Title
SITE SPECIFIC GEOTHERMAL RESERVOIR ENGINEERING ACTIVITIES AT LAWRENCE BERKELEY LABORATORY

Author
Goranson, C.B.

Publication Date
1979-07-01

To be presented at the 1979 Annual Meeting,
Geothermal Resources Council, Reno, NV,
September 24-27, 1979

SITE SPECIFIC GEOTHERMAL RESERVOIR ENGINEERING ACTIVITIES AT LAWRENCE BERKELEY LABORATORY

C. B. Goranson and R. C. Schroeder

July 1979

Prepared for the U. S. Department of Energy
under Contract W-7405-ENG-48

DISCLAIMER

Site Specific Geothermal Reservoir Engineering Activities at Lawrence Berkeley Laboratory

C. B. Goranson and R. C. Schroeder

Earth Sciences Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Abstract

LBL personnel have been engaged in geothermal reservoir engineering since 1975, when T. N. Narasimhan and P. A. Witherspoon tested and analyzed RRGE-1 at Raft River (1). Since 1975 the LBL field capabilities have been expanded and improved. Our studies have included cooperative projects with several private companies, city governments, and federal agencies. Our purpose has been to develop new and improved techniques, tools, and analysis methods for use in assessing and modeling hydrothermal systems. The important tasks in carrying out these activities can be summarized as follows:

- Collect site specific data
- Develop field techniques
- Develop measurement tools
- Develop analysis methods
- Model site specific aquifers

Introduction

The site specific studies include data from many sources, in addition to LBL field measurements. This data includes geological, geophysical, hydrological, and geochemical information about each site. The well testing requires well completion data, well logs, and wellbore geophysical interpretations in order to carry out detailed analyses of the well test data. In general, the purpose for the well testing is:

- Determine hydrological parameters
- Identify aquifer limits (barriers)
- Identify aquifer recharge (if it exists)
- Determine well damage (if it exists)
- Determine thermal characteristics
- Obtain representative reservoir fluid sample

All of this information is used when a resource assessment is initiated and subsequent modeling is carried out. Clearly, the amount of information available for site specific resource evaluation determines the degree of confidence in estimating reserves and resource lifetime for proposed exploitation strategies.

Table 1 and Figure 1 show the specific geothermal sites at which (or for which) LBL personnel have played a role in the reservoir engineering measurements, evaluation, or planning during FY 1978.

Review of Specific Site Activities

1. Desert Hot Springs KGRA (2)

LBL reviewed data from a well test carried out in June, 1977 by B. F. Russell, California State University at Fullerton. The test incorporated 3 wells in the Desert Hot Springs KGRA near Palm Springs, California. The data was analyzed assuming that there is a partial penetration effect which yields a total reservoir height of 300 meters. Transmissivity values between 1.7 and 3.7 x 10^6 md-ft/cp were calculated from the production and observation well data.

However, our confidence in the calculated transmissivity values is small. Analysis of data from well tests is directly dependent on geological and lithological information available for the reservoir. In this case little is known about the aquifer that was tested.

Lithologic and geophysical well logs were not available. Our main conclusions were that the test was not of sufficient duration to estimate the total amount of heat available, maximum producable temperature, geologic extent of the resource, or maximum production capabilities. This anomaly appears to offer promise as a candidate for direct utilization applications. However, a modest investment in well testing, geological studies, and their evaluation is necessary to provide estimates for the resource extent and its hydrothermal characteristics.

2. Mono-Long Valley KGRA - Casa Diablo Site (3)

LBL reservoir engineering personnel visited the Casa Diablo Hot Springs geothermal area in June, 1977 and again in June 1979. We reviewed the site for possible well test activities that LBL could perform to delineate reservoir boundaries and maximum long term production rates for possible use in a Direct Heat Utilization program for the City of Mammoth Lakes. This reservoir has a maxi-temperature of approximately 180°C at about 120 m Preliminary short term flow tests were reported to have flows between 300,000 and 500,000 lbs/hr. These rates and temperatures should be more than sufficient to supply space heating demands for the City of Mammoth Lakes. However, these short term tests do not indicate reservoir extent or the total capacity of the reservoir to produce heated fluids over long periods of time. For heated waters to exist at these shallow depths requires movement of fluids from greater depths into the more permeable shallow "reservoir". To date, the reservoir has not been completely defined.

