CHAPTER 3. WELLS

(Lesson 1 of 4 Lessons)

3.0 GROUNDWATER—CRITICAL LINK TO WELLS

3.00 Importance of Groundwater

The function of a well is to intercept groundwater moving through *AQUIFERS*[1] and bring water to the surface for use by people. Although we are concerned with wells and their construction and maintenance, we must also be concerned with the lifeline to these wells. The aquifers and the quality of water in the aquifers must be maintained if we are going to preserve this precious source of water. Pollution and misuse of the aquifers can seriously affect a good water source. Pollution can render a supply useless while excessive use (overdraft) of our wells can affect both volume and rate of output causing permanent damage to the water-bearing formations of the earth's surface.

Approximately 45 percent of the water used in the United States comes from underground sources. In many locations, water from wells or springs is the only water available to a community. Estimates indicate that there are between 10,000,000 and 20,000,000 water wells scattered throughout the United States. Most are situated in valleys or river-bottom land, although many are located in hilly and mountainous regions. They range from shallow hand-dug wells to carefully designed, large production wells.

The principal reasons for using groundwater are:

1. Groundwater is generally available in most localities although quantities may be very limited in certain areas.
2. Well and pumping facilities cost less than surface treatment facilities.
3. Groundwater is usually clear and, with few exceptions, can meet turbidity requirements.
4. Conditions for growth and survival of bacteria and viruses in groundwater are generally unfavorable when compared with surface waters.
5. The mineral content for a given well is usually uniform.
6. Well water usually has a more constant and lower temperature during the summer (warmer months).
7. Well supplies are particularly suited to the needs of smaller communities in many areas.

3.01 Water (Hydrologic) Cycle[2] (Figure 3.1)

The earth's water cycle, or hydrologic cycle, is the continuous circulation of water (including moisture) on our planet. The cycle has neither a beginning nor an end, but the concept of the hydrologic cycle commonly begins with the waters of the ocean, because they cover about three-fourths of the earth's surface (see Chapter 2, Section 2.10, "The Water (Hydrologic) Cycle," for details).

Water that infiltrates the soil is called "subsurface water," but not all of it becomes groundwater. Basically, three things may happen to that water. First, it may be pulled back to the surface by capillary forces and be *EVAPORATED*[3] into the atmosphere, thus skipping much of the journey through the water cycle we have described. Second, it may be absorbed by plant roots growing in the soil and then re-enter the atmosphere by a process known as *TRANSPIRATION*.[4] Third, water that has infiltrated the soil deeply enough may be pulled on downward by gravity

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[1] *Aquifer* (ACK-wi-fer). A natural, underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water.

[2] *Hydrologic* (HI-dro-LOJ-ick) *Cycle.* The process of evaporation of water into the air and its return to earth by precipitation (rain or snow). This process also includes transpiration from plants, groundwater movement, and runoff into rivers, streams, and the ocean. Also called the WATER CYCLE.

[3] *Evaporation.* The process by which water or other liquid becomes a gas (water vapor or ammonia vapor).

[4] *Transpiration* (TRAN-spur-RAY-shun). The process by which water vapor is released to the atmosphere by living plants. This process is similar to people sweating. Also see EVAPOTRANSPIRATION.

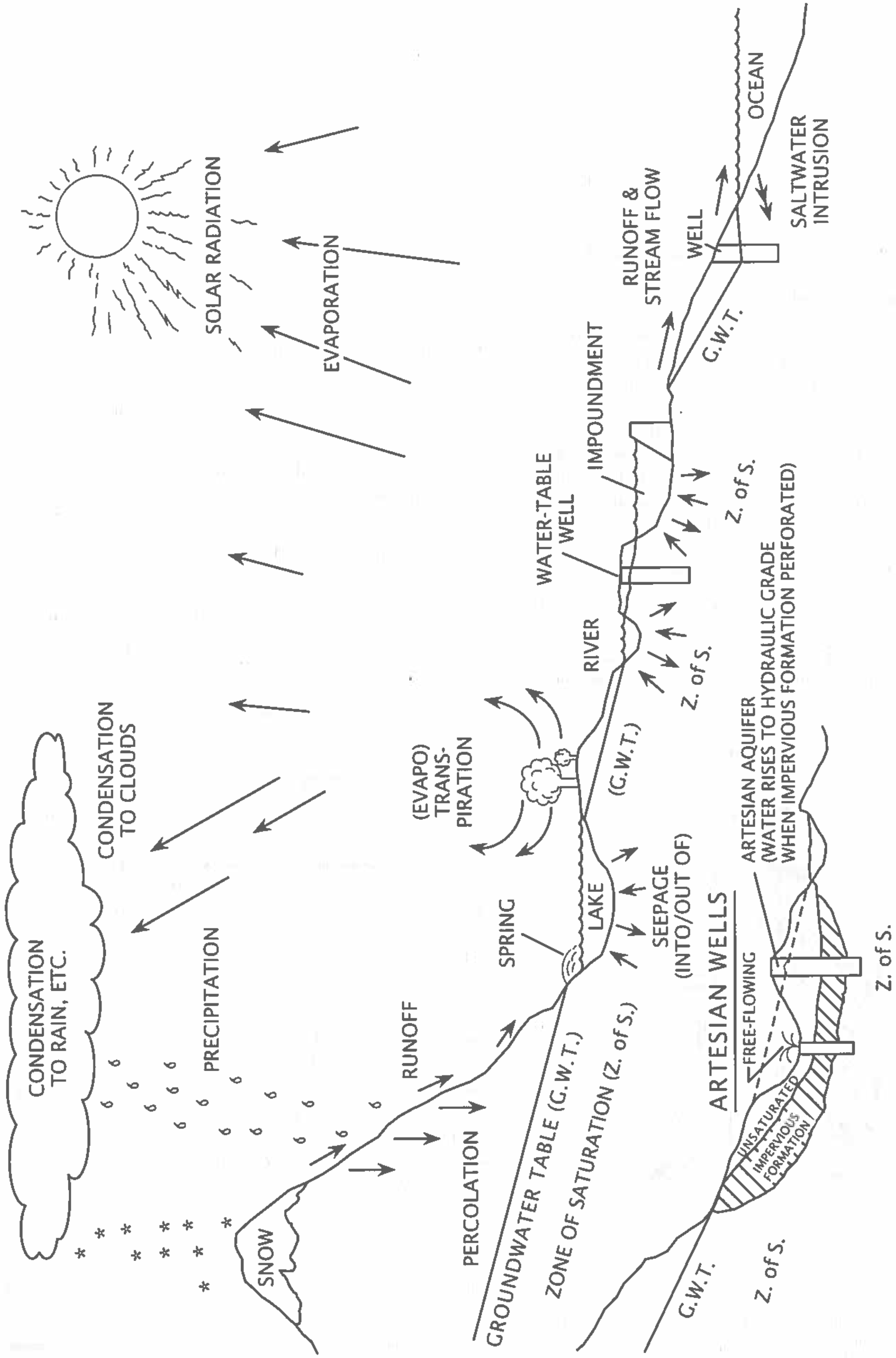


Fig. 3.1 The water (hydrologic) cycle as related to water supply
(Source: *BASIC WATER TREATMENT OPERATOR TRAINING COURSE I*, by Leonard Ainsworth, by permission of California-Nevada Section, AWWA)

until it reaches the level of the *ZONE OF SATURATION*,[5] the groundwater reservoir that supplies water to wells. Groundwater conditions directly affect the design, operation, and performance of a water well.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 137.

3.0A What is the purpose of a well?

3.0B List two potential problems that can affect wells.

