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A Guide to Private Water Systems in Pennsylvania

A Manual for Rural Homeowners on the Proper Construction and Maintenance of Private Wells, Springs, and Cisterns

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Cooperative Extension
College of Agricultural Sciences

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Introduction

Over three million rural residents of Pennsylvania rely on a private water system (individual well, spring, or cistern) for their home water supply. These water supplies generally provide adequate and safe drinking water for rural homes that lie outside the area served by public water supplies. In addition, surveys of homeowners with private water systems have found that more than 80 percent are satisfied with their water supply.

Despite this general satisfaction, rural homeowners often face challenges in managing their water supply. That's because, unlike public water supplies, managing private water systems is entirely the homeowner's responsibility. Some homeowners who grew up in rural areas are accustomed to private water systems, but the increased migration of city dwellers into rural areas has meant that many homeowners are unfamiliar with the basic management of these water supplies.

Homeowners may be unaware of the proper design, construction, testing, and treatment that are often necessary to ensure safe drinking water from these supplies. As a result, many problems go unnoticed. One recent study of 700 private well owners found that fewer than 20 percent were aware of the water-quality problems that existed in their drinking water.

This manual is intended as a guide for private water system owners in Pennsylvania. From proper location and construction to recommended testing and treatment strategies, it will help you make educated decisions about your water supply. Before following any of the suggestions made in this publication, check with your local, county, and state government to make certain that any existing regulations are met.

THE HYDROLOGIC CYCLE

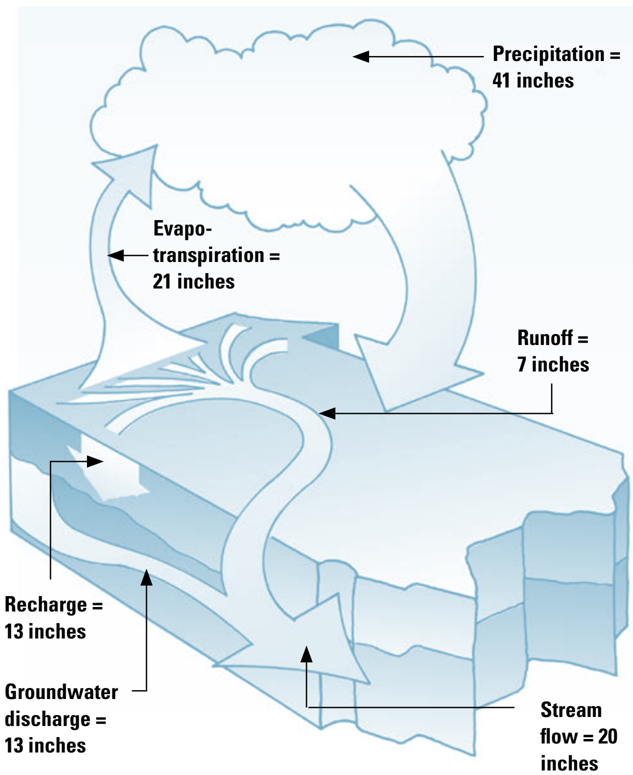
Any discussion of groundwater must start with an understanding of the hydrologic cycle, the movement of water in the environment. As the word "cycle" implies, there is no beginning or end to the hydrologic cycle; it is merely the continuous movement of water between places.

Let's start with precipitation. Rain is the dominant form of precipitation across Pennsylvania, accounting for more than 75 percent of the total annual precipitation on average. Snow is the other major form, which generally accounts for less than 10 percent of the annual precipitation in southern Pennsylvania and up to 25 percent of the annual precipitation in some northern counties. The amount of precipitation is surprisingly variable across the state, ranging from just 32 inches in Tioga County to more than 48 inches along the Allegheny Front and the Poconos. On average, the state receives approximately 40 inches of annual precipitation (rain and melted snow) as a whole.

Where does all this precipitation come from? All precipitation originates from water evaporated somewhere on the Earth's surface. Some of the rainfall in Pennsylvania comes from water that evaporated from tropical parts of the oceans. Near the equator, the sun provides enough energy throughout the year to evaporate huge quantities of water that fall as precipitation all over the world. However, precipitation during isolated thunderstorms or lake-effect snow squalls may originate from evaporation much closer to home.

