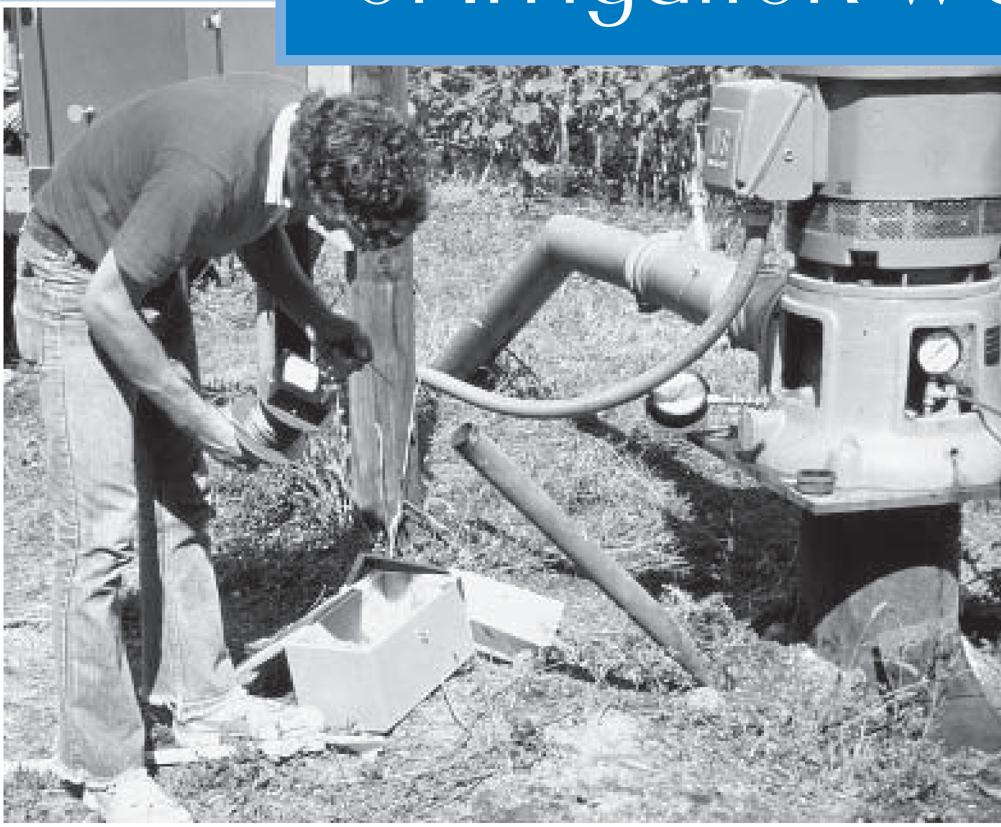
AE-97 (Revised)

Care and Maintenance of Irrigation Wells



Tom Scherer
Agricultural Engineer

Effective irrigation is not possible without a reliable water source. In North Dakota, the availability of relatively shallow aquifers with high-quality water has spurred the development of irrigation in many areas. Irrigation wells must produce a high volume of water during the driest months of the year, July and August. To maintain consistent, high production from year to year, a well requires annual maintenance, just like any other piece of valuable equipment.

NDSU Extension Service
North Dakota State University
Fargo, North Dakota 58105
JULY 2005

A typical drilled-irrigation well has a screen at the bottom to let in water. It also has non-perforated pipe, called casing, which is connected to the screen and rises to the surface (Figure 1). Many wells have a filter pack around the screen to prevent fine sand in the aquifer from entering the well. The filter pack, commonly called a gravel pack, is composed of clean, well-rounded quartz-based grains of uniform size. Generally, a well with a gravel pack can have a screen with larger openings.

The water level in a well that is not being pumped will rise to an elevation determined by the type of aquifer and surrounding geologic conditions. This is called the static water level and can vary from year to year, depending on recharge to the aquifer. If the water rises to the surface and flows from the well, it is called an artesian or flowing well. When a pump is turned on, the water will drop to what is called the pumping water level. The difference between the static water level and pumping water level is the drawdown in the well (Figure 2). Drawdown is a measure of the hydraulic head needed to push water through the aquifer material into the well at the desired flow rate. Drawdown generally will increase over time due to the screen openings becoming plugged, thus annual maintenance is necessary to keep the well producing the desired flow rate.

