# EXPLORATION AND DEVELOPMENT OF THE HEBER GEOTHERMAL FIELD, IMPERIAL VALLEY, CALTFORNIA

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## ABSTRACT

Initial interest in the Heber area in Southern California was as an oil and gas prospect. Interest changed to the geothermal potential when high thermal gradients were discovered in shallow holes. During the exploration program, several geophysical surveys were run: gravity, reflection seismic, resistivity, ground noise, and spontaneous potential. However, temperature holes up to 500 feet deep provided the best data for picking the exploratory well location. Sixteen wells now outline a convective plume of hot water in a predominantly sand reservoir. Initial development is planned in 2 zones: 2000 to 4000 feet and 4000 to 6000 feet. Producing wells will be directionally drilled from "islands" near the center of the field and injection wells will be directionally drilled from "islands" on the periphery. An operating unit has been formed and a contract signed with Southern California Edison to build a 50 MW generating plant, to be operating in 1982.

## INTRODUCTION

The Heber Geothermal field is located in the Imperial Valley, south of El Centro near the Mexican border (Fig. 1). Geologically, it is on a trend of postulated oceanic ridge segments and transform faults which extend from the East Pacific Rise at the mouth of the Gulf of California to the San Andreas fault in the vicinity of the Salton Sea. Heber is one of several geothermal areas in this setting, including Cerro Prieto in Mexico, East Mesa, Brawley, and Salton Sea. Probably the first indication of a geothermal resource near Heber came in 1945 from the drilling of the Amerada No. 1 Timkin to a depth of 6637 feet just west of the town of Heber. Large quantities of dry ice were reportedly used to cool the mud. Even so, a maximum temperature of 280°F was recorded on a Schlumberger E-log run.

## EXPLORATION

In the early 1960's, Chevron conducted an exploration program for oil and gas in the Imperial Valley. A positive Bouguer gravity anomaly just south of the town of Heber was leased for oil and gas. In 1964, Chevron drilled a 500-foot hole on the Heber gravity anomaly as part of a program to investigate geothermal gradients in the Imperial Valley. A gradient of 24.6°F/100 feet was measured between 400 and 500 feet and confirmed that the area was thermally anomalous. Consequently, interest in the oil and gas potential declined.

Interest in Heber as a geothermal prospect grew in 1970 because of the apparent success at Cerro Prieto in Mexico. U. C. Riverside drilled a series of shallow holes (from 31 to 208 feet) in 1970 and early 1971. These indicated that an anomaly of significant size existed as determined by contours of thermal gradients. Comparison of the initial gradient contours with the

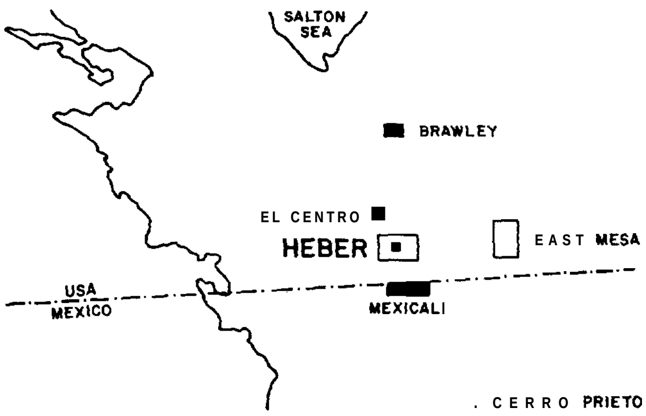



FIGURE I. LOCATION OF HEBER GEOTHERMAL FIELD.

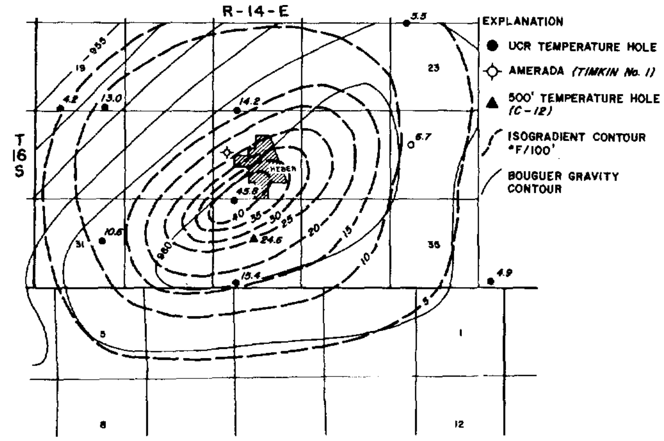



FIGURE 2. INITIAL SHALLOW ISOGRADIENTS AND BOUGUER GRAVITY CONTOURS-HEBER AREA.

