Answers to Your Questions About Flowing Wells for Well Drillers

"More than any other task…artesian grouting requires ingenuity, knowledge of a wide range of approaches, and attention to detail on the specific task." – Australian Drilling Manual

Flowing artesian conditions present unique challenges to the well driller. Understanding the hydraulic pressures involved with artesian flow is essential to prevent blowouts and the flow of water up the outside of the well casing. Wisconsin has special casing specifications for flowing wells that a driller can use to prevent problems while drilling a well that may flow. This document reviews the code requirements for flowing wells and provides additional technical advice for well drillers.

How do I know if I'm going to encounter flowing conditions?
Knowing where artesian conditions may be encountered is the best way to avoid problems during drilling. Artesian conditions are most likely to be encountered in valleys, near water bodies, and in areas with clay or shale layers that act as confining units. Unconfined flowing conditions are most likely to be encountered near water bodies or in areas with spring complexes.

Examples of flowing conditions are shown in the following figures:

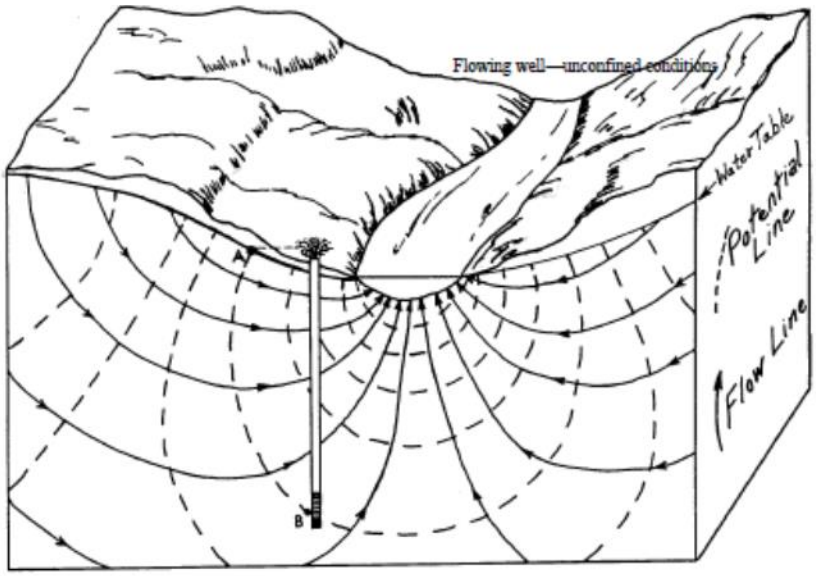


Figure 3. A flowing well in an unconfined aquifer.

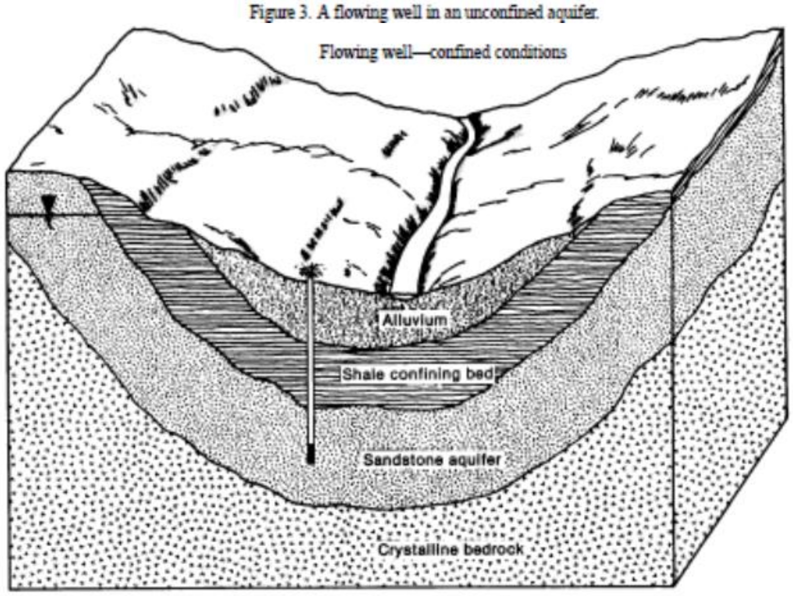


Figure 4. A flowing well in a confined aquifer.

