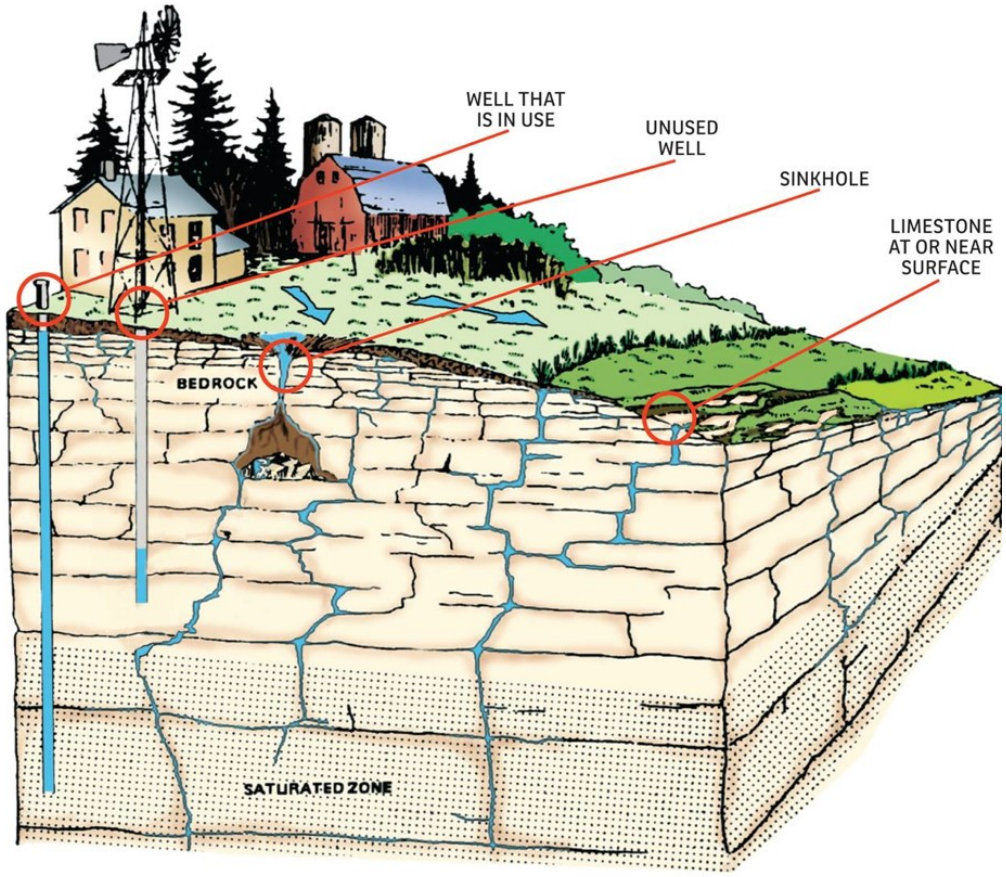
# Karst Hydrology and the Dangers of Contamination: A backgrounder

**Understanding Karst Hydrology**

Karst landscapes are characterized by soluble rock, such as limestone and dolostone, which is prone to dissolution by water. This creates features like sinkholes, caves, and underground streams, forming a unique and highly permeable hydrogeological system. Water flows rapidly through these channels, often traveling miles underground with little to no natural filtration. This permeability means that water – and any contaminants – can move quickly and unpredictably through these regions, posing significant risks to groundwater quality.




**Karst regions** have bedrock with connecting cracks and layers between rocks that easily transport water and pollutants to the groundwater.

**Dangers of Contamination**

The primary danger in Karst regions is the rapid and direct transportation of contaminants from the surface to the aquifer, bypassing natural filtration processes. This is particularly problematic in areas with industrial agriculture, where large quantities of manure and fertilizers are used. Contaminants such as nitrates, phosphorus, and pathogens can quickly enter the drinking water supply, leading to serious public health issues and environmental degradation.

