Randomized Voluntary Assessment of Private Well Water Quality in PGOLID

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ABSTRACT

Private wells are the sole source of drinking water for residents of the Pelican Group of Lakes Improvement District (PGOLID) in Otter Tail County, Minnesota, yet comprehensive well water quality data for the district have been limited. Previous localized testing indicated elevated arsenic and concerns related to water hardness and taste. To characterize groundwater quality and inform future management decisions, PGOLID conducted a randomized voluntary assessment of private wells during summer 2025.

PGOLID comprises 935 property owners across 44 lake-shore beaches. A randomized subsampling design was implemented using a beach-based framework, with target sample sizes proportional to the square root of parcels per beach and a minimum of three samples per beach. Property owners were recruited voluntarily using randomized lists and standardized outreach. Raw water samples were collected from outdoor spigots by a state-certified laboratory to reflect aquifer conditions. Samples were analyzed for arsenic, nitrate, coliform bacteria, hardness, iron, and manganese.

A total of 247 samples were collected (98% of the target of 252). Arsenic was the most prevalent contaminant: 45% of wells exceeded the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 10 µg/L, and an additional 27% had detectable arsenic concentrations between 2 and 9 µg/L. Arsenic occurrence showed no clear spatial pattern and was not correlated with well depth; arsenic was not detected in sand point wells. Nitrate concentrations were generally low, with 94% of wells below 3 mg/L, 5% between 3–9 mg/L, and 1% exceeding the EPA MCL of 10 mg/L, with localized hotspots observed. Coliform bacteria were detected in 11% of raw water samples. Groundwater hardness was uniformly high (median 325 mg/L as $CaCO_3$).

These results indicate that arsenic represents a widespread and significant drinking water concern for PGOLID residents, while nitrate and bacterial contamination are more localized. The study demonstrates the effectiveness of a randomized voluntary, beach-based sampling framework for community-scale groundwater assessment and underscores the importance of routine testing and targeted treatment for private well users in regions with naturally occurring arsenic.

INTRODUCTION

The Pelican Group of Lakes Improvement District (PGOLID) is a taxing district including the parcels touching the lakeshore of Pelican, Little Pelican, Bass, and Fish lakes in Otter Tail County, Minnesota. PGOLID comprises approximately 1,696 parcels with 935 identified property owners. With an estimated market value of $1 Billion, it is a regionally significant group of lakes. Approximately 84% of property owners are seasonal, mainly visiting from North Dakota, and 16% are year-round residents. All residents rely on private wells for drinking water.

Commonly tested parameters in drinking water wells include arsenic, nitrate, coliform bacteria, hardness, iron, and manganese. Arsenic, nitrate, and coliform bacteria are public health concerns, white hardness, iron, and manganese can affect the water’s taste and treatment needs.

Previous local testing indicated elevated arsenic levels in the region, along with complaints about water hardness and taste. To characterize water quality and inform potential infrastructure decisions, PGOLID initiated a randomized voluntary study of private wells during summer 2025.