Bouguer Gravity map suggested that the gravity anomaly and the geothermal system were related (Fig. 2).

Several geophysical surveys were run. These included the gravity survey mentioned above and a north-south reflection seismic line. Both of these were run in conjunction with the oil and gas exploration. The reflection seismic results were poor, but shallow data suggested a very low relief, faulted, anticlinal reversal. Electrical resistivity information has been obtained from roving dipole, dipole-dipole and magnetotelluric surveys. The results are not diagnostic because the geothermal system is not characterized by uniquely anomalous resistivities with respect to the one to five ohm-meter background resistivities. A ground noise survey provided an anomaly coincident with the gravity high but the significance is questioned because of the generally high surface noise. A spontaneous potential survey indicated a weak anomaly just south of the town of Heber but the amplitude does not distinguish it from other anomalies in the area.

Temperature holes, 200 to 500 feet deep, provided the primary basis for locating Chevron's first deep test. A 1972 map of isotherms at 480 feet (Fig. 3) shows a well-defined bulls-eye.

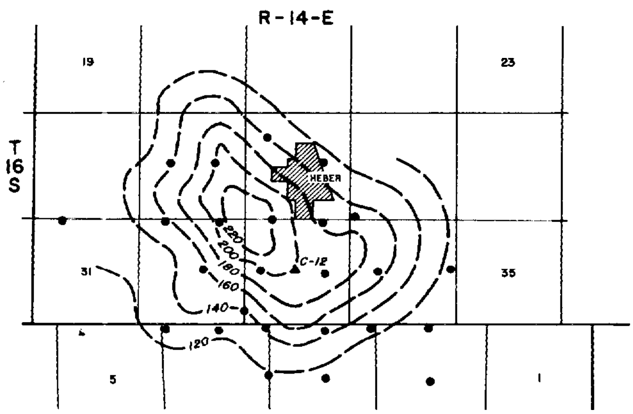



FIGURE 3. ISOTHERMS (°F) AT 480' (BLACK DOTS ARE CONTROL POINTS).

However, a projection of isotherms to 5000 feet (based on shallow gradients) produced a broader target with estimated temperatures as high as 650°F (Fig. 4). A location in the southeast part of the target was picked because shallow temperature data suggested a shift to the southeast with depth.

The first geothermal well was drilled in early 1972 by Magma Energy, Inc. Chevron contributed financial support to this well, the No. 1 Holtz, which was drilled to a total depth of 5147'. The results encouraged Magma to drill a second well a mile to the west. Chevron did not participate in this well but instead drilled its first well, the No. 1 Nowlin Partnership, about a mile to the east in the fall of 1972. A maximum temperature of 368°F was recorded in the No. 1 Nowlin at 2200 feet which declined to 358°F at total depth of 5031 feet. Analysis of water recovered from tests showed a fairly low (14,000 ppm) total dissolved solids. Had the well been drilled in the northwestern area of the target defined by the projected isotherms at 5000 feet, it would have missed the deep thermal system.

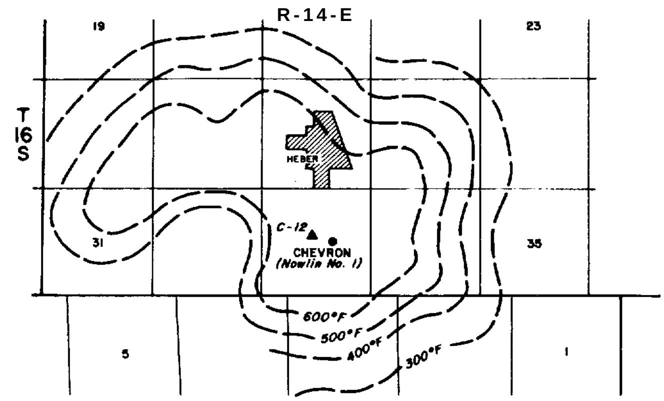
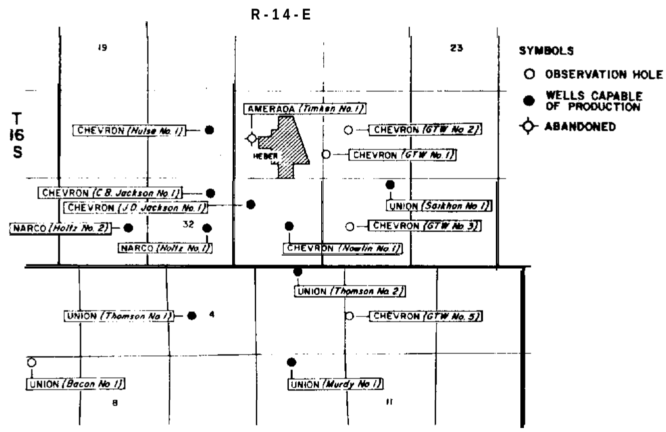



