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CASE HISTORIES OF GEOTHERMAL FIELD MANAGEMENT IN THE USA

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1. INTRODUCTION

The US is the world leader in installed geothermal power generating capacity (2828 MWe in 2005; about 460 MWe on standby; GEA, 2006). The bulk of this capacity is in California (2492.1 MWe; Fig. 1) and in Nevada (274.4 MWe; Fig. 2).

Until a few months ago, geothermal electrical production was restricted to the states of California, Nevada, Utah and Hawaii. Recently (i.e. in July 2006) a 400 kWe power plant began producing electricity in Alaska (Chena Hot Springs, 2006). According to a March 2006 survey, new geothermal power projects were under development in Alaska, Arizona, California, Hawaii, Idaho, New Mexico, Nevada, Oregon and Utah (GEA, 2006).

Most of the installed capacity in the US came on line in the 1970s and 1980s. Since 1989 only 110 MWe have been added (Bertani, 2005). This slow growth was mainly due to the low fossil fuel prices, a lack of interest by most of the electrical power industry in investing in renewable energy projects because of the prevailing low fuel prices and the large upfront costs of geothermal projects compared to those of oil or natural gas burning power plants, complex and time-consuming leasing, siting and permitting requirements, and, in some cases, public opposition.

The situation, however, has changed recently because of four main reasons,

(1) oil prices have jumped to unprecedented levels reaching above 70 dollars per barrel a few months ago. Since then the prices have fallen, but the oil market continues to be unstable because of geopolitical reasons and a growing demand worldwide;
(2) improved geothermal technology in the areas of exploration, drilling, reservoir engineering, materials, fluid handling, and energy conversion. Now it is possible to produce electricity using geothermal fluids of lower temperature (about 74ºC at Chena Hot Springs, Alaska), and high salinity (above 20 wt% total dissolved solids at the Salton Sea field, California; Fig. 1);
(3) several states have enacted Renewables Portfolio Standards. This market-driven policy ensures that a minimum amount of renewable energy (including geothermal) is included in the portfolio of electricity resources serving a state; and
(4) Tax incentives at the federal, state and/or local level

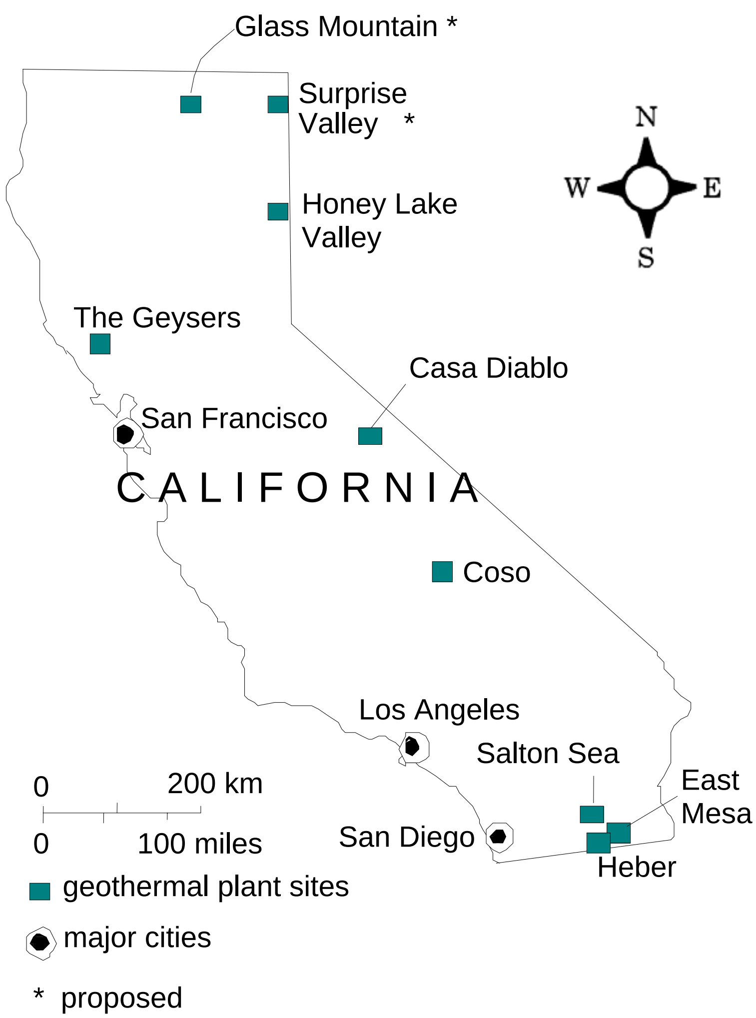

FIGURE 1: Location of geothermal fields in California, USA (from Lund et al., 2005)

