INJECTION AT RAFT RIVER - AN ENVIRONMENTAL CONCERN?

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ABSTRACT

Injection is an acceptable disposal method for geothermal fluid; however, use of injection can be limited by environmental considerations. This is the case in Raft River. The primary concern is that injection will affect either the quality or quantity of irrigation water in the closed groundwater basin. Data indicate that there is a natural migration of geothermal fluids into shallower aquifers and this migration is thought to be fracture-controlled. A series of wells have been drilled to monitor the response of shallow aquifers to intermediate-depth injection. Several of these monitor wells have shown marked pressure response to injection in RRGI-4 and RRGI-6. These data will be used to evaluate both current injection practices and fluid disposal alternatives in Raft River.

INTRODUCTION

Injection is considered one of the most environmentally acceptable methods of geothermal fluid disposal. While minimizing the potential for contaminating surface water, injection also reduces the risk of subsidence, and may prolong the life of the resource by partially maintaining reservoir pressure. Injection must be suited to site geology, hydrology, and environmental constraints. The Raft River geothermal development site is an area where injection options may be severely limited by environmental considerations.

The geothermal resource in Raft River is being developed by the Department of Energy (DOE) to demonstrate the feasibility of utilizing a moderate-temperature resource for power production and various direct-use applications. Seven production and injection wells, ranging in depth from 1176 m to 1994 m, have been completed since drilling began in 1975 (figure 1). The 150 l/s required to operate the 5-MW(e) binary power plant will be supplied by four wells - RRGE-1, RRGE-2, RRGE-3, and RRGP-5. Two injection wells, RRGI-6 and RRGI-7, are located approximately 2.5 km southeast of the main production field. The injection wells were completed so that the injection zone is at depths of 520 to 1180 m, while production will be from deeper zones. The "intermediate" injection is designed to (1) reduce the possibility of injected fluids short-circuiting the system, (2) recharge the geothermal resource, and (3) reduce well construction and pumping costs.

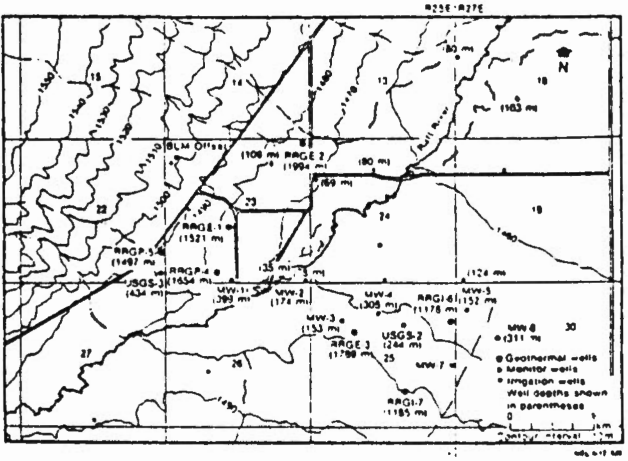

Fig. 1 Location map - geothermal and monitor wells.

ENVIRONMENTAL CONCERNS

In 1963, the State of Idaho closed the Raft River basin to further development of groundwater resources, due to declining groundwater levels. This closure currently includes the geothermal resource and limits geothermal development to the extent that neither the quantity nor quality of irrigation waters can be adversely affected. Recently proposed federal and state regulations control injection practices and require evidence that the injected fluids will not migrate to potable water sources. Geophysical and geochemical evidence suggests that the Raft River resource is fracture-controlled, with primary production related to two major fracture systems through which geothermal fluids probably move. Fluid temperatures of 100°C have been encountered at depths as shallow as 125 m.

The two main questions regarding geothermal development in Raft River are: (1) Can 25 l/s of geothermal fluids be consumptively used in the 5-MW plant process under the restrictions of the basin closure? and (2) How can the spent geothermal fluids be disposed of without adversely affecting shallow groundwater systems?

The presence of hot water at depths of 100 m and an analysis of the water quality in shallow domestic and irrigation wells indicate that, locally, geothermal fluids migrate naturally into shallow aquifers. As can be seen in table 1, water quality in the injection receiving zones is such that chemical contamination of these zones is not a concern. However, injection may increase pressures in the disposal horizons to the extent that increased volumes of fluids may migrate to the shallow aquifer system. This could lead to a temperature increase and a decline in water quality in the shallow aquifers. The fluoride levels and sodium values are the major water quality concerns.