3. Coso Hot Springs KGRA, China Lake, California (4, 5)

An exploratory well - Coso Geothermal Exploratory Hole Number 1 (CCGEH #1) was completed at the China Lake Naval Weapons Center on December 2, 1977 to a total depth of 4845 from ground level ([CER] completion report). The subsurface geology consists of a fractured granitic complex overlain with rhyolitic debris and intruded by rhyolitic dikes (Galbraith, 1977).

Three large fractures were encountered during drilling. These fractures are illustrated in Figure 2 as zones where large mud losses occurred. LBL personnel monitored the downhole thermal equilibrium of the well, and a flow test was performed in the latter part of 1978. The maximum temperature (196°C) was recorded at 1900 ft., and the static water level is at 900 ft.

Flow tests were performed in September 1978 and November 1978. A nitrogen stimulation technique was utilized in assisting initial flow. The well was blown dry using nitrogen injection. The water level build up in the well was estimated at 4 gpm. However, a 60 gpm influx of water was encountered at about 2100 ft. during drilling. This is also the zone of highest measured temperature. The quantity of fluid and producibility of this zone has not been determined to date. The prospects in this area are good and could be illustrated with additional well-drilling and testing.

4. Susanville-Honey Lake KGRA, Susanville, California (6)

The Susanville geothermal anomaly is located in the Susanville-Honey Lake KGRA in Northeastern California. Extensive resource identification has been undertaken by the Bureau of Reclamation in the Susanville-Honey Lake KGRA. Geological surface mapping has also been completed. (7) As part of the exploration project being carried out by the Bureau of Reclamation several shallow (50m) temperature gradient (TG) holes and several deeper (120m - 650m) exploratory holes have been drilled to date. Lithologic and electric logs were obtained for most of the wells. Temperature gradients in the shallow holes ranged from .12°C/m to .21°C/m. The maximum temperatures measured in the deeper holes vary between 35°C to 70°C. Figure 3 illustrates contoured temperatures in this area at 100m of depth. In several wells the temperature profiles illustrate a reversal at depth, indicating that heated fluids may be transported from depth along faults and then dispersed into this more permeable "reservoir" strata.

Neither the lateral extent, nor the "reservoir" thickness of the geothermal anomaly have been completely identified to date. However, preliminary studies indicate that the portion of the resource that has been explored by well testing is a fracture dominated, high permeability, low storage resource. The most recent drilling suggests higher temperatures are present in the Northwestern portion of the anomaly.

5. Klamath Falls Geothermal Anomaly, Klamath Falls, Oregon (8)

Klamath Falls, Oregon has been designated as a known Geothermal Resource Area (KGRA). The city is one of the earliest large scale users of geothermal energy in the continental United States. There are approximately 350 hot water wells in the area used for space heating in about 450 structures. Downhole water well temperatures range from 30°C - 105°C. Large quantities of data have been published by the Oregon Institute of Technology Geo-Heat Utilization Center on the properties and characteristics of the Klamath Falls resource.

LBL has analyzed data from two well tests in the area performed by Oregon Institute of Technology. One test was performed in July, 1976, another test was carried out in July, 1978 with LBL participation. The production and injection wells for the second test were located on Old Fort Road about one mile from the center of town. These wells are in an area where maximum downhole temperatures of 105°C have been measured.

All the observation wells had shallow completions (200-350 ft) while the production well was completed to 900 ft. Drawdowns in the observation wells were quite small (15 cm) and the formation parameters could not be uniquely defined. The test again was not long enough in time to classify the reservoir from a hydrological standpoint. However, communication between producing and observation wells has been proven. Additional testing to determine the characteristics of the aquifer system is needed to confirm preliminary resource models of the area.

6. Cerro Prieto Geothermal Field, Baja California, Mexico (9)

The joint LBL-CFE well testing plan was designed to encompass the complete Cerro Prieto Geothermal Field located in the southern extension of the Imperial Valley - Salton Sea trough in southeastern California and northern Mexico (denoted the Mexicali Valley in Mexico). This area has many faults associated with crustal block movements where the Pacific Plate contacts the North American Plate.

The well locations are shown in Figure 4. Well depths in this field range from 1200 to 2200m. Temperatures range between 200 and 360°C. Flow rates vary between 60 and 300 tonnes/hr. There are no artesian geothermal wells in this area and wells are usually stimulated after drilling using a small air compressor.

