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RAFT RIVER INJECTION SYSTEMS EVALUATION STUDY

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October 1979

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INTRODUCTION AND SUMMARY

The objectives of this study are to present the alternatives available at Raft River for handling geothermal effluents, to evaluate the costs and impacts of those alternatives, and to propose the most cost-effective and environmentally acceptable means of disposing of the effluents.

The hydrologic system is described and injection requirements detailed. A matrix of the major alternatives considered is presented.

The recommended approach to meeting injection needs prior to plant startup is to drill and test the "thief zone" present from 1400 ft. to 2000 ft. If successful, two additional similar wells may be required. A secondary proposal, if the thief zone proposal does not yield anticipated injection results or should this well show significant pressure response, would be to drill an intermediate zone injection well. ?

BACKGROUND

The Raft River Hydrologic System

1st sentence bad geology

The Raft River geologic structure is a complex arrangement of faults buried by fluvial, lacrustrine, and continental sediments, tuffs, rhyolites, alluvial fans, and fan gravels of Tertiary & Quaternary Age. Fault exposures along the east side of the Jim Sage Mountains indicate the presence of high-angle normal faults, typical of Basin-Range tectonism. Other geologic interpretations suggest an "incompletely understood structural lineament" (the Narrows Structure)[1] intersecting the heart of the southern Raft River Valley; and "marked folding and great low-angle overthrust faults"[2] bounding the Valley on the east and west (Albion & Black Pine Ranges).

The only perennial stream in this part of the valley is the Raft River, which has an average discharge near the Narrows of 16.7 cfs. Discharge extremes for the period of record are 2.7 and 2060 cfs. The Raft River is considered to be a losing stream in the reach between The Narrows and Bridge.

Shallow aquifers in the valley have been developed for irrigation and are located in fan gravels, conglomerates, and sands of the Raft River Formation and the Upper Salt Lake Formation. Irrigation wells in this part of the Raft River Valley range in depth from 225 to over 500 feet. Some wells encounter moderately-warm to boiling waters (specifically the BLM and Crank wells). These wells have probably intersected fractures or conduits connected to the deeper geothermal resource.

Water quality in irrigation wells ranges from good to marginal for irrigation purposes. Very shallow wells (less than 150 ft.) produce water that is similar in quality to the Raft River (conductivity 1100 μmhos/cm, fluoride 1.0 mg/l). Conductivity averages 1600 μmhos/cm in deeper irrigation wells near The Narrows and near Bridge. Water quality in those irrigation wells near the geothermal development decreases markedly, indicating natural upward leakage from the geothermal system.

Little information is available on the water quality or hydrology of intermediate aquifers (1000-4000 ft). A major lost circulation zone has been noted at depths of 1500-2000 feet during the drilling of some of the deep geothermal wells. This zone may be an important factor in the upward leakage of geothermal fluids. No sections exist in the intermediate zone below this depth that can be identified as valley-wide aquifers. Some of the poorest quality water in the valley has been observed in this interval in wells RRGI-6 and RRGI-7 (conductivity 12,000 μmhos/cm).

The Raft River hydrothermal resource appears to be controlled by a complex network of faults and fracture systems. Matrix permeability has been found to be a minimal contributor to hydrothermal flow and typical matrix reservoir models cannot be applied to the Raft River resource. A summary of the production and injection characteristics will provide input to reservoir modeling which is designed to predict the long-term hydrothermal system behavior. This modeling and analysis may also provide some insight into the connection between the geothermal system and shallow aquifers and the factors which control that connection.

Current interpretations suggest that hot water in RRGE-1, RRGE-2, and RRGP-5 is produced from detached-normal fault zones near the base of the bedrock or Precambrain quartz monzonite. Primary production in RRGE-3 is probably from fractures associated with the Narrows Structure. (detached-normal) ?

