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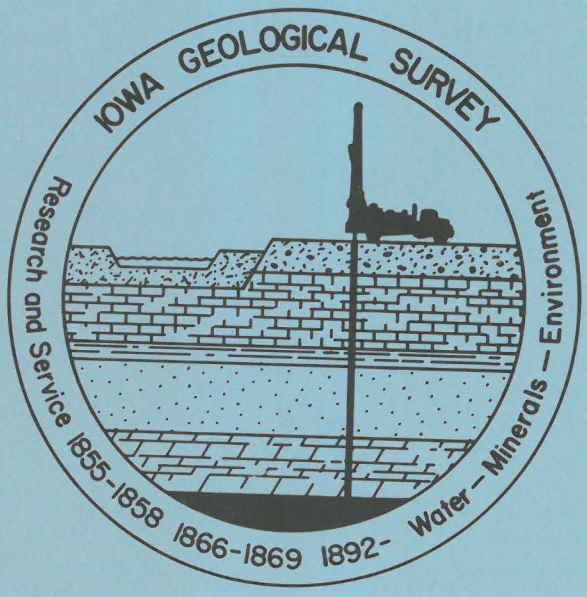

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PLUGGING PROCEDURES
for
DOMESTIC WATER WELLS

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In an earlier publication titled Optimal Well Plugging Procedures (Van Eck, 1971) a rationale was established for plugging abandoned wells. That rationale persists. A well is a potential entryway for pollutants or contaminants into the groundwater system, whether it be a shallow domestic well or a deep municipal-industrial well that penetrates multiple aquifers. Therefore, any well that is no longer in use and will not be properly maintained, or that has deteriorated to the point of no longer being serviceable, should be properly plugged.

It has been called to the author's attention that although the plugging procedures recommended in the above referenced publication were optimal, there existed a need for a guide to less expensive and complex methods of plugging relatively shallow domestic wells. The following is meant to fulfill that need, while at the same time maintaining the same standard of protection for groundwater.

PLUGGING MATERIALS

To be of any real value in plugging a well, the material to be used must have a very low permeability, such as is present in clay. Permeability is a measure of how rapidly fluids are able to move through the material, and the smaller the individual grains are that make up that material, the lower the permeability. Thus in selecting the material to be used in plugging, it is important that the predominant grain size be very small

(diameter less than 1/256 mm.) with a very low amount of particles in the silt and sand size grades. A quick and practical way for testing whether or not a clayey material contains a significant amount of silt or sand-sized particles is to rub the material vigorously in the palm of the hand, or for the more adventurous, to grind the material between one's teeth. A gritty feeling is the indication of the presence of larger sized particles.

Cement is an excellent plugging material. The cement is to be used without the addition of any aggregate, such as sand and gravel, which when mixed with cement forms the product termed concrete. The use of concrete mix for well plugging is discouraged because when the mix is placed in water the coarser sand and gravel materials separate from the mix and settle to the bottom, forming a permeable zone in the plug. As mentioned above, this is a condition to be avoided in plugging a well.

Agricultural lime has been used rather infrequently for well plugging, but should be acceptable. In fact, for wells that are completed in highly fractured or creviced limestone or dolomite aquifers, this may be a very desirable plugging material. Agricultural limestone, as the name implies is limestone finely ground to be used as a soil additive. It has the property of compacting and "setting up" much like cement when wetted.

There is available a material called bentonite that is widely used in the drilling industry. Bentonite contains a high percentage of the clay mineral montmorillonite that has the characteristic of swelling when wet. That characteristic makes it suitable for use as a plugging material. Bentonite can be purchased from well drillers or drilling supply houses.

TABLE 1. Capacity of Hole

Diameter of hole (inches	Volume per Lin. Ft. (cu. ft.)	Capacity per Lin. Ft. (gals.)	Sacks Cement per Lin. Ft.*	Lin. Ft. Per sacks cement
2	0.022	0.16	0.02	50.25
2½	.034	0.25	.03	32.15
3	.049	0.37	.04	22.52
3½	.067	0.50	.06	16.47
4	.087	0.65	.08	12.64
4½	.117	0.88	.11	9.94
5	.136	1.02	.12	8.06
5½	.165	1.23	.15	6.67
6	.196	1.47	.18	5.60
6½	.230	1.72	.21	4.77
7	.267	2.00	.24	4.12
7½	.307	2.30	.28	3.59
8	.349	2.61	.32	3.15
8½	.394	2.95	.36	2.79
9	.442	3.31	.40	2.49
9½	.492	3.68	.45	2.23
10	.545	4.08	.50	2.02
10½	.601	4.50	.55	1.83
11	.660	4.94	.60	1.67
11½	.721	5.39	.66	1.53
12	.785	5.87	.71	1.40
12½	.852	6.37	.77	1.29
13	.922	6.90	.84	1.19
13½	.994	7.44	.90	1.11
14	1.069	8.00	.97	1.03
15	1.227	9.18	1.12	0.90
16	1.396	10.44	1.27	.79
17	1.576	11.80	1.43	.70
18	1.766	13.21	1.61	.62
19	1.969	14.73	1.79	.56
20	2.182	15.95	1.98	.50
22	2.640	19.75	2.40	.42
24	3.142	23.50	2.86	.35
26	3.687	27.58	3.36	.30
28	4.276	31.99	3.89	.26
30	4.909	36.72	4.46	.22
36	7.069	52.88	6.43	.16

* Cement calculations based on the volume of an average cement mixture being 1.1 cubic feet per sack of cement.