**Case Study: Kewaunee County, Wisconsin (Niagara Escarpment)**

Located along the west side of the Niagara Escarpment adjacent to Lake Michigan, the Karst of Kewaunee County offers a cautionary tale. When industrial agriculture with large animal barns entered the area, a community was devastated by severe groundwater contamination. The high density of livestock operations led to manure leaking from storage lagoons, and excessive manure spreading. Pathogens, pesticides and especially nitrates infiltrated Karst aquifers. Over 30% of wells in Kewaunee County have been found to exceed safe drinking water standards for nitrates and bacteria, and many homes required cisterns and weekly water trucks. Many residents have faced severe health issues, including gastrointestinal illnesses and increased risks of cancer, due to contaminated drinking water. The values of affected properties plummeted, as did the tourism economy. Here in our part of the Niagara Escarpment in Grey Bruce, reports indicate that several wells have tested positive for high levels of nitrates and bacteria, also linked to nearby agricultural operations.

Without stringent regulations and proactive measures, Ontario's Karst areas will face a similar fate. Yet, the Kewaunee region offers research and policies that are relevant for our area. Are we putting similar policies into place ***before*** or ***after*** our region experiences a similar disaster?

## Ontario's most susceptible Karst regions

The counties of Bruce and Grey have one of the most susceptible and vulnerable Karst aquifers in Ontario. Most aquifers in Northern and South Bruce Peninsula, Georgian Bluffs, Meaford, Chatsworth, and Grey Highlands are considered "highly vulnerable" by the province (Figure 2).

Provincial data shows that soil thickness is less than one metre in many of these areas. Without the filtering effect of soil and permanent vegetation, surface contaminants can enter aquifers easily (Figure 3).

Interestingly, neither the Walkerton Tragedy nor some ongoing contaminations of private wells occurred in areas with extremely thin soil cover. Rather, sinkholes surrounded by 2-5m soil cover helped concentrate contaminants and rapidly move them deep into the ground. Karst geology is too complex, too random, and too variable to understand exactly how water flows and where exactly contaminants could enter the underground. Instead we require precautionary management, and broadly avoiding activities that pose the highest risk. Best Management Practices designed for "normal" geological conditions are insufficient to protect citizens here, as other Karst regions have demonstrated again and again.

