EG&G Idaho

2.1.4.4

# INTEROFFICE CORRESPONDENCE

date July 16, 1979

to Distribution

from M. R. Dolenc MRD

subject RGI STIMULATION PLAN - MRD-18-79

The enclosed plan outlines RGI's fracture plans, etc. for wells RRGP-4 and RRGP-5. Bob Nicholson stated verbally that the "Kiel Process" will be used on the #4 well treatment. Please review and comment back by Wednesday, July 18, if you see major problems. Otherwise we will proceed to prepare a test plan covering the RRGP-4 stimulation.

sw

Enclosure:
As stated

Distribution

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Central File

FORM EG&G-954
(Rev 2-77)

PROPOSAL FOR PRODUCING WELL
HYDRAULIC FRACTURE STIMULATION
RAFT RIVER FIELD
GEOTHERMAL RESERVOIR WELL STIMULATION PROGRAM

JUNE 1979

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c) The well is a non-producer and successful stimulation would enhance the Raft River project;

d) RRGP-4 has higher temperature than RRGP-5 and is mechanically less risky than RRGE-3.

Wells RRGE-1 and RRGE-2 were also evaluated as stimulation candidates. These wells are now adequate producers. Although production could possibly be increased by a successful stimulation job, the Raft River production needs would be endangered by working on either well. In addition, because of the large open fractures in the wells, hydraulic fracturing may not be technically feasible.

## 4.0 STIMULATION PROGRAM

The study of stimulation techniques for the Raft River wells started by considering the existing wellbore configurations. Many hours of study and discussion went into planning the most effective way to stimulate these wells. The best producers were eliminated from consideration, as were those wells with unsuitable completions. Early conclusions were that hydraulic fracturing would be the most cost effective method of stimulation and that the reservoir temperature of slightly less than 300°F could be handled with today's existing technology. Wells RRGP-4 and RRGP-5 emerged as the best potential candidates for stimulation.

One mechanical method for hydraulically fracturing the wells was to use open hole straddle packers with a frac string to isolate the producing interval. While this is a relatively inexpensive way to proceed with the frac job, it is also the most risky. Open hole packers cannot seal properly unless the wellbore is smooth, hard or competent, and fracture free. In the

Raft River wells, none of these conditions are assured at the desired pack-off depths. With open hole packers, several adverse results can occur. First, they can leak or not hold pressure which will prevent zone isolation and will effectively prevent the frac treatment. Second, the packer may be stuck in the hole on the way in or out of the hole and prevent the well from producing. For these reasons, combined with the extremely washed out open hole section found in Well RRGP-4, the use of an open hole packer was eliminated from the options. The chance of success is minimal and the risks are great.

By using a casing liner and a properly sized polished bore receptacle in either RRGP-4 or RRGP-5, the chance of effectively stimulating the well will be increased greatly. This liner can be left open at the bottom (Figures 6 and 7) or fully cemented in place and perforated. In either of these cases, zone isolation is assured and the likelihood of getting tools stuck in the hole is greatly reduced.

## 4.1 Hydraulic Fracturing Design

In selecting the most suitable type of treatment, the four main variables that can be controlled during the job must be quantified. They are the fluid and its behavior (viscosity), the proppant (amount of sand or other material), the rate (hydraulic horsepower) and the schedule. Specific consideration of each of these variables is provided below. In general, however, the fracture at the wellbore will grow longer if more fluid is used or if the fluid leaks off from the fracture to the surrounding formations more slowly. Figure 8 shows a mini-frac and a massive hydraulic fracture (MHF). Characteristic lengths of the small fractures may be only 50 to 150 feet in length while large fractures may have wings extending from the wellbore for thousands of feet.

In geothermal wells producing only hot water, it is logical to use only compatible water-based fluids. Fluids not considered here are oils, emulsions, foams and very heavy brines since they will not be compatible and could actually damage the well instead of stimulating it. Water with high molecular weight water-soluble polymers will be used as the frac fluid at Raft River. The polymers provide temporary viscosity to carry the proppant out into the fracture; and after several hours, the polymers are degraded by the high temperatures.

As proppants, low to medium concentrations of sand and/or cohesive resin coated sand (called Super Sand) can be used to retain fracture width and conductivity after the treatment is completed. The proppant normally settles to the bottom of a planar fracture during the job and forms a conductive path from deep in the reservoir to the wellbore. Figure 9 shows how the sand bank builds up with subsequent slugs of sand forming additional top layers of sand in the fracture.

### 4.1.1 Planar Fracture Design

Two fracture designs are being considered for the Raft River experiment, the planar fracture and the Kiel-dendritic fracture. A planar fracture is a fracture that grows in a plane perpendicular to the direction of the minimum stress. Almost always this is a vertical fracture with wings extending hundreds of feet away from the wellbore.

Because of the very warm geothermal temperatures, the fracture job should be carried out quickly before the polymer fluids can degrade and lose viscosity. Also, the safety factor is increased by a short job since fluid loss is minimized and the job is less likely to sand out prematurely. For these reasons, a high flow rate has been chosen to get maximum benefits from the job and to have the best chance of success.

For the two wells, RRGP-4 and RRGP-5, a rate of 50 BPM was chosen as an average rate and two volumes were considered, 2500 BBL and 10,000 BBL. These represent a small and large fracture treatment, respectively, giving between 465 ft and 1015 ft of frac length. This assumes a 500 ft frac height. Using a more realistic frac height of 200 ft, frac lengths of between 625 ft and 1340 ft can be achieved. The schedules showing fracture geometry versus time are shown for the above cases in Table 3.

The fluid chosen is a HEC polymer in water at a concentration of 20 to 40 pounds of polymer per 1000 gallons. The proppant is mainly 100 mesh and 20/40 mesh sand carried into the fracture at low concentrations. The tail-in proppant is chosen to be "Super Sand" or cohesive sand that will lock the sand in place during production.

An approximate schedule is shown in Table 4 for the 10,000 BBL treatment. To get the schedule for a 2500 BBL treatment, the sand and polymer weight is scaled down by a factor of 4. However, the same hydraulic horsepower is required in either case. An approximate calculation for hydraulic horsepower (HHP) is given in Equation 1:

$$HHP = \frac{Q \times P}{40.8} \qquad (1)$$

where:

$Q$ = Flow Rate (BPM)

$P$ = Wellhead Pressure (psi)

For these cases, about 6100 HHP is needed at the rate and pressures anticipated.

### 4.1.2 Kiel-Dendritic Fracture Design

Figure 10 shows a schematic of a dendritic fracture with branched fractures caused by in situ stress modification resulting from periodic shut down or staging.

The Kiel Frac or Dendritic Frac design starts with an assumed frac length and fluid efficiency, and then the design proceeds from there to size the job.

Mr. Kiel in this design started with the assumption of a fracture wing 1500 ft in length with a fluid of 30 percent efficiency (where 30% of the fluid injected remains in the fracture, 70% leaks off). The amount of fluid required by his calculation to do this was approximately 2000 BBL. Equation 2 shows the calculation procedure.

$$\text{Volume of Stage (BBL)} = 0.357 \times L \times H \times W \times EFF \qquad (2)$$

where:

L = Frac Wing Length (feet)

H = Frac Height (feet)

W = Frac Width (feet)

EFF = Fluid Efficiency (fraction)

In this case, a frac height of 200 ft and a frac width of 0.75 inch was assumed to give a stage volume of 2000 BBL.

Five stages were chosen so that areal coverage would be very large. Total fluid volume was 10,000 BBL. Rate was selected at 50 BPM and the hydraulic horsepower required based on a frac gradient of 0.8 was 6000 HHP.

The fluid is a combined polymer of guar gum and XC at low concentrations (12 lb per 1000 gal). The schedule of the Kiel Frac showing sand additions and events is given in Table 5. It should be noticed that the sand slugs at moderate concentration are widely separated by clear fluid during the treatment and each stage includes a shut-down and flow-back period to aid in diverting or branching the fracture. Also, during the shut-down period any broken pumps, blenders, or leaky lines can be repaired or replaced.

## 4.2 Field Program

The field program will consist of the activities in Table 6. Some pre-stimulation well work discussed below is recommended to prepare the well(s) mechanically for the fracturing operation. Also, the procedures and cost estimates for the proposed work in both RRGP-4 and -5 are discussed below and detailed in Appendices B and C.

4.2.1 Well Preparation. In both RRGP-4 and RRGP-5, it is recommended that a liner be cemented in the present open hole interval, either to a point near TD or to the top of the intended fracture interval, as shown in Figures 6 and 7. In the case of a liner extending to TD, the intended fracture interval would be jet perforated and the possibility of future selective treatments within the interval would remain open. A liner extending just to the top of the intended fracture interval would cost approximately $25,000 less and would leave open the possibility of a borehole televiewer inspection of the open hole fractured interval. In either case the liner provides reliable isolation of the treatment interval and facilitates selective treatments of shallower zones in the future.