The US geothermal industry, working with the federal and state agencies, is trying to simplify the leasing, siting and permitting requirements and speed up the handling of the paper work. Unfortunately, the public tends to react negatively to any projects that will be built near their homes. Only by informing the public of the environmental advantages of geothermal energy, the pollution control measures that will be implemented, and what the project would mean in terms of employment and the local economy the opposition can be reduced.

Because of prevailing market conditions, advances in technology and changes in policy and taxation, some 58 new geothermal energy projects are now under development in the US (GEA, 2006). According to the Geothermal Energy Association (GEA) ─ the US geothermal industry trade group ─ these projects, when developed, would provide up to 2250 MWe of additional electrical power capacity, generating approximately 18 GWh of electricity annually. The projects include the construction of new plants, many of them binary plants, and the modification/optimization of older flash plants

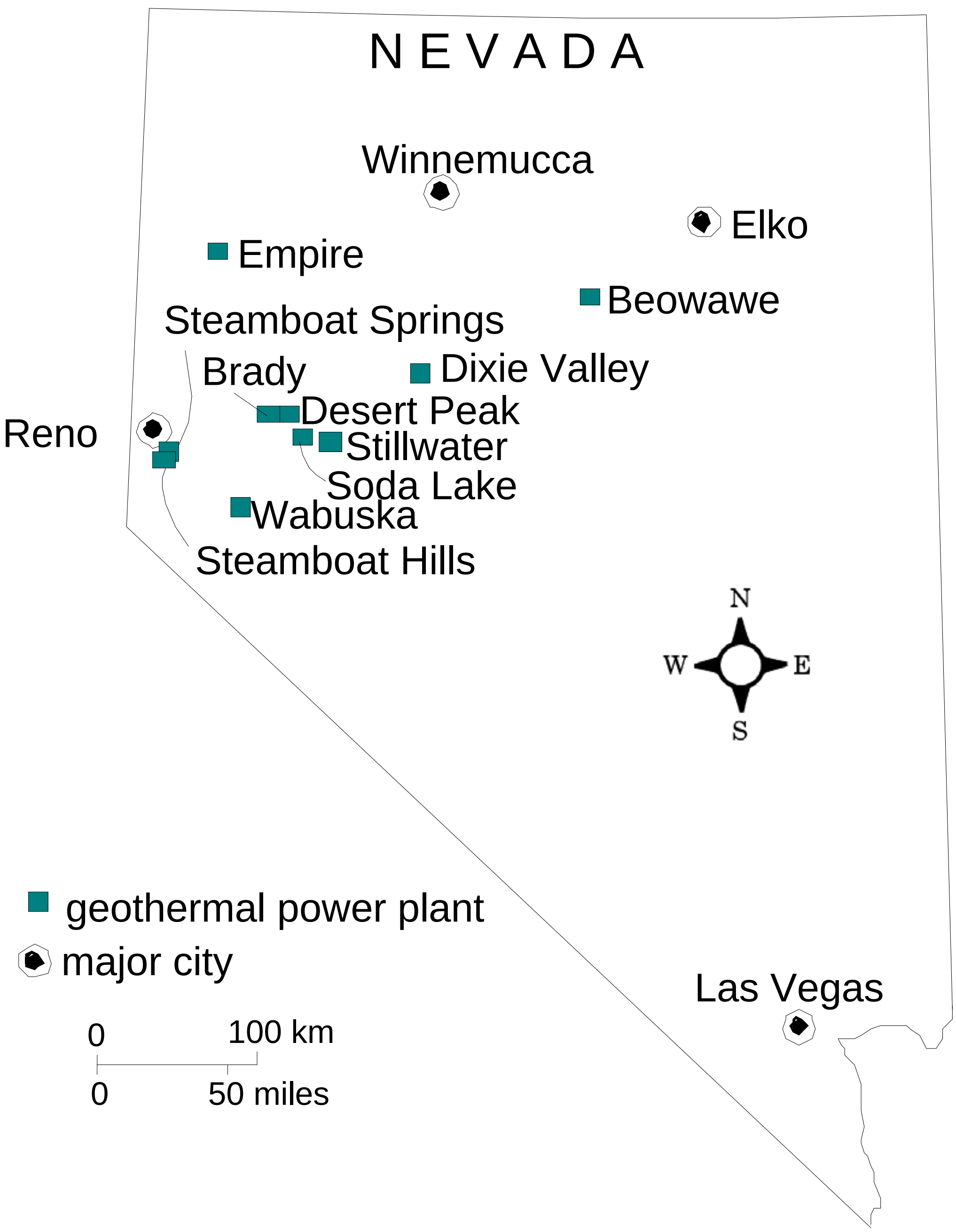

FIGURE 2: Location of geothermal fields in Nevada, USA (Lund et al., 2005)

2. GEOTHERMAL RESERVOIR MANAGEMENT PROGRAMS

Because of the large capital investment for geothermal development a carefully designed management of both reservoir production and power plant operations is required.

The main goals of a reservoir management program (or plan) for a given geothermal field is to:

(1) Optimize resource production
(2) Sustain production capacity over the lifetime of the plant
(3) Reduce possible environmental impacts
(4) Maximize profitability

In order to reach those goals it is important that such plans consider,

(a) the geology of the area (including faults, fractures and seismicity)
(b) the properties of the geothermal reservoir
(c) the hydrology of the geothermal system
(d) the chemistry and temperature of the geothermal fluids
(e) the characteristics of the power plant (or heat extraction plant)
(f) the energy market conditions
(g) the societal and environmental concerns and regulations

This information is obtained from the open literature, company reports and by collecting field data.

Once (a) to (g) are known (or estimated), various possible field management plans should be studied and compared against Goals 1 to 4 (see above). In those plans, one has to specify,

