I have been retained by Little Lake Ranch ("LLR") to assist in the evaluation of the environmental impacts that would arise from the pumping of groundwater to supply the Coso geothermal power plant ("Coso") with reinjection water, and to address reasonable alternatives to the Project. My professional background is in geothermal power generating systems. I have attached a copy of my C*urriculum Vitae* to demonstrate my competency in commenting upon the matters set forth herein.

Previously I have submitted comments on the Draft Environmental Impact Report (DEIR). At this time, LLR has asked me to review and comment on two documents:

A. **Coso Geothermal Power Project Conversion from Wet to Dry Cooling Evaluation, March 2, 2009, Power Engineers ("PE").**
B. **Letter dated March 3, 2009 to Mr. Chris Ellis, Coso Operating Corp., from Mr. Mehul Patel, Veizades & Associates.**

Document A: My general impression after a reading of the document was that the report focused on a worst-case scenario, apparently intended to discredit the option of converting at least some of the nine Coso geothermal flash-steam power units from water cooling to air-cooling. Whereas some of the statements in the report are undisputable, such as air-cooling usually being associated with geothermal binary plants rather than flash-steam plants (see my **Tables 1** and **2** below for status of air-cooled geothermal plants in the U.S. and the rest of the world), nevertheless the report is too quick to dismiss air-cooling as a technically viable option for Coso.

Table 1: Air-Cooled Geothermal Power Plants in the United States. (1)

State	**Plant (all binary)**	**Start-up Year**	**Power, MW**
California	Mammoth (Casa Diablo)	1984 (1), 1990 (2)	7, 15, 10
California	Amedee (2)	1988	2 x 0.8 MW
California	Wineagle (2)	1985	2 x 0.35 MW
Hawaii	Puna (flash-binary)	1992	25
Nevada	Desert Peak 2	2007	12
Nevada	Steamboat I	1986	6
Nevada	Steamboat IA	1988	1.1
Nevada	Steamboat 2, 3	1992	14, 14
Nevada	Burdette	2006	20
Nevada	Galena	2007	10
Nevada	Soda Lake 1, 2	1987, 1991	3.6, 12
Nevada	Stillwater 1, 2	1989, 2009	13, 42
Nevada	Brady 2	2002	3
Nevada	Salt Wells	2009	14
Utah	Blundell 2	2007	11
Wyoming	Teapot Dome (NPR)	2008	0.25
		Total	**235.25 MW**

(1) All are binary-type except as noted. (2) Uses wet-dry hybrid cooling system.

Table 2: Air-Cooled Geothermal Power Plants outside the United States.

Country	Plant	Type	Start-up Year	Power, MW
Austria	Bad Blumen	Binary	2001	0.25
Austria	Altheim	Binary	2002	1
Azores	Ribeira Grande	Flash-Binary	1994	2 x 2.5 MW
Azores	Ribeira Grande	Flash-Binary	1998	2 x 4 MW
Azores	Pico Vermelho	Flash-Binary	2006	11.5
Ethiopia	Aluto-Langano	Flash-Binary	1998	1 x 3.9 MW, 1 x 4.6 MW
Germany	Landau	Binary	2008	3.2
Germany	Neustadt-Glewe	Binary	2003	0.2
Guatemala	Amatitlan	Flash-Binary	2007	20
Guatemala	Zunil	Flash-Binary	1999	7 x 3.5 MW
Japan	Uenotai	Flash (1)	1994	28.8
Japan	Hatchobaru	Binary	2003	2
Japan	Otake (pilot)	Binary (1)	1978	1
Kenya	Oserian	Binary	2004	1.8
Kenya	Oserian	Flash-Binary	2007	1.4
Kenya	Olkaria III-1	Flash-Binary	2000	2 x 6.5 MW
Kenya	Olkaria III-2	Flash-Binary	2008	3 x 11.7 MW
Mexico	Los Azufres	Binary	1993	2 x 1.5 MW
New Zealand	Kawerau TOI	Binary	1989	2 x 1.3 MW
New Zealand	Kawerau TG2	Binary	1993	3.9
New Zealand	Mokai I	Flash-Binary	2000	1 x 25 MW; 5 x 1.6 MW
New Zealand	Mokai II	Flash-Binary	2006	1 x 34 MW; 8 x 1.1 MW
New Zealand	Mokai IA	Flash-Binary	2007	7.3
New Zealand	Ngawha	Flash-Binary	1998	2 x 4.5 MW
New Zealand	Rotokawa	Flash-Binary	1997	1 x 13 MW, 3 x 4.5 MW
New Zealand	Rotokawa Ext.	Flash-Binary	2003	4.5
New Zealand	Wairakei	Binary	2005	3 x 5 MW
Nicaragua	Momotombo	Binary	2002	7.5
Philippines	Upper Mahiao	Flash-Binary	1996	12 x 10 MW
Russia	Verkhne-Mutnovsky	Flash	1998	3 x 4 MW
Turkey	Salavatli-Dora	Binary	2006	7.4
Turkey	Denizli-Sarakoi	Binary	2008	6.9
			Total	**466.55 MW**