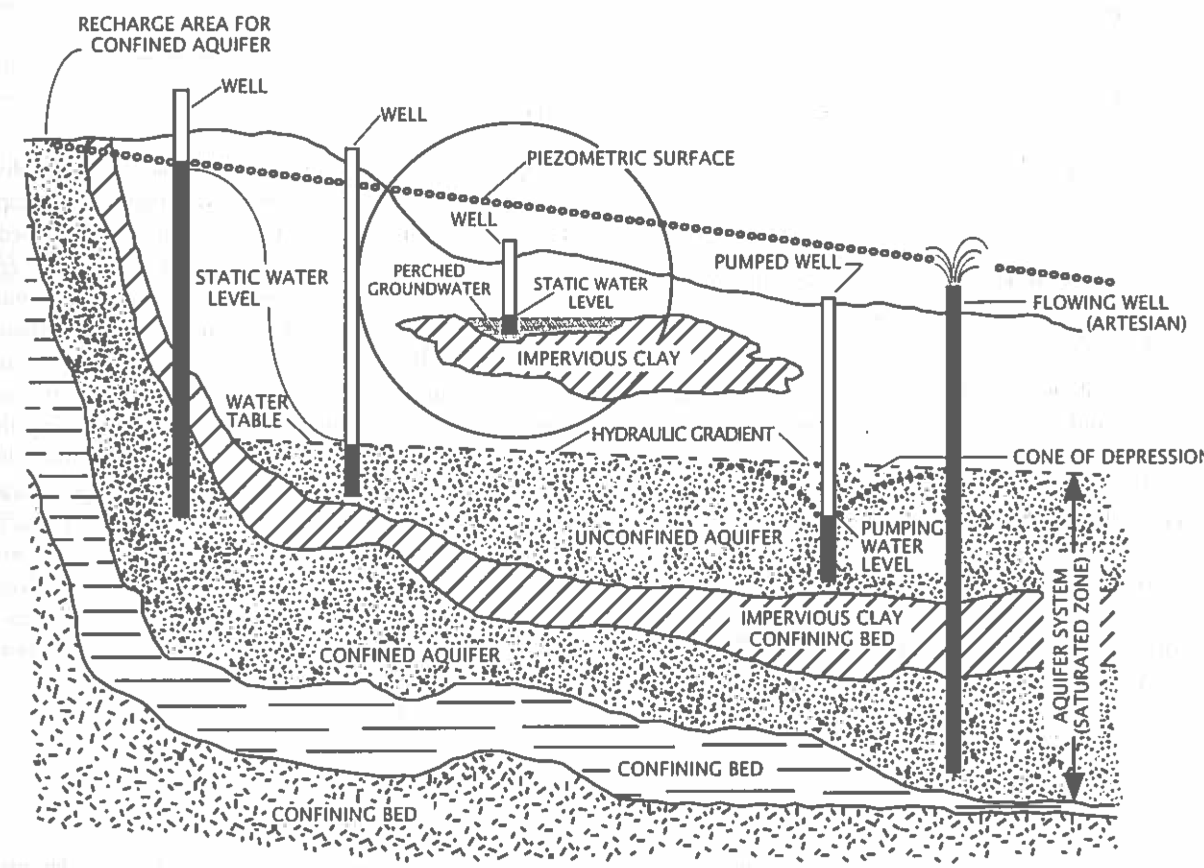
3.0C List as many of the principal reasons as you can recall for using groundwater.

3.0D What is the hydrologic cycle?

3.02 Aquifers

An "aquifer," shown in Figure 3.2, is an underground layer of pervious material, such as sand, gravel, cracked rock, limestone, or other porous soil material capable of transporting and storing water. At the bottom of the aquifer will be an impervious layer of clay or rock that holds the aquifer in place.

If the water table is unconfined, the aquifer is known as a "water table aquifer" and a well in this aquifer is called a "table well." If the aquifer is confined between two impervious layers, it is known as an "artesian aquifer" and from this type of aquifer we get what is referred to as an "artesian well." Both types of aquifers and wells are shown in Figure 3.2. The artesian aquifer is under pressure and quite often this natural pressure reduces pumping requirements and thereby reduces pumping costs.



Note perched aquifer inside circle

Fig. 3.2 Water (hydrologic) cycle as related to groundwater
(Source: *WATER WELLS AND PUMPS, THEIR DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE*, Division of Agricultural Sciences, University of California, Davis)

[5] *Zone of Saturation.* (1) The soil or rock located below the top of the groundwater table. By definition, the zone of saturation is saturated with water. Also see WATER TABLE. (2) Where raw wastewater is exfiltrating from a sewer pipe, the area of soil that is moistened around the leak point is often called the zone of saturation.

For a saturated material to qualify as an aquifer, it must have: (1) *POROSITY*,[6] area, and thickness sufficient to store an adequate water supply; (2) sufficient *SPECIFIC YIELD*[7] to allow the stored water to drain into a well; and (3) hydraulic *TRANSMISSIVITY*[8] to permit a well to drain water from the aquifer fast enough to meet flow requirements.

3.020 *Porosity and Specific Yield*

"Porosity" (usually expressed as a percentage) is a measure of the openings or voids (*PORES*[9]) in a particular soil. Porosity measurements represent (quantify) the amount of water that a particular soil type or rock can store.

$$\text{Porosity, \%} = \frac{(\text{Volume of Voids})(100\%)}{\text{Total Volume of Soil Sample}}$$

EXAMPLE:

V_v = Volume of Voids = 0.2 cu ft

V_s = Total Volume of Soil Sample = 1.0 cu ft

$$\text{Porosity, \%} = \frac{(V_v)}{(V_s)}(100\%)$$

$$= \frac{(0.2 \text{ cu ft})}{(1.0 \text{ cu ft})}(100\%)$$

$$= 20\%$$

Large porosities are usually associated with fine-grained, highly sorted materials while small porosities are representative of dense rock and soils.

Only a portion of the stored water can be used to supply water to wells or aquifers. A certain amount of water will be retained and not affected by forces of gravity. The water volume that can move through the pores in the rock is affected by gravitational forces and is termed the specific yield (Y_{sp}). Table 3.1 shows the relationship in percentage between porosity and specific yield of various types of soil. Notice that although high porosity may be a good indicator of water storage capacity, it does not necessarily guarantee a high specific yield. Clay, for example, has a high porosity but a low specific yield.

TABLE 3.1 SELECTED VALUES OF POROSITY AND SPECIFIC YIELD[a]

Materials	Porosity[b]	Specific Yield[b]
Soil	55	40
Clay	50	2
Sand	25	22
Gravel	20	19
Limestone	20	18
Sandstone (semiconsolidated)	11	6
Granite	0.1	0.09
Basalt (young)	11	8

[a] *BASIC GROUNDWATER HYDROLOGY,* US Geological Survey Water Supply Paper 2220. Prepared by Ralph C. Heath in cooperation with the North Carolina Department of Natural Resources and Community Development.

[b] Values in percent by volume.

3.021 *Overdraft*[10]

Aquifers have a certain *YIELD*[11] that can normally be replaced each year through recharge due mainly to precipitation. This yield, commonly called "safe yield," is determined during well development through analysis by a qualified *HYDROGEOLOGIST.*[12] Overdraft (overpumping) of the aquifer can cause permanent damage to the water storage and transmitting properties of the aquifers. If an excessive amount of water is removed (overdraft) from an aquifer, the soil may settle and cause compaction of the aquifers, which results in closing the pores through which water moves and in which the water is stored. This compaction and closing of pores also produces what we call subsidence (sub-SIDE-ence) of the land. Over the past three decades, ground subsidence has been measured from 0.91 foot (0.27 meter) in Savannah, Georgia, to over 27 feet (8 meters) in the San Joaquin Valley in California. Sinkholes in Florida can also be attributed to overdraft of the groundwater supplies.

[6] *Porosity.* (1) A measure of the spaces or voids in a material or aquifer. (2) The ratio of the volume of spaces in a rock or soil to the total volume. This ratio is usually expressed as a percentage.

$$\text{Porosity, \%} = \frac{(\text{Volume of Spaces})(100\%)}{\text{Total Volume}}$$

[7] *Specific Yield.* The quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity. Specific yield may be expressed as a ratio or as a percentage by volume.

[8] *Transmissivity* (TRANS-miss-SIV-it-tee). A measure of the ability to transmit (as in the ability of an aquifer to transmit water).

[9] *Pore.* A very small open space in a rock or granular material. Also called an INTERSTICE, VOID, or void space. Also see VOID.

[10] *Overdraft.* The pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin. This pumping results in a depletion or "mining" of the groundwater in the basin.

[11] *Yield.* The quantity of water (expressed as a rate of flow—GPM, GPH, GPD, cu m/day, ML/day, or total quantity per year) that can be collected for a given use from surface or groundwater sources. The yield may vary with the use proposed, with the plan of development, and also with economic considerations. Also see SAFE YIELD.

[12] *Hydrogeologist* (HI-dro-jee-ALL-uh-jist). A person who studies and works with groundwater.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 137.

3.0E What does porosity measure?

3.0F What causes water to move through pores in the soil or rocks?

3.0G What problems can be caused by the overdraft of a groundwater supply?

3.022 *Saltwater Intrusion*

A special phenomenon occurs where salt water comes in contact with fresh water. A natural boundary (Figure 3.3) exists because of the differences in *SPECIFIC GRAVITIES*[13] of the two waters. The specific gravity of salt water is greater than the specific gravity of fresh water. This boundary prevents mixing of fresh and salty waters. As long as the natural movement of fresh water within the aquifer replaces water drawn by a well, the boundary between fresh and salty water will remain stable and little mixing will occur. When more fresh water is removed (by overpumping or overdraft) than can be replaced naturally, the salt water will intrude into the aquifer and may be drawn into the well.

Care must be exercised when installing or operating wells near any saltwater source to prevent intrusion and pollution of those and neighboring wells. Any well operated in the freshwater area of Figure 3.3(a) will create a *CONE OF DEPRESSION*[14] from the salty groundwater upward toward the well as shown in Figure 3.3(b); a second cone of depression will form from the surface of the water table downward toward the aquifer. Excessive drawdown can bring the salt water into the aquifer and close enough to the well that salt water will be drawn into the cone of depression and into the well. As a general operating guideline, the ratio of "d" to "h" (shown in Figure 3.3(a)) should be at least 40 to 1 (40:1); for example, if "h" equals 1 foot, "d" would equal 40 feet.

