corrosion is not as great a consideration. Beyond this, since the fish are grown in the geothermal water, oxygen must be added later at the growout tanks.

On the west side of the Salton Sea, the wells typically produce water between 90 and 120 °F depending upon depth. Shallow wells in the 200 ft range, produce water toward the lower end of these values and "deeper" wells of greater than 600 ft produce water toward the higher end. All of the wells in this area of the valley require pumps to produce the water. Most of the larger growers have 2 to 3 wells, with a few of the smaller operations dependant upon a single well.

Due to the desert climate, high water temperatures are a major concern for the growers in the warmer portion of the year; particularly, those whose only water source is the geothermal fluid. Many use ponds to cool the water. A novel solution to this problem is illustrated in Figure 1. Pacific Aqua Farms uses a "cooling tower" of their own design to cool the geothermal water in the summer. Reportedly, these towers are capable of reducing the 140 °F water to 90 °F under favorable conditions. Their steel construction, however, is subject to high rates of corrosion and rebuilding is an ongoing task.

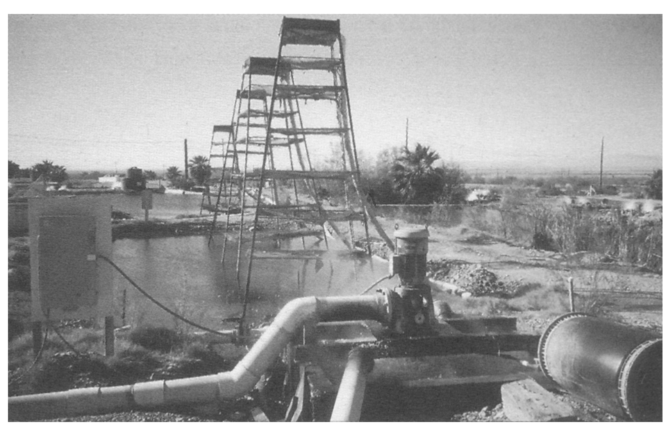

Figure 1. Cooling tower at Pacific Aquafarms.

LOCATIONS

Figure 2 provides a map of the area indicating the locations of the individual operations. The largest concentration of operations is in the southern Riverside County region on the northwest fringe of the Salton Sea. The largest single fish farm in the valley, Kent Seafarms with a production of approximately 3,000,000 lbs per year, is located in this area. Kent grows primarily stripped bass and because these fish cannot be shipped live most of the production is shipped on ice.

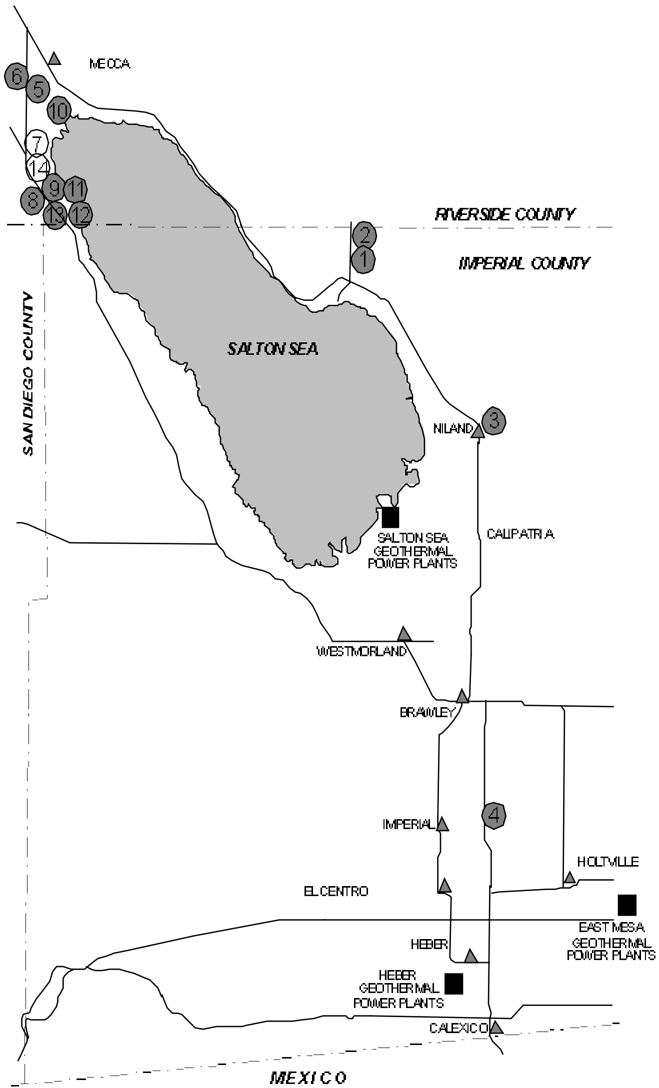

Figure 2. Locations of aquaculture and geothermal power generation operations - Imperial Valley (numbers are keyed toTable 2).

The largest single tilapia producer, Pacific Aqua Farms, as mentioned above, is located on the east side of the Sea. Pacific produces approximately 1,000,000 lbs per year and ships most to the Los Angeles market.

Fish Producers the Valley's largest catfish facility and one of the oldest aquaculture operations having started business in the late-1960s. It is located just east of the town of Niland. Catfish is the primary product here and annual production is in the range of 1,300,000 lbs per year. Fish Producers has used a conventional pond culture (Figure 3) approach in the past. Much of the water source for this portion of the operation is irrigation canal water. A recently constructed "raceway" facility (Figure 4), along with two new geothermal wells, will allow them to increase production by an additional 300,000 lbs per year and also permit some development work with other species than catfish.

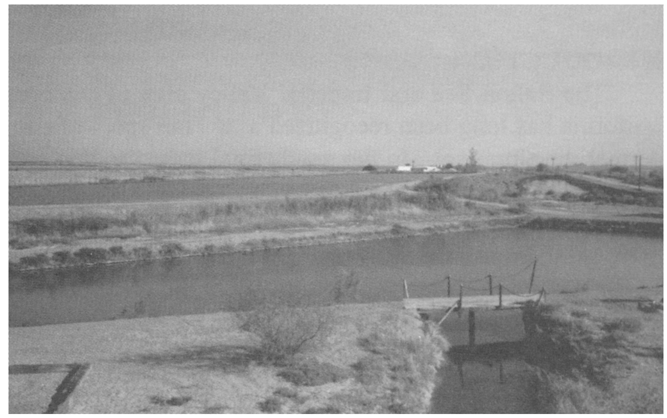

Figure 3. A small portion of the 70 acres of catfish ponds at Fish Producers.

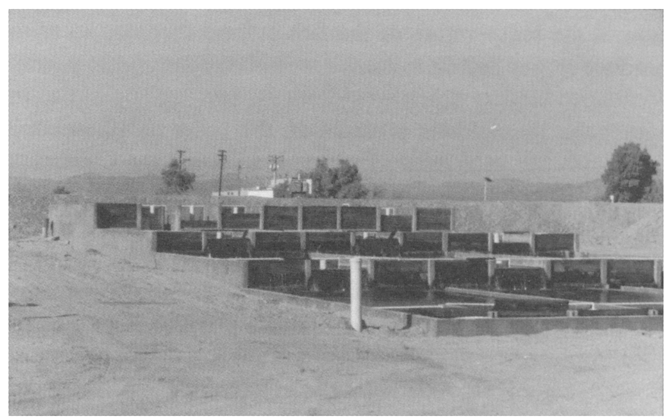

Figure 4. Newly constructed "raceway" designed for a production of 300,000 lbs per year.

Table 2 provides additional information on some of the fish farms appearing in Figure 2.

Table 2. Species and Annual Production Data

No.	Farm Name	Species[1]	Annual Prod.[2]	Years
1	California Desert Fish Farm	T	390,000	7
2	Pacific Aqua Farms	T	1,000,000	12
3	Fish Producers	C	1,300,000	30
4	Valley Fish Farm	C	600,000	12
5	Kent Sea Farms	HSB	3,000,000	12
6	Blue Aquarius	C	125,000	10
7	Dashun Fisheries	T	320,000	13
8	Coachella Valley Fish Farm	C	450,000	unk
9	Arbia Farm	?	in start up	new
10	Unknown	?	in start up	new
11	Oceanridge	T	300,000	4
12	H&T	T	150,000	5
13	Hsiang Niching	C,T	200,000	2
14	S S Vong	T	225,000	15
15	Unknown	C	unknown	unk

1. T = Tilapia, C = Catfish, HS = Hybrid Striped Bass
2. Estimated production in lbs per year.

ANATOMY OF A TILAPIA FISH FARM

The following description is based on a tilapia farm producing approximately 400,000 lbs of fish per year. It is important to understand that all farms are a reflection of their management and as a result, two farms growing the same species with the same annual production can be quite different in configuration. The overall layout of the farm appears in Figure 5. Figures 6 through 10 provide a close up of each major aspect of the operation

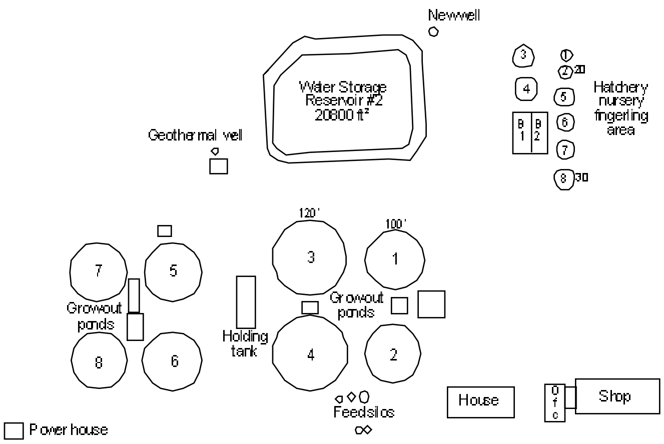

Figure 5. Typical fish farm layout for tilapia production.

Most fish farms operate their own hatchery to maintain product quality and assure an adequate supply of fingerlings for production. The hatchery typically includes tanks for brood stock, egg collection, fry and fingerling handling. Figure 6 shows the hatchery/fingerling portion of the California Desert Fish Farm facility. Brood fish are kept in the long rectangular tanks at the upper right, eggs and fry in the small building beyond the brood tanks and various size fingerlings in the 20- and 30-ft diameter circular tanks in the foreground.

Figure 6. Hatchery area.

At a size of approximately 3 to 6 inches, the fingerlings, now referred to as juveniles, are moved to the larger tanks (Figure 7) for growout. Due to the very high density of fish in the tanks, artificial aeration is necessary to maintain adequate levels of oxygen. Electric motor driven paddle wheel type devices are most common. Two paddle wheel aerators (approx 3 to 7 hp each depending on pond size) are oriented on opposite sides of the pond and operated in reverse rotation relative to each other. In addition to aeration, this also promotes a circular flow in the tank. This flow helps to drive waste products toward the center for collection. Feed for the fish is in pellet form and size varies according to the fish size. The feed is often distributed to the pond surface using a trailer mounted hopper equipped with a blower. The circular growout tanks are of concrete and block construction.

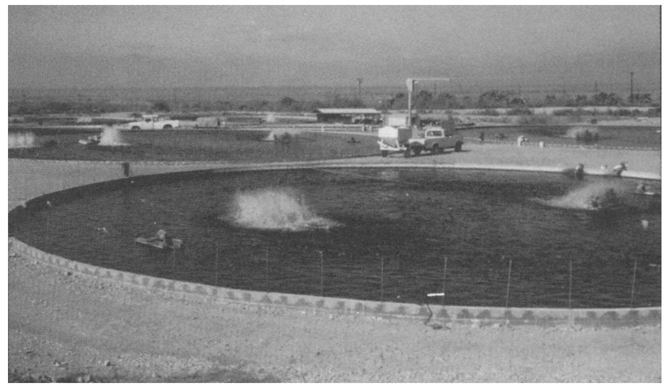

Figure 7. 100- and 120-ft diameter growout tanks.

In a desert climate, many growers are constrained by the available supply of water. Raising fish at high density results in the need to remove waste products (solids, ammonia etc) from the recirculated water. With irrigation canal water generally unavailable to most aquaculture operators, a variety of methods are used to "stretch" the geothermal water supply as far as possible. Often this involves passing the water out of the fish tanks to several large earthen ponds arranged in such a way as to cause the water to flow through them in series. These ponds remove a portion of the impurities in the water allowing some of the flow it to be recirculated.

At approximately nine months, the tilapia are large enough for sale into the market place. Market size varies according to the needs of the particular retailer at which the fish will be sold. Generally, fish in the 3/4-lb to1-lb range are considered "small" and those larger than 1 1/4 lb "large." Prices are often better for the larger fish. At this point, the fish in the large circular tanks are gathered into one corner using a large siene net. They are sorted as to size and placed in a transfer net equipped with a scale (Figure 8), for delivery to the shipment holding tank (Figure 9) and eventually to the transport truck.

Figure 8. Sorting and moving fish from growout to transfer tank.

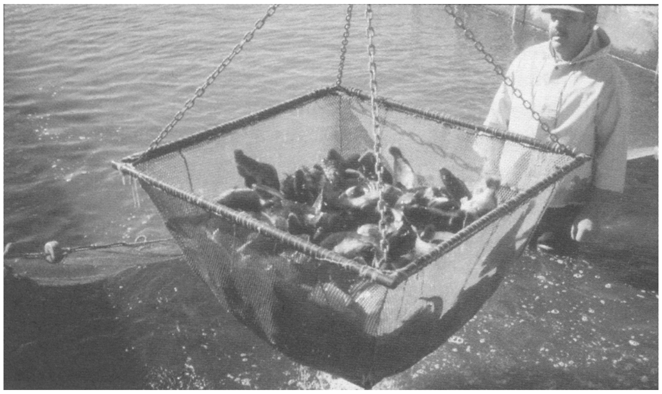

Figure 9. Transferring fish to delivery truck.

The fish are shipped live to the retail level in a truck equipped with a series of tanks and a liquid oxygen distribution system for aeration (Figure 10). A few of the largest operations employ their own trucks and deliver directly to the markets and restaurants. In most cases, however, the grower sells to a "middle man" who owns and operates the truck and sells to the retail store or restaurant operator. Figure 11 shows a view of the transport truck in San Francisco's Chinatown.

