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Do Deeper Wells Mean Better Water?

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How deep should a well be? When is a well considered "deep"? Do deeper wells always provide better quality water?

This publication answers these questions to help you understand the differences in water quality that can occur between shallow and deep wells. You'll learn where the water in your well originates. You'll discover that a "shallow well" in one location might be a "deep well" in another part of the county or state. And you'll learn why, in some cases, a shallow well is actually a better choice than a deep well. The information presented here focuses on domestic wells that draw water from two sources in Arizona: (1) the Basin and Range aquifers located in southern Arizona (which generally consist of unconsolidated (loose accumulations of) gravel, sand, silt, and clays) (USGS) and (2) the Colorado Plateaus aquifers in northeastern Arizona (these aquifers are composed of permeable sedimentary rocks like sandstone, siltstone, and shale) (USGS). Groundwater in the Basin and Range aquifers is found in pore spaces between the soil particles. However, groundwater in the Colorado Plateaus aquifers is found in the fractures within the rock.

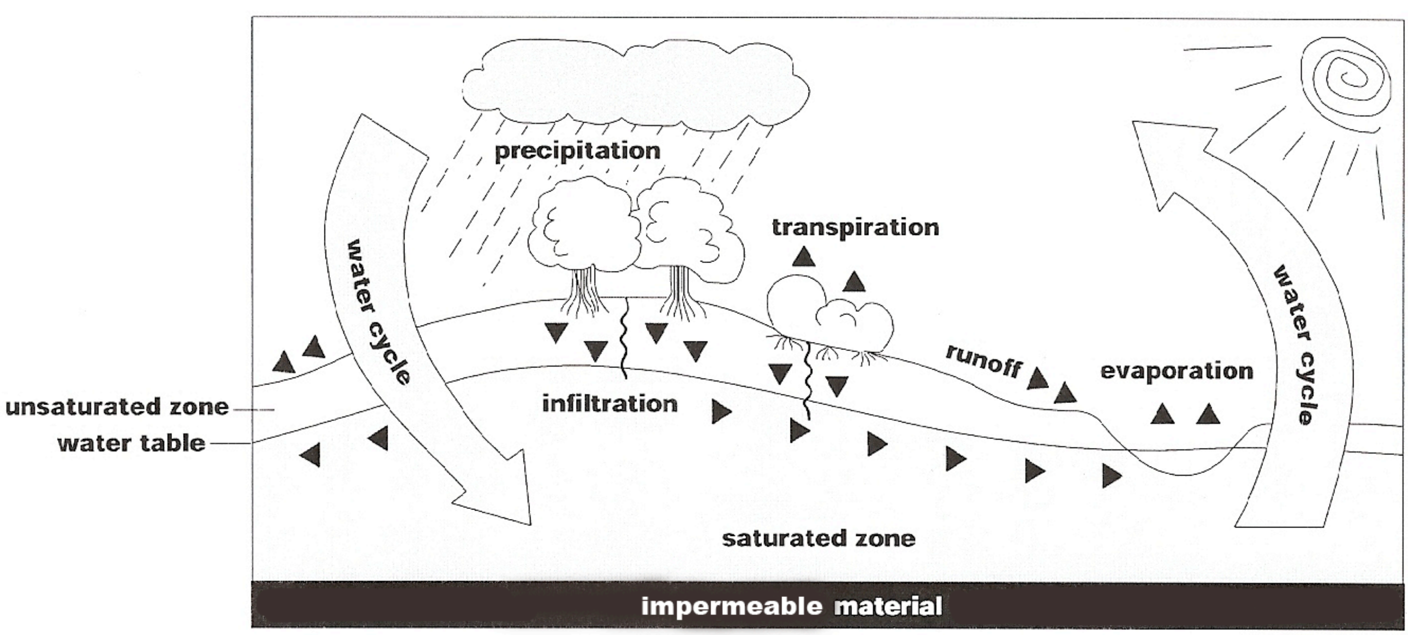


Figure 1. In the water cycle, precipitation that falls may run off into the stream (runoff) or soak into the ground (infiltration). Some of the water that falls, returns to the air by evaporation or passing through plants (transpiration). Water pulled through the soil by gravity into the saturated zone becomes groundwater.

