RAFT RIVER GEOTHERMAL RESERVOIR ENGINEERING AND WELL STIMULATION

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In 1973 the Idaho National Engineering Laboratory (INEL) was funded by the Energy Research and Development Administration (ERDA) to pursue a program of research and development into the geothermal potential of the Raft River Valley, Cassia County, Idaho. A cooperative effort was then undertaken involving Aerojet Nuclear Company, U.S. Geological Survey, State of Idaho, and the Raft River Rural Electric Cooperative.

The basic geological investigations (principally the USGS) were completed in late 1974. A meeting was then held to present all available data and select a drilling site for RRGE-1. The site was finally located in the middle of Section 23, R26E, T15S. The second site, RRGE-2, was located in the extreme northeast corner of Section 23.

Geologic Structure

The Raft River Valley is a typical downfaulted north-trending basin lying in the northern portion of the Basin and Range province. The basin is terminated on the north by the Snake River Plain of the Columbia River Plateau province. The major local structural control consists of the Narrows structure (NE-SW) and the Bridge Fault (N-S) as depicted in Fig. 1.

RRGE-1 and RRGE-2 Wells

The Raft River Valley is composed of young alluvium derived from the surrounding mountain ranges, tuffaceous silt and clay of the Raft Formation; tuffaceous silt and sandstone of the Salt Lake Formation and quartzite and quartz monzonite of the Pre-Cambrian basement complex. Cross-sectional views of RRGE-1 and RRGE-2 are shown in Figs. 2 and 3.

The essential information pertaining to both wells is listed below

		RRGE-1	RRGE-2
1.	Drill start date	1-4-75	4-27-75
2.	Drill completion date	3-31-75	6-27-75*
3.	Average flow	650 gpm	800 gpm
4.	Maximum bottom temperature	294°F (146°C)	297°F (147°C)
5.	Total depth	4989 ft.	5988 ft*
6.	Main production	4350-4900 ft	4300-5000 ft
7.	"Hot" shut-in pressure	~11 atm	~10 atm

*RRGE-2 may be deepened by 500 feet in an attempt to further enhance natural artesian production.

Reservoir Engineering

1. Downhole Logging

Several standard and special well logs were run in both wells and include the following:

temperature, caliper, natural gamma, compensated neutron-formation density, dual induction-laterolog, spontaneous-potential, dipmeter, compensated gamma density, sonic, televiewer, and flowmeter.

2. Cor ng-Sample Testing

Sev ral cores were taken at different depths in both wells. Permeability varies from 0.002 millidarcies for tight caprock to 5-10 millidarcies for some producing tuffaceous sediments as measured under "in situ" condition. Further pressure testing of the aquifer have included fracture permeability and indicate much higher aquifer permeability.

3. Flow Testing

Both RRGE-1 and RRGE-2 have undergone extensive flow testing over extended periods of time (5 weeks at 200-400 gpm). RRGE-2 discharges approximately 800 gpm just prior to reaching the flash point at the surface, starting from a subcooled condition. Once flashing begins, the back pressure generated is a result of the discharge nozzle configuration and determines the total mass flow. For instance: with 275°F outlet temperature at the wellhead, the maximum natural flow is only about 400 gpm with the present piping and flasher-separator equipment.

The water quality remained very constant during the extended flow testing averaging 2,000 ppm solid content.

A downhole temperature recorder was run in RRGE-2 several times under flow and static shutin conditions. Under static conditions, the temperature was 290°F at the bottom of the casing (4230 ft) and 297°F at the bottom of the well (5988 ft). Prior information had indicated very little production from below 4800 ft. Such a temperature gradient represents an unusual situation for a non-producing zone. The gradient of 7°F/1758 ft is much less than even a normal gradient of 2°F/100 ft that one would expect. This anomaly may be the result of a "hot plate" effect near the bottom of the well, with circulation above that is apparently not entering the well to any great extent below 4800 ft.

4. USGS Data Correlation

The coring, logging, and drilling information provided the data necessary to make a correlation between the well lithology and the USGS geophysical data acquired in the area. The well information agreed totally with the interpreted geophysical data except for the basement rock type. it was logically inferred, from geophysical data, that the basement rock would be Paleozoic sediments. However, the Paleozoic rock sequence, as well as Mesozoic, are apparently missing within the basin.

5. Well-Killing Technique

RRGE-1 was drilled into the production zone before the production casing (13-3/8 in.) was emplaced. This necessitated "killing" the artesian flow from the well in order to install the casing. Cold water injection into the well proved unsuccessful in stemming the flow. The well was filled with 881 ft of sand and a cement plug (120 ft) installed which allowed casing to be set.