The sun powers the hydrologic cycle, evaporating water from all over the Earth's surface, including water in oceans, lakes, fields, lawns, rooftops, and driveways (Figure 1.1). Plants also use the sun's energy to evaporate water by taking it from the soil, using it to grow, and releasing it into the atmosphere through their leaves in a process called transpiration. Evaporation and transpiration are commonly combined and referred to as evapotranspiration (ET). Nearly all the precipitation that falls during the growing season in Pennsylvania is returned to the atmosphere through ET. During the winter months, however, very little ET occurs because plants do not use much water and the sun is too low in the sky to cause much evaporation. Over the entire year, about 50 percent of the precipitation that falls across the Commonwealth returns to the atmosphere through ET.

Figure 1.1. The hydrologic cycle for an average year in Pennsylvania.



What happens to precipitation that reaches the earth and is not evaporated or transpired by plants? About 7 inches of Pennsylvania's annual precipitation enters streams directly as runoff, either as overland flow, which travels over the land surface, or as interflow, which moves toward streams through soil. The remainder of the precipitation, about 13 inches, is in the form of recharge—precipitation that infiltrates the soil surface, trickles downward by gravity, and becomes the groundwater that feeds the springs, streams, and wells of Pennsylvania. Most of this recharge occurs from rain and melting snow during early spring and late fall when the soil is not frozen and plants are not actively growing. Adequate precipitation and snowmelt during these short time periods is critical for supplying groundwater. All groundwater was once surface water, and it will be again because groundwater is an integral part of the hydrologic cycle. This is nature's way of recycling water.

GROUNDWATER BASICS

Precipitation that does not quickly run off into streams, is not evaporated by the sun, or does not get taken up by plant roots slowly infiltrates through layers of soil and rock to become groundwater. This infiltrating water eventually reaches a saturated layer of sand, gravel, or rock called an aquifer. Aquifers may occur a few feet below the land surface, but they are more commonly found at depths greater than 100 feet in Pennsylvania. Some groundwater occurs in the pore spaces of solid rock, but most occurs in cracks and fractures in rock layers or between sand and gravel particles. Therefore, groundwater normally occurs in small spaces within the different aquifer materials and not as underground lakes or rivers (Figure 1.2).

Geologic formations called aquitards may also lie within the saturated zone. These formations are usually made of clay or dense solid rock that inhibits infiltrating groundwater from moving through it. Aquitards restrict groundwater movement to and between aquifers. Aquitards located above and below an aquifer form a confined aquifer. If this aquifer is tapped with a well, artesian pressure forces the trapped water to rise in the well to an elevation higher than the top of the aquifer unit. If the pressure is great enough, the water may rise to the land surface, creating a flowing artesian well. An aquifer with no aquitard above it is an unconfined aquifer. In wells penetrating this type of aquifer, the water level within the well and the aquifer are the same. At any given location, several distinct aquifers may exist below the ground surface at different depths separated by aquitards.

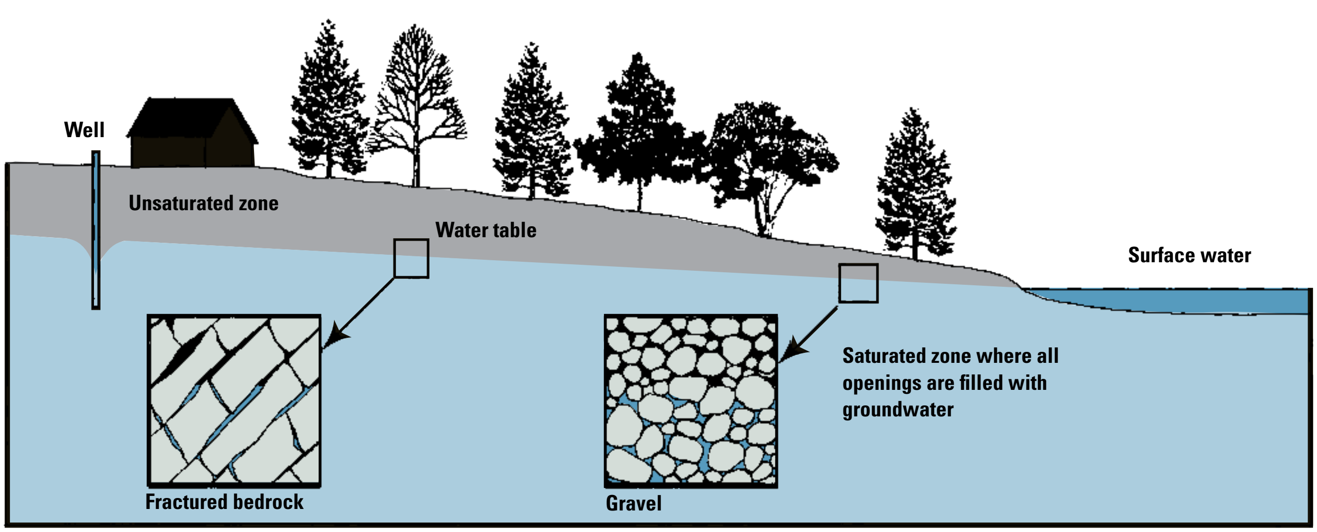
The top of the uppermost unconfined aquifer is called the water table. During rainfall, the water table rises toward the ground surface as percolating rainfall is added to the groundwater aquifer. During dry periods, the water table will fall deeper underground as groundwater is discharged from the aquifer into springs, streams, and wells.