Checking well construction reports in an area is the best way to determine the potential for flowing conditions. A driller needs to pay attention to the water level reported on a well construction report. Drillers should look for wells that have the depth to water listed as above ground surface and for reported depths that are less than 10 feet below ground surface. Wells flow when the hydraulic potential, or head, of the water table is higher than the ground surface. Any indication of upward pressure should be a red flag for a driller that flowing conditions may occur. Another indicator of the potential for flowing conditions is the presence of a confining layer at depth. Clay is the most common confining layer in unconsolidated formations and shale is the most common confining layer in bedrock. Any time a driller encounters a clay or shale unit at depth, they should consider the possibility that the well will be artesian and should consider using construction techniques that will minimize the potential for losing control of the borehole.

The links below provide useful information that can help you identify areas where wells may flow:

Post 1988 well construction reports: http://prodoasext.dnr.wi.gov/inter1/watr$.startup

Pre 1988 well construction reports: http://datcpgis.wi.gov/WellLogs/

Information on the distribution of springs: http://wgnhs.uwex.edu/water-environment/springs/

Water table maps:
http://wgnhs.uwex.edu/publications/?adv_search=wc&post_type=product&relation=AND&tax%5B0%5D=none&op%5B0%5D=IN&s=water%20table

What steps can I take to minimize problems when drilling in a flowing aquifer area?
The Well and Pump Code, Chapter NR 812 <Hyperlink to NR 812.15> contains construction specifications for dealing with flowing well conditions. Confined aquifer conditions can be especially difficult to deal with. Properly grouting casing into, but not through, the confining unit is essential to maintaining control of flow. In cases where artesian conditions are encountered in unexpected areas, getting control of the flow will be the greatest challenge.

In unconfined aquifers, it will be necessary to use heavy drilling mud that has a mud weight of at least 11 pounds per gallon during construction of the upper enlarged drillhole.

In confined aquifers, one of the methods illustrated in the following figures may be used:

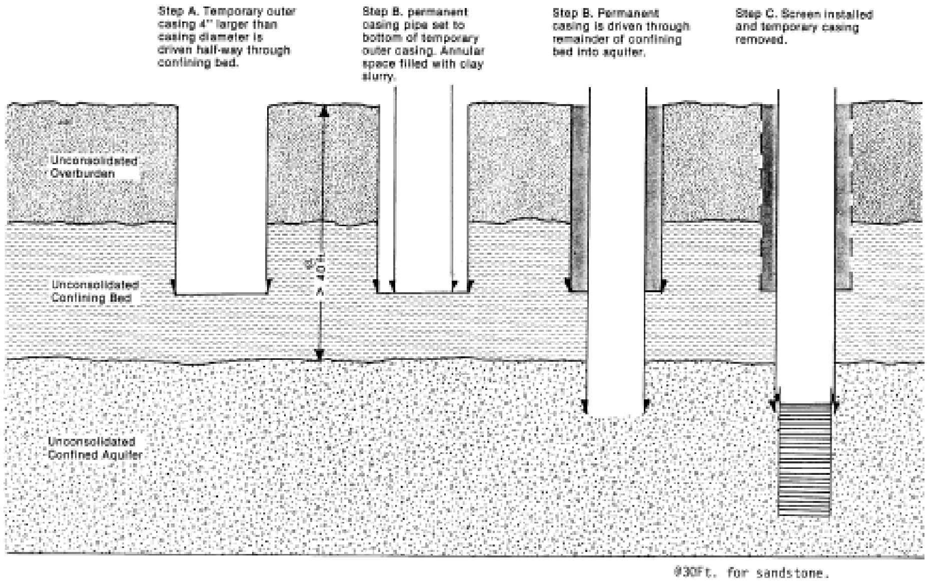


Figure 5. (b) 1. Percussion method for flowing well construction—confined unconsolidated aquifer more than 40@ feet below the ground surface with an unconsolidated confining bed.