The alternative to a liner is to isolate the treatment interval in open hole with an inflatable packer, as discussed in the preceding section. This method, if successful, would save approximately $45,000. However, the risk of a packer failure during the frac job is considered quite high and such a failure would result in a loss of $100,000 to $200,000.

Additional work is recommended in RRGP-4 to permanently plug Leg A. Leg A is currently obstructed by drill cuttings from Leg B, as shown schematically in Figure 6. However, it is most likely that much of Leg A is open, or partially open. In the event that a fracture induced by Leg B intersects Leg A, the frac fluids would escape to a shallower depth and the objective of the treatment would be lost. On the optimistic side, if a fracture induced in Leg B grew parallel to the major fault planes, a likely but not certain occurrence, it would miss Leg A. (Refer to Figure 11.) Therefore, it is recommended that a reasonable attempt be made to re-enter and plug Leg A with cement. If Leg A cannot be re-entered with a reasonable effort, then it is recommended that the frac job be done anyway, recognizing the possibility of interference with Leg A.

4.2.2 Frac Job Procedures. The proposed frac treatments involve large volumes of frac fluid and high pumping rates. A 4-1/2" tubing frac string in the well, as shown in Figures 6 and 7, will be required for the pumping rates and pressures to keep the parasitic horsepower losses (costs) to reasonable values.

The lined pit now under construction at RRGP-4 will provide convenient storage for the frac fluid and thus minimizing the number of rented storage tanks required. The frac fluid will be the field produced water with a polymer gelling agent. Whether the fluid will be pre-gelled in the pit or gelled "on the fly" during the frac job has not been decided. Either of the two types of fracture treatments proposed, conventional planar frac or the Kiel-dendritic frac, require basically the same equipment and materials. The principle factor in the $26,500 estimated cost difference is the quantity of gelling agent specified in the design.

Post-fracturing well work will first involve flowing the well for clean up and preliminary evaluation, a period of 8-12 hours. Then the rig will circulate any remaining sand from the wellbore and move off.

After the rig moves off, the stimulation effect of the treatment will be evaluated by measuring producing rates and downhole pressures with the wells on natural flow. Further evaluation is recommended using the borehole televiewer and/or production logs to determine the location and orientation of the induced fracture(s).

## 5.0 FIELD ACTIVITIES AND RESPONSIBILITIES

A number of field activities are required to accomplish the stimulation job. Since EG&G is the field operator, close coordination will be maintained between the geothermal well stimulation team and the EG&G site management.

A list of the major field activities, together with the activity responsibility for EG&G and the GRWSP project, is shown in Table 6. In addition the responsible GRWSP personnel are indicated. The field organization is depicted in Figure 1 as mentioned previously.

During the field work two concurrent activities will be taking place. One involved the well work described in the previous section and the other includes the hooking up of the field fracturing equipment and the fluid preparation. During this period of time there will be three members of the well stimulation team on site. The maximum number of people anticipated to be on site at any time from the geothermal well stimulation project is five.

## 5.1 Institutional Review

EG&G and the Idaho DOE personnel are responsible for permitting and environment matters concerning this proposed stimulation work. A meeting was held between GRWSP personnel, EG&G, DOE and a representative of the Idaho Department of Water Quality Control in June 1979. During the meeting, Water Quality Control concerns about the upcoming production well stimulation project were adequately resolved. However, the GRWSP project is keeping all parties informed in case any problems do arise.

A meeting between GRWSP and the DOE legal council in Idaho Falls helped resolve some questions about well liability. The DOE lawyer will draft an agreement with Republic Geothermal, Inc. concerning the respective liabilities.

The GRWSP operation will adhere to the EG&G Idaho, Inc. "Health and Safety Guide for Construction Contractors" requirements which were supplied to the GRWSP by EG&G. There appear to be no problems within the GRWSP in these matters since it is recognized that EG&G will retain all responsibility for health and safety of personnel on site.

TABLE 4

Schedule of Events for Planar Fracture

Rate = 50 BPM

| Event No. | Volume Injected (bbl) | Time Elapsed (Min) | Sand Concentration | Comments |
|---|---|---|---|---|
| 1 | 0-200 | 4 | 0 | Prepad - Establish Rate and Breakdown |
| 2 | 200-500 | 10 | 0 | Pad - Cool Formation |
| 3 | 500-1000 | 20 | 1#/gal | 100 Mesh Sand |
| 4 | 1000-3000 | 60 | 2#/gal | 100 Mesh Sand |
| 5 | 3000-9400 | 188 | 1#/gal | 20/40 Mesh Sand |
| 6 | 9400-10000 | 200 | 2#/gal | 20/40 Mesh Super Sand |
| 7 | 10000-10100 | 204 | 0 | Flush Sand to Perforations. Clear Tubing and Casing Stop |

| Total Requirements | | |
|---|---|---|
| | Fluid: | 10,000 bbls |
| | 100 Mesh Sand: | 179,000 lb |
| | 20/40 Mesh Sand: | 269,000 lb |
| | 20/40 Mesh Super Sand: | 50,000 lb |
| | HHP: | 6,100 HP |

TABLE 5

KIEL FRACTURING PROCESS

U.S. PATENT NO. 3,933,205

Fracturing Treatment Process

COMPANY: Raft River Geothermal — DATE: 5/31/79

FORMATION: Quartz Monazite — RES. TEMPERATURE: 290°F

CSG TYPE: 4 1/2" to 3500 / 7" to 4800' — STAGE NO. 1 thru 5

| | EVENT NO. | FLUID, BBL. INCR. | FLUID, BBL. CUM. | SAND #/GAL | SAND SIZE |
|---|---|---|---|---|---|
| Pad Set Rate Get Ready for | #1 | 200 | | | |
| | 1 | 25 | 225 | 4 | 80/100 |
| | 2 | 200 | 425 | | |
| | 3 | 25 | 450 | 4 | 80/100 |
| | 4 | 200 | 650 | | |
| | 5 | 25 | 675 | 4 | 80/100 |
| | 6 | 200 | 875 | | |
| | 7 | 25 | 900 | 2 | 20/40 |
| | 8 | 200 | 1100 | | |
| | 9 | 25 | 1125 | 4 | 20/40 |
| | 10 | 200 | 1325 | | |
| | 11 | 25 | 1350 | 4 | 20/40 |
| | 12 | 200 | 1550 | | |
| | 13 | 25 | 1575 | 4 | 20/40 |
| | 14 | 200 | 1775 | | |
| | 15 | Shut Down | Flow Back | | |
| | 16 | 200 | 1975 | | |

Ready for Next Stage - Repeat all 16 steps for 5 stages.

Total Fluids: 5 x 1975 or 10,000 bbls

Total Sand: 12,000 lb 100 Mesh

18,000 lb 20/40 Mesh

TABLE 6

Field Activities and Areas of Responsibility

| | RESPONSIBLE PARTY |
|---|---|
| I. Field Mobilization | |
| A. Prepare Well | |
| 1. Strip off surface equipment (lines, etc.) | EG&G |
| 2. Pits | EG&G |
| B. Rig-up Tanks and Services | |
| 1. MIRU frac tanks and sand storage | GRWSP (RVV) |
| 2. Install water (come off main line w/temp lines to frac. tanks) | |
| 3. Forklift (?) | |
| 4. Generator & lights (?) | |
| 5. Trailer (RV rent) | GRWSP (RVV) |
| II. Field Job Activities | |
| A. Rig Operations to Prepare Well for Stimulation | |
| 1. Re-enter Leg A & cement | GRWSP (RWN) |
| 2. Cleanout Leg B and sand back to casing seat | GRWSP (RWN) |
| 3. Run the liner & cement | GRWSP (RWN) |
| 4. Cleanout liner and sand | GRWSP (RWN) |
| B. Stimulation Operations | |
| 1. Downhole work | GRWSP (RWN) |
| - Run GR/CBL | |
| - RIH w/frac string | |

| | | | RESPONSIBLE PARTY |
|---|---|---|---|
| | 2. | Surface Work | GRWSP (RVV) |
| | | - Quality control of sand & frac matl's. prior to mixing & mix (A.R.S. & O.J.V.) | |
| | | - QC after mixing (A.R.S. & O.J.V.) | |
| | | - Rig/up frac pumps | GRWSP (RVV) |
| | | - Pump job (A.R.S., O.J.V., R.V.V.) | |
| | 3. | Wait on Super Sand, flow well thru workstring, cleanout if necessary (bring bailer) | GRWSP (RWN) |
| C. | Production Testing | | |
| | 1. | Bring well on with tbg & stripper rubber | GRWSP (CG) |
| | 2. | Install welt w/flowline to pit | |
| | 3. | Run the borehole televiewer log | GRWSP (CWM) |
| | 4. | Run BHP & BHT and flow well 2 days max. (run spinner) | GRWSP (CWM) |
| | *5. | Run pump | EG&G |
| | *6. | Move rig off of #4 | GRWSP (CG) |
| | 7. | Pump well for 14 days (O.J.V. & C.W.M.) | EG&G |

