Evaluation of Geothermal Potential of Lightning Dock KGRA, New Mexico

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ABSTRACT

Lightning Dock currently houses the largest geothermal greenhouse complex in the United States, one of the largest aquaculture farms, and a binary geothermal power plant. With the addition of Cyrq Energy's (formerly Raser Techonologies) 10MW geothermal power plant, it will be the most utilized geothermal resource in New Mexico. This paper presents an evaluation of the geothermal potential of the Lightning Dock area. The evaluation was performed by examining the following attributes: physiography, geology, tectonics and structure, water resources, infrastructure, population and target markets, other geothermal considerations, and economic considerations and available incentives. This was accomplished by using a combination of literature reviews and data analyses in conjunction with the interpretation of information obtained from digitized map layers created in ArcGIS®.

The evaluation indicates that the Lightning Dock area has high geothermal potential without requiring significant infrastructure additions or upgrades. Using the reported heat flow of 650 mW/m^2 (Cunniff and Bowers, 2005) it is estimated that the 90ºC and 180ºC isotherms will be reached at depths of 0.3 km (984 ft) and 0.7 km (2,165 ft) respectively. Hence, various applications including direct use and electricity production using binary power plant technology are viable in the area.

Introduction

The Lightning Dock known geothermal resource area (KGRA) is located in the Animas Valley in western Hidalgo County of New Mexico (Fig.1). The area is bordered by the Pyramid and Animas Mountains on the east and the Peloncillo Mountains on the west (Fig. 2). Since its discovery in 1948 (Summers, 1976) the resource has been used for greenhouse heating, aquaculture, and electric power production.

The Burgett geothermal greenhouses, the largest geothermally heated greenhouse complex in the U.S., have been in operation since 1977. This facility covers 426,700 m^2 (32 acres) and uses geothermal water with temperatures of 104 to 113ºC (220 to 235ºF) at a maximum flow rate of 126 liters per second (l/s) (2,000gallons per minute (gpm)). The complex uses 53,900 MW (184 billion Btu) of geothermal energy annually which amounts to cost savings of about $736,000, as compared to using propane (Witcher et al., 2002). In addition, Two PureCycle model 280 systems were installed in the complex in July 2008. These units use the geothermal water at 107ºC (225ºF) to produce more than 500 kW which is consumed on site for the greenhouse and facility operations.

Americulture owns and operates an aquaculture complex which uses geothermal heating to produce between four to seven million fish annually. This facility uses a down hole heat exchanger to circulate 6.3 l/s (100 gpm) of "cold water" through the 122 m (399 ft) well, which has an average temperature of 110ºC (230°F). This results in an annual energy use of 3220 MW (11 billion Btu) (Witcher et al., 2002).

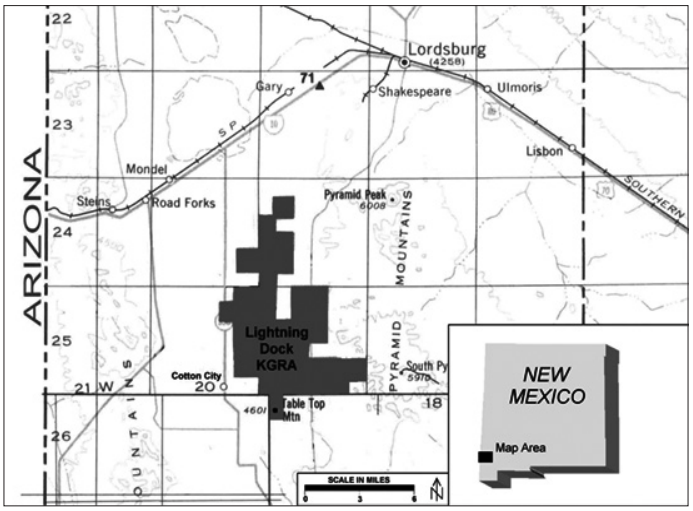

Figure 1. Location of Lightning Dock KGRA (from Cunniff and Bowers, 2005).