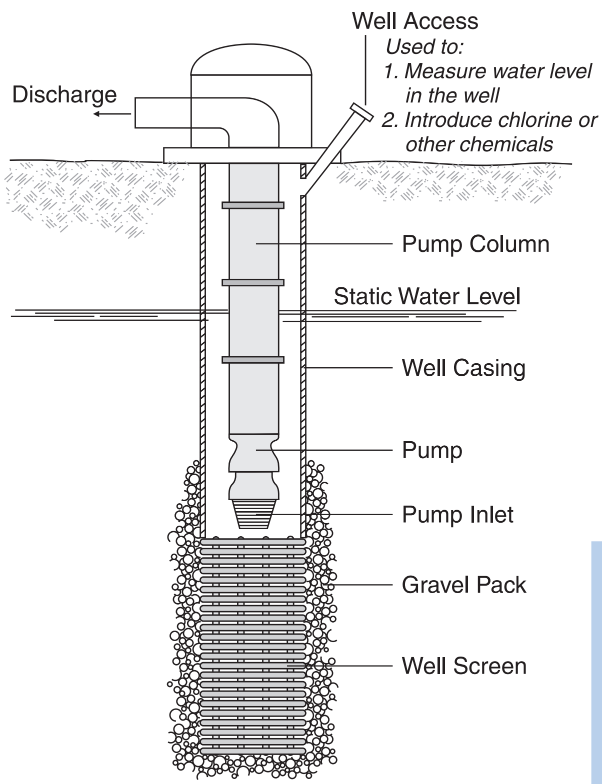


Figure 1. Typical irrigation well and pump.

Measuring Well Performance

Accurate well performance records are the key to maintaining an irrigation well. After construction, a well will produce a certain flow rate at a given amount of drawdown. The total flow it can produce often is called the "well yield." Specific capacity is a common measure of well performance. It is calculated by dividing the flow rate by the drawdown. The units of specific capacity are gallons per minute per foot of drawdown (gpm/ft). The specific capacity of a well should be measured and recorded at the same time each year as shown in Table 1. August is the best time because it generally is the driest month. During August, most irrigation pumps have been on for some time, causing both pumping and static water levels to be at their lowest of the year.

As the years pass, the performance of most wells will decrease without some form of maintenance. Years three and five have been left out of Table 1, but examining the data from year six shows that the performance has decreased significantly. Increased drawdown often will reduce the flow rate due to the greater lift required from the pump, and it can increase pumping energy requirements. Therefore, having an accurate flow meter

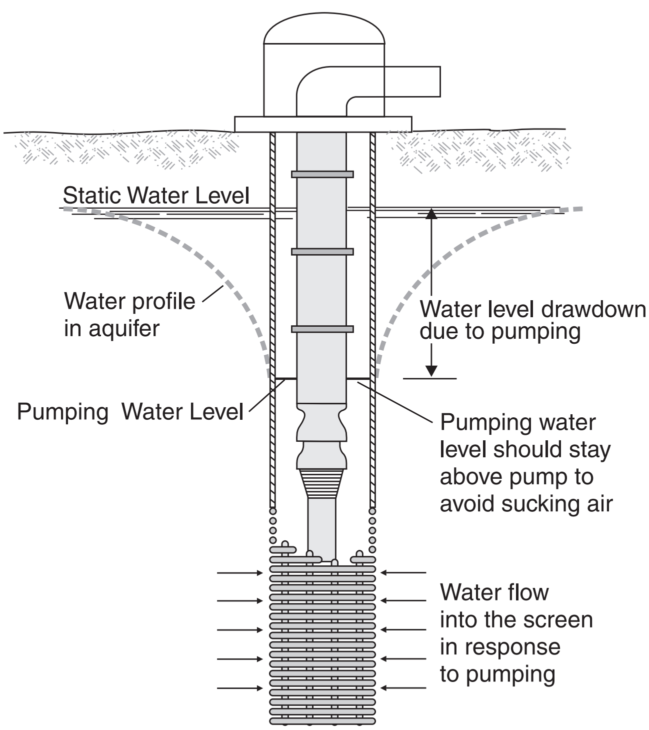


Figure 2. Side view of pumping irrigation well.

on each well and a useable access port to the well casing, Figure 3, is important. The access port is used to measure the water level in the well and to add chlorine or other chemicals to the well. It should be at least 1 inch in diameter, but a 2-inch diameter access is preferred. For your convenience, a sample well performance data sheet has been included with this publication.

Table 1. Example: Yearly record of specific capacity of irrigation wells.