Reservoir Modelling

From the limited data, it would appear that the majority of geothermal water originates in the Almo Basin (next valley west of Raft River) and feeds a large reservoir in the Raft River Valley. Only about 22% of the annual precipitation in the Almo Basin can be accounted for by surface runoff. Further investigation is continuing to affirm this model.

Power Plant Development

Geothermal power plants operating from medium temperature (about 150°C) water can be expected to generate 1 MW (net electric) for every 250,000 lb/hr of geothermal water (the best of wells can be expected to produce 1 million lb/hr. or 2000 gal/min. or 120 liters/sec). Normal well spacing will dictate that a power plant feeding from a 4 to 10 square mile area of reservoir might generate typically 50 MW(e). A larger plant module will pull from a still larger area, needing longer pipelines, and offsetting any cost advantage of lower unit cost of the power plant equipment. Thus, it appears that 50 MW is the nominal optimum size. Such a plant will be rejecting 300 to 400 MW of waste condenser heat; and the question is how to best accomplish this rejection of heat. Once-through condenser cooling from the near surface cold water aquifer seems a likely method. The net effect would then be transfer of heat from the geothermal aquifer to the near surface aquifer, except for 10 to 15% converted to electricity. The efficiency of the power plant would be significantly improved as the condenser operated at 20°C instead of 35 to 45°C as with cooling towers.

Reservoir engineering *of* the withdrawal and reinjection from the cold water aquifer has received as much attention in the Raft River Program as the reservoir engineering from the geothermal aquifer. Fortunately, nature usually provides more and larger cold water aquifers than geothermal aquifers, so solving the condenser cooling requirements should not be as difficult as supplying the heat input to the plant. It should be noted that such once-through condenser cooling is only pertinent for small power plant modules (approximately 50 MW). For instance, a 2000 MW(th) heat rejection requirement such as that of a large nuclear plant would need to draw and reinject from too large an area to make piping the water an economic practicality in most situations.

Well pumping tests have been conducted over the last year, from which transmissivity and storage coefficient have been determined. Application of these to a digital computer reservoir model show that the cooling requirements for a 50 MW power plant can be supplied with a well pattern that has drawdowns and "drawups" (from reinjection) of less than an atmospheric equivalent pressure head over many years of operation.

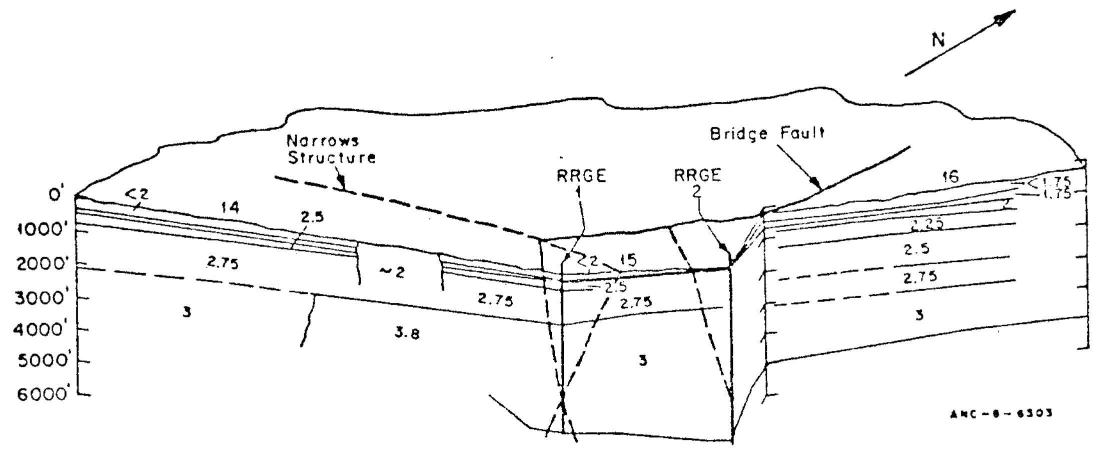
Well Stimulation

1. Water Drilling - drilling with water through the production zone in both wells has proven highly successful. This method has eliminated the possible sealing of the production zone by mudcake.

2. Hydrofracturing - RRGE-l was subjected to limited hydrofracturing employing the drilling rig mud pumps at 550 gpm and 1400 spi for short periods (up to 3 hours). No noticeable effect was observed in increased production.

3. Drill Stem Testing - a drill stem test was conducted on RRGE-2 at the bottom of the hole (4247 ft) before production casing was installed. The test showed no flow from the bottom 90 ft of the hole. Drilling was conducted using mud to this depth. Immediately upon drilling deeper with water, flow was encountered.