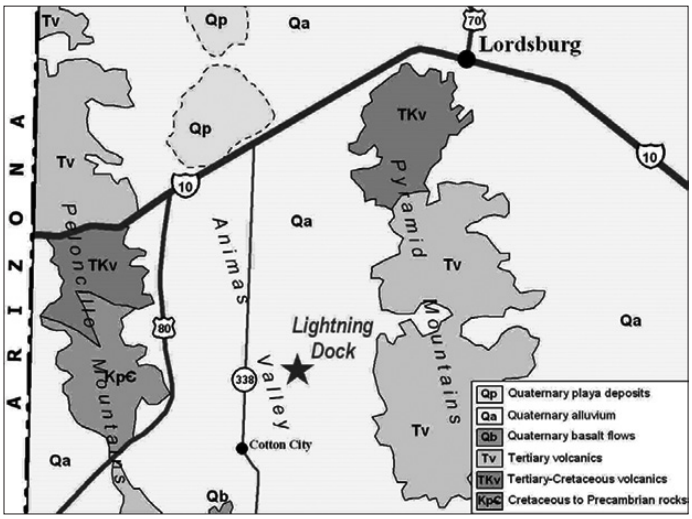

Figure 2. Map showing Animas Valley (from Elston et al., 1983).

In May 2012, Public Service Co. of New Mexico announced its intention to enter into a 20 year Power Purchase agreement with Cryq Energy (formerly Raser Technologies)for the 10 MW Lightning Dock Geothermal Power plant which is currently undergoing well field development and that is expected to be operational by January of 2014 (Geothermal Resource Council, 2012)

Physiography

The elevation of the area is approximately 1,402 m (4,600 ft) above sea level (Lienau, 1990). Data from the Western Regional Climate Center indicates that the average temperature in the Lightning Dock KGRA area varies from 14.6ºC (58.3ºF) to -2.8ºC (27ºF) in the month of January and 34.9ºC (94.8ºF) to 17.7ºC (63.8ºF) in the month of July. The average annual temperature is 15.8ºC (60.5ºF). The average annual precipitation in the area is 27.7 cm (10.9 in.).

Geology

The Lightning Dock KGRA is located in the Animas Valley which ranges in a width from 11 to 21 km (7 to 13 miles) and has a length of about 145 km (90 miles). The geothermal area lies at the foot of the Pyramid Mountains which border the Animas Valley in the east (Schochet and Cunniff, 2001). North trending Basin and Range features and a caldera ring fracture zone are the primary structures of the area. Because of the presence of small volcanic hills on the valley floor and based on the results of extensive drilling, Schochet and Cunniff (2001) conclude that the valley fill is relatively thin and mention that the "Quaternary sediments consist of alluvial fans and pediment deposits, fluvial deposits, and modern eolian and sheetwash deposits."

Elston et al. (1983) mention that during late Pleistocene and Holocene times the Animas Basin was occupied by Lake Animas, which left lacustrine deposits and shoreline features. The exposed rocks found in the bordering mountains are Precambrian granodiorite, Paleozoic and Mesozoic sedimentary rocks, Tertiary/Cretaceous volcanic rocks, Tertiary intrusive rocks, Tertiary conglomerate, Quaternary/Tertiary basalt flows, and Quaternary conglomerate (Schochet and Cunniff, 2001; O'Brien and Stone, 1984). The Pyramid Mountains form the Muir Cauldron, a complex volcanic sequence and contain rocks that are mostly Cretaceous in age or younger.

Using gravity and magnetic data, Blackwell and Wisian (2001) developed a model of the Lightning Dock KGRA. The authors observed the high north-south magnetic and gravity anomalies near the Burgett green house complex where Paleozoic sedimentary rock underlies volcanic rock. This layered structure reaches a low point at the west side of the Lightning Dock where the limestone has a modeled depth of about 1.7 km (1.1 miles).

Tectonics and Structure

Three major regional tectonic features, a mid-Tertiary caldera ring fracture zone, a major basement structure zone, and a young incipient normal fault tip, enclose the Lightning Dock geothermal system. The upflow zone is believed to be due to the intrusion of the mid-Tertiary caldera ring fracture in the horst block of the normal fault system (Witcher et al., 2002).

