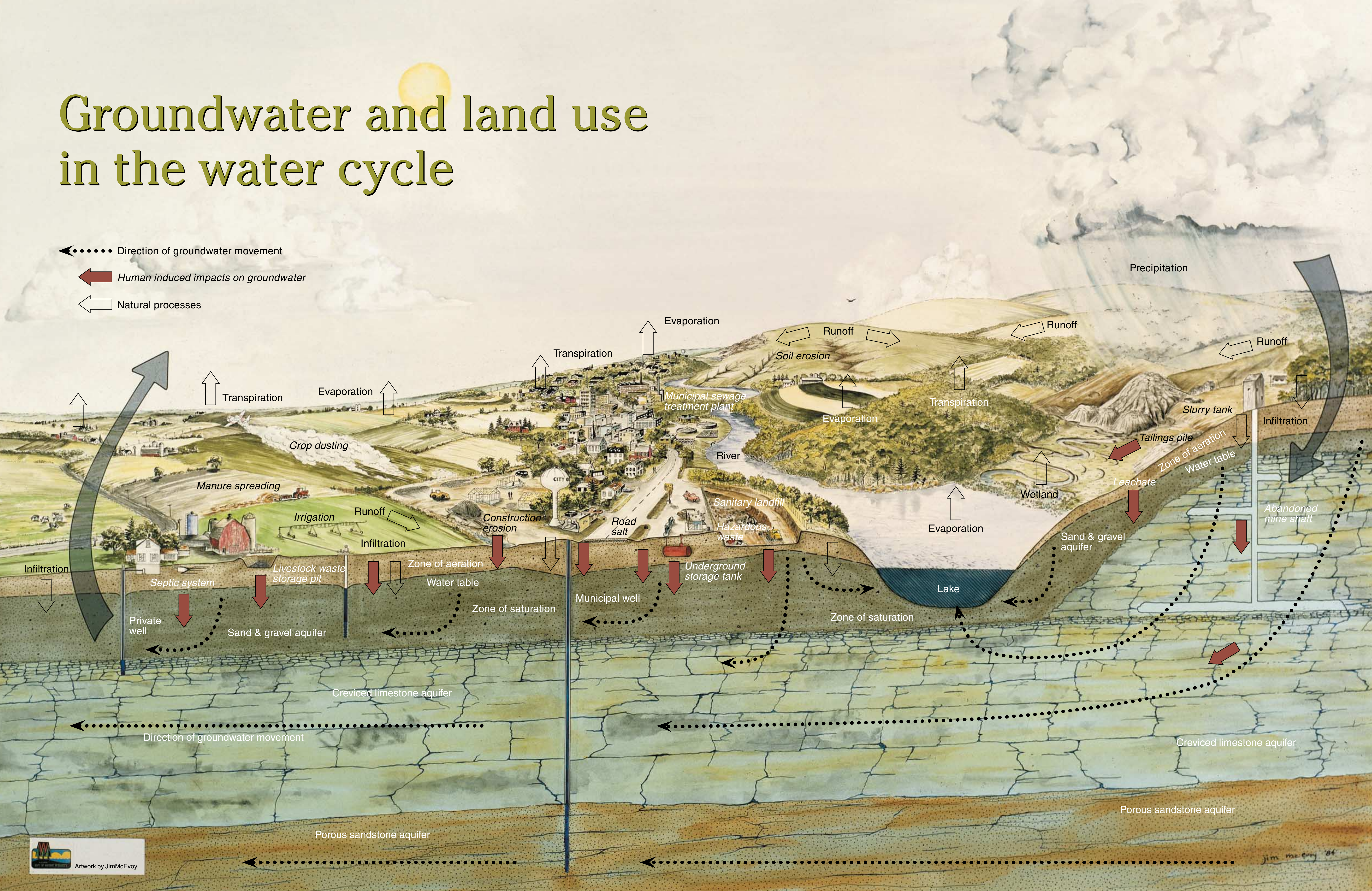
Groundwater and land use in the water cycle



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Groundwater and Land Use in the Water Cycle

Water might be called our most recycled resource. Consider, for example, that the water you bathed in this morning may have contained the same water molecules that washed over a South Pacific coral reef millions of years ago. The distribution of the earth's total supply of water changes in time and space, but the amount has remained basically constant. Distribution of water changes according to a phenomenon known as the hydrologic cycle, kept in motion by solar energy and gravity.

