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Olene Gap Resource Assessment Case Study

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ABSTRACT

At Olene Gap, a nominal 10 MWe geothermal power project is planned. Preliminary engineering indicates that 10 MWe could be generated with 5000 gpm of geothermal brine at 265 deg F. There is a known shallow hydrothermal geothermal system in the Olene Gap area (at depths of 420 to 550 feet). In 2011, Kodali drilled the first deeper well in the area (well OG-1) to a total depth of 3775 feet. A highly productive 265 deg F hydrothermal resource was encountered at a depth of 2400 to 2450 feet. Analysis of well test data indicates that resource conditions at the OG-1 location could provide 2800 gpm of pumped production at approximately 265 deg F.

Well OG-1 was drilled to 3775 feet, however, permits allow an additional drilling of 700 feet to a total depth of 4500 feet. Static temperature surveys show a temperature gradient that suggests temperatures at 4500 feet could be as high as 310 deg F. While this temperature and the coexistence of permeability are not yet proven, they provide a possible upside to the 10 MWe initial project. The planned project of 10 MWe with 5000 gpm of pumped production at 265 deg F is within P90 for both reserves and measured permeability, with currently available information, the resource potential is statistically most likely (P50) at 22 MWe, and the minimum likely resource (P90) is 12 MWe.

1. Introduction

A preliminary reserves assessment of Olene Gap was completed using all available reports (which pre-date the drilling of well OG-1) and data supplied to Geothermal Science, Inc. (GSI). This resource size estimate was later revised higher, considering the successful deep production well. Data provided were two reports describing geothermal resources in the area, two well completion reports for nearby wells, and well test data from OG-1. Based on Monte Carlo reserves estimation, with currently available information, the resource potential is statistically most likely (P50) at 22 MWe, and the minimum likely resource (P90) is 12 MWe.

The Olene Gap area has been the subject of much research, study, and data gathering in the past approximately 30 years. GSI has been supplied with several reports. A 1978 study of these area by the Geo-Heat Utilization Center of Oregon Institute of Technology (OIT) (Lund, 1978) included a discussion of the geothermal potential of the Olene Gap area.

To summarize the findings, a review of the geology, surface, and subsurface temperatures indicated that the highest potential for geothermal fluids is in the Olene Gap area. The hot springs there were measured for temperature and flow while the Lost River was at its lowest level and most of the spring orifices were exposed in the river bed. Temperatures measured ranged from 70 to 81 deg C (158 to 178 deg F) at six separate spring vents on the south bank of the river, south of the bridge, and the largest spring in the concrete culvert north of the flume on the north bank of the river had the highest temperature at 87 deg C (189 deg F). A traverse of the north shore of the river shows several areas of warm ground between the bridge and the flume. The total volume of water flowing from the springs at Olene Gap was estimated to be from 30 to 50 gal/min. Water well projected thermal gradients both east and southwest of the gap indicate that the geothermal anomaly extends some distance to the east and to the south.

Figures 1 and 2 illustrate the location of the significant geothermal resource area at Olene Gap, and well locations. Before recent drilling, there were existing data on 26 test wells in the study area vicinity. The 1978 study by OIT (Lund 1978) examined existing well and indicated "high potential" areas (those that exhibited a greater than average potential for 50 to 100 deg C (122 to 212 deg F) water at depths of 500 to 1,000 meters).

The resource at Olene Gap is a liquid-dominated hydrothermal resource. Completion reports from two shallow existing wells in the area (Jones-1 and Jones-2) show a shallow hydrothermal resource. These wells were drilled in the late-1970s to depths between 420 and 550 feet. These wells encountered hot water with temperatures in the range of 160 to 182 deg F. Current plans are to drill two production wells to depths up to 3500 feet, and a hotter hydrothermal resource is anticipated, but not yet proven by drilling. The first deep well is currently being drilled and the operator expects resource temperatures in the range of 270 to 300 deg F. This temperature of resource, combined with high permeability would be a commercial grade hydrothermal resource.