7. East Mesa KGRA, Imperial Valley, California (10)

East Mesa is at the eastern edge of the Salton Trough in Southern California. In FY 1978 an Agreement was negotiated for well testing at the East Mesa site shown in Figure 5. The agreement included a review of all past well testing and analysis. In addition, productivity tests for well 6-1, 6-2, 8-1, and 31-1 were agreed upon. The well 31-1 has no surface piping from the wellhead, and environmental restrictions prevented surface disposal. Hence, 31-1 was not subsequently tested, but the remaining tests were completed. A long term intereference test was also completed using 8-1 as the flowing well while monitoring nearby wells.

The review of previous well testing at East Mesa provided estimates for the well productivity also. In Tables 1, 2, 3, and 4 in the reference (Benson, et al., 1978), all of the data is summarized for the BuRec, Magma, and Republic wells from which the test data is available. This data has outlined the resource in terms of well productivity and temperature decline at wellhead as a function of time. This area is being developed by several companies. 10 Mwe is expected to be on line this year.

Acknowledgement

This work is supported by the Department of Energy under Contract #W-7405-Eng-48.

References

1. Narasimhan, T., and Witherspoon, P., "Reservoir Evaluation Tests on RRGE-1 and RRGE-2, Raft River Geothermal Project, Idaho" May, 1977, LBL-5958.

2. Goranson, C., McEdwards, D., Schroeder, R., "Review of Desert Hot Springs Well Test" March 1978, UCID-4028.

3. Long Valley Sumposium, Vol. 81, No. 5, pp. 810-1038, February, 1976.

4. Goranson, C., Schroeder, R., "Static Downhole Characteristics of Well CGEH-1 at Coso Hot Springs, China Lake, CA", June, 1978, LBL-7059.

5. Goranson, C., Schroeder, R., Haney, J., "Evaluation of Coso Geothermal Exploratory Hole No. 1 (CGEH-1), Coso Hot Springs KGRA, China Lake, CA", January, 1979, LBL-8675.

6. "Susanville Geothermal Investigations: Special Report", 1976, and "Susanville Geothermal Investigations: Supplemental Technical Data - Special Report, 1976", U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

7. Rudser, R., "The Geology and Geothermal Potential of Susanville, Lassen County, CA", 1978, Masters Thesis, U.C. Davis.

8. Sammel, E., and Peterson, D., "Hydrologic Reconnaissance of the Geothermal Area Near Klamath Falls, Oregon", U.S.G.S. OFR WRI76-127, 1976.

9. Proceedings of the First Symposium on the Cerro Prieto Geothermal Field, Baja, California, Mexico, LBL-7098, In Print.

10. "Geothermal Resource and Reservoir Investigations of U.S. Bureau of Reclamation Leaseholds at East Mesa, Imperial Valley, CA", Earth Sciences Division, Lawrence Berkeley Laboratory, LBL-7094

Table 1

Desert Hot Springs	- well test analysis
Casa Diablo	- well test planning
Coso Hot Springs	- measurements, workover, and resource evaluation
Susanville	- measurements, well siting, and resource evaluation
Klamath Falls	- measurements, planning, and resource evaluation
Cerro Prieto	- measurements and resource evaluation
East Mesa	- measurements, workover, and resource evaluation

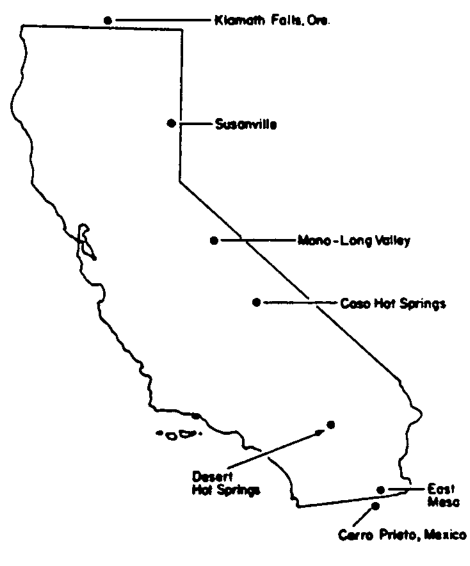

Figure 1: Location map of geothermal sites under investigation by LBL personnel.