Year	Flow Rate from Well (gpm)	Pumping Water Level (PWL) (feet)	Static Water Level (SWL) (feet)	Drawdown (PWL-SWL) (feet)	Specific Capacity *Flow Rate divided by Drawdown* (gpm/ft)	Comparison to New Well
1	900	80	30	50	18	
2	900	73	22	51	17.6	98 %
4	880	85	31	54	16.2	90 %
6	850	89	30	59	14.4	80 %

Figure 3. Measuring the water level in a well with a steel tape.

Annual Maintenance

Here are some recommended procedures and practices for increasing the irrigation well's useful life and to prevent iron-reducing bacteria and/or mineral incrustation from accumulating.

- Keep continuous records of well operation by measuring and recording well performance on an annual basis. Make a copy of the well performance data sheet for each well and use it to keep track of annual measurements. If the specific capacity drops to around 80 percent of new, rehabilitate the well.
- Never allow the pumping level to drop below the top of the screen. Exposure to air (oxygen) will accelerate the buildup of mineral deposits and incrustation.
- Annually chlorinate the well. Ideally, it should be done before and after the irrigation season, but most irrigators do it once in the fall. Chlorination in the fall is preferred because many bacteria grow best in still water during the winter.

Causes of Well Problems

Well screen problems generally fall into three categories: physical blockage, biological blockage and chemical blockage. No matter how screen blockage happens, it increases the drawdown and pumping energy requirements. For example, an extra 10 feet of drawdown from a well producing 800 gallons per minute will increase pumping energy costs about $110 per growing season. This calculation is based on 900 hours of pumping time and an off-peak electric rate of 5.5 cents per kilowatt-hour.

Physical Screen Blockage

An accumulation of sand, silt and other materials inside the well screen can reduce water flow into a well. As they accumulate in the bottom of the screen, the inlet area is reduced. These materials can find their way into the well through a variety of ways. The most common are holes in the casing from corrosion, migration of fines from overpumping, poor placement or sizing of the gravel pack, screen openings that are too wide and poor well development following construction.

"Bailing" these materials from a well is relatively easy, but the pump has to be removed. After they have been cleaned out, the source of the problem has to be identified. Often this requires a down-hole camera to examine the casing and screen, Figure 4.

Biological Screen Blockage

Naturally occurring, common soil bacteria are found in almost all aquifers and are the cause of biological screen blockage. The bacteria are in three main types: iron-reducing, sulfate-reducing and slime producing. Of the three, iron bacteria and slime producing bacteria are the most familiar to irrigators.

Iron-reducing Bacteria

The water in most aquifers in North Dakota contains some level of dissolved iron. The amount of iron may vary from very low to very high, depending on the depth and location of the aquifer. Determining the presence of iron in irrigation water is easy because a rusty color will stain pumps, pipelines and irrigation systems. Often the rotten-egg smell of hydrogen sulfide gas also will be noticeable when the pump is operating. Generally, if the iron amount in the water is greater than 0.3 parts per million (ppm), iron bacteria problems will arise. Even small quantities of iron provide a source of energy for the growth and development of iron bacteria. These bacteria form a slimy organic substance on the well screen, pump intake and pump column, and in the water-bearing aquifer materials surrounding the screen, Figure 5. As the bacteria build up, they reduce the open area of the screen and the open spaces in the aquifer materials surrounding the screen, thus reducing well yield. If exposed to air, this buildup hardens and becomes much more difficult to remove.

Sulfate-reducing Bacteria

Many aquifers in North Dakota have relatively high levels of sulfate in the water. Sulfate-reducing bacteria consume the sulfate in the water and the byproducts are an organic acid and hydrogen sulfide gas (rotten-egg smell). These bacteria are anaerobic in nature (don't need oxygen). They reside behind scale and other low-oxygen environments, thus they are harder to kill than other types of bacteria.

Slime-producing Bacteria

Bacteria that produce a biofilm or slime coexist with iron and sulfate-reducing bacteria. The byproduct of these bacteria is a slime that often can be seen on pumps removed from a well. The slime can plug screen openings, the gravel pack and sometimes the aquifer materials outside the screen.

Figure 4. Underwater camera about to be lowered into a well to look for problems in the casing and screen.

Figure 5. Iron bacteria on pump column riser pipe just removed from a well.