Saltwater intrusion is a common problem along coastlines, but also occurs inland where groundwater supplies contain more than 1,000 mg/*L* of total dissolved solids. Figure 3.4 shows areas within the United States where saltwater intrusion could be a problem. Local geologic conditions need to be known prior to placing wells in saltwater areas.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 137.

3.0H What usually keeps salt water from mixing with fresh water in an aquifer or underground basin?

3.0I How can excessive drawdown of a well lead to saltwater intrusion?

3.0J Where can saltwater intrusion develop?

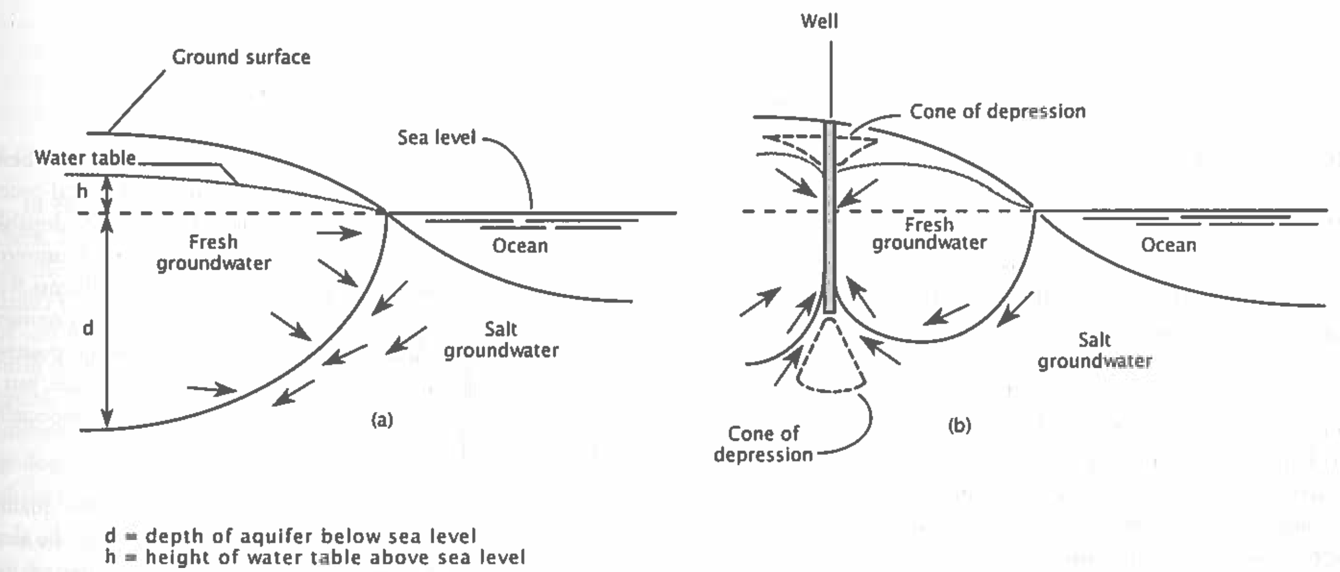


Fig. 3.3 (a) Saltwater intrusion along coastal areas; (b) Effect of excessive drawdown near a saltwater source

[13] *Specific Gravity.* (1) Weight of a particle, substance, or chemical solution in relation to the weight of an equal volume of water. Water has a specific gravity of 1.000 at 4°C (39°F). Particulates with specific gravity less than 1.0 float to the surface and particulates with specific gravity greater than 1.0 sink. (2) Weight of a particular gas in relation to the weight of an equal volume of air at the same temperature and pressure (air has a specific gravity of 1.0). Chlorine gas has a specific gravity of 2.5.

[14] *Cone of Depression.* The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. Also called the CONE OF INFLUENCE. Also see CIRCLE OF INFLUENCE.

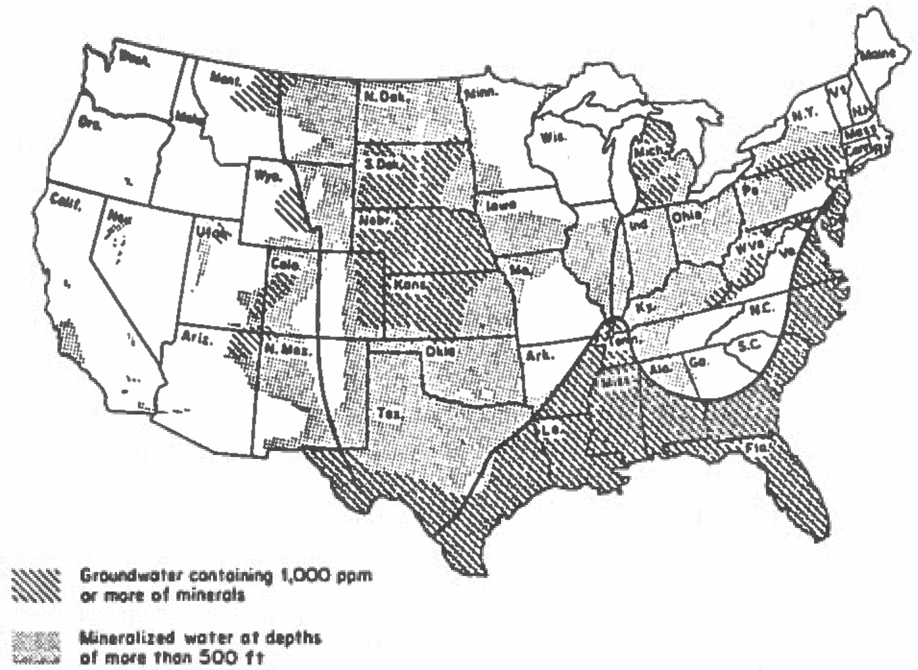


Fig. 3.4 Map of the conterminous United States showing depth to groundwater containing more than 1,000 mg/L total dissolved solids

(From paper by Bill Katz, *TREATING BRACKISH WATER FOR COMMUNITY SUPPLIES*, published in Proceedings in "Role of Desalting Technology," a series of Technology Transfer Workshops presented by the US EPA Office of Water Research and Technology)

3.03 Pollution

3.030 Pollution Control

Groundwater moves very slowly through the soil purifying itself of suspended particles as it travels. If water should be contaminated on its journey to a well and the distance from the source of contamination is far, there is a possibility that we will not see adverse effects at the well. The soil mantle acts as a natural filter for suspended material to bring us a good, clean product. Unfortunately, the soil mantle does not always filter out or remove dissolved pollutants and contaminants (such as organic chemicals) found in water. Chemicals used for farming, waste disposal pits, wastewater disposal, mining, leaks from gas storage tanks, oil spills, hazardous waste disposal, and urban drainage are a few of the factors contributing to groundwater pollution. Human wastes containing pathogenic organisms are also a source of pollution.

If sources of pollution are allowed to increase without limit and without regard to proximity to our wells, the earth's surface will become saturated with pollutants that no known treatment process can remove. Because water moves so slowly through the soil, we may end up with a water supply that cannot be used for years, even after the sources of pollution are eliminated.

Cleaning a polluted aquifer is difficult and expensive at best. Aquifers contaminated with oil spills and other chemical problems are almost impossible to clean up. The most reasonable course against groundwater pollution is prevention. Common sense and strict adherence to health agencies' requirements will go a long way in protecting this vital resource. The Environmental Protection Agency, and others, are making positive strides in keeping our groundwater supplies clean and safe, but a vigorous effort and awareness from all the public (and especially the public water supplier) are necessary.

The well operator has a responsibility to preserve the quality of wells through preventive maintenance of the aquifers. Be alert for any construction that might result in wastes entering the groundwater stream. Septic tanks, subsurface leaching systems, mining operations, agricultural practices, solid waste disposal sites, and wastewater collection facilities are all potential sources of groundwater pollution. Any such activity should be reported to the proper authorities so that adequate safeguards can be taken. Also, you must make sure that none of your wells allow direct contamination of an aquifer due to inadequate grouting or seals. Although unsanitary conditions are not as common in the United States as in some countries, they still pose potential problems to our groundwater supplies.

Operators must always be alert for potential sources of groundwater pollution to the aquifers providing drinking water to their communities. Some of the possible sources include[15]:

1. Leaks from oil and gas pipelines
2. Leaks from storage tanks
3. Fertilizers, pesticides, and irrigation water
4. Improper management of animal wastes
5. Liquid wastes and solid-waste tailing piles from surface and underground mining operations
6. Drainage from abandoned mines
7. Saltwater encroachment from saline aquifers and the ocean
8. Improper construction and use of injection wells for the disposal of industrial, nuclear, and hazardous wastes
9. Accidental spills of liquid wastes, toxic fuels, gasoline and oil
10. Abandoned wells that were not properly plugged

3.031 Geologic and Hydrologic Data

To protect aquifers, operators must know something about them. Recordkeeping can be an invaluable tool for understanding the aquifer and its performance. Geologic data from the well driller's logs (records of depths of various layers of soil and type of soil in each layer), mining operations in the area, and data from the US Geological Survey, US Natural Resources Conservation Service, and from other sources will help operators to understand how water is getting into a well. Consultation with a geologist is recommended for a more complete understanding of the underground formation.