Directly above the water table lies the unsaturated zone, where the spaces between soil and rock particles contain both air and water—air in the larger openings, water in the smaller ones. Moisture conditions in the unsaturated zone vary greatly depending on the weather. Immediately after a heavy rain, even the large pores of the unsaturated zone may hold water. During a drought, most pores are filled with air, and the little remaining water exists in thin films around soil particles.

Groundwater does not simply remain stagnant under the ground. Rather, it moves underground from upland to lowland areas. Groundwater flows downhill—the direction of groundwater flow underground can often be approximated by visualizing how water would flow on the ground surface. Flowing groundwater eventually reaches a discharge point where the water table meets the land surface. Springs are a classic discharge point where groundwater bubbling to the surface can be seen. Low-lying wetlands are another example of a discharge point where groundwater is at the soil surface.

Streams and lakes are the normal points of discharge for groundwater. Every stream has a watershed, which encompasses the land area that drains surface and groundwater into the stream. Very small streams

Figure 1.2. How groundwater occurs below the Earth's surface.



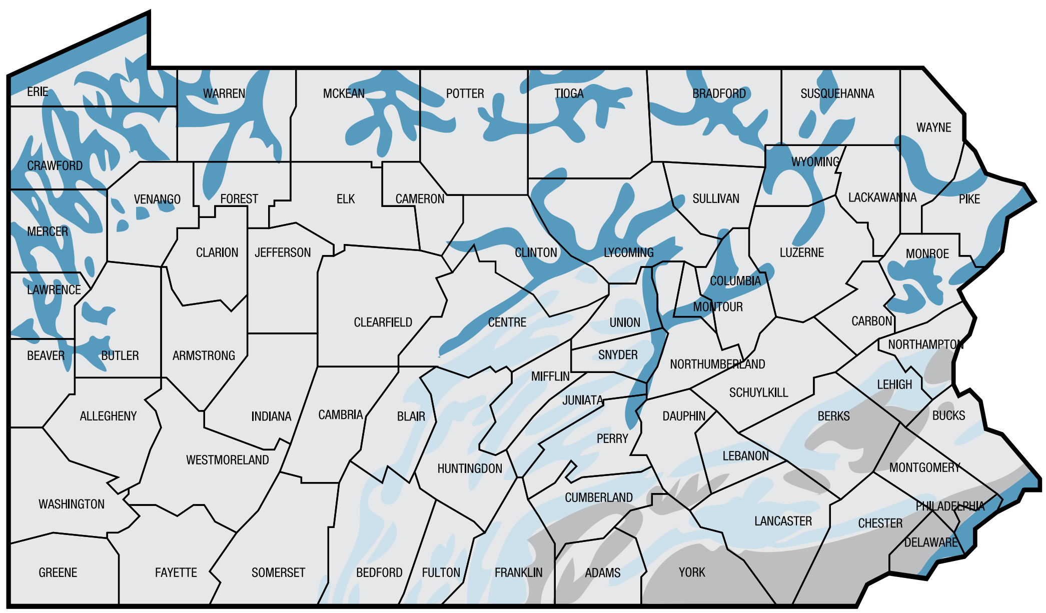
may have a watershed of only a few acres, while major rivers have watersheds that encompass millions of acres. No matter where you stand, you are located within one small watershed that is part of many other larger watersheds. The largest rivers forming the major watersheds of Pennsylvania all flow toward one of the oceans.

The average Pennsylvania stream gets about two-thirds of its flow from groundwater. Except for a short time during and after rainstorms and snowmelt, streams carry water provided only by groundwater that seeps through stream banks and streambeds into the channel (this is called baseflow). The groundwater that forms a stream's baseflow during dry weather often takes a year or more to make the journey underground to the streambed. In some groundwater flow paths, it may take thousands of years for an individual water molecule to travel to the stream after it reaches the land surface as precipitation.

