Surprise Valley Electric Paisley, Oregon Geothermal Power Project

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Rural electric power, power generation, rural development, rancher/coop coordination

Introduction

The geothermal project at Paisley, Oregon is a unique project where a rural electric utility and a local rancher have worked together to develop geothermal power. The Paisley Surprise Valley Electrification Corporation (SVE) geothermal project started with discussions between the rural electric cooperative and the rancher, who had a well that was flowing over 1000 GPM at a temperature of 239°F (115°C). This well was used for irrigation only after discharge into a large pond to allow the water to cool before applying to crops. The Paisley Geothermal project is located in south central Oregon 300 miles southwest of Portland, Oregon and 140 miles west of Klamath Falls, Oregon. (See Figure 1.)

Rural electric cooperatives were formed in the early 1900s and have played a major role in bringing electrical power to rural America. They are now poised to play a major role in developing small geothermal resources scattered throughout their service territories. These power distribution systems built and operated by the rural electric cooperatives serve many small communities and reach rural areas where substantial geothermal resources exist. (See Figure 2.) In fact many ranchers throughout the West have inadvertently tapped into hot water during development of ground water for irrigation purposes. The rural electric cooperatives supply power to those same ranches, which have hot wells and/or geothermal potential beneath their lands. These ranchers are members of the rural electric cooperative and therefore make logical partners to develop the resource for local use.

The development of small modular low temperature geothermal power systems within the last few years has opened a large potential market. A little over a decade ago, geothermal power development was only viable for geothermal resources with temperatures of 300°F (149°C) or above. Newer binary systems are now allowing development of geothermal resources between 200° to 300°F (93-149°C). Chena Hot Springs Resort near Fairbanks, Alaska is producing electrical energy with a geothermal resource temperature of 165°F (74°C) and cooling water at an average of 37°F (3°C). Other systems, such as one in Klamath Falls at the Oregon Institute of Technology, are producing power at temperatures below 250°F (121°C).

Rural electric cooperatives have recently become very interested in this low temperature binary power production for several

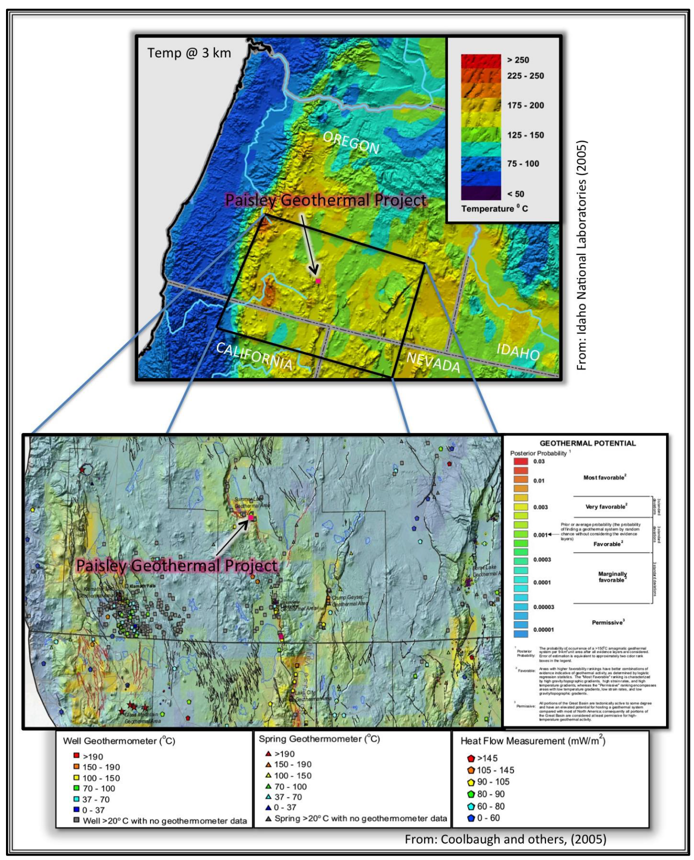


Figure 1. Location Map of the Paisley Oregon Geothermal Project owned by Surprise Valley Electrification Cooperative, Alturas California.

