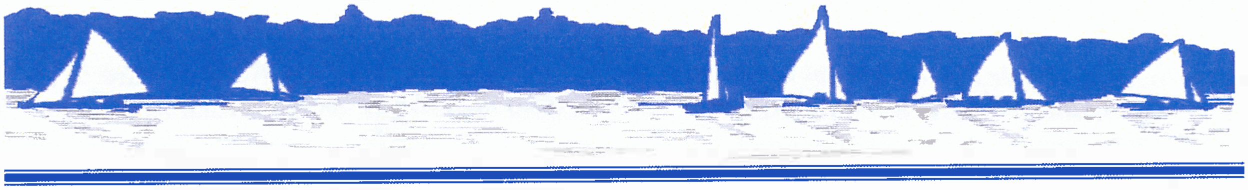

GROUNDWATER AND GENEVA LAKE

INTRODUCTION

For years it was assumed that *groundwater* was a significant source of water to Geneva Lake. Local folklore once contended that the water in Geneva Lake came all the way from Lake Superior in underground streams. Initial studies on the *hydrogeology* of the area indicated that was no more than "old-time stories."

Previous *lake modeling* indicated that groundwater was responsible for a net contribution of 6-10 percent of the annual water coming into Geneva Lake. Although little groundwater *quantitative monitoring* actually was conducted, these values seemed reasonable from *a mass balance* perspective. Knowing the basic components of Geneva Lake's hydrologic budget (Figure 1) and compensating for changes in lake level, the difference in the sum of known inputs and the sum of known losses was from groundwater.

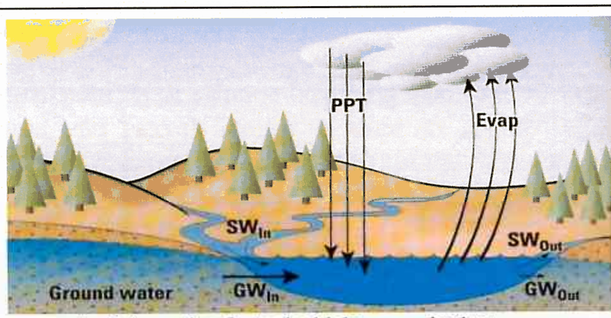

Figure 1. Schematic of a typical lake water budget.
Source: USGS

Beginning in 2005 with the assistance of the Wisconsin Geological and Natural History Survey (WGNHS), UW-Extension, and Geneva Lake communities, the Geneva Lake Environmental Agency coordinated several comprehensive groundwater studies in the Geneva Lake area. The goal of these studies was to understand more accurately the importance of groundwater, not only to Geneva Lake but as the major source of drinking water to the Geneva Lake populace.

GROUNDWATER STUDIES

In 2006, working with WGNHS, an extensive inventory of existing groundwater information and data from the Geneva Lake area was compiled and analyzed. This study identified and mapped the water table elevation, bedrock thickness and depth, *cones of depression* for major wells, bedrock geology, and sensitive areas relative to groundwater quality.

In 2008, with the financial help of more than 13 area groundwater stakeholders, WGNHS was contracted to conduct modeling of Geneva Lake's area groundwater under different conditions. Produced from the modeling were impacts on the groundwater from present pumping rates, future pumping rates, and no pumping (to simulate predevelopment conditions). *Lake budgets, ground watersheds,* and groundwater movement were identified for all three scenarios. Areas and relative rates of *infiltration* also were identified.

In 2011, the GLEA and the Linn Sanitary District conducted an Education and Information Program that included mailing several groundwater information flyers. In late summer, a well-testing program for arsenic, nitrate, bacteria, and chloride was offered to area residents owning private wells.

2006-07 INVENTORY

Over the years much information on the *hydrogeology* of Geneva Lake has been collected. Much of this data is on a regional basis, with little specific information about the immediate Geneva Lake area. The first step to understanding the groundwater is to bring together and review existing groundwater information and data. This inventory resulted in the creation of several geologic and *hydrogeology* maps.

The second step in this phase was to assess the suitability of using an existing groundwater flow model to simulate surface water and groundwater interaction in the Geneva Lake area. Based upon what was found in the first step, the

Italicized and blue-colored words are defined in the glossary on this Summary Information Sheet's last page.

This Summary Information Sheet is a compilation of several reports prepared by UW-Extension, Wisconsin Geological and Natural History Survey, and Geneva Lake Environmental Agency.

Geneva Lake area had a rich set of existing information that made modeling groundwater a viable tool for managing and understanding the area's groundwater.