Records of pumping amounts and dates, depths of the water at the start and end of pumping, time of pumping, and water quality results remain the best sources of information about a well's performance. Using past performance data, an engineer, hydrologist, geologist, and well operator can predict the well's performance with a high degree of accuracy. Recordkeeping is very important and it is not possible for operators to accumulate too much information. So, if records are not now being kept, a program should be started immediately.

[15] Source: *The Johnson Drillers Journal*, Second Quarter, 1982.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 137.

3.0K As groundwater moves through the soil, what type of pollutant is removed by the soil mantle?

3.0L What types of groundwater pollutants are not usually removed by the soil mantle?

3.0M What actions should an operator take to preserve the quality of wells through preventive maintenance of the aquifers?

3.0N What types of records should be kept by the operator to document a well's performance?

3.04 Wellhead Protection

3.040 Statement of the Problem

Groundwater contamination can originate on the surface of the ground, in the ground above the water table, or in the ground below the water table. Table 3.2 shows the types of activities that can cause groundwater contamination at each level. The contaminant may be microorganisms or toxic substances.

TABLE 3.2 ACTIVITIES THAT CAN CAUSE GROUDWATER CONTAMINATION[a]

Origin	Activity	
GROUND SURFACE	Infiltration of polluted surface water Land disposal of wastes Stockpiles Dumps Sewage sludge disposal	De-icing salt use and storage Animal feedlots Fertilizers and pesticides Accidental spills Airborne source particulates
ABOVE WATER TABLE	Septic tanks, cesspools, and privies Holding ponds and lagoons Sanitary landfills Underground storage tank leaks	Underground pipeline leaks Artificial recharge Sumps and dry wells Graveyards Waste disposal in excavations
BELOW WATER TABLE	Waste disposal in wells Drainage wells and canals Underground storage	Exploratory wells Abandoned wells Water-supply wells Groundwater withdrawal Mines

[a] *CITIZEN'S GUIDE TO GROUNDWATER PROTECTION*, Office of Groundwater Protection, US Environmental Protection Agency, Washington, DC 20460. EPA 440/6-90-004, April 1990.

Where a contaminant originates is a factor that can affect its actual impact on groundwater quality. For example, if a contaminant is spilled on the surface of the ground or injected into the ground above the water table, it may have to move through numerous layers of soil or other materials before it reaches the groundwater. As the contaminant moves through these layers of soil, a number of treatment processes are in operation in the soil (for example, filtration, ion exchange, adsorption, dilution, oxidation, biological decay) that can lessen the eventual impact of the contaminant once it finally reaches the groundwater. The effectiveness of these processes also is affected by both the distance between the groundwater and where the contaminant is introduced and the amount of time it takes the substance or microorganism to reach the groundwater. If the contaminant is introduced directly into the area below the water table, the primary process that can affect the impact of the contaminant is dilution by the surrounding groundwater.

Cleaning up a contaminated groundwater supply is a complicated, costly, and sometimes impossible process. In general, a community whose groundwater supply has been contaminated has five options:

1. Contain the contaminants to prevent their migration from their source.
2. Withdraw the pollutants from the aquifer.
3. Treat the groundwater where it is withdrawn or at its point of use.
4. Rehabilitate the aquifer by either immobilizing or detoxifying the contaminants while they are still in the aquifer.
5. Abandon the use of the aquifer and find alternative sources of water.

Given the importance of groundwater as a source of drinking water for so many communities and individuals and the cost and difficulty of cleaning up groundwater, the best way to guarantee continued supplies of clean groundwater is to prevent contamination. The National Program for Wellhead Protection is designed to protect groundwater supplies of drinking water.

3.041 National Program

The 1986 Amendments to the Safe Drinking Water Act (SDWA) formalized the concept of state wellhead protection (WHP) programs to protect wellhead areas of public water supply wells from contamination. The act contains requirements for the minimum program elements necessary to develop and implement a WHP program. Each state program may be slightly different depending on the sources and types of groundwater supplies a state is attempting to protect. This section provides an overview of important aspects of all wellhead protection programs, and emphasizes the program components that an operator can control or influence.

Operators have the responsibility of protecting the drinking water supply of their community and delivering safe drinking water to all of their consumers. A wellhead protection program is designed to protect the source of a groundwater supply. Important components of a successful wellhead protection program in which an operator can be involved include:

1. Community involvement and support
2. Surveys to identify potential and actual sources of contaminants
3. Determination of characteristics of basin and groundwater supplies
4. Development, implementation, and enforcement of land use regulations to protect groundwater supplies

3.042 Community Involvement and Support

Effective wellhead protection programs require control of sources of contaminants; this requires land use planning and control of certain types of development activities on private and public lands. Control of land use is difficult to achieve and requires support of the public and also public officials. Success in this effort must start with a program to educate the public and public officials on the nature of the problem and ways the problem can be controlled. Once everyone understands the problem, support to control or prevent the problem should be easier to achieve.

"What are the threats to our groundwater drinking supply?" is a question of concern to all responsible citizens in a community. Community involvement can start with this question and an explanation of the existing situation. Citizens should be informed that the quality of a groundwater is at risk: (1) if a land use presents the capacity to leach contaminants into a groundwater supply that is used for drinking water, and (2) if the contaminants are of sufficient quantity and type to endanger human health. Contamination of groundwater that is not used for drinking does not present an immediate threat because there would not be the potential for health consequences unless the water could be used for drinking in the future. Similarly, just because a land use may contaminate groundwater does not necessarily mean that there is a threat to public health; the contamination may be in quantities small enough that no adverse health consequences would result.

The importance of broad public support and the fullest possible participation cannot be overstressed. Time and effort spent at this stage educating the community about the goals and process of establishing a wellhead protection program will greatly improve the chance of successfully implementing the program.

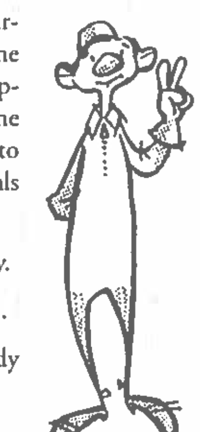
3.043 Step One—Community Participation

If a community does not have the financial resources to hire a hydrologist, engineer, or other qualified water professional, the community must rely on the leadership of its water supply system operation and on volunteer community efforts to conduct the risk assessment. This is central to the success of the project. Representation from all community boards is essential, as well as the highway superintendent, the fire chief, and other concerned citizens.

While broad representation will help the process along, the most important members of the risk assessment committee will be volunteers with backgrounds in geology, planning, and engineering. Without some in-house expertise in geology and groundwater dynamics, the committee's efforts will be significantly more difficult. Often, local colleges and universities can provide students who may assist the community effort in return for academic credit. In this way, the necessary technical support can be supplied without significant financial commitment.

The committee should plan to meet as a group at least once a month, with substantive work being done between meetings. While this is a volunteer effort, it will not be cost free. The community should budget enough money for the committee to mail surveys, meeting reminders, and press releases; purchase office supplies and mapping supplies; photocopy documents and surveys; and print their report. Ideally, there will also be funding for water quality testing.

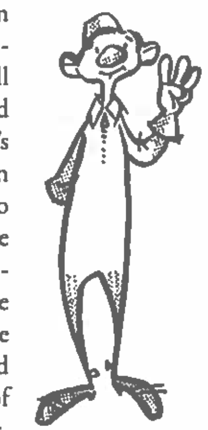
3.044 Step Two—Collecting Existing Data



The community already has access to a surprising amount of information concerning the community's geology, hydrology, water supplies, and risks to water supplies. Once the committee is formed, their first task will be to start collecting this information. Their goals will be to:

1. Understand the geology of the community.
2. Gather information on the local aquifer(s).
3. Identify groundwater information already available in the community.
4. Locate underground storage tanks.
5. Locate septic tanks and identify their ultimate disposal methods.
6. Locate the wells in the community.
7. Locate businesses that may present threats to groundwater quality.
8. Identify what community regulations and by-laws are already in place.
9. Identify town and state public works practices.

3.045 Step Three—Filling in the Data Gaps



Despite the reams of valuable information that can be accumulated from the above procedure, it is unlikely that this process will have provided all of the information needed about threats to a particular community's groundwater. A community-wide survey can be very helpful. The goal of the survey is to learn as much about specific sites as possible in order to determine what risks to groundwater quality may exist. For example, the survey will try to identify patterns of land use (relative to siting of wells), underground storage tanks, septic systems, proximity of roads to wells, location of abandoned wells, and other important information.

Conducting surveys can present several problems. There can be considerable community resistance to providing information about private property to anyone—especially to community officials. Residents frequently fear that the information will somehow be used against them. Therefore, it is important that there be adequate publicity about the survey, the reasons for it, and assurances that the information is not intended to be used as a basis for action against any individual.

