Fernald Preserve Aquifer Restoration Extraction Well and Pump Maintenance Improvements – 9427

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ABSTRACT

This paper presents the results of 2008 maintenance improvements on the extraction well field at the Fernald Preserve. The maintenance of the extraction well pumps and screens was improved by changing both the chemical mixture used to clean the wells and pumps, and the cleaning technique. Initial results are very favorable. Pump life and well yield appear to be significantly improved. The improvements have also mitigated hazards that workers face and substantially decreased spending.

INTRODUCTION

The 186-acre groundwater uranium plume in the Great Miami Aquifer, beneath the Fernald Preserve, is being remediated by the pump-and-treat method. The well field consists of 23 extraction wells with design target pumping rates from 100 to 300 gallons per minute (gpm) each. The total well field design target pumping rate is about 4,800 gpm, or 6.9 million gallons per day. The pumps are Byron Jackson submersible multi-stage pumps with five, seven, or eight stages, depending on the diameter of the well and the pumping set point. Seventeen of the pumps are controlled by variable frequency drives (VFDs), but the six oldest do not have VFDs. The flow rates from the oldest six wells are controlled by flow control valves.

Most of the extraction wells are screened across the water table. The pumped water has high concentrations of iron, manganese, and carbonate, which in the past have precipitated out of solution and clogged the well screens, the pumps, and the discharge pipes. The precipitate appears to be held together by filamentous bacteria. The clogging is so severe that the output from some pumps was reduced by over 50 percent in less than 1 year. Figure 1 shows a clean pump impeller, and Figure 2 shows a clogged pump impeller.

Fig. 1. Clean Pump Impeller

Fig. 2. Clogged Pump Impeller

In the past, site personnel typically alleviated the clogging by removing the pump, motor, and discharge pipe from the well; rehabilitating the well with hundreds of gallons of concentrated hydrochloric acid; disinfecting the well with concentrated sodium hypochlorite; and replacing the clogged pump with a new one. A new pump typically costs between $8,000 and $10,000. Cleaning the well was a 2- to 3-week process that cost $20,000 to $30,000. All work was performed by a well maintenance subcontractor. The subcontractor made several unsuccessful attempts to use sodium hypochlorite to clean the pumps in the wells. After the pumps were removed from the wells, they were torn down and cleaned with hydrochloric acid on site to remove residual uranium contamination before being shipped to the well maintenance subcontractor for rebuilding at a cost of $4,000 to $5,000 each.

Routine well performance tests have been conducted quarterly for all wells at the Fernald site since 1996. The tests consisted of operating the pump at multiple flow rates and recording discharge pressure and drawdown. The data allowed for the calculation of well-specific capacity and the pumps' total discharge head at enough points for a graph of each pump's performance to be drawn. The graphs clearly showed the decrease in pump performance from the time of installation to the time of the test. A comprehensive review of all well performance data was performed in mid-2007 and showed that the time between pump replacements was decreasing, in some cases to less than

9 months. In most cases, the well-specific capacity had not decreased significantly; only the pumps were clogged. Research was conducted to determine if other options existed for cleaning pumps while they were still in the wells.

CLEANING-PROCESS IMPROVEMENTS

In the fall of 2007, Aquifer Restoration Project staff attended a day-long well-maintenance class that covered the use of several different chemicals that could be used to clean the pumps in the wells [1]. A well-cleaning expert was brought to the site in January 2008 to look at one of the clogged pumps and recommend effective cleaning chemicals. Two different acid combinations were recommended for use; one was a mixture of hydrochloric and glycolic acids, and the other was a mixture of sulfamic and glycolic acids.

TEST PROGRAM

In late February 2008, Aquifer Restoration Project staff developed a test program to determine the effectiveness of the two acid mixtures. Wells were included in the test program if their pumps could not meet the target pumping rate, if they showed a steady decline since the dates their pumps were installed, and if the well-specific capacity had not decreased significantly over the past year. A performance test of the wells to be treated in the test program was performed beforehand.

In order to focus the cleaning on the inside of the pump, the chemicals needed to be added to the discharge pipe at the top of the pump. Minor modifications were made to some of the discharge pipes to allow a hose to be placed at the desired location. The chemical was added through the hose, using a drum pump. Originally, the amount of chemical used was based on maintaining approximately a 10 percent solution in the water column above the pump. Based on the results of initial testing, the concentration of the chemical solution has been increased to about 50 percent. The cleaning chemicals were allowed to sit in the pump for approximately 3 hours; then the pump was operated for about 5 to 10 seconds before it was stopped. This brief surging allowed the chemicals to circulate throughout all stages of the pump and made it easier to remove the material that constituted the clog, which had been loosened by the treatment solution. The surging was performed manually for some of the wells and through the automated control system for others. Since all of the cleaning chemicals used were acid-based, pH was used to determine when the cleaning ability of the chemicals was exhausted and when to pump the solution from the well.