(1) Uses (used) a wet-dry hybrid cooling tower.

In this commentary, I will not delve into technical design details but attempt to provide general comments understandable to a layperson. My earlier commentary on the DEIR contains a technical description of the Coso facility.

Point 1: The PE report analyzed the wrong plant configuration.

The Power Engineers report ("PE") made a fundamental error in my view by assuming that the proposed new air-cooled system would use an air-cooled heat exchanger ("ACHE") to provide cooling water to cool and condense the turbine exhaust steam using the present condensers.

The purpose of the air-cooled condenser ("ACC") is to replace both the existing condenser and the existing water cooling tower. To make this point in clear graphic terms, I include two diagrams from my DEIR commentary: See **Figures 1** and **2**. **Figure 1** shows the current operation with a water cooling tower. When the new ACC system is installed, the exhaust steam from the turbine would be sent directly to the ACC where it is condensed (**Fig. 2**).

There is no process flow diagram in the PE report, but from the text one can conclude that their design includes a new ACHE to replace only the water cooling tower. This error is amplified because their design requires the ACHE to produce cooling water at a temperature of 78.4^{o}F, the same that is produces from the water cooling tower. Since the temperature in the existing condensers is 122^{o}F and its corresponding pressure is 1.79 psia, according to the heat balance diagram used in the PE report, the new ACC needs to meet that temperature in order to maintain the same exhaust pressure. The additional 44^{o}F of temperature drop that their system imposes will clearly render their system very inefficient, given the climate at Coso, but this is not the system that we have proposed to replace the existing system. As proposed by PE, the size of the ACHE would be overstated and its cost will be highly exaggerated. The PE report shows a lack of understanding of the function of an air-cooled condenser, or it may attempt to mislead the reader about more feasible design alternatives.

To analyze, design and cost out their ACHE, PE used a software program from Hudson Products Corporation, a manufacturer of air-cooled heat exchangers. This preliminary sizing and pricing estimate tool is freely available on the Hudson website, http://www.hudsonproducts.com/ Unfortunately PE used "engine jacket water" as the input fluid to the software, not geothermal exhaust steam from a steam turbine. That is, the calculations of the size and the price of the air-cooled system are based on input conditions that are not the same as the actual conditions at Coso. Thus, the PE report again is misleading.

This error is especially important since the heat transfer coefficient for condensing steam is about one order of magnitude larger than for liquid cooling. The PE calculations will over-estimate the required size of the ACHE and thus over-estimate its cost.

Thus, the PE report results should be dismissed. A completely new assessment is called for, one in which a proper design is posited and analyzed. Only then can the true replacement costs be ascertained.

