AE966 (Revised August 2021)

(NDSU photo)

A Guide to Plugging Abandoned Wells

Revised by

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(NDSU photo)

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Sand and gravel, native clay, commercial sodium bentonite and neat cement grout are the most common materials used for plugging wells. Use of one or more of these materials will plug many types of abandoned wells effectively.

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How many abandoned wells does North Dakota have?

Farm numbers in North Dakota peaked at 85,000 in the 1930s. Today the state has about 32,000 farms. That means approximately 53,000 farmsteads have been abandoned during the last 70 years. Assuming that each of those farmsteads had at least one well, an extremely conservative estimate of abandoned wells in North Dakota would be 53,000. The total number in North Dakota is much higher if abandoned wells on active farmsteads and in towns are added. Although an actual survey has not been conducted, North Dakota probably has approximately 100,000 abandoned wells.

What are the hazards associated with abandoned wells?

SAFETY HAZARD – This hazard is obvious to anyone who has encountered an unmarked and uncovered large-diameter well. Accidents involving abandoned wells have occurred. The liability associated with abandoned wells has not really been tested in North Dakota. A good question for a landowner with an abandoned well to ask is, "Do I want to be the first legal test case?"

GROUNDWATER CONTAMINATION – An abandoned well is a direct conduit from the surface to the aquifer below. Contaminants that enter the well are introduced directly into the aquifer with no opportunity for natural filtration by soils or geologic materials. If a contamination incident occurs with a concentrated chemical, the potential for health-threatening levels in the surrounding aquifer is high. This puts other wells in the aquifer at risk, particularly those wells on the same farmstead that are close to the abandoned well. Just 1 gallon of 2,4-D herbicide can contaminate about 7,000,000 gallons of water. In terms of groundwater, approximately that much water would be held in the upper 3 feet of an aquifer in a 20-acre area.

COMINGLING OF GROUNDWATER – A well open to more than one aquifer will allow water from an aquifer with higher pressure head to enter an aquifer with lower pressure head. In many areas of North Dakota, deep aquifers under high pressures are extremely salty. In the early years of settlement, people utilized high-pressure aquifers to avoid pumping. In many cases, shallow aquifers with less salt were drilled through in the process of reaching the high-pressure aquifers. When the casing from a flowing well deteriorates and the well is abandoned without proper plugging, continual upward flow of salty water will cause contamination of the shallower fresh aquifer.

LOSS OF AQUIFER PRESSURE HEAD – Pressure head in artesian aquifers is depleted as water discharges either at land surface or to less pressurized aquifers. Unplugged abandoned wells contribute to the regional depletion of pressure head within an aquifer. Eventually the decline in pressure head causes flowing wells to stop flowing and the water level in nearby wells placed in the same aquifer to decline.

Regulations and standards pertaining to abandoned wells

North Dakota regulations for water well construction and water well abandonment are outlined in Article 33.1-18-01 of the North Dakota Administrative Code. The article defines an **"abandoned well"** as a well that the use has been permanently discontinued. The article further states, "Any abandoned water wells, including test wells, uncompleted wells, and completed wells shall be sealed by restoring as far as possible the controlling geological conditions which existed before the wells were drilled."

Part VI in the appendix of Article 33-18-01 contains information regarding methods and materials suggested for abandoned well plugging. For wells in unconsolidated materials under watertable conditions (no artesian pressure), a combination of sand, clay or concrete and neat cement grouts are considered acceptable plugging materials. As stated in the appendix, "Clay in a relatively dry state, clay and sand, or sand alone may be used advantageously as sealing materials, particularly under watertable conditions where diameters are large, depths are great, formations are caving, and there is no need for achieving penetration of openings in casings, liners, or formations, or for obtaining a watertight seal at any given spot."

Certain types of abandoned wells are regulated strictly. These types of abandoned wells are 1) public drinking water supply wells, 2) irrigation wells and other wells that require a water permit and 3) flowing artesian wells. For any doubts about the abandoned well type, contact the following North Dakota agencies:

North Dakota Department of Environmental Quality
Division of Water Quality
918 Divide Ave. E., 4th Floor
Bismarck, ND 58501-1947
Telephone 701-328-5210
https://deq.nd.gov/WQ/

North Dakota State Water Commission Water Appropriations
900 Boulevard Ave. E., Dept. 770
Bismarck, ND 58505-0850
Telephone 701-328-2750
www.swc.state.nd.us/

Well-plugging materials

Sand and gravel, native clay, commercial sodium bentonite and neat cement grout are the most common materials used for plugging wells. Use of one or more of these materials will plug many types of abandoned wells effectively.

