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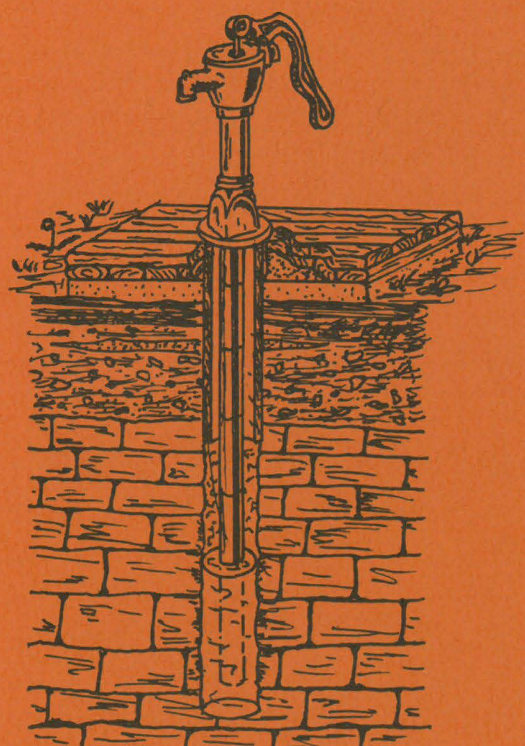

OPTIMAL WELL PLUGGING PROCEDURES

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INTRODUCTION

The proper plugging of abandoned wells is a fundamental practice in the preservation of groundwater quality. Any well, whether it be for domestic, municipal, or industrial use, is a potential site for pollution, either as an egress for liquids from the surface or as an avenue for the mingling of different quality water from the various aquifers penetrated by the well. Before the details of the differences in water quality in the many aquifers in Iowa were known, it was common practice to drill and case wells in a manner that permitted water from many, if not all, of the penetrated aquifers to enter the well bore and hence to move freely from aquifer to aquifer. As the water in some of these aquifers is naturally of a poorer quality than others, contamination resulted. Modern well construction is aimed at preventing this type of contamination. However, failure of well casing after a number of years is normal and this will result in contamination as surely as in an uncased well. Therefore, it is important that all wells, regardless of depth or construction, be properly plugged when no longer in use.

PROCEDURE

To be effective as a plug, the material used must be relatively impermeable and stable in the environment in which it is placed. The materials most commonly used in the oil and gas tests in Iowa, where plugging requirements are strict for the very same reasons cited above, are cement and drilling mud. The drilling mud is usually a mixture of commercially prepared bentonite and water, but an ordinary clay can be used in place of bentonite. If clay is used, it is a good practice to add chlorine to the mixture to kill any bacteria that may be contained in the clay. The mud should be mixed to the consistency of a heavy slurry with a weight of about 14 pounds per gallon or a specific gravity of about 1.68.

The best plugging method would be to fill the well from bottom to top with cement. In relatively shallow wells this probably is the quickest and easiest way to accomplish the purpose. However, in the deeper wells the cost becomes prohibitive. The standard procedure is to have a cement plug about 20 feet long emplaced at the bottom and top of each hydrogeologic unit that produces a quality of water different from adjacent hydrogeologic units and to have the remainder of the well bore filled with drilling mud. The use of sand or gravel to fill the well bore between the cement plugs is strongly discouraged.

GEOLOGIC PROVINCES

Figure 1 is a listing of the geologic and hydrogeologic units in Iowa (Steinhilber and Horick, 1970) and shows the optimal plugging schedule. Obviously it is impossible to find a location in Iowa where all the units listed would be encountered in a single well. This is because of the erosion or nondeposition of some of the units. For discussion purposes, the state has been divided into three somewhat overlapping geologic provinces as follows: 1) the Paleozoic province in the northeastern two-thirds of the state, 2) the Cretaceous province in the northwestern part and extending into the southwestern part of the state, and 3) the Pennsylvanian province in the southwestern part (fig. 2). There are no definite boundaries that delineate these provinces, but general guidelines to govern the plugging of wells in these areas are outlined below. The danger of surface pollution warrants special emphasis upon the need to provide adequate plugging in the upper portion of any well, regardless of the province in which it may be located. A well that is inadequately plugged in the upper portion may provide access for pollutants to a series of aquifers.

1. The Paleozoic Province: Except for the Cretaceous and Pennsylvanian, all the hydrogeologic units listed in figure 1 are present in this province, and all of the aquifers are utilized. In the extreme northeast portion of the province the quality of water in each of the aquifers, except for the water in the Dresbach, is of about the same quality. It would seem on first inspection that isolating the various aquifers under these conditions is not especially important. However, the hydraulic head in each aquifer is somewhat different than in the others and a loss of hydraulic head can readily result if proper precautions are not taken. In general, the quality of the water in all the aquifers deteriorates toward the south and west parts of the province, some more rapidly than others. For example, in the central and southern part of the state the water in the Devonian-Silurian aquifer is of very poor quality and should be isolated. Much the same is true,

although to a lesser degree, for all the aquifers with the exception of the Cambrian-Ordovician aquifer. Even the St. Peter Sandstone, the uppermost part of the Cambrian-Ordovician aquifer, contains dissolved minerals in sufficient quantity to warrant special plugging procedures to isolate it from the remainder of the aquifer.