Chemical Screen Blockage

Chemical blockage results from the deposition of minerals in the form of scales or incrustation on the well screen, Figure 6. It also cements parts of the gravel pack and aquifer materials on the outside of the screen, Figure 7. Most mineral deposits on well screens either are calcium and magnesium carbonates or calcium and magnesium sulfates. They precipitate out of the water where the water velocity is highest and the pressure is lowest — at or near the entrance to the well screen. These are the same materials that build up around the ends of faucets in many houses. These minerals bond the aquifer materials into a solid mass that over time will plug the well screen openings and cement the materials outside the screen. A properly designed well screen will have entrance velocities of less than 0.1 foot per second. Water entering the well screen at a rate greater than 0.1 feet per second can contribute to more rapid mineral deposition. The rate of incrustation accelerates with time because as some of the screen openings become plugged, the water enters the remaining slots at a higher velocity, which causes more incrustation.

Iron-reducing bacteria and mineral incrustation are different in origin and require different treatments for removal. However, having both of these problems in the same well is common.

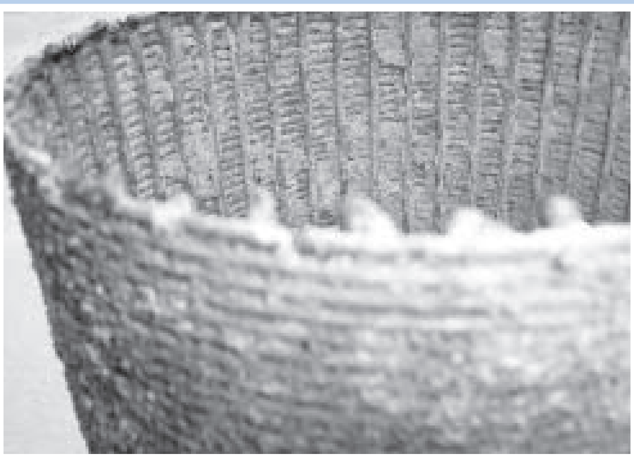


Figure 6. Encrusted minerals on the inside of a totally plugged well screen.

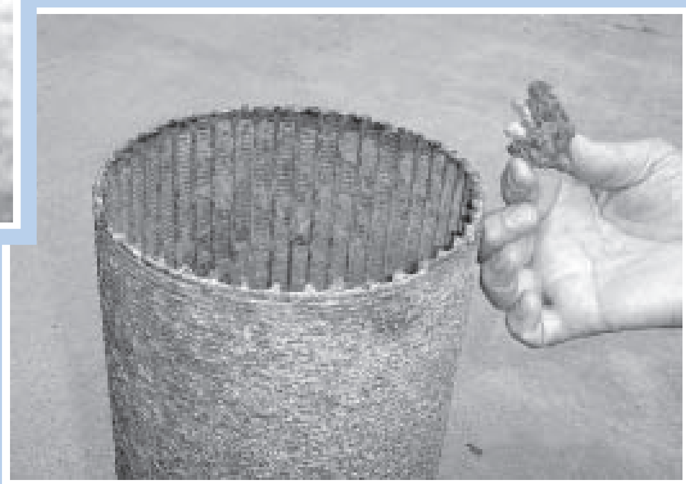


Figure 7. Encrusted and plugged well screen along with an example of cemented gravel from the aquifer materials outside the screen.

Chlorination Procedure

Many irrigators do their own well chlorination each year, but if you are unsure about how to do it, contact a well driller or irrigation dealer. The object of well chlorination is to raise the chlorine level in the well to around 500 ppm and hold it there for at least 24 hours to allow the chlorine to attack and kill the bacteria. Getting the chlorine out into the aquifer material surrounding the well screen, Figure 1, also is very important. Chlorine comes in either dry or liquid formulations. Use formulations designed for water wells. Do not use stabilized chlorine products designed for swimming pools because the chlorine's release time is too long. Wells need a quick-acting form of chlorine.

Chlorine Products

Calcium hypochlorite (sometimes referred to as HTH) is a dry, white to yellowish material. It comes in pellets, powder or granular forms. It contains about 65 percent available chlorine by weight. Calcium hypochlorite requires careful storage to avoid contact with organic materials, especially petroleum-based products. If calcium hypochlorite is mixed with petroleum products, it will become hot enough to start a fire. When mixed with water, calcium hypochlorite will create heat. If preparing a mixture to pour into the well, **never add water** to the container holding the calcium hypochlorite because of the excessive heat and noxious gases that will be produced. Rather, add a measured amount of calcium hypochlorite to a sufficient quantity of water (at least 30 gallons) to control the heat.

