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David Schafer & Associates
5207 141st Street North
Hugo, MN 55038
651-762-8281

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MEMORANDUM

To: Ardyth Simmons, Steve Pearson, Rich Koch, Danny Katzman

From: David Schafer

Subject: Interflow Estimates For R-22 Screens 1 Through 5

This report summarizes an analysis of the flow potential from one screen to another within R-22 that would occur when the Westbay isolation packers are removed for rehabilitation work. This information has been prepared to evaluate the impacts of opening the well for a period of time to purge screen 5 and perform the work needed to convert R-22 to a two-screen well, salvaging screens 2 and 3, while abandoning screens 1, 4 and 5. Work would include removing the Westbay equipment, conducting extended pumping of screen 5, abandoning screens 4 and 5, and developing and testing screens 2 and 3. Following this work, temporary packers would be installed in the well to isolate the remaining screens while permanent sampling equipment is manufactured. Once the permanent sampling equipment is obtained, the well would be opened a second time to remove the temporary packers and install the permanent sampling pump.

Flow estimates were calculated by estimating the specific capacity of each production zone using the hydraulic conductivity values presented in the revised version of the hydraulic analysis report prepared by William J. Stone and Stephen G. McLin (2003). These hydraulic conductivity values were derived by applying slug test analysis methods to injection data. Once the specific capacity of each zone was determined, the flow rate into or out of that zone was computed by multiplying the specific capacity by the drawdown that would be applied to that zone. (No hydraulic test has been performed on screen 1. The hydraulic conductivity computed for screen 2 was assigned to screen 1 for the purposes of this analysis.)

The drawdown for a given zone was computed as the difference between its static water level and the composite water level that will occur when the well is opened. An exception to this was made for any zone where the composite water level dropped beneath the well screen. If this occurred, the drawdown value used in the flow rate calculations was limited to the difference between the static water level and the midpoint of the initially saturated portion of the well screen. Even though drawdown actually would be applied to the bottom of the

screen, limiting the value used in the computations in this way provided a mathematical correction for loss of capacity associated with dewatering of the screen.

The Stone and McLin report presented hydraulic conductivity values computed using multiple slug test methods. The values selected for this analysis were those obtained using the Bouwer and Rice procedure (1976). This was because the Bouwer and Rice method is based on relatively short pumping times, consistent with the duration of typical slug tests. To compute specific capacity, however, an equation from Hvorslev (1951) was used that is based on extended pumping time. It was felt that the Hvorslev prediction based on late time would be consistent with the extended time that R-22 would be open to conduct the necessary work on the well.

One form of the Hvorslev equation, in mixed units, is as follows:

$$\frac{Q}{s} = \frac{KL}{70.55 \log \frac{L}{r_w}}$$

where,

Q = discharge rate, in gpm
s = drawdown, in feet
K = hydraulic conductivity, in feet per day
L = screen length, in feet
r_w = borehole radius, in feet (0.51 feet)

To perform the computations, an iterative approach was used in which the composite water level was adjusted until the net discharge was zero, that is, until the total flow into the well from the upper well screens equaled the total flow exiting the well through the bottom screens. Table 1 summarizes the results of the calculations for the case in which the entire well would be open, exposing all five screens at the same time.

The tops and bottoms of the screens shown in Table 1 were obtained from construction drawings of the well. The static water level elevations were provided by Rich Koch of SAIC and represent recent observations. The hydraulic conductivity values are those from the Stone and McLin report, while the specific capacity values were computed using the Hvorslev formula presented above. The discharge values (Q) shown in the table are positive for water entering the well and negative for water exiting the well.

As shown in Table 1, to balance incoming and outgoing flow, it was necessary to adjust the composite water level in the well to an elevation of 5703.29 feet. With this level inside the well, screens 1 and 2 would yield 0.16 gpm and 0.64 gpm, respectively. Simultaneously, screens 3, 4 and 5 would receive 0.07 gpm, 0.56 gpm and 0.18 gpm, respectively.

As a check on the results, the predicted composite water level was compared to a measured value obtained in December 2000 when the well was open. The December 2000 open-hole water level was 5703.2 feet, in agreement with the predicted value of 5703.29. It is likely that R-22 water levels have declined over the past seven years and that the open-hole level currently would fall below 5703.2 feet. Thus, the apparent agreement between the observed and predicted values may be overstated somewhat.