Elston et al. (1983) report that the Animas Valley fault (AVF) has a surface expression with the presence of a northeasterly trending fault zone and the ring-fracture zone of the Muir cauldron. Using gravity data, Schochet and Cunniff (2001) concluded that the upper Animas Valley was displaced and rotated by the major fault which strikes roughly southwest to northeast. Using the residual gravity pattern, Blackwell and Wisian (2002) identified the horst block on the pre-valley fill units and estimated that it is 2 km (1.2 miles) wide (Fig. 3). They also concluded that the westward fault is the major horst bounding structure while the Animas Valley fault passes through the middle of the horst and with the volcanic layer thinning on the west side of well 55-7(star in Fig.3). Moreover, Blackwell and Wisian (2002) predicted that the uplift in the basement of Animas Valley is due to faults bounding both sides and that the mapped Animas Valley Fault (AVF), which runs through the previously mentioned horst does not bound the west side of the uplift. Instead, a different fault bounds the west side of the uplift and an unmapped fault bounds the east side of the uplift. Both of these faults appear to converge on the north side of well 55-7.

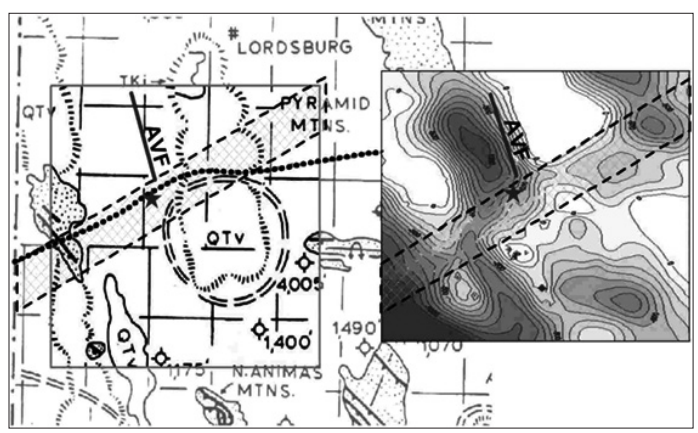

Figure 3. Integrated Regional Geology with depth to basement map generated from gravity inversion (from Cunniff and Bowers, 2005).

Geothermal

In a study conducted by Lightning Dock Geothermal Inc. (Cunniff and Bowers, 2005), the rocks found in a recent temperature gradient hole were predominantly lakebed sediments deposited in the Pleistocene to Recent Lake Animas. Unconsolidated sand and gravel beds, reported to be about two feet thick, were interbedded with thin layers of greenish clay. Witcher et al. (2002) reported that the total natural heat loss for the geothermal system at Lightning Dock is less than 10MWt.

Elston et al. (1983) mention that hydrothermal alteration in the Lightning Dock KGRA occurred during the collapse of the Muir cauldron in Oligocene time and during the activity of Miocene or younger hot springs and shallow vein-forming hydrothermal fluids. From their model, the authors conclude that the deep geothermal reservoir is located in fractured volcanic rocks at a depth of approximately 1.5 km (0.9 miles). They add that the northeast trending high-angle fault system intersects this reservoir. Small volumes of hot water rise through this northeast trending fault and leak into shallow aquifers near the surface. Because of the formation of highly permeable conduits in the area where a northeast trending fault intersects the Muir cauldron ring-fracture zone and a basin and range fault, large volumes of water move up into a mixing zone. In this zone, the authors postulate that water at 250°C (482°F) mixes with the cold ground water in one to three ratios to produce mixed water at 150–170°C (302-338°F). The Riedel shear zone structurally controls the rise of this mixed water towards the aquifer located near the surface (Elston et al., 1983; Cunniff and Bowers, 2005).

Dismissing the assumption that the thermal anomaly at the Lightning Dock geothermal resource is a point source upwelling along a single fault, Cunniff and Bowers (2005), suggested that the reservoir is "either a pervasively fractured zone or a series of small faults and shears in the shallow volcanic rocks and deeper sedimentary rocks, created by the relative recent possible lateral offset of the AVF resulting from strong tectonic extension forces. "Furthermore, Cunniff and Bowers (2005) observed the depth to Precambrian bedrock to be 2.5 km (1.6 miles) and the depth interval had a measured average temperature of 145°C (293°F). They also calculated the heat flow around the area to be about 650 mW/m^2 (15.5 HFU). Based on this heat flow value and an annual surface temperature of 15.8°C (60.5°F), the 90°C isotherm would be encountered at a depth of approximately 0.3 km (984 ft) and the 180°C isotherm would be reached at a depth of approximately 0.7 km (2,165 ft).