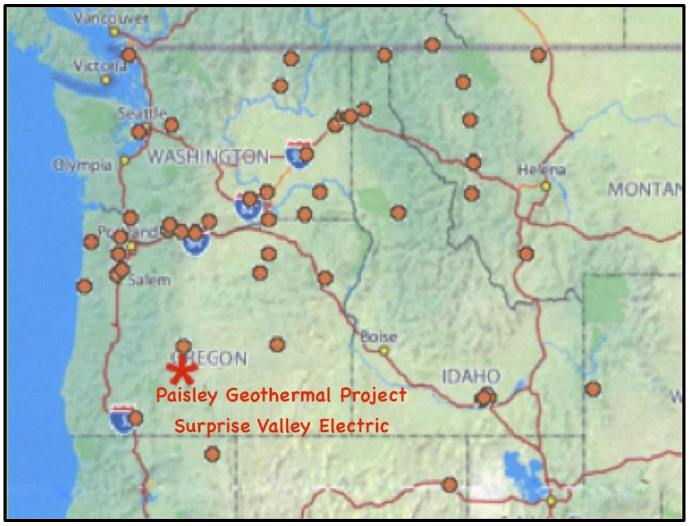


Figure 2. Map of Electrical Cooperatives in the Pacific Northwest United States.

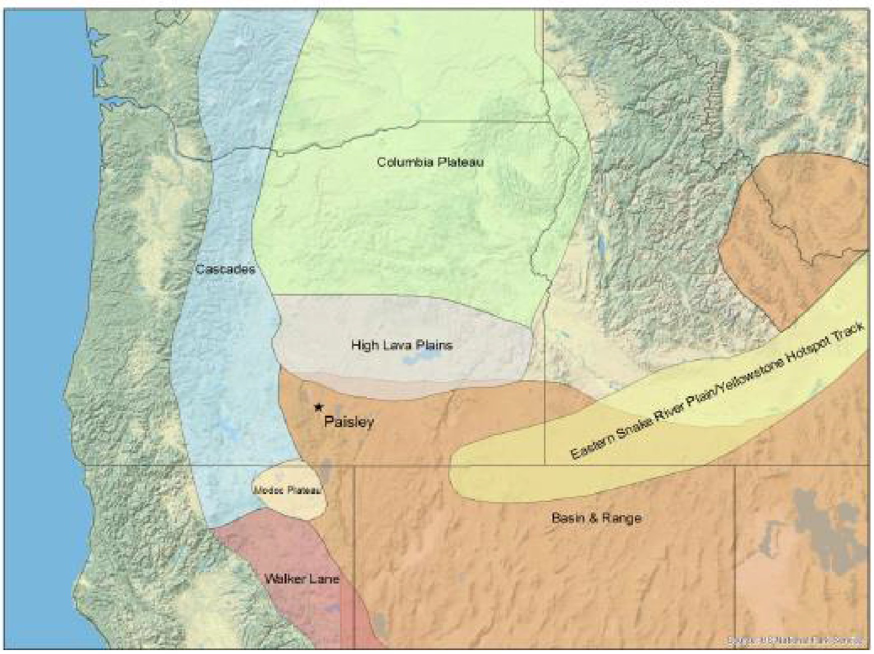
reasons. First, it is a base-load renewable energy with a very high on-line efficiency of above 90 percent without the issues of intermittent and unpredictable on-line power such as wind and solar. Second, the generation technology is in modular form. This makes installation easy and allows the ability to tie into their grid without major transmission upgrades. The modules of from 30 kW to 5 Mw size are often at remote locations at the end of the rural electric cooperatives' lines. Base load power in these locations serves their grid well by reducing the potential power outages at remote locations in their service system. As a result of technology built into their systems, modern modular power systems are also easier to operate and maintain, thus allowing the rural electric cooperative to function with local experienced staff.