A mixture of sand and gravel makes an excellent filler because little settling will occur as long as it is shoveled (not dumped from a loader bucket or dump-truck box) into the well. Mixtures with excessive amounts of cobbles and boulders should be avoided. Although sand and gravel are good filler, they allow water and contaminants to pass through easily. Less permeable material is placed over the sand and gravel to reduce the potential for contaminant movement from the surface to the aquifer below.

Native clay serves as a filler, but is much less permeable to water flow. Native clay is defined as any material that is found locally below the topsoil that has a medium or loamy texture (excluding sandy loam), according to the USDA Classification System. Comparable materials are classified in the Unified Soil Classification System as silty (CL-ML) or lean clay (CL).

The native clay should be excavated from a zone deep enough below the topsoil so that it is free of organic matter. The clay should be shoveled (not dumped) into the well and tamped continually during the shoveling process. If this procedure is used, little subsequent settling will occur. Because native clay must be tamped, it cannot be used effectively below the depth of 15 feet. The combination of native clay over sand and gravel is similar to natural conditions over shallow aquifers in many areas of North Dakota. It is an effective deterrent to contaminant movement into groundwater.

Commercial sodium bentonite, hereafter referred to as bentonite, is a natural, expanding clay that swells and forms an impermeable layer when wet. Bentonite is available in many forms, not all of which are recommended for abandoned well plugging. Bentonite chips that have been processed and graded according to size generally are packaged in 50-pound bags (0.7 cubic feet) and can be an effective plugging material when poured directly into the well. Only bentonite chips that are graded medium to coarse (¼- to ¾-inch chips) should be used. When the chips come into contact with the water in the well, they sink to the bottom of the well and then expand to fill the voids.

About 3 to 4 gallons of water will saturate a 50-pound bag of bentonite chips thoroughly and fill the voids between the chips. Bentonite should not be hydrated beyond this point because further addition of water will allow the bentonite to expand beyond its original dry bulk volume (0.7 cubic feet/bag). For example, 8 gallons of water added to a 50-pound bag will allow the bentonite to expand to two times its original dry bulk volume.

Unfortunately, bentonite loses moisture through the process of evaporation and does have the potential to dry back to its original chipped form. We know that drying of bentonite is extremely slow, particularly if it is placed near the watertable and covered by other materials. Predicting future environmental conditions that may cause drying is impossible; therefore, we don't recommend that bentonite be allowed to expand beyond its original dry bulk volume.

On the other hand, sufficient water should be on hand during well plugging to ensure adequate expansion and sealing. When water is added to dry bentonite at the bottom of a dry well, a significant amount of water may be lost initially before the bentonite begins to expand and seal. In this circumstance, calculations of 3 to 4 gallons of water per bag will underestimate the amount of water needed for adequate sealing.

Neat cement grout forms a nearly impermeable layer when hardened. One bag of Portland cement (94 pounds or 1 cubic foot) is mixed with about 6 gallons of water to make neat cement grout. Neat cement grout should have the consistency of thick cream when it is placed in the well. Because of its consistency, it will flow into odd shapes and holes that other materials may not fill. Neat cement grout will shrink only minimally as it hardens. Depending on the exact proportion of water and cement mixed, one bag of Portland cement will make a little more than 1 cubic foot of neat cement grout.

General well-plugging recommendations

Before the well-plugging procedure begins, decisions must be made regarding the level of health and safety protection desired. Well plugging will provide two levels of protection. **Primary protection** covers personal injury from falling or unintentional dumping of concentrated contaminants into an unplugged well. Filling an abandoned well with any of the materials listed above effectively will provide the landowner with primary protection. However, techniques that avoid subsequent settling or slumping must be used. This generally can be accomplished with little financial input other than the landowner's time.

Secondary protection covers future health problems that may occur due to accidental spillage over the abandoned well site and percolation of contaminants through the fill materials into the aquifer. Justification for this type of protection will depend on the location of the abandoned well site in relation to possible contaminants.

Secondary protection is accomplished by filling all or part of the well with materials that are impermeable to water flow. A layer of impermeable material, such as bentonite, may be combined with a permeable layer, such as sand and gravel, for secondary protection. The degree of secondary protection from contamination depends on the thickness of the bentonite layer.

Watertable fluctuations play an important role in determining whether a bentonite layer will be an effective deterrent to aquifer contamination. If the watertable rises above the bentonite plug, the deterrent is lost. Therefore, if bentonite is used to prevent secondary contamination, it must be thick enough to account for the normal fluctuations of the watertable. Under most conditions in North Dakota, a 10-foot plug should be adequate.

Native clay is not as impermeable as a layer of hydrated bentonite, but it does slow the movement of water significantly, compared with sand and gravel. A 15-foot layer of native clay provides secondary protection from contamination.