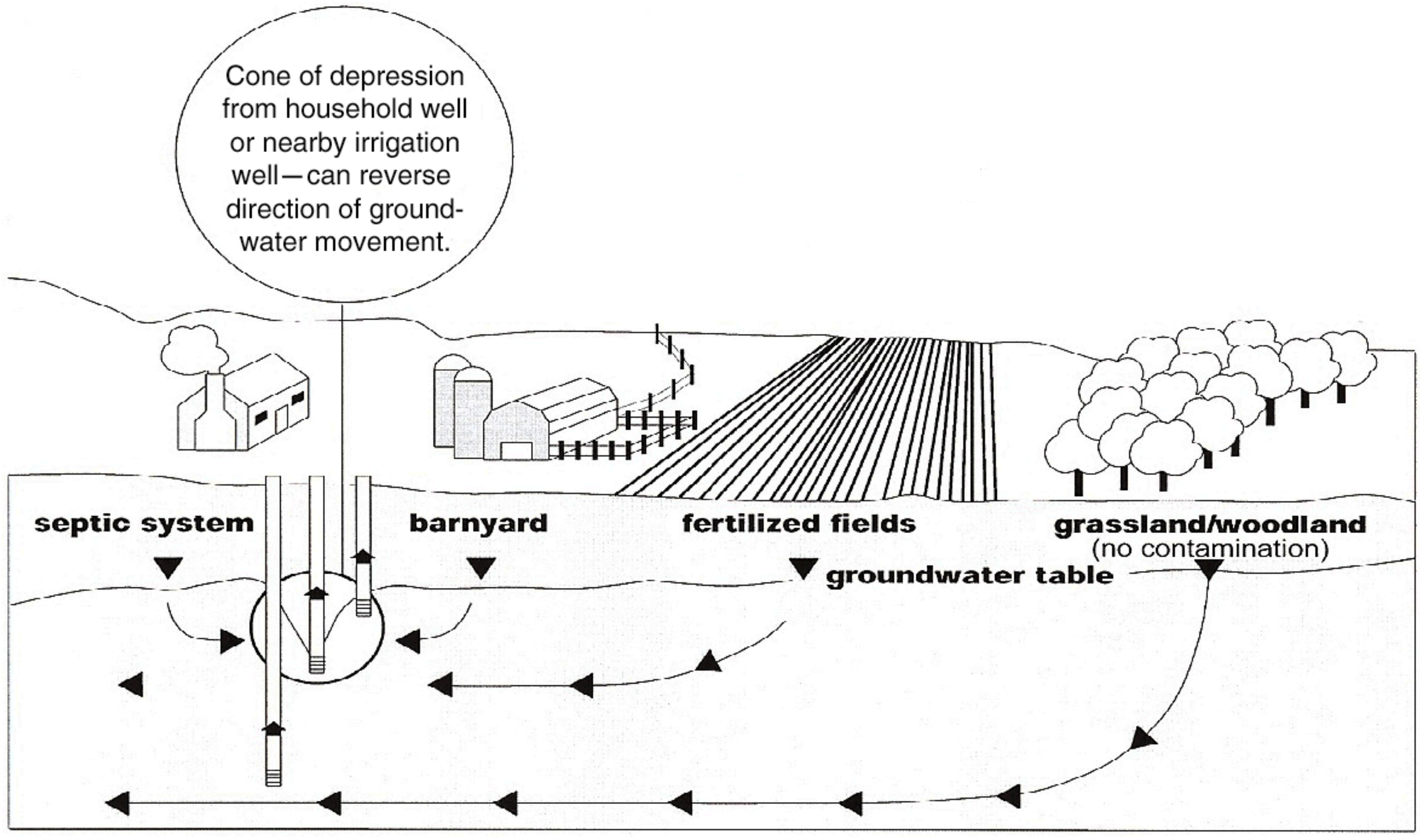


Figure 2. Direction of groundwater movement of a pumping system and potential sources of contamination.

