Maine Farm-A-Syst

Farmstead Assessment System — Fact Sheet 12

Reducing the Risk of Groundwater Contamination by understanding
Groundwater, Aquifers, and Watersheds

Topics Covered:

- Groundwater
- Aquifers
- Glacial History
- Watersheds
- Understanding Water in Your Well
- Source Water Protection/ Well head Protection
- Threats to Groundwater
  - Threats to Quantity
  - Threats to Quality
  - Potential Sources

Groundwater

Groundwater: Found beneath the surface of the ground in cracks and fractures of bedrock and between the individual grains of unconsolidated sediments.

Zone of saturation: Occurs where every pore space between rock and soil particles is filled with water.

Zone of aeration, or unsaturated zone: Above this saturated zone is an area where both air and water are found in the spaces between soil and rock particles Water percolates (moves downward) through this aerated zone until it reaches the saturated zone. The water table is the top of the saturated zone.

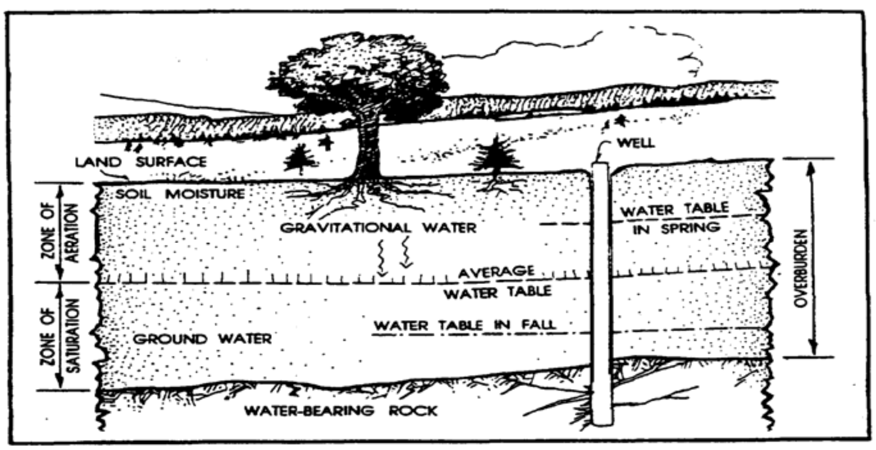


Figure 1 From Maine Geological Survey. *Ground Water Handbook for the State of Maine*, 1987.

The source of groundwater is precipitation. Rain and melting snow soak into the ground and saturate the pores between rock and soil particles. This process is called groundwater recharge. The places where it occurs are called recharge areas. Only a portion of the water that falls as rain or snow in Maine actually recharges the groundwater. The rest runs off into surface water bodies, is taken up by plants and transpired, or evaporates. Once it reaches the zone of saturation under the ground, groundwater moves slowly by the force of gravity through the interconnecting pore spaces toward a discharge area. Here it seeps or flows out into a wetland, spring, river, or pond to become surface water.
Water returns to the atmosphere from surface water bodies and land surfaces and by transpiration from plants. Water in the atmosphere condenses into rain. Some of the rain recharges groundwater and the cycle keeps repeating.

- Groundwater is part of the hydrologic cycle.

- Groundwater and surface water are interconnected.

- Groundwater becomes surface water when it discharges to the surface. Most streams keep flowing during the dry summer months because groundwater discharges into them from the zone of saturation. However, under certain conditions the flow may be reversed and the surface water may recharge the groundwater.

- Groundwater moves from higher elevation recharge areas to lower elevation discharge areas.