Surveys in search of contaminated well water should be limited to areas affecting public water supplies unless there is evidence to suggest that private wells are also contaminated. It could be extremely costly to test home wells and analyze all the data. Public support could erode quickly and bog down the process, and many people simply will not believe any assurances that the results will not be used against them.

Mapping all the information accumulated through the processes described above is very difficult and not necessarily helpful. Key pieces of information plotted on map overlays can be very productive. Important overlays include:

1. Sand and gravel deposits
2. Locations and depths of wells
3. Locations and identification of land uses that present threats to groundwater quality
4. Locations of underground storage tanks

5. Septic system locations
6. Wells within 100 feet of a septic system
7. Wells within 20 feet of a roadway

These overlays are a critical first step in determining what threats to groundwater quality may exist in the community. Through the use of the overlays, it is possible to begin to see the relationship between activities and wells, and the overlays can highlight areas of critical concern in a clear and simple way.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 137 and 138.

3.0O When water passes through a soil, what kinds of wastewater treatment processes might occur that could lessen the eventual impact of the contaminant once it finally reaches the groundwater?

3.0P How can a wellhead protection program achieve control of sources of contaminants and certain types of development activities on private and public lands?

3.0Q List the various types of data that need to be gathered to develop a wellhead protection program.

3.046 Step Four—Which Land Uses Constitute a Threat to Groundwater Quality?

Not all threats to groundwater quality are of equal significance. Some land uses, while appearing on a list (Table 3.3) of businesses that present risks for groundwater contamination, present a low risk. This determination is based upon the types of contaminants, how they interact with the environment, how they degrade in soil and water, how fast they move, and how dangerous they are to human health. It is important in the analysis of threats to groundwater that the specific characteristics of the community are taken into consideration. Many types of activities identified in Table 3.3 may not occur in a specific community. Therefore, it is an important step to identify which land uses with potential risk to groundwater do occur in a given community and to determine the level of risk that they present. Railroad tracks, yards, and maintenance stations are listed as a "slight" risk in Table 3.3. However, in some communities in certain locations, a railroad yard could be considered a "severe" risk. Also, any other types of activities that there is a reason to be concerned about but that have not appeared in the table should be identified and included.

3.047 Step Five—Learning from What Information Has Been Collected

There should now be enough information gathered to critically assess the potential for groundwater contamination in the community. It will be important to study the geological maps, location of sand and gravel deposits, clay layers, and depths of wells to determine general patterns of groundwater use in the community. It is in this step that the assistance of someone with geologic and hydrogeologic expertise is critical. That person will be able to study the well logs, geologic maps, survey results, and USGS (United States Geological Survey) studies to describe the hydrogeologic setting of the community.

Once the hydrogeologic setting is understood, the information that has been collected about types of land use and risks that they may present can be analyzed. Some land uses present great risks to shallow wells, but may present little to no risk to bedrock/deep wells. For example, a problem could develop if a town stores its winter sand and salt piles outdoors. This may present a groundwater contamination threat to shallow wells in the vicinity. By knowing that there are shallow wells nearby, rational judgments can be made about water testing programs and appropriate town response to protect against contamination.

There may also be locations where septic system failures are more likely due to hydrogeologic settings, and this can be analyzed by the expert in geology. Small-capacity home wells are particularly susceptible to organic chemical contamination from nearby septic systems. Domestic wastewater has frequently been found to contain trace amounts of petroleum distillates as well as benzene, toluene, chlorinated hydrocarbons such as trichloroethane, trichloroethylene, tetrachloroethylene, dichlorobenzene, and alkyl phenols. Municipal wells can be less susceptible because they derive some protection from their large volumes of mixing and withdrawal, whereas private wells are not so protected.

Unlike nitrogen and biological pollutants, organic chemicals do not enter household wastewater continuously. Gasoline, paint thinners, solvents, and even pesticides are typically discharged only at irregular intervals. Furthermore, once discharged into wastewater, some proportion of these chemicals is absorbed into soil particles or broken down by bacterial action. However, some organic chemicals are very persistent. If a neighbor's septic system lies within the recipient well's zone of contribution, a quantity of a discharged chemical will probably enter that well and the volume may be sufficient to exceed recommended maximum concentration levels of the contaminant in drinking water.

3.048 Step Six—Now What?

By studying the proximity of various land uses with wells, the depth of those wells, and the degree of risk presented by the land use, decisions can be made about what to do next. At this point, it should be apparent what activities in the community may have already contaminated groundwater, or that may in the future. If there is reason to believe that groundwater may already be contaminated, the community should immediately implement a water quality testing program.

The water quality testing program should be designed to test for the contaminants that are believed to be present. For example, if the study indicated that septic tank system failure may have occurred in proximity to shallow wells, the tests would be looking for nitrate and coliform contamination. If the threat is presented by road salt, saline concentration would be highlighted. On the other hand, perhaps the threat is seen to be from agriculture. It will be necessary to identify the types of pesticides believed to have been used in order to test for them in the groundwater. An annual community water testing program will help monitor long-term and changing groundwater conditions.

Without water quality testing, it will not be possible to know if there is an existing problem with groundwater quality. If there is a problem, it is important to take remedial action to protect the health of the water users. If there is no contamination, then it is important to take steps to ensure against future contamination. Town regulations and by-laws, as well as public education, can be key in safeguarding future water quality. Examples of town regulations and by-laws that can work to protect groundwater quality include: aquifer protection zoning, private well regulations, hazardous materials and underground storage tank regulations, required septic tank pumping regulations, unregistered motor vehicle by-laws, and wetlands protection by-laws. Other community actions can include: covering salt piles; decreasing use of road salt, land acquisition and protection activities; community supported water quality testing; public education efforts; hiring professional health agents and planning staff; and cooperation in regional efforts to protect groundwater.

TABLE 3.3 RELATIVE LEVELS OF RISK FROM LAND USES TO GROUNDWATER
Taking Into Consideration Volume, Likelihood of Release,
Toxicity of Contaminants, and Mobility
(Compiled and Analyzed by Vermont Department of Health, 1988)

SEVERE
- Dry Cleaners
- Gas Stations
- Car Wash with Gas Station
- Service Station—full or minor repairs
- Painting and Rust Proofing
- Junk Yards
- Highway De-Icing—application and storage
- Right-of-Way Maintenance
- Dust Inhibitors
- Parking Lot Runoff
- Commercial Size Fuel Tanks
- Underground Storage Tanks
- Injection Wells: automobile service station disposal wells; industrial process water, and waste disposal wells
- Hazardous Waste Disposal
- Landfills
- Salt Stockpiles

SEVERE TO MODERATE
- Machine Shops: metal working; electroplating, machining
- Chemical and Allied Products
- Industrial Lagoons and Pits
- Septic Tanks, Cesspools, and Privies
- Septic Cleaners
- Septage
- Household Cleaning Supplies
- Commercial Size Septic Systems
- Chemical Stockpiles
- Clandestine Dumping

MODERATE
- Carpet and Upholstery Cleaners
- Printing and Publishing
- Photography and X-Ray Labs
- Funeral Homes
- Pest Control
- Oil Distributors
- Paving and Roofing
- Electrical Component Industry
- Fertilizers and Pesticides
- Paint Products
- Automotive Products
- Home Heating Oil Tanks, Greenhouses, and Nurseries
- Golf Courses
- Landscaping
- Above Ground Fuel Tanks
- Agricultural Drainage Wells
- Raw Wastewater Disposal Wells, Abandoned Drinking Wells

MODERATE TO SLIGHT
- Water Softeners
- Research Laboratories
- Above Ground Manure Tanks
- Stormwater and Industrial Drainage Wells
- Stump Dumps
- Construction

SLIGHT
- Beauty Salons
- Car Wash
- Taxidermists
- Dyeing/Finishing of Textiles
- Paper and Allied Products
- Tanneries
- Rubber and Miscellaneous Plastic Products
- Stone, Glass, Clay, and Concrete Products
- Soft Drink Bottlers
- Animal Feedlots, Stables, and Kennels
- Animal Burial
- Dairy Wastes
- Poultry and Egg Processing
- Railroad Tracks, Yards, and Maintenance Stations
- Electrical Power Generation Plants and Powerline Corridors
- Mining of Domestic Stones
- Meat Packing, Rendering, and Poultry Plants
- Open Burning and Detonation Sites
- Aquifer Recharge Wells
- Electric Power and Direct Heat Reinjection Wells
- Domestic Wastewater Treatment Plants and Effluent Disposal Wells
- Radioactive Waste

3.049 Step Seven—Establishing Wellhead Protection Areas (WHPAs)[16]

Contact your state regulatory agency for recommended procedures to define *WELL ISOLATION ZONES,*[17] which are the areas that require land use controls to protect a wellhead or well field. Some states have issued minimum distance guidelines or requirements. EPA's "Guidelines for Delineation of Wellhead Protection Areas"[18] lists the following six primary methods in order of increasing technical sophistication:

1. Arbitrary fixed radii
2. Calculated fixed radii
3. Simplified variable shapes
4. Analytical methods
5. Hydrogeologic mapping
6. Numerical flow/transport methods

These methods range from simple, inexpensive methods to highly complex and costly ones.

