

Moana Geothermal

Thomas Flynn Describes the Geology and Evolution of This Important District-Use Area in Reno, Nevada

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The Moana geothermal area, in southwest Reno, supports the largest low-to-moderate temperature, direct-use development in Nevada. More than 250 geothermal wells, ranging from 10 to 1,000 feet in depth and 100°F to 215°F in temperature, have been drilled in an area of approximately three square miles. Residential and commercial development is concentrated in Sections 23 through 27, Township 19 North, Range 19 East, Mount Diablo Base and Meridan (Fig. 1).

Geothermal development in the Moana area began in the early 1900s at the site of the former Moana Hot Springs. The City of Reno and former Nevada Governor John Sparks both took advantage of the proximity of the thermal water for heating the municipal swimming pool and supporting rudimentary geothermal aquaculture, respectively. By 1975, it is reported that 35 geothermal wells in the area were in use for residential space heating (Bateman and Scheibach, 1975). By 1984, the number of documented wells had increased to 143 (Flynn and Ghusn, 1984). There are more than 200 documented wells, but the present number probably exceeds 250.

Figure 2 shows the historical development of wells (from this database) drilled between 1950 and 1995. The histogram shows clearly that the introduction of residential federal energy tax credits, amounting to 40 percent of investment between 1978 and 1985, resulted in a dramatic increase in well drilling and geothermal direct use. Important historical events that impacted energy supplies worldwide had a very limited effect on geothermal well drilling.

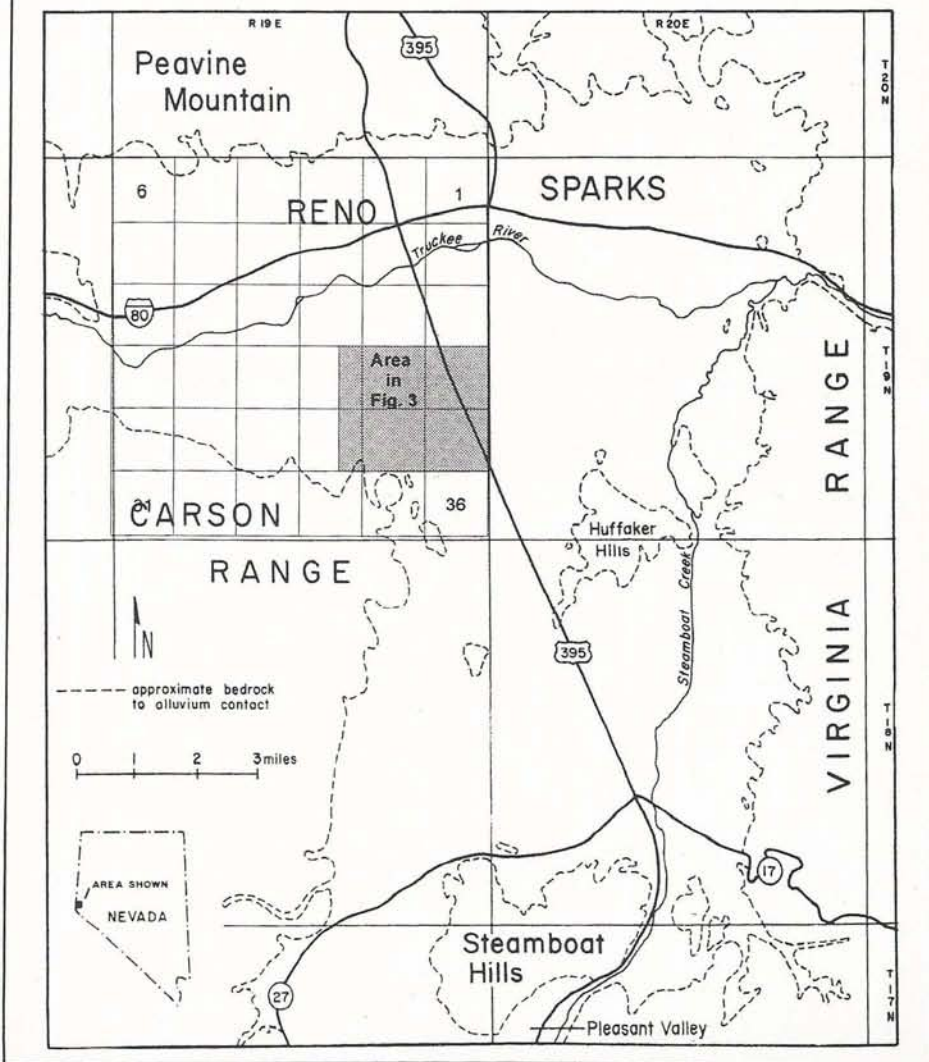
The Moana thermal anomaly is believed to be the result of forced convection of deeply circulating groundwater along north-

