

STUDIES ON THE 3-WELL RESERVOIR SYSTEM IN RAFT RIVER

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The geothermal reservoir at Raft River, Idaho, was penetrated with a third deep well in the spring of 1976. The information deduced from this well and the subsequent testing of all three wells is presented in this report. This supplements the paper presented at the 1975 Reservoir Engineering Conference (1), which discussed in detail the experiences with the first two wells (5000 ft and 6500 ft deep, respectively, 4000 ft apart). Figure 1 shows the location of these wells, and the pipeline between them.

The Third Well

The third well, about 7000 ft southeast of the other two, was drilled with water and rather thoroughly tested on the way down until it appeared the resource of the desired temperature had just been entered. Casing was then installed (before the well became too difficult to handle) and drilling proceeded into the resource again with water. However, the well was initially a poor (<100 gal/min) producer from depth.

It has been planned to dig several channels at depths below the casing, each at a 10° to 15° angle away. Calculations had indicated that up to 50% increase in flow might be expected if the second channel could be 300 to 400 ft separated from the first in the main producing zone. It was decided, nevertheless, to try the technique on this poor producer. Shortly after beginning the second channel (from 4500 ft depth), the well began to produce significant artesian pressures. Yet a third channel was drilled, and after completion the well developed artesian flows of 800 gpm (51 liters/sec) initially. Flow was 350 gpm when steam flashing choked the flow in the well bore.

(1) Raft River Geothermal Reservoir Engineering and Well Stimulation, J. F. Junze, L. G. Miller, and R. C. Stoker, page 117 of SGP-TR-12, December 15-17, 1975 Conference.

