FACT SHEET

Office of Drinking Water & Municipal Assistance – Environmental Assistance Center 800-662-9278

WATER WELLS IN SHALLOW CARBONATE BEDROCK

Everyone who lives outside a public water system service area wants a safe on-site water supply for their household use. Throughout Michigan, well drilling contractors are generally successful at obtaining adequate quantities of potable water. However, geologic conditions and land use practices in some limited areas of Michigan can result in unpredictable groundwater quality. Public health can be threatened if proper precautions are not taken.

What is Karst?

A geologic condition of concern is known as "Karst". These environmentally sensitive hydrologic systems occur in soluble bedrock (limestone, dolomite, or gypsum) close to the ground surface. Over time, and under certain circumstances, the bedrock is susceptible to extensive vertical and horizontal fracturing, solution channeling, and cave production. Common natural Karst features include:

1. Sinkholes – Depressions in the ground surface caused when sediment overlying the bedrock washes into bedrock channels and cavities or by the collapse of cave roofs. Sinkholes vary in size and have slopes ranging from gradual to severe. Small sinkholes are referred to as "swallow holes." Surface water draining into sinkholes and swallow holes can enter nearby wells quickly.
2. Bedrock outcroppings – Limestone or dolomite bedrock protruding from the ground surface.
3. Springs – Water flowing out of the ground from subsurface flow paths.
4. Disappearing or sinking streams – Small surface streams that enter subsurface flow paths.
5. Earth cracks – cracks from a few inches to several feet formed when a limestone formation leans toward an unsupported area such as a valley.
6. Flaggy soil – soil with "flags" of small limestone pieces mixed with the soil. The mapping of flaggy soils is a useful identifier of limestone bedrock a short distance beneath the surface.

Areas of the Fiborn Karst Preserve in the eastern Upper Peninsula, the Stevens Twin Sink Preserve, the Bruski Sink in Alpena County, the Garden Peninsula of Delta County, Presque Isle County, and southern Monroe Counties contain unique Karst geological features.

Well Contamination in Karst

Waterborne illness outbreaks have occurred in Karst areas in Chippewa, Mackinac, Monroe, and Presque Isle Counties. Over 150 people suffered from gastrointestinal symptoms (nausea, vomiting, diarrhea, stomach cramps) and six were hospitalized in the four outbreaks that occurred between 1959 and 1991.

In 2004, a large waterborne illness outbreak involving 1,450 individuals occurred on South Bass Island, a popular resort area within an Ohio Karst region. Wells at 12 island businesses were shut down after coliform bacteria were detected. Of 42 household wells that were tested in the Ohio outbreak, 76 percent contained coliform organisms and E. coli (fecal bacteria) was found in 26 percent. After sampling public and private wells, Ohio officials concluded that substantial microbiological contamination of groundwater exists across the island.

In the two most recent Michigan outbreaks, investigators confirmed direct hydraulic connections between on-site sewage systems and water wells by using fluorescent, nontoxic tracing dye. During a well contamination investigation in Presque Isle County, dye traveled at a rate over 750 feet/day. The detection of the dye in well water, after being flushed into a septic tank, is a vivid reminder of the need for diligent water supply surveillance by well owners, well drillers, and public health officials.

Water Supply Concerns in Karst

Karst groundwater quality and quantity issues can be challenging. While drinking water quality is the more predominant concern, well yield or capacity problems may be encountered. Karst aquifers are sometimes called "triple-porosity aquifers." Groundwater moves in three interconnected but distinct frameworks: matrix, fractures, and conduits. The speed of groundwater movement varies within the framework. Movement through the bedrock matrix is relatively slow, with higher velocities within fractures and the fastest rates occurring in conduits. Water table fluctuations due to heavy rainfall or flooding can be more dramatic and flashy because of conduit patterns. Some points to remember are:

- Wells can be vulnerable to contamination and unpredictable water quality because of geological characteristics and land use activities.
- Shallow unsafe Karst aquifers can produce large volumes of water because of the bedrock fractures and crevices. In seeking a safe, but deeper water supply, it is not unusual to encounter tight bedrock with very few water-yielding fractures.
- Caution must be used when drilling deeper because deeper aquifers can contain high levels of naturally-occurring minerals. The poorer quality groundwater can be aesthetically-unpleasant, and difficult and expensive to treat.
- A thin layer of fine-grained unconsolidated material such as glacial till is often located above the bedrock. The fine-grained material limits the amount of natural filtration and purification that can occur as rain and meltwater percolate downward.
- Contaminants, such as microbes (bacteria, viruses, etc.) and chemicals, may not be naturally filtered out by the time they enter the groundwater.
- Contaminants in Karst bedrock can move quickly in fractures and conduits that extend for considerable distances. Groundwater flow rates can be as rapid as several hundred feet per hour. The transport of viable disease-causing microbes over greater distances is more probable in Karst bedrock than in unconsolidated glacial deposits.
- Minimum separation distances between water wells and contaminant sources (such as on-site sewage systems) are less effective in Karst settings. The effectiveness of minimum separation distances relies on the inability of many harmful microbes to survive for long periods in groundwater. The uncertainty of a contaminants' flow path due to heterogeneous and anisotropic conditions, combined with rapid groundwater velocities, and less time for natural microbial die-off and attenuation of chemicals, makes separation distances less reliable as a means of protecting water supplies.
- Testing for coliform bacteria and chemical contaminants should be done at least annually, or if the water's taste, odor, or appearance suddenly change.
- If the well water was sampled immediately after disinfection, a bacteriological water test may not be a true indicator of natural groundwater because of residual effects of the chlorine. Retesting is advised.
- If well water turns cloudy or becomes discolored after a rainstorm or during spring snowmelt, the well may be under direct influence from surface water. Well construction may be deficient. Well owners should refrain from drinking the water until defects are corrected and water tests confirm its safety.
- Karst bedrock can result in significant variability in well construction success. A well that taps a conduit or crevice can be highly productive with a high transmissivity. A well completed at the same depth just a few feet away may not intersect the permeable conduit network and the tight bedrock may yield little water.
- Atmospheric barometric pressure changes can cause air to rush in or out of vent openings in well caps as the upper bedrock voids react to the pressure changes. Whistling or wheezing sounds may come from the well. In winter, high pressure can cause cold air to freeze up the pump drop pipe if the pitless adapter connection is too shallow.