How deep should my well be?

To answer this question, consider the following points:

- **Arizona's groundwater comes from mountain-front recharge and precipitation during wet years.**

The water pumped from wells is called groundwater. Contrary to popular belief, the state's groundwater does not come from underground rivers or lakes. According to the United States Geological Survey (USGS), groundwater in Arizona comes primarily from recharge by the mountains and within ephemeral stream channels (ephemeral streams can be defined as those streams that flow only after it rains or with snowmelt), with the majority occurring during abnormally wet years. Groundwater can also be recharged through surface infiltration, interbasin flow (flowing from one basin to another), and underflow (water moving from pore to pore). Groundwater is part of nature's water cycle.

Figure 1 helps you visualize how water moves around the Earth. The upper layer of soil is known as the unsaturated zone. Pulled downward by gravity, the water in this zone moves slowly through pores in the soil, some of which also contain air. Below the unsaturated zone, the saturated zone exists, where all the pores between the sand grains and gravel particles are filled with water. The boundary between the saturated and unsaturated zones is called the water table. Water in the saturated zone, below the water table, is called groundwater: The saturated sand and gravel is referred to as an aquifer. An aquifer holds water in the spaces between grains of sand or cracks in rocks, and pumps then draw the water out of the aquifer and into wells.

- **Shallow wells are more susceptible to contamination.**

Figure 2 provides a generic diagram showing pathways that groundwater may follow. It also shows several potential sources of groundwater contamination. Various land uses and human activities, such as the septic system, barnyard, or fertilized field depicted in Figure 2, may contribute to groundwater contamination. Gravity pulls water that soaks into the ground under these areas down to the water table. Contaminants may be dissolved and carried along as well. The soil filters out some of these materials, but may not be able to remove them all.

When water reaches the water table, it can change direction. Below the water table, all the space between sand grains is already filled with water. As a result, incoming water moves laterally in the direction of regional groundwater flow, and slowly makes its way deeper into the aquifer as more water descends. That process is shown by the black arrows below the water table in Figure 2. Groundwater moves quite slowly, even in sand and gravel – a few inches to a few feet per day is common.

Notice in Figure 2 that the water flow to the shallowest well originates in the barnyard, while water in the deepest well comes from the woodland farther away. Figure 2 also illustrates how the normal direction of groundwater flow can be temporarily changed by well pumping. Pumping causes a temporary lowering of the water table around the well called a cone of depression.

• In Arizona, groundwater can flow in many directions.

Another observation you might make about Figure 2 is that it appears that all the groundwater moves towards the well. This is true in a pumping situation. The pump pulls the water toward it, often times against its natural flow. Besides flowing downward, groundwater can move across a region from higher to lower elevations. In Arizona, groundwater moves from points of recharge to points of discharge. Points of recharge include mountain fronts (largest component), stream infiltration (second largest component), surface infiltration, from one basin to another, and underflow. (Note: interbasin and underflow are not common recharge components.) Groundwater in Basin and Range aquifers is mainly recharged, or replenished, at the base of mountains or through washes and ephemeral streams. It generally moves toward waterways such as arroyos, washes, ephemeral streams, lakes, rivers, and wetlands, where it can discharge as it reemerges from the ground as seepage or spring water. The distance that groundwater can flow depends on the gradient (amount of change in the elevation) and the permeability of the aquifer material(s). Permeability is the property of soil that allows water to flow through it; a high permeability means a high rate of flow.