Figure 10. Live fish delivery truck--liquid oxygen storage tank at back.

Figure 11. Delivery truck in San Francisco's Chinatown.

CONCLUSION

Agricultural statistics, gathered for the Coachella Valley for the year 1995, provide some interesting data. At that time, there were 34 individual types of crops grown on lands irrigated by the Coachella Canal. Of the approximately $432,500,000 in gross value for these crops, approximately 3.1% was attributed to fish farm production. Interestingly, the gross revenue produced by the fish crops, per acre of land, ranks 4th out of the 34 crops raised in the area. Only dates, bell peppers and nursery crops produced higher gross earnings per acre of land.

The substantial growth in the number of operators and annual production for aquaculture in this region is impressive. Much of the growth has been in the production of tilapia. This reflects the national trend in the growth of aquaculture. Since 1991 the national production of tilapia has approximately quadrupled (Aquaculture, 1998). At some point, this level of growth will begin to approach equilibrium with the market demand in certain areas. In California, where 40% of the U.S. production is located, this may already be occurring. Prices have dropped recently, from a high of $2.30 per pound in 1995 to approximately $2.00 per pound currently. The price situation was a commonly discussed topic at all of the farms visited in the course of gathering information for this article.

Based on the limited shipping distance for live fish and the finite size of the Asia-American market, it may be in the best interests of the growers to explore the establishment of some new markets for the tilapia. Tilapia burgers maybe?

Finally, the estimate of the geothermal installed capacity and annual energy use for the 15 famrs is 85 MWt and 1.5 trillion Btu/year, or about 500 Btu/yr/lb of fish.

ACKNOWLEDGEMENTS

I would like to thank Maria L Schwander, owner and Maria Soledad "Sol" Delgadillo, manager of the California Desert Fish Farm for their generous hospitality, guidance, great food and patience in explaining aquaculture to an engineer. I am also indebted to the owners of Pacific Aquafarms, Fish Producers, Ocean Rich Fisheries Inc, H & T Aquatics Inc and Aquafarming Tech, Inc for the time they took to show us their facilities.

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KLAMATH FALLS GEOTHERMAL DISTRICT HEATING SYSTEMS

Brian Brown, P.E.
Brian Brown Engineering
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INTRODUCTION

The city of Klamath Falls, Oregon, geothermal district heating system was constructed in 1981 to initially serve 14 government buildings with planned expansion to serve additional buildings along the route. After a difficult start-up period, the system has provided reliable service since 1991. For more information on the system development, see Lienau, et al., (1989 and 1991).

The district heating system was designed for a thermal capacity of 20 million Btu/hr (5.9 MWt). At peak heating, the original buildings on the system utilized only about 20 percent of the system thermal capacity, and revenue from heating those buildings was inadequate to sustain system operation. This led the city to begin a marketing effort in 1992 to add more customers to the system (Rafferty, 1993).

Since 1992, the customer base has increased substantially, with the district heating system serving several additional buildings and extensive areas of sidewalk snowmelt. Figure 1 shows the service area of the district heating system.

In the winter of 1998 to 1999 the district heating system served the highest load ever, with peak loads estimated at 50 to 60 percent of the original design capacity. The system showed some strain under the load, with operational difficulties related to capacity, controls, and equipment failures. System upgrade and maintenance work is scheduled for the summer of 1999 to improve system capacity, control, and reliability.

BUILDING HEATING

The original and continuing primary purpose of the district heating system is to serve building space heating requirements. The original buildings connected to the system included:

- County Museum
- Fire Station
- Post office
- City Hall
- City Hall Annex
- County Library
- County Courthouse
- Old County Jail
- Veteran's Memorial Building (County offices)
- County Annex

The courthouse, jail, and Veteran's buildings were all extensively damaged by an earthquake in 1993 (Lienau & Lund, 1993). The earthquake damage caused the loss of that building space for County government use, and the loss of the heating revenue for the district heating system. These buildings were subsequently demolished and replaced.

The HVAC system controls in the County Library were upgraded in 1996, resulting in a 50% reduction in the heating costs; from about $12,000 to $6,000 per year. That was good for the County, but reduced revenue for the district heating system.

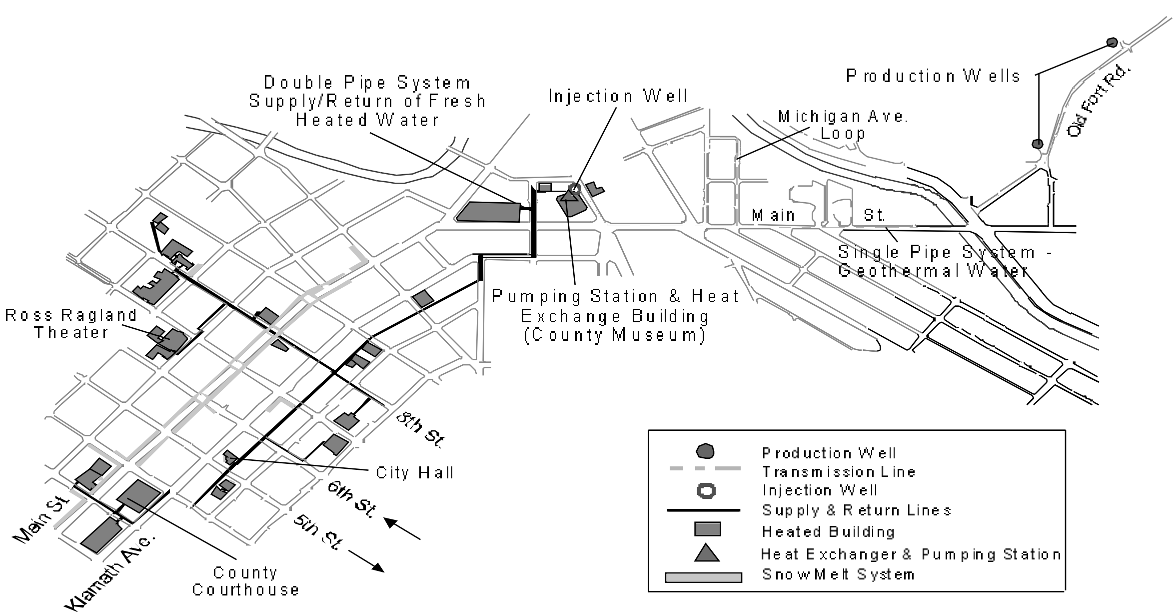

Figure 1. Map of Klamath Falls geothermal district heating system.

New facilities added to the district heating system in1993 through 1997 included:

- Christ Lutheran Church (served off the geothermal production main)
- Balsiger Building (replacing heating from a private geothermal well)
- Eagles Club
- Gospel Mission
- Ross Ragland Theater
- First Presbyterian Church
- First Baptist Church
- Sacred Heart Catholic Church (complex of 4 buildings)
- South Valley State Bank
- US Bank
- Pacific Linen (commercial laundry)

New in 1998:

- Klamath County Government Center building. This building is a renovation of the old County Annex building with a significant new addition. The construction included a complete new HVAC system.

New and under construction for 1999:

- Howard's Body Shop
- Klamath County Courthouse. This is a new replacement for the earthquake damaged and demolished original courthouse.
- Addition to the Ross Ragland Theater. This addition will increase the heated floor space from about 12,000 ft^2 to about 22,000 ft^2 The total heating load is expected to remain about the same due to added insulation and improved heating system controls in the original building.

As of the winter of 1998 - 1999, the estimated design peak load for the buildings on the district heating system is about 8 $x10^6$ Btu/hr (2.3 MWt).

DESIGN OF THE COUNTY GOVERMENT CENTER BUILDING HEATING SYSTEM

The new county buildings are the first on the geothermal district heating system with efficient use of the system incorporated in the original design. Important features of the heating system design include:

- Heating coils are selected for low flow and high water-side temperature drop (delta-T).
- Heating water control valves are mostly 2-way valves, resulting in a variable heating water flow and a high heating water system delta-T.
- Heating water pumps are controlled by adjustable frequency drives, minimizing pumping energy use and accommodating the variable heating water flow.
- The building heating water supply temperature is aggressively reset to a lower temperature at higher outside air temperatures and lighter building heating demand.
- Lower temperature loads, such as the sidewalk snowmelt system, are served from the heating water return, increasing overall delta-T.
- The control valve on the district heating water supply is closely controlled to meet building heating loads while minimizing the flow and maximizing the delta-T.

Figure 2. Klamath County Government Center Building.

The beneficial result of these design features is the maintenance of high system delta-T, meeting the heating demand with the minimum flow from the district heating system. The high delta-T benefits the geothermal district heating system all the way back to the production wells. Operation of the system at high delta-T reduces pumping costs, improves performance of heat exchangers, and increases the energy delivery capacity of the system.

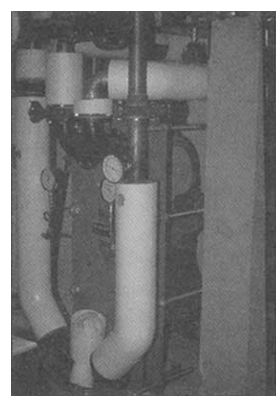

Figure 3. Government Center district heating heat exchanger.

The city does not guarantee uninterrupted service, as is the case with other utilities, from the district heating system; consequently the county building heating system includes a back-up boiler. The controls in the County Government Center building monitor the status of the district heating system and automatically operate the back-up boiler to supplement the heat available from the district heating system or to provide complete back-up heating. The controls compare the supply temperature available from the district heating system with the set-point temperature for the building heating water system. If the district heating system is colder than the required building heating water temperature, the district heating control valve is closed to prevent heat loss from the building system. Once the district heating system is returned to service, the controls initiate an automatic warm-up sequence to purge the cold water from the system piping. After the district heating supply temperature returns to normal and is adequate to meet the building heating demand, the boiler shuts off automatically.

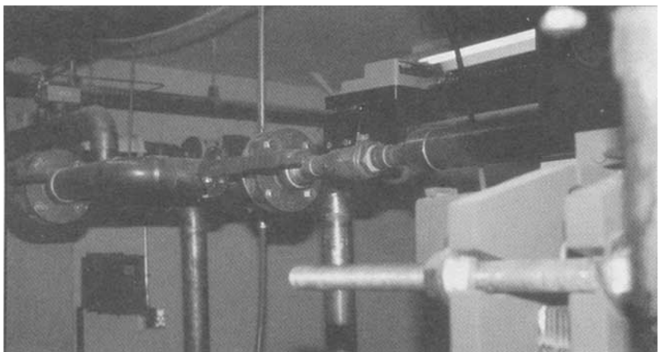

Figure 4. Klamath County Government Center district heating flow control valve. Good flow control is vital for efficient operation.

Over the 1998 to 1999 heating season, the district heating system experienced more than the ususal number of service interruptions from power outages, control problems, and production well problems. In all cases, the boiler controls provided automatic, uninterrupted heat to the building, while minimizing boiler run time.

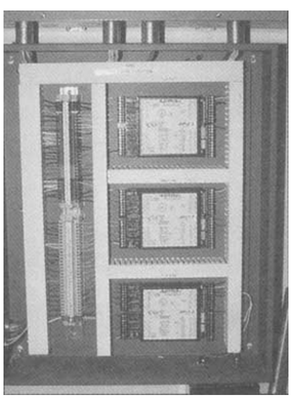

Figure 5. Government Center heating water, boiler, and snowmelt controls.

The County Government Center building includes about 37,000 ft^2 of conditioned floor space and about 10,000 ft^2 of heated sidewalks. The peak heating design load for the building and sidewalks was estimated to be 2.4 x 10^6 Btu/hr (0.7 MWt), requiring a peak flow rate from the district heating system of 120 gpm at 40°F delta-T, based on a 180°F supply temperature from the district heating system and 140°F return temperature. The peak measured load in February, 1999 (after installation and setup of the meter) was 1.3 x 10^6 Btu/hr (0.38 MWt) with a peak flow of 50 gpm. Annual energy consumption is estimated to be about 1.8 x 10^9 Btu (520 MWht).

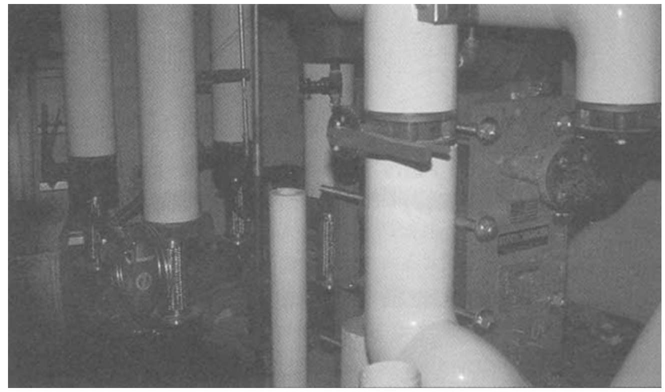

Figure 6. Government Center snowmelt heat exchanger.

Performance of the building heating system has been excellent, exceeding design expectations. Typical district heating return water temperature is 110°F when the snowmelt system is operating in the IDLING mode; and 120°F when the snowmelt system is off or operating in the higher temperature MELT mode. This return temperature is well below the design 140°F, and reflects the capability of the heating system to operate in a higher than design delta-T. The performance of the system can be attributed to a combination of system design, conservative heat exchanger sizing, and careful design and programming of the Alerton DDC control system.

SIDEWALK SNOWMELT

Geothermally heated sidewalks and crosswalks have been incorporated into a downtown redevelopment project along Main Street, starting with the 800 block in 1995. (Brown, 1995). That snowmelt system has been extended to cover nine blocks of sidewalks and crosswalks, from 2nd Street to 11th Street. The heated sidewalk and crosswalk area currently served by the city snowmelt system is about 51,000 ft^2. Anticipated additions to the city system in 1999 will bring the total area to about 60,000 ft^2.