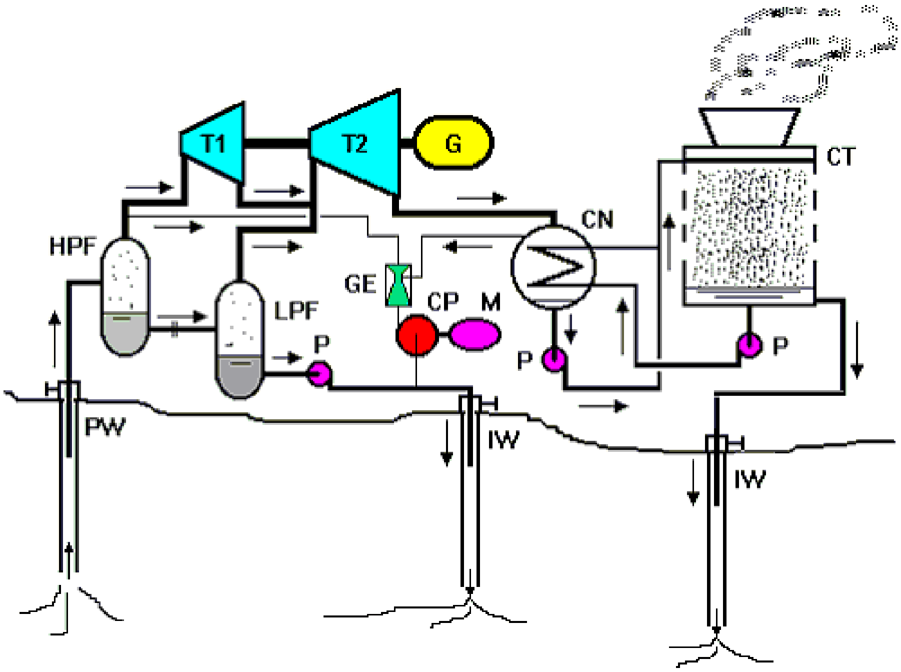

Figure 1. Coso-type plant equipped with a water cooling tower. Nomenclature: Same as Fig. 1 except: HPF, High-Pressure Flasher; LPF, Low-Pressure Flasher; GE, Gas Ejector; CP, Compressor; M,Motor; CN, Condenser; CT, Cooling Tower; P, Pump.

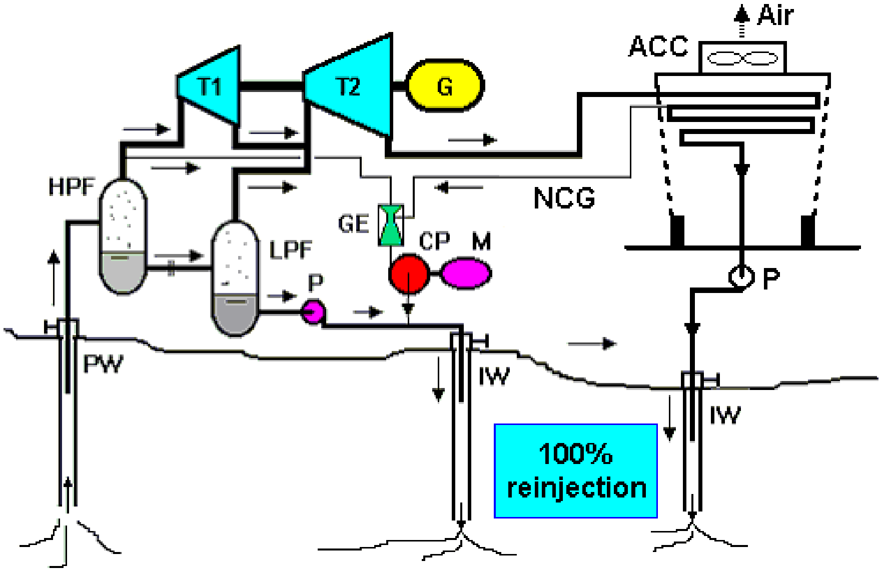

Figure 2. Coso-type plant equipped with an air-cooled condenser; possible design. Nomenclature: Same as Fig. 12A except: NCG, Noncondensable Gases; ACC, Air-Cooled Condenser.

Point 2: The PE report is predicated on the original design conditions and not on the conditions that currently exist at the field and at the plant.

The PE report is based on a “Heat Balance Diagram – P00-0016-A” from the Mitsubishi Heavy Industries, Ltd. That diagram shows all major equipment items and temperatures, pressures and flow rates throughout the plant. However, it is not dated. It seems that this diagram is the original heat balance diagram when the plant was brand new. We all know that Coso is not operating the same as it did in 1988, nor has the reservoir maintained the same properties it had back then. Of course, this is the reason that Coso is seeking permission to pump ground water wells to replace some of the water in the reservoir that has been extracted and not returned, but evaporated into the atmosphere through its water cooling towers. Thus, the basic premise on which the report is predicated is not reflective of today’s conditions at the field and at the plant.

Point 3: The PE report wrongly denies that there is room at Coso Navy I and Navy II to install an air-cooled system.