Surface lineament features have been recently identified which provide an interpretation of geochemical observations noted across the field. These lineament features are projected on Figure 1. The east-west lineament is probably intersected in the RRGI-6 injection zone; while RRGI-7 may possibly be intersected by the NW-SE feature. The east-west feature may be a factor in the postulated upwelling of geothermal fluids near the Crook's well which is indicated by geochemical modeling.[3] called Crank well on previous page

The Injection Requirements

The injection needs of the Raft River Geothermal Pilot Plant and experiments are presented in Table 1. Differences exist between the produced fluid and the summation of injection and consumptive use due to density/viscosity effects of hot water (290°F) as compared to cooler water (150°F). A maximum injection capacity of 2900 gpm would be necessary, if all experiments were operational. A more likely figure of 2500 gpm is used as a target goal in this report. (See Figure 2).

All injection tests run at Raft River have been conducted at temperatures up to 270°F. The power plant effluent will have a temperature of 140-150°F. The effect of this temperature differential is that all previous injection capacity projections are high, due to either physical (density, viscosity) and/or chemical effects (calcite-silica deposition or montmorillonite alteration). Theoretical calculations of injection capacity, based only on density and viscosity, suggest the injectability of RRGE-6 and RRGI-7 to be 1700-1900 gpm total. It is obvious that the Raft River Injection System, as presently designed, cannot meet the effluent requirements. A deficiency of approximately 800-1000 gpm exists, which must be corrected if the plant is to be operational. ? ?

Based upon the limited data and theoretical assumptions made, it appears that injection of 150°F fluid into RRGI-6 and RRGI-7 may