and northwest-trending faults. Previous studies have provided inventories of wells drilled (Bateman and Scheibach, 1975; Garside and Schilling, 1979; Flynn and Ghusn, 1984). Miscellaneous engineering investigations of individual wells have been completed by the Geo-Heat Center/Oregon Institute of Tech-

nology. This is the first time subsurface temperature data have been used to delineate patterns of temperature distribution in three dimensions in the Moana area.

Geothermal fluids in Moana are relatively dilute (800 ppm TDS), near-neutral pH, sodium-sulfate dominated waters. It is widely

Figure 1. Location map showing the Moana geothermal area and the Steamboat geothermal area (modified after Bateman and Scheibach, 1975).



recognized that the Moana geothermal area is a typical, low-to-moderate temperature reservoir that is controlled principally by faults and fractures, and secondarily by lithology. Structurally and chemically similar thermal areas include Walley's Hot Springs, Hobo Hot Springs, and Saratoga Hot Springs in Douglas County. There is little or no relationship between the Moana geothermal area and the higher-temperature (350°F) Steamboat geothermal area, located 15 miles to the south.

Most of these wells were drilled to meet the heating requirements of single family homes. Historically, residential geothermal wells were completed much like conventional water wells, with steel casings (perforated near the bottom) and cement-sealed annuli to a depth of 50 feet. Eight-inch diameter casing was typically used to accommodate either a steel or copper trombone-shaped downhole heat exchanger (DHE) and a small capacity submersible pump used to stimulate flow into the well.

Many of these wells are completed in the hydrothermally-altered Kate Peak Andesite, which consists of various proportions of sand and "blue clay." The larger the percentage of clay, the less productive the well, prompting the need for a submersible pump. Nevada regulations now prescribe a cement seal from the surface to the top of the thermal aquifer, and have eliminated the pumping option unless a fluid injection well is available for the discharge. Several wells have been drilled for commercial properties, including casinos, churches, and a space heating district that supplies geothermally heated water to more than 100 homes for a single well. The total estimated private investment in Moana is about \$15 million dollars with an approximate annual savings of 500,000 therms of natural gas.

Objectives and Scope

A database consisting of locations, depths, temperatures, temperature profiles, water levels, drilling dates, and in some cases, fluid chemical composition, has been compiled for more than 200 residential and commercial geothermal wells in the Moana area. These data, when used in combination with existing geologic and hydrologic data, reveal the areal extent, possible structural controls and magnitude of the thermal anomaly. Contoured temperatures show that the highest temperature wells are distributed

along two faults that intersect near the center of the thermal anomaly. Temperature logs from 80 geothermal wells were used to develop three cross-sectional slices through the thermal anomaly, revealing its approximate size, shape and subsurface temperature distribution to a depth of 1,000 feet. The diagrams show the shape of the presently exploited reservoir, which is the result of an uncoordinated, quasi-wildcat drilling program that was, by most accounts, a success.

It is not the intent of the author to provide or suggest any direction or recommendations for future development. Historically, geothermal well drilling has been guided by individual preferences and budgets; that tradition is likely to continue. This report does help to explain the variable success that well drillers have experienced in Moana. The data indicate that the geothermal reservoir is not uniformly distributed; its highest temperatures and productivities are located along specific fault segments.

Plan View Map

Figure 3 shows the distribution of maximum measured temperatures in geothermal wells in the Moana area. Temperature contours close around and suggest two divergent linear trends: one to the north-northeast, associated with NNE-trending surface faults, and one to the northwest, which does not appear to be associated with any mapped faults. The maximum linear contour for the NNE trend is 180°F; its length is less than 0.5 miles and it is about 0.25 miles wide. The larger, NW-trending trend has a maximum linear contour of 200°F, which is about 0.75 miles long and 0.25 miles wide.