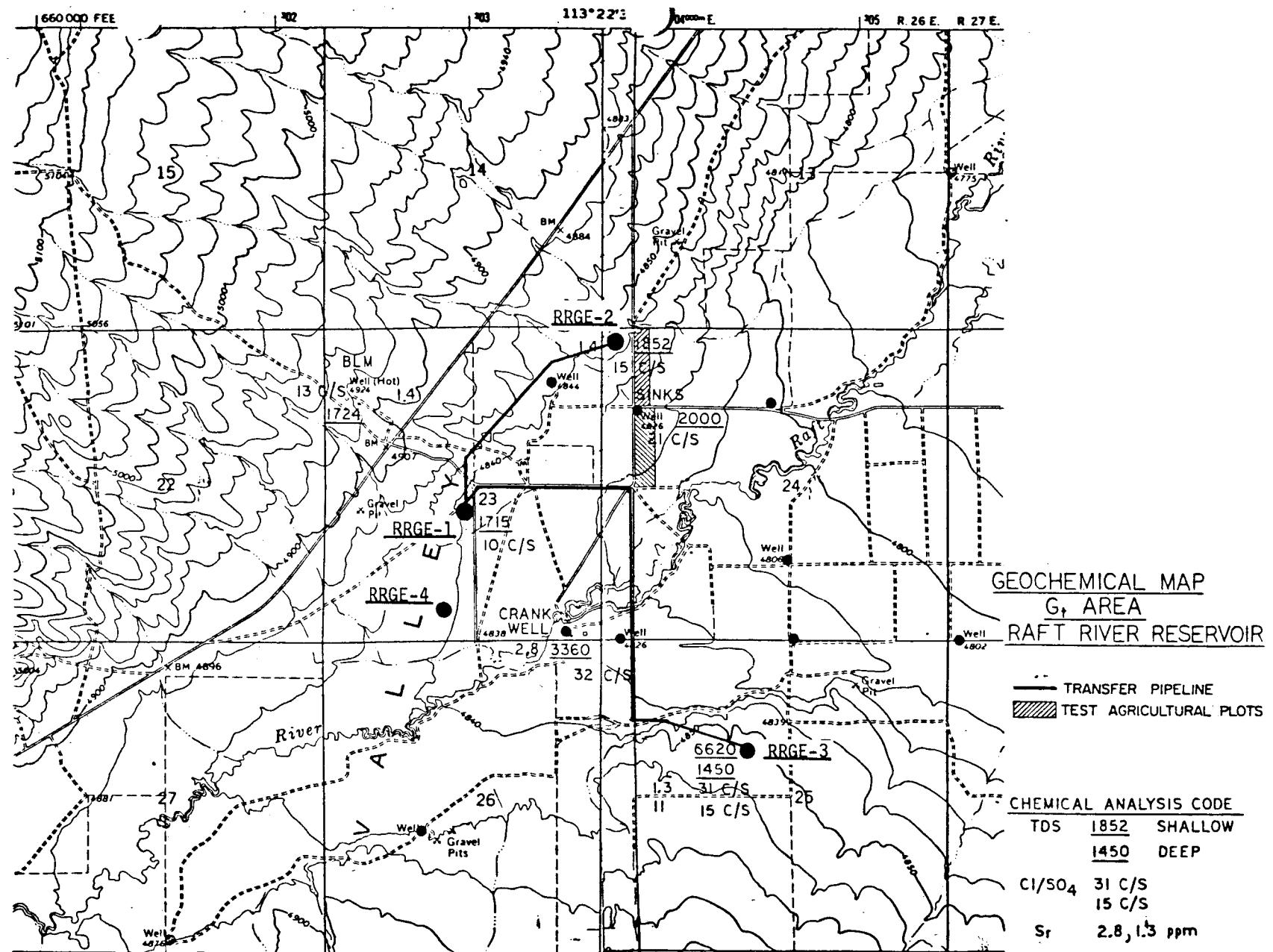
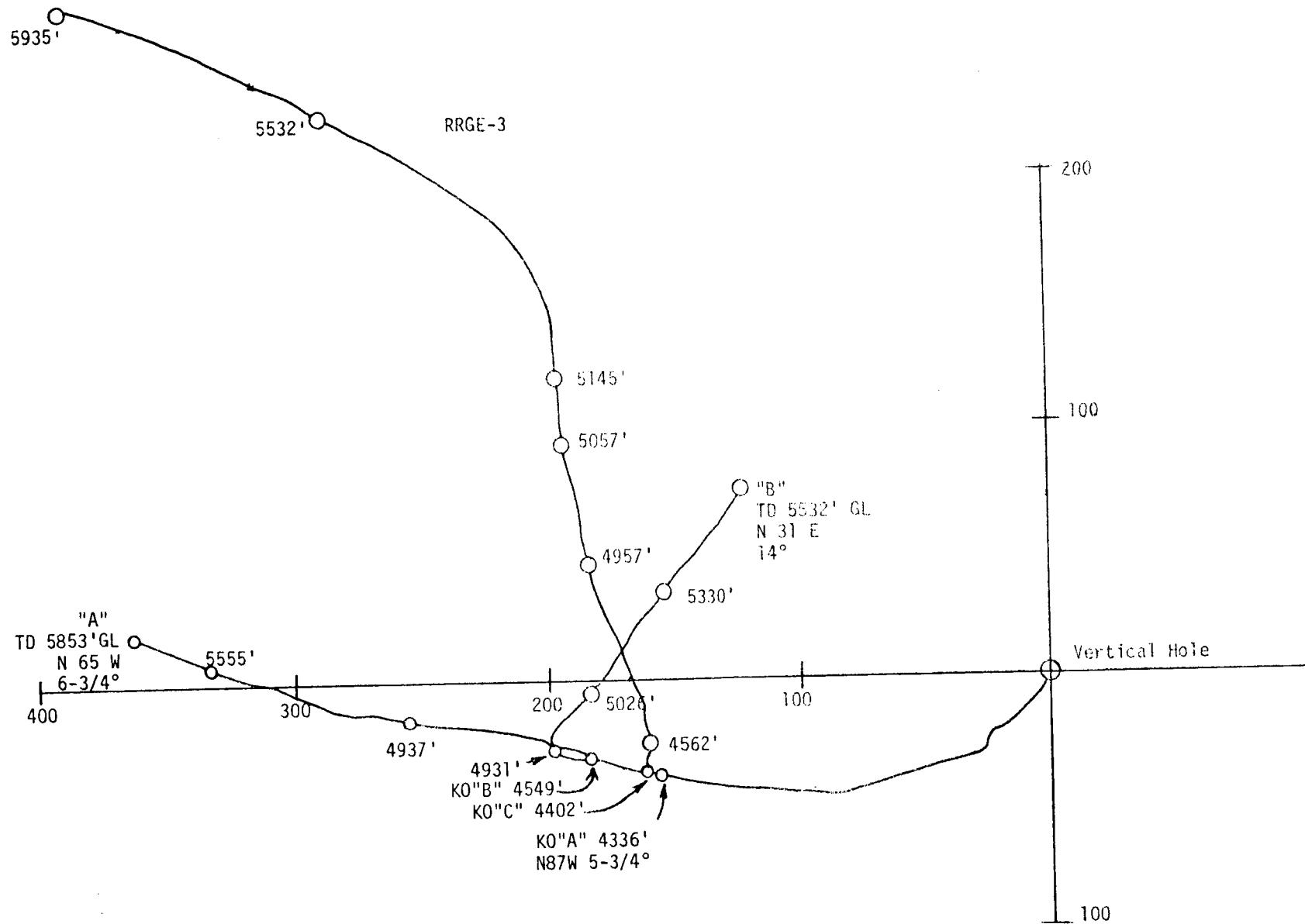


FIGURE 1

FIGURE 2.