Knowing the direction of groundwater flow helps you determine the most desirable location and the appropriate depth for your well. For example, in Figure 2, a well owner might look at the land uses upgradient, or uphill in the groundwater flow system. Knowing that several potentially polluting land use activities are conducted near the well site, and that a natural area is located farther upgradient might help a well owner decide that a deeper well would provide better quality water. Failing to consider groundwater flow direction and well depth might lead to unintentionally "recycling" water from the barnyard that may have an odor or other undesirable material.

Determining the direction of groundwater flow can be a complicated matter; however, if the land around you slopes toward a major stream, it is not a bad assumption that the groundwater underneath your land flows toward the river; but keep in mind, it may not. Some areas have groundwater elevation maps that can help you determine the direction of groundwater flow in your area. Check at your county Extension office or the Arizona Department of Water Resources at the address listed on the back page.

• "Shallow well" and "deep well" are relative terms.

In Arizona, depth to groundwater ranges from just below land surface to more than 1,000 feet. So, when is a well considered "deep"? The most important aspect of depth is not the well's absolute depth–30 or 40 or 100 feet–but rather how far its casing extends below the water table. A well casing is steel pipe that serves as the lining of your well. It keeps the well from caving in and helps protect the well from contamination from surface water.

Well depth can affect both the quality and quantity of water pumped from a well. As shown in Figure 2, the quality of water in a well is influenced by the land use activities that take place in its recharge area. [A recharge area is where water from precipitation is transmitted downward to an

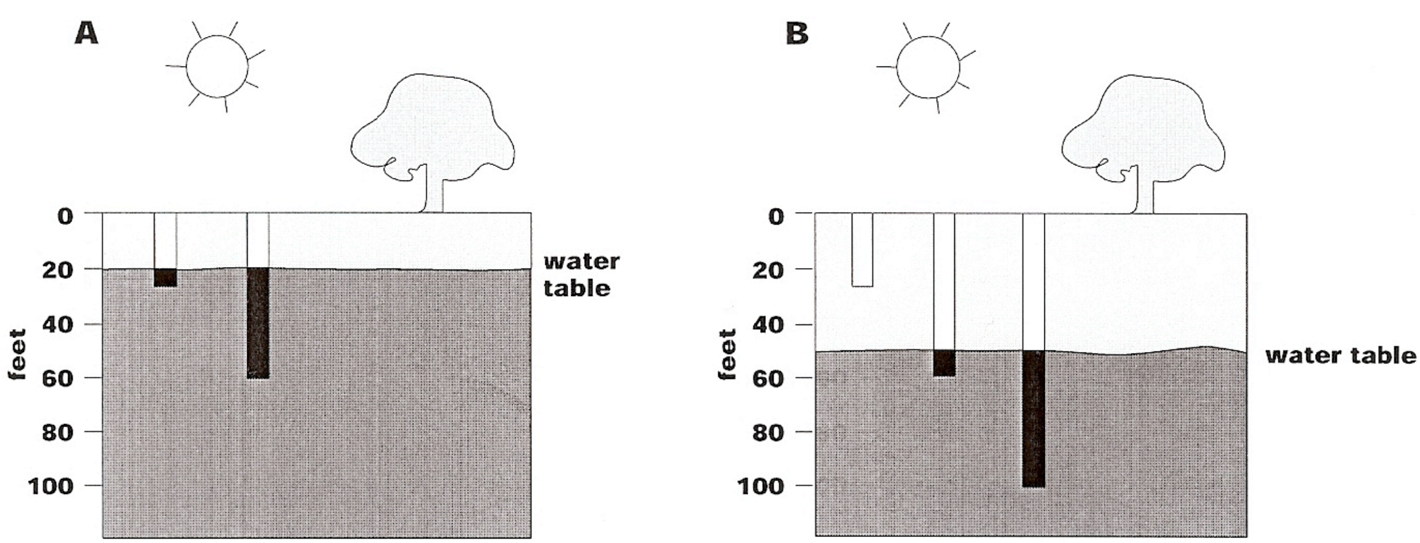
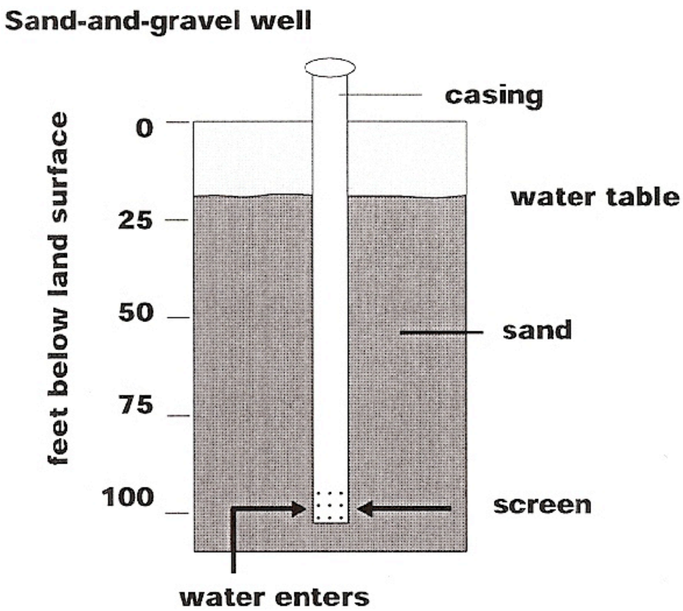