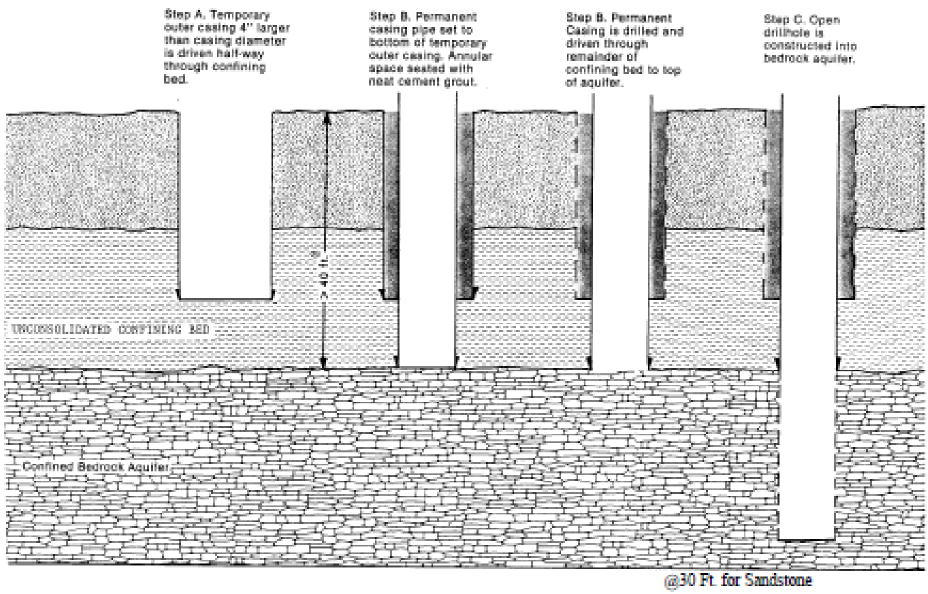
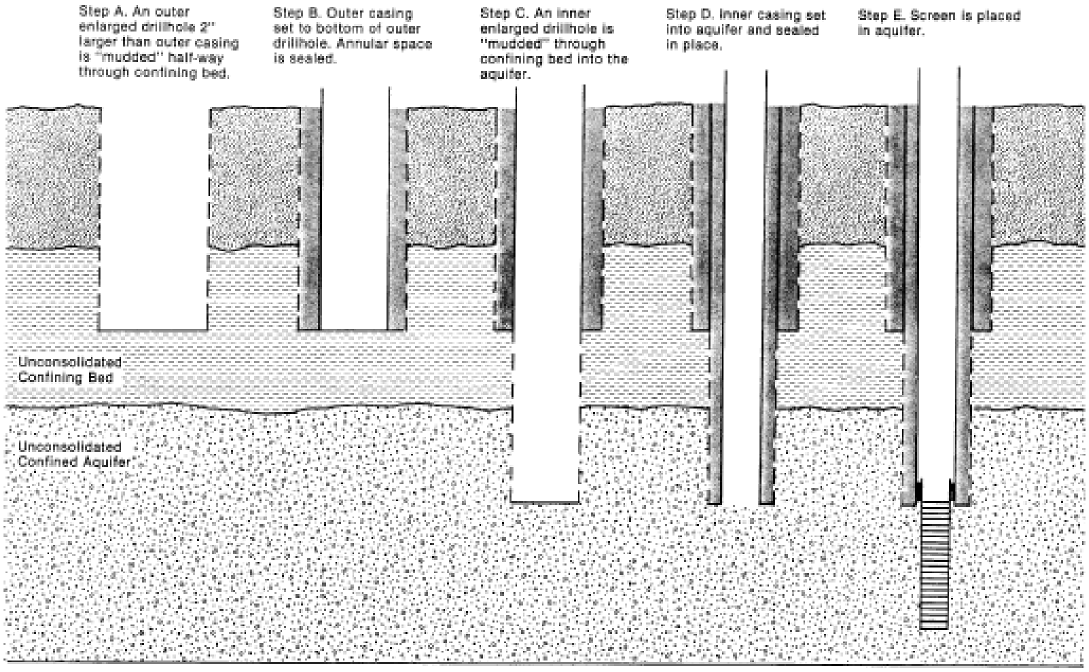
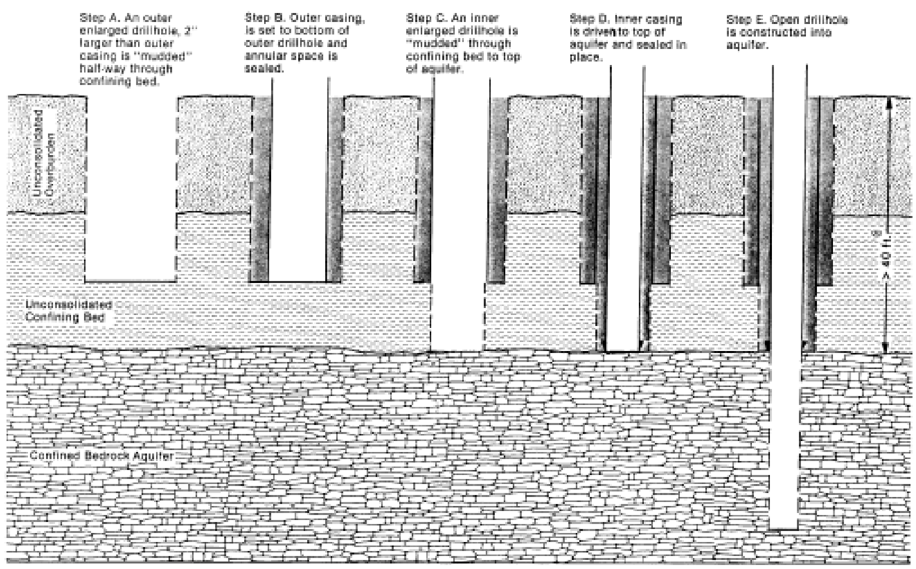