The situation is sometimes reversed—streams may lose some of their flow to groundwater. This happens when the water table lies below a stream and does not intersect it. In some cases, different sections of streams behave differently, with some portions gaining groundwater and other losing it. In general, as streams become larger as they near the ocean, they contain increasing amounts of groundwater.

Groundwater aquifers vary in size and composition, and the amount and quality of groundwater yielded is also different from aquifer to aquifer. There are four major types of groundwater aquifers in Pennsylvania (Figure 1.3).

Figure 1.3. The four major types of groundwater aquifers in Pennsylvania.



Aquifer type and description		Depth (ft) Common range	Depth (ft) May exceed	Yield (gal/min) Common range	Yield (gal/min) May exceed	Typical water quality
Unconsolidated sand and gravel aquifers: sand, gravel, clay, and silt		20–200	250	100–1,000	2,300	Soft water with less than 200 mg/l dissolved solids; some high iron concentrations
Sandstone and shale aquifers: fractured sandstone and shale		80–200	400	5–60	600	Sandstone layers have soft water with less than 200 mg/l dissolved solids; shale layers have hard water and 200–250 mg/l dissolved solids
Carbonate rock aquifers: fractured limestone and dolomite		100–250	500	5–500	3,000	Very hard water with more than 250 mg/l dissolved solids
Crystalline rock aquifers: fractured schist and gneiss		75–150	—	5–25	220	Soft water containing less than 200 mg/l dissolved solids; some moderately hard water with high iron concentrations

Note: ft = feet; mg/l = milligrams per liter; gal/min = gallons per minute

From ***Pennsylvania Geological Survey***, 1999

An Important Resource

Groundwater in Pennsylvania is a vast resource and is estimated to be more than twice as abundant as the amount of water that flows annually in the state's streams. Pennsylvanians have tapped into this important resource. Each day more than one billion gallons of groundwater are pumped from aquifers throughout the state for various uses. More than half of this groundwater is used for domestic drinking-water supplies, which demand high-quality, uncontaminated water. Although smaller amounts of groundwater are used for agricultural and mining purposes, groundwater still accounts for the majority of all the water used for these activities (Figure 1.4).

Groundwater is especially vital to rural areas of the state. Second only to Michigan for the largest number of private water wells, Pennsylvania has more than one million private water wells, supplying water to more than three million rural residents (Figure 1.5). An additional 20,000 new private wells are drilled each year around the state.

Although more groundwater wells are drilled each year, the total groundwater usage across the state has remained relatively stable over the past few decades. Water conservation measures and education have played an important role in keeping groundwater use constant. From 1985 to 1995, Pennsylvania's population increased by nearly 300,000, but average water use fell from 66 to 62 gallons per person per day. Water conservation measures, such as low-flush toilets, front-loading washing machines, low-flow showerheads, and outdoor rain barrels, can reduce household water use by 30 percent. Reduced outdoor water use is especially important because it saves water that largely evaporates (consumptive water use) as opposed to water that is simply used and put back into the ground (nonconsumptive water use).

In addition to water savings, water conservation can also reduce yearly home energy costs by several hundred dollars in every home. Thus, conserving water means conserving energy. More information on water conservation can be found in Chapter 6.

THREATS TO GROUNDWATER

People from many parts of Pennsylvania are concerned about the future availability of adequate groundwater for meeting home and business needs. In some cases, these concerns are due to increasing local use of groundwater that exceeds the amount of recharge supplying the aquifer. More often, groundwater supplies are threatened by expanding impervious coverage of the land surface. Each year, more land area is being covered by roofs, sidewalks, driveways, parking lots, and other surfaces that do not allow rainwater to recharge the underlying groundwater aquifers. Every acre of land that is covered with an impervious surface generates 27,000 gallons of surface runoff instead of groundwater recharge during a one-inch rainstorm. Without recharge water feeding the aquifer, groundwater mining—water being removed from the aquifer more quickly than it can be recharged—may occur.

Groundwater mining has been documented in parts of southeastern Pennsylvania, where impervious cover has increased rapidly and groundwater withdrawals have also increased. Water-resource planning efforts initiated in Pennsylvania in 2003 aim to document areas where groundwater resources are currently overused or may be overused in the future. With this information, local government planning officials can more adequately guide future development based on existing water resources.

Figure 1.4. Groundwater use in Pennsylvania.