Figure 3. "Shallow" wells and "deep" wells.



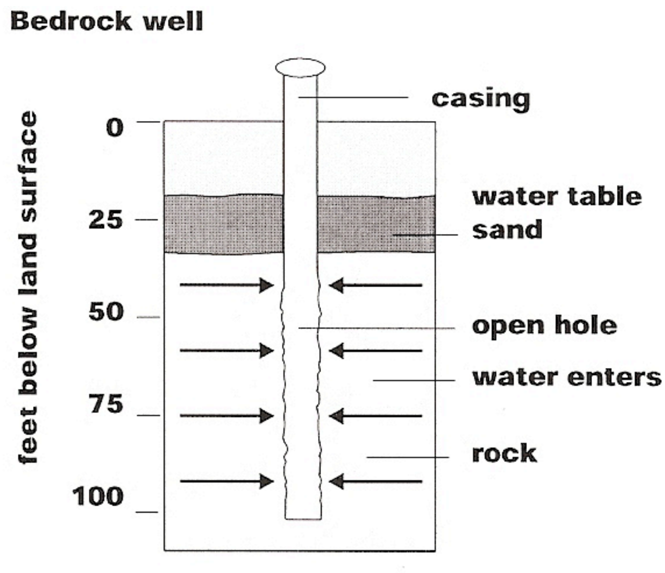


Figure 4. Casing depth in a bedrock and a sand-and-gravel well.

aquifer.] As for quantity, a well that is not deep enough to reach the water table will yield no water at all. Figure 3 shows two examples.

1. In location A, the depth from the land surface to the water table (the depth to water) is 20 feet. A 25-foot deep well would be a shallow well. It would be most susceptible to contamination from activities in the local area. Some part of the year it might be dry because of seasonal fluctuations in the water table. A deep well in this case might be 60 feet deep. Such a well would be better protected from local contamination and would not likely go dry even during drought years.
2. In location B, the depth to water is 50 feet. Our 25-foot deep well from the previous example is a dry hole. The 60-foot well is now a shallow well. It draws water from the top ten feet of the aquifer. It is susceptible to contamination from local activities, and might even be dry at times. If the water table is at 50 feet, a deep well might be 100 feet deep as shown in the figure.

• The amount of casing in a well is usually more important than the well's total depth.