Figure 6. (b) 1. Percussion method for flowing well construction—confined bedrock aquifer more than 40@ feet below the ground surface with an unconsolidated confining bed.



@30 Ft. for Sandstone.

Figure 7. (b) 2. Rotary method for flowing well construction—confined aquifer more than 40@ feet below the ground surface—both confining bed and aquifer are unconsolidated—double casing construction.



@30 Ft. for sandstone.

Figure 8. (b) 2. Rotary method for flowing well construction—confined bedrock aquifer more than 40@ feet below the ground surface with an unconsolidated confining bed.

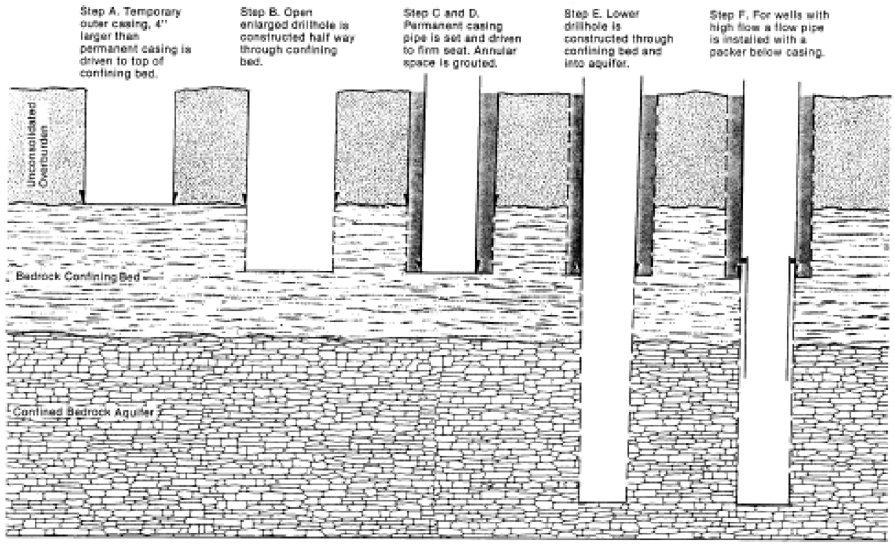


Figure 9. (c) 1. Percussion method for flowing well construction—confined bedrock aquifer more than 40@ feet below the ground surface with a bedrock confining bed.

What can I do if I unexpectedly encounter flowing conditions?
When uncontrolled flow occurs, follow these four steps: 1) determine the cause of the flowing condition, 2) understand the pressures involved, 3) develop a plan, and 4) regain control of the borehole. Controlling the hydrostatic pressure and directing water away from the well is very important for establishing control. Pumping on a nearby well that is completed in the same aquifer may help to reduce the flow. In some cases, it may be necessary to fill and seal the entire borehole and start over. Any material introduced into the borehole will need to be pumped at a sufficient flow rate and pressure to overcome the hydrostatic conditions. You may need to pump water from the borehole during the grouting operation.