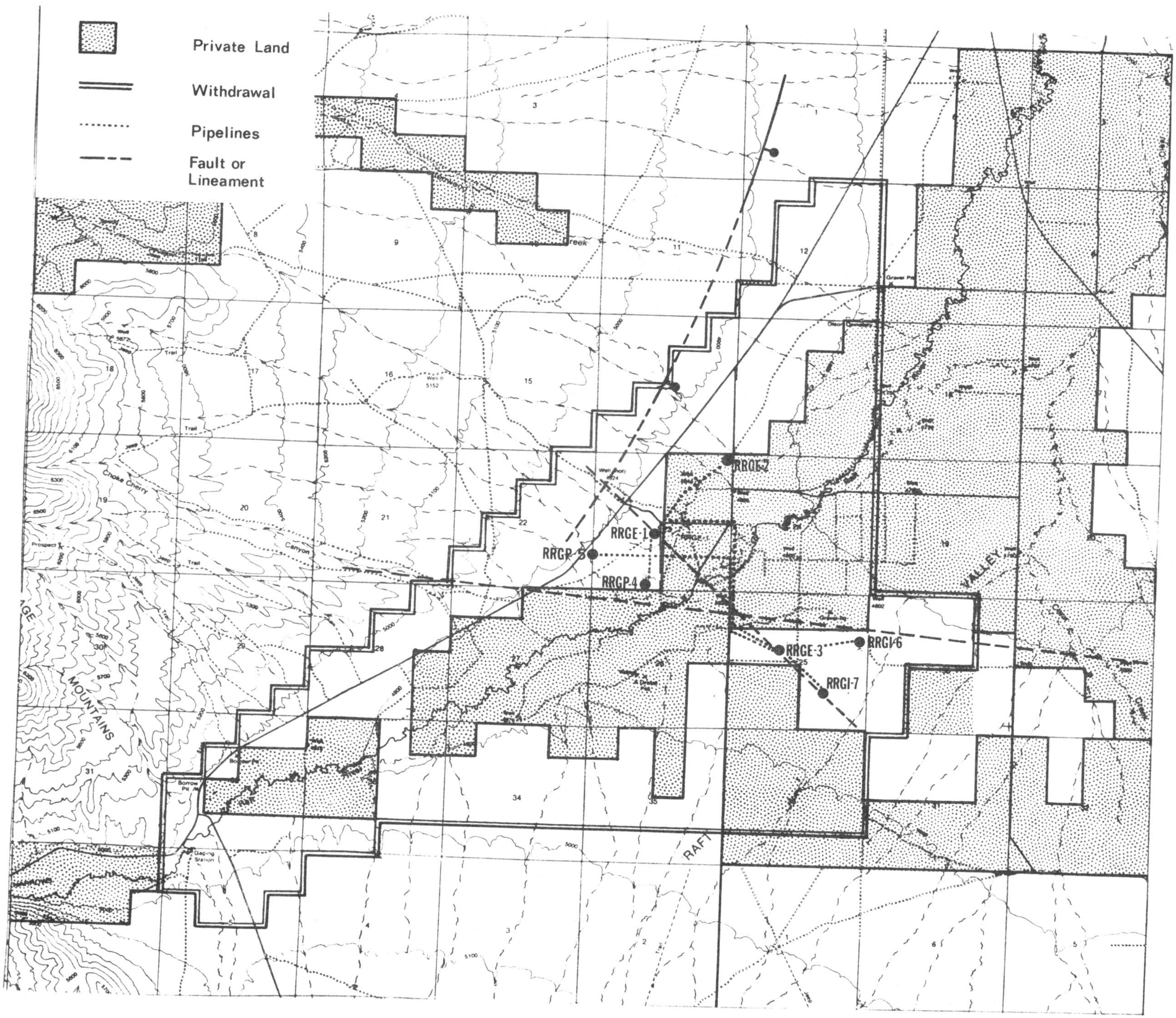

Figure 1 - Structural Geology, Land Ownership & Pipelines in Raft River Area

TABLE 1

Water Use

(gpm)

	Supply*	Consumptive Use**	Injection**
5MW(e)	2475	375 (Summer)	1960 (Summer)
		120 (Winter)	2210 (Winter)
Prototype	116	10	100
500 KW	370	50	300
Site Heating &AC	50	0	50
Acuaculture	120	0	120
Agriculture	55 A-ft.	25 A-ft. (Summer)***	0
		0 (Winter)	
Fluidized Bed Experiments	50	0	50
Other Experiments	100	1	99
TOTAL	3315	451 (Summer)	2679 (Summer)
		196 (Winter)	2929 (Winter)