Neat cement grout that has hardened provides a nearly impermeable layer. Capping more permeable materials with 3 feet of neat cement grout is an alternative that provides secondary protection. An advantage of neat cement grout is its relative stability, compared with other materials. Disadvantages include the need to adhere strictly to mixing and grouting techniques. Compared with 10 feet of bentonite or 3 feet of neat cement grout in a large-diameter well, 15 feet of native clay is the most economical option. Under some circumstances, the landowner may desire more than one form of secondary protection, such as a 10-foot bentonite layer capped with 15 feet of native clay. The landowner always should weigh the benefits of different types of secondary protection against their cost. The landowner considering well plugging also should keep in mind that primary protection is the most important benefit gained.

Well-plugging steps

The list of well-plugging equipment and tools in Appendix I should be reviewed. Making sure that the proper equipment and materials are on hand will make the job much easier, quicker and effective.

Step 1. Measure the dimensions of the well.

Measurements must be taken of the well diameter, depth and water level. Accurate measurements (not estimates) will allow the correct calculation of the total well volume and the volume of water in the well. This information is needed to determine the amount of materials needed for plugging. Remember that volume calculations depend on the shape of the well. Most wells are cylindrical; however, some have other shapes that must be considered for accurate calculation of volume. **Refer to Appendix II, Area Formulas, and Appendix III, Table of Volumes.**

Step 2. Remove all obstructing materials from the well.

Making sure that fill materials do not slump or settle is critical; therefore, obstructions that may cause incomplete filling of the voids must be removed. Remove the pump, rods, pipes and any other equipment from the well. Floating debris, such as wood staves, also should be removed. One method used to accomplish debris removal is flushing. If water is pumped into the well, floating debris will move to the top as the well fills with water. Flushing may not be possible with larger diameter wells due to the volume of water required. In any event,

Initial well-plugging steps include accurate measurement of the well dimensions and removal of all obstructions. (NDSU photo)

The chlorination procedure disinfects the well so that disease-causing microorganisms are not sealed in the aquifer after the well is plugged.

(NDSU photo)

as much debris as possible must be removed from the well before plugging.

Step 3. Disinfect the well by adding household bleach.

All wells containing standing water must be disinfected to kill existing microorganisms. This can be accomplished by adding chlorine bleach at the rate of 1 gallon of bleach for every 500 gallons of water and is equivalent to a "shock" chlorination concentration of 100 parts per million of chlorine. The chlorination process ensures that disease-causing microorganisms are not sealed in the aquifer.

Step 4. Fill the well with plugging materials.

Plugging always starts from the bottom of the well. The exact procedure for plugging will depend on well construction, depth, diameter, aquifer type, availability of materials and the level of protection required.

Step 5. Remove the upper 3 feet of the well casing.

This step never should be done before the fill material is within 3 feet of the surface. Upper casing removal is particularly important if the abandoned well site is farmed. Removing the upper 3 feet of casing eliminates potential damage to tillage equipment.

Step 6. Fill the final 3 feet with topsoil and mound.

Shaping the site is necessary to prevent ponding of water over the plugged well. Topsoil should be packed into the well and mounded up to 1½ feet over the site. Mounding will help direct surface water away from the site and also will help absorb any settling of fill materials.

Large-diameter wells (10 inches or greater in diameter)

Abandoned wells with diameters of 10 inches or greater usually are plugged with a combination of materials, such as sand gravel and native clay. These materials always should be shoveled into the well, as opposed to being dumped rapidly in large quantities.

For both primary and secondary protection, most large-diameter wells can be plugged effectively by filling with a combination of sand and gravel, native clay and topsoil **(Figure 1A in Appendix IV)**. A mixture of sand and gravel is shoveled into the well up to a depth of 15 feet below the surface. Native clay then is shoveled and tamped into the well up to 3 feet below the surface. Tamping often is started with a 16-foot 2-by-4 and finished with an 8-foot length. If more than 2 or 3 feet of standing water remains on top of the sand and gravel, it should be pumped from the well prior to the addition of native clay. If the water is not removed, the addition of native clay creates a muddy slurry that cannot be tamped.

Warning: Adding materials such as sand and gravel or native clay at excessively rapid rates will cause bridging of the materials and inadequate plugging. Dumping directly into the well from a loader bucket or dump-truck box is not acceptable.

Tamping native clay as it is shoveled into the well is an important step to ensure that all voids are filled and minimal settling will occur.

Abandoned wells with diameters of 10 inches or greater are usually plugged with a combination of materials such as sand gravel and native clay. These materials should always be shoveled into the well, as opposed to being dumped rapidly in large quantities.

(NDSU photo)

Tamping native clay as it is shoveled into the well is an important step to insure that all voids are filled and minimal settling will occur.

(NDSU photo)

Commercial chipped sodium bentonite (left jar) is a natural clay that expands in water (right jar). Ten feet of bentonite placed near the water table provides additional protection in locations where secondary contamination is a concern.