2. <u>The Cretaceous Province:</u> Within this province most groundwater supplies are dependent upon the surficial or the Dakota aquifers. Thus the plugging of most abandoned wells in the province involves segregating the Dakota aquifer from the surficial aquifers and sealing out surfacewater. If deeper aquifers were penetrated, they should be isolated in the same manner as in the Paleozoic Province.

3. <u>The Pennsylvanian Province:</u> Throughout most of this province the surficial aquifers are relied upon for groundwater supplies. The shallow bedrock aquifers are generally capable of producing only relatively small quantities of water that contain large amounts of dissolved minerals. Thus, plugging wells in this province is usually a matter of separating the Pennsylvanian from the surficial aquifers and protecting the surficial aquifers from surface pollution. Wells that penetrate the deeper aquifers, with the exception of the Jordan Sandstone, generally encounter water that is objectionably high in dissolved solids. Within this area the Maquoketa Formation undergoes a facies change and is largely dolomite rather than shale as it is in eastern Iowa. Thus, the rock section from the top of the Devonian to the base of the Galena is probably all hydraulically interconnected and can be treated as a single unit in plugging the deep wells that penetrate the Jordan Sandstone. Where this is the case, the cement plug shown on figure 1 at the base of the Silurian could be omitted.

It must be recognized that the discussions for the provinces are very generalized and cannot be strictly applied, especially near the boundaries of the provinces. It is urged that the Iowa Geological Survey be consulted if there are any doubts about the best plugging schedule for any well. Although the plugging schedules must be flexible to assure the best possible plugging within economic limits, the standards of plugging must be rigid to protect groundwater resources.

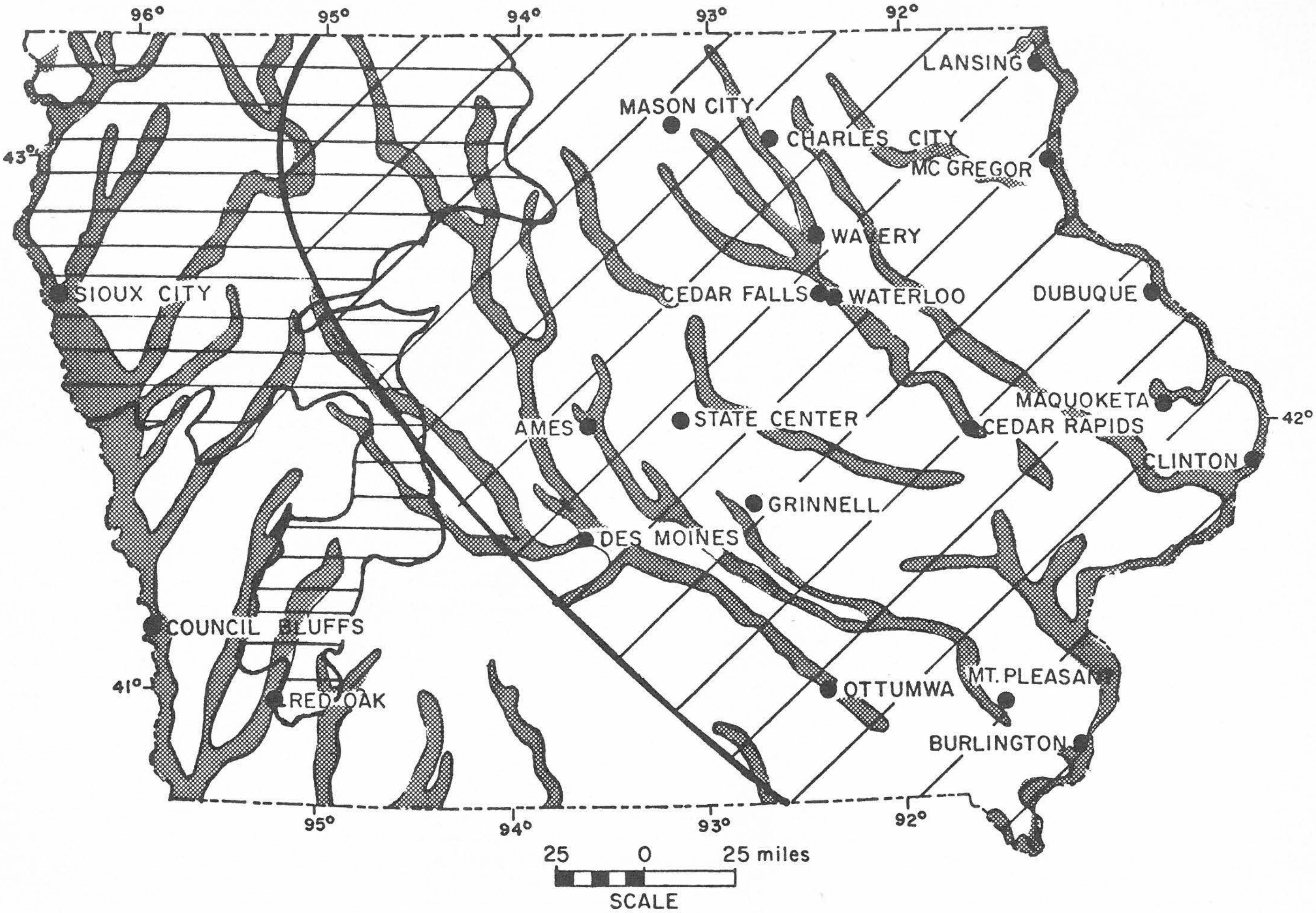
Reference:

Steinhilber, W. L., and Horick, P. J., 1970, Ground-Water Resources in Iowa in Water Resources of Iowa - A Symposium: Iowa Acad. Sci. Proc., p. 29-49.

Figure I.—Geologic and hydrogeologic units in Iowa and an optimal plugging schedule

AGE		ROCK UNIT	DESCRIPTION	HYDROGEOLOGIC UNIT	PLUGS
Cenozoic	Quaternary	Alluvium	Sand, gravel, silt and clay	Surficial aquifer	
		Glacial drift (undifferentiated)	Predominantly till containing scattered irregular bodies of sand and gravel		
		Buried channel deposits	Sand, gravel, silt and clay		
Mesozoic	Cretaceous	Carlile Formation Graneros Formation	Shale	Aquiclude	
		Dakota Group	Sandstone and shale	Dakota aquifer	
Paleozoic	Pennsylvanian	Virgil Series Missouri Series	Shale and limestone	Aquiclude	
		Des Moines Series	Shale; sandstones, mostly thin		
	Mississippian	Meramec Series	Limestone, sandy	Mississippian aquifer	
		Osage Series	Limestone and dolomite, cherty		
		Kinderhook Series	Limestone, oolitic, and dolomite, cherty		
	Devonian	Maple Mill Shale Sheffield Formation Lime Creek Formation	Shale; limestone in lower part	Devonian aquiclude	
		Cedar Valley Limestone Wapsipinicon Formation	Limestone and dolomite; contains evaporites in southern half of Iowa	Silurian-Devonian aquifer	
	Silurian	Niagaran Series Alexandrian Series	Dolomite, locally cherty		
	Ordovician	Maquoketa Formation	Shale and dolomite	Maquoketa aquiclude	
		Galena Formation	Limestone and dolomite	Minor aquifer	
		Decorah Formation Platteville Formation	Limestone and thin shales; includes sandstone in SE Iowa	Aquiclude	
		St. Peter Sandstone	Sandstone		
		Prairie du Chien Formation	Dolomite, sandy and cherty	Cambrian-Ordovician aquifer	
	Cambrian	Jordan Sandstone	Sandstone		
		St. Lawrence Formation	Dolomite	Aquiclude (wedges out in northwest Iowa)	
		Franconia Sandstone	Sandstone and shale		
		Dresbach Group	Sandstone	Dresbach aquifer	
Precambrian		Sioux Quartzite	Quartzite	Base of ground-water reservoir	
		Undifferentiated	Coarse sandstones; crystalline rocks		

Cement   Drilling mud



EXPLANATION

PALEOZOIC GROUND-WATER PROVINCE

The upper carbonate aquifers commonly yield 50 to 300 gpm to individual wells; occasionally 300 to 500 gpm; and rarely 500 to 2000 gpm. The Cambrian–Ordovician aquifer commonly yields 500 to 1000 gpm and occasionally as much as 1500 gpm. The Dresbach aquifer in extreme east-central part generally yields 1000 to 3000 gpm.

CRETACEOUS GROUND-WATER PROVINCE

The Dakota aquifer commonly yields 50 to 100 gpm; occasionally as much as 700 gpm; and rarely 1000 to 1500 gpm.

PENNSYLVANIAN GROUND-WATER PROVINCE

The Pennsylvanian rocks generally yield only 10 to 20 gpm. Intermediate carbonate aquifers generally yield 50 gpm and rarely as muc.. as 200 gpm. The deeply buried Cambro-Ordovician aquifer generally yields 100 to 200 gpm and rarely as much as 300 gpm.

ALLUVIAL AQUIFERS

Yields of 1000 to 2000 gpm per well are available from Mississippi and Missouri River valleys. Alluvium of larger interior streams commonly yields 200 to 300 gpm and occasionally 300 to 600 gpm; yields of 1000 to 2000 gpm are available locally where buried channel aquifers underlie alluvium.

Figure 2.--General Availability of Groundwater in Iowa