Table 1. Chemical analyses of Raft River geothermal wells

	RRGE-1	RRGE-2	RRGE-3	RRGP-4	RRGP-5	RRGI-6	RRGI-7
Na	469	331	1245	718	179	2,020	2,100
K	33	31	103	---	34	32	---
Ca	53	32	127	81	50	199	315
Sr	1.4	0.8	5.2	---	1.2	8.0	---
Mg	0.6	0.7	1.0	---	0.5	1.4	1.6
Li	1.6	1.0	3.4	---	1.6	5.1	---
Cl^-	709	701	2116	1370	590	3,636	4,085
F^-	5.7	7.9	3.7	6.4	6.2	5.8	4.9
$SO_4^=$	40	29	44	---	40	60	64
HCO_3^-	34	42	26	35	40	62	26
SiO_2	134	155	158	---	136	91	83
TDS	1607	1161	4280	---	1481	6,330	---
Cond. (us/ml)	2987	2157	7997	4000	2857	11,594	12,000
pH	7.3	7.6	7.2	7.0	7.5	7.3	

The spatial polarization of production and injection wells may also lead to significant changes in shallow groundwater levels. If pressure declines around the production wells are not balanced by pressure increases at the injection wells, interconnection between the deeper and shallow aquifers may result in shallow groundwater declines in the vicinity of the production wells and water level rises around the injection wells. Water level declines in shallow aquifers could lead to compaction of unconsolidated sediments, a mechanism thought to be responsible for subsidence of up to 0.9 m in the lower Raft River valley (Lofgren, 1975). In areas of water level decline, an additional consideration is the economic hardship imposed on local irrigators.

MONITORING PROGRAM

Because of the difficulty in assessing the degree of interconnection between aquifers in Raft River, all available geologic, hydrologic, and geochemical data are utilized in attempts to predict long-term impacts of geothermal development. Data have been collected on water levels and water quality in local irrigation wells; however, uncertainties about the construction and operation of these wells limit the usefulness of the information for predictive purposes.

To provide more information about the shallow and intermediate aquifers, a network of monitor wells has been established. To date, seven monitor wells, ranging in depth from 150 to 400 m, have been drilled (figure 1). These wells were located to monitor the effects of injection into what was RRGI-4 and into the current injection wells, RRGI-6 and RRGI-7. Three USGS holes (USGS-2, USGS-3, and BLM offset) and four 30-m water table wells near RRGE-3 and RRGP-5 are also used in the monitoring program. Each of the monitor wells is cased to within 10 to 50 m of total depth so that selected aquifers can be monitored.

Conditions in the monitor wells vary with both depth and location and provide important information on the degree of communication between the geothermal system and shallower aquifers. MW-1 and MW-2 have the highest average temperature gradients (0.3°C/m), and MW-5, MW-6, and MW-7 have the lowest (0.1°C/m). MW-1, MW-2, and MW-4 are flowing at land surface, while the water levels in the remaining wells probably represent local artesian conditions. The water in MW-1 is some of the poorest quality water encountered in the area (TDS = 6300 mg/l). The water quality in MW-5 and MW-7 is very high, with total dissolved solids averaging 1300 mg/l and fluoride levels as low as 0.5 mg/l, indicating that these wells are probably not affected by natural communication from the geothermal system.

Because pressure or water level responses to hydrologic changes generally occur much more rapidly than resultant changes in water quality, the monitoring program emphasizes measuring wellhead pressure or water levels. MW-1 and MW-2 are equipped with digiquartz pressure transducers, a Bristol recorder is installed on USGS-3, and Stevens A35 or F water level recorders are installed on the remaining wells. MW-4 is equipped with a dual system because the water level is at ground level.

TEST RESULTS

Between March 21, 1978 and June 10, 1978, a total of 12,800 m³ of water was injected into RRGI-4 (open hole from 550 to 850 m), at rates ranging from 16 to 51 l/s. The longest injection test lasted for more than nine days, at an injection rate of 44 l/s. During this test, pressure increases of 34 and 97 kPa were seen in MW-1 and USGS-3, respectively, and the water level in the shallow BLM offset well rose over 1 m (figure 2). The responses at USGS-3 and the BLM offset well were much larger than expected and were larger than the wells' responses to seasonal hydrologic changes or to past geothermal development activity. The difference in the response magnitude between USGS-3 and MW-1 indicates that the intermediate aquifer system is both heterogeneous and anisotropic. Comparisons of well logs with known fracture systems indicate that USGS-3, BLM offset, and RRGI-4 penetrate the same fracture system at different depths, while MW-1 penetrates unfractured rock adjacent to the fracture system.