RVV - Robert V. Verity (RGI)

RWN - Robert W. Nicholson (TSI/RGI)

CWM - Charles W. Morris (RGI)

ARS - A. Richard Sinclair (MEI)

OJV - Otto J. Vetter (VR)

CG - Curley Grimley (Mapco)

* Pump flow test may not be required

FIGURE 1

PROJECT ORGANIZATION FOR RAFT RIVER WELL STIMULATION

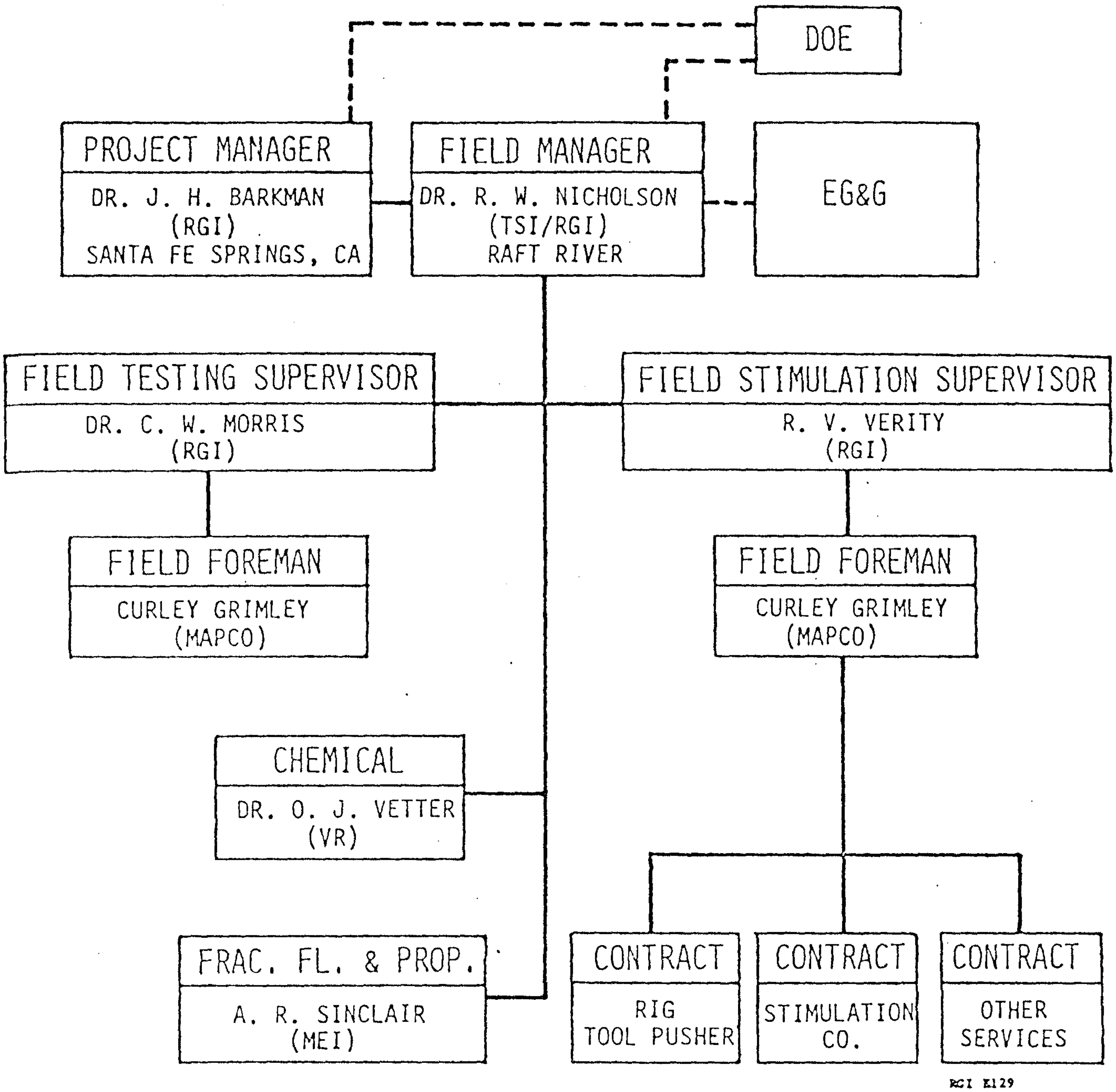