Factors that need to be considered when determining the wellhead protection area include:

1. Circle or area of influence around a well or well field
2. Depth of drawdown of the water table by such well or well field at any given point
3. Time or rate of travel of various contaminants in various hydrologic conditions
4. Distance of source of contaminants from well or well field
5. Other factors affecting the likelihood of contaminants reaching the well or well field

Threats to wells or well fields include direct introduction of contaminants into well casings, microbial contamination, and chemical contamination. The fate, degradation, or assimilation of both microbial and chemical contaminants as they move from their sources toward the well or well field are important considerations. Also, it is important to realize that water flowing underground may follow unusual paths. Recharge water carrying contaminants that enters an aquifer through an area of influence of a well will not necessarily travel to the well, and recharge water that enters the aquifer outside of the area of influence may travel to the well.

The procedures used by a community to delineate wellhead protection areas (WHPAs) will depend on available state regulatory requirements, guidelines, and technical assistance. Also, the community will need to assess the seriousness of contaminant threats to its wells or well field and make optimum use of the resources available. Also see Section 3.12, "Well Site Selection," in the Appendix to this chapter for additional information on minimum recommended distances between wells and potential sources of contamination.

3.0410 Step Eight—FINALLY

The results of the volunteer risk assessment must be well publicized and presented to the community. Public education and support for the effort are essential if behavior is to be changed and town regulations and by-laws passed. Copies of any reports should be distributed around the community and made generally available.

Unless the community takes affirmative steps as a result of the study about threats to groundwater quality, it is inviting contamination to occur. Perhaps the most important result of this study will be to educate the community officials about the threats to public safety that exist in the community and the actions they can take to protect the public health.

Major portions of this section were adapted from a paper titled "Model for Rural Communities to Assess Threats to Groundwater Quality," by Lynn Rubinstein, Land Use Planner, Franklin County Planning Department, Greenfield, Massachusetts. The information is used with her permission and is sincerely appreciated.

3.05 Groundwater Protection Tips

The preventive practices listed below are effective means for operators to work with various groups in their community to prevent the contamination of groundwater.

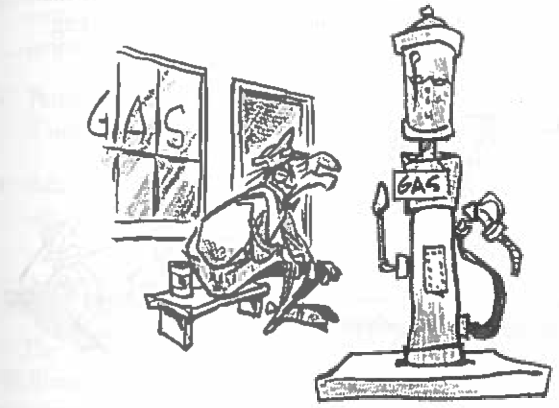
3.050 Agriculture

THE POTENTIAL PROBLEM

Pesticides, such as insecticides, and herbicides may contaminate groundwater if improperly applied or spilled in a wellhead protection area. Fertilizers applied in greater amounts than can be taken up by plants may release nitrates into groundwater. Storage and improper application of manure in wellhead protection areas may result in nitrates and bacteria leaching into groundwater.

PREVENTIVE PRACTICES

- Do not mix, rinse, or store pesticides in a wellhead protection area.
- Minimize or avoid pesticide use in wellhead protection areas by using integrated pest management or alternate methods for pest control.
- Move manure storage out of wellhead protection areas.
- Apply nitrogen according to a crop nutrient budget, which includes analysis of soil suitability and cropping practices.



3.051 Gas Stations

THE POTENTIAL PROBLEM

Gas stations pose a threat to groundwater because of the many possibilities of incidental, small spills or leaks of hazardous materials. While major leaks from tanks or transfers are now under much improved legal and technical control, small spills can occur as customers fill their gas tanks. Waste oil, solvents, and hydrocarbons from repair facilities are also a hazard to the groundwater.

PREVENTIVE PRACTICES

- Use available technology to prevent overfilling of tanks.
- Install a secondary containment structure around tanks to prevent leaks and install a monitoring system to detect water inflow.
- Test tanks and pipes regularly.
- Connect floor drains in repair stalls to a holding tank.
- Dispose of waste fluids in licensed facilities, never on the ground or in a septic system.
- Use absorbents to clean up minor fluid leaks and spills.

3.052 Fuel Storage

THE POTENTIAL PROBLEM

Corrosion may cause fuel oil to leak, go through the soil, and contaminate groundwater. Gasoline may float on top of groundwater and move along with it. Heating oils are less likely to be soluble and mobile; however, they are both persistent in groundwater.

Underground tanks, because they are out of sight and closer to the groundwater, pose more of a threat than above-ground tanks. They are tightly regulated and are not likely to be a threat if replaced since 1986. Small, domestic, above-ground tanks are not now regulated, but owners can monitor their condition and prevent extensive loss of fuel and contamination. Buried, abandoned tanks may continue to cause problems far removed in time and place from the original leak.

It has been demonstrated that the cost of prevention is dramatically lower than the cost of remediation and cleanup.

PREVENTION TIPS

- Be sure you have a complete inventory of all tanks in your wellhead protection area.
- Inform the owners that the tank is in a sensitive area. Ask if they are aware of the programs available for replacement, if such programs are available.
- Surround above-ground tanks with a dike or berm with a concrete base. Protect the area from rainwater by installing a permanent roof or install a manually operated valve to drain the diked area.
- Monitor the condition of above-ground tanks and replace them at the first sign of corrosion.

3.053 Photo Labs/Printers, Dry Cleaners, Furniture Strippers/Painting, Medical Labs

THE POTENTIAL PROBLEM

Several organic compounds used in developing color film and printers' inks contain resins, solvents, and heavy metals. If flushed into septic systems, these chemicals may destroy the bacteria essential to proper functioning of the system. Common sources of contamination include improper outdoor storage, accidental spills, disposal of spent fluids, or wash water in the ground or in the septic system.

Solvents such as trichloroethylene, methylene, chloride, naphthalene, and benzene used in dry cleaning and furniture staining are among the most hazardous for wells. Even the smallest amount, once in the groundwater, may sink to deep locations in the aquifer, then migrate in unpredictable ways. Many solvents are very persistent.

PREVENTIVE PRACTICES

- Install permanent covers over outdoor storage facilities for chemicals and construct berms to hold spills or leaks.
- Separate chemical wash water from domestic wastewater.
- Connect floor drains and sinks used for washing chemicals to holding tanks, not sewer or septic systems.
- Dispose of waste chemicals at licensed hazardous waste disposal facilities.
- Equip exhaust fans to catch dripping liquid.
- Store spent acids and caustic bottles containing methylene chloride, ink, and sludges in secure, clearly labeled containers and dispose of them at licensed facilities.
- Contact a rag rental/cleaning service to recycle cleaning rags contaminated with solvents.
- Recycle wastes (for example, spent fixer to recover silver).

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[16] *Wellhead Protection Area (WHPA).* The surface and subsurface area surrounding a public water system water well or well field, through which contaminants are reasonably likely to move toward and reach such water well or well field. Also see WELL ISOLATION ZONE.

[17] *Well Isolation Zone.* A surface or zone with restricted land uses surrounding a public water system water well or well field. The zone is established to prevent contaminants from a nonpermitted land use to move toward and reach the water well or well field. Also see WELLHEAD PROTECTION AREA.

[18] Available from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Order No. PB93-215861. Price, $73.00, plus $6.00 shipping and handling.

3.054 Septic Systems, Subsurface Waste Disposal

THE POTENTIAL PROBLEM

Properly designed, installed, and maintained septic systems will remove pathogenic organisms, such as bacteria and viruses, before effluent reaches the groundwater. Systems that do not allow for percolation of wastewater wastes through a sufficient amount of unsaturated soil may not effectively remove viruses and bacteria.

Nitrate and many other chemicals and solvents are not removed by septic systems. Moving easily through the soils, they may enter groundwater. More than 10 mg/*L* nitrate is particularly toxic to fetuses and babies.

PREVENTIVE PRACTICES

- Do not flush any chemicals or cleaners down the drain, not even septic tank cleaners. They are not only ineffective, but kill beneficial bacteria. If you do not know what it is, do not flush it, *please!*
- Avoid garbage disposals; they can cause costly drain field clogging.
- If there are many small, old systems within the wellhead protection area, consider piping the wastewater to a community treatment system.
- Since the least costly way to treat nitrate is by dilution, ensure adequate setbacks between septic systems, wells, and surface water.
- Have septic tanks pumped regularly, every two to three years, to prevent solids from clogging the disposal field.