Sodium hypochlorite is a clear, yellow liquid familiar to most people as laundry bleach. Common laundry bleach sold in stores contains about 6 percent chlorine, but commercially available formulations can be up to 12 percent chlorine.

Irrigators with oil-lubricated, deep-well turbine pumps should be especially careful if they use any dry form to chlorinate their wells. These wells commonly have a layer of oil on top of the water. Mixing chlorine and oil can be explosive. In addition, dry forms of chlorine will collect on the flanges of the column pipe and over time will eat holes in the pipe. Therefore, if irrigators use a granulated or pellet form of chlorine, they should mix it with a suitable amount of water before pouring it into the well.

Chlorinate the well before pumping out the pipelines for the winter. Then you have the option of pumping the chlorinated water from the well to waste through the irrigation system.

Use the following procedure to chlorinate your well(s)

Procedure to chlorinate your well(s)

1. Determine the depth of the water standing in the well. This is the total well depth minus the depth to static water.
2. From Table 2, determine the amount of chlorine needed. For example, if your well is 12 inches in diameter and 100 feet deep with a static water level at 20 feet, the column of water is 80 feet or eight 10-foot increments. The amount of chlorine bleach needed is 8 x 2 quarts/10 feet or 16 quarts (4 gallons). The amount of dry 65 percent chlorine product needed would be 8 x 0.4 pounds/10 feet or 3.2 pounds.
3. Introduce the chlorine into the well. Use protective gloves and goggles since chlorine solutions this strong can cause skin burns. If you are using the dry form of chlorine, always read the label to make sure you are using the correct amount.
   a. When using liquid bleach, mix with at least 50 gallons of water and pour into the well. Add another 100 gallons of water or more to distribute the chlorine mixture throughout the well.
   b. When using chlorine granules or powder, dissolve slowly by mixing with 50 gallons of water or more. Pour slowly into the well. Add another 100 gallons of water or more to distribute the chlorine mixture throughout the well.
   c. When using chlorine pellets, drop them through the well access port very slowly (about 20 to 30 pellets every minute). When that is completed, pour 10 to 20 gallons of water down the access hole to wash off any pellets that might be stuck in the access pipe or hung up on pipe flanges.
4. Wait at least four hours for the chlorine to disperse throughout the water column.
5. Surge the well for one hour (surging is starting and stopping the pump intermittently, but not allowing water to discharge from the well). This action also is called "rawhiding" a well. With deep-well turbine pumps, allow five minutes between starts with no more than six starts in an hour. **Caution:** *Don't start the pump while it is rotating in the reverse direction. On some pumps, water flowing back into the well causes the impellers to rotate backward and starting the pump may loosen the impellers from their seats.*
6. **Let the chlorine stand in the well for 24 hours. Chlorine needs time to kill iron bacteria.** Don't leave the chlorine in the well during the winter. Concentrated chlorine will attack the metal in the pump, casing and screen and weaken these components.
7. Surge the well at least two more times, then pump the water to waste. The water should be quite dirty and it should smell – an indication that the chlorine did its job. However, this water might plug sprinklers or pressure regulators on center pivots. If you pump it through a center pivot, remove the sand trap plug. Stand upwind because the chlorine smell could be strong. Pump until the odor of chlorine is gone.

Rehabilitating a Well

When the specific capacity of a well decreases to around 80 percent of new, or the pump starts sucking air, that usually means flow blockage is significant. When a pump starts sucking air, the pumping water level has dropped to the point where air is entering the pump intake. Air in the water will produce a surging action in the discharge piping and can be heard easily.

Water production problems often occur during the irrigation season and the irrigator has three options: partially close the discharge valve to reduce the flow rate and stop the pump from sucking air, rehabilitate the well or drill a replacement well. Partially closing the discharge valve will reduce the flow rate to the irrigation system and can jeopardize yield potential. It is a temporary solution.

Rehabilitating a well requires specialized knowledge, equipment and powerful chemicals. **Hire a licensed well driller to perform irrigation well rehabilitation.** To be done properly, the pump should be removed from the well. This is a good time to have the pump and motor examined for wear and other problems. Rehabilitating a well and the surrounding aquifer formation should be a four-step process using a combination of mechanical tools and chemical treatment. In practice, chemical treatment and redevelopment often are done at the same time.