FIGURE 6
SCHEMATIC OF RAFT RIVER RRGP-4
WITH WORKSTRING AND RETRIEVALBE PACKER
PACKED-OFF IN THE 7" CASING

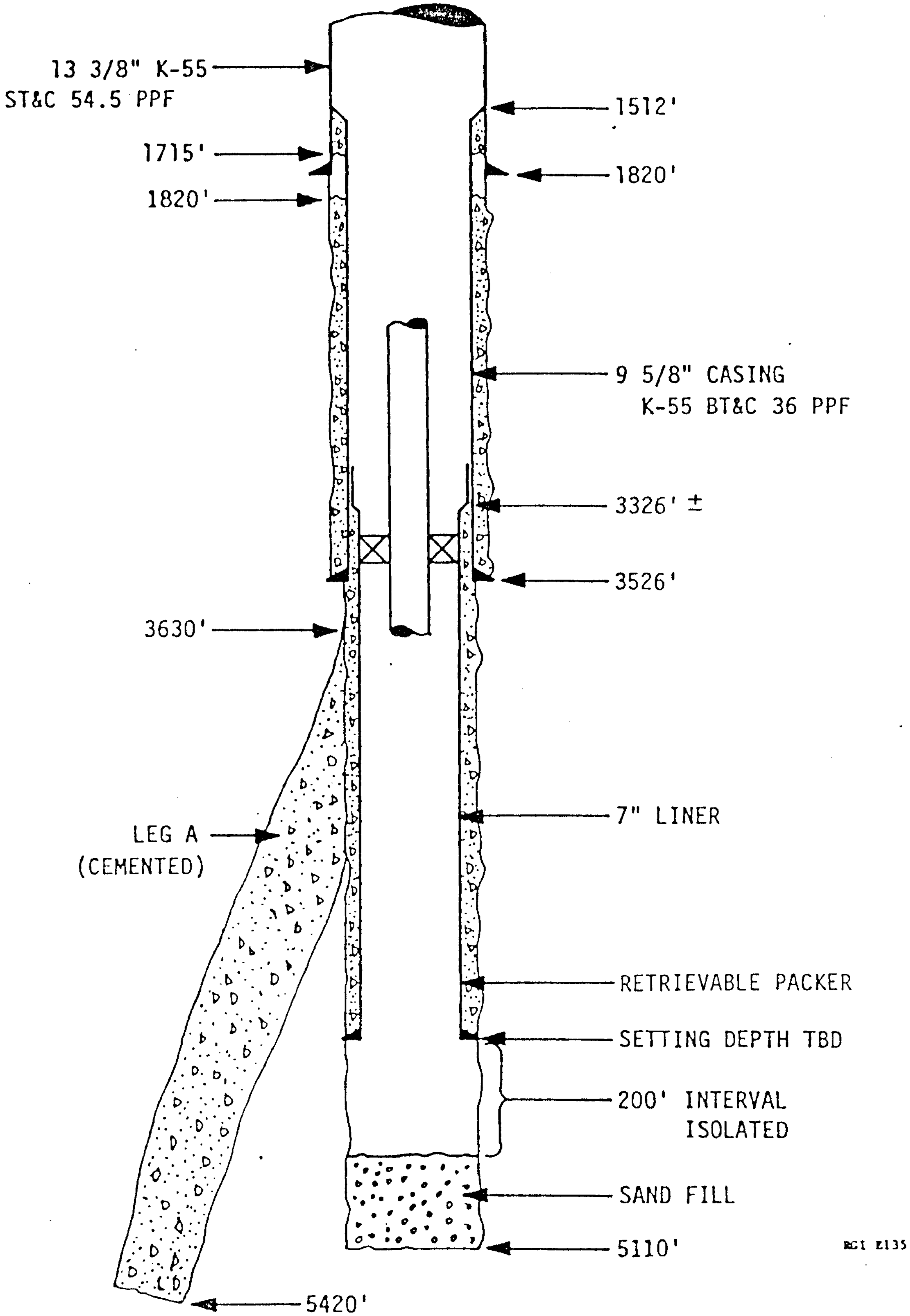


FIGURE 7

SCHEMATIC OF RAFT RIVER WELL RRGP-4
WITH WORKSTRING PACKED-OFF AT 7" LINER TOP

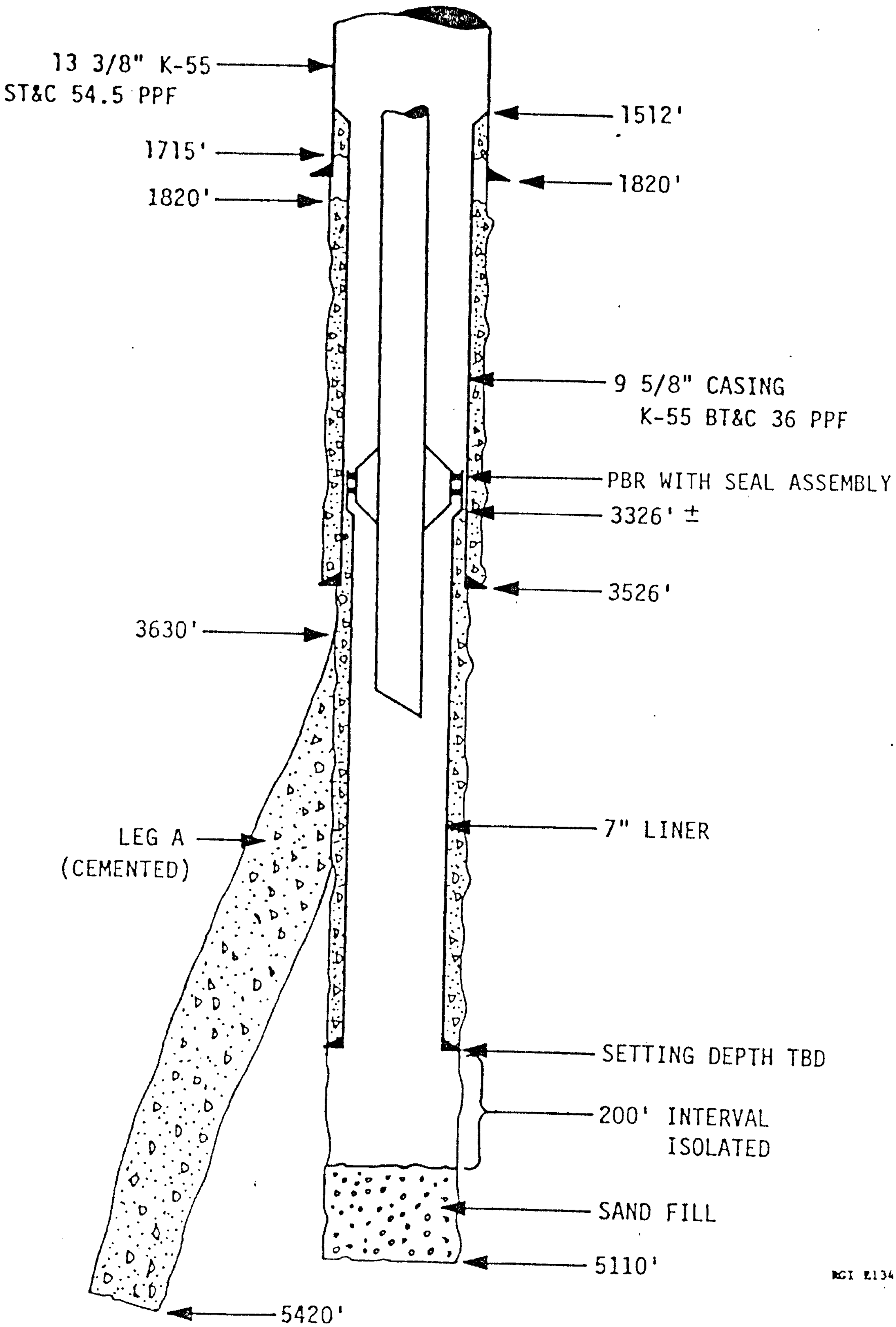
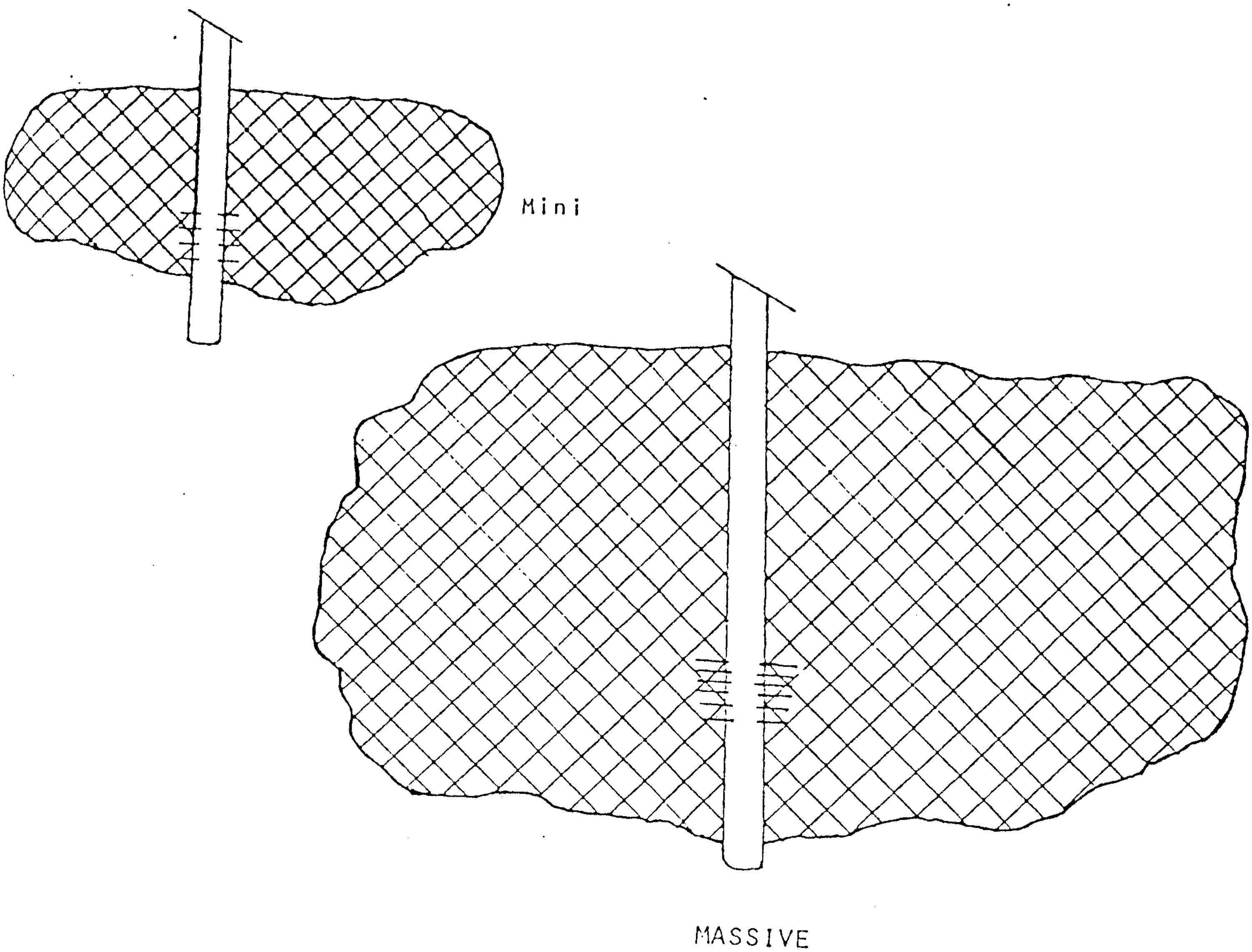