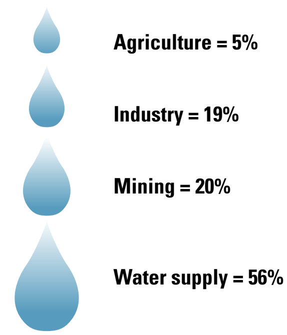
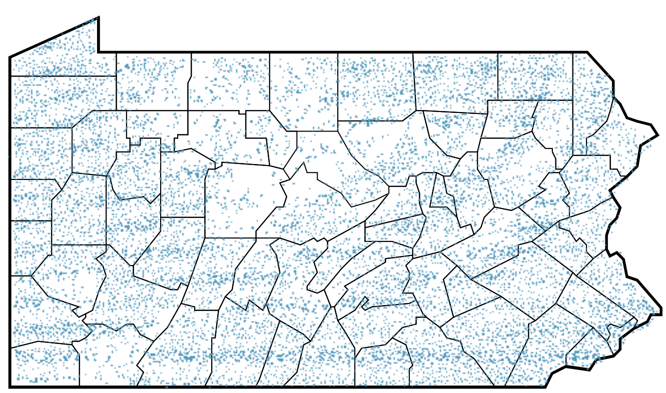


Figure 1.5. Private water wells reportedly drilled between 1963 and 1994 to serve individual homes in Pennsylvania. Each dot represents one drilled well. *Data from the Pennsylvania Groundwater Information System compiled by the Pennsylvania Geological Survey.*



Chapter 2—Private Water Systems

Over one million homes in Pennsylvania rely on a private water system. A private water system is any well, spring, or cistern that provides the drinking water supply for an individual household. Unlike public water systems, all the maintenance, testing, and treatment of a private water system is the homeowner's responsibility. For this reason, it is important for homeowners to understand private water systems and do periodic inspections and maintenance.

A private water well is a hole in the ground that is drilled, driven, or hand dug to supply water for an individual household. Most wells today are drilled by means of a cable tool (percussion) or by the air-rotary method. Hand-dug wells are usually very old but do still exist; they need to be closely monitored since they are very susceptible to pollution from surface sources and may also contribute to aquifer contamination. All private wells should be constructed using sanitary materials, such as a water-tight, vermin-proof well cap and a cement or bentonite grout seal between the borehole and the well casing.

A spring occurs where groundwater discharges to the earth's surface. If developed properly and treated for bacteria, springs can provide a safe and reliable source of water for an individual homeowner. Considerations such as the quantity of water that the spring produces throughout the entire year should be evaluated before the spring is used as the sole source of drinking water for the home.

Cisterns are the third type of private water system found in Pennsylvania. Although uncommon in most of the state, they are used in areas where the groundwater supply is grossly polluted and there is no alternative source for drinking water. A cistern is a tank, usually installed underground, that stores water for drinking and other household uses. Cisterns can store water that is trucked to the home or they can store treated rainwater. For a household to use rain as a source of drinking water, a roof catchment area needs to be installed and the appropriate treatment systems implemented. Water from rainwater cisterns must be disinfected before it can be used as a drinking water supply.

More information about each type of private water system can be found in this chapter. Regardless of which system is used in your home, it is important that the water supply be tested at least annually by a certified laboratory to ensure that the water is safe for consumption. In Pennsylvania, private water supplies are not monitored or regulated by the state, so homeowners need to evaluate their own systems periodically.

WATER SYSTEM PLANNING: ESTIMATING WATER NEEDS

Whether you are building a new house in a rural area or increasing the size of a dairy herd, an adequate supply of water from a private well or spring is critical to your plans. Planning should be done before you have a well drilled or spring developed to ensure that enough water is available.

This section allows a homeowner or farmer to estimate water needs and calculate how much water must be delivered from a private water supply to meet these needs. These planning assumptions are based on long-term averages for various water uses in Pennsylvania. Your actual water use may vary significantly from these averages.

Estimating Home Water-Use Needs

In general, we use 50 to 100 gallons per person per day in our homes (200 to 400 gallons per day for a family of four). The household water use estimates given in Table 2.1 can be used to calculate more specific daily water use values for your home.

For the purposes of planning a water system, the total daily water use is less important than the peak daily water use or the *peak demand*. In reality, most of

Table 2.1. Typical water uses for various appliances and fixtures in the home.