Water Resources

Geothermal waters at Lightning Dock contain sodium sulfate and carbonate with TDS values around 1,100 mg/L and no detectable arsenic (Witcher et al., 2002). Very low concentrations of carbon dioxide and hydrogen sulfide have also been reported in the thermal waters. The transmissivity of the geothermal reservoir is more than 25,000 gpd/ft. Due to the relatively low elevation of the resource, it is in a favorable location for forced or advective discharge of fluid and heat from a regional bedrock groundwater flow system and the combination of Cretaceous and Tertiary uplift has facilitated non-deposition or erosional stripping of regional aquitards to create a local "geohydrologic discharge window" (Witcher et al., 2002). This system is recharged from the surrounding higher terrains, mountains and valley. Oxygen isotope analysis on the geothermal waters indicates that that recharge occurs relatively quickly with an estimated age of the water from Pleistocene to Recent (Elston, 1983).

Witcher et al. (2002, p. 38), report that "All currently producing geothermal wells at Lightning Dock area are between 107 to 183 m (350 to 600 ft) depth, and produce from the shallow outflow plume reservoir. Well production ranges from a few hundred gpm to 1,200 gpm (76 liters/s), typically at 99 to 113°C (210 to 235°F)."

The Lightning Dock KGRA does not have an abundance of surface water resources. Lack of permanent streams and the low average annual precipitation (27.7 cm (10.9 inches)) makes groundwater the primary source for irrigation and domestic needs. The groundwater for irrigation is obtained from saturated sand and gravel beds at depths ranging from 4.6 m (15 feet)in the north to 61 m (200 feet)in the south. Piezometric data indicates that the groundwater moves north towards the Gila River. The groundwater of the Animas Valley was designated as a groundwater basin and was closed for further appropriation in 1948. The average transmissivityof the aquifer is about 50,000 gpd/ft with the coefficient of storage at about 0.10 (Reeder, 1957).

The water at the hot wells in the Lightning Dock KGRA is considered to be mixed water containing approximately 25% of deep geothermal fluid at around 250°C (482°F) (Elston et al., 1983). As mentioned before, and as shown on Figure 4, the mixed water ascends in the area of the hot wells and then cools as it disperses in the aquifer, mainly to the north-northwest and to the southwest (Schochet and Cunniff 2001).

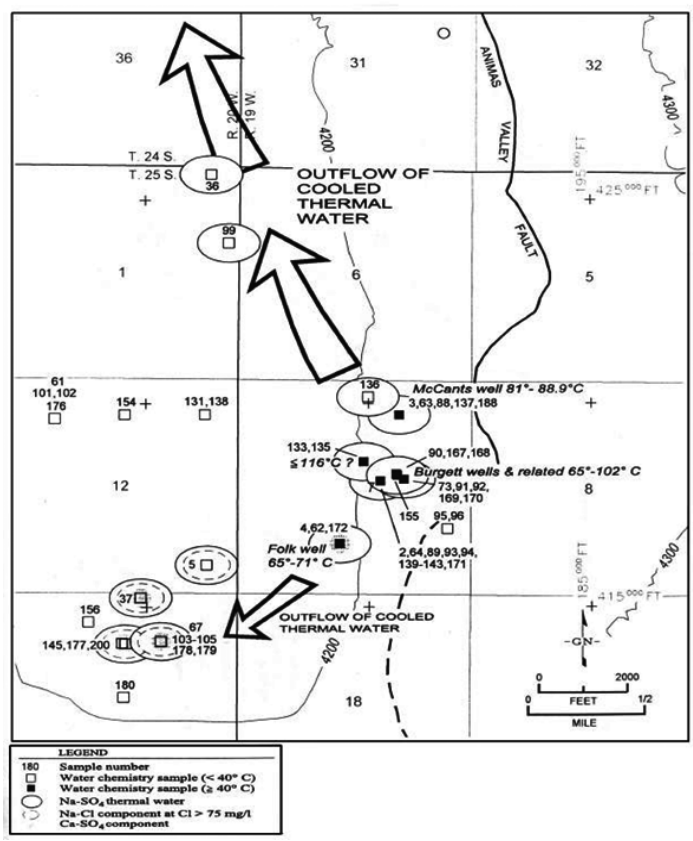

Figure 4. Flow pattern of geothermal water (from Klein, 2001).