The Paisley Geothermal project was first initiated through a feasibility study funded jointly by USDA and the local rancher. This study conducted preliminary resource and economic investigation to determine the technical and economic feasibility of developing electrical power from a hot well on the ranch property. Through this effort, Colahan Ranches teamed with Surprise Valley Electric to apply for a DOE grant though the Government Economic Recovery Investment Act Funds. That funding along with an Oregon Business Energy Tax Credit allowed for more detailed geotechnical resource definition and engineering studies with a goal of developing the geothermal resource.

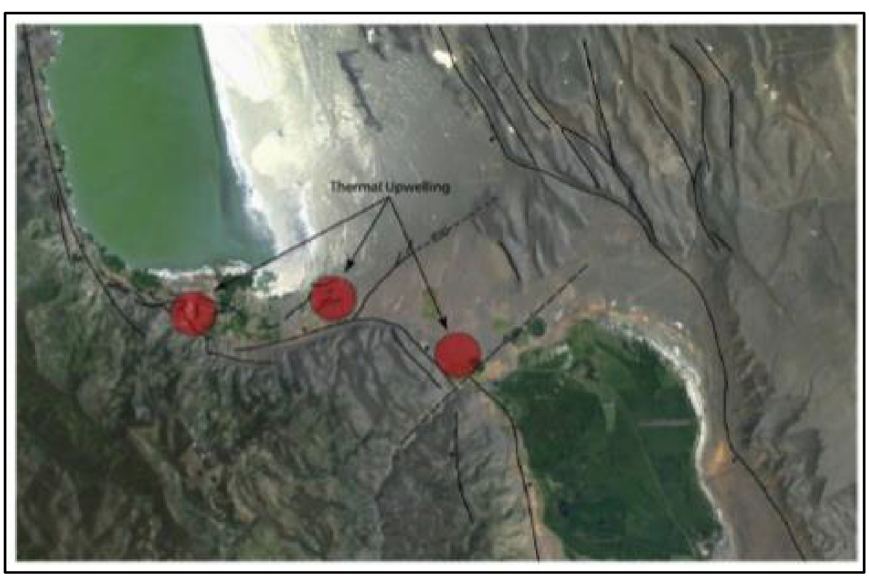
Geologic Setting

Paisley, Oregon is located in the northwest portion of the Basin and Range Geology Province with the Cascade Province to the west and Columbia Plateau Province to the north. (See Figure 3.) High regional heat flow of the North Basin and Range is the major reason for a large number of geothermal resources identified in the area. Regional extension causing thinning of the upper crust bringing the asthenosphere nearer the surface creates the elevated gradient. (Blackwell 1983, Makowsky 2013)

As with the Paisley geothermal system, faults and fractures created by the basin and range extension provide the permeable pathways for deeper thermal water to occur at economic developable depth. Bennett (2011) described the relationship of extensions and relevant seismicity to active geothermal potential of transtensional plate boundaries.



↑ **Figure 3.** Physiographic Provinces.



← **Figure 4.** Map of the Paisley Transfer zone. Red circles indicate areas of thermal water upwelling.

Intersection of regional faults occurring in southeast Oregon which intersect in the Paisley area, are important factors in understanding the existence of a geothermal resource. The Paisley transfer zone connects two *en-echelon* normal faults to the west of Summer Lake, and Paisley is thought to control the regional thermal fluid flow. (See Figure 4.) (Makowsky 2013, Pezzopane and Weldon 1993)