As mentioned above, this trend is not parallel to any nearby mapped faults. It is, however, parallel to NW-trending faults (N50°W) that are mapped in exposures of the Kate Peak Andesite, immediately southwest of the map shown here (Bonham and Rogers, 1983). Those faults have been mapped only in the Kate Peak Andesite,

Figure 2. Histogram showing temporal distribution of geothermal wells drilled in the Moana geothermal area, T19N, R19E, MDB&M.

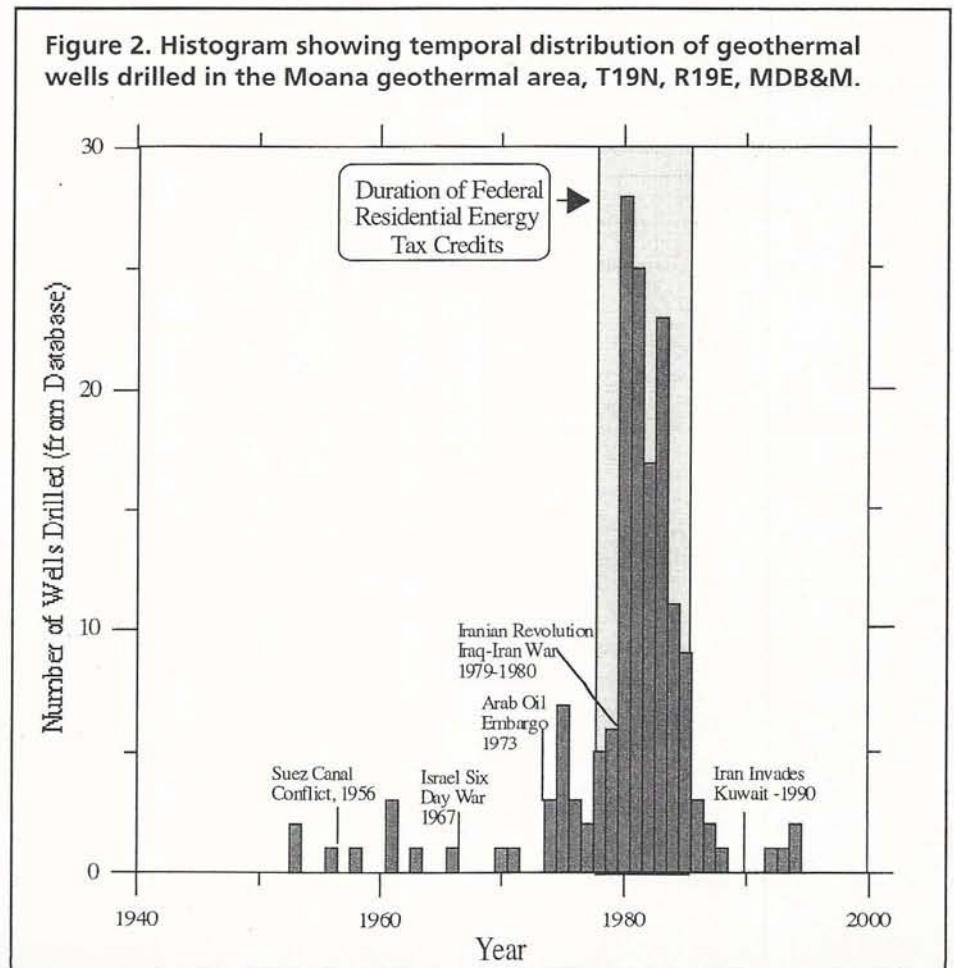


Figure 3. Relationship between contours of maximum measured temperatures in residential geothermal wells and principal mapped faults in the Moana geothermal area, Washoe County, Nevada: T19N, R19E, MDB&M.