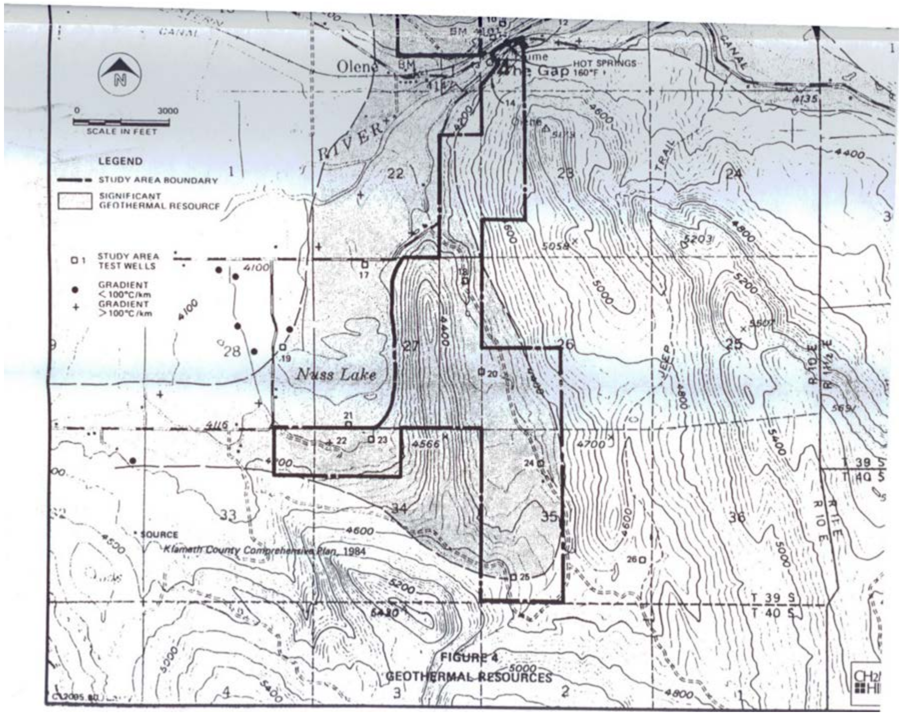


Figure 1: The Olene Gap Resource Area

Figure 2: Map showing location of well OG1 and OG2 in relation to existing wells Jones-1 and Jones-2 that showed shallow geothermal resource