How do I determine the cause of the flow?
The first step is to review the geology of your location. Knowing the depth that the flow originated from is important. It is also important to know how high above the ground surface that the water will flow, this is also called the 'hydraulic head' of the artesian aquifer. Without knowing the hydraulic head, it will be very difficult to come up with a plan to regain control of the borehole.

How do I determine the hydraulic head?
To measure the hydraulic head above ground surface, it may be necessary to extend the casing until the flow stops and measure the distance above ground and add it to the distance below ground to the top of the confined aquifer. This can also be accomplished by sealing the top of the well and attaching a large diameter hose that can be raised into the air to measure the head. Every 2.31 feet of head is equivalent to 1 pound per square inch (psi).

The next step is to determine the pressures that need to be overcome when grouting a flowing well to prevent flow up the outside of the casing. During drilling, upward pressure can cause drill strings to become bound or stuck and can also cause erosion of soil at the surface which can endanger the drill rig and the safety of the drilling crew. Upward flow of as little as 20 gallons per minute and 5-10 psi can begin separating grout mixtures as they are being pumped into an annulus.

How do I determine the down-hole hydraulic pressure?

To determine the down-hole hydraulic pressure, it is necessary to determine the depth to the top of the confined aquifer and the height above ground where the upward flow is equalized. Once the total artesian head is calculated, by adding the depth to the top of the artesian aquifer to the head above the ground surface, the total head is then divided by 2.31 to get the pressure head expressed in pound per square inch (psi). For example, if the top of a confined aquifer is encountered at 100 feet and stops flowing at a height of 5 feet above ground surface, the total head would be:

105 ft ÷ 2.31 ft/psi = 45.45 psi of down-hole pressure head

The same calculation could be done by multiplying the head by 0.433 psi/ft

105 × 0.433 = 45.45 psi.

How will I know if I'll be able to complete the grouting?
You will only be able to prevent flow up the outside of the casing if the material in the annulus has enough weight to overcome the upward pressure. Once the down-hole pressure head is determined, you can also calculate the amount of neat cement grout needed to prevent flow up the outside of the well casing. If the weight of the grout isn't enough to hold back the artesian head pressure, it won't stop the flow and the cement will not set. For example, neat cement grout mixed with 5.2 gallons of water per sack has a density of 15.6 pounds per gallon and a hydrostatic pressure of 0.81 psi/ft. If the casing extends to a depth of 100 feet it should be able to hold back 100 ft. x 0.81 psi/ft = 81 psi. As long as the down-hole hydraulic pressure is less than 81 psi, the cement will be able to prevent flow up the outside of the casing. The psi/ft for a given grouting material can be obtained by multiplying the wight of the grout in lb/gal by 0.052.

What else can I do to help with the grouting process?
It is also important to be able to overcome the upward flow of water during grouting. To achieve this, it will be necessary to either pump water out of the borehole at a rate that is close to the rate of flow or to install a temporary casing and stop the flow at the surface. Pumping water out of a nearby well that is connected to the artesian aquifer may also relieve some of the upward pressure.

Using a large diameter tremie and a positive displacement pump that can pump grout at a high flow rate and high pressure is also recommended. Grout with a high density with a volume two times greater than the borehole should be ordered from a mixing plant and pumped as quickly as possible to overcome the upward flow. Filling the entire upper borehole, not just the annular space may be required. The casing can be set after the cement is in the hole and set to a firm seat and then the cement can be drilled out of the casing into the lower formation. A flow-through packer can stop the flow to allow the grout to get into the annulus and set.

How long should I allow the grout to set?
Be sure to let the cement grout set for a minimum of 24 hours before proceeding with any further drilling activity to allow the grout to reach its full structural strength.

How do I disinfect a flowing well?
Flowing wells are generally less susceptible to bacterial contamination. Getting the proper contact time during the chlorination of a flowing well is difficult. It is usually necessary to stop the flow by extending the top of the well casing until the flow is stopped or to valve off the flow. A chlorine solution can be pumped into the well using a

hose connected through the top of the sealed well cap or over the top of the casing extension.