FIGURE 8

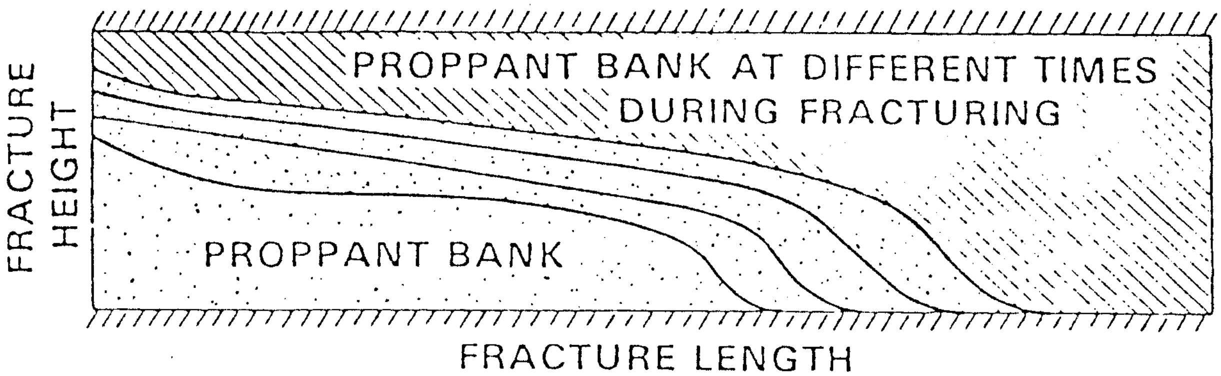
SCHEMATIC OF MINI AND MASSIVE HYDRAULIC FRACTURES




RGI E144

FIGURE 9

SCHEMATIC SIDEVIEW OF PLANAR FRACTURE
SHOWING SAND SETTLING IN LAYERS

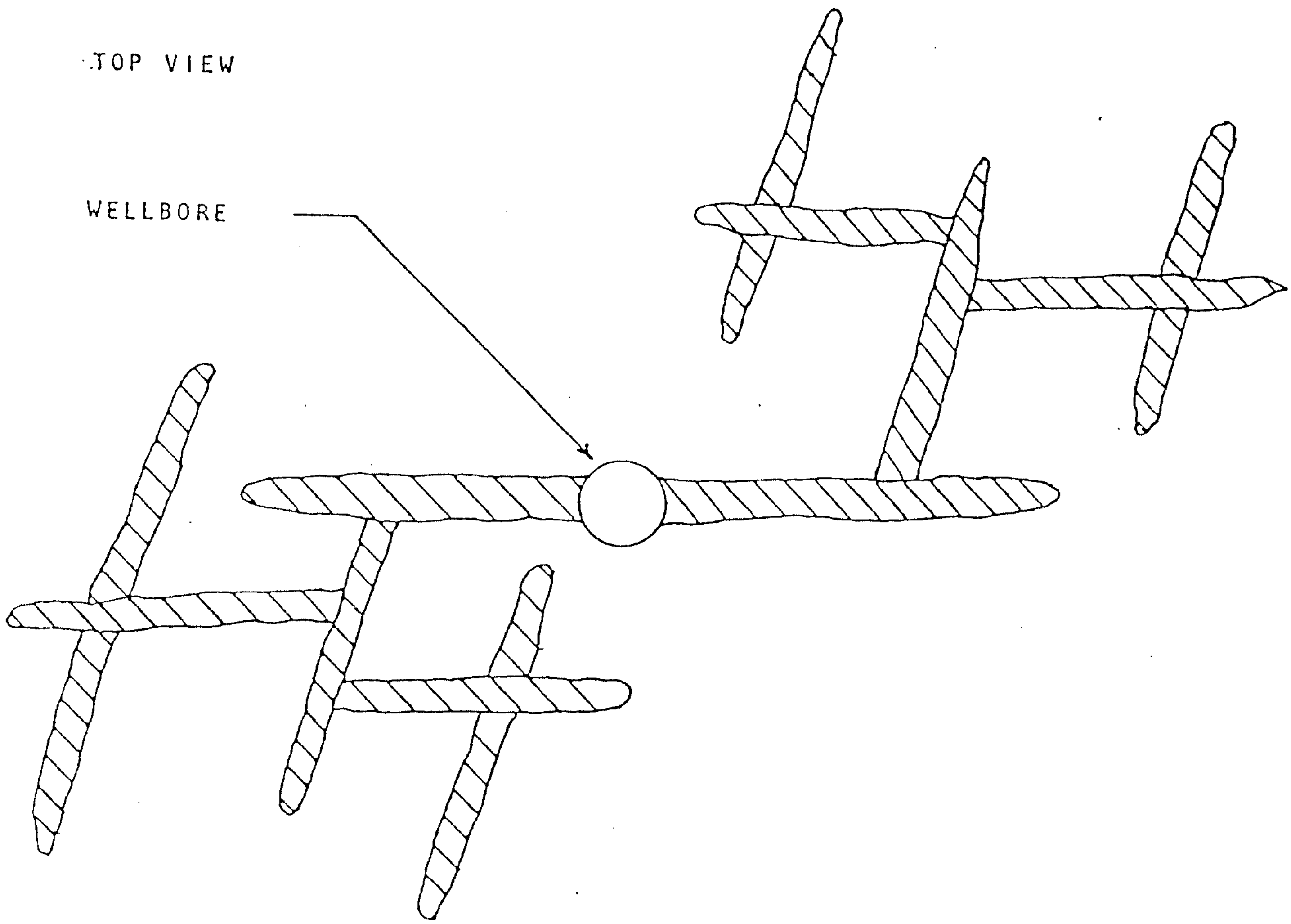



EQUILIBRIUM SAND BANK IS FORMED WHEN
PROPPANT SETTLES THRU FLUID

RCI E145

FIGURE 10

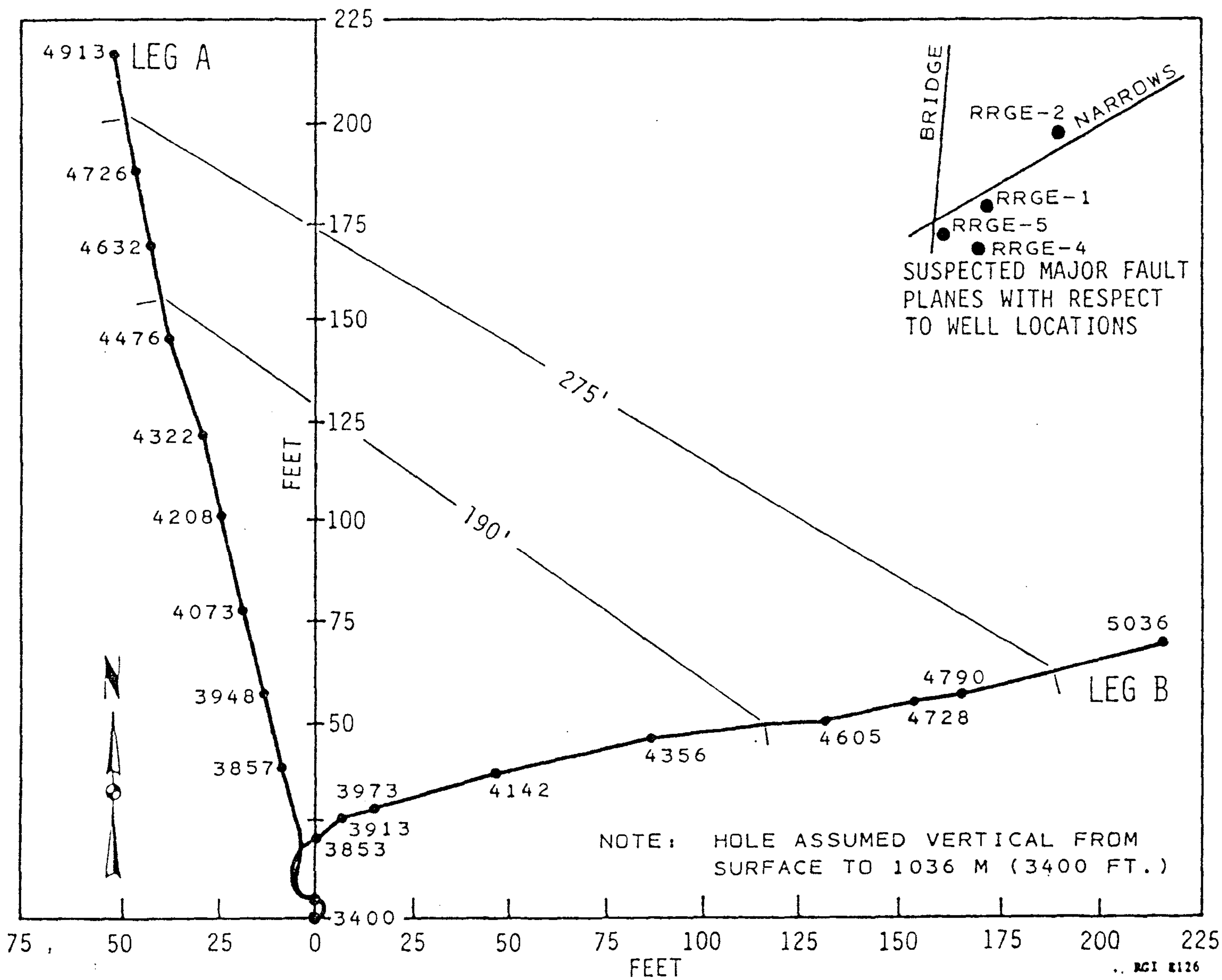
SCHEMATIC OF A DENDRITIC FRACTURE
(AFTER KIEL)