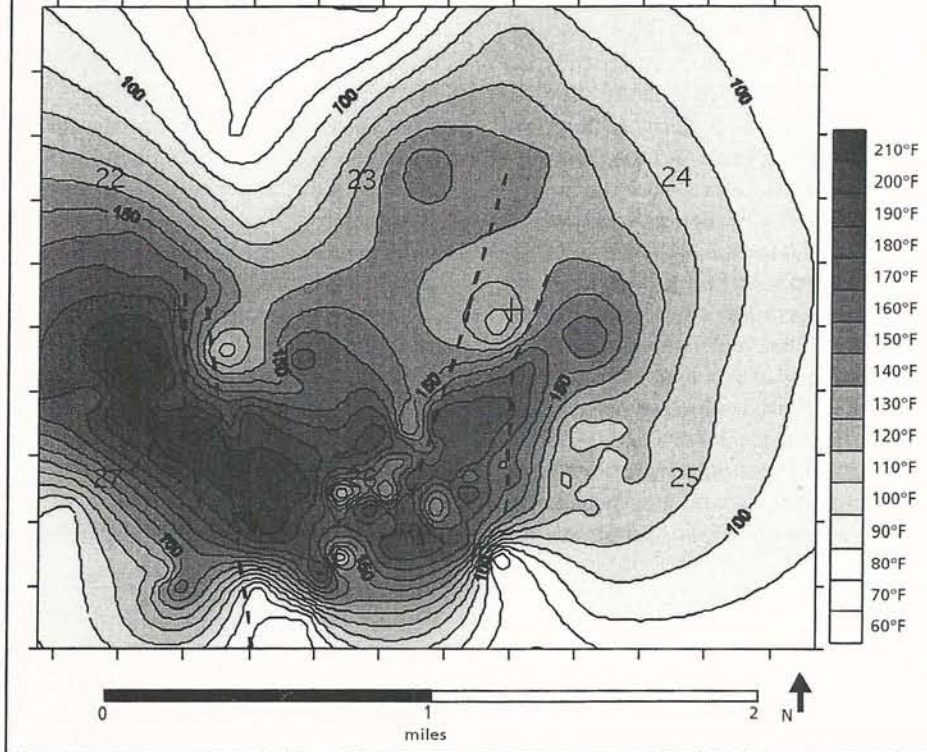
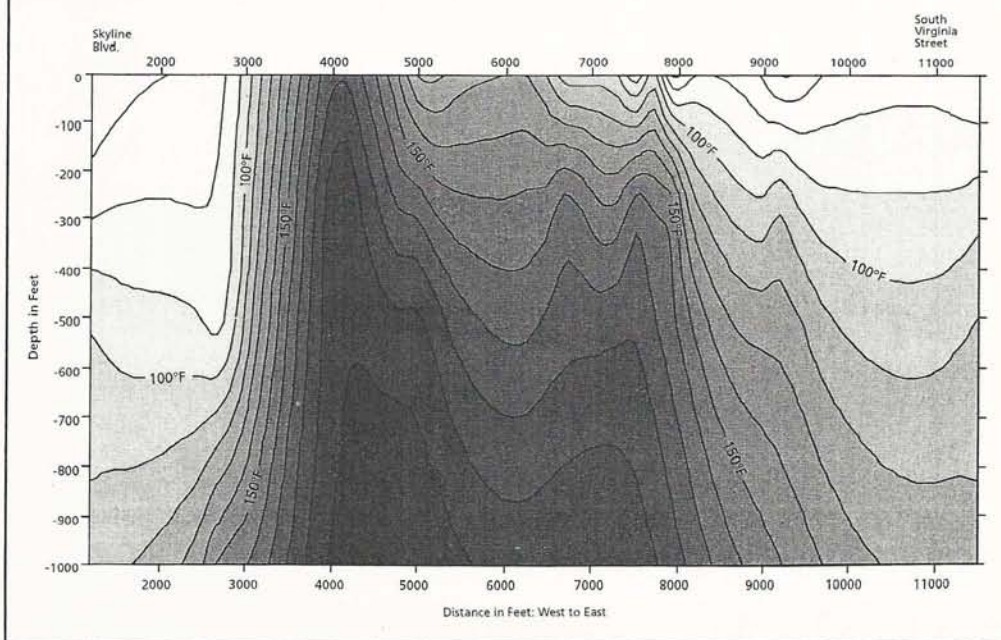


Figure 4. Temperature-depth model across the south end of the Moana geothermal field.



which is both the underlying bedrock and in some cases, the geothermal reservoir rock (the andesite is hydrothermally-altered to a "blue clay") in the Moana area.