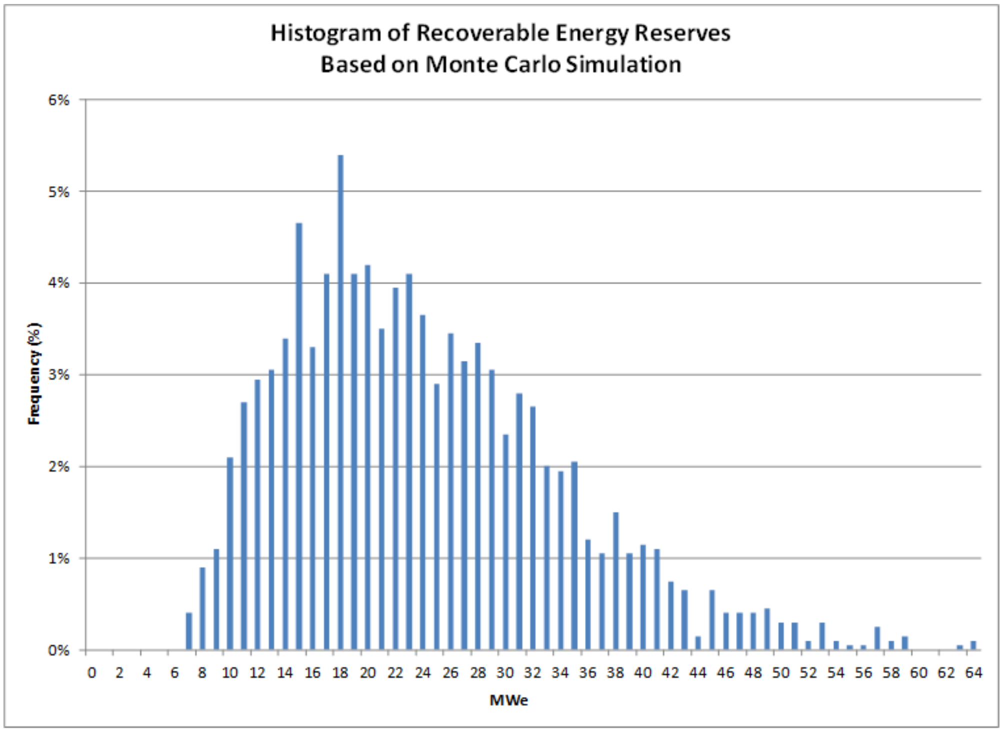
2. Reserves Estimate

The USGS made an estimate of the potential size of the shallow geothermal system at Olene Gap (Reed 1982). It was estimated that the shallow resource (140 deg F) covers 12 square miles. To estimate the potential of the deeper resource, Monte Carlo simulation was used. The calculation method used was the technique described in USGS Circular 790 (Muffler 1979). It was assumed that the deep resource has a temperature between 270 and 310 deg F, and covers an area in the range of 4 to 12 square mile (see Figure 3 for listing of input parameters, and Figure 4 for presentation of output parameters).

- Using the input parameters in Figure 3, the Monte Caro simulation indicates a most likely (P50) resource size of 22 MWe, with a minimum resource size (P90) of 12 MWe. As drilling continues it is likely that additional data will be considered.

English Units					
Parameters	**Best Guess (Mode)**	**Units**	**Probability Distribution (Type)**	**Minimum Value**	**Maximum Value**
Monte Carlo Sampling	*2000*	*NA*	Fixed		
Injection Temperature	100	deg °F	Single Valued		
Ambient Temperature	50	deg °F	Single Valued		
Total Project Life	30	*Years*	Single Valued		
Plant Capacity Factor	0.9	*fraction*	Single Valued		
Reservoir Area	8	miles^2	Triangular	4	12
Reservoir Thickness	1100	feet	Triangular	600	1600
Porosity	0.06	*fraction*	Triangular	0.03	0.07
Reservoir Volumetric Specific Heat	39.5	BTU/ft^3 deg °F	Constant	37	42
Average Reservoir Temperature	290	deg °F	Triangular	270	310
Fractional Reservoir Volume Containing a Steam Zone	0	*fraction*	Single Valued		
Average Steam Saturation in the Steam Zone	0	*saturation*	Single Valued		
Heat Recovery Factor	0.2	*fraction*	Constant	0.1	0.3

Figure 3: Input parameters for Monte Carlo reserves estimation



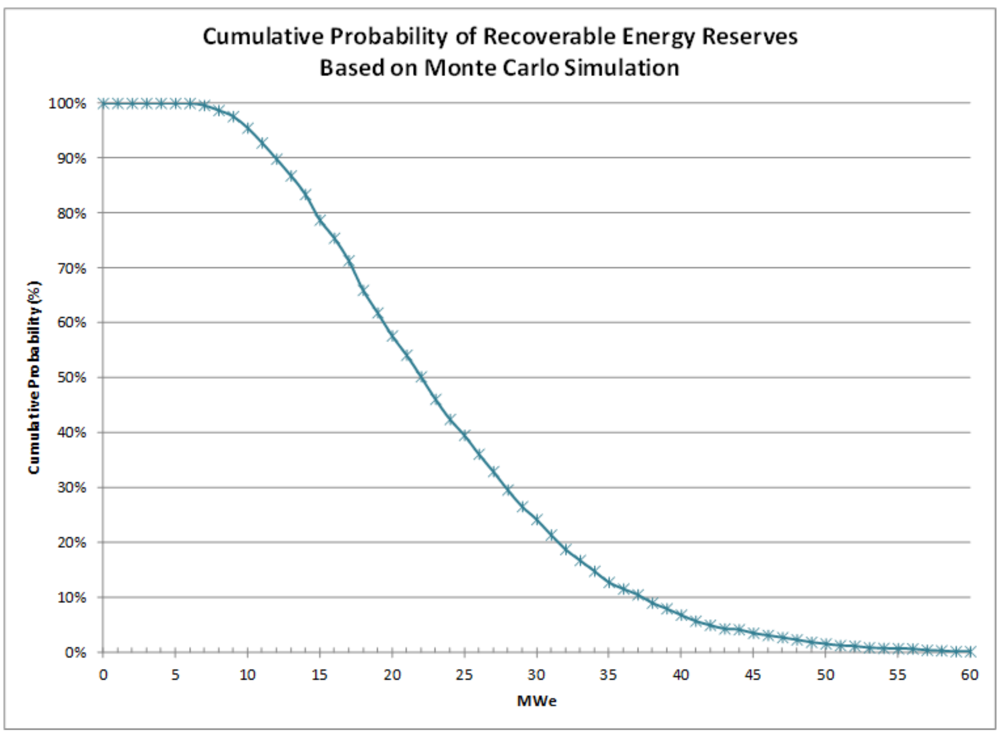


Figure 4: Output from Monte Carlo reserves estimation.