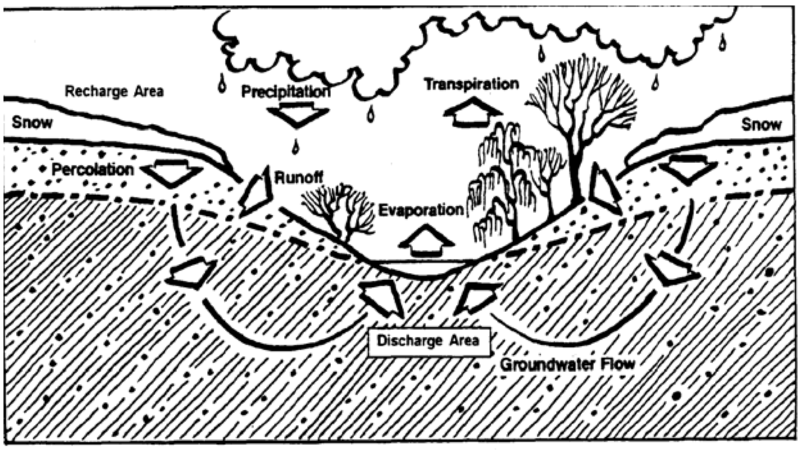


Figure 2: Ground water flow

This groundwater flow is measured in feet per day or in some cases, feet per year. In contrast, surface water flow is measured in feet per second. In a groundwater system like the one in figure 2, rain that percolates into the recharge area in April might move only 300 feet by August or September. The speed at which groundwater moves is determined by the material it must flow through and the steepness of the gradient from recharge area to discharge area. Water moves more easily through the large pores of sand and gravel or an open, interconnected bedrock fracture, than through the small pores of fine silt and clay or a constricted, discontinuous bedrock fracture.

The water table, the top of the zone of saturation, doesn't remain at one level all the time. The rise and fall of the water table occurs seasonally and is a natural part of the groundwater system.

- In the late winter and early spring (March, April, May), groundwater recharge comes when melting snow and rain raises the water table to its annual high level.

- During the growing season, rainwater is used by plants for transpiration or it evaporates. As a result, little or no groundwater recharge occurs during the late spring and summer months. During that time, however, groundwater continues to discharge into streams, lake, and wetlands, so the water table drops.

- By fall (September and October) the water table usually drops to its lowest annual level. Groundwater is recharged again by rains that fall after the growing season.

- There is very little recharge in the winter when the ground is frozen. During the winter, water is stored in the snow pack. In the spring, the melting snow recharges the groundwater, raising the water table to its annual high level again.

Ignoring the natural fluctuation in groundwater levels can cause expensive problems. For example, septic systems, drainage systems, and foundations designed and built for groundwater conditions during a drought, when the groundwater level is very low, can be flooded when the water table returns to more usual levels.

Aquifers

Although groundwater can be found beneath all land surfaces in Maine, not all groundwater can be drawn into wells. To yield significant amounts of water, wells should be located in aquifers. An aquifer is a geologic formation that is capable of yielding a significant amount of water to a well or spring. The amount of water a well will yield depends on the porosity and permeability of the formation it's in.

The porosity of a material determines how much water it will hold - the more pores, the more water. Porosity is expressed as a percentage of the total volume of a material. For example, the porosity of sand might be 30 percent; that is, 30 percent of the total volume of the sand is pore space and 70 percent is solid material. That means that 30 percent can be filled with water or more than 2 gallons per cubic foot of sand. The porosity of consolidated rock is determined by the degree of fracturing. Highly fractured rock holds more water than less fractured rock.

The ability of a material to transmit water is called permeability. It is important to understand this concept because permeability determines whether groundwater can actually be drawn into a pumping well. In consolidated rock, such as granite, permeability depends on how well the fractures in the rock are interconnected. In an unconsolidated material, such as sand and gravel, permeability depends on the size of the pore spaces between the grains of material. A material can be very porous and hold a large volume of water, but not be very permeable. For example, clay may be twice as porous as sand, but a pumping well will not be able to pull the water from the pores between the clay particles fast enough to supply the well. Very small pore spaces create a resistance to flow which reduces permeability.

Porosity and permeability are related, but they are not the same thing.