RCI E146

FIGURE 11

RAFT RIVER WELL RRGP-4
DIRECTIONAL DRILLING SURVEY SUMMARY




RGI 8126

APPENDIX A

MEMORANDUM FROM EG&G ON "RECOMMENDED ZONES FOR STIMULATION OF WELLS RRGP-4, RRGP-5 AND RRGI-7-DG-26-79"

EG&G Idaho

# INTEROFFICE CORRESPONDENCE

date June 6, 1979

to M. R. Dolenc

from D. Goldman

subject RECOMMENDED ZONES FOR STIMULATION OF WELLS RRGP-4, RRGP-5, and RRGI-7 - DG-26-79

On Thursday, May 30, 1979, a meeting was held in Denver at Scott Key's office. The purpose of the meeting was to recommend zones for stimulation of wells RRGP-4, RRGP-5, and RRGI-7. The meeting attendees were as follows: Scott Keys, Hans Ackermann, Harry Covington, Fred Pelie, Steve Allrich, and Dennis Goldman. The results are summarized by well as follows:

RRGP-4

| | |
|---|---|
| 4,000-4,630 ft (sediments) | horizontal (0-20°) bedding and schistosity planes visible; strike is north-south; dip is east |
| 4,630-4,800 ft (schist) | 30-40° fracture dip visible; strike is north-south; dip is east |
| 4,800-TD (quartzite and adamilite) | 60-90° fracture dip visible; strike is east-west |

All commercial geophysical logs were off on footage by 13 ft (the logs are 13 ft deeper than Key's logs).

Wells #1 and #2 show some 60-90° dip fractures in sediments.

Well #1 appears to produce from 4500-4600 ft zone from horizontal fractures. Data very weak.

Well #2 produces from all three rock types from horizontal and vertical fractures.

Major open fracture at 4670 ft; 20-30° dip to east (same as schistosity); aperture of approximately 1/2 ft.

Vertical fractures would most likely not propagate into Salt Lake Formation.

Well is silicified from 3000 ft to TD.

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Recommend:

1st choice - a 300-ft zone at 4570-4870 ft.
2nd choice - a 200-ft zone at 4570-4770 ft.
3rd choice - two 100-ft zones at 4590-4690 ft and 4770-4870 ft.

Note: There is an extreme lack of fracturing in the entire well as compared to other Raft River wells. There is no zone in which one could set open hole packers due to hole rugosity.

RRGP-5

Well has numerous fractures, but most are tight. Unlike well #4, there are horizontal and vertical fractures throughout the entire open-hole section.

At 4430 ft, there is a 20-30° fracture with an aperture of approximately 1 ft. At 4550-4560 ft, there is a 20-30° fracture with an aperture of approximately 1-5 ft.

Below 4600 ft, all fractures are very tight.

Recommend:

1st choice - a 200-ft zone at 4400-4600 ft.

RRGI-7

Open-hole portion of well is mostly sand. Siliceous zones are at 2050 ft and 3500 ft. Behind casing there is gravel. There is almost no alteration. Information is insufficient concerning type of stimulation or what date needed in order to give any recommendations.

sw

cc: C. A. Allen
D. W. Allman
R. E. McAtee
K. P. McCarthy
L. B. Nelson
W. L. Niemi
Central File

PRELIMINARY
FRACTURE STIMULATION WORKSHEET
RRGP-4
SEC. 22, T15S, R26E
CASSIA COUNTY, IDAHO

(All depths refer to KB, 14 ft. above ground level.)

MECHANICAL DETAIL

| | |
|---|---|
| 30" | Conductor cemented at 40' |
| 20" | 94PPF H-40 surface casing cemented at 400' |
| 13-3/8" | 54.5 PPF K-55 ST&L casing, surface to 1820' cemented in 12-1/4" hole. |
| 8-3/4" bit | Open hole 3526' - 5420' (TD Leg B) |

PROPOSED WORK

Re-enter and plug Leg A. Clean out Leg B and cement 7" liner to T.D. Perforate and fracture treat the interval 4570'-4870'. All work will be done without killing the well. Normal SIWHP ≃ 125 psig.

PROGRAM

1. MIRU workover rig with rotary and circulating equipment.
2. Strip off wellhead equipment down to top of master valve. Install flow tee, 12" class 900 double ram hydraulic BOP with 3-1/2" pipe rams and 12" class 90 annular BOP.
3. Strip in hole with 6-1/8" bit on bent sub and attempt to re-enter and clean out Leg A. (Run 2 float valves in drill pipe string.) Entry into Leg A will be evidenced by encountering fill at N3600' and can be confirmed by surveying hole angle. If successful, lay a cement plug from TD (5420') to ∿ 3800'. Pull up to 3600', circulate and WOC 8+ hours. (Job will require use of rotating head belonging to Raft River Project.)
4. Tag cement plug and strip out of hole if cement top is above 4000'.
5. Strip in hole with 8-3/4" bit and drill collars and clean out Leg B to 5110' (TD). Strip out of hole.

6. Make up and strip in hole with 7" 26 PPF N-80 liner, to be hung and cemented in the interval 5100'-3300'. Run float shoe in bottom and stab-in float collar one joint from bottom. (Double floats are for increased protection against flow up the casing.) Set liner hanger and strip out of hole with drill pipe.

7. Pick up stab in tool and Hydril drop in drill pipe float valve sub with valve in place. Insert cup packer in string to pack off in liner top while cementing. Strip in hole, stab into float collar and cement liner. Pull up and circulate out excess cement. Strip out of hole. W.O.C.

8. Pressure test 9-5/8" X 7" liner lap to 1000 psi. If necessary, strip in hole with 9-5/8" squeeze packer to test and squeeze cement liner lap.

9. If squeeze job is necessary, clean out 9-5/8" casing to liner top with 8-3/4" bit and clean out 7" liner to top of float collar with 6-1/8" bit.

10. Run GR/CCL correlation log and CBL. Perforate the interval 4870'-4570' with 100 holes using premium charges in 4" select fire gun. Avoid perforating collars.

11. Change pipe rams to 4-1/2". Pick up 7" squeeze packer, float valve sub with valve in place and 2 joints of 3-1/2" drill pipe and strip in hole on 4-1/2" N-80 tubing. Set packer at ∿ 330'. Pressure test annulus. Rig up frac manifold and retrieve float valve.

12. Pump frac job, either conventional frac or Kiel frac, to be determined before final worksheet is issued.

| FRACTURE DIMENSIONS | CONVENTIONAL FRAC | KIEL FRAC |
|---|---|---|
| Fracture length (measured from wellbore) | 1000' | 1000' |
| Fracture height | 300' | 300' |
| FRACTURE FLUID PROPERTIES | | |
| Fracture fluid viscosity | 10 cp | 10 cp |
| Gelling agent | HEC<br>20 lb/1000 gal | Mod. guar<br>10 lb/1000 gal and<br>XC polymer 2 lb/1000 gal |
| PUMPING RATE | | |
| | 50 BPM | 50 BPM |

## TREATMENT VOLUMES

### Conventional Frac

| Event No. | Fluid Vol. (BBLS) Incr. | Cum. | Sand ppg | Size | Fluid |
|---|---|---|---|---|---|
| 1 | 500 | 500 | – | – | Clear water prepad |
| 2 | 500 | 1000 | 1 | 100 | gelled water pad |
| 3 | 2000 | 3000 | 2 | 100 | " " " |
| 4 | 5800 | 8800 | 1 | 16-40 | " " " |
| 5 | 1200 | 10,000 | 1 | Supersand 16-40 | " " " |
| 6 | 500 | 10,500 | – | – | clear water flush at 10 BPM |

### Kiel Frac

| Event No. | Fluid Vol. (BBLS) Incr. | Cum. | Sand ppg | Size | Fluid |
|---|---|---|---|---|---|
| 0 | 200 | 200 | – | – | gelled water pad |
| 1 | 25 | 225 | 4 | 80-100 | " " " |
| 2 | 200 | 425 | – | – | " " " |
| 3 | 25 | 450 | 4 | 80-100 | " " " |
| 4 | 200 | 650 | – | – | " " " |
| 5 | 25 | 675 | 4 | 80-100 | " " " |
| 6 | 200 | 875 | – | – | " " " |
| 7 | 25 | 900 | 2 | 20-40 | " " " |
| 8 | 200 | 1100 | – | – | " " " |
| 9 | 25 | 1125 | 4 | 20-40 | " " " |
| 10 | 200 | 1325 | – | – | " " " |
| 11 | 25 | 1350 | 4 | 20-40 | " " " |
| 12 | 200 | 1550 | – | – | " " " |
| 13 | 25 | 1575 | 4 | 20-40 | " " " |
| 14 | 200 | 1775 | – | – | " " " |
| 15 | Shut down pumping and flow back | | | | |
| 16 | 200 | 1975 | – | – | " " " |

Repeat steps 1-16 four times, total 9075 bbls.