Clothes washer (top-loading)	43 to 51 gallons per load
Clothes washer (front-loading)	27 gallons per load
Dishwasher (standard)	7 to 14 gallons per load
Dishwasher (efficient)	4.5 gallons per load
Garbage disposal	4 gallons per day
Kitchen sink	3 gallons per minute of use
Bathroom sink	2 gallons per minute of use
Shower or tub	5 gallons per minute of use
Toilet (low-flush)	1.6 gallons per flush
Toilet (standard)	5 gallons per flush
Outside hose (1/2-inch)	5 gallons per minute of use
Water softener regeneration	50 to 100 gallons per cycle

the water used in the home occurs over very short time periods, usually in the morning and evening. As a result, for planning purposes it is recommended that a water system be able to supply all of the day's projected water use in a 2-hour peak demand period. If you estimate that your home water use will be 400 gallons per day, the water system should be sized to provide this much water in a 2-hour period.

The amount of water that can be delivered from your well or spring in a given period of time is referred to as the well or spring yield. The yield from a spring can be easily measured by determining how many gallons of water flow from the outlet pipe every minute. This flow rate will likely vary considerably with weather conditions, but, for planning purposes, it would be best to measure flow during a dry time period. For a well, the yield is considered the maximum rate in gallons per minute (gpm) that a well can be pumped without lowering the water level in the borehole below the pump intake.

For most single-family homes, a minimum flow of 6 gpm is suggested from a well or spring. This flow would provide 360 gallons of water each hour, which would be sufficient to meet most home water peak demands. Higher flow rates may be necessary for larger homes with more fixtures, appliances, and residents that may all be using water at the same time. The values in the table below give the suggested minimum flow rates for various numbers of bedrooms and bathrooms in a home.

Ideally, the yield from the well or spring will exceed the recommended minimum flow rates in Table 2.2. If not, you may need to rely on water storage to meet peak demand periods. For a drilled well, the borehole can provide a significant amount of water storage. A typical 6-inch-diameter well stores about 1.5 gallons of water for every foot of standing water in the borehole, and a 10-inch well stores about 4 gallons of water per foot. Therefore, a 6-inch-diameter well with about 100 feet of standing water in the borehole would contain about 150 gallons of stored water. However, in some geologic settings, using a significant amount of the borehole storage (i.e., significant drawdown for each pumping cycle) may tend to dislodge particles from the borehole and may result in the need to filter the water.

In the case of a spring, a large spring box can be constructed where the spring emerges, or a water storage tank can be added after the spring box to provide extra water storage to meet peak demand. The water stored in the borehole, spring box, or storage tank is helpful when water use in the home exceeds the amount of water flowing from the well or spring.

Well storage and spring flow can vary dramatically with the natural groundwater level, with the highest levels typically occurring in spring and the lowest levels in fall. These natural variations can be accentuated by drought conditions. So, while water storage can allow for the use of wells and springs with lower flow rates than shown in Table 2.2, it may not be reliable during severe droughts. An approximate estimate of the amount of water needed before a well or spring is developed can allow the professional contractor to use the combination of local knowledge, yield, and storage to meet water demand. For wells that yield extremely low amounts of water, an intermediate storage system can be added (see "Low-Yielding Wells" in Chapter 6).

Estimating Farm Water-Use Needs

Planning for water supply needs is generally much more important for farms because much larger amounts of water are often needed, especially for dairy operations or farms with large acreages in irrigation. Midwest Plan Service guidelines suggest that farms using 2,000 gallons per day (gpd) will need a water source flow rate of 16 gpm, those using 6,000 gpd will need 36 gpm, and those using 10,000 gpd will need 48 gpm. Planning for larger operations starts with an estimate of total daily water use from Table 2.3.

Using the estimates from Table 2.3, current and future daily water demands on the farm can be estimated. The farm water system would need to be designed to include sustained yield and storage from one or more wells or springs. Where large quantities of water are needed from a well, it may be worthwhile to hire a professional hydrogeologist to locate a high-yield well using fracture trace mapping or other technique for locating a productive well.

It should also be noted that farms using more than 10,000 gpd must report their annual water use to the Pennsylvania Department of Environmental Protection as required by the Water Resources Planning Act.

Table 2.2. Minimum flow rates (GPM) for homes based on number of bedrooms and bathrooms.

Number of bedrooms in home	Number of bathrooms in home			
	1	1.5	2	3
2	6 GPM	8 GPM	10 GPM	
3	8 GPM	10 GPM	12 GPM	
4	10 GPM	12 GPM	14 GPM	16 GPM
5		13 GPM	15 GPM	17 GPM
6			16 GPM	18 GPM

From *Private Water Systems Handbook*. 1002. Midwest Plan Service. MWPS-14.

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