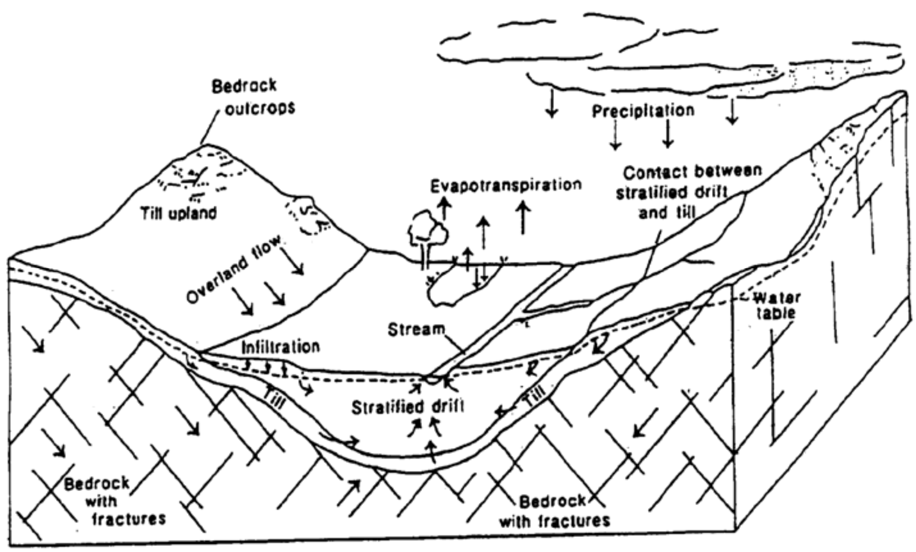
- Porosity determines the capacity of a material to hold water.
- Permeability determines its ability to yield water.

Bedrock, commonly called ledge, is the rock that lies beneath all the unconsolidated material (soil and loose rocks) on the surface of the earth. If a well is drilled into bedrock fractures that are saturated with water, bedrock can serve as an aquifer. Fractures intercepted by wells within the first 200 to 300 feet of the surface generally will supply enough water for private, domestic use. Some highly fractured zones known as faults can yield many thousands of gallons per day, and may be developed for municipal or industrial use. In northern and coastal Maine, there are a few areas where the bedrock is composed of limestone, a relatively soft carbonate rock. Over time, water can enlarge the fractures in this rock by dissolving the surfaces of the fractures along which it flows. Wells drilled in these areas may also provide enough yield for industrial and municipal use.

Most of Maine is underlain by highly fractured bedrock.

Most people would call it soil, but geologists call the sand, gravel, soil, rock and other loose materials that lie on top of the bedrock surficial deposits or overburden. Most surficial deposits consist of a wide variety of material types and sizes. In these deposits, almost all the spaces between the larger materials are filled with smaller particles. For example, the spaces between pebbles and large stones are filled with sand and the spaces between the grains of sand are filled with clay. This leaves few pore spaces for groundwater storage and makes it difficult for water to move through the pores. Thus, deposits that are a mixture of types and sizes of materials are not usually porous and permeable enough to serve as aquifers.

In other surficial deposits, particles are similar in size and don't fit closely together. This creates many interconnecting pore spaces which can hold water. Some of these deposits are very fine grained silt and clay. They are porous but not permeable because the pores are too small to transmit water easily. In some surficial deposits of similar sized particles such as coarse sand, the pores are large and water can flow through them easily. Thus, these deposits are both porous and permeable and make excellent aquifers.



Glacial History

Maine has been covered by glaciers a number of times during the last two million years. The last glacier receded from Maine between 13,000 and 10,000 years ago. As the glacier receded, soil and rock debris that had been incorporated into the glacier were deposited. This material was deposited either directly from the ice or by meltwater streams running off the glacier. Surficial deposits in Maine are made up of this glacial debris, topped by a thin layer of soil that has developed since the glacier melted.

Some glacial debris was carried away by torrents of water that flowed off the melting ice in meltwater streams.

- **At the front of the glacier**, these streams flowed so fast that they could transport glacial debris of all sizes except large boulders.

As the meltwater moved further away from the glacier, it slowed down.

- **The slower moving** water could no longer carry pebbles and gravel, so they settled out.

- **Further along**, when the water slowed more, sand grains settled out. By this time, only very small particles remained suspended in the moving meltwater stream.

- **Still further downstream**, the water reached a lake or the ocean, and the small particles settled out to form very fine deposits of silt and clay on the bottom of the lake or ocean.

Thus, as they moved away from the glacier, the meltwater streams sorted the sediment they carried into separate layers of gravel, sand and fine sand. These deposits are called stratified drift. Many stratified drift deposits were eroded and re-deposited over and over again by flowing water. This repeated sorting action created porous, permeable, stratified drift deposits that often make excellent aquifers.