Several snowmelt systems have also been installed separate from the main City snowmelt system, served from the district heating system through a building heating system or directly from the district heating mains. These installations include the County Government Center building, the Basin Transit bus transfer station, Sacred Heart Catholic Church, City Hall, City Hall Annex, South Valley Bank, and KOTI. The installed area of these systems is about 19,000 ft^2. About 15,000 ft^2 of additional private snowmelt system area is anticipated for 1999.

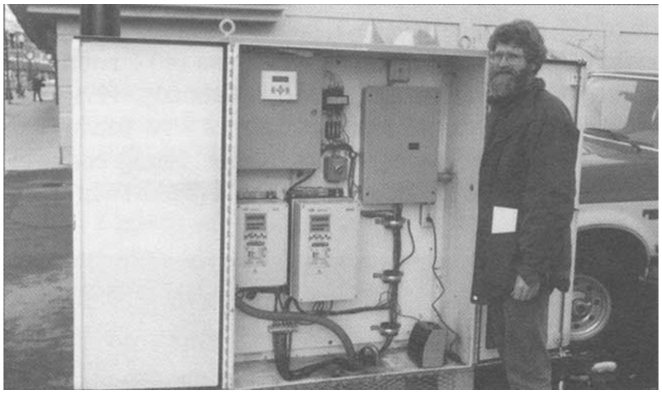

Figure 7. Klamath Falls snowmelt system control panel with author Brian Brown, P.E., consulting engineer.

The sidewalks are heated by circulation of a heated anti-freeze solution through a network of polyethylene tubes imbedded in the sidewalks or in a sand or slurry base under the sidewalks. The solution is heated through a heat exchanger from the building heating water system or the district heating water. Where feasible, the heat is extracted from the return water side of the heating system to increase the overall district heating system delta-T.

Figure 8. Snowmelt tubing in slurry backfill under sidewalks.

Most of the snowmelt systems are designed for a heat output of 60 to 80 Btu/h·ft^2 of heated sidewalk. That design heat output is adequate for convenience snow melting under most conditions in Klamath Falls. It will not keep the sidewalk above freezing in extremely cold conditions, or keep up with high snowfall rates. Figure 9 shows the slush accumulation after a heavy snowfall this past winter. Figures 10 and 11 shows a section of sidewalk after the system had a chance to catch up. The sidewalk beyond does not yet have the snowmelt system installed. The trees are protected with styrofoam insulation to keep them from budding in the winter during system operation.

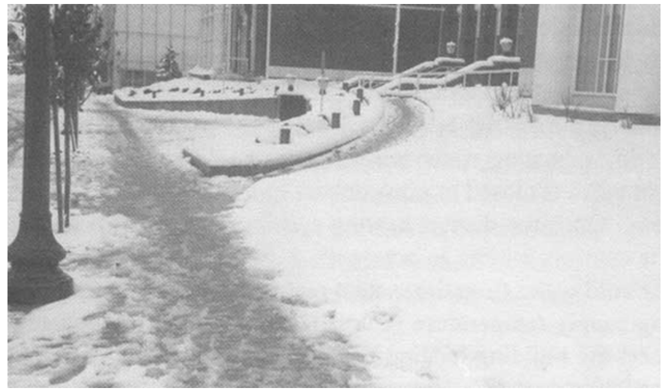

Figure 9. Slush accumulation after a heavy snowfall.

Figure 10. Clear sidewalk after snowfall. Tree well is protected from heat by insulation. Sidewalk beyond is not heated.

Figure 11. Basin Transit transfer station snowmelt.

The snowmelt systems have become a significant portion of the total district heating system load, with an estimated design peak load of about 4 x10^6 Btu/hr (1.2 MWt).

SYSTEM GROWTH AND CAPACITY

The peak load under normal design winter conditions for currently connected users is estimated to be about 60% of design system capacity, or 12 x10^6 Btu/h (3.5 MWt). The peak load is not precisely known, since the system has not had flow and energy monitoring. With improved controls and monitoring on-line for the '99-'00 heating season we will be better able to track system operation and project system reserve capacity.

Without system flow and energy instrumentation, evaluation of system load and reserve capacity has been based on general observations of system performance. Operation in the '95-'96 heating season indicated pump flow capacity concerns in the district heating closed loop, primarily due to poorly controlled flow at many of the users and the resulting low system delta-T. Improved flow control at three of the larger users improved that situation, and there were no capacity problems in the '96-'97 and '97-'98 heating seasons.

In the '98-'99 heating season the circulation pump still showed adequate capacity, maintaining more than 15 psi pressure differential between the district heating supply and return at the far end of the system. The system delta-T remained lower than design, with a typical delta-T of about 13°F and maximum delta-T of about 24°F; compared to the design delta-T of 40°F. This indicates that more work on flow control is necessary.

The system was designed to operate both production wells at design capacity, but that has never been necessary. Typically the lower, cooler (206°F) well is operated in the mild seasons and the hotter (226°F) upper well is used in the colder part of the winter. In December, 1998 the temperature dropped to -10°F, the coldest it has been for several years. Under those conditions, the upper well was unable to maintain the desired district heating supply temperature of 180°F. That may be partially due to fouling on the heat exchangers, but it also indicates a need to either increase the pumping capacity of the upper well, or begin operating both wells to meet the peak heating loads.

OPERATION AND IMPROVEMENTS

The district heating system has run close to nonstop since 1993, with short or partial shutdowns for system connections or maintenance. Extensive system maintenance is planned during a system shutdown in the summer of 1999. Planned work includes:

- Replacement of all critical isolation valves to facilitate future maintenance
- Installation of a second large circulation pump on the closed-loop system with an adjustable frequency speed control
- Improved control of flow to connected buildings
- Rehabilitation of the upper geothermal well pumps and replacement of the Nelson fluid drives with a larger motor and adjustable frequency speed control. Pump capacity will be increased 60%, from 500 gpm to 800 gpm.
- Cleaning of the main heat exchangers and addition of about 50% more plates
- Replacement of the system controls with digital programmable logic controller (PLC) based controls, with radio telemetry between the heat exchanger building, the remote pump stations, and the system manager's office
- Installation of new magnetic flow meters for geothermal and closed loop flow and energy measurement
- Cleaning and painting exposed pipe and fittings in tunnels and vaults
- Improved ventilation of expansion joint vaults and the production pipeline tunnel to reduce moisture accumulation and corrosion
- Maintenance of the pipeline cathodic protection systems

The planned system maintenance and improvements will improve the reliability and capacity of the district heating system to meet the existing and planned heating load. The improved flow control and adjustable speed pumping are also anticipated to reduce the electrical cost of operating the system by about 75 percent.

CONCLUSIONS

The city of Klamath Falls geothermal district heating system has experienced considerable growth in the past few years. Additional expansion is scheduled for 1999, and there is considerable additional interest in hooking onto the system. System maintenance and control system improvements scheduled for 1999 will make the system more reliable and less expensive to operate. This combination should help the district heating system make the transition from a subsidized experiment in renewable energy to a fully self-sustaining utility.

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THE OREGON INSTITUTE OF TECHNOLOGY GEOTHERMAL HEATING SYSTEM - THEN AND NOW

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INTRODUCTION

Oregon Institute of Technology (OIT) is located on a hill, which gently slopes from the east to the west, in the northeast part of Klamath Falls. The campus has been using geothermal water, for its heating and domestic hot water needs, since it was relocated to this location in 1964. It has been in continuous operation for 35 years and now heats 11 buildings (~600,000 ft^2 / 55,700 m^2). It is the oldest of the modern geothermal district-heating systems, and due to the lack of experience with the design of large systems in the early-1960s, it has experienced some difficulties through the years. These difficulties have been resolved and the experience has provided a substantial body of information concerning the applicability of various materials and designs for low-temperature use.

The original system, which provided heating and domestic hot water for the five original buildings, consisted of constant-speed, water-lubricated lineshaft pumps located in well pits. The pumps were run manually according to the level in the storage tank. The distribution system consisted of direct-buried Schedule 40 carbon steel piping which was field insulated with "Foamglas" type insulation and covered with a "mastic" vapor barrier. The geothermal water was used directly in the buildings' mechanical heating systems; then, the effluent was disposed of to the surface through the storm drainage system than eventually emptied into Upper Klamath Lake. Cooling for the campus was accomplished by an electric-powered chiller.

Figure 1 shows a general layout of the OIT system as it is today. Geothermal water for the system is produced from three wells at a temperature of 192^{o}F (89^{o}C), which are located in the southeast corner of the campus. The wells are from 1300-1800 ft (400-550 m) in depth. The water is pumped individually from each well (total flow of all the wells is 980 gpm/62 L/s). The water is then collected in a 4000-gal (15-m^3) settling tank in the Heat Exchanger building before it is delivered to each building via gravity through the distribution system according to demand on the system. The settling tank (Figure 2) provides the necessary head for the gravity flow system and allows the fines from pumping to settle out of the water. The heat exchanger building also housed a fuel-oil boiler from the old campus as a backup; but due to lack of use, it was dismantled several years ago. The geothermal system saves approximately 11,000 bbl (1650 tonnes) of oil or $225,000 each year.

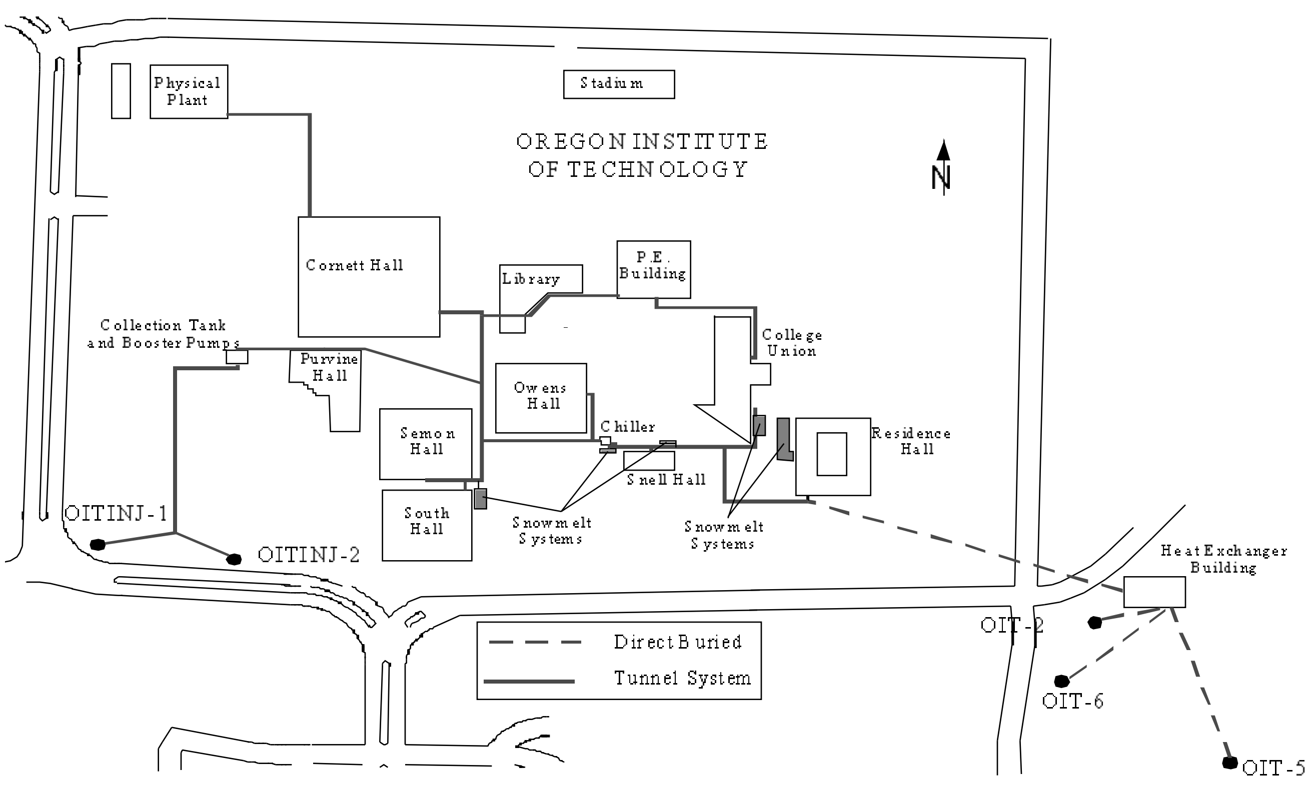

Figure 1. General layout of the OIT geothermal system.

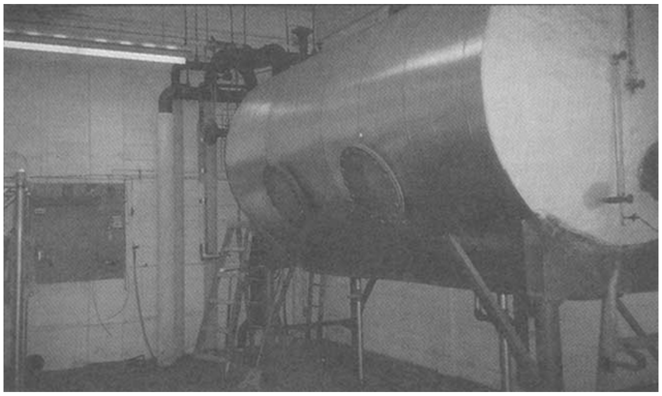

Figure 2. The 4000-gal (15-m^3) settling tank located in the Heat Exchanger building.

THE PROBLEMS ENCOUNTERED AND THE SOLUTIONS

Pumps

After approximately six years of operation, a major redesign of the pumping system was carried out. The original constant-speed, water-lubricated lineshaft pumps, were virtually the same as cold-water irrigation pumps and were located in wellhead pits. Placing the pumps in the pits didn't allow for air circulation which lead to overheating and condensation problems. The earlier pumps also didn't provide for the expansion of the piping in the well; therefore, the lineshaft had to be preheated to produce sufficient clearance before the pump was started. This meant one pump had to be kept running all the time. The pumps also experienced other failures. The original bronze impellers were attached to the shaft with collets and the failures occurred when the impellers detached from the shaft. The most serious problem was related to the failure of the shaft bearings. A number of bearing types were used, but none proved to have acceptable lifetimes. It was reported that the bronze bearings "burned up," and the rubber and teflon bearings "swelled."