The diagram suggests that the highest temperatures recorded in Moana are associated with the natural preferential flow along a limited length of existing faults in the basement and overlying sedimentary rocks. The temperature decrease occurs most rapidly immediately adjacent to the faults. The gradients are more gradual further from the faults as thermal waters mix with non-thermal groundwaters to the north, east and south. The western extent of the Moana thermal anomaly is not fully defined by this map due to a lack of data.

Additional plan maps that may be derived from this data set include: lateral variations in fluid chemical composition, especially silica, arsenic, boron and fluoride; depth-to-water; depth to the "blue clay," and depths to the 150°F and 175°F isotherms.

Cross Sections

Selected temperature profiles projected onto west-to-east cross-sectional slices through the thermal anomaly are presented in Figures 4, 5 and 6. Figure 4 slices through the southern end of the anomaly approximately through the center of sections 27 and 26. Two general observations can be made. The first is that the overall thermal anomaly appears as an abrupt, near vertical intrusion, on both the west and east, with the highest temperatures to the west. The second is that the thermal anomaly is bimodal, possibly indicating that the controlling faults have independent structural control over the thermal fluid dispersion in the near subsurface.

Figure 5 slices through the northern edge of sections 27, 26 and 25. This diagram suggests that the two nodes themselves may be bimodal, but that may also be explained by the distribution of data points and the extrapolation limits of the contouring program. The diagram does indicate that the two thermal nodes are now spatially separated by nearly one mile, and that the western node has begun to "submerge" while the eastern node has begun to "emerge." The diagram

shows the nearly vertically thermal contours, continuing to suggest a mechanism of forced convection along selected faults.

The final slice (Fig. 6) cuts through the center of sections 22, 23 and 24, and shows that the thermal anomaly is deeper and more diffuse. Usable temperatures (120°F+) exceed 500 feet in places, which is the approximate economic limit for development. In addition to lower temperatures, well productivity is extremely variable due to the abundance of clay in the overlying sedimentary rocks.

Limits of Interpretation

Because this study relies largely on existing data points that have an intrinsic bias, it is important to acknowledge that there are limits to the interpretation. These data are not, in the strictest sense, statistically representative, because they are the result of the personal preferences and budgets of the resident population. The study is a pragmatic evaluation of the resource.

The plan view map (Fig. 3) covers all or parts of sections 22 through 27, and is based on data from more than 200 geothermal wells. The contours plot the maximum measured temperatures at any depth in the well. This is a somewhat different approach from contour maps that plot temperatures at a specific elevation or those that plot and contour specific temperatures at various elevations.

Typically, temperature-depth profiles (temperature logs) in Moana are completed in wells during drilling, shortly after completion, or both. Temperature measurements typically begin at the top of the static water level, which may be in excess of 100 feet from the ground level. In some wells, especially those in close proximity to faults and fractures, natural forced convection results in very high well bore temperatures beginning at the static water level.

Figure 7 illustrates two different wells in the Moana area: one profile was measured from the surface to total depth, the other profile begins at a depth of 100 feet. In the absence of measured temperatures above the static water level, the program artificially extrapolates temperatures to the surface. As a result,

it appears that a temperature of 175°F occurs at the surface in Figure 4; when in fact, there are no such measurements at the surface.

Conclusions

Direct-use geothermal development (well drilling) in the Moana area peaked in the early- to mid-1980s. Seventy percent of

the geothermal wells in this database were drilled between 1980 and 1985. Data from those wells and others were compiled and used to prepare a series of digital maps and cross-sections that delineate the areal extent of the thermal anomaly. The data also show that the Moana geothermal area is structurally-controlled by at least two near-vertical

Figure 5. Temperature-depth model through the center of the Moana geothermal field.