FIGURE 4. ISOTHERMS PROJECTED TO 5000' BASED ON 200' AND 500' GRADIENT HOLES. LOCATION OF CHEVRON-*NOWLIN No. 1* (CHEVRON'S FIRST DEEP TEST) IS SHOWN.

## FIELD DEVELOPMENT

Sixteen wells (including one oil and gas exploration well) have been drilled in the Heber anomaly. These wells range in depth from 3002 to 9701 feet. (See Fig. 5.)




All of the geothermal wells were drilled to evaluate and delineate the reservoir and, with possibly three exceptions, are not in suitable locations to be used as producers or injectors in a commercial development. In most cases, however, they will be used as observation wells to monitor reservoir temperature and pressure as the reservoir is developed. These wells outline a convective plume of hot water of 375°F or higher rising from depths below 10,000 feet. Above 4500 feet, horizontal flow shifts the plume northerly giving it an overall shape of a lopsided mushroom. The plume centers near the Chevron Nowlin #1 well at 2000 feet but shifts about 1/2 mile south at 4000 feet. (See Fig. 6.) A predominantly shale section provides a caprock above 2000 feet where heat flow is primarily conductive. Sands predominate (SO-80%) below 2000 feet with intergranular porosities of 15 to 30%.

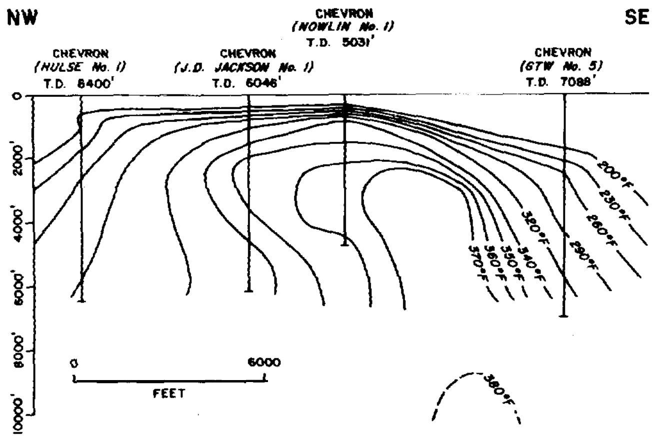



FIGURE 6. NW-SE CROSS SECTION SHOWING ISOTHERM CONFIGURATION.

Extensive well testing has been carried out in the field to provide reservoir and operating data needed to predict reservoir performance and capacity with various development schemes. The predicted reservoir capacity of 500 MW was established initially using a two-dimensional layered streamtube simulator model and secondly with a three-dimensional radial single phase water flow numerical simulator (Tansev and Wasserman, 1978).

The development plan selected to optimize heat recovery from the Heber anomaly anb to support a generating capacity of 500 MW for abnut 30 years provides for unitization of approximately 7400 acres under lease to Chevron, Union Oil Company and New Albion Resources Company. Chevron will be the Unit Operator. Production wells will be directionally drilled into the temperature high of the anomaly with bottom hole locations evenly distributed in a circular pattern with a radius of about 2000 feet. Cooled brine from the power plants will be piped (30" to 42" pipelines) to injection islands located near the periphery of the reservoir (1½ - 2½ mile radius from center of anomaly) where the produced brine will be re-injected. Wells directionally drilled to the 265°F isotherm will provide the optimum reinjection pattern for economic reservoir life. An area approximating 7300 acres has been rezoned by Imperial County to allow for surface operations required to develop the Heber geothermal anomaly. (See Fig. 7.) Production and injection intervals for each well are limited to 2000 feet to allow for a satisfactory balance between wellbore and reservoir flow capacity. For the 500 MW development plan, four production/injection zones have been defined. These zones begin at 2000 feet of depth, are 2000 feet thick and extend to 10,000 feet. Initial plants will use brine produced from zone 1 (2000-4000 feet) and zone 2 (4000-6000 feet).