3. Resource Testing

In January 2008, a water sample from the Olene Gap area was sent to a leading chemical analysis firm to analyze for constituents needed to calculate geothermometry based resource temperatures. The analysis indicated geothermometry-based temperatures in the range of 250 to 300 deg F, which is consistent with measured temperatures

After being perforated from 2400 to 2450 feet, well OG-1 was tested by an injection test and found to be highly permeable, with an injectivity index of 40 gpm/psi (which is very high). It is recommended that a productivity index of 30 gpm/psi be used in calculations related to long-term production and pump design. Currently the well is completed with 7" casing to 2700 feet, which limits the size of pump. However, after being reconfigured to allow 13 3/8" casing to a depth of at least 1000 feet (possibly up to 1500 feet). This will allow installation of a commercial-sized production pump.

- In this configuration (13 3/8” casing), OG-1 is predicted to be able to produce up to 2800 gpm of 265 deg F brine.

OG-1 was completed with 7" casing to 2700 feet, and open hole to a Total Depth (TD) 3785 feet. On July 8th, 2011, the casing in well OG-1 was perforated from 2400 to 2450 feet depth. An injection test was conducted after the perforation with a maximum injection rate of 591 gallons per minute (gpm). The well's water level changes in response to injection were used to estimate the injectivity index of the well.

Figure 5 shows the data collected during the injection test. Well OG-1 was injected into while measuring depth to water. (Figure 6 shows the same data expressed in terms of pressure). Initially, the water level fell as is expected when colder, denser displaces hot water in a static well. By the end of the injection test the water level had risen within the well. When injection stopped, the water level began to falloff (a pressure falloff test).

Horner analysis of post-injection water level indicates that the stabilized water level is 103 feet below the surface, depicted in Figure 7 (Earlougher 1977). Based on this water level, the pressure change during injection is 14.3 psi. The resulting injectivity index is 41 gpm/psi. Based on this injectivity, GSI recommends using a well productivity of 30 gpm/psi for design calculations. This will make allowance for the possibility of long-term pressure decline and pressure interference with other production wells. This level of productivity (30 gpm/psi) is considered very high in the geothermal industry.

Static pressure and temperature logs were taken after drilling and cleaning on 6/23 and 6/24/2011. Static reservoir pressure at 1500 feet is approximately 600 psig. Figure 8 shows a comparison of several static temperature surveys, while the well is heating up after being cooled by the circulation of drilling fluids. The main production zone is expected to be in the perforations at 2400 to 2450 feet. In these surveys, this zone had a temperature of approximately 225 deg F. However, comparison with a survey taken on 3/23/2011 by the Oregon Institute of Technology indicates that the well will heat up approximately 30 degrees before reaching thermal equilibrium. Therefore, based on this analysis the temperature in the perforated zone was expected (by Horner analysis) to heat up another 30 F to approximately 255 F (see Figure 9). Actual measurements of equilibrium and flowing temperature of OG-1 reported by Kodali, however showed ultimate heat up to 265 deg F.