On page 5, the PE report rules out of hand even the possibility of installing ACCs at Navy I and Navy II owing to lack of land and topography constraints. Firstly, the area they estimate for the new ACCs is probably too large given the problems cited earlier with their analysis. Secondly, from aerial views of the Coso units (*Google Earth*), it is clear that ample, reasonably flat, open area is available at all four plant locations to accommodate ACCs. For example, Navy I is situated at an elevation of about 1295 masl, and there is a lot of open land to the north-northeast, just behind the present water cooling towers to host ACCs even of the size PE determined. And the elevation only drops off a few meters to the northeast of Navy I. Since ACCs are mounted on tall support beams (see **Figure 3**), any difference in ground elevation can be accommodated by varying the length of the structural supports. Navy II is located in a valley between hills, but even here there is some flat land to the southwest of the plant that seems more than adequate to host the ACCs. BLM East is also in a valley, but it is similar to Navy II in that there is a large flat area west of the plant. BLM West is totally flat, particularly to the west of the plant. Of course there will need to be some excavation for footings and new piping, but the argument that ACCs cannot be accommodated at the plant sites owing to topography and lack of land seems unfounded.

Figure 3. A section of the ACCs at the Steamboat 2 binary power plant in Nevada. Photo by R. DiPippo.

Document B: In general, the Veizades letter (VL) basically restates the conclusions of the PE report, while emphasizing that it is not feasible to install ACCs at Navy I and that extensive modifications, excavations and demolitions would be needed at the other plants. I have already commented on this argument. However, it is unlikely that demolition of all of the existing water cooling towers will be needed because land appears available to accommodate the ACCs even leaving the existing cooling towers in place.

Point 4: There are ACCs operating at both geothermal flash-steam plants and at large coal-fired steam plants.

The VL states that they know of no dual flash plant that uses dry cooling. It turns out that there is one such plant at Mutnovsky in Russia; see **Figure 4**.

Perhaps less well-known is that the Republic of South Africa operates at least nine very large coal-fired Rankine steam power units at two power stations that use ACCs. One of them is the Majuba Station; see **Figure 5**. It consists of six power unit: three of them, each 665 MW, are air-cooled; the other three, each 716 MW are water-cooled. This plant has been running for 13 years with an availability of 97%. Furthermore, the three ACC units have averaged 89% capacity factor most recently, according to Eskom's (the South African utility) website.

Fig. 4. Verhkne-Mutnovsky (Russia) 12 MW flash-steam plant with ACCs. Photo from *Geothermal Power Plants, 2nd. Ed.*, 2008 by R. DiPippo.

Fig. 5. Majuba Station, RSA; ACCs in foreground.

Another ACC coal-fired steam station in the Eskom system is Matimba Station near Ellisras. Here there are six 665 MW units, all air-cooled, in operation for about 20 years; see **Figure 6**. These units have averaged 74% capacity factor over the last three years, according to Eskom.

Eskom is planning to install six more units of this type in the next couple of years. The reason is that the climate is so dry that makeup water for water cooling towers is just not available. As it happens, that region of South Africa receives much more rainfall than does Coso and they do not need to worry about depleting a geothermal reservoir. Yet they have invested in and continue to invest in water-saving ACCs for their very large steam power stations without any significant degradation to the performance of the plants.

Fig. 6. Matimba Station, RSA, with ACCs to the right of the powerhouse; from *Google Earth*.

By comparing the average monthly temperatures and precipitation at Ridgecrest and at Johannesburg (the nearest weather stations to Coso and the Eskom plants, respectively), it can be seen that Coso has higher summertime temperatures than this region of the RSA, but it has lower winter temperatures. The precipitation at Coso is only 17% of that received at Johannesburg.

Conclusions:

1. Air-cooled condenser (ACC) technology is commercially available, economic to install and operate, and reliable in operation.

2. ACCs are operating at a geothermal flash-steam plant in Russia.

3. ACCs are operating at nine large steam power units, totaling nearly 6,000 MW, in the Republic of South Africa.

4. ACCs could be designed for the Coso environment. They could be built and installed with a minimum of disturbance to the existing plants. It would not be necessary to retrofit all nine Coso units if the objective is to eliminate the need to pump groundwater from the Hay Ranch aquifer.

Respectfully submitted,

Ronald DiPippo, Ph.D.
March 16, 2009