Other types of glacial debris were deposited directly by the ice. These deposits, termed glacial till, were not subject to the sorting action of meltwater streams.

- **Basal till**, sometimes called hardpan, was deposited at the base of the ice, usually directly onto the bedrock surface. Basal till is very dense, unsorted, and does not readily transmit water.

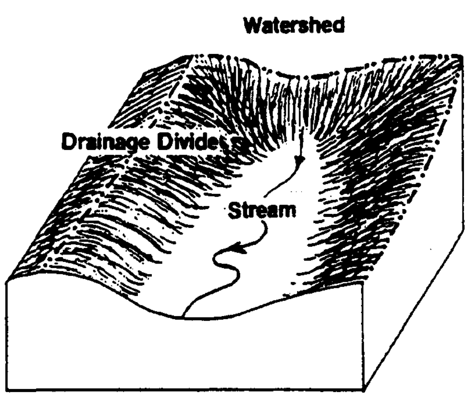
- **Ablation till** results as sediment settled out of, or from the surface of, melting ice. Although it is less dense than basal till, ablation till is poorly sorted and again, does not readily yield water.

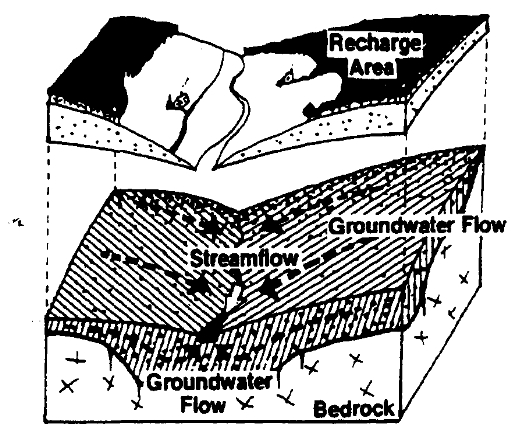
Watersheds

All land is part of one watershed or another.

When rain falls or snow melts, much of the water runs across the surface of the land toward a stream, river, pond or lake as surface runoff. The land area that drains runoff to a stream or other surface water body is called a watershed or drainage basin. Watershed boundaries, also called drainage divides, are the highlands that divide one watershed from another.

Every stream or pond has a watershed that drains to it. The watershed of a larger stream includes the watersheds of all the smaller streams that flow into it. If the larger stream flows into a river, the watershed of the stream becomes part of the watershed of the river and so on.





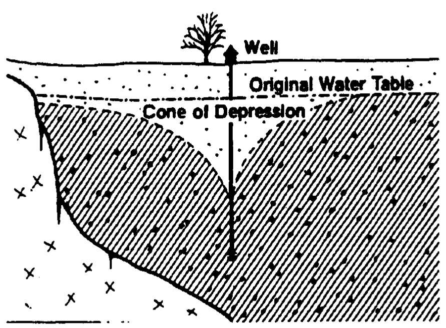
Groundwater is found beneath the land surface within the drainage basins. The source of all groundwater in each watershed is the precipitation that falls there. It does not move in underground rivers from distant watersheds. Groundwater divides generally coincide with surface water divides, although irregularities on the bedrock surface may cause the location of the groundwater divide to vary slightly from the surface water divide. Since groundwater occurs within watersheds, and groundwater divides are usually approximately beneath surface water divides, watersheds are often used as the basic hydrologic unit for both surface water and groundwater planning purposes.

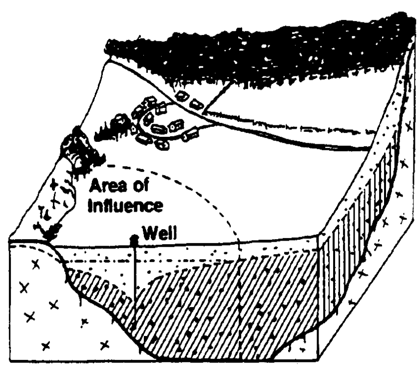
The fact that groundwater and surface water are interconnected can't be overemphasized. Groundwater moves slowly from recharge areas, where precipitation is absorbed, down through the watershed to the discharge area, where it flows or seeps out of the ground and becomes part of the surface water. Along the way it may pass through an aquifer that supplies water to a home or business.