4. Side-Track Drilling - investigation is being conducted at present to evaluate the potential production benefits to be derived from drilling two and three holes off the main hole.



SECTION B-B

Fig. 1 Geologic Structure, RRGE-1 and RRGE-2, Raft River Valley, Idaho

RRGE NO. 1

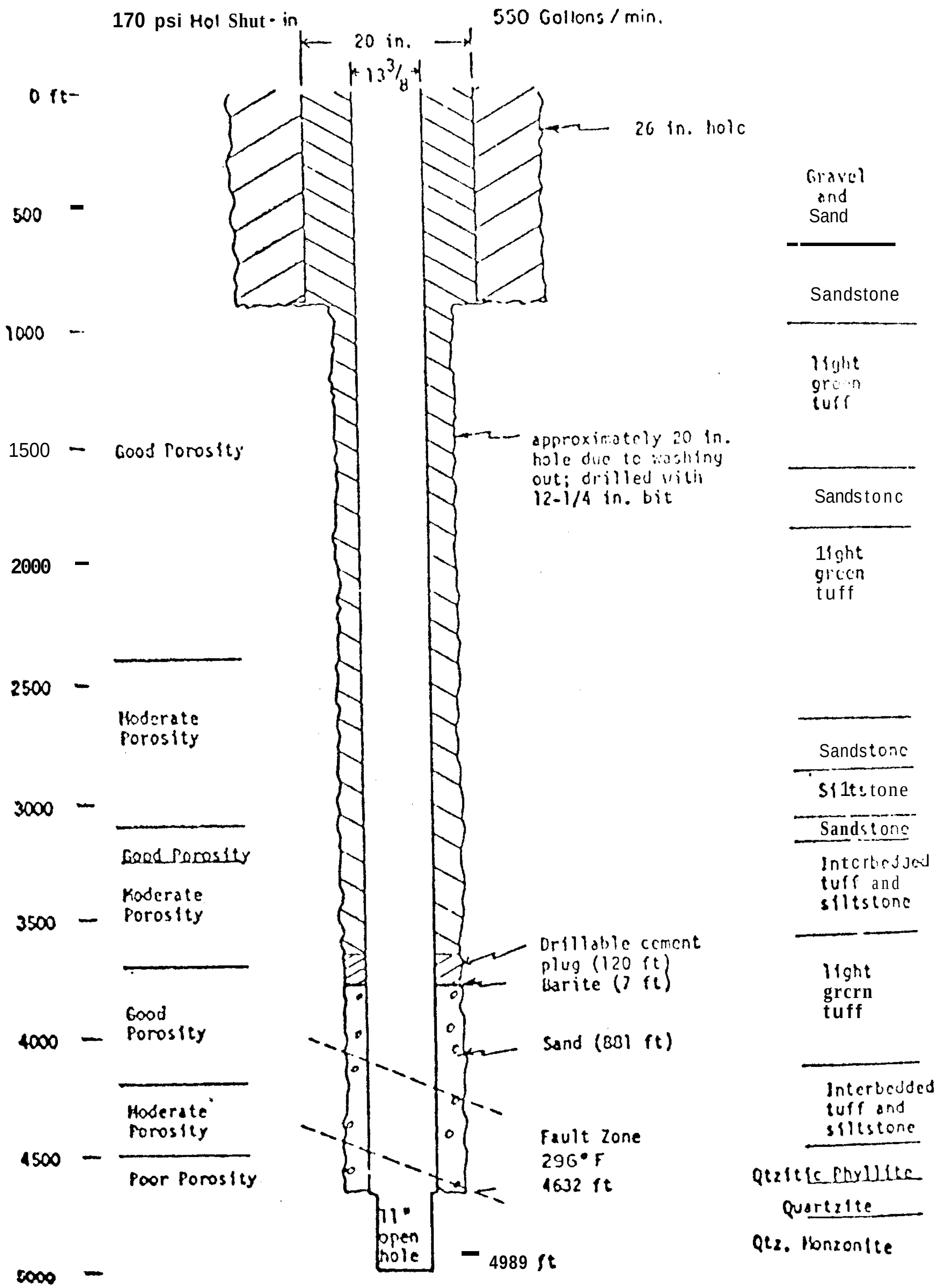


FIGURE 2.