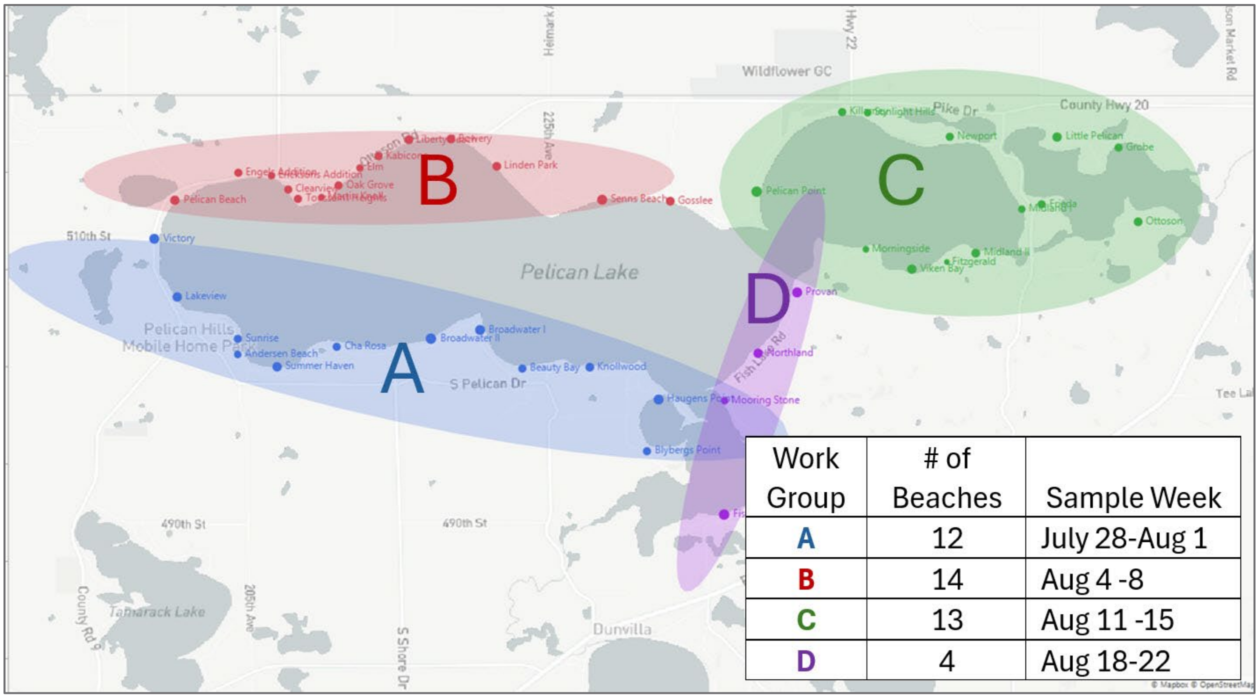
METHODS

Sampling Design

There are 935 property owners in PGOLID, but due to the cost and difficulty in getting samples from all properties, a randomized voluntary subsampling approach was designed. PGOLID properties are divided into 44 beaches. Selection was based on the square root of parcels per beach, rounded up plus one spare, with a minimum of 3 samples per beach. The target sample size was 252 wells across the 44 beaches.

Voluntary Recruitment

A randomized list of properties on each beach was generated using Microsoft Excel. Recruitment for voluntary participation in the study involved volunteer Beach Captains contacting property owners using a standardized script emphasizing confidentiality and voluntary participation. They called property owners in order on the random list to opt in or out of the study. Once they reached the target sample size per beach they stopped. Property owners that opted in were also asked about their well type (drilled or sand point), well depth, installation year, and if they are satisfied with the water. Beach Captains were given approximately three weeks to finish their sample list per beach and turn it into the PGOLID Board. The sample list from each beach was combined into one list and then separated into four sample groups based on proximity for efficient field work (Figure 1).



Work Group	# of Beaches	Sample Week
A	12	July 28-Aug 1
B	14	Aug 4 -8
C	13	Aug 11 -15
D	4	Aug 18-22

Figure 1. Sample work groups and sampling schedule in 2025.

Sample Collection

A state-certified local laboratory (RMB Environmental Labs in Detroit Lakes, MN) was hired to collect raw water samples from outside spigots. This enabled the results to reflect the aquifer quality and avoid conditioned water. It also enabled efficient sampling because samples could be collected without the property owner being home. Tests performed included hardness, iron, manganese, nitrate, coliform bacteria, and arsenic. The testing was conducted over a span of four weeks in August of 2025 (Figure 1).

RESULTS

Samples Collected

In total, 247 samples were collected (98% of target) (Table 1). There were no samples collected from Robinswood Beach. There were less than three samples collected from Fitzgerald Beach, so to keep n≥3, Fitzgerald Beach results were merged with neighboring Midland II Beach.

Table 1. Targeted samples and actual samples completed per beach.