How is a flowing well filled and sealed?
Reducing or stopping flow is needed to properly fill and seal a well. Methods that may be used to reduce or stop flow include; extending the casing, pouring clean washed pea gravel into the bottom of the well, or using an inflatable packer.

Illustrations of these methods are shown below:

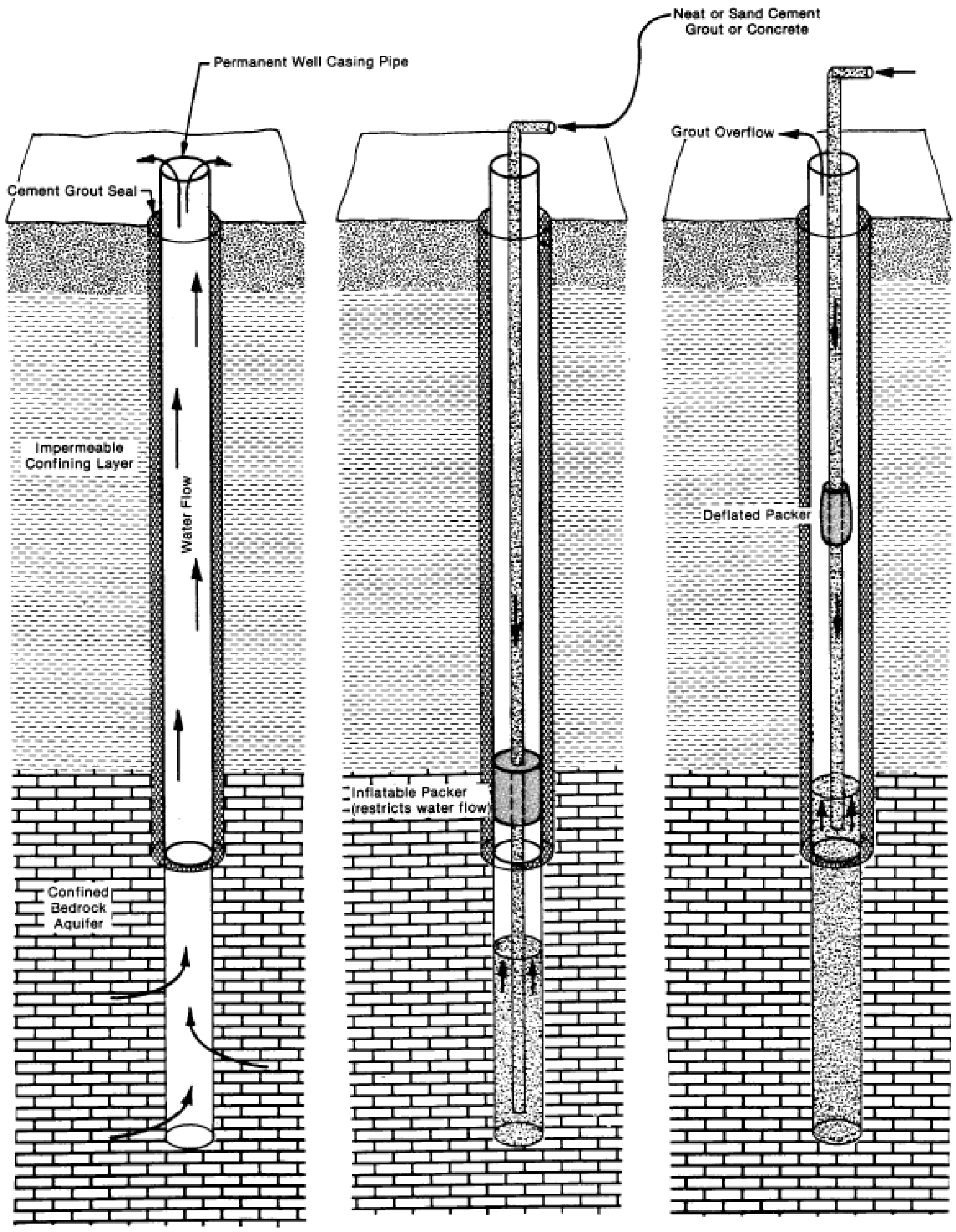


Figure 20. Inflatable packer method for permanently abandoning a flowing well.