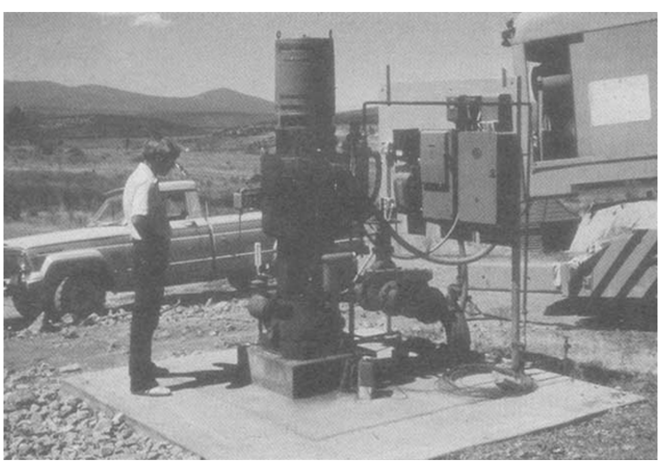

Figure 3. One of the pumps and variable-speed controllers with the housing removed.

During the redesign of the pumps, extra lateral bowls were installed to eliminate the need for shaft preheating. The impellers were attached with both keys and collets. At this point, it was also decided to isolate the bearings from the geothermal water using an oil-lubricated enclosed lineshaft arrangement. To help with the overheating and condensation problems, it was decided to raise the pumps to ground level and enclosed them in housing (Rafferty, 1989). Figure 3 shows one of the pumps with the housing removed.

Distribution System

The original distribution system consisted of direct-buried Schedule 40 carbon steel piping, field insulated with "Foamglas" insulation and covered with a "mastic" vapor barrier. This piping system suffered internal and exterior corrosion. The external corrosion was due to the expansion and movement of piping which caused the mastic vapor barrier to break. This failure allowed groundwater and salt water from deicing to come in contact with the piping, resulting in the external corrosion. After 14 years of service, an examination of the piping revealed an internal buildup of scale. The scale consisted of mainly silica and iron oxide with the iron oxide being closest to the pipe. In many places, the piping wall thickness was reduced to one-third of its original thickness. The fact that the main settling tank was vented to the atmosphere permitted oxygen to enter the system, which promoted the internal corrosion. The storm sewer system used for disposal of the effluent also encountered failures. This part of the system consisted of cast iron and carbon steel piping located in the buildings, galvanized culverts from the buildings to the main line, and concrete culverts in the main line. All of the failures occurred in sections with galvanized culverts. This could have been a result of dezincification (galvanized coating removed) and eventually corrosion of the unprotected steel surface (Rafferty, 1989).

In response to the piping failures, it was decided to construct a new distribution system and a dedicated collection system along with the construction of utility tunnels to connect all the buildings. The design of the tunnel (6 ft x 6 ft / 2 m x 2 m) provides access for maintenance personnel and space for other campus utilities. During construction the concrete was formed and poured in place to allow for forming around building foundations and utility pipes running at an angle to centerline (Figure 4). The floor of the tunnel is 8 in. (20 cm) thick and the sides 6 in. (20 cm) thick. The pipes are held to the side with pipe clamps and Unistrut hangers. In some cases, the tunnel also serves as a sidewalk; thus, snow-melting is enhanced due to the heat loss through the system. The cost of constructing the tunnel system (including excavation and backfill) was extremely high at about $160/lf ($525/m), which didn't include the cost of the piping. The cost of the piping varied from $15/ft ($50/m) for 6-in. (15-cm) diameter to $22/ft ($72/m) for 8-in. (20-cm) diameter pipe. When new extensions to the tunnel system were added, a 6-ft (2-m) diameter corrugated galvanized steel culvert was used instead of concrete. Its estimated cost was only 25 percent of the cost for concrete tunnels (Lund and Lienau, 1980).

Figure 4. View of the tunnel under construction.

Heat Exchangers

In the original design, the geothermal water was used directly in each of the building mechanical systems. This "once through" approach eliminated the need for circulation pumps in the buildings. The direct use of the geothermal fluids caused problems due to the corrosive nature of the water. The original chemical analysis of the water failed to consider the effect of H_2S (hydrogen sulfide) and NH_4 (ammonia) on the copper and copper alloys used in the mechanical system. There were a number of different types of failures identified that occurred as a result of using the water directly. The most important ones are listed below:

- Failure of the 50/50 tin/lead solder connections,
- Rapid failure of 1% silver solder,
- Wall thinning and perforation of copper tubing was a common occurrence,
- Control valve failures where plug (brass) was crimped to the stem (stainless steel). The threaded ones experienced no problems, and
- Control valve problems associated with packing leakage.

To address these problems, it was decided to isolate the geothermal water from the building heating systems using plate heat exchangers. Based on an analysis study, heat exchangers with 316 stainless steel plates with Buna-N gaskets were selected. The stainless steel heat exchanger used to heat the campus swimming pool failed within the first three years of operation. This failure occurred on the pool's water side of the heat exchanger, probably as a result of the high chorine content. The pool's heat exchanger was eventually replaced with titanium plates (Rafferty, 1989).

Some of the building systems utilize two loops through the heat exchanger. The College Union building plate heat exchanger, shown in Figure 5, utilizes two loops. The first loop provides 1,350,000 Btu/hr (1,350 MJ/hr) using the geothermal water at 100 gpm (6.3 L/s) and the building water at 54 gpm (3.4 L/s). The building water is then circulated through finned-tube pipe heat convectors located along the outside walls of the building. The second loop provides 30,000 Btu/hr (30 MJ/hr) using geothermal water at 25 gpm (1.4 L/s) and building water at 12 gpm (0.65 L/s). The building water is then circulated through reheat coils, which provides heating through a forced-air system for the interior of the building (Lund and Lienau, 1980).

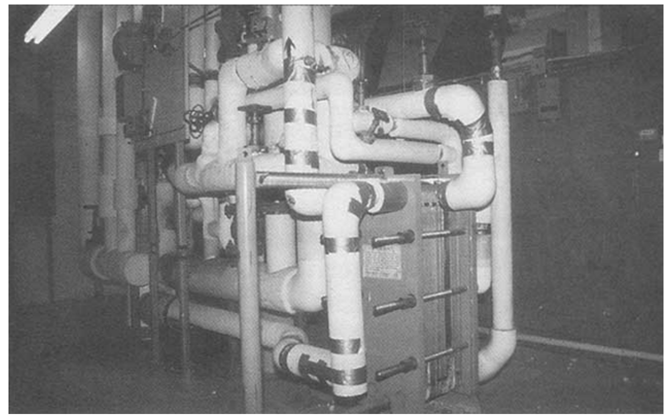

Figure 5. The College Union heat exchanger.

Fluid Disposal

Discharge to the surface was the original approach for disposal of the geothermal effluent. Although surface discharge is the simplest and least expensive option, there were several possible potential problems. The discharge temperature of the waste effluent was still quite high (135°F/57°C-winter and 170°F/77°C-summer) when it was delivered to the ditch. This method presented a safety hazard. A local city ordinance was passed which banned surface disposal and required all operations in the city to establish an injection program by 1990. OIT now has two injection wells to compile with the ordinance. The first injection well was drilled using standard mud-rotary techniques, and the second well used a combination of methods with air drilling in the injection zone. During the initial pumping test of the first injection well, the maximum obtainable pumping rate was only 200 gpm (12.6 L/s). It was believed that a considerable amount of drilling mud had invaded fractures in the primary production zones. The well was acidized (13% hydrochloric acid, 3% hydrofluoric acid) twice; this increased the capacity from 200 to 400 gpm (12.6 to 25.2 L/s). Analysis of test data indicated that the aquifer was still clogged with drilling mud at about 25 times the effective radius of the well. The maximum injection rate was estimated to be 600 gpm (37.8 L/s). The second injection well easily handles 1,000 gpm (63 L/s) and could possibly accept as much as 2,500 gpm (158 L/s) at 50 psi (3.4 bar) injection pressure is allowed at the wellhead. This well is being used as the primary injection well. Experience with these injection well suggest that air drilling can be quite beneficial in terms of subsequent well performance (Lienau, 1989).

NEW ADDITIONS TO THE SYSTEM

Snowmelt System

The newest additions to the OIT system are two sections of sidewalk snowmelting located by the Residence Hall. This brings the total amount of sidewalk snowmelting to 2,300 ft^2 (214 m^3). The other sections include the wheelchair ramp in front of South Hall and a couple of stairwells (Figure 6) leading to upper sections of the campus. All systems utilize 5/8-in. (1.6 cm) diameter cross-linked polyethylene tubing (PEX). The wheelchair ramp has four loops with the tubing spaced 10 in. (25 cm) apart. The stairs has three loops with the tubing tied to the existing stairs. Figure 7 shows the placement of tubing on a stairwell before the form work was added. The systems should be able to maintain a slab surface temperature of 38°F (3°C) at -5°F (-21°C) air temperature and 10 mph (16 km/h) wind when the entering 50/50 propylene glycol/water temperature is144°F (62°C). Each stair section uses a brazed-plate heat exchanger to isolate the glycol-filled snowmelt loop. The new snowmelt systems installed have slab temperature sensors which will activate the system when the outside air is 30°F (-1°C)(Geothermal Pipeline, 1994).

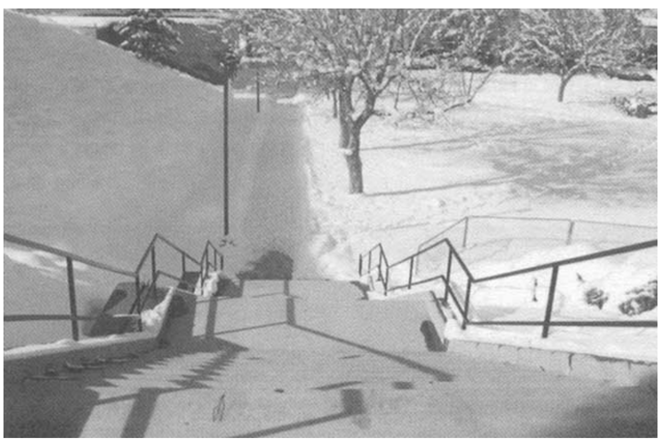

Figure 6. One of the stairwell leading to the College Union.

Figure 7. Placement of the snowmelt tubing before the formwork was added.

Purvine Hall

Purvine Hall utilizes the geothermal waste effluent from the rest of the campus for its space heating and domestic hot water heating. The temperature of the effluent as it enters the building is around 155°F (68°C) and leaves at a temperature of around 130°F (54°C). The main components of heating system include a 4,000-gal (15-m^3) storage tank, circulation pumps and heat exchangers. On the building heating side, space heating is accomplished by 54 variable air volume terminals equipped with hot water coils (Fields, 1989).

Absorption Chiller

A lithium-bromide absorption chiller was installed in 1980. It has a nominal 312 ton (1095 kW) capacity; but due to the low temperature of the water entering the system (192°F/89°C), it only produces 150 tons (526 kW) of cooling. The chiller requires 685 gpm (37.8 L/s) of geothermal fluid and only takes a 20°F (11°C) delta T out of the water. Recorded installation cost for the chiller was $171,300. The geothermal chiller supplies a base cooling load to five campus buildings or 277,300 ft^2 (25,800 m^2). The original electrical centrifugal chiller is now being used for peaking above the capacity of the absorption chiller. Since the geothermal water is used directly in the generator tubes of the absorption chiller there is a potential for corrosion to occur. The generator tubes are constructed of 90-10 cupro-nickel; but, no failures have occurred in the past 18 years (Lund and Lienau, 1980). Due to the low efficiency and high water usage, the absorption chiller will be replaced this summer with a centrifugal water chiller.

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RECONSTRUCTION OF A PAVEMENT GEOTHERMAL DEICING SYSTEM

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HISTORICAL BACKGROUND

In 1948, US 97 in Klamath Falls, Oregon was routed over Esplanade Street to Main Street and through the downtown area. In order to widen the bridge across the U.S. Bureau of Reclamation "A" Canal and to have the road cross under the Southern Pacific Railroad main north-south line, a new bridge and roadway were constructed at the beginning of this urban route. Because the approach and stop where this roadway intersected Alameda Ave (now Hwy 50 - Eastside Bypass) caused problems with traffic getting traction in the winter on an adverse 8% grade, a geothermal experiment in pavement de-icing was incorporated into the project.

A grid system within the pavement was connected to a nearby geothermal well using a downhole heat exchanger (DHE). The 419-foot well provided heat to a 50-50 ethylene glycol-water solution that ran through the grid system at about 50 gpm. This energy could provide a relatively snow free pavement at an outside temperature of -10°F and snowfall up to 3 inches per hour, at a heat requirement of 41 Btu/hr/ft^2. The grid was composed of 3/4-inch diameter iron pipes place 3 inches below the surface on 18-inch centers. The pipes were field wrapped in what appears to be an asphalt impregnated material to protect them from external corrosion.

The temperature drop in the grid was approximately 30 to 35°F with the supply temperature varying from 100 to 130°F and the return temperature 70 to 10°F. This was estimated to supply a maximum of 3.5 x 10^5 Btu/hr to the grid at the original artesian flow of 20 gpm, and 9.0 x 10^5 Btu/hr at the pumped rate of 50 gpm. (Lund, 1976).

REHABILITATION OF THE ODOT WELL

Over time, the well temperature drop from 143 to 98°F at the surface. In order to maintain the downhole heat exchanger temperature, a pump was added to the well which pumped and discharged approximately 10 gpm of geothermal water into the storm system to increase the heat flow. However, in 1985, the City of Klamath Falls adopted the Geothermal Resource Act which required all sewer or surface discharge from geothermal wells be eliminated. Since discharge from the well to the sewer was not longer permitted, the well was modified in 1992 by deepening it to about 1000 feet and casing it to 900 feet. The greater depth increased the temperature of the entering water. In addition, the Schedule 40 black iron pipe with malleable couplings was changed to Schedule 80 steel in the top leg of the DHE, the U-trap at the bottom constructed of Schedule 80, and the balance of the DHE fitted with Schedule 40 pipe. The DHE was extended to 900 feet to provide additional energy and to be exposed to more of the hotter water. Several section of Roscoe Moss standard louvre-type screen was installed and a lower seal added. The total cost of the modifications was about $115,000. The net result was that the "new" well produced approximately the same temperature in the grid loop as the "old" well with the pump discharging geothermal fluid to the sewer (Thurston, et al., 1995).