Rain water that falls within the drainage area of Animas Valley is the ultimate source of recharge for the groundwater aquifer; however due to the high average annual temperature and low precipitation, only a fraction of rain water actually penetrates into the groundwater body (Reeder, 1957). Although the groundwater has been used extensively for agricultural and domestic purposes, there is no indication that the volume of the groundwaterbody has decreased. As reported by Schochet and Cunniff (2001), the water level at the hot wells was at a depth of about 21 m (70 feet), which had been maintained for about 10 years (Schochet and Cunniff, 2001).

Infrastructure

Lightning Dock is located in western Hidalgo County of New Mexico. New Mexico Highway 338 connects Lightning Dock with U.S Interstate I-10, which is located 23 km (14 miles) north. U.S. Interstate I-10 provides access to Las Cruces, located 193 km (120 miles) to the East; Tucson, 257 km (160 miles)to the west; and El Paso, 266 km (165 miles) to the southeast. The only available transmission line near the Lightning Dock area is a 69kV line which is owned and maintained by Columbus Electric Cooperative who currently provides the electrical service to the area. New transmission lines must be created in order to utilize the full electrical production potential of the Lightning Dock KGRA. However, the development of 10 MW geothermal power plant by Cyrq Energy may strengthen the available infrastructure, thus, eliminating the need of additional significant upgrades. Figure 5 shows the available roads and transmission lines around Lightning Dock KGRA.

Assessment and Conclusions

Geothermal resources in the Lightning Dock KGRA have long been used on a commercial scale. This area houses the largest greenhouse complex and one of the largest aquaculture farms in the U.S. Although previous attempts at producing electric power had failed, the recent developments in geothermal technology have allowed the installation of two binary power plants, which produce more than 500 kW of electric power at the Burgett greenhouse. Cyrq Energy is planning to install a binary power plant using 140 – 154°C (284–309°F) water. Upon completion, this power plant is expected to produce 10 MW of electric power.

A 2005 study by Cunniff and Bowers has shown that the geothermal reservoir extends deep to the southwest of the Lightning Dock KGRA. This area should be explored and studied as a potential site capable of producing electric power.

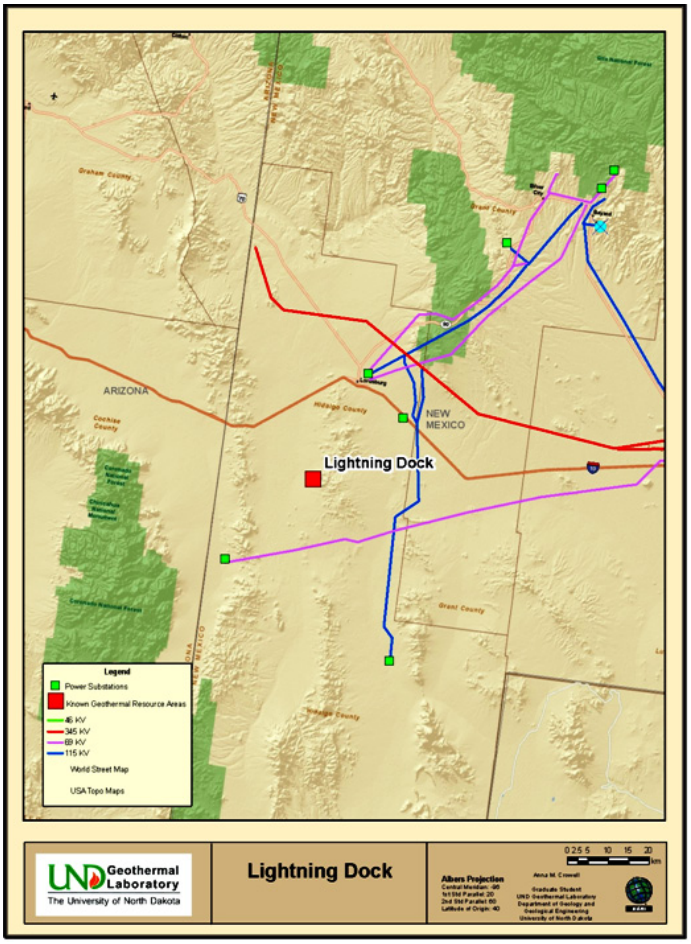

Figure 5. Infrastructure in the Lightning Dock area.

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