*at 290°F

**at 150°F

***Approximately 50% consumptive loss

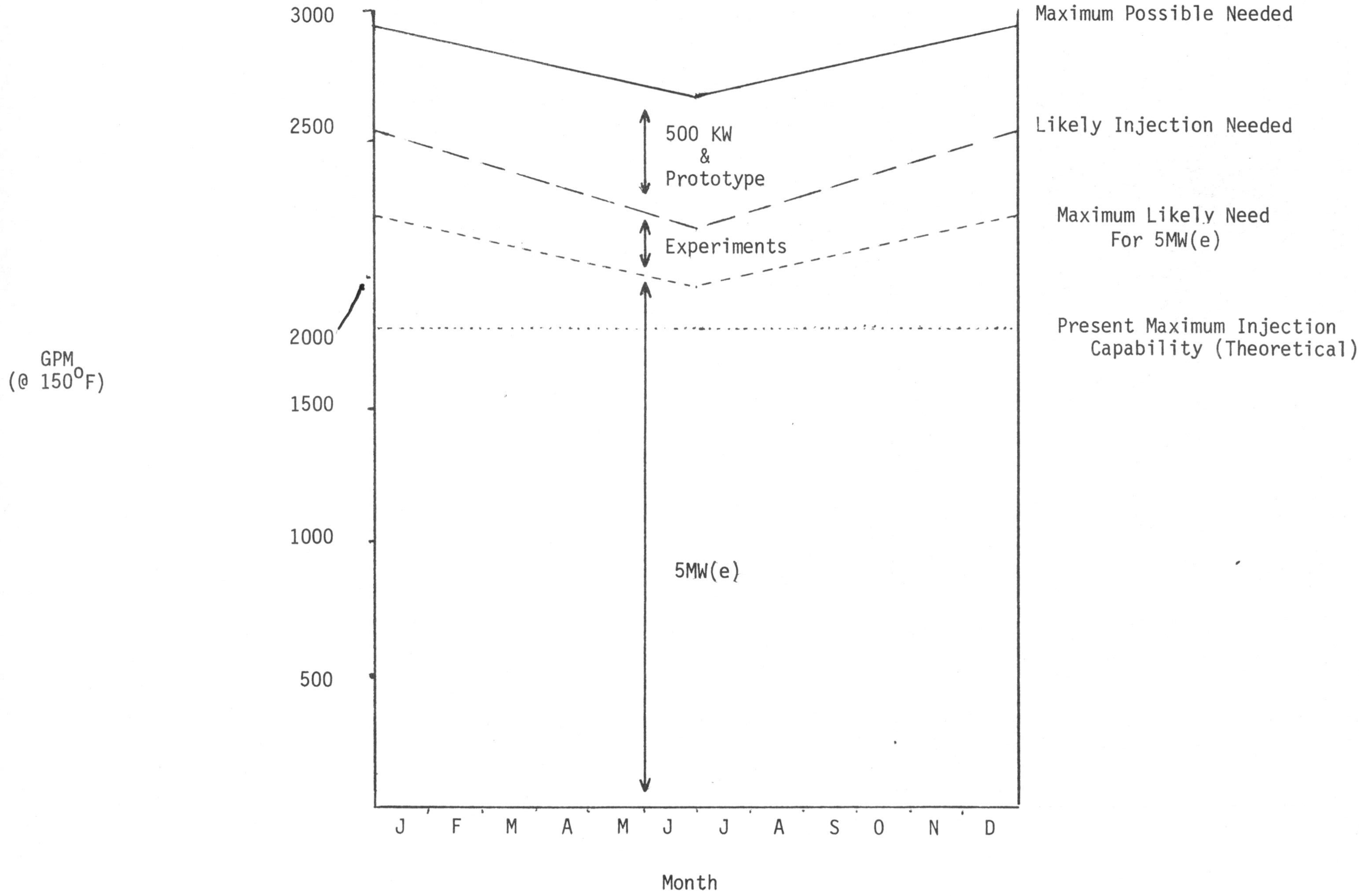

Figure 2 - Injection requirements at Raft River

result in wellhead pressures exceeding 600 psi, the working pressure of the surface equipment. If the power plant is operational only 85% of the time, it appears the injection wells may marginally meet the injection needs of the plant (but not of the other experiments). In addition, no standby or backup injection capacity would be present and the injection system would completely control plant operation.

There are also environmental concerns associated with injection in the existing wells.[4] Injection tests have shown that there is a pressure communication and possibly fluid communication between the injection zone in RRGI-6 and shallower aquifers. The pressure response in the shallow aquifer to injection in RRGI-6 is much greater than the response seen in RRGI-7. This is an indication that the fracture-controlled communication is more prevalent vertically than horizontally. The water quality of the injection zone in RRGI-6 and RRGI-7 is very poor and communication with shallower aquifers could lead to water quality degradation.

FLUID DISPOSAL ALTERNATIVES

Fluid disposal alternatives are being evaluated because the current injection capacity is not adequate to meet the effluent needs, and there is a concern that injected fluids may degrade shallow ground-water quality. The seven alternatives evaluated are:

1) Intermediate injection-expand the existing system.

2) Replace existing system with deep (below 4000 ft.) injection wells.

3) Inject into the "thief zone" (1400-2000 ft).

4) Inject into the shallow aquifers (less than 1000 ft).

5) Use wetlands for effluent treatment.

6) Use geothermal fluids for irrigation.

7) Discharge fluids to the Raft River.

Based on information currently available, these alternatives are evaluated based on their advantages and disadvantages. Each alternative is evaluated individually, even though a combination of disposal methods could be used. A matrix is presented in Table 2 to summarize impacts and costs as now known.

1. Intermediate injection - expand the existing system.

The advantages to this alternative include the use of existing wells and pipelines and the probability that this type of injection will have little effect on the resource. The two existing injection wells have an estimated capacity of 1700-1800 gpm, 800-1000 gpm short of the required capacity. There is a high probability that any additional well(s) drilled would have low capacity. These well(s) would have to intersect fractures to be effective.

It is the fractures which are the cause of the primary disadvantage of intermediate injection - connection with shallower aquifers. Tests have indicated that there is a significant pressure communication between RRGI-6 and MW-4. This communication could lead to an annual piezometric rise of as much as 150 ft in this well. While this effect on shallower aquifers is, in itself, a beneficial impact, the communication could lead to degradation of the water quality in these aquifers over time. Another disadvantage is that the high injection pressures required for intermediate injection result in the utilization of a major portion of the power plant output for pumping power. ?