A gravity survey conducted in the Paisley area indicated a well-defined density contrast coinciding with a fault mapped during the geologic mapping. Lithologic sampling during drilling of the production wells indicated alluvial/colluvial deposits of brown sand, gravel, and cobbles to a depth of 400 feet (122 meters). Between 400 and 540 feet (122 and 165 meters), a decrease in sand and silt was noted with more embedded clay and ash layers. An increase in clast size to more abundant gravel and boulders was evident from 540 to 680 feet (165 to 207 meters). Bedrock consisting of fractured basalt inter-bedded with cinders was found from 680 to 905 feet (207 to 276 meters). The basalt in this interval was highly altered containing euhedral quartz, calcite, and pyrite. An increase of cinders was evident from 905 to 1030 feet (276 to 314 meters) with altered ash beds more dominant below 1030 feet (314 meters). (See Figure 5A and 5B.) (Makowsky 2013, Pezzopane, 2014)

The conceptual geologic model of the Paisley geothermal system places a NW trending range bounding fault as the mechanism producing permeability for upwelling geothermal fluids. This system is considered to be typical of the extension basin and range geothermal system with minimal to no influence from an active magmatic system. The controlling fault system dips at approximately 65° northeast and is the structure protracted by the two production wells drilled by Surprise Valley Electric. (See Figure 6.) (Pezzopane 1993)

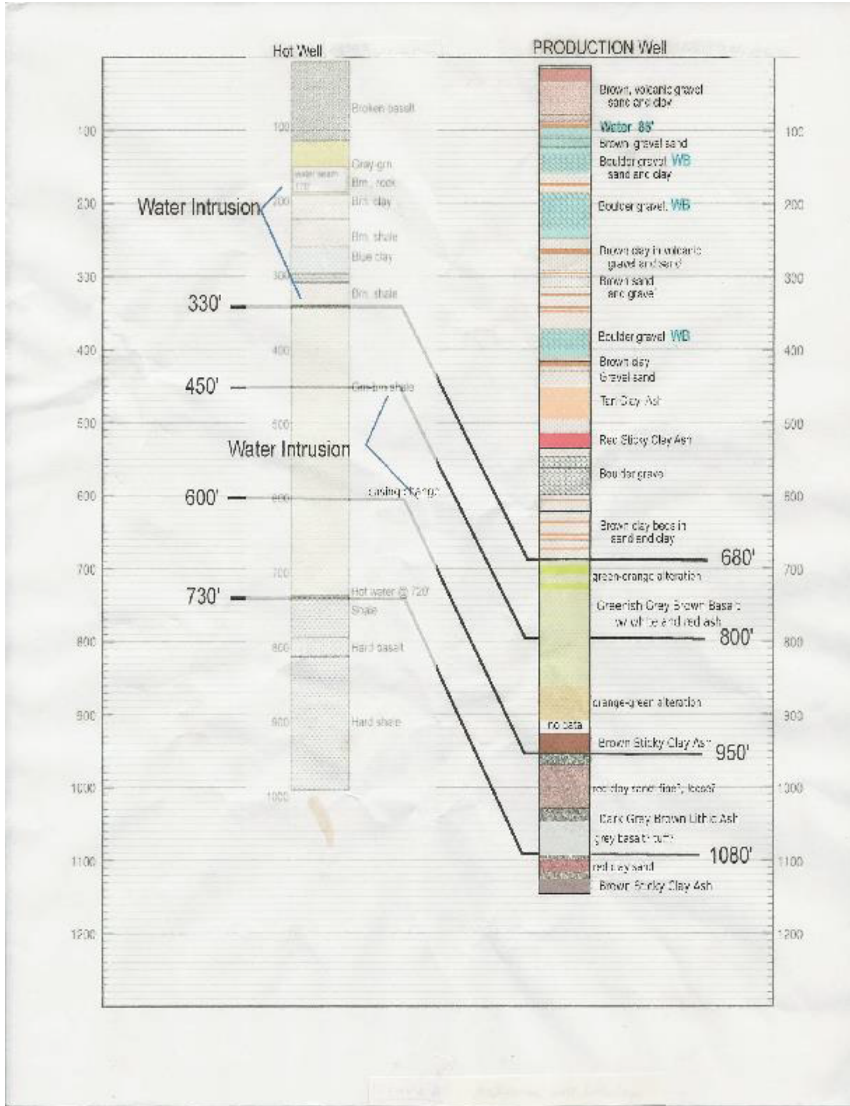


Figure 5A. SVE-1 Production Well and original Hot Well Lithology.