(A) the fluid and temperature requirements for the plant or plants
(B) the number, location and design of production and injection wells
(C) the fluid production or injection rates for each of the wells
(D) the minimum temperature of the re-injected fluids (to reduce scaling risks)

Parameter (A) is determined considering the characteristics of the plant that will be installed in the field [see (e)], which will mainly depend on prevailing and estimated future energy market conditions [see (f)]. Parameters (B) and (C) are mainly established by carrying out well and tracer tests, and by performing numerical simulation studies to estimate the response of the field to different fluid production and injection scenarios.

During the development and exploitation stages of a geothermal project, additional geologic, geochemical and reservoir engineering data [see (a) to (d)] will be gathered which might lead to an adjustment of (B) to (D). Only if the new information requires to drastically changing the characteristics of the power plant [see (e)], the field management plan will have to be significantly modified, but generally some adjustments might be needed. These will be done with the help of numerical models that calculate the effects of these changes on system behavior.

As the exploitation of the field proceeds, the performance of the reservoir, wells and plant have to be monitored, and the recorded information incorporated into the numerical models. The results of the updated modeling studies might dictate further adjustments of the field management plan.

In all US geothermal fields, management plans include the re-injection of the heat- depleted fluids. The purpose is to maintain reservoir pressures and resource sustainability, and to avoid polluting surface and near-surface waters.

A good re-injection example is that of The Geysers steam-dominated geothermal field of northern California, USA (Fig. 1). The commercial development of this system began in 1960 and The Geysers continues to be the largest field under production. Geothermal steam output and electricity generation grew until the late 1980s (Fig. 3); at that time the "running" capacity was about 1600 MWe (the installed capacity was around 2000 MWe). Because of overdevelopment, lack of natural recharge and low artificial recharge, pressures in the reservoir, and consequently steam output, declined (Stark et al., 2005).