RECONSTRUCTION OF THE BRIDGE AND PAVEMENT SURFACE

At the time of the well rehabilitation, a study by the Bridge Section of the Oregon Department of Transportation (ODOT) recommended that the roadway and the geothermal heat distribution system be reconstructed in six years. This recommendation was based upon the age and condition of the existing portland cement concrete (PCC) surface, leaks in the heating grid, and the annual maintenance costs. The wrought iron tubing cast into the bridge deck and pavement leaked so badly from corrosion that the deicing system was approaching complete failure. Annual maintenance costs were estimated at $9,000 to $10,000 a year, increasing approximately $2,000 a year due to the deterioration (Thurston, et al., 1995).

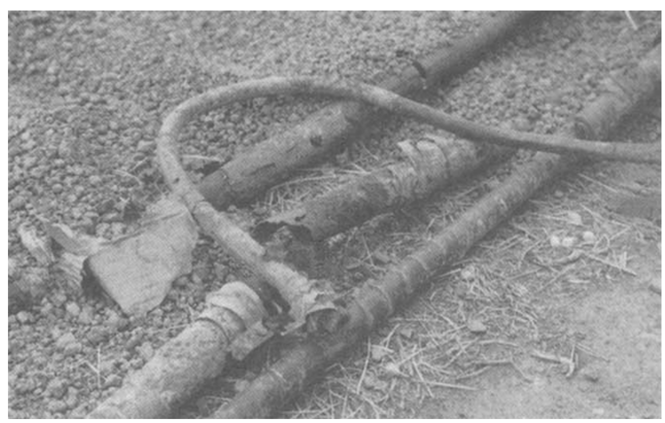

Figure 1. Original iron header pipe showing external corrosion at a break on the protective mastic covering.

In the fall of 1998, a contract was issued for the reconstruction of the bridge deck and highway pavement along with replacing the grid heating system. In addition to replacing the surface and tubing, the circulating pump was upgraded and electronic monitoring and control system added. Except for landscaping, the project was completed by early December, 1998 and is now in operation and is proving effective at keeping the bridge free of ice and snow. The deicing portion of the pavement is 442.5 feet long and 53.5 feet wide with about a 160-foot by 10-foot section removed for the piers supporting the railroad bridge and for landscaping.

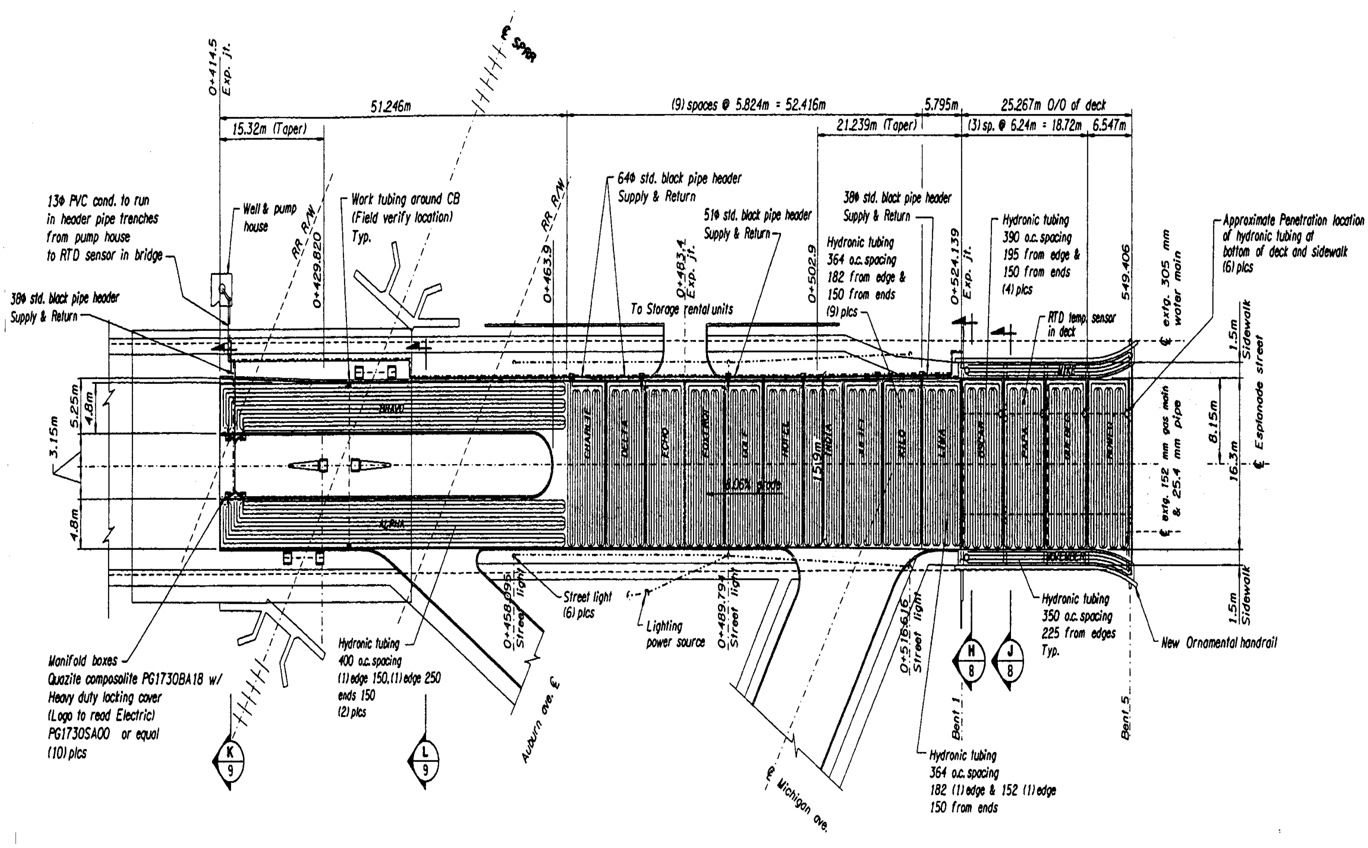

Figure 2. Overall project design.

The top portion of the bridge deck was hydro-blasted to remove six to seven inches of the PCC pavement. Holes were drilled through the deck to the header pipes hung underneath. Wirsbo 5/8-inch ID hePEX (a cross-linked polyethylene) tubing was placed in a double overlap pattern at 14-inch on center spacing across the deck on top of a mat of reinforcing steel. These tubes were then covered with a fresh layer of PCC. An RTD temperature sensor was placed in the bridge deck and an ambient sensor on an adjacent power pole.

The pavement section from the edge of the bridge deck, through the railroad underpass and to a point opposite the well building was completely removed. The subgrade was excavated to make room for about six inches of gravel base. Forms were installed and a steel mesh placed on top of the compacted subgrade within the forms. Geothermal black iron header pipes (supply and return) varying from 1.25 to 2.5 inches in diameter were placed outside the forms along the north side of the roadway. These header pipe had a brass manifold placed at about 40-foot intervals, to allow for four supply and return PEX pipes to be attached. The 3/4-inch PEX grid system pipes where then attached by wire to the reinforcing steel at 14-inch on center transverse to the roadway. Under the railroad underpass, the tubing was placed longitudinally at about 16 inches on center, due to the narrowness of the pavement at this point. Concrete (PCC) was then placed which provided for a cover over the pipes of about 3 inches. The header pipes, were insulated with about one inch of Armstrong Armflex pipe insulation and then covered with an aluminum foil vapor barrier. The manifolds were placed in concrete boxes for easy access for future maintenance. The header pipes, provided with two expansion loops and a concrete anchor, were covered with earth and then had concrete slope paving placed on top for protection.

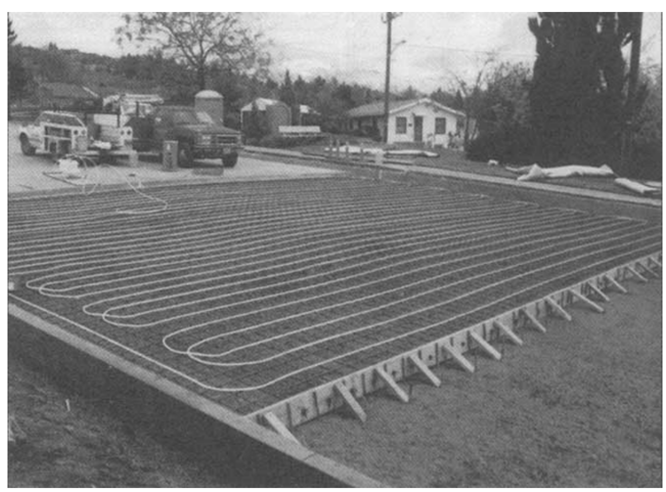

Figure 3. A four-loop section ready for concrete placement.

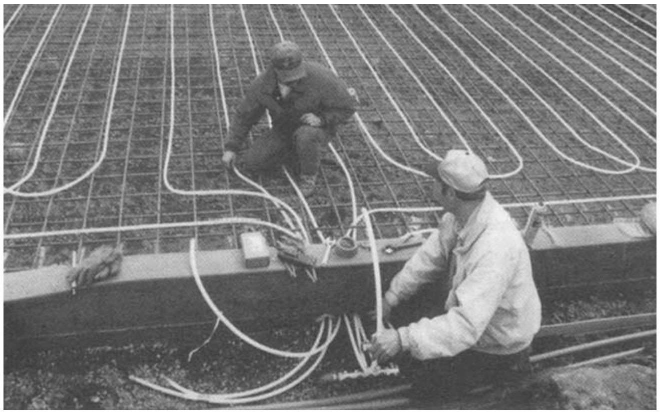

Figure 4. Attaching the loop pipes to the manifold.

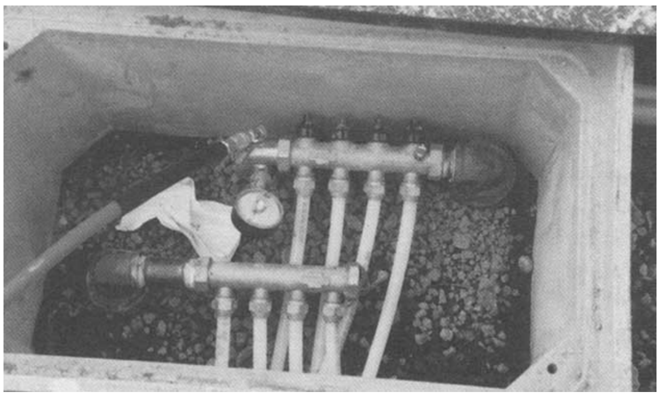

Figure 5. Details of the manifold box.

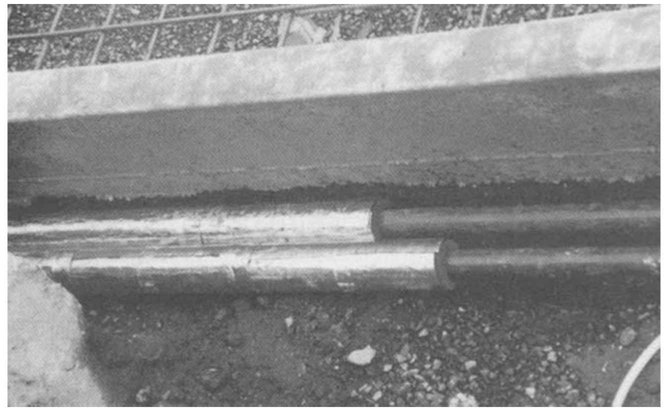

Figure 6. Iron header pipe with insulation.

Each manifold had four supply and return pipes that made four loops for a total length of about 430 feet each. Two loops were staggered on top of each other to balance the temperature loss in each loop - i.e. the hot end of one was placed adjacent to the cold end of the other, since there could be as much as 35°F temperature drop in each loop. The PEX grid pipe is designed for 180°F at 100 psi and 200°F at 80 psi according to ASTM specification F 876. The pipes are filled with an ethylene glycol mixture through an air vent at the high point on the bridge deck.