> Any activity that may alter water quality has the potential to affect the groundwater down gradient from the site, any wells that may draw that water and any stream or pond to which the water may discharge.

Understanding Water in Your Well

When a well is pumping, groundwater flow changes direction in a portion of the watershed. Instead of moving toward the natural discharge area, the groundwater within the influence of the pump flows toward the well from every direction. The pumping well creates an artificial discharge area by drawing down (lowering) the water table around the well. This area of drawdown is called the cone of depression and the area it affects is the area of influence.



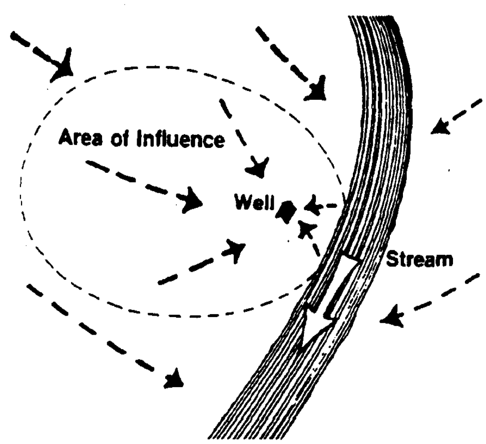


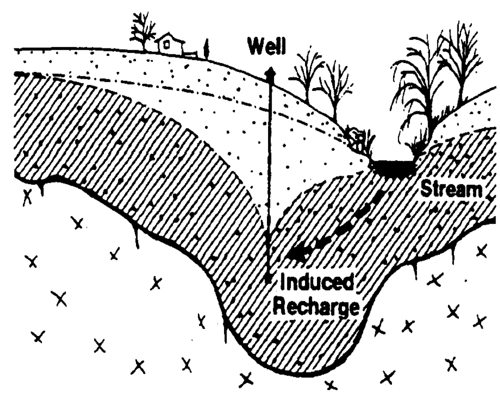
Every pumping well is surrounded by a cone of depression. When the amount of groundwater that is withdrawn by the pumping well is equal to the amount of groundwater recharge within the area of influence, the cone stops expanding. However, the cone of depression does not always remain the same size. If there is no precipitation to recharge the aquifer and the well keeps pumping, the pump will pull water from a greater distance and the cone of depression will get deeper and wider. After heavy precipitation, with good recharge, it will get smaller.

Dug, driven point, or gravel packed wells which draw water from the surficial deposits have a cone of depression that is generally round or oval showing that recharge is being drawn from all directions. Bedrock wells drawing water from linear fractures may have a narrow, elongated cone of depression reflecting recharge along the fracture.

Land use can change the size and shape of the cone of depression and the ability of the aquifer to supply water. If impermeable surfaces (such as paved areas or buildings) cover a portion of the area of influence or its upland recharge area and the runoff from those surfaces flows overland to streams instead of recharging the groundwater, the cone of depression for the pumping well will have to expand to compensate for the lost groundwater recharge. As a result, land areas formerly outside the area of influence will become primary recharge areas for the well, if they can absorb precipitation. If there is no porous permeable land within reach of the pumping well that can provide the recharge needed, the yield of the well may decrease.

A well draws water from only a portion of the watershed, specifically the cone of depression and the upland recharge areas. Outside these areas, collectively termed the areas of contribution, groundwater does not move toward the well. Instead it moves in its normal pattern from the recharge area down to the discharge area. The boundaries of the area of influence can be determined by groundwater studies.





If the area of influence of a well reaches to the banks of a stream, the well may draw surface water from the stream in a process called induced recharge. Induced recharge occurs when the cone of depression extends to a stream, lowering the water table beneath it. If there are no impermeable barriers such as clay or thick deposits of organic muck in the streambed, the pump will pull water from the stream down through the aquifer and into the well. If the stream was polluted the well would draw that water into the aquifer degrading groundwater quality. Understanding groundwater and how it moves is essential to understanding where to site a new well or how to protect your existing one.