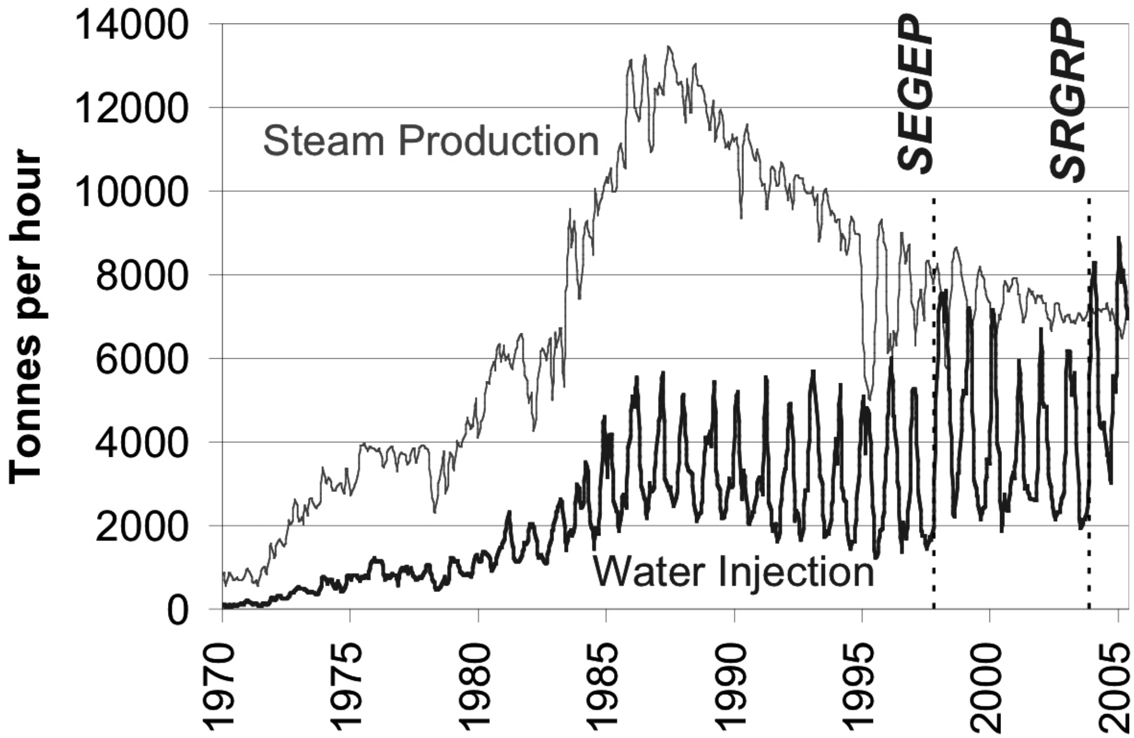

FIGURE 3: History of The Geysers field-wide monthly steam production (light line) and water injection (heavy line), 1970-2005. Dashed vertical lines indicate startup dates for the Southeast Geysers Effluent Project (SEGEP) and the Santa Rosa-Geysers Recharge Project (SRGRP) (from Stark et al., 2005).

In response to the drop in steam production and low electricity prices, power generation was curtailed and the companies operating the field began looking for source of water to be re-injected into the reservoir. At present there are two pipelines, tens of kilometers long, which carry waters to the field. The waters are pumped uphill, and injected into the fractured reservoir to build up steam pressures. The results have been very positive (Fig. 4). It is estimated that the power generation in this field has increased by 77 MWe because of this artificial fluid recharge (Bertani, 2005) and electricity generation is at a stable level of about 900 MWe (M. Stark, pers. com., November 200