After surging for several hours manually or overnight using the control system, the pH of the solution in the discharge pipe was checked. If the pH was less than 4, pump surging was continued. When the pH reached or surpassed 4, the solution was pumped to a portable tank, using the well pump. The color of the solution being pumped was observed, and the pH was tested after about 200 gallons had been pumped. Pumping was continued in approximately 200-gallon increments until the pH of the solution was between 6 and 7 and the discharge water was clear. The pump was restarted, with its variable frequency drive or flow control valve set to allow the maximum possible flow rate. The pump was allowed to run at maximum capacity for at least 2 hours, and then the controller was reset to the desired set point. After a day or 2 of routine operation, another performance test was conducted. The results of the before-and-after performance tests were compared to the performance test conducted when the pump was new. Figure 3 below shows the results of cleaning Well 2 with the hydrochloric/glycolic mixture. Treating the well restored its performance almost completely.

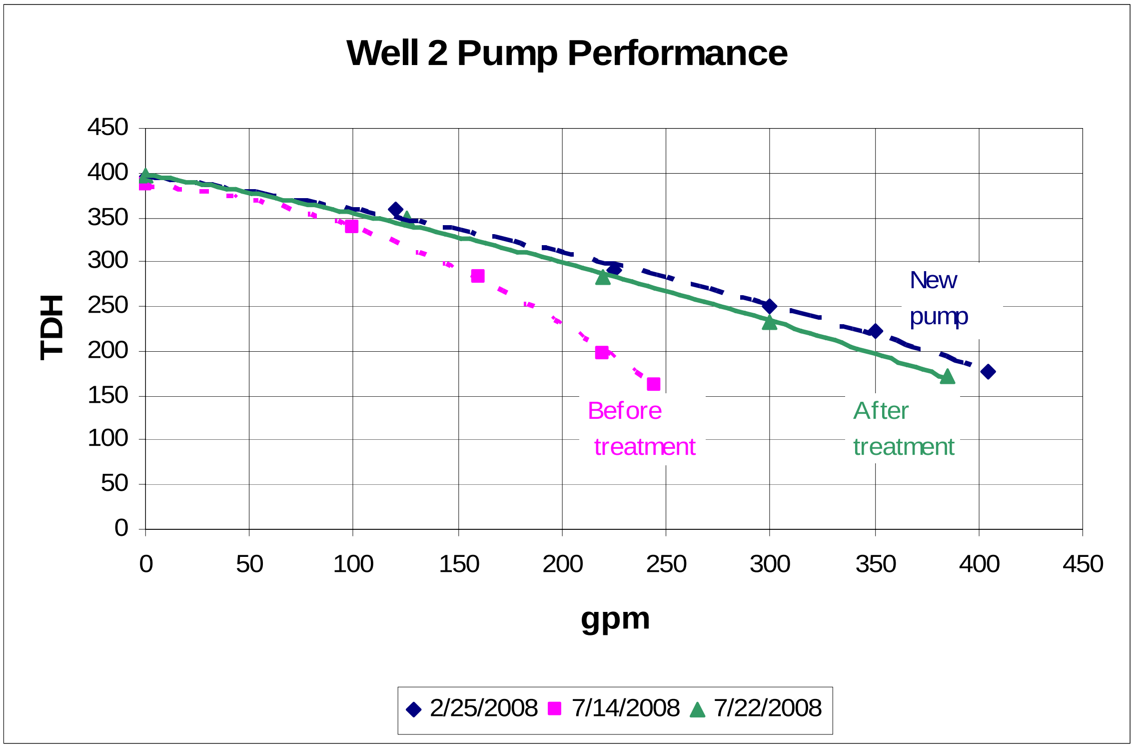

Fig. 3. Performance of Well 2 Pump Before and After Treatment

After three wells were treated with each chemical combination, it was determined that the mixture of hydrochloric and glycolic acids was much better at improving pump performance than the mixture of sulfamic and glycolic acids was. As of the writing of this paper, 14 of 23 wells have been treated with the hydrochloric/glycolic mixture.

Results of Chemical Treatments

The hydrochloric/glycolic mixture was found to be very effective, and initial results of the testing are encouraging. The increase in pump output has ranged from 3 percent to 44 percent in the 18 treatments performed through early October 2008. The pumps that were treated had been in operation from 5 months to 10 years. The length of time the pump had been in the well did not seem to affect the improvement in flow; however, the pretreatment condition of the pump did appear to be a factor in how much the flow could be improved (i.e., if pump clogging is allowed to progress beyond a certain point, testing to date indicates that pump yield cannot be restored as well as when pumps have been treated before pump performance is seriously degraded). Table I summarizes the results of the first 18 treatments.