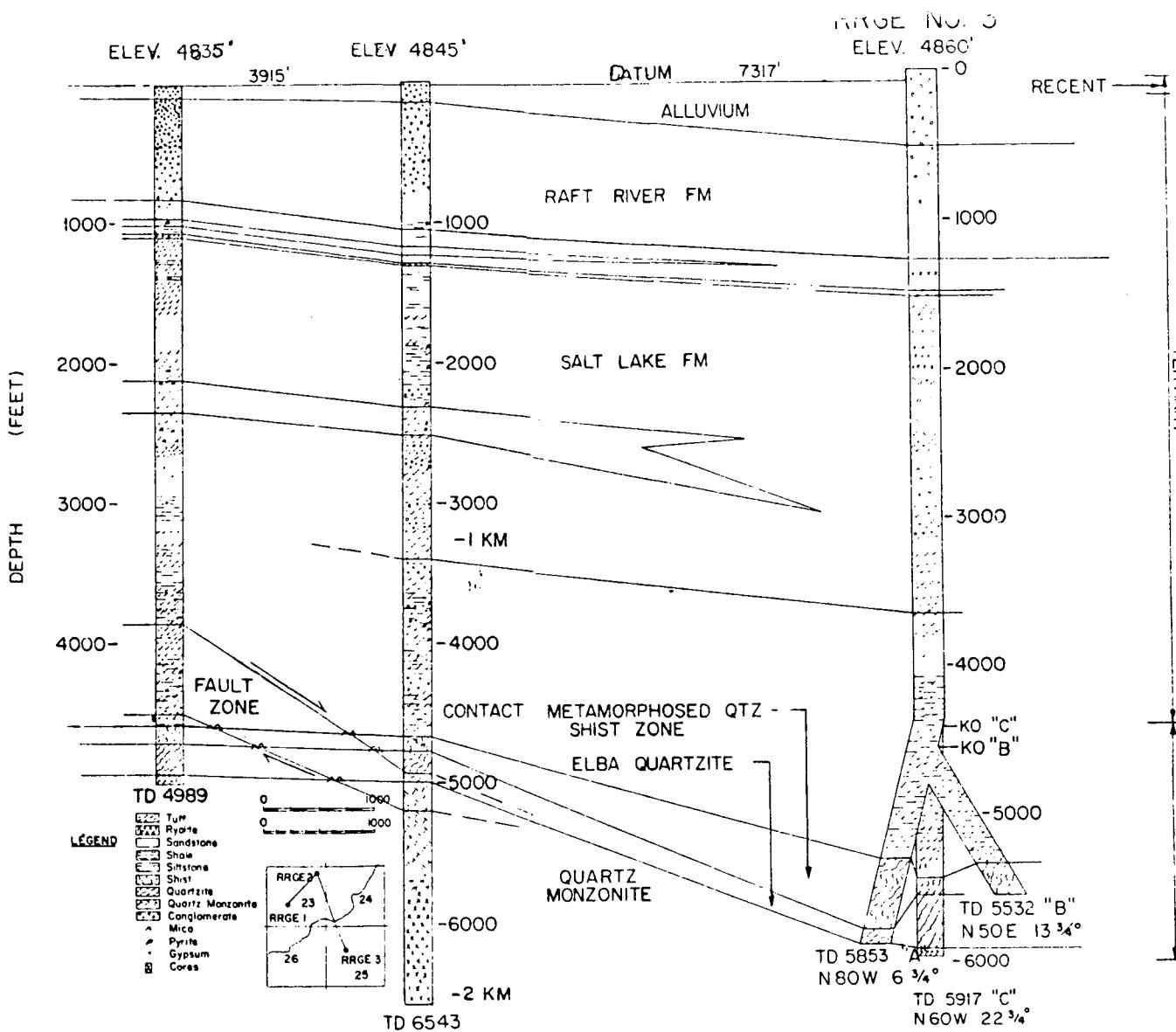


FIGURE 3

Figure 2 shows a cross section of this well, in comparison with the other wells. Figure 3 shows the paths of the three channels of the third well, shown on a horizontal projection.

Logging, Coring, and Reservoir Analysis

A full complement of the standard logs was taken on each well. Though neutron and sonic logs give some clue (after the fact) of where the production zones might be, there is still no reliable correlation to use such logs to indicate producing regions prior to running production casing. (In the case of fracture permeability, the well must be left open hole or slotted casing installed.) Perhaps the main difficulty is that to date it is not positively known where the producing zones are. Flow meters from a number of organizations have failed to work in the down hole environment. Re-injection of cold water into formation has, where done, given clues from resulting temperature logs where the formation is taking water. These might correspond to the producing zones.