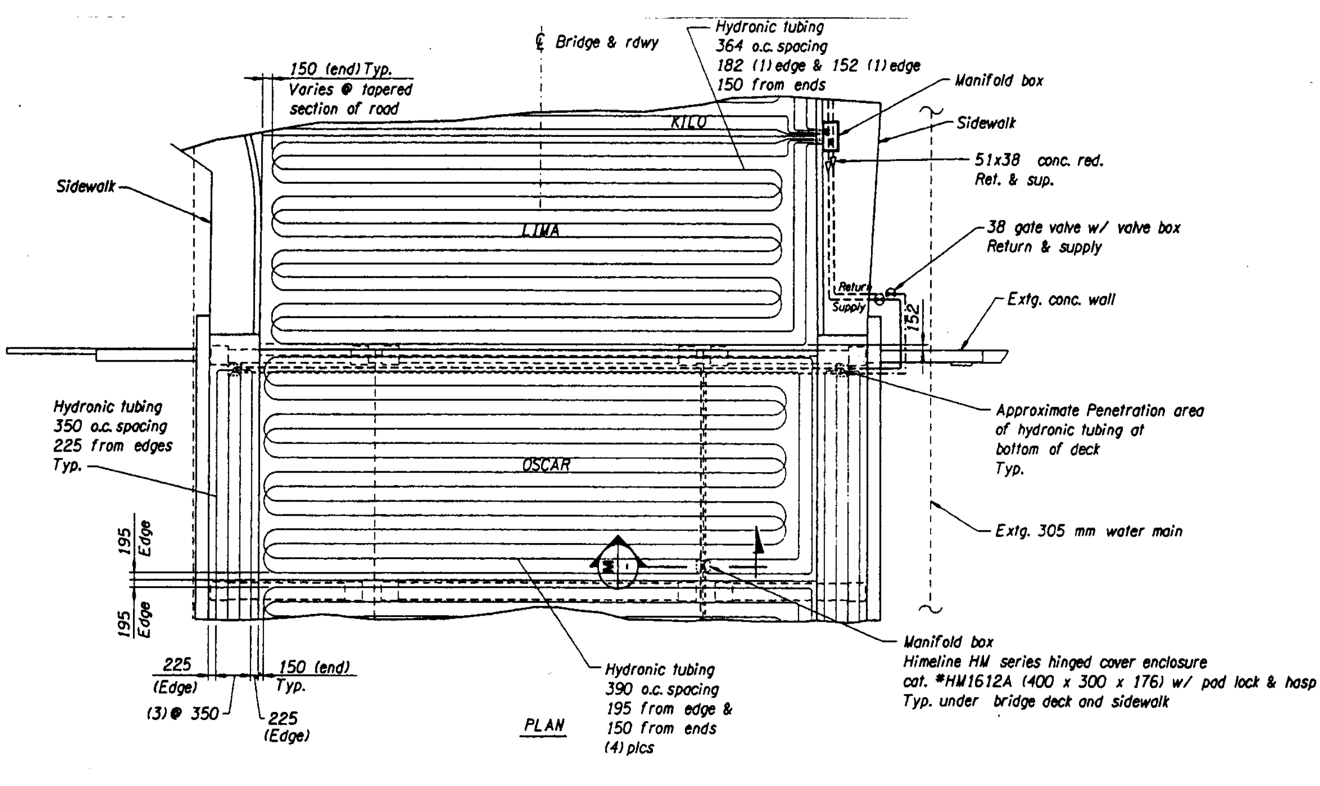

Figure 7. Details of a four-loop section with manifold.

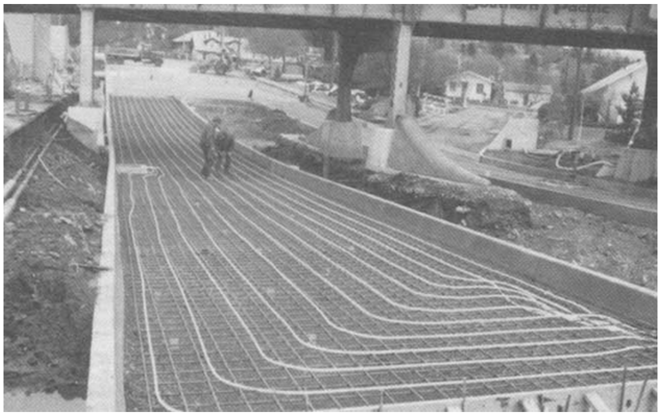

Figure 8. Longitudinal loops under the railroad bridge.

The entire cost of the reconstruction project was approximately \$430,000 and the estimated annual maintenance cost will be \$500 and the operating cost (for the circulating pump) \$3,000. The heated bridge deck covers 22,000 square feet and is designed for a heat output of 50 Btu/sq.ft/hr. This is suppose to keep the deck clear during heavy snowfall down to -10°F. During the first days of operation after a snowfall, the DHE supply temperature was 100°F and the return temperature 76°F for a delta-T of 24°F. Once the ground and concrete temperatures reach equilibrium, it is expected that the supply and return temperatures will increase by as much as 30°F. The renovated deicing system appears to be operating effectively, based on substantial snowfalls in January and February, 1999.

Figure 9. End of project and pump house in background.

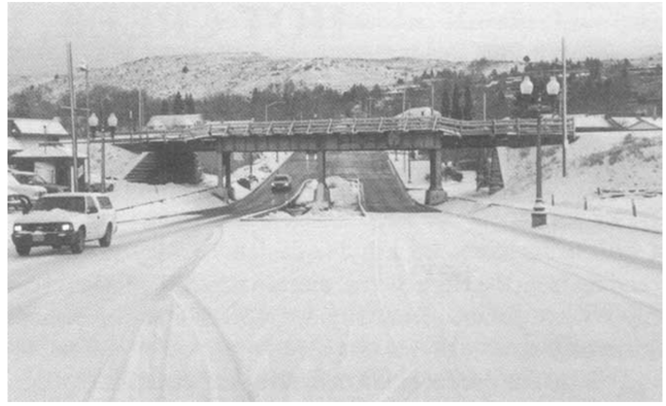

Figure 10. January snowfall looking east

Figure 11. January snowfall looking up the 8% grade to the traffic signal and bridge deck.

ACKNOWLEDGEMENTS

Special thanks to the Oregon Department of Transportation for providing plans and information, especially to Ms. Meredith E. Mercer, project designer; Jason Armstrong, the inspector; and to Powley Plumbing, Inc. of Klamath Falls, the geothermal system installers, for answering many of author's questions.

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LOVE THREE HOT SPRINGS OUT OF THE THOUSANDS - HOT CREEK, FIELDS AND ASH -

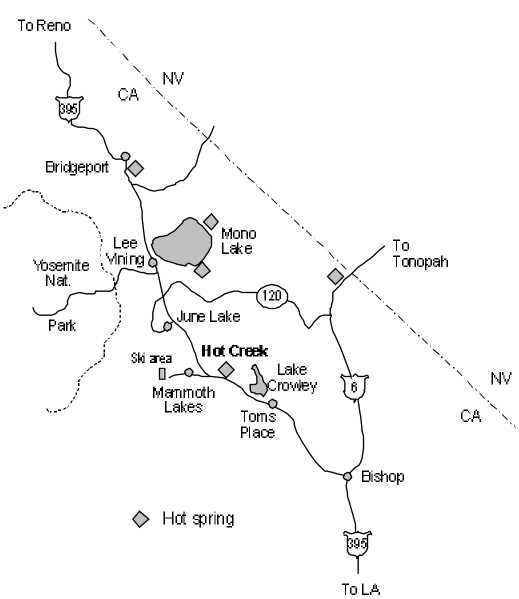
Bill Kaysing
King City, CA

HOT CREEK

This has to be a divine design. An icy stream descending from the High Sierras meets a stream-bed steam vent only a short distance from Highway US 395 above Bishop, California.

What this produces is a delightful and varied hot springs bath . You have your choice of toasting your toes by probing the stones of the creek bottom or having the feeling of being in an ice-cube-filled cocktail shaker. And you can enjoy every temperature in between! There's a thrill in knowing that you are cavorting in a "crack in the cosmic egg," dancing in a geothermal miracle.

I should mention that I have not been there in years and things could have changed; but, I hope not. This is one of our Great Spirit's finest aquatic playgrounds.

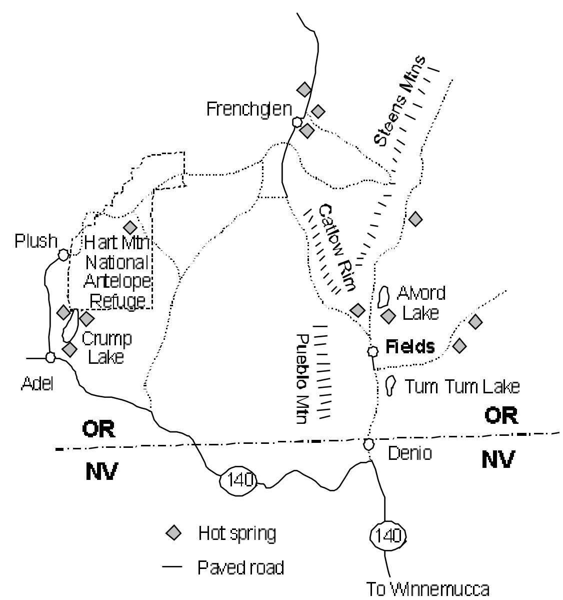


Hot Creek Springs

FIELDS

I call it this because it is close to a tiny village with that name. To find it, just take the dirt road north from Fields in far eastern Oregon and watch for a small lake to your right. On cold days, the vapors rising from the surface will tag it. Just imagine a lake of about an acre in size full of water around 100°F. No one in sight. The mysterious Steen's mountains to the west and not a sound. This has to be either an energy votex or a metaphysical feng shui or simply a super wonderful geothermal spring.

I recall swimming to the center of the lake and remembering that someone in Fields said it was 7,000 feet deep. What a mystical and magical concept.... to be suspended by warm water over a deep chasm in Mother Earth. My beloved and recently departed soul mate and fellow hot springs lover, Ruth, loved it. And I will always remember how she was sunbathing on the crusty beach when a small snake slithered under her neck. I was shaken by the thought it could be venomous; but, Ruth was in a state of hot springs euphoria along with her usual courage and elan, and she never even quivered.

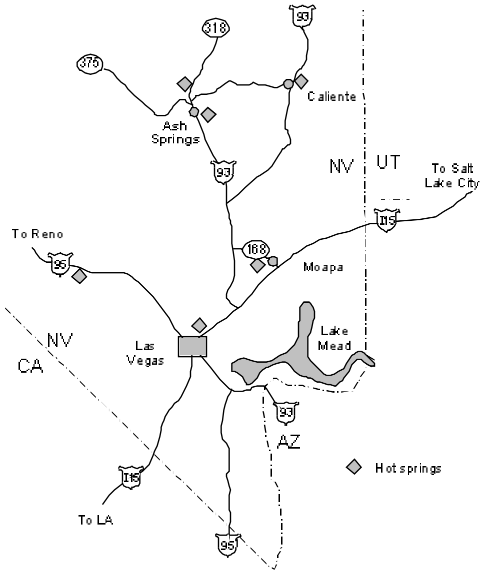


Fields Springs

ASH

If you drive northeast from Vegas on I15, you will intersect the Pan-American Highway US 93. Turn north and drive between the towering Sheep Range and the charming Meadow Valley Wash for about 80 miles. You'll know you're at Ash Springs when you see a totally gigantic cottonwood on your left along with a small store. Turn right into a dirt road for less than a block and you should see a small concrete-lined pool. Toss your clothes off if no one is there and leap in. No shock, just bliss as the water is just about body temperature. It pours out of a sub-surface pipe, keeps the pool sparkling clean and then flows down to a warm water lake of about two acres. The pool is on BLM land and open to the public all year. The lake is privately owned and you should make inquiry before using it.

I once spent an entire week at Ash, bathing in that luxurious, velvet-textured water amidst a forest of willows and cottonwoods, roaming through the nearby desert hills and enjoying campfire meals in the evening. Experiences like that convinced me that being a hot springs gypsy was quite possibly the highest and best use of my life or anyone's life for that matter.



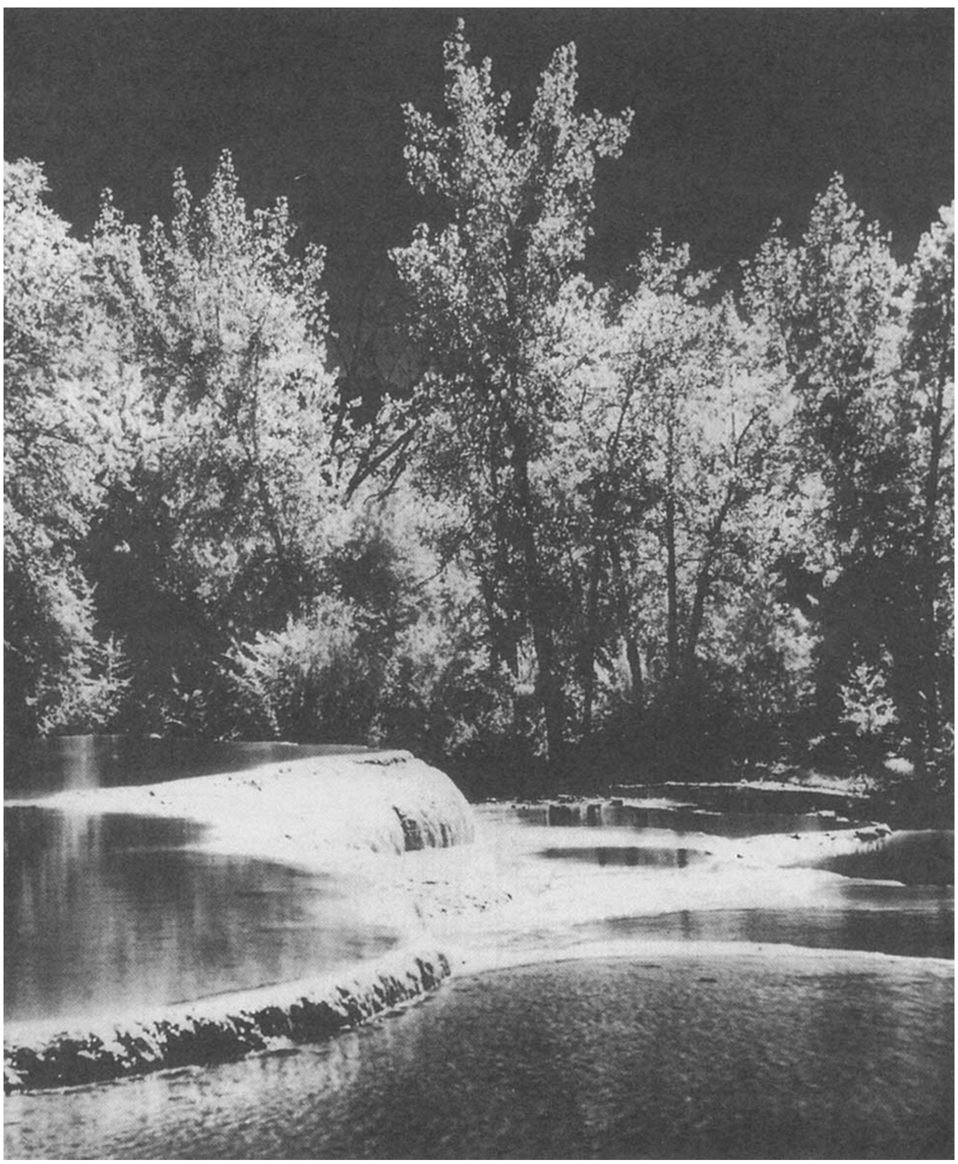
EPILOG

Hot springs, how I love them and how fortunate to have visited so many in the last four decades. If readers have questions, I'll be happy to try to answer them. Bill Kaysing, PO 1095, King City, CA 93930 [only 20 miles from Paraiso (Paradise Hot Springs)].