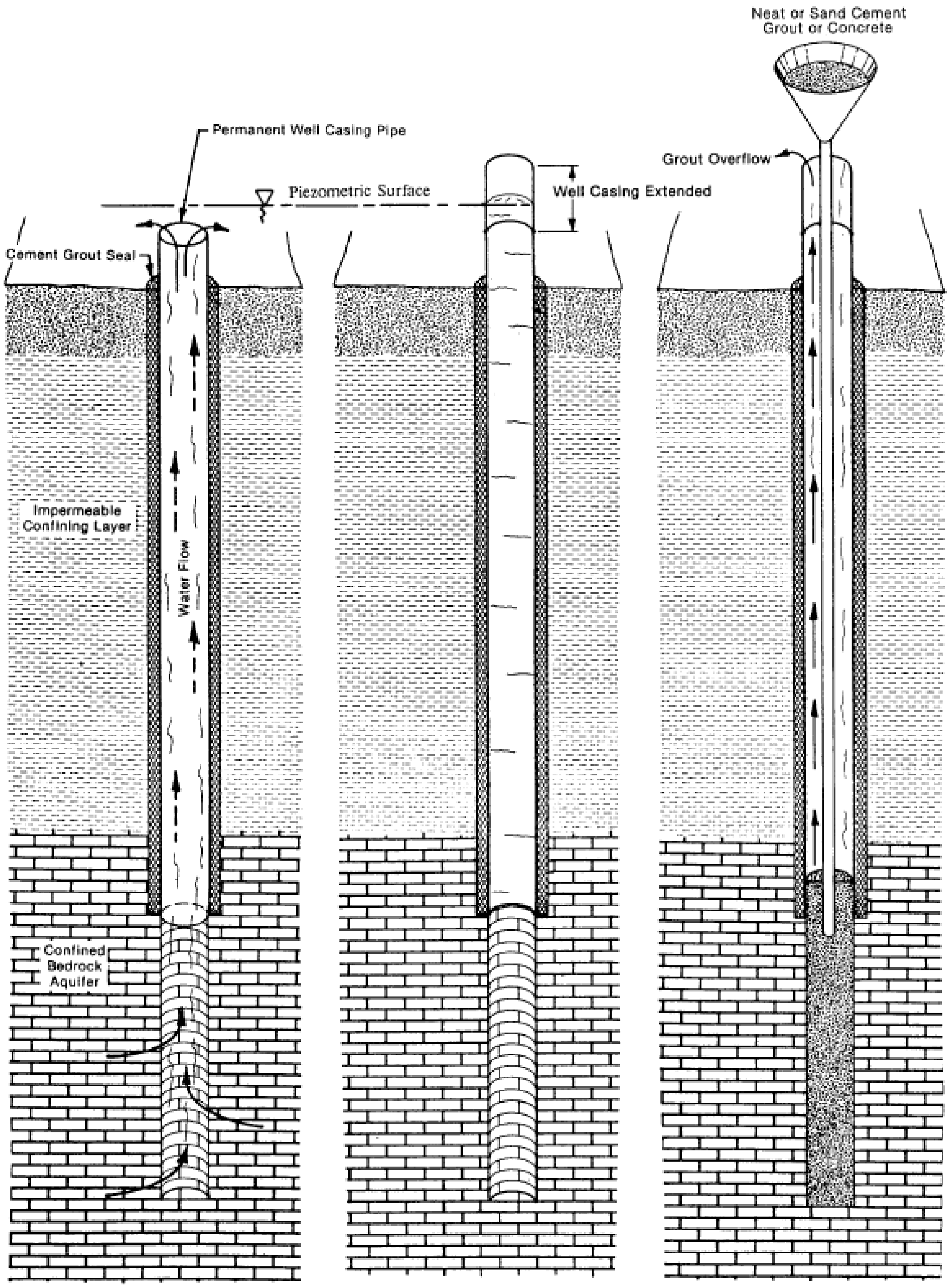


Figure 21. Method for reducing flow in a flowing well by extending the well casing pipe before permanently abandoning the well.

Where can I learn more about flowing wells?
The Michigan Department of Environmental Quality has a 'Flowing Well Handbook, March 2005' that can be found by searching the internet using the keywords, 'Michigan flowing well handbook'.