For many wells drilled into the aquifer, the amount of casing (the pipe that lines the well hole) is nearly the same as the depth of the well itself. For example, a well that is 100 feet deep may possess 97 feet of casing and a 3-foot section of screen at the bottom that allows water to enter. Without casing, sand and gravel would quickly collapse back into the hole causing it to close (see Figure 4).

Holes drilled into consolidated materials (like bedrock), such as limestone or sandstone, are less likely to collapse. Therefore, it is not necessary to install casing all the way to the bottom. Rather, a minimum depth of casing is often installed while the remainder of the hole is left unlined, allowing water to flow into the hole from surrounding bedrock. For example, a well that is 100 feet deep in a sandstone formation may have 40 feet of casing and 60 feet of open hole below the casing. Groundwater may enter this well at any point below the end of the casing—in this case, at any depth below 40 feet.

In Figure 4, both wells are drilled to the same depth into an aquifer. However, the well drilled into bedrock is able to draw water from a much shallower depth than the screened well drilled into the sand, gravel, silt, and/or shale. The depth of well casing can therefore be a very important factor in the quality of water taken from a well. When applying the information in this publication to consolidated aquifer wells, it is important to substitute the words "shallow-cased" or "deep-cased" for "shallow" or "deep."

• Well depth and construction are regulated by the Arizona Department of Water Resources (ADWR).

All water-producing wells must meet the minimum standards outlined by the Arizona Administrative Code. Article 8: Well Construction and Licensing of Well Drillers describes proper well location, including minimum separation distances from potential sources of contamination. It also prescribes proper well construction techniques and materials. It is critical that you consult the Arizona well code for guidance on construction materials, techniques, and proper well location (http://www.azsos.gov/public_services/Title_12/12-15.htm). And remember that the code provides minimum standards, so you can take more precautions if you choose.

• There are good reasons why you might want a deep well.

By now, you may be getting the idea that choosing the right depth for a well isn't always easy. If you install a shallow well, your water quality will be most influenced by your activities and those of your neighbors. If you install a deeper well, your water quality will be generally influenced by the soil, rock, and geology that the water flows through. There is one other element to consider in this problem, and that is time. The water that you draw from a deeper well is likely to be older, having been in the ground for a longer time than water from a shallow well. That fact gives rise to some important consequences.

1. The water quality you see in a shallow well today is probably the result of land uses in the past year or two. The water quality in a deep well *may* reflect land uses of ten or more years ago, but not necessarily. Deep wells may only be influenced by the surrounding rock and soil formations through which the water flows. However, if your neighbor spills five gallons of gasoline, it might show up in your shallow well fairly quickly, especially if there has been abundant rainfall, irrigation, or other water-using activities. You can taste and smell gasoline at 1 part per million (so, 1 gallon of gasoline can contaminate 1 million gallons of water). If the landfill a mile uphill leaks, it could take many years for the contaminants to show up in your deep well. Groundwater in Basin and Range aquifers moves very slowly compared to water in streams–approximately a foot per day, or a mile in 16 years.
2. Water quality in a deep well usually changes more slowly than in a shallow well. That's because groundwater does some mixing as it moves through the aquifer. A spill a mile away from your deep well in the Basin and Range aquifer might be substantially diluted with clean aquifer water before it gets to your well. Shallow wells are quite sensitive to what's going on immediately around them, and their quality may vary season by season.
3. Some chemicals, such as pesticides or gasoline residues, break down or change over time. If a pesticide soaked into the ground a mile away from you, it might be substantially changed in the time it would take to reach your deep well. In a shallow well, where your water may only have been in the ground for a year, there is much less time for such changes to occur.

• There are also good reasons why you might want a shallow well.

The fact that the water in a deeper well is older than the water in a shallow well has some benefits, as we saw earlier. However, that same fact can lead to several significant problems.