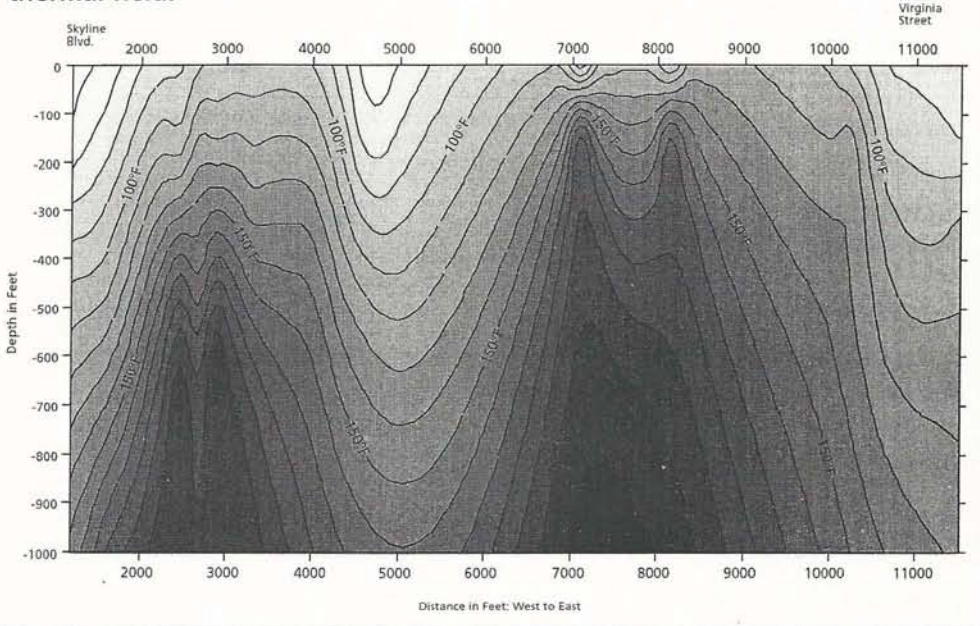
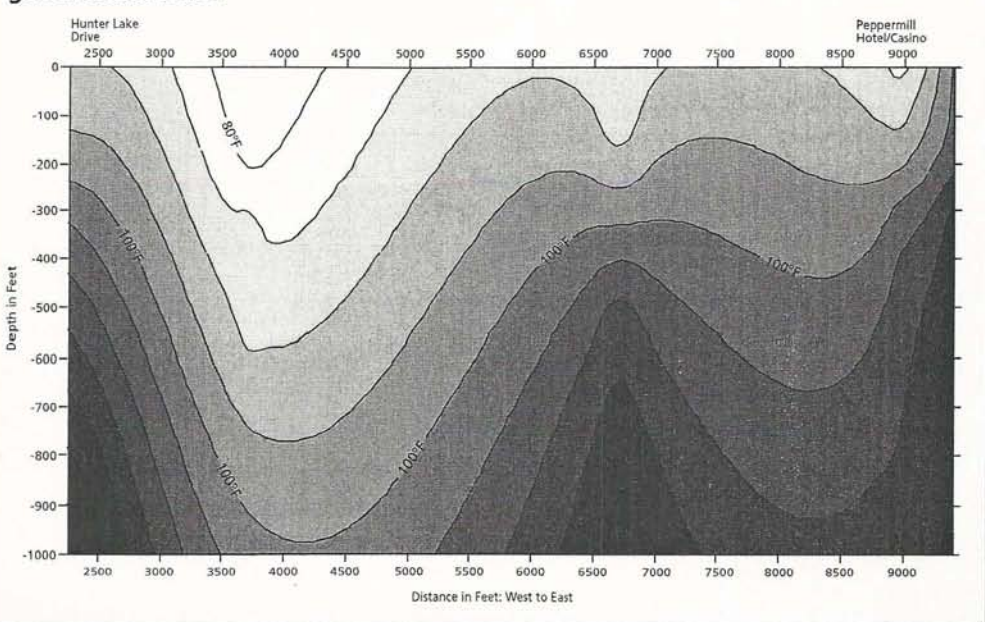


Figure 6. Temperature-depth model across the north end of the Moana geothermal field.



Geothermal Direct Use

faults: one trends northwest, the other trends north-northeast. Residential wells are concentrated in the vicinity of these faults.

Since 1995, well drilling has all but stopped due to depressed costs of natural gas and the added expenses associated with drilling and completing both a production and injection geothermal well. There has been renewed interest in geothermal direct use with the recent rise in the cost of natural gas. However, as Figure 2 illustrates, energy cost increases and/or global energy predicaments have a limited impact on residential development. A renewal of the federal residential energy tax credit program, for a portion of the private investment, is much more likely to promote new geothermal development.