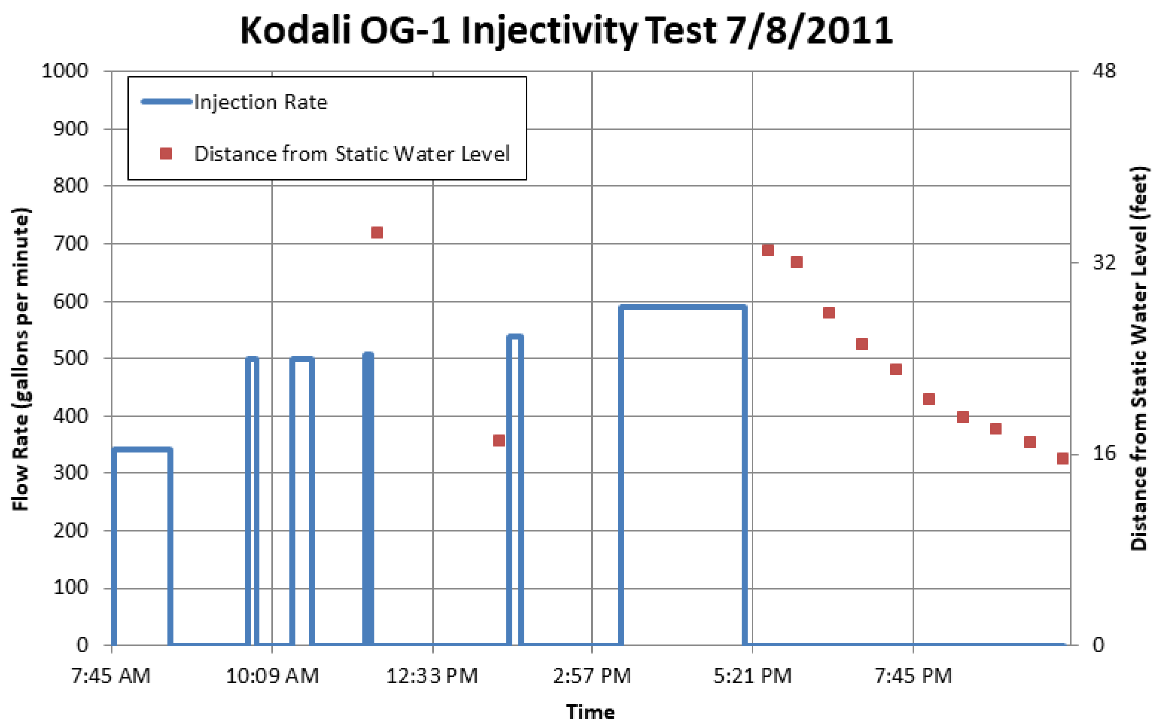


Figure 5: Injection test data summary expressed in units of feet of water

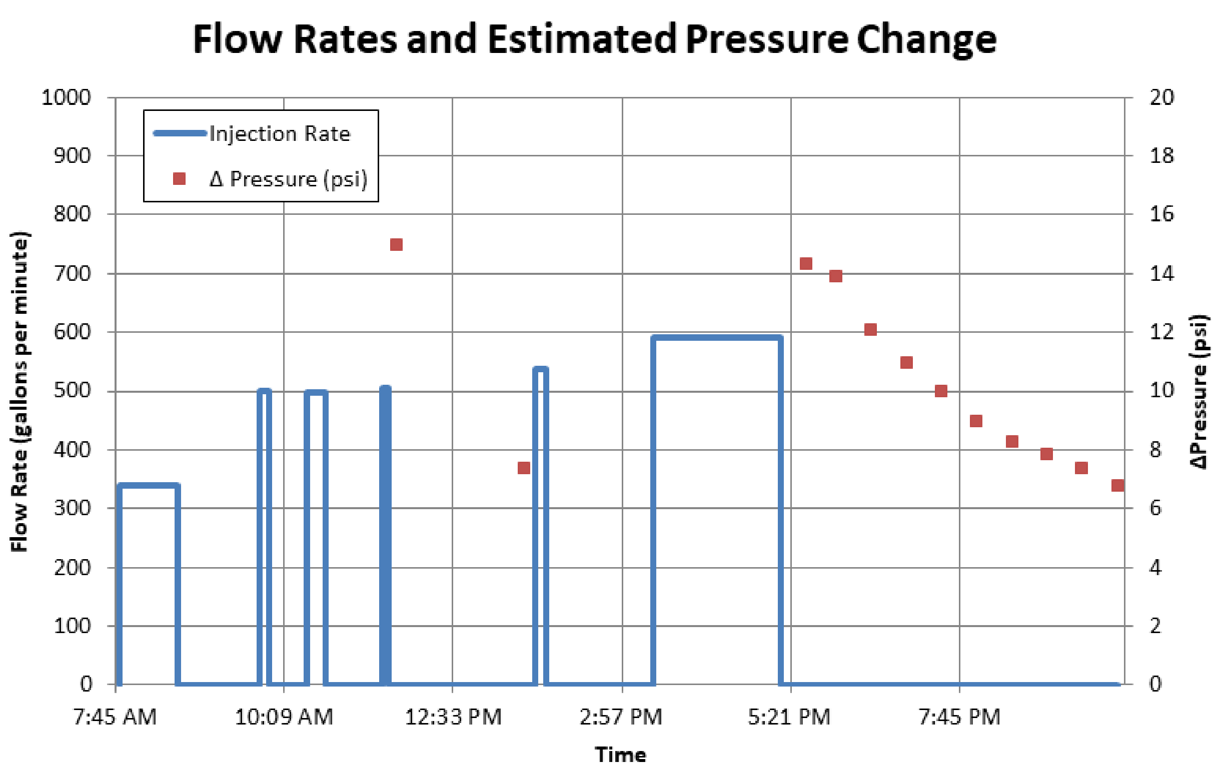


Figure 6: Injection test data summary expressed in units of pressure

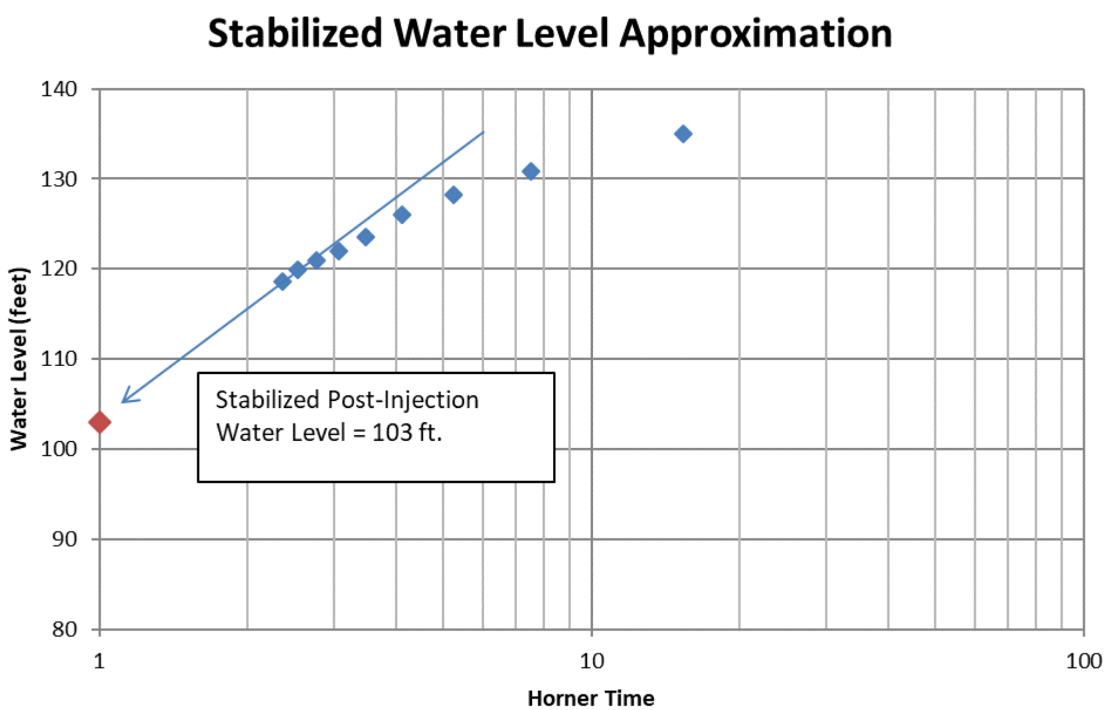


Figure 7: Horner plot approximation for stabilized post-injection water level

Table 3 - Productivity Index Calculations

Productivity Estimate		
Flow Rate	591	gpm
Injection Pressure Change	14.3	psi
Short Term Injectivity Index	41.3	gpm/psi
Est. Long Term Productivity Index	20	gpm/psi