During well rehabilitation and conversion activities, not all five screens will be open for flow at all times. Periodically, packers will be set in various intervals, restricting and altering the flow patterns. At other times, zones will be purged or tested, causing net removal of water from the well. Also, as screens 4 and 5 are abandoned, they will cease accepting water from overlying zones. Thus, at various times, there will be several different combinations of screens in hydraulic communication with one another.

To account for interflow that would occur during the various rehabilitation procedures considered for R-22, interflow calculations were performed for the combinations of screens that are expected to be in hydraulic communication during the work. Tables 2 through 7 show anticipated water levels and interflow rates applicable to those anticipated combinations of open screen zones. The information in Tables 1 through 7 was used to prepare a description of water volume movement throughout R-22 during the rehabilitation effort.

Obtaining accurate estimates of the interflow volumes required an analysis identifying the individual tasks that would be performed on R-22, the time that each task would take, and which screens would be in hydraulic communications during each procedure. Table 8 shows the results of this analysis, presenting a summary of the operations considered for R-22, estimates of their execution times, and the screen zones involved.

All execution times shown in Table 8 were rounded to the nearest whole number of days. Actual times will involve fractions of days in many instances. However, the execution times are considered only approximate. Actual work performance rates will be affected by extraneous factors including weather, equipment down time, availability of personnel, weekends and holidays, post-development cleanup time, and other factors. The time estimates shown in Table 8 are simply nominal predictions that are considered reasonable based on experience with similar activities in other wells on the plateau.

The tasks shown in Table 8 were consolidated by combining adjacent tasks for which the same set of screens were in hydraulic communication. For the consolidated chronology, the relevant time durations and individual screen interflow rates were used to compute the total volume of water that would flow into or out of each screen. Table 9 shows the results of these calculations with positive numbers indicating water contributed to the well and negative numbers indicating water received by a given zone.

It is apparent that screen 1 always contributes water to the well, while screen 2 nearly always does so. Conversely, screen 4 almost exclusively receives water from the overlying screen zones. Screen 5 receives water except for the substantial purging event, with an estimated total of 289 gallons of water flowing into the zone following purging.

Screen 3 is unique in that it receives and contributes somewhat similar volumes of water alternately throughout the rehabilitation/conversion process, with a net acceptance of more than 2400 gallons by the end of the project. Because the last flux occurrences for screen 3 correspond to injection of 5760 gallons of water, including more than 5000 gallons during installation of the permanent sampling system, it would be prudent to purge this interval extensively following installation of the sampling equipment.

In most cases, the volume of water received by a particular zone can be assumed to consist of a blend of water from the overlying contributing zones that is roughly in proportion to each zone's contribution to the well. As an example, during task 4, screen 1 contributes 230 gallons of water and screen 2 contributes 922 gallons. Therefore, the relative proportions of contribution are 20 percent and 80 percent for screens 1 and 2, respectively. This means, for example, when examining the 806 gallons of water received by screen 4, as a first approximation, it can be assumed to consist of 20 percent screen 1water (161 gallons) and 80 percent screen 2 water (645 gallons). The actual blend proportions will sometimes be slightly different than this because the antecedent water volume stored in the blank casing above the receiving zone prior to each task may have different contribution percentages than those for the active task. Nevertheless, this discrepancy is expected to be insignificant in most cases.

Note that Table 9 may appear to include redundant steps. For example, it includes a line item for task 12 (identified previously in Table 8 as "purge well") plus a subsequent line item entitled "Purge Well." The two sets of entries are included to represent the interflow that occurs during pre-purging preparation activities (the task 12 entry) as well as removal of water during the purging itself (the "Purge Well" entry).

It is important to point out that the projected water removal volumes shown in Table 9 corresponding to jetting, purging and testing are merely estimates. The pumping rates that will be applied and the duration of the episodes are not known with certainty. Therefore, it is likely that the actual volumes removed during these activities will be different than the

estimates shown in the table. Because much of the pumping will occur after thorough development procedures are applied to screens 2 and 3, it is possible that pumping performance will be better than current projections and removal volumes will exceed the estimates in Table 9.