The groundwater flow model simulates a real-world hydrologic system, in this case groundwater in the Geneva Lake region. The model can produce groundwater elevations and movement relative to different levels of pumping. This allowed for the creation of groundwater conditions under predevelopment, existing, and future development scenarios.

FINDINGS

There are two major *aquifers* in the Geneva Lake area: a shallow sand and gravel *aquifer* about 200 feet thick that overlays a deep bedrock *aquifer* of sandstone and limestone (Figure 2). Except for the far western portion of Geneva Lake, these *aquifers* are separated by an *impervious* Maquoketa shale *aquitard.* As such, these two *aquifers* act independently of each other. Geneva Lake interacts primarily with the shallow sand and gravel *aquifer.* Groundwater in the shallow aquifer moves toward the lake on all sides, except the northeast end where the lake *recharges* groundwater. Precipitation *recharges* the shallow groundwater relatively fast. The deep *aquifer recharges* much more slowly due to the *impervious* layer that limits the downward movement of water.

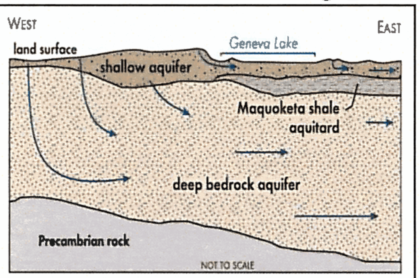

Figure 2. Regional hydrology of the Geneva Lake area.
Source: UW-Extension/WGNHS

As a result of high *infiltration* in the sand and gravel, the shallow water table is very vulnerable to surface pollution. Those pollutants can move extremely quickly to groundwater discharge areas such as springs, seepages, surface waters, and wells.

As wells pump water from the aquifer they form a *cone of depression* in the water table (Figure 3). A cone of depression is a conical-shaped depression in the water table radiating away from a well, with the widest part at the surface and the narrowest part at the well head.

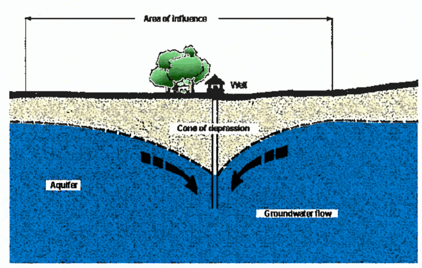

Figure 3. A cone of depression.
Source: UW-Extension/WGNHS

Some of the high capacity wells on the western end of the lake form cones of depression that drop the water table as much as five feet as far away as 2½ miles. *High-capacity wells* on the eastern end of the lake have relatively small *cones of depression* because of the rapid *recharge* by the lake and groundwater.

The many springs and seepages located predominately on the west and south sides of Geneva Lake receive most of their water from the shallow sand and gravel *aquifer*. Pumping from the shallow sand and gravel *aquifer* can reduce flows in the shallow springs and seepages that deliver water to the lake.

Annually, *high-capacity wells* remove as much as a half billion gallons of water from the *aquifer* or one-half of one percent of lake volume or about three inches of water. In the spring when the lake water level is above the spillway, this pumping has no impact on the lake level. However, when the lake level is below the spillway, pumping results in a larger drop in lake level and appears to be increasing over time.

Groundwater elevations have changed as a result of *high-capacity well* pumping. This is most pronounced at the western end of the lake. *High capacity well* pumping in the Geneva Lake area results in lowering the water table on the Big Foot Prairie and an extension of Geneva Lake's *ground watershed* to the west.

2008-09 GROUNDWATER MODELING

With the local groundwater information gained from the first phase of the groundwater study and an understanding that groundwater follows basic principles of physics and mathematical equations, modeling can tell a lot about what is happening with groundwater even though it is under the ground and out of sight. Adapting a groundwater model that was developed by the United States Geological Survey (USGS) and Southeastern Wisconsin Regional Planning Commission (SEWRPC) for regional groundwater studies, a fined-tuned version of the

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model was used to specifically investigate the groundwater/surface relationships in the Geneva Lake area.

The model simulates three aspects of that relationship: groundwater recharge, flow through aquifers, and discharge to wells and surface water. The model can simulate the *water table* and estimates of groundwater flow rates under different pumping rates. By adjusting pumping rates, past, present, and future groundwater flow rates can be simulated. By adjusting the model's calibration, the impacts of wet, dry, and normal precipitation also can be simulated.

FINDINGS

A close relationship exists between Geneva Lake and the *shallow groundwater*. The *ground watershed* of Geneva Lake is larger than its *surface watershed*, extending farther to the west and south than the surface watershed (Figure 4). Not only is the *ground watershed* significantly different than the surface watershed, the predevelopment and post-development watersheds also differ (Figure 4).