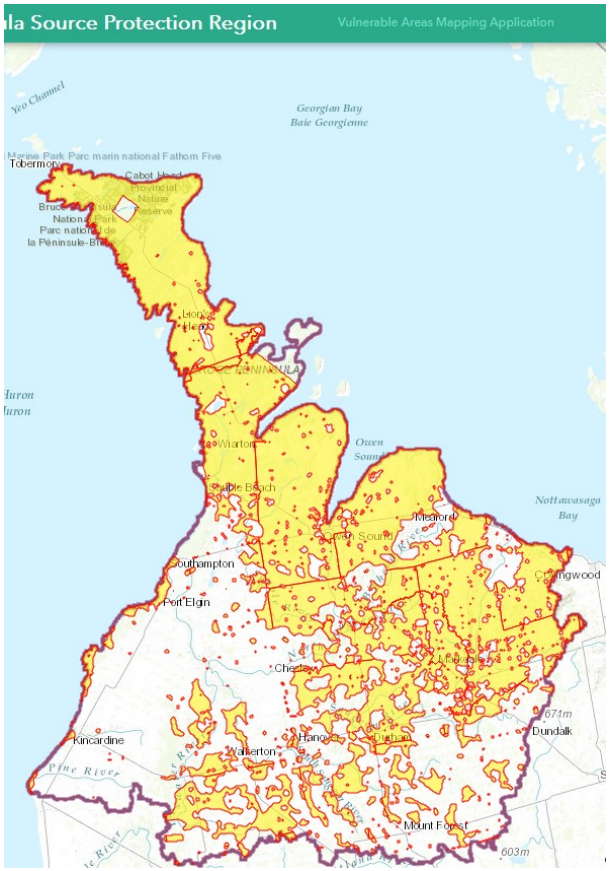



**Figure 2. Highly Vulnerable Aquifers in Grey Bruce. Source: Drinkng Water Source Protection**

**Soil cover above bedrock, in m**

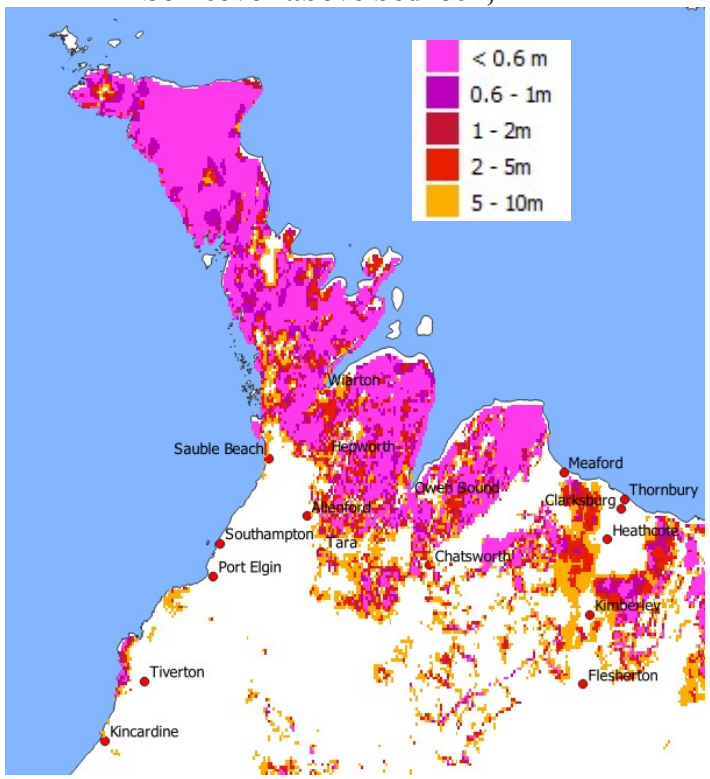



**Figure 3. The thinness of aquifer protection with soil ("overburden" or "drift") in metres. Data source: Bedrock & Overburden, MNR**

**Ontario's public agencies** currently monitor nitrates only in few test locations, even though this is the contaminant of biggest concern in Karst. Normal Drinking Water Tests are not testing for nitrates, so no one knows how severe our aquifer contamination already is. Yet, health research already indicates that Grey Bruce is a hotspot for water-derived diseases.

After Walkerton, Ontario's government agencies now have rich lessons on what can happen without appropriate government oversight. However, there has not been a concerted government effort to protect our Karst aquifers, and the rural communities whose lives depend on these. Again, will we start acting ***before*** or ***after*** disaster strikes? The following pages summarize how contamination happens, and what can be done about it.

**Leaks from Manure Storage are rarely detected before aquifers are contaminated.**

## Point Contamination from Feedlots

Point contamination means that one location contributes large amounts of contaminants, e.g. when cattle deposit a significant volume of manure around and into a sinkhole, or when silage and manure storage leak. Wherever agriculture meets Karst aquifers, concentrated animal feeding operations (CAFOs) and other large accumulation points of manure and/or nutrients pose a major risk for point contamination. Design and construction improvements can mitigate some of these risks. However, case studies have repeatedly demonstrated how time, freeze-thaw-cycles, spring melt, lack of oversight, and lack of enforcement have caused repeated accidents that led to massive damages, complicated class action lawsuits, and community disruptions. We are not aware of a single similar Karst area where feedlot agriculture did NOT cause dangerous and expensive water contamination.

**Pathogens and Nutrients in Aquifers.** Manure from feedlots contains high levels of nitrogen, phosphorus, and pathogens, including E. coli and salmonella. When these contaminants seep into Karst aquifers, they can cause nitrate poisoning in humans and outbreaks of diseases. The rapid transport of contaminants through Karst systems means that even well-managed operations can pose significant risks. For example, one gram of cow manure can contain billions of E. coli bacteria, which can easily contaminate water supplies.

**Sinkholes are rapid conduits for pathogens into the Karst aquifer. Even if farmers fill in sinkholes, they reappear as fill seeps downward.**

**Ontario's Walkerton Tragedy** killed 7 Canadians in the year 2000 and sickened 2,300, many with life-long chronic health issues from Kidney damage. In a following inquiry, Justice O'Connor emphasized the necessity for stringent and proactive government oversight of water safety, robust regulatory frameworks that protect the areas/aquifers where drinking water is drawn from, and clear communication between government agencies, water providers, and the public. The tragedy underscored the dangers of complacency and inadequate training among staff responsible for water quality and enforcement in preventing severe illness and death.