Geochemistry

Water chemistry of the thermal water in the Paisley area indicates there is mixing of thermal waters and shallow ground water in the area. The geo-thermal fluid is acid sulfate-type water and non-thermal waters in the area are carbonate-type water. Stable isotopes data indicate the thermal water is isotopically distinct from the shallow ground water. Thermal wells (SVE 1, 2, 3) appear to originate from the same source and appear to be a mix of meteoric water and andesitic brines. The fluid from the geothermal reservoir is relatively benign chemically when compared to other geothermal systems worldwide. Geo-thermometers indicate the reservoir has a maximum temperature of 320°F (160°C). Geo-thermometers applied to thermal waters in the Paisley area range from 203°F to 331°F (95° to 166°C) with the SVE production well geo-thermometers calculating reservoir temperature of 241 - 304°F (116 - 151°C). Production fluid from the wells of the Surprise Valley Electric project are at a temperature of 232°F (111°C). (Makowsky 2013 and Geologica 2013)

Figure 5B. Photograph of rock sample from Paisley production well SVE-1 at a depth of approximately 1100 feet. (Blue squares are 1/4 inch.)

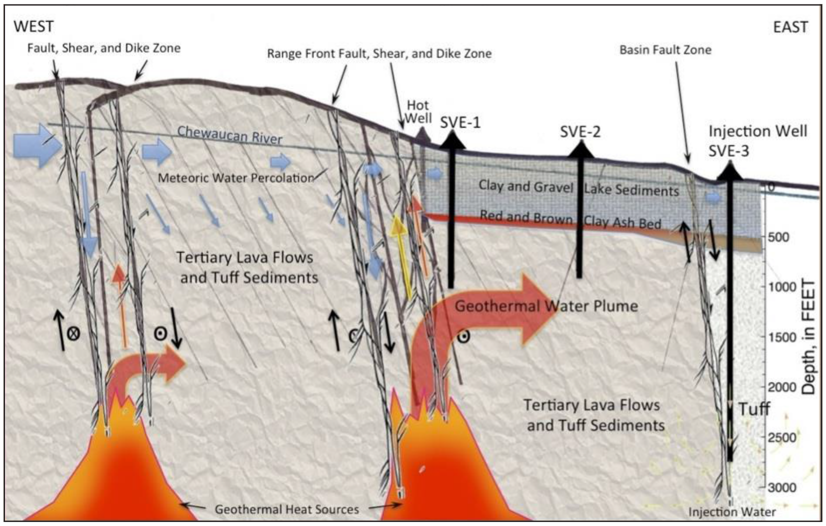


Figure 6. Conceptual model of the geothermal reservoir west of Paisley.

Location of the SVE Geothermal Wells and Paisley Power Plant

Figure 7. Vertical image showing location of Paisley geothermal wells, power plant, and pipelines.