Pick a bursting cloud as the start of the cycle. Its rain falls to earth. Some flows downhill as runoff (to a stream, lake, eventually the ocean); some evaporates; some is taken up by plants. The rest trickles down through unsaturated subsurface soil and rock formations, traveling through pore spaces and open cracks. This water eventually reaches the top of the saturated layer which is called the water table. The water contained in the saturated layer below the water table is called groundwater.

Groundwater seeps from upland to lowland areas, eventually discharging in low places where the water table intersects the land surface in streams, lakes, wetlands. Solar energy will cause evaporation from these surface waters.

In Wisconsin, an average of 30 to 32 inches of precipitation per year falls on the state. Most precipitation (75%) evaporates or transpires through plants and never reaches surface or groundwaters. The fate of the six to 10 inches per year that doesn't evaporate immediately or get used by plants, depends on local topography, soil, land use and vegetation. Ideally, these would retard runoff and let water soak into the ground, but conditions vary. In gently rolling Dane County, for example, for every one inch of water that runs off the land to a stream or lake, two inches seep down to the water table. But in the sandy plains of Portage County, nine inches are able to seep into the ground for each inch running of the land.

This is what makes groundwater. It doesn't come from Canada or Lake Superior in some mysterious underground stream.

All groundwater moves continually toward an area of discharge. But rates of movement vary greatly.

The reason for this variability is a matter of geology. The size of the cracks in the rocks, the size of the pores between soil and rock particles and whether the pores are connected, all contribute to the rate of movement to, through and out of the saturated zone.

For example, water generally moves more quickly into, through and out of coarse sand as compared with other materials, sometimes as much as several feet per day. Openings between the grains are large and interconnected, resulting in high permeability. Very fine-grained material like clay has many pores where water can be stored, but the pores are small so moving water through or out is difficult. Such formations are relatively impermeable; movement here may be only a few inches a year. Permeability in limestone rock, on the other hand, depends not on pore spaces but on the size, frequency and distribution of fractures and cracks.

Groundwater flow systems

Groundwater moves through the water cycle as part of a dynamic flow system, from recharge areas where infiltration occurs to discharge areas (streams, lakes, springs and many wetlands). It may move downgradient following the configuration of the water table, or in deeper confined layers of rock or soil under artesian pressure. In Wisconsin, the natural movement is always from upland recharge areas to lowland discharge areas. Because groundwater naturally moves to and discharges into lowland areas, it is a significant factor in the development of our lakes, streams and wetlands.

Did you ever wonder why some streams continue to flow during dry periods, or during winter even though there is no rainfall? The answer is that winter stream flow is largely groundwater discharge (called baseflow), which is relatively warm (about 50° F). Streams, and most lakes and wetlands, are constantly replenished during the winter by groundwater in the uplands surrounding that stream, wetland or lake. The water table steadily lowers during the winter discharge period, and it isn't until the following spring thaw that water can once again infiltrate the soil to recharge the groundwater and thus cause the water table to rise.

Groundwater in Wisconsin doesn't move hundreds of miles. Most precipitation which recharges groundwater moves only a few miles from the point of recharge to the point of discharge. In the vast majority of cases, it stays within the same surface runoff watershed.

Aquifers of Wisconsin

An underground rock or soil formation that can store and transmit water efficiently is called an aquifer. In a few areas of northern Wisconsin, clay soils overlay granite or some similar hard nonporous rock. This geology makes it unsuitable for storing and transmitting water efficiently or economically and as a result, substantial well water supplies aren't available.

Wisconsin is favored with thick sequences of permeable deposits across most of the state. These layers of soil and rock formations comprise the four principal aquifers of the state: the sand and gravel aquifer, the eastern dolomite aquifer, the sandstone and dolomite aquifer and the crystalline bedrock aquifer.

Sand and gravel aquifer

The sand and gravel aquifer is the surface material that covers most of the state, except for parts of southwest Wisconsin which weren't glaciated. It is made up mostly of sand and gravel deposited from glacial ice or in river floodplains. The deposits are unconsolidated so they are often called soil, even though they are different from agricultural soil and are more than 300-feet thick in some places. The groundwater occurs and moves in the void spaces (pores) among the grains of sand and gravel.