Editor's Note: Bill Kaysing - author, inventor, sailor and vagabond - has written a classic book on "Great Hot Springs of the West" covering 1,700 known hot springs that flow in the 11 western states.

We have since learned from the U.S. Fish and Wildlife Service that there is a species of fish in Ash Springs (Crenicthys baileyi baileyi), that is listed federally by the Endangered Species Act.

Ash Springs



THE GEO-HEAT CENTER WEBSITE

Tonya "Toni" Boyd
Geo-Heat Center

The Geo-Heat Center, located at the Oregon Institute of Technology campus, (under U.S. Department of Energy sponsorship), has provided technical and information services to geothermal direct-use project developers since 1975. In keeping with the times, the Geo-Heat Center established a website (www.oit.edu/~geoheat or www.oit.edu/other/geoheat) on the Internet in early 1996.

The website has had numerous additions to its pages since it was first established. It contains a wide variety of menus to select from depending on your surfing needs. A listing of the menu includes:

What is Geothermal?
Services Offered
Publications List
Geo-Heat Center Quarterly Bulletin
Where are Geothermal Resources Being Used?
Where are Geothermal Resources?
Geothermal Heat Pump Owner Information Survival Kit
Directory of Consultants and Equipment Manufacturers
Other Places of Interest

The What is Geothermal? section includes a brief introduction to geothermal. The "Services Offered" section includes information on what the Geo-Heat Center offers.

The Publications List section contains a listing of technical papers, research reports, and past bulletin articles which can be requested (though not transmitted electronically) over the Internet. Some new additions to this section includes a page where some publications can now be downloaded and the Outside the Loop Newsletter (a newsletter for geothermal heat pump designers and engineers) webpage.

The Geo-Heat Center Quarterly Bulletin section features the Quarterly Bulletin articles since October 1995. As of this writing, there are 13 issues on line with the latest issue being in a PDF (downloadable) format.

The Where are Geothermal Resources Being Used? section provides information on more than 440 individual geothermal direct-use sites. It has an interactive U.S. map (Figure 1) showing the direct-use sites and resource areas. There are several ways to use this map. You can click on an individual state to reveal a full screen of that state or click on the application icons located at the bottom of the map to get a complete listing for that project type (e.g., all aquaculture projects). The application icons include aquaculture, greenhouses, industrial, space heating, district heating, resorts and spas, power plants, and national labs.

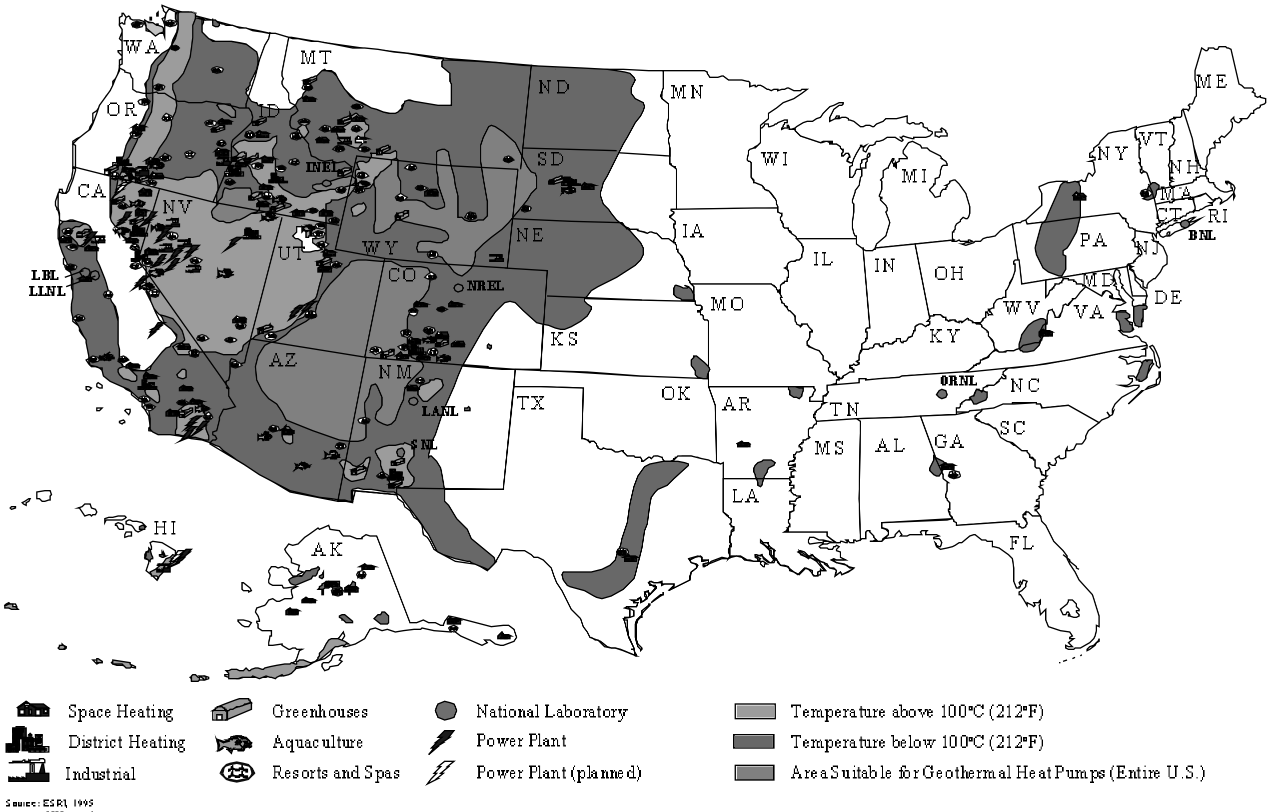


Figure 1. Interactive U.S. Geothermal Projects and Resource Areas map.

When you click on a state from the U.S. map, that state map (Oregon in this example) will be displayed with the application icons and resource areas shown (Figure 2). If you are interested in a particular direct-use site, click on the icon and a summary of what that icon represents will appear, or click anywhere else on the map to get a listing of the sites for that particular state, by application (Figure 3).

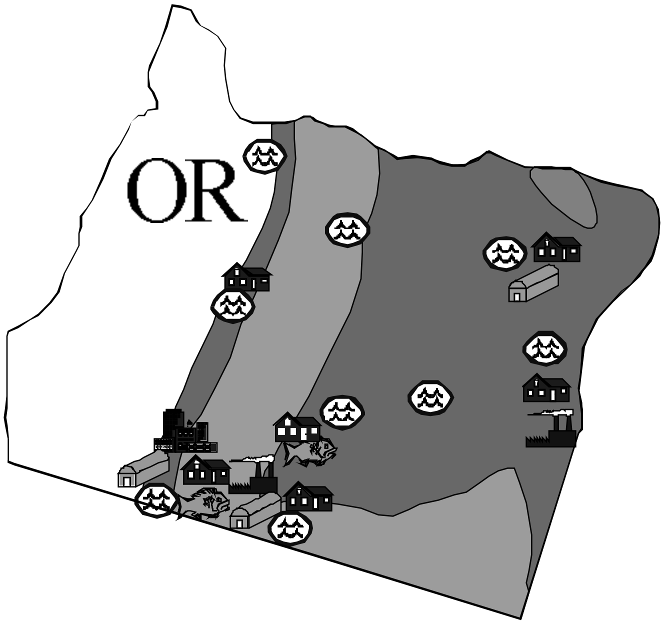


Figure 2. Oregon map showing direct-use icons and geothermal resouce areas.

Figure 3. List that represents a district heating icon in Oregon.

To get more information concerning a particular site, follow the link to the summary. This next page (Figure 4) features information concerning the location, application, temperature of the resource, flow, capacity, contact information, etc. This information will be improved with the addition of project summaries, photographs, and website links for more information.

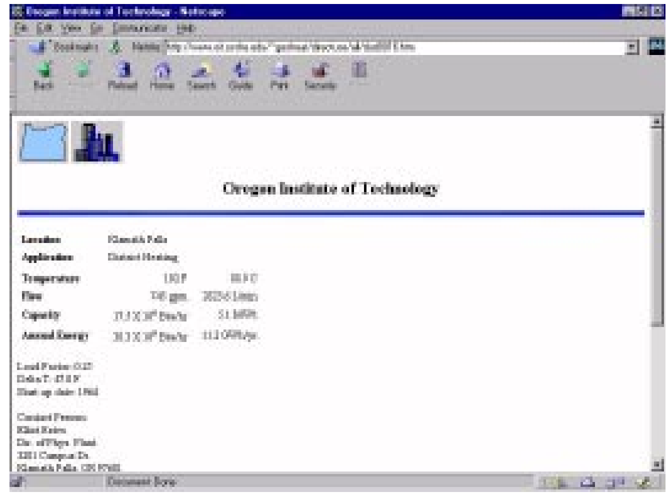


Figure 4. Summary of information for one of the direct-use sites.

Have you ever wondered if there are geothermal resources located close to your community? The Where are Geothermal Resources? section identifies 271 collocated communities, within the 10 western states, that could potentially utilize geothermal energy for district heating and other direct-use applications. The main page for this section contains a brief description of what a collocated resource is and provides links to the 10 western states. Following the link to each state will include a graphic of the state with the collocated locations shown, a brief description of the state and a listing of the communities by county. Information such as location, well depth, resource temperature, flow, and TDS is included.

The Directory of Consultants and Equipment Manufacturers section contains a listing of consultants and what they do. There is also a listing of equipment manufacturers for various types of geothermal equipment such as well pumps, heat exchangers, piping and heat pumps.

The Other Places to Visit section has several links to other websites including such sites as the Geothermal Technologies - USDOE, the Geothermal Education Office, the Geothermal Resources Council, and American Tilapia Association to mention a few.

The Geo-Heat Center website has much to offer and is always under continuous improvement. So come check us out at www.oit.edu/~geoheat or www.oit.edu/other/geoheat and feel free to e-mail us with your suggestions, comments or additions.

IN MEMORY OF
DR. TIBOR BOLDIZSAR (1913 - 1998)

Tibor Boldizsar, the "Father" of direct-use geothermal development in Hungary, died in Budapest on November 26, 1998, at the age of 85. He was born in Budapest on June 9, 1913. In 1931, he matriculated at the Hungarian Royal University of Mining and Forestry Engineer. He received his Ph.D. in 1952 and a Doctor of Science degree in 1956. From 1936 to 1944, he worked for the First Danube Shipping Company as a mining captain and mining engineer near the city of Pecs. He was the chief mining engineer at the Hungarian Bauxite Co., Inc., from 1945-46, and was then nominated to be the managing chief engineer of the Hungarian National Coal Mines Co., Inc., in Budapest. From 1949-50, he was head of the department at the Mining Research Institute, and in 1952 became professor and head of the department at the Polytechnical University of Heavy Industry. He was a professor at the University of Miskolc from 1959-80, and retired in 1980.

During his retirement, he had advisory functions at the Hungarian National Committe of Technical Development; Development Institute of the Mining Center; European Economic Committee of UNO (Geneva); the United Nations University, Tokyo; and the International School of Geothermics (IIRG), Pisa, Italy.

His main field of research and university teaching was on the organization and direction of mechanization of mining processes. He wrote a book on "Modern Mining Machinery," and edited four volumes of the "Handbook of Mining," including chapters on ventilation and geothermal heat recovery of deep mining operations. He published about 200 studies and articles, nine books or portions of them, and about 90 papers that were published in about 50 international periodicals. He also performed research and lectured on geothermal energy and vulcanology in California, Oregon, Hawaii, New Zealand, the Canary Islands and several universities in Europe.

He received a number of Hungarian and international decorations and certificates of merit. In 1979, he became a member of the New York Academy of Sciences; an honorary member of the American Geophysical Union in 1980; and a member of the American Institution of Mining, Metallurgical and Petroleum Engineers. In 1993, he was decorated with the Officer's Insignia of the Republic of Hungary.

He was invited to make a presentation at the first U.S. geothermal direct-use conference on the Oregon Institute of Technology campus in October of 1974. At this conference, on the Multipurpose Use of Geothermal Energy; he presented a paper on "Geothermal Energy Use in Hungary." He has also published papers on heat flow in the Hungarian Basin (Nature, Journal of Geophysical Research, and Bulletin of Volcanology) and on "Geothermal Energy Production from Porous Sediments in Hungary" in Geothermics Special Issue, Part 1 (the UN Symposium on the Development and Utilization of Geothermal Resources, Pisa in 1970). At that time, he was a member of the Geothermal Board in Budapest. His publications go back to at least 1968 in the geothermal field. The GHC Bulletin of October 1995 (Vol. 16, No. 4 - p. 1) has a photo of the presenters at the 1974 OIT conference with Dr. Boldizsar seated in the front row.

His contributions to the geothermal community will be missed. Our condolences to his wife, Viola, and to his family.

INTERNATIONAL GEOTHERMAL DAYS
OREGON 1999

You are invited to attend the International Geothermal Summer School: "International Geothermal Days - Oregon 1999" at Oregon Institute of Technology in Klamath Falls, Oregon. This meeting, from October 10 through 16, will feature of a series of workshops, courses and seminars; a continuation of earlier ones held in Europe since 1990. Klamath Falls is an ideal setting for colleagues from all over the world to meet and discuss the development and utilization of geothermal energy. With over 500 geothermal wells in the area and many types of geothermal utilization, the setting is an excellent field laboratory to demonstrate the direct utilization of this sustainable resource.

The program is organized by the International Summer School of Macedonia and the staff of the Geo-Heat Center, the latter which is famous for its international coopeation, technical assistance, information dissemination, and Geo-Heat Center Quarterly Bulletin. Presenters from the U.S. and Europe will be supplemented by speakers from Latin American and the Pacific Rim nations. The International Summer School has organized past meetings in the Azores, Turkey, Bulgaria, Slovenia, Romania and Macedonia. Dr. Kiril Popovski and Dr. John Lund are the conference co-chairmen.