13. Run and set drill pipe float valve. Strip out of hole, laying down 4-1/2" tubing.

14. Flow well to pit to clean up.

15. Change pipe rams to 3-1/2". Strip in hole with 6-1/8" bit on drill pipe, circulate out fill if necessary, and strip out of hole.

16. Install flow tree and RDMO rig. Prepare well for flow test.

PRELIMINARY
FRACTURE STIMULATION COST ESTIMATE
RRGP-4

| | | |
|---|---|---|
| 1. | Move in rig, 12 hours travel time | $ 2,400 |
| | Rig up - 4 hours at $250/hr | 1,000 |
| 2. | Install BOPE | |
| | Rig - 4 hours | 1,000 |
| 3,4. | Clean out Leg A and plug with cement | |
| | Cement and service | 13,000 |
| | Rig - 36 hours | 9,000 |
| | Directional surveys, bit, etc. | 2,500 |
| 5. | Clean out Leg B | |
| | Rig - 8 hours | 2,000 |
| | Bit | 700 |
| 6. | Run liner | |
| | Liner - 1800' of 7" 26# at $11.11/ft. | 20,000 |
| | Liner hanger, running tools and service | 10,000 |
| | Casing equipment | 2,000 |
| | Rig - 16 hours | 4,000 |
| 7. | Cement liner | |
| | Rig - 12 hours | 3,000 |
| | Cementing service, including 24 hrs. standby | 7,400 |
| 8. | Pressure test and squeeze cement | |
| | Rig - 8 hours | 2,000 |
| | Cement and service, including 16 hours standby | 4,100 |
| | Squeeze packer | 2,000 |
| 9. | Drill out cement | |
| | Rig - 14 hours | 3,500 |
| | Scraper rental and service | 1,500 |
| 10. | Log and perforate | |
| | Rig - 24 hours standby | 1,000 |
| | Mileage & service charge | 2,100 |
| | Logging | 2,500 |
| | Perforating (assume 20 intervals, 5 shots each at 1 shot/ft.) | 7,000 |
| 11. | Run and set squeeze packer | |
| | Rig - 6 hours | 1,500 |
| | Squeeze packer | 1,500 |
| 12. | Pump frac job | |
| | Rig - 6 hours | 1,500 |

Conventional Frac

| | |
|---|---|
| Mobilize frac equipment, 300 miles | $ 9,000 |
| HHP, 6000 active and 2000 standby | 19,000 |
| Blenders, 2 active and 2 standby | 2,400 |
| Bulk sand storage | 1,100 |
| Pump truck to pressure annulus | 1,600 |
| Set up charge, say 2 days at $15,000 (negotiable) | 30,000 |
| 16-40 sand 122 tons at $21/ton + tax | 2,700 |
| 100 mesh sand, 94 tons at $18/ton + tax | 1,800 |
| Rail & motor freight for sand from Pueblo | 20,000 |
| Supersand, 50,000 lb. at $.33/lb FOB site | 16,500 |
| Service company sand handling charge, 4820 cu. ft. X $.90 | 4,400 |
| HEC polymer, 10,500 lb at $3.50/lb | 36,800 |
| Subtotal conventional frac | $145,300 |

Kiel Frac

| | |
|---|---|
| Mobilize frac equipment, 300 miles | 9,000 |
| HHP, 4000 active and 2000 standby | 25,000 |
| Blenders, 2 active and 2 standby | 2,400 |
| Bulk sand storage | 600 |
| Pump truck to pressure annulus | 1,600 |
| Set up charge, say 2 days at $15,000 (negotiable) | 30,000 |
| 20-40 sand, 37 tons at $22/ton + tax | 900 |
| 100 mesh sand, 32 tons at $18/ton + tax | 600 |
| Rail & motor freight for sand from Pueblo | 6,400 |
| Service company sand handling charge 1380 cu. ft. X $.90 | 1,300 |
| XC polymer, 6300 lb. at $4.50/lb | 28,400 |
| Modified guar, 4200 lb at $3.00/lb | 12,600 |
| Subtotal Kiel frac | $118,800 |

| | | |
|---|---|---|
| 13. | RDMO frac equipment and POH<br>Rig - 8 hours | $ 2,000 |
| 14. | Flow well<br>Rig - 8 hours | 2,000 |
| 15. | Check sand fill and clean out<br>Rig - 24 hours | 6,000 |
| 16. | Install tree and RDMO<br>Rig - 15 hours | 3,750 |
| | Miscellaneous transportation | 5,000 |
| | Miscellaneous expendables including repair of rot.hd. | 7,500 |
| | Rentals (see attached table) | 21,750 |
| | Total conventional frac | $301,500 |
| | Total Kiel frac | $275,000 |
| | Total rig hours, excluding travel and standby | 169 |

| RENTAL EQUIPMENT | NO. OF DAYS | RENT | TRANS | TOTAL |
|---|---|---|---|---|
| Blow out preventers | 10 | $3,050 | $ 720* | $3,770 |
| 4-1/2" slips and elevators | 10 | 500 | | 500 |
| 3-1/2" slips and elevators | 10 | 420 | | 420 |
| Drill collars | 10 | 700 | | 700 |
| 3500' 4-1/2" tubing $.10/ft/day | 10 | 3,500 | 900 | 4,400 |
| 5200' 3-1/2" D.P. $.04/ft/day | 10 | 2,080 | 1,300 | 3,380 |
| 7" slips, elevators and tongs | 3 | 570 | 160 | 730 |
| Subs and other miscellaneous items | 10 | 2,500 | 500 | 3,000 |
| 5 - 500 bbl frac tanks, $25/day | 10 | 1,250 | 3,600 | 4,850 |
| Total Rentals | | | | $21,750 |

*Includes transportation of other small items to job site

APPENDIX C

PROCEDURE AND COST ESTIMATE TO PREPARE

AND HYDRAULIC FRACTURE

RRGP-5

PRELIMINARY
FRACTURE STIMULATION WORKSHEET
RRGP-5
SEC. 22, T15S, R26E
CASSIA COUNTY, IDAHO

(All depths refer to KB, 14 ft. above ground level.)

MECHANICAL DETAIL

| | |
|---|---|
| 26" | Conductor cemented at 60' |
| 20" | Surface casing cemented at 172' |
| 13 3/8" | 54.5 lb. K-55 casing, surface to 1510' cemented in 17 1/2" hole with 850 sacks class G Dowell thixotropic RFC cement. |
| 9 5/8" | 36 lb. K-55 casing, 1284'-3408' cemented in 12 1/4" hole with 1200 sacks class G with 1.1 Perilite? Liner Hanger: 9 5/8" x 13 3/8" Baash-Ross plain type with fluted cone and circulation ports. |
| 8 3/4" bit | Open hole 3408'-4925' (TD) |

STATUS

Shut in. Recently completed production test with submersible pump. REDA submersible pump landed at 1000' on 8 5/8" 32 lb. casing as tubing. (Refer to drawing No. 411900, Sheet 1.)

PROPOSED WORK

Remove pumping equipment. Run and cement 7" liner. Perforate and fracture stimulate.

All work will be done without killing the well. Normal SIWHP 125 psig.

PROGRAM

1. MIRU workover rig with rotary circulating equipment.
2. Pull and lay down 8 5/8" casing and REDA pump. Spool up cable and 1/4" bubble tube as pump is pulled.

3. Install flow TEE, 12" class 900 double ram hydraulic BOP with 3 1/2" pipe rams and 12" class 900 annular BOP. Pick up packer, milling tool, and RIH on 3 1/2" drill pipe. Mill over and recover Baker Model KB packer, 9AA - 47, Prod. No. 495 - 31. (Refer to drawing No. 411900, Sheet 1.) (Job will require use of rotating head belonging to Raft River Project.)

4. Strip in hole with 8 3/4" bit and clean out to TD (4925'). Strip out of hole.

5. Make up and strip in hole with 7" 26 PPF N-80 liner, to be hung and cemented in the interval 4920' - 3220'. Run float shoe on bottom and stab in float collar one joint from bottom. (Double floats are for increased protection against flow up the casing.) Set liner hanger and strip out of hole with drill pipe.

6. Pick up stab in tool and Hydril drop in drill pipe float valve sub with valve in place. Insert cup packer in string to pack off in liner top while cementing. Strip in hole, stab into float collar and cement liner. Pull up and circulate out excess cement. Strip out of hole. WOC.

7. Pressure test 9 5/8" x 7" liner lap to 1000 psi. If necessary strip in hole with 9 5/8" squeeze pakcer to test and squeeze cement liner lap.