Sample Group	Beach Number	Beach	Properties	Target Samples	Samples Completed	Difference
A	30	Blybergs Point	12	5	5	
A	31	Haugens Point	32	7	8	1
A	32	Knollwood	23	6	6	
A	33	Beauty Bay	16	5	5	
A	34	Broadwater I	43	8	8	
A	35	Broadwater II	51	9	9	
A	1	Lakeview	30	7	7	
A	2	Victory	33	7	7	
A	37	Cha Rosa	13	5	5	
A	38	Summer Haven	34	7	7	
A	39	Andersen Beach	6	4	4	
A	40	Sunrise	10	5	5	
B	3	Pelican Beach	29	7	7	
B	4	Engels Addition	11	5	5	
B	5	Ericksons Addition	5	4	4	
B	6	Clearview	13	5	5	
B	7	Toussaint Heights	11	5	5	
B	8	Martin Knoll	4	3	3	
B	9	Oak Grove	14	5	5	
B	10	Elm	7	4	4	
B	11	Kabicona	14	5	5	
B	12	Liberty Beach	19	6	6	
B	13	Bowery	18	6	6	
B	14	Linden Park	24	6	6	
B	15	Senns Beach	46	8	8	
B	16	Gosslee	24	6	6	
C	21	Robinswood	3	3	0	-3
C	17	Pelican Point	60	9	9	
C	18	Killarney	15	5	5	
C	19	Sunlight Hills	8	4	4	
C	20	Newport	14	5	5	
C	22	Midland I	15	5	4	-1
C	23	Midland II	20	6	6	
C	24	Fitzgerald	4	3	2	-1
C	25	Viken Bay	31	7	7	
C	26	Morningside	8	4	3	-1
C	41	Little Pelican	31	7	7	
C	41A	Grobe	16	5	5	
C	41B	Ottoson	17	6	6	
C	41C	Frieda	13	5	5	
D	27	Provan	45	8	8	
D	28	Northland	32	7	7	
D	29	Mooring Stone	8	4	4	
D	42	Fish Lake	53	9	9	
		TOTALs	**935**	**252**	**247**	**-5**

Well information

Out of the 80% of property owners knew their well type, 78% are drilled wells and 22% are sand point wells. Well depths varied from 9 feet to 300 feet, with a median depth of 96 feet. Out of the 50% of property owners that knew their well installation year, well ages ranged from 1946-2025, with a median of 2006. Most of the property owners responded with their satisfaction of their well water, with 79% saying they were satisfied and 21% saying they were not satisfied (Figure 2).

