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Most wells eventually lose capacity and experience lower pumping water levels, resulting in increased pumping costs. Implementing a time-based maintenance program can avoid potential problems. Ongoing performance monitoring can signal when it's time for rehabilitation to maintain or restore performance. **BY RAY REECE, BILL PREHODA, AND RANDY MOORE**

MAINTENANCE

WELL ASSET MANAGEMENT INCREASES SERVICE LIFE

Editor's Note: *This is the second of a three-part series of articles based on a series of AWWA webinars on distribution system issues. The first article, which appeared in the September 2013 issue, described what biofilms are, what problems they create, how they relate to coliforms, and how to evaluate them. This article reviews water well rehabilitation technologies and discusses how they can be incorporated into a well asset management program. The final article, which will appear in the November 2013 issue, will cover new leak-detection technologies coming to the United States. For more information, visit www.awwa.org/webinars.*

WATER WELLS, like other distribution system assets, require periodic maintenance and rehabilitation. An effective condition assessment can help you select the proper rehabilitation technology (or technologies) from a wide array of options.

It's possible to develop a sustainable well asset management program and, with some rehabilitation technologies, install hardware in the well that allows periodic maintenance without removing the pump. Based on the condition assessment and ongoing monitoring data, a cleaning schedule can be established to maintain performance and water quality.

PHOTOGRAPHS: SUBSURFACE TECHNOLOGIES

Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology. With some technologies, such as carbon dioxide, hardware installed at the wellhead allows the cleaning technology to be installed into the well while the pump is in place.

WELL PLUGGING

Nearly all wells experience plugging, which can result in lost capacity, water quality changes or deterioration, increased pumping costs, and possible increased treatment costs. Most well plugging is caused by naturally occurring groundwater bacteria and biofilm that deposit minerals in pore spaces, gravel pack, and well screen intervals.

Run to failure often has been the accepted approach to well rehabilitation and maintenance. Run to failure means wells are operated until the production rate declines, the well begins to pump sand, or water quality declines to an unacceptable level from customers' or regulatory compliance perspectives.

A customized, sustainable asset management program employs rehabilitation technology to restore a well to or near its original design parameters based on a full condition assessment. Then, based on each well's specific characteristics, a time-based preventive maintenance program should be developed and implemented to maintain well performance and water quality, extend the well's service life, and reduce or eliminate the need for future rehabilitations.

EFFECTIVE REHABILITATION

Well rehabilitation requires several steps to be successful. The following nine-step process will assure effective rehabilitation:

- Conduct an accurate pre-rehabilitation pump test using a calibrated flow device, such as a manometer and orifice system, to determine the current performance of the well and pump.
- Use an adequate pump-removal rig to safely remove pumping equipment.
- Inspect and repair the pump. When the rehabilitation is complete, replace the pump.
- Video-inspect the well to confirm its construction and identify integrity concerns within the casing or screen intervals.
- Conduct pretreatment using mechanical tools (wire or polypropylene brushing).
- Based on information obtained in the condition assessment, apply the appropriate rehabilitation technology.
- Redevelop the well using a down-hole airlift or pump-equipped double-disk swab made specifically for this type of work. Removing plugging materials is critical to the rehabilitation effort's longevity.
- Conduct a post-development video inspection to confirm cleaning results and inspect the casing/screen for integrity.
- Install pumping equipment with optional in-hole preventive maintenance tools.
- Conduct a post-rehabilitation pumping test to confirm well and pump performance conditions, set a benchmark

CASE STUDIES

CUSTOMIZED STRATEGIES RESTORE WELL PERFORMANCE

Each well is unique and requires an effective condition assessment to determine the optimum rehabilitation technology or technologies. The following case studies demonstrate that each well requires a customized rehabilitation strategy to restore performance and water quality.

Wells 29/29A. Well 29 is a vertical, screened well that taps a shallow sand aquifer. With an original design of 1,400 gpm, pumping Well 29 resulted in entrained sand caused by high-velocity water entering and clogging the well, which reduced capacity. Although rehabilitations using surge blocks with simultaneous air pumping regained some capacity, rehabilitations couldn't remove all of the clogging sand. Therefore, a new well was drilled.

Well 29 was replaced by Well 29A, which was designed to operate at 1,000 gpm or less to reduce entrance velocities and limit sand migration while retaining short-term peak-production capabilities of 1,400 gpm. Periodic pumping tests to monitor performance confirm Well 29A's ability to maintain the designed pumping rate. Periodic well rehabilitation focuses on physical energy to mobilize and remove sand.

Well 29A rehabilitations have included surging with simultaneous pumping and pressurized nitrogen. Nonphosphate surfactants have been used during surging to help mobilize fines. During rehabilitation, daily monitoring of the discharge flow rate and water levels allow personnel to track the rehabilitation's efficacy and a particular technique's effectiveness. Using high-pressure nitrogen at Well 29A has helped loosen compacted sediments and potential cementation of sediments. By removing the surge equipment, conducting high-pressure nitrogen pulses at about 1,200 psi, and reinstalling the surging equipment, nitrogen can be used during the surging process. A combination of rehabilitation techniques is helping Well 29A regain and maintain well capacity.