The conference will cover three main topic areas: (1) Small-Scale Power Projects, (2) Geothermal Heat Pumps, and (3) Direct Utilization of Geothermal Energy. These will be supplemented with two evening workshops on computer applications of (1) Software for Geothermal Heat Pumps, and (2) HEATMAP© Software (a district heating design program). The conference will also have three field trips (1) to Medicine Lake (Glass Mountain) in northern California to view the sites of the proposed Calpine Corp. and CalEnergy Co., Inc. 49.9 MWe power plants, (2) direct-use sites in the Klamath Falls area, including the OIT heating system, the Klamath Falls City district heating/snow mel system, greenhouses and an aquaculture project, and (3) district heating, binary and hybrid power generation projects on the way to Reno. The last field trip will occur on Saturday, October 16, after the conference and will end in Reno in time for the GRC Annual Meeting in Reno, NV. Participants can then take the Sunday field trip offered by GRC of local power plants (field trip #2 - Steamboat and Brady's Hot Springs) and return in time for the Sunday evening opening reception at the Reno Hilton Hotel. (The costs of the GRC events are not included in this conference.)

Additional information, the program and registration forms can be obtained by contacting the Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR 97601 (phone: 541-885-1750, fax: 541-885-1754), or the entire program can be viewed on our website: www.oit.edu/other/geoheat/iss/issindex.htm.

GEOTHERMAL PIPELINE

Progress and Development Update
Geothermal Progress Monitor

MEETINGS

European Geothermal Conference, Basel, Switzerland, September 20-30, 1999

Co-sponsored by the German and Swiss Geothermal Association, Geothermal Conference, Basel '99 will be held at the Kongresszentrum Messe Basel. The purpose of the conference is to provide a forum for a European exchange of scientific, technological and economic information on geothermal resources and their development and utilization. All aspects of the state-of-the-art will be examined, as well as the new market situations presented by electric restructuring and privatization. Field trips are planned to Poland, Germany, Italy, France and within Switzerland. For more information, contact: OC Secretary EGC Basel '99, Bureau Inter-Prax, Dufourstrasse 87, CH-2502 BIEL/BIENNE. Phone/Fax: +44/ 32 341 45 65. E-mail: interprax@bluewin.ch.

Geothermal Resources Council Annual Meeting - Reno Hilton Hotel, Reno, NV, October 17-20, 1999

The meeting will feature a thematic opening session, special and technical session on a broad range of geothermal resource and development topics, workshops, field trips and the Geothermal Energy Association Trade Show. Deadline for first draft of papers is May 3, 1999. Further information can be obtain from the Geothermal Resources Council, PO Box 1350, Davis, CA 95617-1350, phone: 530-758-2360, email: grc@geothermal.org.

World Geothermal Congress 2000, Kyushu - Tohoku, Japan, May 28 - June 10, 2000

The World Geothermal Congress 2000 will be co-convened in Japan by the International Geothermal Association (IGA) and the Japanese Organizing Committee for WGC2000 (JOC). The main purpose of WGC2000 is to provide a forum for exchange of scientific, technical and economic information on geothermal development. The Congress will offer opportunities to learn about recent scientific results and state-of-the-art technologies for geothermal energy development and for exchanges of information with worldwide experts in the field. The IGA and JOC invite the participation of all persons with an interest in geothermal resource development; countries, organizations and enterprises of countries engaged in the research, development and use of geothermal energy; and the manufactures of geothermal-related equipment.

The technical sessions will be held in two separate locations: Beppu City on Kyushu from May 31 to June 2 and in Morioka City, Tohoku on Honshu from June 5 to 7. Transportation will be provided between the two sites by JOC. The call for papers has been issued and the receipt of abstracts is by December 31, 1998. Draft papers will be received by July 31, 1999 and receipt of the final papers is January 31, 2000. The abstract form can be obtained from the WGC2000 official web site. For further information, contact the Secretariat of the WGC2000, %New Energy and Industrial Technology Development Organization (NEDO), 3-1-1 Higashi-Ikebukuro, Toshima-ku, Tokyo 170-6028, Japan, phone: 81-3-3987-5793, fax: 81-3-3987-5796 and email: info@wgc.or.jp, or webpage: www.wgc.or.jp.

CALIFORNIA

CalEnergy to Break Ground for New Geothermal/Zinc Recovery Facility

CalEnergy Company will break ground in early 1999 on its new geothermal facility and zinc recovery plant near the Salton Sea in Imperial County, CA. The $285 million, 49-megawatt geothermal facility and zinc recovery plant represent the largest single renewable energy investment in the U.S. in nearly a decade. Approximately two-thirds of the electricity generated by the plant will be sold into California's emerging "green" electricity market, while the remaining one-third will be used onsite to provide power for the zinc recovery plant. "The minerals recovery program will bring several major benefits to California, more renewable energy at lower prices, more jobs, environmentally benign mining, and enhanced economic security," according to Jonathn Weisgall, VP of GEA. (Geothermal Energy News, GEA, Vol. 1, No. 7, Oct/Nov 98)

Stone and Webster of Boston have been authorized to proceed on two contracts with an estimated combined value of $141 million for geothermal power projects owned by affiliates of CalEnergy Co., in the Salton Sea geothermal area of Imperial Valley. The contracts cover engineering, procurement and construction of the new 49-megawatt geothermal plant and additional facilities. The new power plant will be located near CalEnergy's existing Salton Sea units 3 and 4. It is being built to support a zinc-recovery facility scheduled for completion in June 2000. (CE - News, Oct. 1998)

Calpine Grows Greener

Calpine Corp's proposal to buy most of the Geysers, announced on January 19, puts the San Jose company on track to become the state's largest producer of green electricity in the new world of electricity deregulation. The purchase will add about 800 MWe of green power to the company (a MWe powers about 1,000 households). Calpine currently owns interest in 4 of the 21 power plants there and 6,100 acres of the steam fields that supply the power plants. If it successfully completes its proposed acquisitions, it will own 18 of the power plants and 16,600 acres of the steam fields. The company has just signed a contract to wholesale some of its Geysers energy to a retailer that is telling its customers the green power they're getting is from The Geysers – the first time the Geysers energy will be marketed directly to consumers for its environmental qualities. The retailer is the Commonwealth Energy Corp. of Austin. (Mary Fricker, Santa Rosa Press Democrate, Jan. 1999)

NEBRASKA

CalEnergy Sells Unit Ownership to El Paso

Power company CalEnergy Co. Inc. on February 23 said it agreed to sell 50 percent of its ownership in CE Generation LLC, the holding company for 14 of its U.S. generating facilities, to an affiliate of El Paso Energy Corp. for about $259.6 million. CalEnergy said it would retain the remaining 50 percent ownership interest in the facility. The sale is scheduled to close on March 3, according to CalEnergy.

Last month, CalEnergy said it agreed to sell its minority stake in the Coso geothermal power projects to Caithness Energy LLC for $277 million, including the assumption of $67 million in debt. (NYSE:EPG - news, 23 Feb. 1999).

NEVADA

Nevada's Mineral Production in 1997

Nevada's 1997 mineral production (including petroleum and geothermal energy) is estimated at $3.3 billion, a 4% decrease from 1996. Gold production was the largest mineral source, extracting 7.83 million troy ounces worth about $2.54 billion. Silver production was 24.6 million troy ounces worth $114 million.

Nevada's geothermal electric power sales in 1997 were 1,348,000 megawatt-hours worth $107 million, about the same as in the four previous years. Total geothermal power generating capacity of Nevada's 14 plants (on the sites) stands at 237 megawatts, also about the same as during the past four years. No new plants have been installed in the past five years. (Nevada Geology, No. 34, Nov. 1998)

NEW MEXICO

Sandia Receives Patent

Sandia recently received a U.S. Patent for a well-pump alignment system. The line-shaft pump alignment system is an acoustic device for measuring the axial alignment of the drive shaft on downhole geothermal pumps. The present measurement method does not work when the shaft is turning requiring the pumps to run with more impeller clearance than would otherwise be necessary and results in increased maintenance costs. Sandia and Johnson/Paco, a pump manufacturer, are planning a field test in a commercial production well in 1999 and if successful, Sandia and Johnston/Paco plan to initiate patent licensing negotiations. This device will double pump life from 18 to 36 months and save over $100,000 per well. These pumps are used in the majority of geothermal power plants built in the last decade. Overall this project will result in a 50:50 cost share with industry. (Lew Pratsch, Nov. 1998)

VIRGINIA

Geothermal System to be Installed at Fort Eustis, VA

EVANTAGE, a division of Virginia Power, has started a $2.2 million energy efficiency project at the 260,000-sq. ft. training facility at Ft. Eustis, VA. To heat and cool the building, EVANTAGE will install a 240-ton geothermal heat pump system with an earth-coupled, ground-loop heat exchanger. It will also install energy-efficient lighting in offices and classrooms and a direct digital control energy-management system for all mechanical equipment.

"In the earth-coupled, ground-loop system, a series of 200 wells with underground pipes will use energy stored in the earth to cool and heat the buildings" said Bob Andrus, EVANTAGE's staff engineer for the project. The annual energy saving in the building is estimated at more than $150,000. Projected operating and management savings are $47,000 each years. EVANTAGE estimates the projected payback through energy savings is 7.4 years. The project is slated for completion in March 1999. (Business Wire, Dec. 17, 1998)

GeoExchange Earns "A Place in History"

Several of the buildings in the historic district of Williamsburg, Virginia are using geothermal heat pumps for heating and cooling (GeoExchange). The largest system can be found at the Shields Tavern, a reconstruction of a tavern originally built in the early 1700's. The reason for selecting geothermal heat pumps, is that they are hidden from sight, unlike traditional air conditioning units that hang from windows. In addition, is their virtual silence, geothermal heat pumps do no rely on noisy pumps and exhaust fans to heat and cool interior space.

"It's an ideal technology for an historical district, when you can't afford to have any outdoor air source cooling equipment humming," said Clyde Kestner, director of engineering for the Colonial Williamsburg Foundation. "The overriding concern is authenticity. You don't want to see these modern systems, hear them, or even know that they are there. You just want them to do their jobs quietly behind the scenes."

Aesthetics aside, GeoExchange installations are also very flexible, therefore they are generally the easiest systems to incorporate into an historic building, " explained Conn Abnee, executive director of the Geothermal Heat Pump Consortium. "One successful strategy is to use smaller heat pumps installed in closets, basements, and attics to provide space conditioning and ventilation with minimal ducting." (Geothermal Heat Pump Consortium - PRNewswire, Oct. 28, 1998)

WASHINGTON

2 Companies Settle Mount St. Helens Claim

Nearly two decades after Mount St. Helens blew its top, two corporate landowners are getting $4.2 million for geothermal development rights they never planned to exercise. The settlement with Weyerhaeuser Co. and Burlington Resources Oil & Gas Co. that took effect in mid-December was designed to resolve a dispute stemming from creation of the Mount St. Helens National Volcanic Monument. Rather than cash, the government is paying in credits the companies can either sell or apply toward acquisition of mineral, oil or geothermal rights on other federal lands.

Officials at both companies admit they had no plans to tap the heat beneath the mountain before it erupted in May of 1980. In 1982, congress established the monument on 110,000 acres, including 11,000 acres that Weyerhaeuser and Burlington Resources agreed to exchange for timberland elsewhere in Washington state. The land deal did not include underground mineral and energy rights, but Paul Tittman, chief appraiser for the U.S. Forest Service, said the agency was nonetheless surprised when the two companies filed a claim in 1986 for compensation of energy rights. The claim, based on calculations that heat beneath the 8,355-foot mountain could be tapped for a 55-megawatt electrical generating plant, was "not supported" and contained questionable "assumptions," Tittman said. A private appraisal done for the companies in 1991 set the negotiating range at $5.6 to $6.9 million, Weyerhaeuser spokesman Fran Mendizabal said. (The Associated Press - Oregonian, Dec. 28, 1998)

INTERNATIONAL

China's Geothermal Energy Resources to be Tapped

China will energetically tap geothermal energy resources in the southwest region and Tibet. In western Yunnan and western Sichuan a number of medium-scale geothermal energy plants will be established in the next two decades. China will erect power plants with unit capacity of 3 to 5 kW in west Yunnan and primarily Ruili. Geothermal energy resources in Tengchong and western Sichuan will be tapped in 2000. China has discovered over 3,000 geothermal springs, of which there are over 2,200 with water temperature exceeding 250 degree Celsius. (AsiaPort Daily News, Nov. 1998)

Oxbow, Marubeni, Costa Rica Celebrate Power Project Ground Breaking

Oxbow Power Corporation announced that business and government leaders from the U.S., Japan and Costa Rica, including President Miguel Angel Rodriquez, met today to formally kick-off active construction of the Miravalles III Geothermal Power Project. The 27.5 MWe geothermal power plant is located in the Costa Rican province of Guanacaste, and will provide clean, reliable and low-cost electricity to Instituto Costarricense de Electricidad (ICE), the Costa Rican national utility. (Business Wire, Feb. 8, 1999)

World Renewable Energy Capacity and Production

A new "Survey of Energy Resources 1998" was published in connection with the World energy Congress in Houston, TX, in September 1998. The table below is complied from the survey. The installed capacities are at the end of 1996 and the electricity generation is for the year 1996 for all the four energy sources:

	Installed Capacity		Production per Year	
	MWe	%	GWh/yr	%
Geothermal	7,049	52.0	42,053	79.6
Wind	6,050	44.7	9,933	18.8
Solar	175	1.3	229	0.4
Tidal	264	2.0	602	1.2
TOTAL	3,538		52,817	

The table demonstrates clearly one of the strong points of geothermal energy, i.e. that it is available day and night throughout the year and is not dependent on whether it is cloudy or whether the wind blows or not. It is often difficult to compare the advantages and disadvantages of different energy resources, as the data for these is often presented in variable forms. The good thing about the data presented in the WEC Survey of Energy Resources is that all the data is handled in the same way and all the data originates from the national energy authorities of the countries of the world. (Ingvar Fridleifsson, International Geothermal Association letter to the Board of Directors, 28 Nov. 1998).