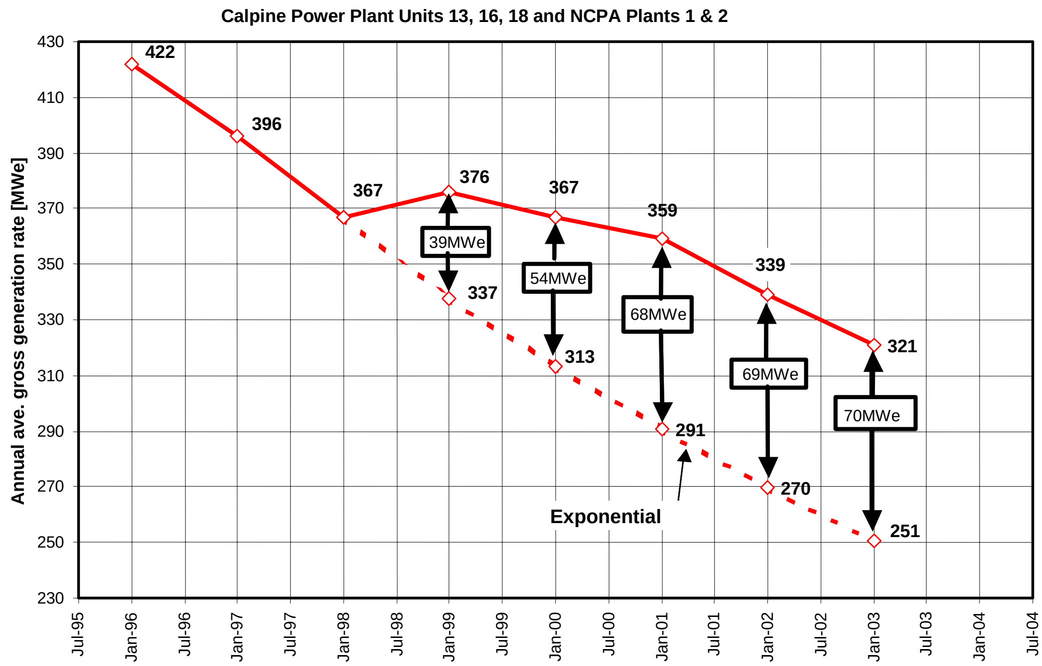

FIGURE 4: Reinjection effects at The Geysers steam-dominated geothermal field (from Bertani, 2005)

In a number of fields [like Coso, California (Fig. 1) and Desert Peak, Nevada (Fig. 2)] step-out wells and deeper wells have been drilled to increase and/or maintain fluid production, and, at the same time, to learn more about the physical and geochemical characteristics of the geothermal resource.

The management plans of some geothermal fields that have fluids rich in carbonates and/or silica (e.g. Dixie Valley, Nevada; Fig. 2), include the injection of scale inhibitors into the fluid stream to avoid, or significantly reduce, the precipitation of calcite or silica in wells and surface installations. Without such treatment the productivity and/or injectivity of the wells, the fluid carrying capacity of surface pipelines and the performance of power plant equipment will be negatively affected and strongly impact the operation and sustainability of the project.
In the Salton Sea field (Fig. 1) the hot (above 350ºC) produced brines are so loaded with salts that they have to be acidified before the spent brines are injected back into the reservoir, otherwise the injectors would be plugged in a very short time. Because of the high heavy metal content in the spent brines, the company operating the field built a zinc-recovery plant. However, because of financial and technical problems the project was abandoned.

In several US geothermal areas Enhanced Geothermal System (EGS) projects are underway with the goal of creating engineered reservoirs to produce energy from geothermal resources deficient in commercial amounts of water and/or permeability. In some fields (Coso Springs, California, and Desert Peak, Nevada) the permeability of natural fracture networks is being enhanced by hydraulic stimulation, i.e. by injecting fluids into the reservoir at very high pressures. On the other hand, at The Geysers, California, large volumes of treated sewage and lake waters are being injected into the fractured reservoir to recharge the system so that more heat can be extracted from the subsurface rock masses. The injection also serves to abate corrosion issues in the NW Geysers field, where the produced steam contains high amounts of non-condensable gases.

Even though the smaller, lower-temperature, direct application geothermal projects (i.e. heating of building and greenhouses, district heating, balneology, industrial applications) have not been mentioned, they also need to have a reservoir management plan to avoid the loss of investments. These plans should include numerical studies to estimate the energy capacity of the geothermal reservoir, and predict future changes in fluid temperature, flow rate and chemistry, as well as monitoring programs to record these parameters. With this information one can calculate the commercial lifetime of the venture. In many direct-use projects the spent fluids are not re-injected into the producing reservoir because their low content of salts, a practice that should be discouraged because it may deplete the resources at a rate too fast to recover the cost of the installations.

3. FINAL COMMENTS

All geothermal projects including those using the Earth's heat in direct applications should have a reservoir management program and such plan should be updated periodically on the basis of newly collected data. Otherwise the fluid and heat production capacity of a field might significantly decrease before the end of the installation/plant lifetime, and may even damage the environment, particularly the groundwater resources of the area. If that occurs it is quite possible that the profitability of the project will be lower than initially estimated.

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REFERENCES

Bertani, B., 2005. World geothermal generation 2001-2005. Geothermics 34, 651-690.

Chena Hot Springs, 2006. Website: http://www.yourownpower.com/.

GEA, 2006. Geothermal Energy Association – Power plants Webpage. (http://www.geo-energy.org/information/plants.asp).

Lund, J.W., Bloomquist, R.G., Boyd, T.L., Renner, J., 2005. The United States of America country update. In: Proceedings of the World Geothermal Congress 2005, 24-29 April 2005, Antalya, Turkey, 19 pp.

Stark, M.A., Box, T.W., Jr., Beall, J.J., Goyal, K.P., Pingol, A.S., 2005. The Santa Rosa-Geysers Recharge Project, Geysers Geothermal Field, California. Geothermal Resources Council Transactions 29, 145-150.