Table 2. Quantity of chlorine material to use for each 10 feet of water in an irrigation well.

Well Diameter (inches)	Gallons of Water in 10 feet of Well Casing	65% Chlorine per 10 feet of Water (dry pounds)	Laundry Bleach 6% Chlorine per 10 feet of Water (liquid quarts)
4	6.5	0.05	0.25
6	15	0.1	0.5
8	26	0.2	1
10	41	0.3	1.3
12	59	0.4	2
14	80	0.5	2.5
16	104	0.6	3.5
18	132	0.8	4.5
20	165	1.0	5.4
24	235	1.5	7.75

Step 1: Mechanical Tools

Mineral incrustation and bacteria buildup in easy-to-reach areas, such as within the casing and screen, often can be dislodged and removed using mechanical tools, such as wire brushes, disk swabs or surge blocks, combined with airlift pumping, Figure 8. All debris from this operation should be removed from the well. Removing much of the mineral and biological buildup mechanically will increase the effectiveness of the chemical treatment greatly.

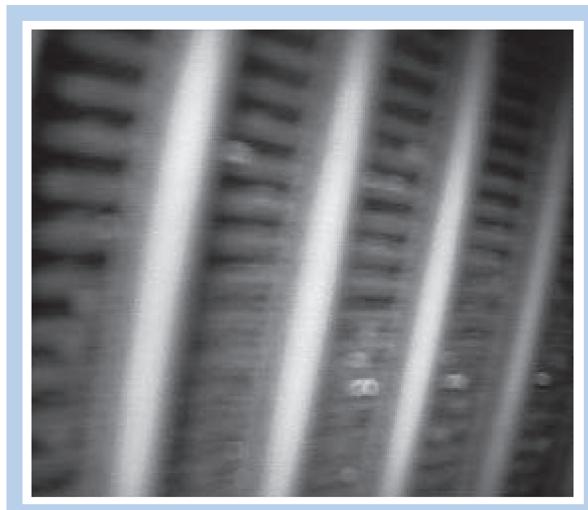


Figure 8a. View of a clean, cage-wound stainless steel well screen using an underwater camera. Note that some of the gravel pack can be seen through the screen slots.

Figure 8b. View of an encrusted, cage-wound stainless steel well screen using an underwater camera. Note that no slots are visible and the white between the vertical wires are slots encrusted with minerals.

Step 2: Chemical Treatment

Chemically treating a well usually refers to using some form of strong acid to dissolve the mineral incrustation on the screen, casing, and in the gravel pack or aquifer surrounding the screen. Often this is called "acidizing" a well. However, sometimes because of water chemistry, using a strong base might be better than acid. Many types of acid can be used (see sidebar on "Common Well Cleaning Acids") for this purpose, but the well driller should remember that acid selection is site specific and depends on the materials used to make the casing and screen, as well as water quality and aquifer materials. Screens made from plastic, fiberglass and stainless steel are resistant to most strong acids and bases used for chemical treatment. Strong acids can damage screens made from perforated iron casing, galvanized iron cage-wound screens and steel screens.

Common Well Cleaning Acids

All chemicals to clean wells should be labeled for use in water wells. The amount of chemical added to a well should be based on the quantity of water in the well. Often adding too much acid to a well may not help and actually can hinder the rehabilitation process. With severe mineral incrustation, doing the acidizing in two steps often is better. Use the first batch of cleaning chemicals to dissolve some of the minerals, then pump them out and add the second batch to dissolve the remaining parts. Wear the proper safety equipment, as recommended by the chemical manufacturer, when handling well-cleaning acids. Equipment should include goggles, masks, rubber gloves and full clothing coverage. In addition, a supply of clean water for eyewash and rinsing spills should be available.

Muriatic Acid

Muriatic acid, a common product used for acidizing a well, is an industrial name for a hydrochloric acid solution with about 30 percent concentration – a very strong acid. It provides a fast chemical reaction to dissolve carbonate scales and incrustation. It is particularly effective against iron and manganese oxides but doesn't remove biological buildup very effectively. Although good for cleaning wells, hydrochloric acid can be dangerous to handle. Excessive amounts in the well can produce large amounts of toxic fumes. Inhaling these fumes can cause death. Use only the recommended amount of acid for the volume of water in the well. Only professionals with training and access to proper safety equipment should handle this acid.