Well Completion Considerations

The most reliable means of providing an acceptable on-site water supply is to determine the depth of a protected, safe aquifer and extend a grouted casing into that formation. Some successful well completion strategies in Karst areas are:

- Existing wells that produce unacceptable quality water may need additional casing. Cementing in a liner casing that extends beyond the original casing, can solve water quality problems. Liners that rely on packers to seal against the liner pipe and borehole rather than full length cement grouting are more susceptible to leakage and future water quality problems.
- Using neat cement grout, rather than bentonite clay grout, for casing grouting and abandoned well plugging is critical. Rapid groundwater movement in Karst areas may cause clay grout to fail. The well code requires cement grout when bedrock is within 25 feet of the surface.
- The upper weathered part of the bedrock often has a more extensive network of fractures. Well casing pipe should extend below major fracture zones in the upper bedrock. Casing and grouting through the shallow fractures and fissures will seal off upper contaminated water. While the state well code requires that a well casing extend at least 25 feet below ground, over 100 feet of casing may be needed in these special circumstances.
- A test well combined with a downhole camera inspection of the bedrock can help decide the depth of casing placement for new wells.
- The well casing should terminate at least 25 feet below the static water level.
- If large voids are encountered during drilling (drill rods drop a few inches or more and loss of circulation), casing should extend below the void.
- If a confining bedrock layer is present beneath the fractured zone, water quality may be more consistent if the casing is grouted into the confining layer.
- Increasing horizontal isolation distances should not be a substitute for proper well design.

- Well drilling contractors are urged to carefully record the depths and sizes of crevices and large voids encountered. The data should be reported in the geological formation description section on the water well record form. This data assists with geologic mapping efforts.

Despite the best planning efforts, the nature of Karst makes water supply development somewhat unpredictable. Contaminants can suddenly show up in wells that were previously potable. Secondary solution channels can be formed when recharge water flows downward through the bedrock. Rainwater picks up carbon dioxide (CO_2) from the atmosphere. As rain and snowmelt move through soil and bedrock fissures, additional CO_2 is picked up. The CO_2 is formed when organic debris in the soil and sediment within the bedrock fissures are broken down by microbes. The water and CO_2 forms a weak acid that slowly dissolves the carbonate bedrock below. Resistance to hydraulic flow within a fissure is reduced by the breakdown of debris. The additional and widened fissures and channels give contaminants a pathway in which to spread within the bedrock.

Preventive Practices

County health officials who issue well permits in Karst regions should carefully monitor water sample results and compare well construction records to water quality. This helps identify well and casing depth combinations that produce safe water. By carefully tracking water quality data, well permit applicants can be advised about unique well construction practices that are needed for their site. This approach helps eliminate costly and frustrating trial-and-error.

Every effort should be made to promote extension of community water supplies into groundwater problem areas. A community water supply is the best long-term solution for regions with groundwater limitations. If community water is not an option, the local adoption of a “well first” ordinance can help avoid the construction of homes in areas with unsuitable water quality or quantity. It requires successful well completion before a site is developed. Another useful tool for local well permitting programs in Karst regions is the designation of “special well casing depth areas” through a local ordinance or policy. Drilling a well within a designated area would require that (1) a specific minimum amount of well casing be installed or (2) a certain distinguishable bedrock formation be targeted as the point of casing termination.

Vigorous efforts are needed to find all unplugged or improperly plugged abandoned wells. Unplugged abandoned wells or older wells with ungrouted casings are potential pathways for surface water and agricultural runoff to enter aquifers. An open borehole can carry contaminants into deeper aquifers that are otherwise protected. One poorly constructed or unplugged well in a Karst area can impact several neighboring wells. Conducting an abandoned well survey, plugging open wells in accordance with state regulations, and plugging old wells when replacement wells are drilled are critical steps toward protecting groundwater.

A significant long-range step is to make local planners and decision-makers aware of land use practices that influence groundwater quality. The widespread installation of state-of-the-art on-site sewage disposal systems that produce higher quality effluent is advised. Industries with the potential for chemical spills, improper waste disposal practices, agricultural field drainage tiles that discharge into sinkholes, and ditches above Karst aquifers are threats to drinking water quality.

New home development should not occur in areas where aquifers are vulnerable to contamination (e.g., Karst aquifers) unless community public water is furnished. Relying on water treatment as the sole means of providing bacteriologically safe drinking water is risky. Many homeowners are not familiar with water treatment system maintenance. Consequently, when the treatment system no longer works, exposure to illness-causing microorganisms can occur. Since Karst groundwater is under the influence of surface water, treatment beyond continuous chlorination is needed when there is no other water supply alternative for an existing dwelling. Frequent bacteriological and chemical monitoring and maintenance contracts with certified water treatment professionals are recommended to help ensure acceptable water quality.

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