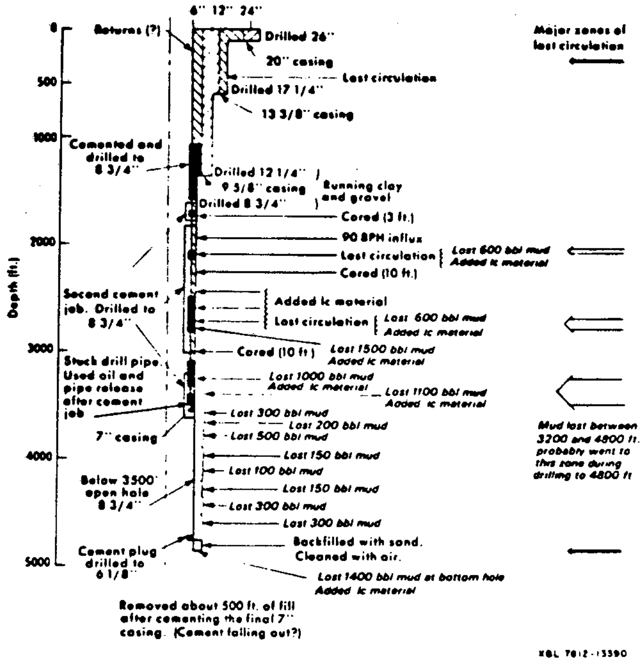

Figure 2: Summary of drilling log for CCGEH#1.

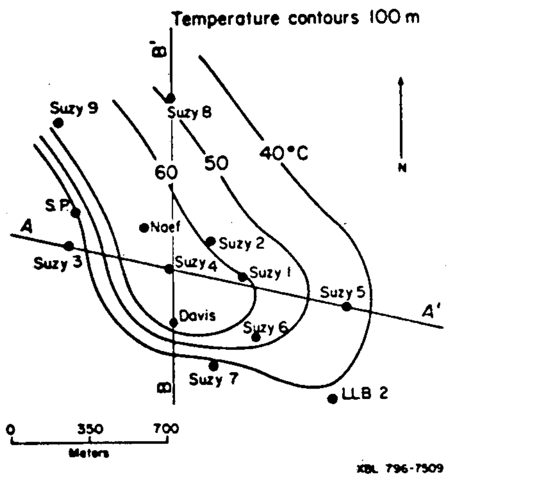

Figure 3: Well locations and temperature contours at 100 m depth at the Susanville geothermal anomaly.

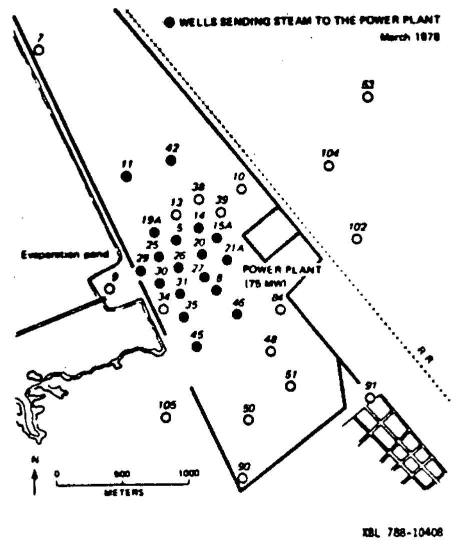

Figure 4: Well locations at the Cerro Prieto geothermal resource, Cerro Prieto, Mexico.

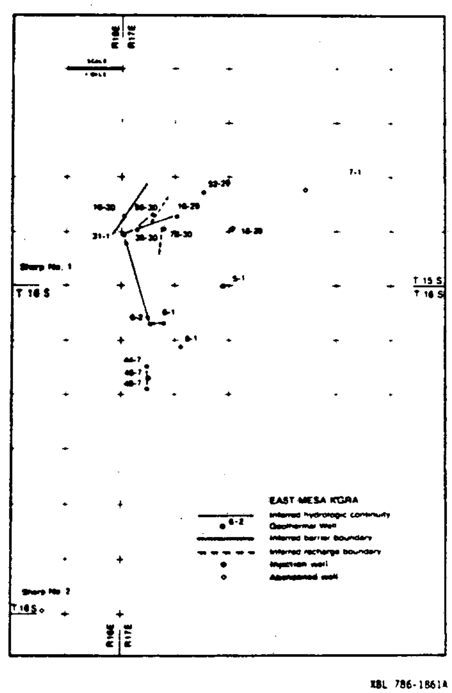

Figure 5. Well locations and inferred hydrologic continuity at the East Mesa KGRA, California.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720