1. Deeper wells may possess higher levels of a number of naturally occurring nuisance and health-related contaminants. Minerals that dissolve in water such as calcium and magnesium (which cause hardness) are more plentiful deeper in the aquifer. Also, as the aquifer gets deeper, the amount of oxygen decreases, making it easier for certain minerals like iron and manganese to dissolve.
2. If you live in a sparsely populated non-agricultural area, and have control over land uses upgradient, or uphill, in the groundwater flow system, installing a shallow well allows you to maximize control of your own drinking water quality. For example, if you have 40 acres of natural forest land, you might be able to install a well with water that is mainly recharged from that non-polluting land use. Remember, however, that you and your well driller must construct your well to certain minimum depths, using the Arizona well construction code as your guide.

• The amount of radioactivity in the water depends on the geology.

Although radioactivity is dependent on the local geology, deeper wells may possess higher levels of naturally occurring radioactivity than shallow wells. However, this is not the case of several shallow wells located in the Navajo Nation around Tuba City. Also, studies by the Arizona Department of Environmental Quality, the Arizona Geological Survey, and Arizona State University found that radon concentrations greater than 300 picocuries per liter are normal for groundwater in several areas across the state. Human-induced contamination of groundwater has also resulted from uranium mining activities (waste dumps and mine tailings) and mine dewatering. These uranium mining activities mainly occur in the Plateau Uplands Province (the northeastern part of the state). See Artiola and Uhlman (2009) for more discussion on radon and groundwater.

• The well construction report.

Your well's construction report contains important information. If it's not currently in your possession, make a point to obtain one. The actual well driller's logs, if available, can be examined and copied at ADWR's main office in Phoenix. Some well information may be found online at **http://azwater.gov** or **http://sahra.arizona.edu/wells**. If there is a problem with your well water, or if you are concerned about water quality, this information is critical. The well construction report includes information about the:

- depth of the well;
- depth to the water;
- type and size of casing(s); and
- stratigraphy (study of rock strata including the composition and distribution of material) identified during construction.

Unfortunately, it is nearly impossible to know the ideal depth of a well before you install it. If you have neighbors, learning the depth of their wells and the corresponding water quality might provide you with some clues. A good rule of thumb for well construction is "as shallow as possible, as deep as necessary," keeping in mind that you must observe the requirements of the well code. Choosing the "best" well depth is not an easy matter, and may not even be an option. And, if land uses change, a well that once produced good quality water could become contaminated. However, looking at the direction of groundwater flow, the surrounding land uses, any existing groundwater contamination, and the natural quality of groundwater in the area will all help you to choose a well depth that will provide the best quality water for you and your family. Regular (annual in some cases) water testing for several contaminants is recommended. See Extension Publications AZ1486f-k, especially AZ1486f *Well Water Testing & Understanding the Results* for more information on well water testing.

For Additional Information

Arizona Cooperative Extension (ACE) bulletins contain a variety of information about water, water quality, safe drinking water, and private wells. They are available through your county Extension office or from CALSmart Distribution Center, located in Tucson, at 4101 N. Campbell Avenue; (877) 763-531; (520) 795-8508 FAX; or visit **http://ag.arizona.edu/pubs/**

Resources

- Arizona Cooperative Extension: Publications. **http://ag.arizona.edu/pubs/**; Water Quality. **http://ag.arizona.edu/waterquality**
- Arizona Department of Environmental Quality. **http://www.adeq.gov**
- Arizona Department of Water Resources. **http://www.water.az.gov/adwr**; 3550 N. Central Ave., Phx, AZ 85062. (602) 791-8500
- US Environmental Protection Agency. **http://www.epa.gov/safewater/**
- United States Geological Survey (USGS) Groundwater Information: **http://water.usgs.gov/ogw/**
- Sustainability of semi-Arid Hydrology & Riparian Areas (SAHRA). Arizona Wells Database. **http://www.sahra.arizona.edu/wells**

Sources

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Other sources used to adapt the publication include:

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