Following those injection tests, RRGI-4 was deepened to 1185 m and cased to 1070 m. MW-1, MW-2, and USGS-3 are now being used to monitor the response of the shallow aquifer to geothermal fluid production.

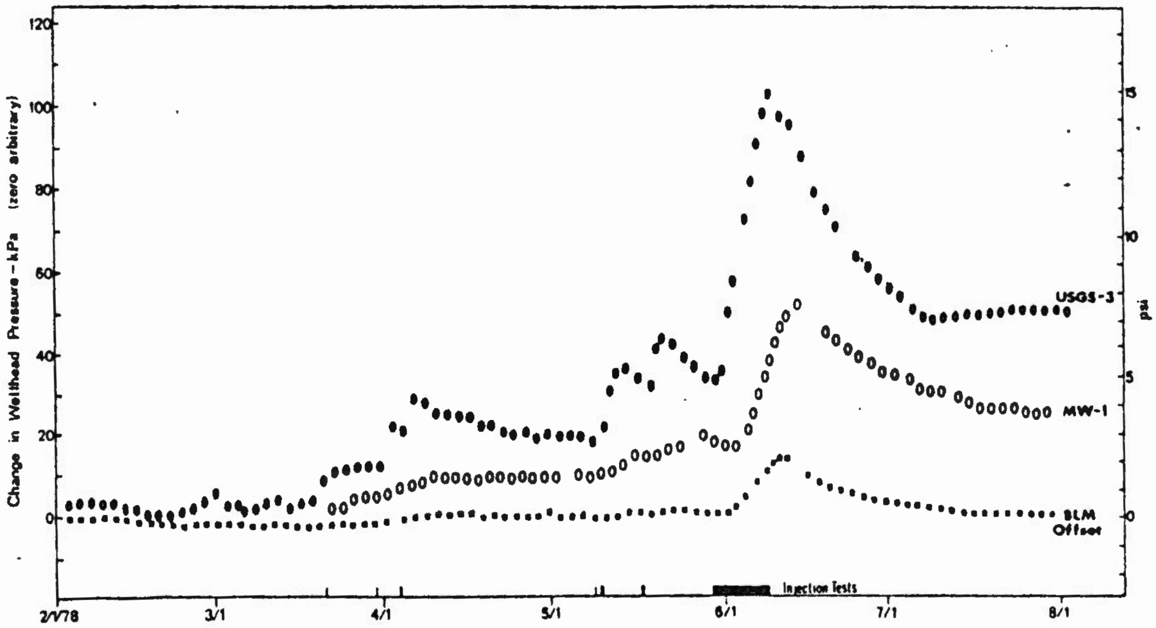

Fig. 2 Monitor well response to RRGI-4 injection tests.