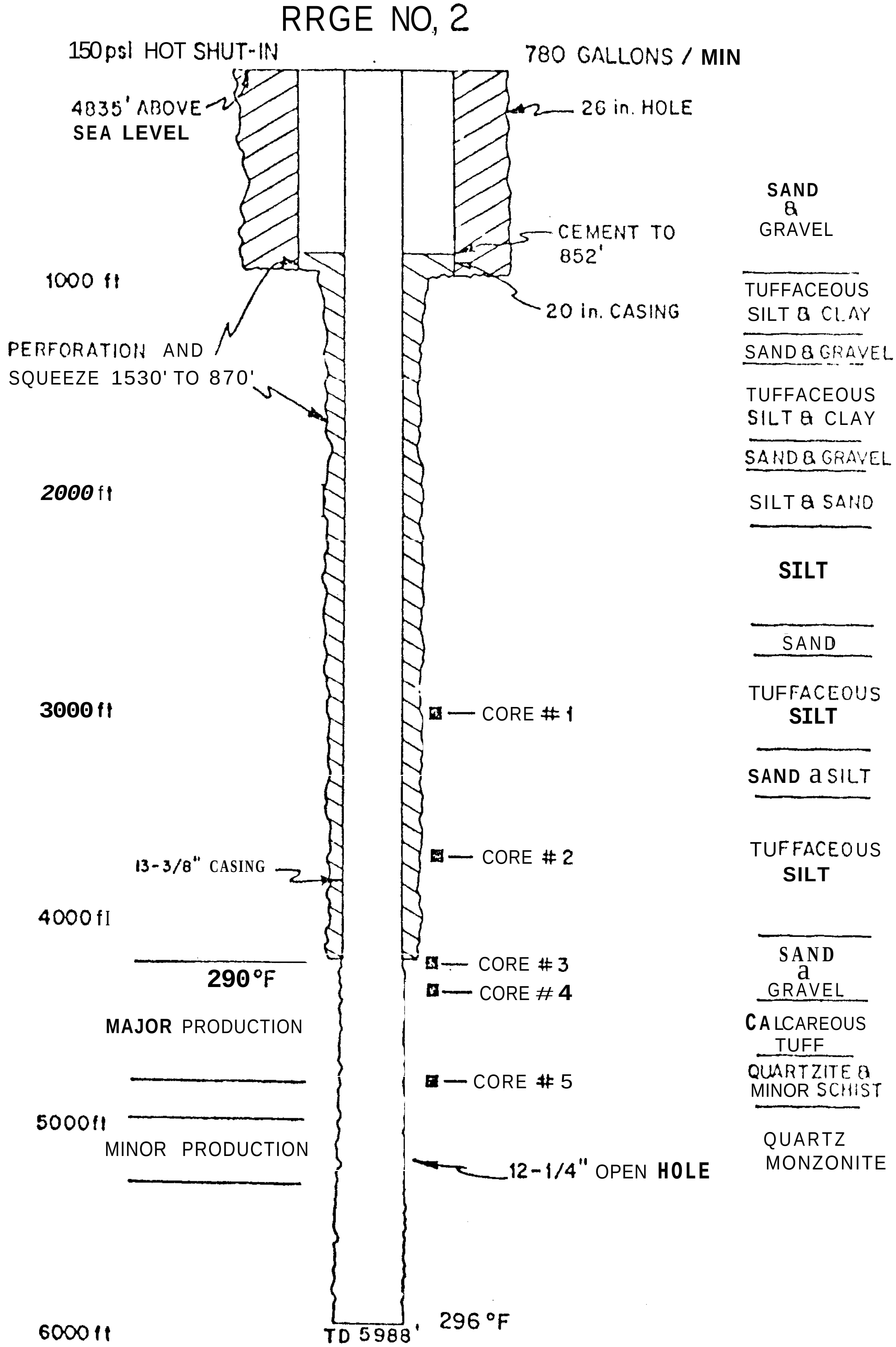

RRGE NO, 2
150psl HOT SHUT-IN
780 GALLONS / MIN
4835' ABOVE SEA LEVEL
26 in. HOLE
CEMENT TO 852'
20 in. CASING
PERFORATION AND SQUEEZE 1530' TO 870'
1000 ft
2000 ft
3000 ft
4000 ft
5000 ft
6000 ft
CORE # 1
CORE # 2
CORE # 3
CORE # 4
CORE # 5
13-3/8" CASING
290°F
MAJOR PRODUCTION
MINOR PRODUCTION
12-1/4" OPEN HOLE
TD 5988'
296 °F
SAND & GRAVEL
TUFFACEOUS SILT & CLAY
SAND & GRAVEL
TUFFACEOUS SILT & CLAY
SAND & GRAVEL
SILT & SAND
SILT
SAND
TUFFACEOUS SILT
SAND & SILT
TUFFACEOUS SILT
SAND & GRAVEL
CALCAREOUS TUFF
QUARTZITE & MINOR SCHIST
QUARTZ MONZONITE

FIGURE 3.