2. Replace existing system with deep (below 4000 ft) injection wells.

An advantage of this alternative is that adverse effects on shallow aquifers could be reduced or eliminated. The present production wells in Raft River have shown no identifiable direct connection with shallow wells. Deep injection could also result in more efficient use of the resource. If the wells were located properly, reservoir pressures could be maintained (reducing the potential for subsidence) and injected fluids could eventually recharge the resource.

TABLE 2

IMPACT AND COST OF DISPOSAL ALTERNATIVES

	Intermediate 2000'-4000'	Deep > 4000'	Thief Zone 1400'-2000'	Shallow < 1000'	Wetlands	Irrigation
Effect on near-surface aquifers	some degradation if fractures connect	not likely	if can maintain low pressure shouldn't effect	chemical degradation highly probable	not available at this time	uncertain - some chemical degradation probable
Effect on cooling the production zone	not likely	highly probable	highly improbable	extremely improbable	extremely improbable	extremely improbable
Capital Cost	≃ \$500K + 2500 ft.* pipeline (1 well)	≃ \$850K + 2500 ft.* pipeline (1 well)	≃ \$600K for 3 wells + 1500 ft. pipeline	≃ 100K for 3 wells + 5000 ft. pipeline	not available at this time	-0-
Maintenance (Power) Cost	(300 KW)	(300 KW)	-0-	~ 100 KW	-0-	-0-

why difference ?

NOTE: Discharge to the Raft River was not included

* pipelines not costed due to uncertainty of distance

The main disadvantage of this alternative is the relatively high probability that deep injection wells will not have the required injection capacity because of low permeability. There is also a high risk that the injected fluids may short-circuit the resource and lead to premature cooling. There is not enough information available on the area to reduce the risks associated with locating deep injection wells.

3. Injection into the "thief zone" (1400-2000 ft).

If the zone of high porosity and permeability encountered in most of the geothermal wells has the capacity, effluents could be injected into it at power plant outlet pressure (less than 90 psi.). This could reduce the projected load on the plant power output. If low pressures can be maintained in this zone, there may be little communication with shallow aquifers. Injection into this zone over the production well field may also counterbalance the expected pressure declines caused by production.

If there is communication with shallow aquifers, injection could lead to water quality degradation. Indications are that the water quality of the receiving zone is better than that in RRGI-6 and RRGI-7. Therefore, water quality degradation as a result of thief zone injection may be less than that resulting from intermediate injection in RRGI-6 and RRGI-7. There is also some question that the 90 psi limitation on injection into the thief zone could be maintained over any long period of injection.

would if connection is assumed

However, there is a lack of information on the hydrology, geology, and water quality of the thief zone and the advantages and disadvantages presented are only speculation at this time. Before implementing this option, a test well must be drilled and evaluated.

4. Shallow injection (less than 1000 ft).

The shallow aquifers in the vicinity of the geothermal development probably have the injection capacity without requiring significant pumping power. Injection into the shallow aquifers would recharge these aquifers and may counterbalance some of the drawdowns expected from geothermal production. However, the quality of the geothermal fluids is poorer than that of many local irrigation wells[4] and water quality degradation would be expected if this method is used. The quality of water in many of the irrigation wells in this area is only marginally acceptable for irrigation and any degradation could result in the water being unsuitable. The most noticeable effects would be increased temperature, conductivity, sodium absorption ratio, and fluoride concentration.

5. Wetlands

Wetlands are potentially a valuable technique for disposal of geothermal effluent. Wetlands ecosystems may act as a biological filter and discharge water suitable for irrigation. The potential for biomass production, fish and pelt production, and improved wildlife habitat make this a commercially attractive disposal scheme for future geothermal development.

Insufficient knowledge exists to properly design a wetlands for immediate use, and research is currently being conducted to gain more information. Prior to installation of a wetlands at Raft River, two areas need to be researched: the accumulation of fluoride in the ecosystem and the potential for shallow groundwater contamination. Wetlands will result in consumptive water use due to evapotranspiration. This may disqualify the use of wetlands at Raft River.