8. If squeeze job is necessary, clean out 9 5/8" casing to liner top with 8 3/4" bit and clean out 7" liner to top of float collar with 6 " bit.

9. Run GR/CCL correlation log and CBL. Perforate the interval 4600'-4400' with 100 holes using premium charges in 4" select fire gun. Avoid perforating collars.

10. Pickup 7" squeeze packer, float valve sub with valve in place, and 2 joints of 3 1/2" drill strip and strin in hole on 4 1/2" N-80 tubing. Set packers at 3330'. Pressure test annulus. Rig up frac manifold and retrieve float valve.

11. Pump frac job, either conventional frac or Kiel frac, to be determined before final worksheet is issued.

| FRACTURE DIMENSIONS | CONVENTIONAL FRAC | KIEL FRAC |
|---|---|---|
| Fracture length (measure from wellbore) | 1000' | 1000' |
| Fracture height | 200' | 200' |
| FRACTURE FLUID PROPERTIES | | |
| Fracture fluid viscosity | 10 cp | 10 cp |
| Gelling agent | HEC<br>20 lb/1000 gal | Mod. guar<br>10 lb/1000 gal and<br>XC polymer 2 lb/1000 gal |
| PUMPING RATE | 50 BPM | 50 BPM |

TREATMENT VOLUMES

## Conventional Frac

| Event No. | Fluid Vol. (BBLS) Incr. | Cum. | Sand PPg | Size | Fluid |
|---|---|---|---|---|---|
| 1 | 500 | 500 | - | - | Clear water prepad |
| 2 | 500 | 1000 | 1 | 100 | Gelled water pad |
| 3 | 2000 | 3000 | 2 | 100 | " " " |
| 4 | 5800 | 8800 | 1 | 16-40 | " " " |
| 5 | 1200 | 10,000 | 1 | 16-40 Supersand | " " " |
| 6 | 500 | 10,500 | - | - | Clear water flush at 10 BPM |

## Keil Frac

| Event No. | Incr. | Cum. | PPg | Size | Fluid |
|---|---|---|---|---|---|
| 0 | 200 | 200 | - | - | Gelled water pad |
| 1 | 25 | 225 | 4 | 80-100 | " " " |
| 2 | 200 | 425 | - | - | " " " |
| 3 | 25 | 450 | 4 | 80-100 | " " " |
| 4 | 200 | 650 | - | - | " " " |
| 5 | 25 | 675 | 4 | 80-100 | " " " |
| 6 | 200 | 875 | - | | " " " |
| 7 | 25 | 900 | 2 | 20-40 | " " " |
| 8 | 200 | 110 | - | - | " " " |
| 9 | 25 | 1125 | 4 | 20-40 | " " " |
| 10 | 200 | 1325 | - | - | " " " |
| 11 | 25 | 1350 | 4 | 20-40 | " " " |
| 12 | 200 | 1550 | - | - | " " " |
| 13 | 25 | 1575 | 4 | 20-40 | " " " |
| 14 | 200 | 1775 | - | - | " " " |
| 15 | Shut down pumping and flow back | | | | |
| 16 | 200 | 1975 | - | - | " " " |

Repeat steps 1-16 four times, total 9075 bbls.

13. Run and set drill pipe float valve. Strip out of hole, laying down 4 1/2" tubing.

14. Flow well to pit to clean up.

15. Change pipe rams to 3 1/2". Strip in hole with 6 1/8" bit on drill pipe, circulate out fill if necessary, and strip out of hole.

16. Install flow tree and RDMO rig. Prepare well for flow test.

PRELIMINARY
FRACTURE STIMULATION COST ESTIMATE
RRGP-5

| | | |
|---|---|---|
| 1. | Move in rig from RRGP-4 | |
| | Rig up - 4 hours at $250/hr | $ 1,000 |
| 2. | Rig - 12 hours pull pump | 3,000 |
| 3. | Install BOP's and recover packer | |
| | Rig - 12 hours | 3,000 |
| 4. | Clean out to TD | |
| | Rig - 12 hours | 3,000 |
| | Bit | 700 |
| 5. | Run liner | |
| | Liner - 1700' of 7" 26# at $11.11/ft. | 18.900 |
| | Liner hanger, running tools and service | 10,000 |
| | Casing equipment | 2,000 |
| | Rig - 16 hours | 4,000 |
| 6. | Cement liner | |
| | Rig - 12 hours | 3,000 |
| | Cementing service, including 24 hrs. standby | 7,400 |
| 7. | Pressure test and squeeze cement | |
| | Rig - 8 hours | 2,000 |
| | Cement and service | 4,100 |
| | Squeeze packer | 2,000 |
| 8. | Drill out cement | |
| | Rig - 14 hours | 3,500 |
| | Scraper rental and service | 1,500 |
| 9. | Log and perforate | |
| | Rig - 24 hours standby | 1,000 |
| | Mileage and service charge | 2,100 |
| | Logging | 2,500 |
| | Perforating (assume 20 intervals, 5 shots each as 1 shot/ft.) | 7,000 |
| 10. | Run and set squeeze packer | |
| | Rig - 6 hours | 1,500 |
| | Squeeze packer | 1,500 |
| 11. | Pump frac job | |
| | Rig - 6 hours | 1,500 |
| | <u>Conventional Frac</u> | |
| | Mobilize frac equipment, 300 miles | 9,000 |
| | HHP, 6000 active and 2000 standby | 19,000 |
| | Blenders, 2 active and 2 standby | 2,400 |
| | Bulk sand storage | 1,100 |
| | Pump truck to pressure annulus | 1,600 |
| | Set up charge, say 2 days at $15,000 (negotiable) | 30,000 |

| | | |
|---|---|---|
| | 16-40 sand 122 tons at $21/ton + tax | $ 2,700 |
| | 100 mesh sand, 94 tons at $18/ton + tax | 1,800 |
| | Rail & motor freight for sand from Pueblo | 20,000 |
| | Supersand, 50,000 lb. at $.33/lb FOB site | 16,500 |
| | Service company sand handling charge, 4820 cu. ft. x $.90 | 4,400 |
| | HEC Polymer, 10,500 lb. at $3.50/lb | 36,800 |
| | Subtotal Conventional frac | $145,300 |
| | Kiel Frac | |
| | Mobilize frac equipment, 300 miles | 9,000 |
| | HHP, 4000 active and 2000 standby | 25,000 |
| | Blenders, 2 active and 2 standby | 2,400 |
| | Bulk sand storage | 600 |
| | Pump truck to pressure annulus | 1,600 |
| | Set up charge, say 2 days at $15,000 (negotiable) | 30,000 |
| | 20-40 sand, 37 tons at $22/ton + tax | 900 |
| | 100 mesh sand, 32 tons at $18/ton + tax | 600 |
| | Rail & motor freight for sand from Pueblo | 6,400 |
| | Service company sand handling charge, 1380 cu. ft. x $.90 | 1,300 |
| | XC Polymer 6,300 lb. at $4.50/lb | 28,400 |
| | Modified guar, 4,200 lb. at $3.00/lb | 12,600 |
| | Subtotal Kiel frac | $118,800 |
| 12. | RDMO frac equipment and POH<br>Rig - 8 hours | 2,000 |
| 13. | Flow well<br>Rig - 8 hours | 2,000 |
| 14. | Check sand fill and clean out<br>Rig - 24 hours | 6,000 |
| 15. | Install tree and RDMO<br>Rig - 15 hours at $250/hr + 12 hours travel | 6,150 |
| | Miscellaneous transportation | 5,000 |
| | Miscellaneous expendables including repair of rot.hd. | 7,500 |
| | Rentals (see attached table) | 21,750 |
| | Total Conventional frac | $281,900 |
| | Total Kiel frac | $255,400 |
| | Total rig hours, excluding travel and standby | 153 |

| RENTAL EQUIPMENT | NO. OF DAYS | RENT | TRANS | TOTAL |
|---|---|---|---|---|
| Blow out preventers | 10 | 3050 | 720* | 3,770 |
| 4 1/2" slips and elevators | 10 | 500 | | 500 |
| 3 1/2" slips and elevators | 10 | 420 | | 420 |
| Drill collars | 10 | 700 | | 700 |
| 3500' 4 1/2" tubing $.10/ft/day | 10 | 3,500 | 900 | 4,400 |
| 5200' 3 1/2" D.P. $.04/ft/day | 10 | 2,080 | 1,300 | 3,380 |
| 7" slips, elevators and tongs | 3 | 570 | 160 | 730 |
| Subs and other miscellaneous items | 10 | 2,500 | 500 | 3,000 |
| 5 - 500 bbl frac tanks, $25/day | 10 | 1,250 | 3,600 | 4,850 |
| Total Rentals | | | | 21,750 |

* Includes transportation of other small items to job site.