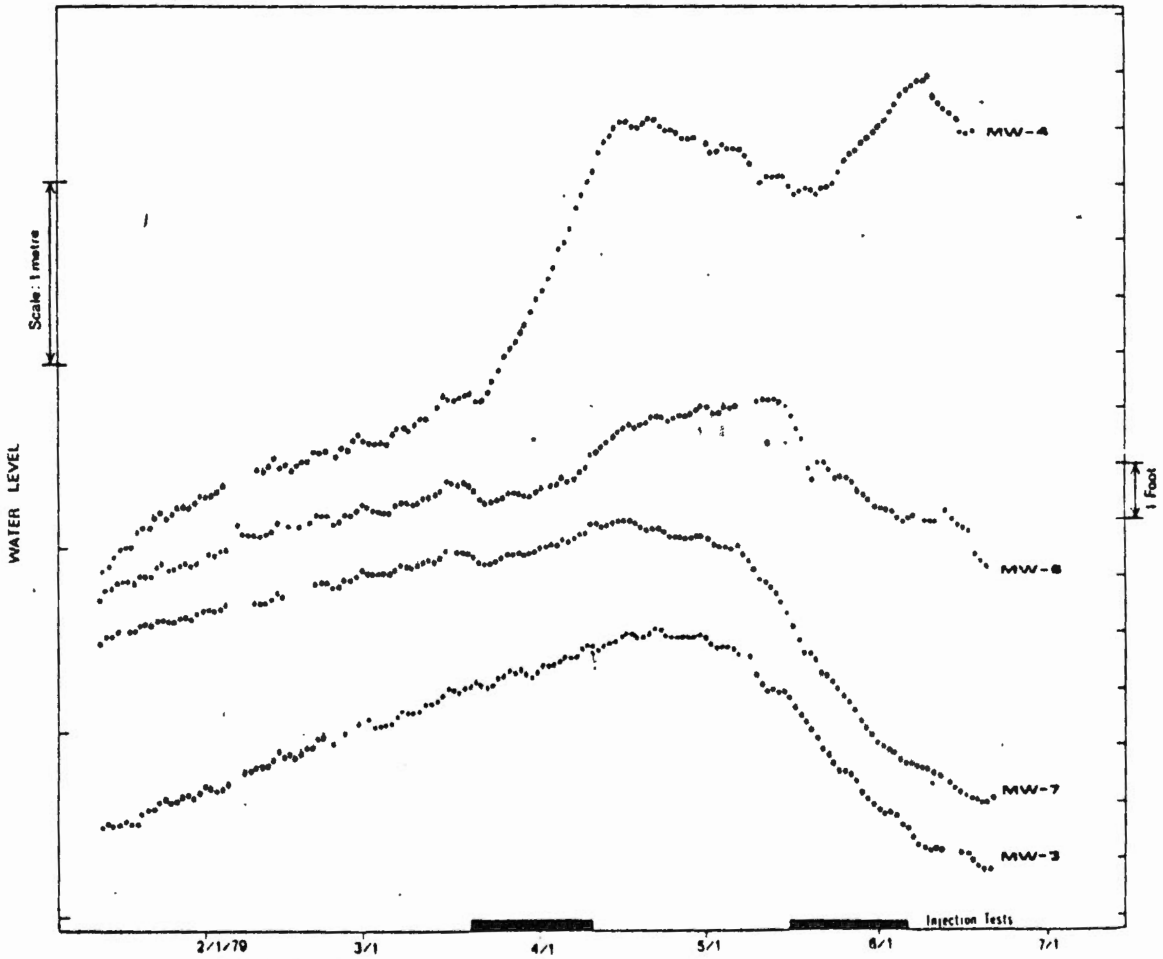

Fig. 3 Monitor well water level records - RRGI-6 injection tests.

The most recent injection tests have been conducted on RRGI-6, which is uncased from 515 m to its total depth of 1185 m. Water level records from the monitor wells during two 21-day injection tests are shown in figure 3. Only one well, MW-4, has shown definite pressure response to the injection. This response, corrected for background trends, averages 0.4 m per week, at injection rates of 38 l/s. The lack of response in MW-6 is, again, an indication that the system is fracture-dominated and traditional intergranular permeability analyses of communication are not applicable. USGS logging in RRGI-6 indicates that a significant fraction of the injected fluids leaves the borehole immediately below the casing. This zone corresponds to a major thief zone seen in nearly all the deep wells, and is probably a primary factor in the interconnection between the geothermal system and shallower aquifers.

Although true hydrologic responses in other monitor wells could not be identified during the injection tests, a water level decline and subsequent recovery corresponding to the beginning and end of the first 21-day injection was seen in MW-5, MW-6, and MW-7. This is thought to be a result of aquifer dilation and this theory will be tested through precise wellhead leveling during subsequent injection tests.

CONCLUSIONS AND FUTURE PLANS

The results of injection tests on RRGI-4 and RRGI-6 indicate a communication between the injection zone and shallower aquifers. As a result, other geothermal fluid disposal options are currently being evaluated. These include deep injection, low-pressure injection directly into the thief zone, and various methods of surface disposal. Stimulation of the injection wells is also being considered, and may increase the injectivity in deeper zones of the injection wells. Plans are being made to drill a dually-completed well, open at depths of 150 and 460 m, near RRGE-1, to test the feasibility of low-pressure shallow injection. Monitoring of long-term injection tests will continue. The results of these tests will determine the restrictions placed on injection and will provice a basis for evaluating the environmental and legal acceptability of excluding the geothermal resources from the basin closure.

REFERENCE

Lofgren, B. E., 1975, Land subsidence - tectonism, Raft River Valley, Idaho, USGS 75-585.