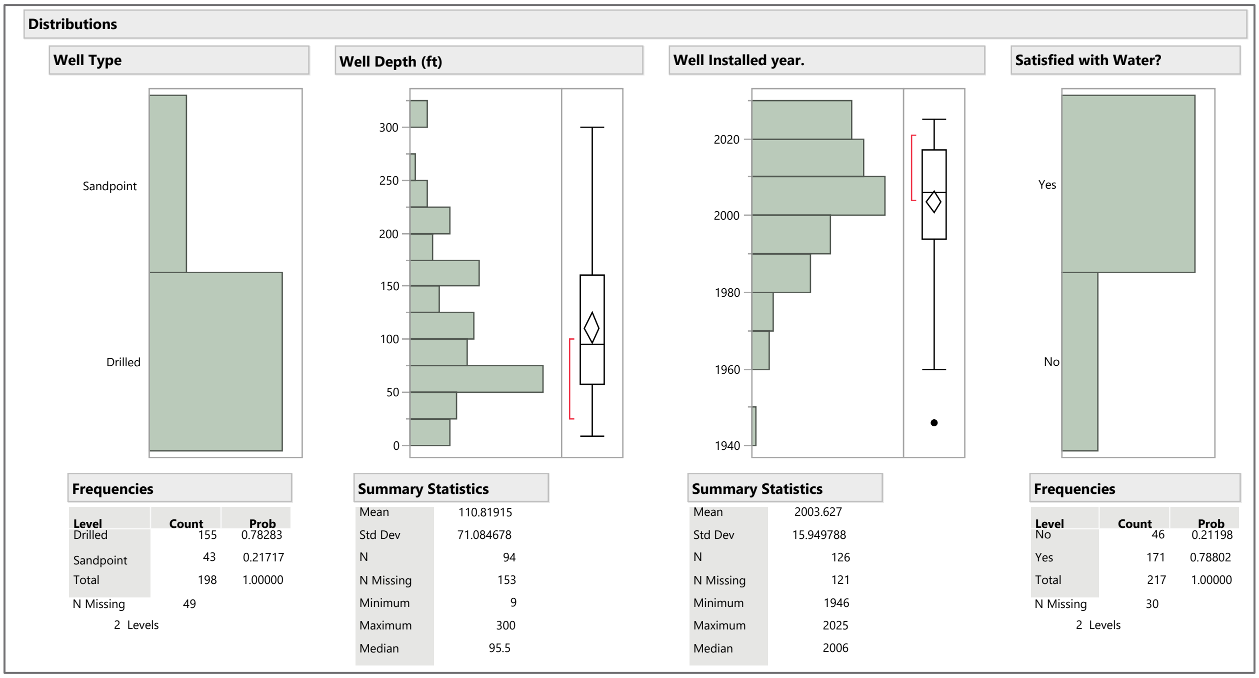


Figure 2. Summary statistics of the property owner well survey.

Hardness, Manganese, and Iron

Distribution analysis of the hardness data indicated that 28 (11%) of the water samples had been softened. These samples were removed from the data set for the analysis per parameter below.

With the softened samples removed, the hardness ranged from 138 to 627 with a median of 325. Manganese ranged from 0 to 930 µg, with a median of 210 µg. Iron ranged from 0 to 10.6 mg/L, with a median of 0.9 mg/L. See the **Discussion** section for interpretation of these results.

Arsenic

Arsenic results showed that 98 (45%) of the wells tested were over the EPA standard for arsenic in drinking water, and 58 (27%) of the wells tested had arsenic detected at 2-9 µg/L (Table 2). The results showed no spatial distribution pattern (Figure 3). In addition, high arsenic results were not correlated with well depth, although arsenic was not present in sand point wells (Figure 4).

Table 2. Arsenic results for PGOLID wells.

Arsenic Range	Number of PGOLID Wells	Percentage
<2 µg/L (less than detection)	62	28%
2–9 µg/L	58	27%
>10 µg/L (over EPA Standard)	98	45%