(NDSU photo)

If additional secondary protection is desired for a large-diameter well, the most common combination of materials is a mixture of sand and gravel, bentonite, native clay and topsoil **(Figure 2A in Appendix IV)**. A mixture of sand and gravel is shoveled into the well up to a point 5 feet below the measured water table. Ten feet of bentonite chips is poured into the well on top of the sand and gravel. Placing the bentonite near the watertable so that it remains wetted and expanded is critical. Dry bentonite does not provide secondary protection from contamination. If the top of the bentonite is within 15 feet of the surface, then native clay is shoveled and tamped on top of the bentonite up to 3 feet below the surface. However, if the top of the bentonite is not within 15 feet of the surface, sand and gravel must be added until the 15-foot depth is reached.

A less common well-plugging method that provides both primary and secondary protection involves placing a 3-foot layer of neat cement grout on top of the sand and gravel. The neat cement layer is placed 3 to 6 feet below the surface.

Small-diameter wells (less than 10 inches in diameter)

Fewer options are available for filling small-diameter wells because sand and gravel and native clay tend to bridge in a small-diameter casing and leave unfilled spaces. Both primary and secondary protection is provided by filling small-diameter wells with medium (¼-inch) to coarse (¾-inch) bentonite chips **(Figure 3A in Appendix IV)**. Both medium and coarse chips are recommended for well diameters from 4 to 10 inches in size. Only medium chips are recommended for well diameters less than 4 inches.

When pouring bentonite chips into small-diameter wells, the chips should be poured over a ¼-inch screen to allow the fines to drop out before the bentonite reaches the well opening. The rate of pouring should be no greater than one 50-pound bag every three minutes. Following this technique will eliminate bentonite bridging over unfilled voids. The bentonite always should be poured into standing water. If insufficient water is in the well, water should be added at appropriate intervals during the filling process. No more than 2 or 3 feet of dry bentonite chips ever should be in the well during the filling process. Wetting dry bentonite after the entire well has been filled is not recommended.

Fill the well with bentonite chips to a depth of 6 feet below the surface. Three feet of neat cement grout then should be added above the bentonite. The plug of neat cement grout over the bentonite will ensure that the bentonite will not dry out and lose its seal.

Most small-diameter wells that have been plugged in North Dakota using bentonite chips have had diameters from 4 to 10 inches and were less than 250 feet deep. Although this technique is untested for wells of diameters less than 4 inches or greater than 250 feet deep, it appears that it should work for some of these wells. The smaller the diameter of the well or the deeper the well, the greater the chance for bridging and inadequate filling of the entire well. Therefore, if plugging wells of diameters less than 4 inches or greater than 250 feet deep with bentonite chips is attempted, making sure the chips are screened and poured very slowly is extremely critical. If the situation dictates that complete filling of the voids is absolutely necessary, experts recommend that bentonite chips not be used. Instead, a certified professional water well contractor should be employed to fill the well using a grouting method.

Because of the ease of application, chipped bentonite is the recommended material for plugging abandoned wells less than 10 inches in diameter. The bentonite chips should be poured slowly over a screen prior to entering the well.

(NDSU photo)

If the abandoned well site is intended for farming, removal of the upper 3 feet of the well casing after the abandoned well has been filled will eliminate the possibility of tillage equipment being damaged.

(NDSU photo)

Grouting

Plugging wells with neat cement grout is always an effective option for primary and secondary protection no matter what the size of the well. However, it is rarely the most economical method. Proper plugging of the entire well with neat cement grout requires specialized equipment **(Figure 1)** and trained professional help. The grout is pumped down the well through a tremie line or grout pipe.

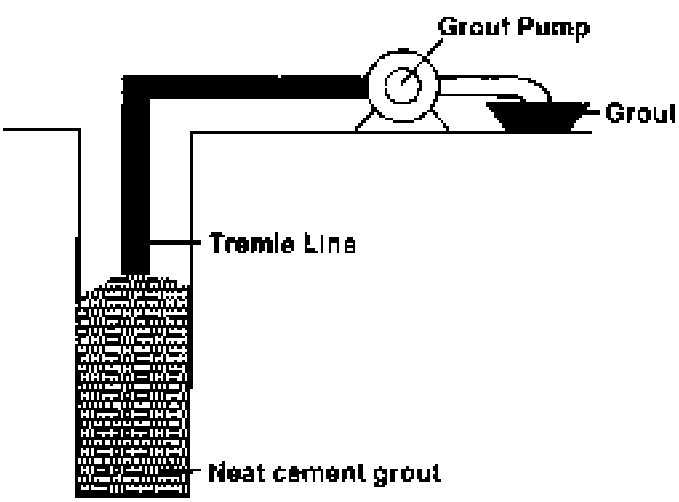

Figure 1. Diagram of an effective well-plugging method for all sizes of wells using neat cement grout.