Be aware of the laws … look up withdrawal regulations by going to the following website: http://www.maine.gov/doc/nrimc/mgs/explore/water/regs/withdraw.htm

Source Water Protection / Wellhead Protection Area

Almost half of Maine's population depends on groundwater for its drinking water supply. That source comes from either a private well or public well/s. We are lucky to have some of the safest water supplies in the world, but it is our job to keep it so. Being aware of potential problems on your property that might pollute source water is important. You may not even know that there is a potential threat, but by taking the time to read and fill out the applicable Farm-A-Syst sections is a great first step. From there you will sit down with a district employee or someone trained in Farm-A-Syst to discuss some possible solutions such as best management practices (BMP) that can be applied. BMPs are a method, measure or practice that, when correctly installed or performed, will prevent, reduce, or minimize water pollution. In this case the focus is on wellheads (a specific location of a well [a hole or shaft dug or drilled to obtain water] and/or any structure built over or extending from a well) and source water.

If you are living or operating in a source water protection zone/wellhead protection area (the surface and subsurface areas surrounding a water well or well field, supplying a public water system through which contaminates are reasonably likely to move toward and reach such water well or well field) you should pay extra special attention. There are some laws that pertain to areas that are within a source water protection zone that don't apply to other landowners. It is the landowner's responsibility to know the laws pertaining to their land, admittedly it is hard to navigate sites and wade through the legal jargon of written laws. We have tried to find pertinent information pertaining to this section. You can find links to these laws along with helpful information in the following Contact & Reference section as well in appendices A: Law and Regulations & B: Resources.

Threats to Groundwater

Threats to Quantity

An increased quantity of groundwater is being withdrawn to meet the demands of a growing population. Some of the typical threats associated with this include overdraft, drawdown and subsidence.

Overdraft occurs when groundwater is removed faster than recharge can replace it. This can result in:

- A permanent loss of a portion of its storage capacity.
- A change that can cause water of unusable quality to contaminate good water.
- In coastal basins, salt water intrusion can occur.

Generally, any withdrawal in excess of safe yield (the amount that can be withdrawn without producing an undesirable result) is an overdraft.

Drawdown differs significantly from overdraft. It results in a temporarily lowered water table generally caused by pumping. In this situation, the water table recovers when the supply is replenished.

Subsidence is one of the dramatic results from over pumping. As the water table declines, water pressure is reduced. This causes the fine particles that held water to become compacted. In addition to permanently reducing storage capacity, the land above the aquifer can sink…from a few inches to several feet…causing a sinkhole. This can damage property and fields.

Threats to Quality

Inorganic compounds, pathogens and organic compounds can harm water quality, affecting the health of humans, fish and wildlife. Scientist continually learn more about contaminants, their sources and prevention practices.

Inorganic Compounds include all compounds that do not contain carbon. Nutrients (nitrogen and phosphorus) and heavy metals are two examples.

Pathogens, including bacteria and viruses, have been credited with causing more than 50% of the waterborne disease outbreaks in the U.S. *Cryptosporidium Parvum* and *Giardia* both commonly cause illnesses when consumed.

Organic Compounds include volatile organic compounds (VOCs) like benzene, toluene, xylene; semi-vollatile compounds like napthaline and phenol; PCBs and pesticides.

Potential Sources

Point sources are easily identified because they usually come out of a "pipe." Examples include sewage treatment plants, large infection wells, industrial plants, livestock facilities, landfills and others. Many point sources were established generations ago, before the threat they posed was understood. Some of these sources have been grandfathered into compliance with some regulations. Most of these former practices would be considered inappropriate now and new point sources have to be permitted.

Nonpoint sources refer to widespread, seemingly insignificant amounts of pollutants which, cumulatively, threaten water quality and natural systems. Nonpoint sources are hard to identify or to connect responsible parties to the pollution because it is usually the accumulation of several people's actions.

Other sources that aren't classified under point or nonpoint sources include underground petroleum storage systems and many large and small businesses like dry cleaners, restaurants, and automotive repair shops. Although a large number of underground storage tanks have been removed or upgraded, a significant number remain. Businesses can threaten groundwater with a wide variety of potentially contaminating substances.

Acknowledgments

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