3.055 What to Tell Homeowners

Dear Neighbor,

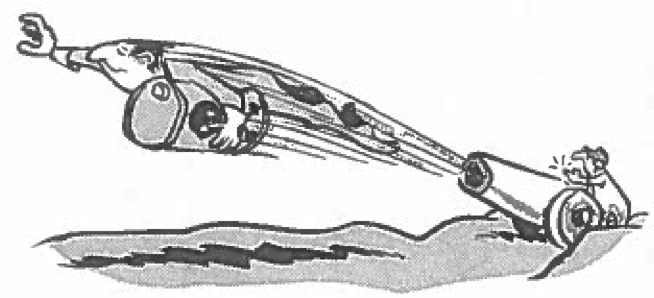
It may come as a surprise to you that your home is on top of a public water supply. We have been asked by Congress and the State Department of Health Engineering to protect our water supply by preventing contaminants from reaching the well. Your house/lot/yard happens to be on the land that recharges our well.

We certainly respect your privacy and the right to go about your life unencumbered by any regulations. We only ask your cooperation in conducting your activities in a way that will least likely cause our well to become contaminated. These tips will also protect your water supply.

If you garden, bear in mind that fertilizers, pesticides, fungicides, and herbicides might be quite soluble in water and leach into the groundwater.

PREVENTIVE PRACTICES

- Try to use organic compost material. It is preferable to nitrate-releasing commercial fertilizer. If you use the latter, a soil analysis will help you use just the right amount.
- Try to use natural pesticides, such as rotenone and BT. Used according to directions, they are unlikely to cause problems.
- If you spill pesticides that are poison, please try to clean up spills as completely as possible. Sweep up granular material and soak up liquids, disposing of them in a ziplock bag.



DISPOSING OF WASTE OIL, PAINT THINNERS, AND SOLVENTS

Remember, these substances pose a high risk to groundwater and drinking water pumped out of a well. They may float or sink to the bottom, but they do not disappear and they make the water unsafe to drink for many years to come. Cleaning it up is expensive and finding an alternate water supply may be impossible.

PREVENTIVE PRACTICES

- Do not dispose of solvents, degreasers, waste oil, cleaning fluids, gasoline, paint thinners, or radiator fluid by pouring them into sinks or toilet or by burying them in the ground.
- If you work on your car, please pick up any spills with absorbent material, place in a ziplock bag, and dispose of it properly (ask your landfill or waste pickup operator how to dispose of it).

SEPTIC SYSTEM

Your septic system, if properly installed, maintained, and located at least 300 feet from a well, should not pose a problem.

PREVENTIVE PRACTICES

- If you have an old system, please have it inspected and consider replacing it, if warranted.
- Please do not flush chemicals, grease, or septic tank cleaners into your system.
- Have your system pumped every two or three years.

STORING CHEMICALS

Please be aware that chemicals or fuel oil improperly stored or exposed to the elements—rain, snow, freezing, and thawing—can pose a threat to our drinking water. When containers give way, hazardous substances or fuel oil may leak into the soil and our groundwater.

PREVENTIVE PRACTICES

- Store chemicals in sound containers, off the ground.
- If they must be outdoors, build a secure cover or place a solid container under a tank, for instance, from which you can empty the rain or snow periodically.
- Periodically check containers for corrosion and replace them if necessary.
- Ask your landfill or garbage pickup operator how you can safely dispose of household chemicals.

3.056 Acknowledgment

The information in this section was provided by Maine's Wellhead Protection Program. The contribution is greatly appreciated.

3.06 Summary

You, as an operator, have as much of a responsibility to preserve the quality and capacities of your wells as you do to oil the bearings on your pumps. The damage from neglect and excessive use of aquifers is sometimes irreversible. You can and should:

1. Be on the lookout for any possible sources of pollution of groundwater in the area around the well.
2. Be careful not to overtax the capability of aquifers to supply water. For example, avoid installing oversized pumps as these could contribute to the overtaxing of aquifers.
3. Ensure that all wells are properly sealed to prevent direct contamination of the aquifer.
4. Develop a recordkeeping program of well production and quality. These records should include geologic as well as hydrologic and hydraulic data gathered during the construction and testing of the well.

3.07 Additional Reading

1. *EPA's MANUAL OF INDIVIDUAL WATER SUPPLY SYSTEMS.* EPA No. 430-9-74-007. Obtain from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Order No. PB-258402. Price, $60.00, plus $6.00 shipping and handling.
2. *GROUNDWATER AND WELLS,* Third Edition, 2008. Published by Johnson Screens, PO Box 64118, St. Paul, MN 55164-0118. ISBN 0-9787793-0-4. Price, $140.00.
3. "Wellhead Protection: A Guide for Small Communities," EPA Seminar Publication. EPA No. 625-R-93-002. Obtain from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Order No. PB93-215580. Price, $60.00, plus $6.00 shipping and handling.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 138.

3.0R List at least five land use activities that are considered to have a severe risk level to groundwater.

3.0S What kinds of organic chemical contaminants may enter well water from domestic wastewater?

3.0T If a septic tank system may have failed in the vicinity of shallow wells, what water quality tests should be performed?

3.0U What could be the most important result of a community groundwater study?

3.1 SURFACE FEATURES OF A WELL

3.10 Purpose of Surface Features

A number of openings are found in the top of a well. These openings are designed to permit the entrance or escape of air or gas and to provide access to the well for taking water level measurements, adding gravel, or for applying disinfection or well cleaning agents. Table 3.4 lists the major surface features of a well and the purpose of each component. The openings in the top of a well must be protected against the entrance of surface waters or foreign matter. Next to the sanitary seal, this is the most important sanitary feature of well construction.

TABLE 3.4 PURPOSE OF SURFACE FEATURES OF A WELL

Component	Purpose
Well-Casing Vent	Allows air to enter well during drawdown to prevent vacuum conditions; vents excess air during well recovery period.
Gravel Tube	Permits operator to see level of gravel and add gravel as necessary.
Sounding Tube	Permits insertion of water level measuring device; also used to add chlorine or well cleaning agents.
Air Line Water Level Measuring Device	Permits measurement of water level by means of air pressure measurements.
Pump Pedestal	Supports the weight of the pumping unit.
Pump Motor Base Seal	Provides watertight seal between the motor base and the concrete support pedestal.
Sampling Taps	Permit sampling of pumped water.
Air Release and Vacuum Breaker Valve	Permits discharge of air in column pipe during start-up and admits air during shutdown.
Pump Blowoff (or Drain Line)	Removes first water (usually sandy) pumped at start-up.

Figure 3.5 is a cross-sectional drawing showing the typical surface features of a domestic water well. Many of the component parts we will be discussing in the following pages are illustrated in this drawing. Study this drawing and become familiar with the basic parts and their relationship to the entire facility.

3.11 Well-Casing Vent

A well-casing vent is provided to prevent vacuum conditions inside a well by admitting air during the *DRAWDOWN*[19] period when the well pump is first started. If vacuum conditions are allowed to develop, contamination may be sucked into the well through some hidden defect in the well or *CONDUCTOR CASING*,[20] or through the top of the well at the pump base.

The well-casing vent also prevents pressure buildup inside the well casing by allowing excess air to escape during the well recovery (refilling) period after the well pump shuts off. If pressures are allowed to build up, they will loosen and blow out the sealing compound around the pump base.

A properly sized and constructed vent should allow the unrestricted flow of air into and out of the well interior. A vent of at least three inches (75 mm) in diameter should be provided. Dual venting is desirable on wells over 14 inches (350 mm) in diameter.

All well vents should be constructed so that openings are in a vertical downward position. Openings should be a minimum of 36 inches (900 mm) in height above the finished surface of the well lot (yard) and should be covered with a fine mesh screen or similar device to keep insects from the well interior.

3.12 Gravel Tube

On gravel-envelope wells, a gravel tube must be provided to monitor the level of gravel and to add gravel as necessary. A typical gravel tube is four inches (100 mm) in diameter and is capped at the top end. Such openings must be elevated above ground level to prevent well contamination during flooding, and they must be kept tightly sealed.

3.13 Sounding Tube[21]

A sounding tube is necessary so that the water level in the well can be periodically determined. This tube can also be used for the addition of chlorine and well cleaning agents. The sounding tube is generally a minimum of two inches (50 mm) in diameter and must be kept tightly sealed. The water level is determined by inserting a disinfected rope or measuring tape into the tube, lowering it down the tube to the water level, and recording the distance. Often, the well-casing vent is also used as a sounding tube by installing a tee in the well-casing vent.

All vent pipes, sounding lines, and gravel fill pipes must be one continuous conduit through the concrete pedestal. Also, all conduits that penetrate the casings must be provided with a continuous watertight weld at the point of entry into the well interior.

If a water level sounding line is to be incorporated, it may be installed either through the upper portion of the concrete pump pedestal or through the pump base. If installed within the concrete pump pedestal, a conduit of sufficient diameter to allow the passage of the sounding line is placed in the pedestal form prior to the placement of concrete. One-quarter inch (6 mm) galvanized pipe or schedule 80 PVC plastic pipe is frequently used as a sounding line. The space between the sounding line and the conduit or the openings around the line passing through the pump base must be provided with a watertight seal.