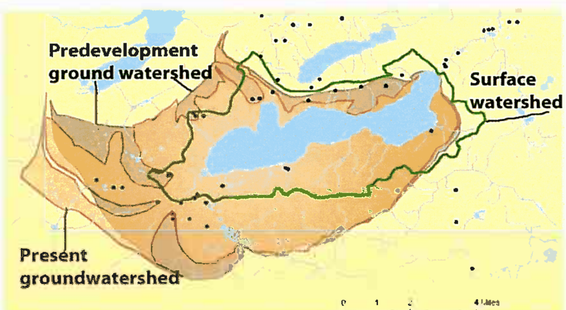

Figure 4. Groundwater and surface watersheds, Geneva Lake. Source: WGNHS,UW-Extension, GLEA

This model also simulated a lake *water budget* by identifying the annual water sources to and losses from Geneva Lake (Table 1.) The water budgets from this modeling identify a larger portion of the lake's annual water inflow from groundwater than the 6-11 percent previously thought. Older values did not involve the actual measuring of groundwater flow as this newer model does.

Under present conditions, the model identified the contribution of precipitation as the largest single annual source of water to the lake at 38 percent. Groundwater accounted for 36 percent, runoff 19 percent, and *stream base flow* seven percent. The major loss of water at 64 percent is flow over the spillway and into the White River. Evaporation accounts for 35 percent of the annual loss, and flow into the groundwater represents about one percent of the total loss.

Present-day pumping reduces the amount of groundwater that flows through the lake system by about four percent as compared to predevelopment conditions (no pumping.) This is a relatively insignificant amount and does not impact the lake level because of the spillway. The pumping does not significantly change the sources, losses, and percentages of water to and from the lake.

It was estimated that by 2035 predicted growth in the area will result in a 30-percent increase in pumping. The model shows this will result in a 4.5 percent decrease in the water flowing through the lake.

Adjusting the model's precipitation to simulate wet and dry years does change the lake's water budget significantly (Table 1). Wet years increase the

Table 1: Geneva Lake Water Budgets Under Different Precipitation Rates

	Precipitation Amounts		
	Present	Wet year	Dry year
Inflow	32"	50"	21"
Groundwater	36%	33%	73%
Precipitation	38%	31%	7%
Surface runoff	19%	25%	8%
Stream base flow	7%	11%	12%
Outflow			
White River	64%	75%	15%
Evaporation	34%	25%	85%
Groundwater	1%	<1%	<1%

Source: UW-Extension, WGNHS, GLEA

total amount of water that flows through the lake but actually decrease the percentages of groundwater and atmosphere as sources. The percentages of water from runoff and *stream base flow* (springs and seepages) that enter the lake during a wet year increase to about 35 percent.

During a dry year, the model showed the groundwater can contribute as much as 73 percent of the water annually entering the lake. As might be expected, precipitation and runoff drop significantly to seven and eight percent, respectively. *Stream base flow* increases to 12 percent.

The White River is the major loss of water from Geneva Lake during normal and wet years. Evaporation is the major loss (85 percent) of water during a dry year. As might be expected during a dry year, the lake level drops below the spillway sooner and less water is lost to the White River.

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Groundwater accounts for less than one percent during both wet and dry years.

The model showed that pumping from high-capacity wells on the western end of the lake not only dropped the water table but in doing so reduced the volume of water in springs, seepages, and streams. These groundwater discharge sites are directly dependent upon the shallow aquifer for their water. In turn, this reduces the amount of water supplied to the lake by not only groundwater but *stream base flow.*

Although the model did not address *wastewater* and its ultimate fate, by knowing the present wastewater treatment options in the lake area some idea of *wastewater* quantitative impact can be ascertained. On the eastern end of the lake, wastewater is discharged to *infiltration ponds* down flow from the lake and has little if any impact on the lake.

Wastewater on the western end of the lake is discharged to surface waters that drain away from the lake. This results in the annual interception of about 340 million gallons of water that normally would be a part of the local hydrologic system.

The remaining portion of the watershed uses *private on-site wastewater treatment systems* (POWTS) or *septic systems and holding tanks.* Systems with *holding tanks* are pumped out periodically, and the waste is discharged into a nearby *wastewater treatment plant*. Functioning septic systems discharge their treated wastewater on-site, where it is treated by the soil and recharges the water table.

Although this model does nothing with water quality, it would be shortsighted not to consider water quality along with water quantity when managing groundwater.