Well pits

If the abandoned well is in a pit, proceed with the appropriate plugging process described above.
To properly abandon the pit after the well is sealed, knock in at least one wall and then fill the pit with compacted native clay, followed by topsoil.

Sand point wells

If the well casing can be pulled, the hole should fill naturally with native material, and no further work is required. However, if the casing cannot be pulled, a certified professional water well contractor's services will be required to grout the well properly. After grouting is complete, the casing should be cut off 3 feet below the surface.

Well-plugging records

Make and keep a record of any plugged well. You may want to recall something about the procedure at a later date. Exact recollection of the site may be useful to avoid interference with future building construction. The record should include: well location, well depth, well diameter, static water level, date work performed, personnel on hand, equipment removed from the well, plugging procedure used, type of material used, volumes of material used and the method of placement.

Consider all your alternatives before plugging

The well-plugging recommendations in this publication are based on field experience with abandoned wells throughout North Dakota during four years. The suggestions for materials and methods are not standards or requirements. North Dakota regulations governing the plugging of most abandoned wells have been interpreted very broadly and allow considerable flexibility regarding plugging techniques and materials.

As with many environmental issues, no consensus has been reached on the level of benefits for certain types of protection or the techniques to attain that protection. Except for those special cases where state agencies have jurisdiction, decisions regarding abandoned well plugging rest with the landowner.

Some of the techniques presented have been adopted or may be adopted by other agencies that do set standards. Further, some of the recommendations made in this document may not agree with standards set by other agencies. Presently, adherence to strict well-plugging standards established by other agencies is not required unless cost-share funds are involved. The landowner must consider that participating in cost-share programs means some of the flexibility to choose alternative well-plugging methods and materials will be forfeited. A much stricter adherence to standards for secondary contamination prevention likely is to be required.

The recommendations made in this publication place the greatest importance on primary protection and practical field methods to accomplish that goal. The task of plugging a significant percentage of the existing abandoned wells in North Dakota is huge. We hope the information and recommendations in this publication will help landowners recognize the problem and implement solutions. A measurable reduction in the number of abandoned wells cannot occur without active public support.

APPENDIX I. Well-plugging Equipment and Tools

1. **10-gallon pail** – used to mix Portland cement and water to make neat cement grout
2. **2-foot by 3-foot ¼-inch screen** – when formed into a cone, it is used to pass chipped bentonite through before it is poured into the well to separate out fines
3. **8-foot and 16-foot 2-inch by 4-inch wood studs** – used to tamp native clay as it is shoveled into the well
4. **Cutting torch** – used to separate upper 3 feet of metal well casing so that it can be removed
5. **Flashlight** – helps illuminate debris and well casing condition in deep wells
6. **Knife** – used to cut open bentonite and Portland cement bags
7. **Logging chain** – used with tractor and front-end loader
8. **Pump and hose** – used to remove excess water before native clay is added to the well
9. **Spades** – needed to shovel sand and gravel and native clay into the well; to dig around the upper well casing so that it can be removed; to mix Portland cement and water to make neat cement grout
10. **Tape measure** – used to accurately determine well dimensions and water table depth
11. **Tractor and front-end loader** – used to pull pumps, pipes, cement pads, upper well casing and other heavy objects from the well
12. **Treblehook and line** – used to hook and remove floating or obstructing debris
13. **Water tank and hose** – additional water supply when insufficient water is available in the well to wet the bentonite
14. **Weighted line** – used to measure well and water depths
15. **Wrecking bar** – serves to loosen obstructions around the well that must be removed

APPENDIX II.
Area Formulas

area of a **circle** = πr^2

where π = 3.14

r = radius of the circle

area of a **square** = s^2

where s = side of the square

area of an equilateral polygon
(**octagon, hexagon,** etc.) = $nr^2 \tan \pi/n$

where n = number of sides

r = radius of the inscribed circle

π = 3.14

tan = tangent expressed as radians

APPENDIX III.
Table of Volumes

Volume according to diameter of a cylindrical well

Hole diameter	Volume per foot of depth		
(in)	(gal/ft)	(ft^3/ft)	(yd^3/ft)
2	0.15	0.02	
3	0.38	0.05	
4	0.68	0.09	
5	1.05	0.14	
6	1.5	0.20	
7	2.0	0.27	
8	2.6	0.35	
9	3.3	0.44	
10	4.1	0.55	0.02
12	5.9	0.79	0.03
14	8.2	1.1	0.04
16	10.5	1.4	0.05
18	13.5	1.8	0.07
20	16.4	2.2	0.08
24	23.6	3.1	0.11
36	53.0	7.1	0.26
40	65.2	8.7	0.32
44	79.5	10.6	0.39
48	94.2	12.6	0.47

APPENDIX IV.
Well-plugging Examples
(pages 10-15)

Two examples of abandoned wells that are representative of large- and small-diameter wells found in North Dakota are shown. The well-plugging methods also represent commonly used techniques that would be effective for these types of wells. These are not the only recommended methods to plug these types of wells, but likely are to be the methods most often selected. These examples are intended to provide the reader with a guide to the general thought process that occurs prior to and during abandoned well plugging.