Sulfamic Acid

This is a type of sulfuric acid and comes in a dry form. It is safer to use than muriatic acid, but has a moderate chemical reaction, so it takes longer to dissolve carbonate scales and incrustations. It is not very effective against sulfate mineral deposits. Sulfate is present in relatively large amounts in much of the groundwater in North Dakota. Sulfamic acid doesn't produce harmful fumes and is not very corrosive. It isn't very effective at removing biological buildup.

Phosphoric Acid

Phosphoric acid is a mild acid that contains phosphorus, which if discharged into wetlands or water bodies can increase algae buildup. It is less corrosive to metal than muriatic acid. It is somewhat effective in dissolving iron and manganese oxides but is not very effective against biological buildup in the well.

Glycolic Acid

Glycolic acid, also known as hydroxyacetic acid, is effective against biological accumulations. It will disperse and help remove biofilms that build up on the screen, pump and casing. The chemical reaction is slow and creates no harmful fumes.

Acid Combinations

To remove both biological products and mineral incrustations effectively at the same time, well drillers often use a combination of acids when rehabilitating a well. One combination is to mix muriatic and glycolic acid together, with each added to a volume of water at about the same percentage by weight or volume. More often, well drillers will use commercial products that are premixed acid combinations designed to address specific incrustation problems.

Step 3. Redevelopment

When a well is drilled, development is the last step of the drilling process. Development entails agitating the water in the vicinity of the screen to remove fine sand and drilling mud in the borehole left over from the drilling process. Redevelopment of a well involves the same procedure, but now the goal is to remove encrusted material in the gravel pack or aquifer material outside of the screen. Quite often the redevelopment process is combined with chemical treatment to dislodge, dissolve and remove minerals and iron deposits in the well. It's common to introduce chemicals (acids) about 24 hours prior to starting the redevelopment operation. Several methods are available for redeveloping a well. They are, in order of increasing effectiveness, as well as cost: airlift pumping and agitation, mechanical surging and jetting.

Airlift Pumping and Agitation

Airlift pumping forces compressed air through an air line to the bottom of the well, Figure 9. As air bubbles rise, they create a surging effect that carries water and dislodged materials out of the well. Airlift pumping is alternated with short periods of no pumping, which forces water and chemicals out into the formation to help break up minerals and bacteria lodged in the aquifer formation surrounding the screen. This method of well development is effective only if the water is deep enough in the well to get the surging action. Airlifting does not work if the lift to the surface is too great.

Mechanical Surging

Surging alternately forces water into and out of the formation through the well screen openings, Figure 10. A pistonlike tool moves up and down in the well to create the surging action. The water surging through the well screen loosens the minerals and fines in the borehole and draws them into the well to be removed

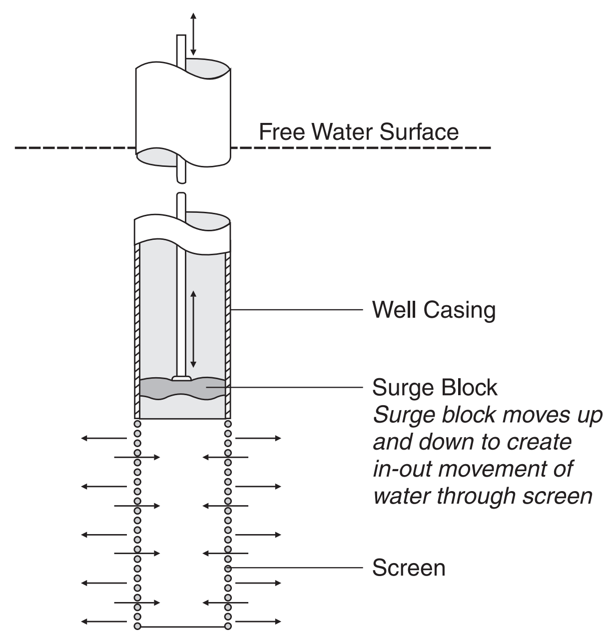


Figure 10. Well redevelopment by mechanical surging with a surge block (drawing courtesy of Midwest Plan Service - MWPS-30).