Acknowledgments

The author appreciates the contributions of Kevin Rafferty, John Lund and the staff of the Geo-Heat Center in the preparation of this

manuscript. This report is not an account of work sponsored by the U.S. Department of Energy, the National Renewable Energy Laboratory, nor any state, county or local government agency. It was privately funded.

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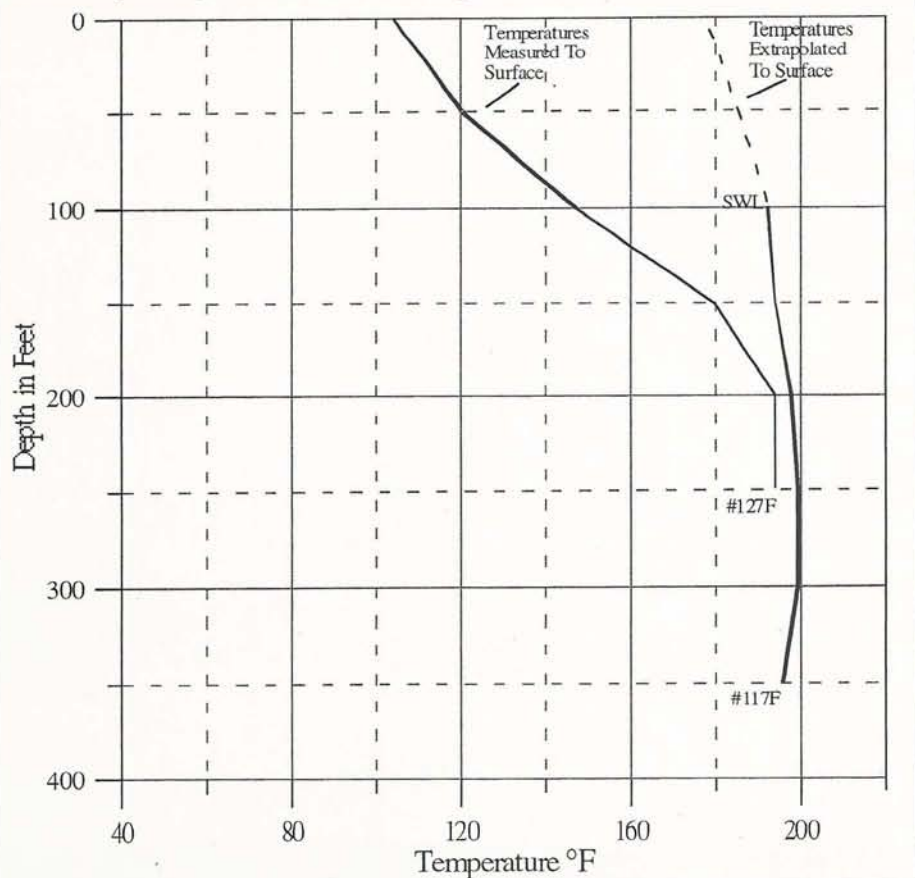
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Figure 7. Temperature logs from two geothermal wells showing the results of measuring to the surface (#127F) versus extrapolating to the surface (#117F) if measurements begin at static water level (SWL).



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Volume 31 / Number 1
January / February 2002

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Moana Geothermal

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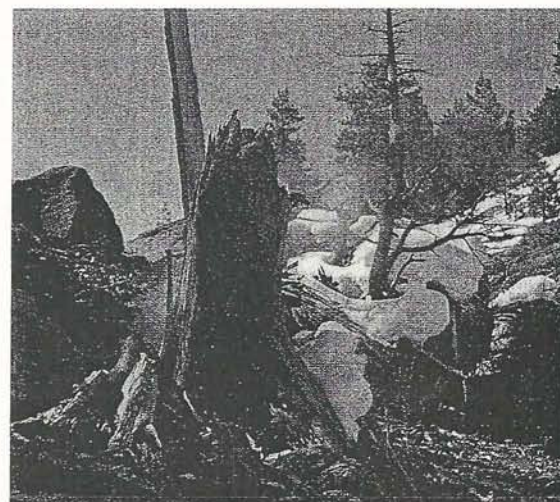
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