6. Use of geothermal fluids for irrigation

During the irrigation season (May-Sept), geothermal effluent could be used to irrigate crops, replacing an equivalent amount of shallow groundwater. Other disposal methods would be utilized during the remainder of the time. This would reduce the direct demand on the aquifers used for irrigation. Pumping power requirements would be minimal and the irrigation schedule could be designed to meet the effluent requirements of the power plant. Irrigation would increase the consumptive loss of geothermal fluids, but this would be offset by the decreased use of shallow groundwater. The quality of the geothermal fluids is poorer than that of the water used for irrigation. As a result, there would be an increase in the salt buildup in the soil and degradation of shallow groundwater quality as a result of infiltration. There may also be some legal entanglements with regard to liability and transfer of water.

SAR → impact on soil structure

7. Discharge to the Raft River

During the non-irrigation season, effluent from the power plant could be discharged to the Raft River. This discharge would not meet the water quality regulations for this stream, particularly for fluoride, temperature, and total dissolved solids. Therefore, some treatment would be required. Such disposal would, like irrigation, increase the loss of the geothermal fluids, but would result in some benefit to the water supply in the basin.

?

RECOMMENDATIONS

The following plan of action is proposed as a mechanism by which the injection needs can be met before plant startup. This program is predicated upon a combination of disposal techniques that would be researched.

The previous section suggested the minimal-impact, minimal-cost approach to fluid handling might best be achieved by drilling a well through the so called "thief zone" and injecting the effluent at plant outlet pressures into this zone. Current data suggest that this injection mode may provide the quickest and most beneficial mode for the injection system.

It has been suggested that "thief zone" injection be evaluated by perforating and testing (with packer) the zone from 1400-2000' in wells RRGI-6 or RRGI-7. This approach is not recommended for the following reasons:

1. Although a less expensive means of evaluating the section over the short-term, the perforations would need to be cemented after testing or the well could not be used as a high-pressure injection well; this incremental cost could be significant, due to rig-time and the cement squeeze jobs necessary to return the well to use as a high-pressure injector.

2. The lower part of the porous section (1700-2000') is probably already exposed in RRGI-6 and spinner data were obtained during a test of that well; although pressures were slightly above 90 psi (the expected plant outlet pressure), over 200 gpm were being accepted in this portion of RRGI-6.

3. The "thief zone" appears (from drilling) to be even more porous down in the valley near the RRGE-1 - RRGP-4 area; a poor evaluation of this zone through selected perforations at RRGI-6 or -7 may result in very conservative injection capacity values.

Available information, specifically the spinner data from RRGI-6[5], allows a preliminary estimate that as much as 300-500 gpm may be accepted by the thief zone. If this proves to be the case, probably only three such wells might be required to adequately cover the shortfall in injectability.

It is recommended that before a location is selected for a thief zone well, two studies be completed. A reflection seismic survey will be performed in the next month or so by the U.S.G.S This will allow for well placement away from critical fault zones. Secondly, a two-dimensional computer model evaluating the chemical impact of "thief zone" injection is in progress. It is recommended this study be completed before proceeding.

bad sentence, model in progress

is it a chemical transport type model?

After EG&G has assessed the studies, a location will be chosen and a 2000' well drilled. Cores will be taken in the "thief zone", and the well tested. The injection well will be located within 500' of the plant or pipeline - if a likely location can be found - to minimize pipeline cost. (see figure 1) One shallow (500') monitor well will be located adjacent to the injection well. If successful upon testing, a recommendation will be made on the number of similar wells and monitor wells necessary to achieve injection needs.

is one well enough?

If the "thief zone" injection well fails to accept fluid readily, or if pressure response is seen in the proposed new monitor well, it would be recommended that an intermediate zone injection be drilled (similar to RRGE-6 or -7). Plans as to location would be made after evaluation of the seismic reflection survey. The well would be 3800-4000' deep and would require a pipeline and injection pump.

will the state go along with this?

This approach should provide the Raft River field with sufficient injection capability to meet maximum power plant and experiment needs. The additional wells should also provide the plant with the capability of maintaining a reduced-power situation should an injection pump fail and other maintenance problems occur.

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