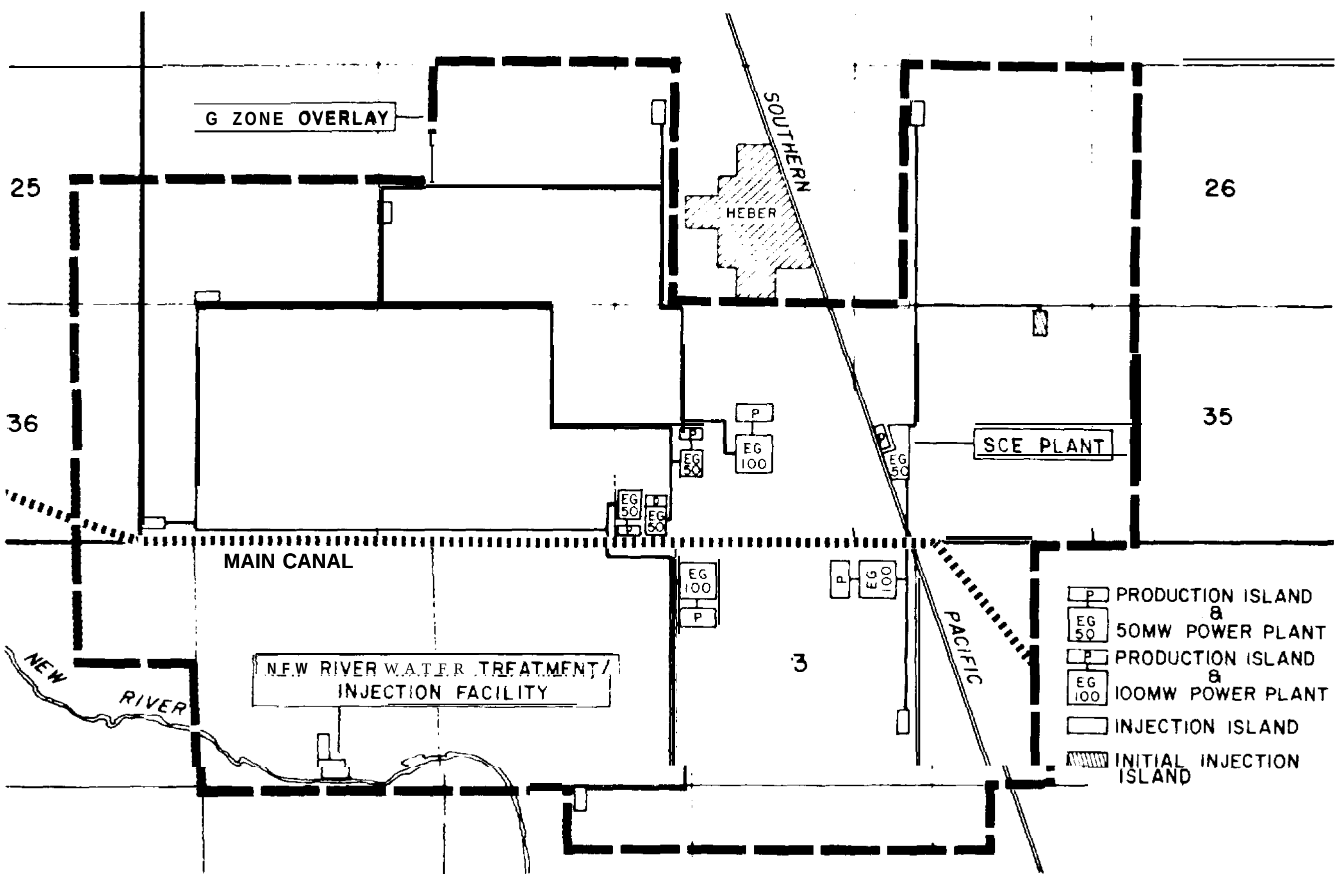



FIGURE 7. PRELIMINARY DEVELOPMENT PLAN- HEBER GEOTHERMAL FIELD.

Chevron signed a fuel sales contract with Southern California Edison Company in November 1978 to supply 2-phase geothermal fluid from the Heber Unit area to a 50 MW gross double-flash power generation plant to be built by Edison. A startup date in early 1982 is planned for this--the first large commercial, privately financed, hot water geothermal power plant in the U.S. Field development is expected to occur in 50-100 MW increments with the total development of 500 MW being targeted for completion in 1989.

## ACKNOWLEDGMENTS

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