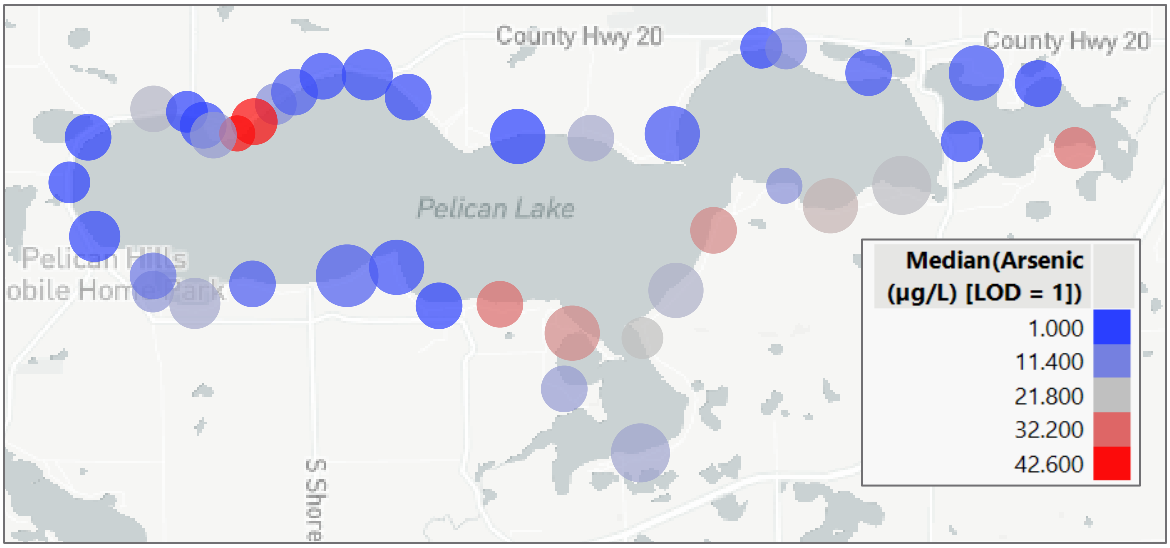


Figure 3. Spatial distribution of arsenic results.

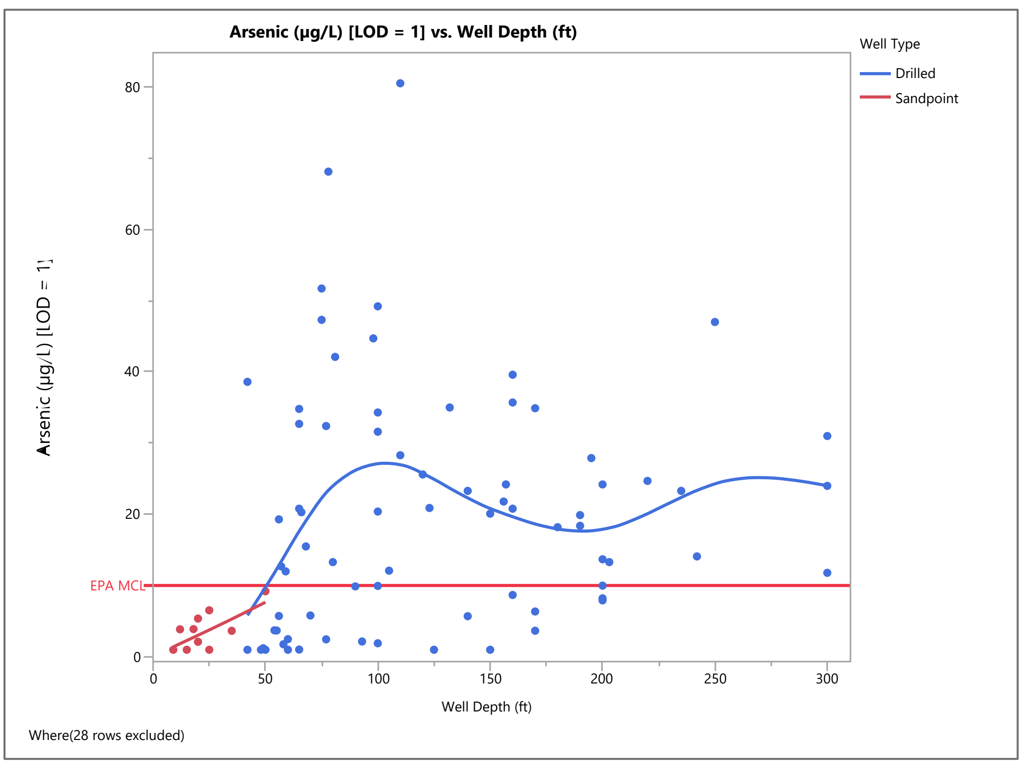


Figure 4. Arsenic results related to well depth.

Nitrate

Nitrate results showed that 2 (1%) of the wells tested were over the EPA standard for nitrate in drinking water, and 11 (5%) of the wells tested had nitrate detected at 3-9 µg/L. The majority of the wells tested had less than 3 µg/L of nitrate, with 176 of them having 0 µg/L (Table 3).

Nitrate was found in particular hotspots, with Liberty, Clearview, Senns, Linden Park, Lakeview, and Broadwater I having three or more non-zero values for nitrate (Figure 5).

Table 3. Nitrate results for PGOLID wells.