Example:

Large-diameter well-plugging

(Figure 1A)

Well Dimensions

15 inch diameter
48 feet deep
40 feet to the water table

Volume calculations

πr^2 = area of a circle
$\pi = 3.14$
r = radius of the circle

$r = \frac{1}{2} d = 0.5 \times d$

d = diameter of the circle
$r = 0.5 \times 15 \text{ in} = 7.5 \text{ in}$

radius in ft = r X (1 ft/12 in)
7.5 in X 1 ft/12 in = 0.62 ft

$3.14 \times (0.62) \times (0.62) \text{ ft} = 1.2 \text{ ft}^2$

The volume in cubic feet (ft^3) now can be calculated for a given length of well casing by multiplying by the area or 1.2 ft^2.

Calculations for chlorine

Depth of well – Depth to water table = Depth of water

48 ft – 40 ft = 8 ft of water

8 ft X 1.2 ft^2 = 9.6 ft^3 of water

1 ft^3 = 7.5 gal

9.6 ft^3 X 7.5 gal = 72 gal water

Need 1 gal of chlorine for 500 gal water

therefore

72/500 = 0.14 gal chlorine to disinfect well.

Calculations for sand and gravel

Depth of well – 15 feet = Thickness of sand and gravel

48 ft – 15 ft = 33 ft of sand and gravel

33 ft X 1.2 ft^2 = 39.6 ft^3

27 ft^3 = 1 cubic yard (yd^3)

therefore

39.6 ft^3/27 ft^3 = 1.5 yd^3 of sand and gravel needed

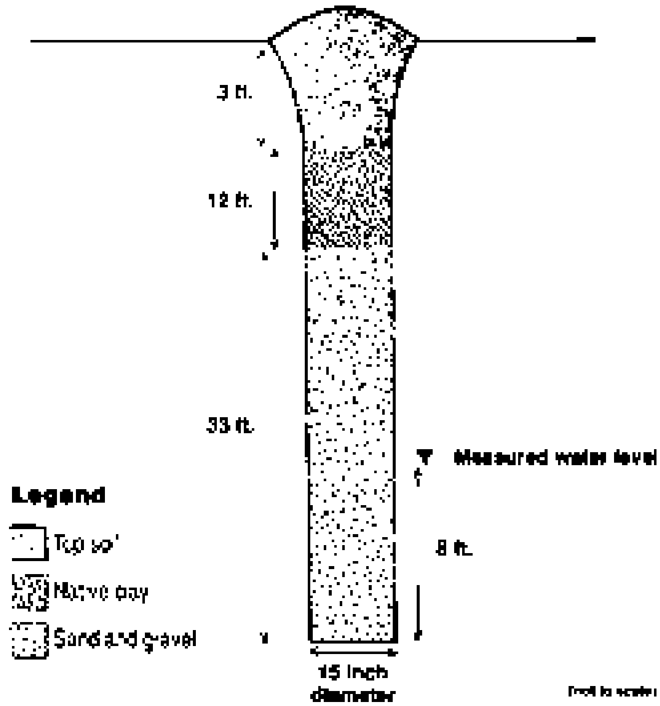

Figure 1A. Diagram of an effective well-plugging method for large-diameter wells (10 inches or greater diameter) using a combination of sand and gravel and native clay.

Calculations for native clay

15 feet – 3 feet for topsoil = 12 feet of native clay

12 ft X 1.2 ft^2 = 14.4 ft^3 of native clay

27 ft^3 = 1 cubic yard (yd^3)

therefore

14.4 ft^3/27 ft^3 = 0.5 yd^3 of native clay needed

Your Large-diameter Well

Well dimensions

______ inch diameter

______ feet deep

______ feet to the water table

Volume calculations

r = 0.5 X ______ in = ______ in

______ in X 1 ft/12 in = ______

3.14 X (______) ft X (______) ft = ______ ft^2

Calculations for chlorine

______ ft – ______ ft = ______ ft of water

______ ft X ______ ft^2 = ______ ft^3 of water

______ ft^3 X 7.5 gal = ______ gal water

______ /500 = ______ gal chlorine needed

Calculations for sand and gravel

______ ft – 15 ft = ______ ft of sand and gravel

______ ft X ______ ft^2 = ______ ft^3

_______ ft^3/27 ft^3 = ______ yd^3 of sand and gravel

Calculations for native clay

12 ft X ______ ft^2 = ______ ft^3 of native clay

______ ft^3/27 ft^3 = ______ yd^3 of native clay

Approximate cost of plugging materials

Chlorine cost = ________/gal X ________ gal = $_________

Sand and gravel = ________/yd^3 X ________ yd^3 = $_________

Native clay = ________/yd^3 X ________ yd^3 = $_________

Total cost of well-plugging materials = $_________

Example:

Large-diameter well alternative

that includes a 10-foot bentonite plug for additional secondary protection from contamination

(Figure 2A)

Calculations for bentonite chips

10 ft X 1.2 ft^2 = 12 ft^3 of bentonite needed

50 lb bag of bentonite chips = 0.7 ft^3

therefore

12 ft^3/0.7 ft^3 = 17.1 bags of chipped bentonite

Calculations for water required to wet bentonite chips

4 gal of water is required to hydrate one 50 lb bag of bentonite chips 17 bags of bentonite chips are needed

therefore

4 gals X 17 = 68 gals needed

Assume 40% porosity and 60% solids for sand and gravel

therefore

3 ft X 0.6 = 1.8 ft of water displaced by sand and gravel

First layer of sand and gravel ends 5 ft below the measured water table

therefore

displaced water + 5 ft = total water available in well for bentonite wetting

1.8 ft + 5 ft = 6.8 ft of water

6.8 ft X 1.2 ft2 = 8.2 ft3 of water

1 ft3 = 7.5 gal

therefore

8.2 X 7.5 gal = 62 gal of water available

Water needed – water available = additional water required

68 gal – 62 gal = 4 gal of additional water is required

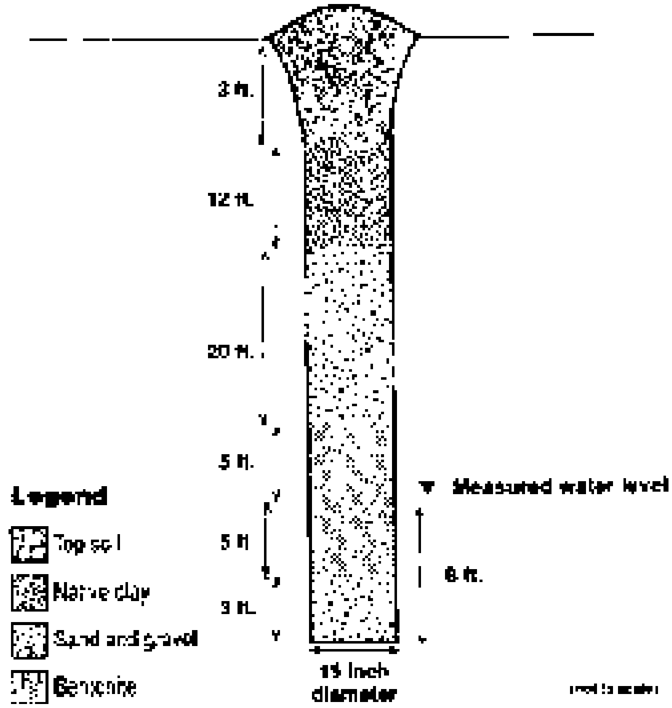

Figure 2A. Diagram of an effective well-plugging method for large-diameter wells (10 inches or greater diameter) that emphasizes secondary contaminant protection using a combination of sand and gravel, bentonite and native clay.

Sand and gravel recalculation

12 ft^3 of bentonite will replace the same amount of sand and gravel used in the first alternative (Figure 1A)

12 ft^3/27 ft^3 = 0.4 yd^3 less sand and gravel needed

therefore

Original sand and gravel calculation – 0.4 yd^3 = sand and gravel needed

1.5 yd3 - 0.4 yd3 = 1.1 yd3 sand and gravel needed

Your Large-diameter Well Alternative

Calculations for bentonite chips

10 ft X ________ ft^2 = ________ ft^3 of bentonite needed

________ ft^3 / 0.7 ft^3 = ________ bags of chipped bentonite

Calculations for water required to wet bentonite chips

4 gals X ________ = ________ gals needed

________ ft X 0.6 = ________ ft of water displaced

________ ft + 5 ft = ________ ft of water

________ ft X________ ft^2 = ________ ft^3 of water

________ X 7.5 gal = ________ gal of water available

________ gal – ________ gal = ________ gal additional water

Sand and gravel recalculation

________ ft^3 / 27 ft^3 = ________ yd^3 less sand and gravel

________ yd^3 – ________ yd^3 = ________ yd^3 sand and gravel

Approximate cost of plugging materials

Chlorine cost = ________/gal X ________ gal = $________

Sand and gravel = ________/yd^3 X ________ yd^3 = $________

Bentonite = ________/bag X ________ bags = $________

Native clay = ________/yd^3 X ________ yd^3 = $________

Total cost of well-plugging materials = $________

Example:

Small-diameter well-plugging

(Figure 3A)

Well dimensions

4 inch diameter

140 feet in depth

20 feet to the water table

Volume calculations

πr^2 = area of a circle

$\pi = 3.14$

r = radius in ft = .17

3.14 X (.17) X (.17) = 0.09 ft^2

The volume in cubic feet (ft^3) now can be calculated for a given length of well casing by multiplying the area or 0.09 ft2.