- The counties of Bruce and Grey continue to be a hotspot for water contamination from livestock. Residents have reported cases of gastrointestinal illnesses, and subsequent testing revealed high levels of E. coli and nitrates in the water, prompting calls for stricter regulatory oversight and improved waste management practices.
- Kewaunee County offers a worse-case example, where numerous wells have been found to contain dangerous levels of nitrates and pathogens, directly linked to nearby CAFOs. In some areas 50% of private wells were unsafe and caused diseases. Yet, the community pushed for better management practices and stronger regulations all the way to the Wisconsin Supreme Court – too late to undo the damage, but at least halting further deterioration.

## Diffuse Pollution from Cash Cropping

Aquifer contamination also happens diffusely, e.g. when manure is applied to a large area and enters the groundwater through a myriad of little cracks as conduits. If pollution sources are diffuse, it is rarely possible to attribute the contamination to any one responsible. A compensation lawsuit, currently the only pathway to justice, would not be feasible and any damages from diffuse contamination remain with the community.

**Nitrates and Pesticides in Agriculture --** Cash cropping involves the extensive use of fertilizers (including manure) and pesticides. In Karst regions, the diffuse pollution from these chemicals can be widespread and difficult to monitor. Fertilizers rich in nitrates are often applied in large volumes to maximize crop yields, while pesticides are used to control pests and weeds and disease. Especially when soils are bare and shallow, and rainfall is sudden (photo on the right), these substances leach into groundwater through the porous Karst system. Best Management Practices exist to minimize this leaching, but fail when soil cover above bedrock is less than a metre, as in most areas between Meaford and Tobermory (Figure 3).

**A Grey County field with almost no topsoil above bedrock remains bare much of the year, and manure is applied each spring. The risk for nitrate contamination is high..**

**Health Impacts of Nitrates --** Nitrates in drinking water are particularly concerning. High levels can cause methemoglobinemia, or "blue baby syndrome," which affects the ability of blood to carry oxygen, posing a serious risk to infants. Long-term exposure can also lead to serious health issues, including thyroid disease and various cancers. The World Health Organization recommends that nitrate levels in drinking water not exceed 50 mg/L, yet many regions with intensive agriculture regularly surpass this limit.

**Monitoring and Source Attribution Challenges --** Due to the diffuse nature of pollution from field cropping, it is challenging to pinpoint specific sources. Nitrates and pesticides can come from multiple fields and farms, making it difficult to implement effective monitoring and remediation strategies. The permeable Karst landscape exacerbates this issue, making it difficult to identify and manage contamination sources effectively. This lack of clear attribution hampers efforts to hold polluters accountable and enforce regulations.

**Example from Grey and Bruce Counties, Ontario -** In Bruce County, extensive cash cropping activities have led to elevated nitrate levels in local water sources (e.g. Goss 1998, and we are aware of recent settlements that are not documented). Residents have expressed concerns about the potential health impacts, particularly for children and pregnant women. In Grey County, monitoring efforts have revealed the presence of various pesticides in the groundwater, highlighting the challenges of tracking and managing diffuse pollution in Karst landscapes. These findings underscore the need for comprehensive monitoring programs and targeted intervention strategies, but also for public education, an open conversation and transparent sharing of data. There is much room for improvement here – most recent buyers of property remain totally ignorant of the issue.

## Impact on Private Well Owners and Need for Policy Change

**Contaminated well water in Grey County**

For individuals relying on private wells, contamination can have devastating effects. Contaminated water supplies can lead to serious health issues, financial burdens from medical expenses and from improvising life without a drinking water source, costs associated with finding alternative water sources, eventually disruption of rural businesses, and devaluation of property value. Families may have to invest in expensive water treatment systems, truck in the water used in their home, or rely on bottled water for daily needs. In rural areas, the lack of alternative water sources can be particularly challenging – each homeowner can easily face hundreds of thousands of dollars in damage.

**Compensation and Legal Protection.** Private well owners often struggle to achieve compensation for contamination. Policies may provide some protection, but the lack of specific regulations around private wells means that families frequently have to resort to legal action against a polluter, to seek redress. This process is costly and time-consuming, with no guarantee of success. The burden of proof remains with the injured party, as does the financial cost of an unsuccessful lawsuit. If the alleged polluter is wealthy, he can easily drag out lawsuits with a series of costly studies. Such legal battles place significant stress on affected families, exacerbating the impact of contamination. With diffuse pollution from cash cropping, chances of success are nil. Without regulatory protection, injured homeowners have no other avenue for seeking compensation and carry the damage fully.