It is important to note also that the basis for the interflow calculations was data obtained from injection tests. These tests are not as accurate as pumping tests for determining yield characteristics of sediments. Clogging of the injection zone with entrained air can restrict flow, causing an underestimate of well and formation properties. Conversely, leakage past the packers that were used during testing can allow flow intended for a specific zone to move into another zone, causing an overestimate of hydraulic parameters. In addition to these limitations, as stated above, there was no hydraulic information available for screen 1. Nevertheless, the results of the interflow calculations provide insight into the patterns of water exchange among the screen zones that can be expected to occur during rehabilitation and conversion of R-22.

TABLES

Table 1. Theoretical Open-Hole Interflow For R-22 Screens 1 Through 5
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5703.29	0.64
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5703.29	-0.07
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5703.29	-0.56
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5703.29	-0.18

Table 2. Theoretical Open-Hole Interflow For R-22 Screens 1 and 2
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5758.73	0.04
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5758.73	-0.04

Table 3. Theoretical Open-Hole Interflow For R-22 Screens 1 Through 3
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5727.75	0.34
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5727.75	-0.50

Table 4. Theoretical Open-Hole Interflow For R-22 Screens 1 Through 4
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5705.24	0.62
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5705.24	-0.10
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5705.24	-0.68

Table 5. Theoretical Open-Hole Interflow For R-22 Screens 2 Through 4
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5703.48	0.64
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5703.48	-0.07
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5703.48	-0.57

Table 6. Theoretical Open-Hole Interflow For R-22 Screens 3 Through 5
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5695.09	0.08
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5695.09	-0.06
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5695.09	-0.02

Table 7. Theoretical Open-Hole Interflow For R-22 Screens 4 and 5
Los Alamos National Laboratory
Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (feet amsl)	Screen Length (feet)	K ft/day	Static Water Level (feet)	Pumping Water Level (feet)	Q (gpm)
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5694.09	0.001
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5694.09	-0.001

Table 8. R-22 Rehabilitation and Conversion Procedures
Los Alamos National Laboratory
Los Alamos, New Mexico

Task		Duration (days)	Open Screens
1	Remove Westbay	3	1,2,3,4,5
2	Assemble and trip double packers	1	1,2,3,4,5
3	Purge screen 5, assess chemistry	7	2,3,4
4	Round trip pump and packers for testing	1	1,2,3,4,5
5	Test screen 3	1	1,2 and 4,5
6	Test screen 2	1	3,4,5
7	Pull pump, run tremie, plug screen 5	1	1,2,3,4
8	Plug screen 4	1	1,2,3
9	Bail clean, tremie sand, swab, prepare to jet	2	1,2,3
10	Jet screen 3	1	1,2,3
11	Jet screen 2	1	1,2,3
12	Purge well	1	1,2,3
13	Round trip pump and packers for testing	1	1,2,3
14	Test screen 3	1	1,2
15	Test screen 2	1	None
16	Pull pump, run temporary packers	1	1,2,3
17	Pull temporary packeres, install pumping system	7	1,2,3

*Assumes that screen 1 would be packed off

Table 9. Individual Screen Flow Volumes
Los Alamos National Laboratory
Los Alamos, New Mexico

Tasks/ Operations	Duration (days)	Open Screens	Water Volume Transfer (gallons)				
			Screen 1	Screen 2	Screen 3	Screen 4	Screen 5
1 and 2	4	1,2,3,4,5	922	3686	-403	-3226	-1037
3*	7	2,3,4	0	6451	-706	-5746	18000
4	1	1,2,3,4,5	230	922	-101	-806	-259
5	1	1,2 and 4,5	58	-58	2400	1	-1
6	1	3,4,5	0	600	115	-86	-29
7	1	1,2,3,4	230	893	-144	-979	0
8, 9 and 10	4	1,2,3	922	1958	-2880	0	0
Jet Screen 3			60	300	1200	0	0
11	1	1,2,3	230	490	-720	0	0
Jet Screen 2			60	300	1200	0	0
12	1	1,2,3	230	490	-720	0	0
Purge Well			120	600	2400	0	0
13	1	1,2,3	230	490	-720	0	0
14	1	1,2	58	-58	2400	0	0
15	1	None	0	600	0	0	0
16 and 17	8	1,2,3	1843	3917	-5760	0	0
Net Total Volume			5193	21581	-2439	-10842	16674

*Assumes 5 12-hour days of pumping.

REFERENCES

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