A number of simulated in situ permeability measurements were taken on the cores withdrawn. The results varied by several orders of magnitude, even from samples a foot apart. This further supports the contention that the production is from fractures and not from homogeneous permeability.

Well down hole pressure response has been measured, both in the producing wells and in the other two wells, for several combinations of the producing well. From the data the product of permeability and reservoir thickness has been calculated, where definitive results were obtained.

Wells #1 and #2 communicate quite readily with each other, with an observable pressure drop within six hours of flowing the other well. Drawdown of 3.6 psi was observed over a month of flowing the other well at 400 gpm.

On the other hand, well #3 appears to be communicating very poorly with the other two. Over a two-month period of flowing well #1 continuously (180 to 350 gpm) and well #2 intermittently (180 gpm for 4 weeks), the well #3 observed only a total drop of 1.3 psi. It also exhibits notably different chemistry than the first two. RRGE #1 and #2 have 2000 gpm dissolved solids, while RRGE #3 has nearly twice this amount.

Summary

The Raft River producing formation itself is tight (low permeability) except for fractures, which are the key to getting

adequate production from its wells. To the extent this area is typical of western valleys, the experience in discovering and extracting the resource is instructive. Since one never knows in advance where the resource is, drilling it with water is essential. Though drill stem testing should overcome the effects of a mud column, the test involved dangers of hole collapse and may be testing a region of no fractures (as occurred in RRGE #2 on a test of a 100 ft column just above the region that first started producing). The advantage of a light density column of drilling fluid, whether water or aerated water, should not be underestimated in allowing the geothermal fluid to enter the hole during drilling.

The variable nature of the distribution of the fractures makes it appropriate to consider multiple channeling below the production casing. Each such directionally drilled channel adds only 10 to 15% to the total well cost, and can mean the difference between a successful producer and a failure. Such channels can also provide an increment to total flow in a homogeneous formation exceeding the incremental cost increase.

To date, logging methods during drilling are inadequate to tell where the resource is. The expense is usually prohibitive for maintaining a drill rig over the well while it is tested adequately prior to a decision on casing the well or drilling further. For this reason, a light drilling fluid that will not even temporarily block the fractures is important. Multiple channeling in the case of Raft River was undertaken in a relatively consolidated region, and the use of only water did not involve problems of hole stability.

The producing zones in the wells have been inferred indirectly from temperature profiles taken after the re-injection of cool water. Further attempts at use of flow meters will be made. Currently, the following conclusions about the individual wells producing zones can be drawn:

1. Various producing zones from 3700 to 4600 ft. No production below 4600 to T.D. at 5000 ft, this latter 400 ft being quartzite and quartz monzonite.
2. Principal producing zones at 4400, 4900, 5200, 5800, and 5900 ft. Essentially no production below. The principal production appears to be at 4400 and 4900 ft, before reaching quartz monzonite.
3. Production from 4500, 4900, 5300 and 5400 ft depths; most of these are fractured zones in the Pre-cambrian.

Re-injection experience with the wells shows almost a direct comparison with the production flow and pressure data, i.e., 400 psi pressure to re-inject 1200 gpm to 1500 gpm typically. None of the three wells was designed specifically for re-injection. Current preference is that such a well should consider regions of good permeability not only in the main producing reservoir but somewhat above it in the mixing zones where already lower temperature water exists. Reduced pumping costs for re-injection are a major emphasis for future efforts.

None of the wells has had the opportunity to be fully developed for long periods of flow, and likewise to be monitored to confirm the deduced Theis Equation parameters reported above from short flow periods. The reason is simple that environmental considerations have necessitated disposing of the water in places other than the surface waterways. For a while the No. 2 well was used to inject over 8 million gallons of cooled geothermal water that had been stored in the reserve pit for a long period of time. Presently this well is being flowed in attempts to restore it to its former production characteristics. Tables I and II list the characteristics known about the wells at this time.

TABLE I

NOMINAL WELL FLOW CHARACTERISTICS
(Values in gallons/min of water)
Artesian

<u>Well</u>	<u>Initial, Cold</u>	<u>Steady State Hot and Flashing</u>	<u>Pumped</u>
No. 1	600	350 +	870 with 450 ft drawdown
No. 2	800 * (200)	400 ‡ (350)	---
No. 3	800 +	350	---

* Recently, since its use to dispose of 8 million gallons of cold water.

TABLE II
WELLHEAD PRESSURE CHARACTERISTICS

<u>Well</u>	<u>Condition</u>	<u>Pressure</u>
RRGE-1	Cold	~50 psig
	Quiescent	146 psig
	Hot	175 psig
RRGE-2	Cold	~60 psig
	Quiescent	129 psig
	Hot	165 psig
RRGE-3	Cold	~40 psig
	Quiescent	100 psig
	Hot	140 psig