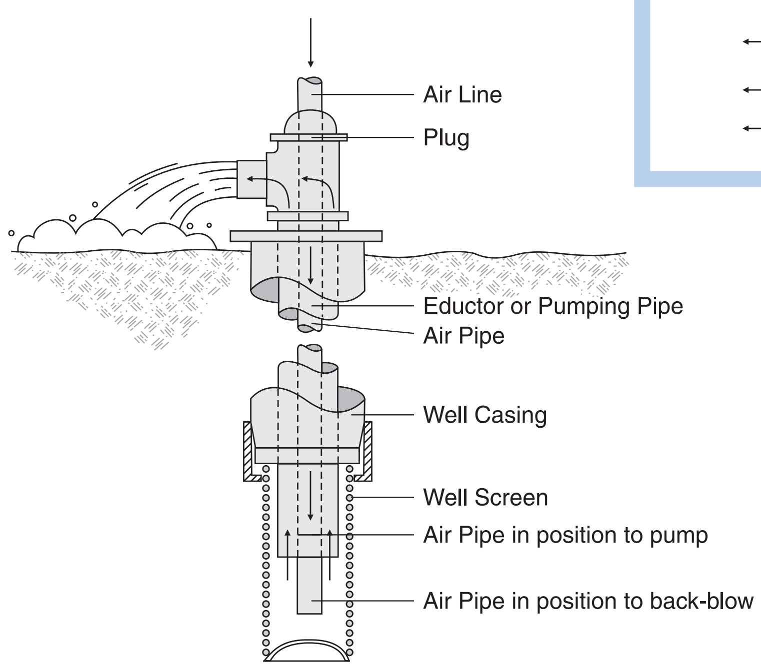


Figure 9. Well redevelopment using airlift pumping and agitation (drawing courtesy of Midwest Plan Service - MWPS-30).

by pumping or bailing. Surging especially is suited to cable-tool drilling. While common for bridge or louvered well screens, surging is not very effective with very deep wells (more than 200 feet) or those with multiple screens.

Jetting

The best well development method is high-pressure water jetting with simultaneous pumping, Figure 11. High-velocity water jets through the screen and gravel pack into the formation to loosen and break down the fine materials. The jetting tool rotates slowly as it moves up and down inside the well screen. Pumping removes the loosened sand and mud as they enter the well screen. The jet stream can be directed at any part of the formation around the well for selective development. Cage-wound screen is best for jetting because its design allows the jet to impinge directly on the gravel pack or borehole. Well screens that use louvered or bridge openings do not respond to this type of development because the opening design interferes with the jet of water. Jetting often is the most costly development method.

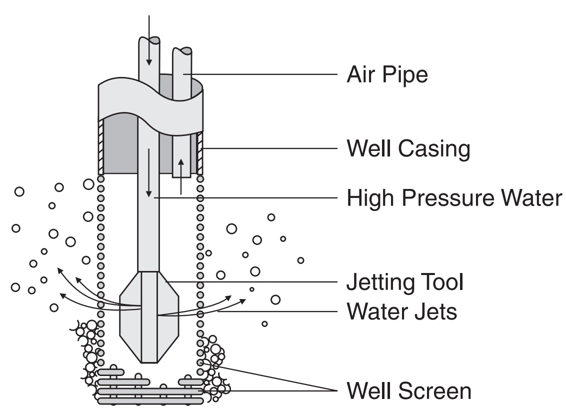


Figure 11. Well redevelopment using high-velocity water jetting (drawing courtesy of Midwest Plan Service - MWPS-30).

Step 4. Chlorination

The last step in rehabilitating a well is to chlorinate using either liquid or solid forms of chlorine. Chlorination will help kill the remaining iron bacteria and other bacteria introduced during the rehabilitation process. Follow the method outlined in the Chlorination Procedure section. **Do not combine acid treatment with chlorination because that can produce dangerous gases.**

Notes

Annual Well Record Data Sheet

Year	**Flow Rate from Well** (gpm)	**Pumping Water Level (PWL)** (feet)	**Static Water Level (SWL)** (feet)	**Drawdown (PWL-SWL)** (feet)	**Specific Capacity** *Flow Rate divided by Drawdown* (gpm/ft)

For more information on this and other topics, see: www.ag.ndsu.edu

NDSU Extension Service, North Dakota State University of Agriculture and Applied Science, and U.S. Department of Agriculture cooperating. Duane Hauck, director, Fargo, N.D. Distributed in furtherance of the acts of Congress of May 8 and June 30, 1914. We offer our programs and facilities to all people regardless of race, color, national origin, religion, sex, disability, age, Vietnam era veterans status or sexual orientation; and are an equal opportunity employer.

1.5M-7-05

This publication will be made available in alternative format, upon request to people with disabilities, (701) 231-7881.

AE-97