Reservoir Evaluation

Initial geo-technical studies identified faulting and fracturing which appeared to control the geothermal fluids. Two production wells were drilled into the fracture zones at depths of 1360 feet and 1260 feet (415 meters and 384 meters) respectively. (See Figure 7.) The SVEC wells and reservoirs were evaluated by conducting a ten-day interference test. Wells SVE-1 and SVE-2 are designed to be production wells delivering 3000gpm to a 3.1 MWe power plant with the spent fluid being injected into SVE-3. Testing of the production and injection wells also involved monitoring four additional shallower wells to determine potential interference. The results of the testing indicated interference between the three production wells SVE-1, SVE-2, and SVE-3 but very limited to non-detectable interference with the shallower wells developed in the upper alluvial system. The results of the reservoir testing indicated the reservoir system supplying fluid to the SVE project had transmissivity values of 1860 darcy-ft which when compared to the worldwide geothermal fields of 100 to 300 darcy-ft, indicated a highly productive system. No boundaries were detected during the testing period. The testing data indicated the system should not have any limitations on production given the rates of 3000 gpm from wells SVE-1 and SVE-2. Those two wells will provide the hot resource needed for the 3.1 MWe power plant. Well SVE-3 will be used as the injection well and should take the total flow from the power plant without additional injection pressure. (Geologica, 2013)

Plant Development

The Surprise Valley Electric Paisley Geothermal power plant is a 3.1 MWe gross (2.4 MWe net) binary power plant constructed by Turbine Air Systems in Houston, Texas. The TAS power plant is a binary unit utilizing R134a as the working fluid. (See Figure 8.) The working fluid is cooled with water through six flow units on the cooling tower. Approximately 2134 meters of pipe is used for the geothermal gathering and injection system. A 1.6 kilometer 69 KV transmission line and a 10 MWe substation was designed and installed connecting the generation from the new geothermal plant with SVE's 69 KV grid.

One of the major issues is the cooling water system. The cooling system for the geothermal power plant requires a flow of 12,000 gpm with expected make-up water of 300 gpm for evaporative loss from the cooling towers and blow down of the makeup water.

Original discussions thought the geothermal brine might be of sufficient quality to be used for the cooling water, but subsequent

Figure 8. Photograph of the Paisley Power Plant generator, turbine, heat exchanger, and condenser piping.

analyses indicated the dissolved solids in the brine could cause problems with the cooling system. As a result, an existing well on the ranch was investigated as a possible source of cooling water. The well however, did not produce the needed volume, so an application for a new well was requested of the State of Oregon. Issues were varied concerning more production that might cause interference with older water rights from the Chewaucan River. To insure no interference as determined from ground water modeling, a new well for the make-up cooling water would have to be at least a mile from the river. Consequently, a drill site was identified more than a mile from the point of interference on the river. However, the State of Oregon would issue only a limited license for 229 gpm of water from this new well. Testing of the newly drilled well proved the yield to be very inadequate at only 70 gpm. SVE requested use of the existing well in conjunction with the new well to obtain the needed volume. The State of Oregon issued a second limited license on the existing well for 146 gpm. The volume from the two wells is about 80 gpm short of the total volume needed during peak use. Spent brine in volumes from 10-80 gpm will be used to make up this short fall until another water source can be developed. Discussions are ongoing with the State of Oregon concerning development of additional sources to insure adequate make-up water for the cooling system.

Summary

The project at Paisley, Oregon is a good example of a rural power development project that has involved the local rural electric cooperative teaming together with a local rancher to develop geothermal energy.

Surprise Valley Electric is a small rural electric cooperative that has gone into uncharted activities to develop a renewable energy resource. The project has provided an economic boost to the rural city of Paisley, population 240, and the surrounding area with less than one person per square mile. Development crews included as many as 30 workers on site at any one time. Many of the crews have stayed in Paisley, Lakeview, and Summer Lake bringing business to motels, restaurants, gas stations and grocery stores. Local contractors, welders, engineers, parts stores and equipment operators have been utilized, as well as regional contractors from Klamath Falls, Redmond, and Bend, Oregon; Fallon and Reno, Nevada; and Chico, California.

The small binary geothermal systems have several benefits. They are base-load power with high 95 percent efficiency ideally suited for rural distributed energy systems. They are modular allowing more rapid and less risky development and better able to be sized to the resource and distributed power systems. Operation and maintenance can be conducted with local trained personnel. This has resulted in many local jobs with companies and contractors.

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