Well 29A and Well 27 are located in a two-well wellfield. Although several years older than Well 29 and constructed similarly in the same aquifer, Well 27 requires periodic rehabilitation but doesn't need to be replaced, illustrating that similarly constructed wells in the same area may react differently over time.

Well 42A. Vertically screened Well 42A taps a shallow sand and gravel aquifer. The well is 70 ft deep with 15 ft of 12-in.-diameter 60-slot screens originally rated at 300 gpm. The well has a history of severe iron- and manganese-related bacteria biofouling. A pre-rehabilitation video showed significant biofilm on the screen, which was in good condition. Pre-rehabilitation pumping tests revealed significant capacity loss caused by biofouling.

Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology.

for future comparisons and monitoring, and produce a final report that includes all results and performance factors associated with the condition of the well and pump.

ASSET MANAGEMENT

Because most wells eventually lose capacity and experience decreased water levels and increased pumping costs, ongoing performance monitoring can signal when it's time for rehabilitation to restore performance and water quality. Sustainable well asset management programs can be developed that avoid the practice of running to failure.

With certain well rehabilitation technologies, such as carbon dioxide, hardware installed at the wellhead allows the cleaning technology to be installed into the well while the pump is in place. When the hardware is installed, mini-cleanings can be performed per a time-based program to maintain well performance:

- A pretreatment (short) pump test determines pre-maintenance performance of the well and pump.
- Maintenance treatment is applied, with the pump in place.
- Post-application, the pump is operated to remove disrupted material from the well until satisfactory water is produced, followed by a pump test and report.

The benefits associated with this asset management approach include

- a significantly extended asset life cycle.
- reduced and/or maintained operational costs.
- improved well performance, consistency, and maintenance.
- predictable costs (flat and fixed annual fee for budgeting).
- consistent water quality by maintaining production from the proper zones.
- improved knowledge of well and system conditions with annual maintenance and associated reports.
- proactive well maintenance, instead of crises repairs or maintenance when wells are run to failure.
- time-based maintenance cleanings to keep well surfaces clean and maintain performance.

AN OUNCE OF PREVENTION

Most wells experience decreased performance and water quality over time. Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology. Develop an ongoing sustainable well management program by conducting periodic cleanings—with the pump in place—that will maintain well performance and water quality, eliminating the run-to-failure practice.

After wire brushing loosened biofouling from the screen, the material was pumped out so subsequent procedures didn't push the material into the aquifer. Next, pressurized carbon dioxide was injected. The well, including the nearby test well, was sealed with a packer to prevent short circuiting of the carbon dioxide. Over two days, 4,000 lb of carbon dioxide were injected to dislodge clogging material, in this case biofouling.

The final technique used surging with simultaneous pumping to remove material dislodged by the carbon dioxide treatment. Because of the action of the carbon dioxide injection, surging duration is usually less (2–3 days in this case) than when carbon dioxide isn't used.

A post-rehabilitation video of the Well 42A screen revealed dramatic cleaning results. The post-rehabilitation pumping test revealed the initial carbon dioxide treatment restored the well's original capacity. Although subsequent rehabilitations didn't restore original capacity, the design rate was maintained but with greater water-level drawdown.

Because more frequent rehabilitations were needed for Well 42A, a permanent stainless steel injection pipe was installed to allow periodic carbon dioxide injections without having to remove the pump. To date, yearly injections have maintained Well 42A's capacity.

Well 100. A 126-ft deep vertical well that taps a sand and gravel aquifer, Well 100 has a design pumping rate of 1,200 gpm. Performance monitoring over time revealed that Well 100 had lost capacity because of small amounts of sand migration, iron biofouling, and iron oxyhydroxide precipitation. A recent pre-rehabilitation video survey showed minor biofouling and iron precipitate as well as a casing perforation (up to 1 in.) attributed to corrosion. The casing perforation, if unchecked, would allow entrainment of sand and gravel in the pump, possibly causing the well to collapse. The ultimate solution would be to redrill the well and provide corrosion protection. However, in the interim, a liner screen was installed to allow the well's continued use.

Before the liner screen was installed, the well was rehabilitated because performance monitoring showed decreased well capacity. Future liner-screen rehabilitations will be more difficult because of additional well losses associated with having two screens.

Well 100 rehabilitation was initiated with a surge block outfitted with a submersible pump for simultaneous pumping. Nonphosphate surfactants (to mobilize fines) and hydrochloric acid (to dissolve precipitates) were also used during rehabilitation.

After rehabilitation, a 40-ft, 125-slot telescoping liner screen with a K-packer was installed within Well 100. Post-rehabilitation pumping test results revealed capacity had increased from the pre-rehabilitation level. Although the liner screen caused some expected capacity loss, Well 100 is operating at its 1,200-gpm design capacity.