PLUGGING PROCEDURES

Regardless of the type of material that is used to plug a well, care must be taken to be certain that the material completely fills the well bore. The easiest way to accomplish this is to mix the material with water to the consistency of a heavy slurry. By doing this the risk of bridging within the well is eliminated. Bridging is the condition that results from materials forming a blockage in the well bore that prevents complete filling.

In preparing a plugging slurry it is recommended that the mixture be brought to a consistency of about 14 pounds per gallon. Table 1 can be used as a guide in determining the amount of material required to fill most wells of nominal size. For example, let us suppose that a well of 6-inch diameter and 100 feet deep is to be plugged. On the 6-inch diameter line we find that the volume of each linear foot is 0.196 cubic foot and that each linear foot has a capacity of 1.47 gallons. Thus for the supposed 100-foot well, the volume is 19.6 cubic feet (.196 x 100) with a total capacity of 147 gallons (1.47 x 100). If the decision was made to fill this hypothetical well with cement, we find that each linear foot would require 0.18 sack of cement, or a total of 18 sacks of cement to completely fill the well.

If a local clay or agricultural lime is used it is recommended that chlorine be added to the mixture to kill any bacteria that may be present in the clay. Probably the easiest way to accomplish this sterilizing effect is by the use of calcium hypochlorite (chlorinated lime) containing approximately 25 percent available chlorine. This can be purchased at most drug stores and in larger quantities at chemical supply houses. If high test calcium hypochlorite (H-T-H) containing about 75 percent chlorine is used, the amount required will be about one-third the amount of chlorinated lime. H-T-H can be purchased from drilling-supply houses.

To attain a level that will be effective in destroying bacteria, the chlorine content of the slurry should be about 0.0075 ounces per gallon. Using chlorinated lime with about 25 percent effective chlorine means that for each gallon of mix, 0.03 ounces of chlorinated lime must be added. Table 2 provides a guide to the amount of chlorinated lime to be used for various quantities of slurry to reach an effective chlorine level.

TABLE 2. Disinfection of plugging slurry

Quantity of slurry in gallons	Ounces of chlorinated lime to be used
50	1.5
100	3.0
200	6.0
300	9.0
400	12.0
500	15.0
1000	30.0
2000	60.0
3000	90.0

Considering the hypothetical well discussed earlier for which the capacity was found to be 147 gallons, the amount of chlorinated lime to be used would be 4.41 ounces (147 x 0.03).

To prepare a chlorine solution to be used as a disinfectant, the following procedure is recommended. To the amount of chlorinated lime determined to be required, add small quantities of water slowly and stir until smooth and there are no lumps. Add from five to 10 gallons of water to the paste and stir for 10 to 15 minutes before allowing the solution to settle. The clearer liquid containing the chlorine should be used in preparing the plugging slurry and should be thoroughly mixed through the slurry. The inert material (lime) that has settled to the bottom of the container can be discarded.

A note of caution is in order here. Prepare the solution in a clean container and avoid using a metal container as it may be corroded by the strong chlorine solution. The standard precautions for protection from all chemical solutions should be followed.

If a clay slurry is used in plugging, it is strongly advised that at least the upper few feet of the well should be filled with cement. This will prevent thinning of the mud slurry by surface water and provide a solid upper surface. If the well is in an area where cultivation or construction is probable, the upper portion of the well casing should be cut off at the level below plow or construction depth. This should be done before plugging begins. With the recommended upper cement plug in place, fill material can then be replaced over the well.

TEMPORARY ABANDONMENT

By definition an abandoned well means a well whose use has been permanently discontinued. A well shall be considered abandoned when its condition is such that continued use is impractical or no longer desired. It is conceivable that there are instances where a well may meet that definition but the owner is reluctant to plug it on the basis that it may be used in the future.

Under those circumstances, steps should be taken to eliminate the entrance of surface water into the well. The well casing should be extended to some level above the adjacent ground surface, and the surface landscaped to provide drainage away from the well. If the well is in a pit, the pit should be filled with a material comparable to that described for plugging purposes. If the pump is to be removed, some type of watertight cap should be provided.

In short, temporary abandonment should not be considered as a way to avoid the plugging of a well, but as an opportunity to bring it to the standard that will protect the aquifer penetrated by the well.

CONCLUSIONS

Most domestic wells are not excessively deep or large in diameter, but nevertheless, they do provide a potential entrance for pollutants or contaminants. All too often domestic wells that are no longer in use are allowed to deteriorate while at the same time a replacement well has been constructed nearby, and is taking water from the same horizon as that penetrated by the old well. Obviously it is in the interest of the owner to protect the new well. The most direct means of obtaining that protection is to properly plug and seal any unused wells on the property. In this way the owner not only protects his own water source, but is protecting a resource that is valuable to everyone that utilizes groundwater.

There are a variety of materials that can be used for attaining that protection, most of which are not expensive. The process is not difficult and does not require sophisticated equipment. What is required is a commitment by the individual to ensure that any well over which he has control will not contribute to the deterioration of groundwater quality.