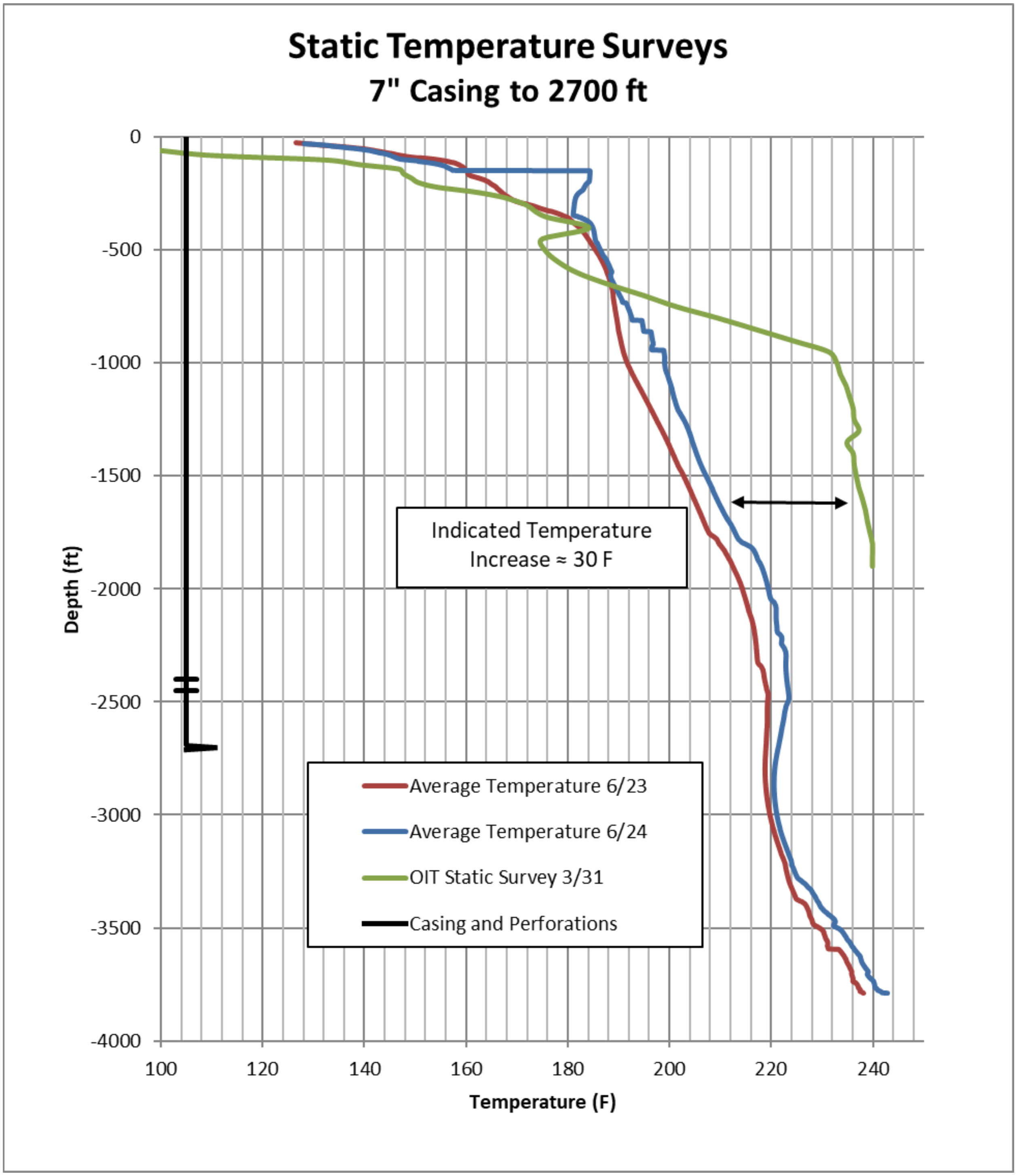


Figure 8: Static temperature surveys showing heat up

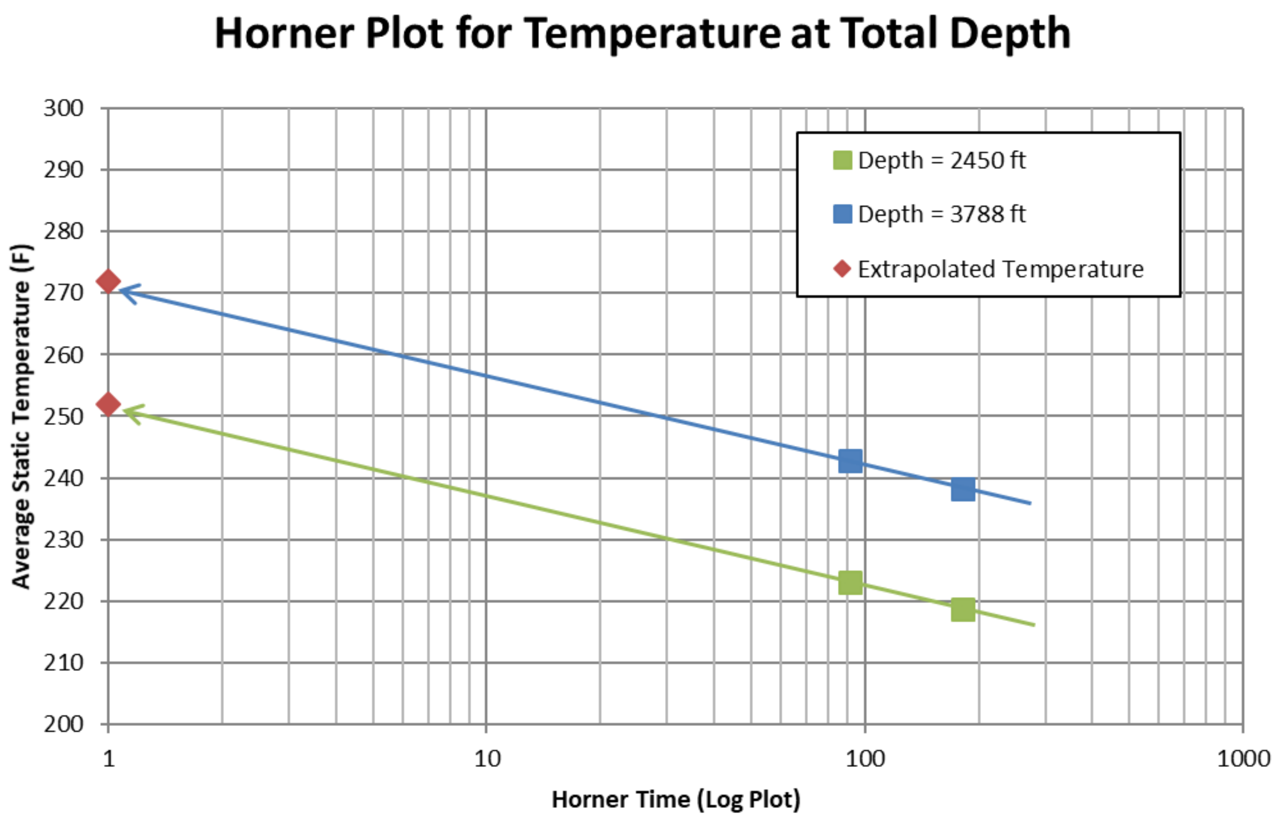


Figure 9: Horner analysis on temperature buildup

4. Conclusions

Monte Carlo simulation was used to estimate resource size. It was assumed that the deep resource has a temperature between 270 and 310 deg F, and covers an area in the range of 4 to 12 square miles. These resource area is consistent with USGS's estimate. The temperature estimates are consistent with recent resource test data. Using those input parameters, the Monte Caro simulation indicates a most likely (P50) resource size of 22 MWe, with a minimum resource size (P90) of 12 MWe. As drilling continues it is likely that additional data will be considered. In 2011, Kodali drilled the first deeper well in the area (well OG-1) to a total depth of 3775 feet. A highly productive 265 deg F hydrothermal resource was encountered at a depth of 2400 to 2450 feet. Analysis of well test data indicates that well OG-1 could provide 2800 gpm of pumped production at approximately 265 deg F.

At Olene Gap, a nominal 10 MWe geothermal power project is being planned with 5000 gpm of geothermal brine at 265 deg F. The level of production is within the P90 reserves estimate of 12 MWe, and based on the productivity of OG-1, sufficient permeability exists to produce 5000 gpm with two 13-3/8" casing production wells configured with commercially available pumps.

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