2011 GROUNDWATER INFORMATION: EDUCATION AND TESTING

In early 2011, the Geneva Lake Environmental Agency and the Linn Sanitary District entered into an agreement to conduct a groundwater education and well-testing program. The goal of the program was to share the information gained from the recently conducted groundwater studies with the residents of the Geneva Lake area and to instruct them on how to test their private residential wells. An opportunity was given to area residents to have their wells tested for *bacteria, arsenic, nitrate, and chloride.*

Over the year, five educational flyers were sent out to Linn Sanitary District residents with private residential wells. The educational flyers were titled "Hydrogeology of the Geneva Lake Area," "Groundwater in the Geneva Lake Area," "Why Groundwater Is Important in the Geneva Lake Area," "Testing Your Drinking Water Well," and "Protecting Groundwater."

RESULTS

Arrangements were made with the Wisconsin State Laboratory of Hygiene to conduct the water analysis. A total of 59 residents took advantage of the opportunity and collected samples from private residential wells for testing. Table 2 shows the drinking water standards for the tested parameters and the number of wells in which the specific parameter was found. Although *total coliform bacteria* were found in 13 of the 59 wells tested, only one well tested positive for *E-coli bacteria.*

Table 2 Drinking Water Standards and Test Results

Parameter Tested	Drinking Water Standards	Tested Wells with Parameter	Tested wells that exceeded the Standard
Total Coliform	0	13	13
E-coli	0	1	1
Arsenic	10 ppb	18	7
Chloride	250 ppm	59	0
Nitrate	10 ppb	5	0

ppb = part per billion Source : GLEA and WSLH

Coliform bacteria can be widely distributed in the natural environment. *E-coli bacteria is* a type of *fecal coliform bacteria* found in the intestines of warm-blooded animals. If found in drinking water, it should be assumed that the water has been contaminated and should not be consumed.

Arsenic in water can be from manmade and natural sources. In the case of *arsenic* in Geneva Lake area well water, it is more often from a reaction that takes place in the deep aquifer. Wells that had *arsenic* were deep wells that withdrew their water from the deep aquifer below the sand and gravel at more than 200 feet.

Chloride was found in all wells, but none of the tested wells exceeded the drinking water standard of 250 parts per million (ppm.) The standard is more of a taste standard than a health standard.

Nitrate is a common form of nitrogen. Nitrogen is an essential nutrient for life and is widely distributed in the environment. All living cells have

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nitrogen in some form. 78 percent of the atmosphere is nitrogen, which must combine with oxygen to form *nitrate*. *Nitrate* is found in fertilizers and animal wastes. The drinking water standard for *nitrate* is 10 ppm. Drinking water in excess of 10 ppm can lead to problems with oxygen delivery in the blood. Although five wells had some level of *nitrate,* no well exceeded the drinking water standard.

MANAGEMENT IMPLICATIONS

Geneva Lake receives a major portion of water from the groundwater that is *recharged* by rainfall entering the ground to the south and west of Geneva Lake. Care should be taken with activities in these recharge areas (Figure 5).

Care also should be taken as to how the shallow sand and gravel aquifer is used to supply water. Future groundwater removal within the Geneva Lake ground watershed may not have a significant impact on Geneva Lake but will change the ground watershed. Because springs and seepages receive their water from this shallow *aquifer*, high withdrawal of this water will impact the many springs and seepages found around the lake.

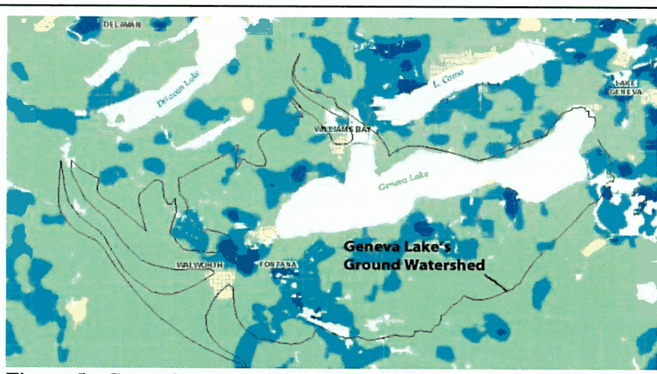

Figure 5. Groundwater recharge areas in the Geneva Lake area. Areas where water soaks into the ground (infiltration). The darker the area the higher the infiltration rates. Source: WGNH, UW-Ex, GLEA

The groundwater model has been refined and calibrated and is ready and available for future use. It would be wise to use the model to assess the impacts of new high-capacity wells upon the groundwater in the study area.