Calculations for chlorine

Depth of well – Depth to water table = Depth of water

140 ft – 20 ft = 120 ft of water

120 ft X 0.09 ft^2 = 10.8 ft^3 of water

1 ft^3 = 7.5 gal

10.8 ft^3 X 7.5 gal = 81 gal water

Need 1 gal chlorine for 500 gal water

therefore

81/500 = 0.16 gal chlorine needed to disinfect well

Calculations for bentonite chips

134 ft X 0.09 ft^2 = 12.1 ft^3 of bentonite needed

50 lb bag of bentonite chips = 0.7 ft^3

therefore

12.1 ft^3/0.7 ft^3 = 17.3 bags of chipped bentonite

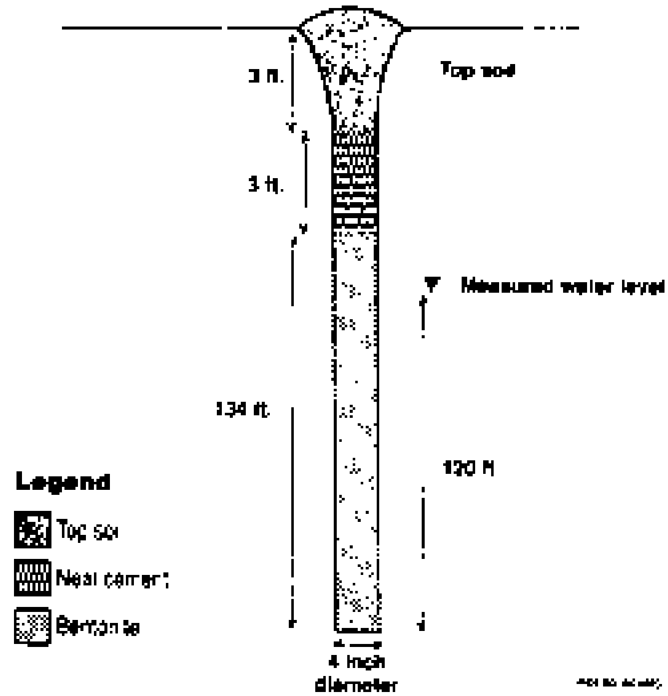

Figure 3A. Diagram of an effective well-plugging method for small-diameter wells (less than 10 inches) using chipped bentonite.

Calculations for water required to wet bentonite chips

4 gal of water is required to hydrate one 50 lb bag of bentonite chips

17 bags of bentonite chips are needed

therefore

4 gals X 17 = 68 gals needed

Water needed – water available = additional water required
68 gal – 81 gal = 0 gal of additional water is required

Calculations for neat cement

3 ft X 0.09 ft^2 = 0.27 ft^3 of neat cement needed

94 lb bag Portland cement = 1 ft^3 neat cement grout

therefore

0.27 ft^3/1 ft^3 = 0.27 bags of Portland cement needed

Calculations for water required to make neat cement

94 lb bag of Portland cement requires 6 gals of water

therefore

0.27 X 6 gals = 1.6 gals of water needed for neat cement

Your Small-diameter Well

Well dimensions

________ inch diameter

________ feet in depth

________ feet to the water table

Volume calculations

r = radius in ft = ________

3.14 X (________) ft X (________) ft = ________ ft^2

Calculations for chlorine

________ ft – ________ ft = ________ ft of water

________ ft X ________ ft^2 = ________ ft^3 of water

________ ft^3 X 7.5 gal = _________ gal water

________/500 = ________ gal chlorine needed

Calculations for bentonite chips

________ ft X ________ ft^2 = ________ ft^3 of bentonite

________ ft^3/0.7 ft^3 = ________ bags

Calculations for water required to wet bentonite chips

4 gals X ________ = ________ gals needed

________ gal – ________ gal = ________ gal additional water

Calculations for neat cement

3 ft X ________ ft^2 = ________ ft^3 of neat cement

________ ft^3/1 ft^3 = ________ bags of Portland cement

Calculations for water required to make neat cement

________ X 6 gals = ________ gals of water

Approximate cost of plugging materials

Chlorine cost = ________/gal X ________ gal = $_________

Bentonite = ________/bag X ________ bags = $_________

Neat cement = ________/bag X ________ bags = $_________

Total cost of well-plugging materials = $_________

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