A quick-disconnect fitting on the sounding line is preferable to a permanent gauge installation. To determine the distance to the water level, air pressure is applied to the sounding line to force out all water. The pressure is measured and the measurement is converted to the depth of water in the line.

$$\text{Water Depth in Line, ft} = (\text{Air Pressure, psi})(2.31 \text{ ft Water/psi})$$

The length of the line must be known to determine the distance down to the surface of the water.

$$\text{Distance Down to Water Surface, ft} = \text{Length of Line, ft} - \text{Water Depth in Line, ft}$$

3.14 Pump Pedestal

The well-casing vent pipe and the gravel tube are generally encased within a concrete pump pedestal designed to support the full weight of the pumping unit.

The pump pedestal should be constructed of continuously poured concrete to a minimum height of 18 inches (450 mm) above the finished elevation of the well lot. A lower pedestal height may be used due to lack of space (entrance to tank less than 18 inches above floor), but in no case should the pedestal height be less than 12 inches (300 mm).

The size of the pump pedestal may vary depending upon the given installation, but in all cases must provide a minimum of three inches (75 mm) of concrete around the outside of the conductor casing grout seal, if one is used. The pedestal should extend down to enclose the top of the grout seal a minimum depth of 12 inches (300 mm). Steel reinforcement of the pedestal is recommended.

[19] *Drawdown.* (1) The drop in the water table or level of water in the ground when water is being pumped from a well. (2) The amount of water used from a tank or reservoir. (3) The drop in the water level of a tank or reservoir.

[20] *Conductor Casing.* The outer casing of a well. The purpose of this casing is to prevent contaminants from surface waters or shallow groundwaters from entering a well.

[21] *Sounding Tube.* A pipe or tube used for measuring the depths of water.

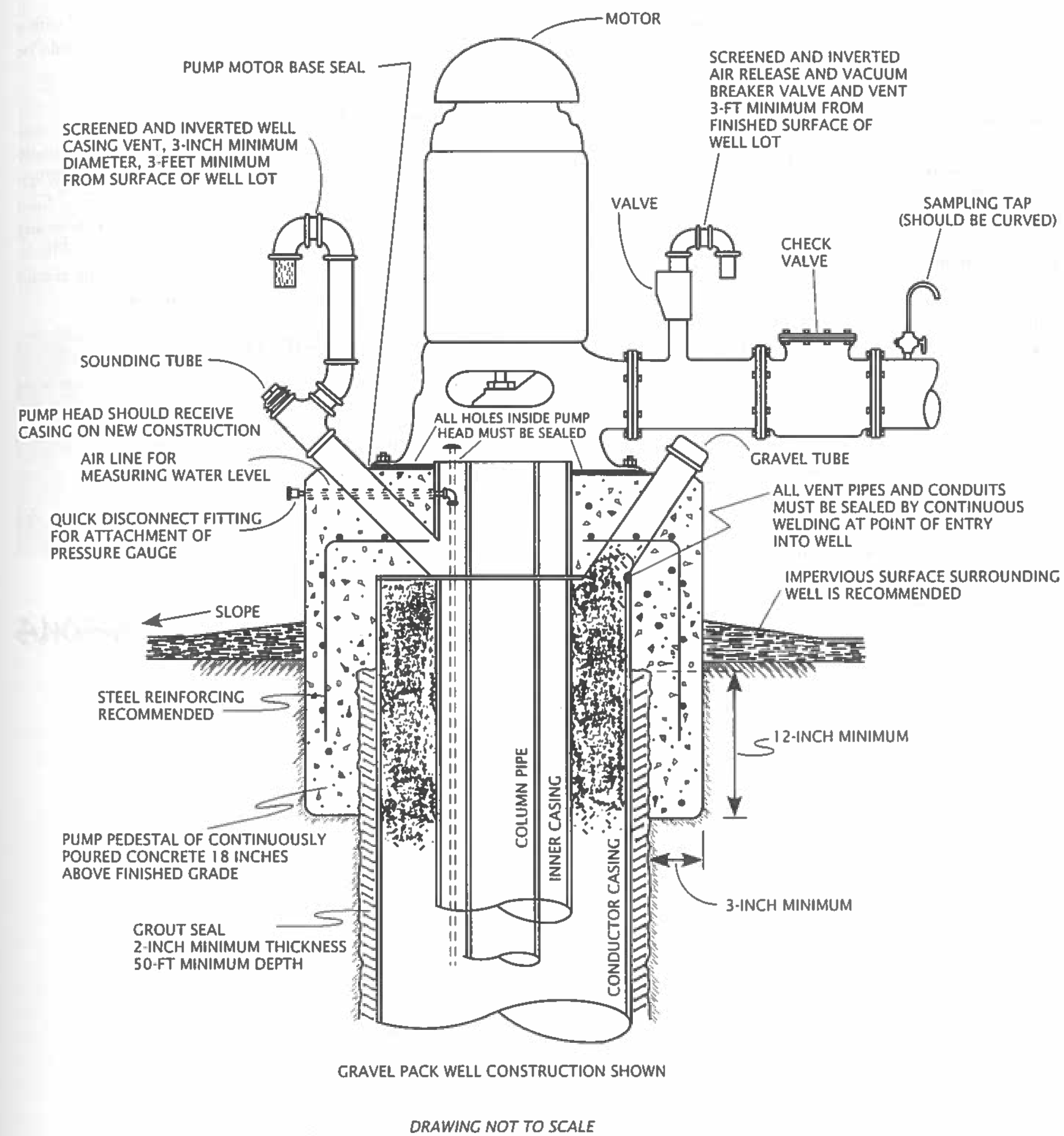


Fig. 3.5 Surface features of a domestic water well

3.15 Pump Motor Base Seal

A watertight seal should be provided between the pump motor base and the concrete pedestal. If the two surfaces are parallel, a neoprene rubber seal cut from flat stock can be used. In many cases, however, these two surfaces are not parallel because wedges may have been installed to correctly align the pump head shaft in the center of the motor hollow-shaft unit. When this occurs, an oil-resistant, nonhardening material such as latex rubber can be used to create a seal. Cement grout is not recommended because it will eventually crack and create openings through the seal. A neoprene rubber or regular gasket material seal is very satisfactory for a submersible pump installation.

3.16 Sampling Taps

A sampling tap is generally provided on the downstream side of the pump check valve. A *PET COCK*[22] valve fitted with a three-eighths-inch (9-mm) copper line with the outlet turned down toward the ground is recommended. No hose bib, faucet, or any other threaded valve should be installed between the well pump and the check valve. This is to prevent any contaminated water from being drawn into the well when the pump shuts down and the water column drains back into the well.

3.17 Air Release and Vacuum Breaker Valves

If a pump is not equipped with a *FOOT VALVE*[23] and you want to discharge the air in the column pipe, install an air release and vacuum breaker valve in the piping between the pump head and well discharge check valve. The valve functions as follows:

1. When the well pump is initially started, air inside the pump column is expelled (forced out) through the valve to the atmosphere instead of into the system.
2. When the well pump is shut down, air is admitted into the pump column, thus freely allowing the column to dewater into the well.
3. The valve should be mounted as close as possible to the check valve in a vertical position on top of the discharge piping.
4. The opening in the top of the valve must be equipped with a downturned, screened assembly, and the opening should be protected from flooding.

3.18 Pump Blowoff

The pump blowoff or drain line is used to remove initially pumped water containing sand away from the system. When there is a blowoff or drain line from the pump discharge or from a pump control valve, the waste line must be located above any known flood levels and protected against the possibility of backsiphonage or back pressure. The blowoff or drain line should not be directly connected to any sewer or storm drain.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 138.

3.1A Why are there openings into the top of a well?

3.1B What is the purpose of the well-casing vent?

3.1C How would you determine the distance down to the water level in a well?

End of Lesson 1 of 4 Lessons on WELLS

Please answer the discussion and review questions next.

22 *Pet Cock.* A small valve or faucet used to drain a cylinder or fitting.

23 *Foot Valve.* A special type of check valve located at the bottom end of the suction pipe on a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

DISCUSSION AND REVIEW QUESTIONS

Chapter 3. WELLS

(Lesson 1 of 4 Lessons)

At the end of each lesson in this chapter, you will find some discussion and review questions. The purpose of these questions is to indicate to you how well you understand the material in the lesson. Write the answers to these questions in your notebook.

1. What is the term used to describe the water volume that can move through the pores in the rock and is affected by gravitational forces?
2. Identify the sources of pollutants that can contaminate a groundwater supply.
3. What kind of preventive maintenance program would you develop for an aquifer serving your wells?
4. To protect aquifers, operators must know something about them. What is the best tool for understanding the aquifer and its performance?
5. What options are available for a community whose groundwater supply has been contaminated?
6. Why is community involvement and support important for a wellhead protection program?
7. What factors need to be considered when determining the wellhead protection area?
8. What are the major responsibilities of an operator with regard to an aquifer and well system?
9. Why should hose bibs, faucets, or threaded valves not be installed between the well pump and the check valve?
10. What is the purpose of a pump blowoff?