Table I. Results of Well Pump Cleaning with Hydrochloric/Glycolic Mixture

Well Number	Set point L/s (gpm)	Maximum Flow Rate before Treatment L/s (gpm)	Pressure at Max. Flow Rate before Treatment (psi)	Maximum Flow Rate after Treatment (gpm)	Pressure at Max. Flow Rate after Treatment (psi)	% Improvement in Max. Flow Rate
1	14 (220)	20 (320)	62	25 (398)	60.4	20%
3	14 (220)	18 (280)	34	23 (358)	40	22%
4	14 (220)	22 (351)	41	29 (462)	54	24%
6	14 (220)	15 (236)	31.9	19 (302)	32	22%
7	14 (220)	19 (295)	27.1	23 (359)	41	18%
17 (first treatment)	11 (175)	9 (144)	37.8	16 (260)	47.8	45%
17 (second treatment)	11 (175)	18 (290)	38	19 (300)	48	3%
20	7 (110)	11 (170)	19.3	14 (215)	23.8	21%
21	14 (220)	16 (250)	24.1	22 (350)	22.8	29%
22	21 (330)	20 (312)	39.7	21 (332)	41.7	6%
23 (first treatment)	21 (330)	24 (388)	30	28 (448)	58	13%
23 (second treatment)	21 (330)	21 (337)	29	26 (413)	31	18%
24	21 (330)	20 (315)	35	25 (397)	41.3	21%
25 (first treatment)	9 (150)	8 (127)	26.3	12 (186)	24.2	32%
25 (second treatment)	9 (150)	13 (204)	23.3	15 (242)	22	16%
30 (first treatment)	14 (220)	15 (235)	28.8	20 (315)	25.4	25%
30 (second treatment)	14 (220)	18 (286)	31.2	19 (296)	26.3	3%
32	14 (220)	14 (222)	23.9	20 (310)	37.1	28%

L/s liters per second
psi pounds per square inch

The maximum flow rate with the VFD or flow control valve set to maximum flow is used as the key data point for determining the immediate success of the treatment. A complete performance test is typically performed after treatment to ensure that pump performance has improved throughout the complete range of flows.

The decision to treat a pump is based on several factors. The first is whether the pump can consistently meet the target pumping rate for the well. Table I shows several wells that could not meet their target rates before cleaning but were able to meet them after cleaning. The second factor is how far the current performance is from the original pump curve. Even if the flow rate is still above the target pumping rate, the pump may be treated if the performance shows significant deterioration during the quarter. The third factor is historical performance. Several pumps have shown a tendency to clog in less than a year. These pumps are being treated before their performance deteriorates significantly in order to prevent the establishment of a clog that cannot be removed in situ.

Safety Improvements

Three main safety improvements have been realized by using the new treatment chemicals. The first is that the pump is treated while still in the well. This eliminated all hazards associated with the use of a crane to pull the discharge pipe, pump, and motor from the well and then reinstall the new pump with the old motor and discharge pipe. Figure 4 below shows workers installing a new pump and motor in a well. The discharge pipe, pump, and motor assemblies typically weigh over 2,000 pounds. The types of hazards eliminated are falling objects from a failed crane or an improper lifting, back injuries from disconnecting discharge pipes, crushed hands from handling discharge pipes, and electrical injuries from improper disconnection or reconnection of the motor.

Fig. 4. Installing Pump & Motor in Well

The second main safety improvement is a significant reduction in the quantity of hazardous chemicals used by personnel. After a clogged pump is removed from the well, it is transported to the wastewater treatment facility for cleaning. Operations personnel dip the pump parts in tubs of hydrochloric acid. Personnel exposure is minimized by using the building bridge crane to lower the parts into, and remove them from, the acid. However, the potential for exposure to acid fumes still exists. If the time between pump removals can be extended by cleaning the pumps in the wells, personnel's exposure to acid fumes while cleaning the pumps can be reduced.

The third safety improvement is related to well-screen rehabilitation. The previously used method for rehabilitation used hundreds of gallons of concentrated hydrochloric acid to clean the well screen and 50 to 100 gallons of 12.5 percent sodium hypochlorite for disinfection. Based on initial testing, the hydrochloric/glycolic mixture appears to be an effective well-screen cleaning agent in much lower concentrations and volumes. Further tests are being performed to validate the agent's effectiveness as a well-screen cleaner.

Cost Savings and Cost Avoidance

These treatments have saved more than $150,000 this year (fiscal year 2008), and ongoing annual savings of this magnitude are anticipated. The savings are realized by extending the life of the pumps, thereby reducing the number of pump change-outs that are required. This results in fewer expenditures for (1) removing and replacing pumps and motor assemblies ($1,000 to $2000 per pump) and (2) buying rebuilt or new pumps ($4,000 to $10,000 each). Additional savings are realized by maintaining well yield without the need for major cleaning operations. As noted in the introduction, the old method of well cleaning typically cost $20,000 to $30,000 per well.

Conclusion

The old way of maintaining the extraction well field at the Fernald Preserve was reviewed and questioned. A new method for well-pump and well-screen cleaning has been developed and continues to be refined. The new method has resulted in significant improvements. The well pumps' lives have been extended, the well screens are kept clean longer, job hazards have been mitigated, and maintenance costs have been reduced.

References

SMITH-COMESKEY GROUND WATER SCIENCE LLC, "Ground Water and Wells Seminar", (2007)