The glaciers themselves were formed by the continuous accumulation of snow and played an interesting role in Wisconsin's groundwater geology. The snow turned into ice, which reached a maximum thickness of almost two miles. The ice sheet spread over Canada, and part of it flowed in a general southerly direction toward Wisconsin and neighboring states.

The ice sheet transported a great amount of rock debris called "drift."

As the ice melted, the drift was reworked by the running water. Large amounts of sand and gravel were deposited to form "outwash plains"; pits were formed in the outwash where buried blocks of ice melted and many of these are now occupied by lakes. The sand and gravel aquifer was deposited within the past million years.

The sand and gravel outwash plains now form some of our best aquifers in Wisconsin. Many of the irrigated agricultural lands in central, southern and northwestern Wisconsin use the glacial outwash aquifer. Many other glacial deposits are also useful aquifers, but in some places, large glacial lakes were formed which accumulated thick deposits of clay. These old lake beds of clay don't yield or transmit water.

Because the top of the sand and gravel aquifer is also the land surface for most of Wisconsin, it is highly susceptible to human-induced and some natural pollutants.

Eastern dolomite limestone aquifer

The eastern dolomite aquifer occurs in eastern Wisconsin from Door County to the Wisconsin-Illinois border. It consists of the Niagara dolomite formation underlain by the Maquoketa shale formation. These formations were deposited 400 to 425 million years ago. Dolomite is a brittle rock that is similar to limestone and contains groundwater in interconnected cracks. As a result, the yield of water from a well depends upon the number of fractures the well intercepts. Closely spaced wells, therefore, can vary greatly in the amount of water that can be pumped.

Where this fractured dolomite bedrock occurs at or near the land surface, the groundwater in shallow portions of the eastern dolomite aquifer can easily become contaminated. In those areas (such as parts of Door, Dodge and Waukesha counties), there is little soil to filter pollutants carried or leached by precipitation. Little or no filtration takes place once the water reaches large fractures in the dolomite. This has resulted in some special groundwater quality problems and should prompt special care to prevent pollution.

The Maquoketa shale layer beneath the dolomite is a rock formation formed from clay that doesn't transmit water easily. Therefore, it is important not as a major water source, but as a barrier between the eastern dolomite aquifer and the sandstone and dolomite aquifer below.

Sandstone and dolomite aquifer

The sandstone and dolomite aquifer consists of layers of sandstone and dolomite bedrock units that vary greatly in their water yielding properties. In these types of rock, groundwater occurs in fractures. In sandstone it also occurs in pore spaces between loosely cemented sand grains. These units occur over the entire state, except in the north central portion where these formations aren't present. In eastern Wisconsin, this aquifer lies below the eastern dolomite aquifer. In other areas, it lies beneath the sand and gravel aquifer. These rock units gently dip to the east, south and west away from the north central portion of the state, becoming much thicker and extending to greater depths below the land's surface.

The rock units that make up the sandstone and dolomite aquifer were deposited between 425 and 600 million years ago. The sandstone and dolomite aquifer is the principal bedrock aquifer for the southern and western portions of the state. In addition, in eastern Wisconsin, most users of substantial quantities of groundwater, such as cities and industries, tap this deep aquifer to obtain a sufficient amount of water.

Crystalline bedrock aquifer

The crystalline bedrock aquifer consists of a variety of rock types formed during a geologic time called the Precambrian Era. The Precambrian Era lasted from the time the earth cooled, more than 4,000 million years ago, until about 600 million years ago, when the rocks that comprise the sandstone and dolomite aquifer began to be formed. During this vast period of 3,400 million years, sediments, some of which were rich in iron and which now form iron ores, were deposited in ancient oceans; volcanoes spewed forth ash and lava; mountains were built and destroyed; and the rocks of the upper crust were intruded by molten rocks of deep-seated origin. The rocks that remain today have a granite-type crystalline structure. These are the "basement" rocks which underlie the entire state. In the north central region, they are the only rocks which occur beneath the sand and gravel aquifer.

The cracks and fractures that store and transmit water in these very dense rocks are spaced many feet apart. The amount of water available to a well can vary within a single homesite. To obtain water a well must intersect some of these cracks.

Many wells in the crystalline bedrock aquifer have provided good quality water. However, most of these wells don't penetrate deeply into the rock. Water samples from mineral exploration holes near Crandon and deep iron mines near Hurley have yielded brackish water near or exceeding mineral concentrations in sea water.

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