**The Need for Better Policy.** Kewaunee-researcher Borchardt found that "*we see a very weak relationship with well construction. The biggest bang for the buck in improving the water quality is the land-use risk factors*." Land-use regulation can protect homeowners from powerful polluters: proven precedents for Karst aquifers with mixed agricultural-residential landuse exist. For example, Ontario can look to Wisconsin's Silurian Bedrock Agricultural Performance Standard as a model for improving protection in Karst regions. This standard includes restrictions on manure spreading, enhanced monitoring, and requirements for protective measures around sensitive areas. This Standard mandates setbacks from sinkholes and Karst features, limits on the application rates of manure, and requires regular groundwater testing to ensure compliance. The question is not whether we will get such standards – it is whether we do so ***before*** or ***after*** a massive disaster for our community.

**Recommendations for Ontario**

- **Immediately recommend Best Practices for farming on Karst**, as developed for similar regions (e.g. the Silurian Bedrock Performance Standard).
- **Proactively implement stricter regulations** around manure spreading and waste management in Karst regions. This should include setbacks from sensitive areas, strict codes for manure and silage storage, limits on manure application, and support for permanent vegetation cover.
- **Enhance monitoring** of groundwater quality in agricultural areas, especially on nitrate loads. Regular testing and public reporting helps identify and address contamination issues more timely and effectively, to mitigate a severe public health tragedy.
- **Establish a comprehensive policy framework** for addressing and preventing groundwater contamination, protecting both public health and the environment. This should include clear guidelines for pollution control, robust enforcement mechanisms, and support for affected communities.
- **Provide support** for private well owners, including testing and financial assistance for contamination mitigation. Government programs should help cover the costs of water treatment systems and alternative water supplies.

Please attend the following meetings, where Dr. Arnold will present the issue to local policy makers. Public participation is critical for its success.

# Invitation to participate in Drinking Water Source Protection Committee Meeting

## July 26, 1pm – 3pm

## Grey Sauble Conservation Authority Building, Owen Sound

The 95th meeting of the Grey Sauble, Saugeen Valley, Northern Bruce Peninsula source protection Committee will take place at Grey Sauble Conservation Authority on July 26th, 1pm. At this meeting, Dr. Thorsten Arnold will present to the committee and request better protective measures for extremely vulnerable Karst aquifers.

## References and further reading

This backgrounder was conplied by Dr. Thorsten Arnold, coauthor of the Drinking Water Source Protection Assessment Report for the Grey Bruce area. If you are interested to learn more about Karst, please visit www.ThorstenArnold.com for several blogs, with links to original sources. Please contact Thorsten at notanotherwalkerton@gmail.com if you want to learn more, write an article about the topic, or participate in a campaign. The following sources are recommended for deeper learning:


- Borchardt MA, Stokdyk JP, Kieke Jr BA, Muldoon MA, Spencer SK, Firnstahl AD, Bonness DE, Hunt RJ, Burch TR. Sources and risk factors for nitrate and microbial contamination of private household wells in the fractured dolomite aquifer of northeastern Wisconsin. Environmental Health Perspectives. 2021 Jun 23;129(6):067004.
- Burch TR, Stokdyk JP, Spencer SK, Kieke BA Jr, Firnstahl AD, Muldoon MA, et al. 2021. Quantitative microbial risk assessment for contaminated private wells in the fractured dolomite aquifer of Kewaunee County, Wisconsin. Environ Health Perspect 129(6):067003. https://pubmed.ncbi.nlm.nih.gov/34160247/, https://doi.org/10.1289/EHP7815.
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- Iowa Dep. of Natural Resources: Contamination in Karst. https://www.iowadnr.gov/environmental-protection/water-quality/private-well-program/private-well-testing/contamination-in-karst
- Majury, Anna, 2017. Beneath the surface: Probing the dynamics of private well water. https://www.publichealthontario.ca/en/About/News/2017/RIA-Private-Well-Water
- Quinte Conservation, Karst (Unstable Bedrock) Investigation Guidelines. https://www.quinteconservation.ca/en/watershed-management/resources/Documents/Reports%20and%20Studies/Karst%20Guidelines/Karst%20Guidelines2023.pdf
- Silurian bedrock performance standards. NR 151.075. https://docs.legis.wisconsin.gov/code/admin_code/nr/100/151/ii/075/10/b/2