SUMMARY

Groundwater moves toward Geneva Lake from all directions except for a small area located at the eastern end of the lake. Here the lake actually feeds or *recharges* the groundwater. The raising of the lake surface by the creation of a spillway and dam has slightly altered the groundwater flow on the northeast shore of the lake where a reduced amount of groundwater flows toward the lake.

During a normal year Geneva Lake receives 36 percent of its annual water input from groundwater. A shallow sand and gravel aquifer underlies all of the lake and is about 200 feet thick. This aquifer allows for rapid *recharge* and offers a good supply of high-quality water to the lake.

Many area *high-capacity wells* that draw from the aquifer intercept water that would flow toward and into the lake. This interception does not have a significant impact on the lake. Modeling has shown that to compensate for this loss, the lake's *ground watershed* has expanded to the west. Depending on the amount of groundwater pumping, it could significantly reduce flow in many area springs and seepages.

The atmosphere and groundwater are major sources of Geneva Lake's inflow, accounting for almost three-quarters of the annual inflow. Surface runoff and *stream base flows* (springs and seepages) make up the remaining water sources. During wet years the runoff and base flow increase slightly, yet groundwater and precipitation remain the largest contributors. During a dry year, the contribution of precipitation drops significantly, and groundwater contribution increases to compensate. Groundwater is a significant source of water to the lake during normal, wet, and dry precipitation years.

The volume of water loss from Geneva Lake varies between normal, wet, and dry years, yet the percentages change little. Water flowing over the spillway into the White River accounts for the largest lost in normal and wet years. Evaporation accounts for the largest lost during a dry year. Loss to groundwater in any of the three scenarios never exceeds one percent

In an attempt to understand groundwater quality, a private well-testing program was conducted. Few wells had issues with drinking water standards.

The groundwater model gives insight into the groundwater-and-lake relationship. The identification of Geneva Lake's *ground watershed* and *recharge* areas is important to protecting the groundwater that ultimately feeds the lake. Knowing the impact of new wells on the groundwater-and- lake relationship is a valuable tool that can be used as future demands for water increase.

Italicized and blue-colored words are defined in the glossary on this Summary Information Sheet's last page.

GLOSSARY

Aquatard – A layer or formation of soil or rock that prohibits the passage of water.

Aquifer – The area in the ground where all open spaces between the soil and rock particle are filled with water.

Arsenic – A highly toxic metallic element that can restrict the use of water. In the Geneva Lake area, the presence of arsenic usually is associated with deep wells (>200 feet) in the deep aquifer below sand and gravel. Arsenic appears there as a result of a natural chemical process.

Chloride – A form of chlorine that is considered an important and widely distributed salt. Chloride tends to accumulate in the environment and can add a salty taste to water in high concentrations.

Cone of depression – A conical-shaped depression in the water table defining the area of influence of the well, with the widest part being at the surface and the narrowest at the well head.

E-coli – *Escherichia coli* bacteria, a specific type of fecal coliform bacteria that live in the intestines of warm-blooded animals.

Fecal coliform – A group of coliform bacteria usually found in association with animal feces.

Ground watershed – That portion of an aquifer that supplies water to a specific surface water.

Groundwater – Water found in the spaces or void between rocks and soil particles.

High-capacity well – A well capable of pumping 70 gallons per minute.

Holding tank – A tank that collects wastewater and holds it to be removed from the site.

Impervious – Not able to pass water.

Infiltration ponds – Ponds designed to allow water to soak into the ground.

Lake budgets– The quantification of sources and losses of a specific lake's component such as nutrients or water.

Lake modeling – A planning tool that allows for computer simulation of real-time lake actions.

Mass balance – Equalizing both sides of an equation.

Nitrate – NO_3, a form of nitrogen in fertilizers and used by plants. When found in water, nitrate often is considered a pollutant.

POWTS – Private on-site wastewater treatment system. Commonly referred to as a septic system.

Ppm – Parts per million, an expression of concentration.

Quantitative monitoring – Monitoring the amount of something. In this case, water.

Recharge – The movement of water into the ground to replenish groundwater.

Septic system – A series of wastewater treatment processes that includes, at the least, a septic tank and a soil-absorption system.

Shallow groundwater – In the Geneva Lake area, groundwater in the shallow sand-and-gravel aquifer that runs in depth from the surface to about 200 feet.

Stream base flow – The amount of stream flow contributed by groundwater and not runoff.

Surface watershed – The area of land that drains into a specific surface.

Total coliform – Includes all forms of coliform bacteria.

Wastewater – Sewage

Water budget – The quantification of water loss and input into a surface water feature.

Water table – The top of the zone of water saturation in the ground.

ACKNOWLEDGEMENTS

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