Nitrate Range	Number of PGOLID Wells	Percentage
<3 (very low)	206 wells	94%
3–9 mg/L	11 wells	5%
≥10 mg/L (over EPA Standard)	2 wells	1%

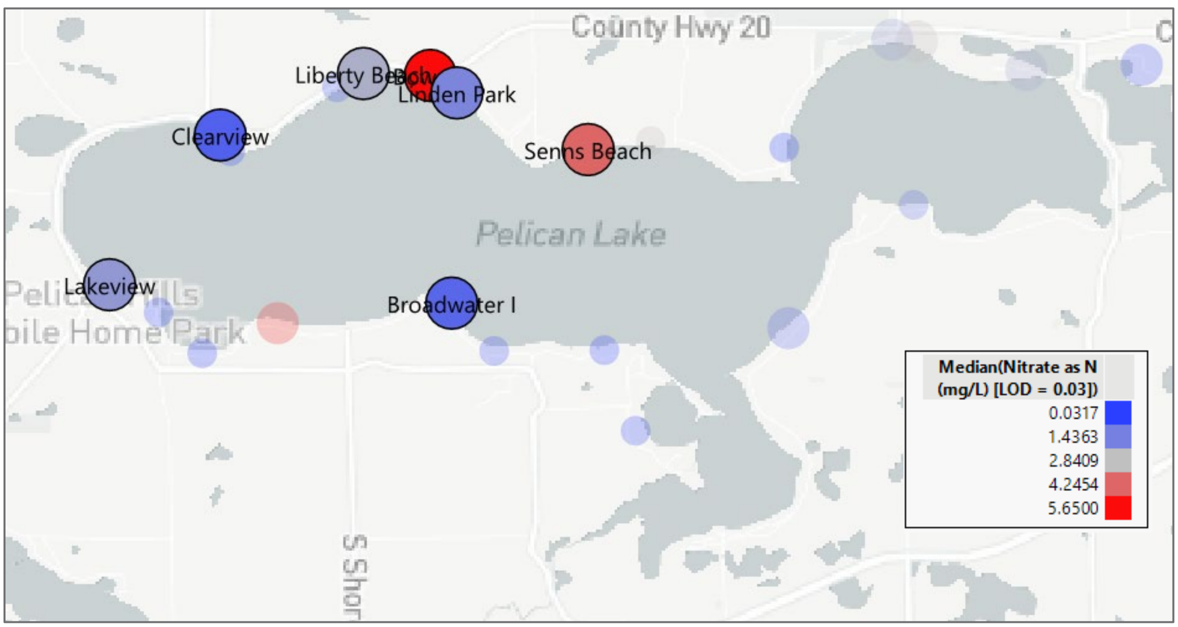


Figure 5. Distribution of nitrate detection by beaches with three or more non-zero values for nitrate.

Bacteria

Coliform bacteria were present in 23 (11%) of the raw water samples.

DISCUSSION

This randomized voluntary assessment provides a comprehensive characterization of private well water quality within PGOLID. The high completion rate (98% of target samples) across nearly all beaches demonstrates that a beach-based randomized voluntary recruitment strategy can be an effective and practical approach for community-scale groundwater assessment in lake improvement districts. The results confirm that while many wells provide acceptable drinking water, a substantial proportion of PGOLID residents are exposed to contaminants of potential health concern, most notably arsenic.

Participants in this study were provided with individual results from the lab. Their results per parameter guide their future treatment needs. The results in this report are aggregated by beach or lake-wide.

Arsenic Occurrence and Implications

Arsenic was the most prevalent contaminant identified, with 45% of sampled wells exceeding the U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 10 µg/L, and an additional 27% detecting arsenic at concentrations between 2 and 9 µg/L. To ensure long-term health, the EPA recommends drinking no arsenic, which then means that 72% of PGOLID wells need arsenic mitigation. These findings are consistent with previously documented naturally occurring arsenic in Minnesota bedrock aquifers and corroborate earlier localized testing that suggested elevated arsenic in the region.

The absence of a clear spatial pattern and the lack of correlation between arsenic concentration and well depth suggest that arsenic occurrence in PGOLID is controlled by localized natural geological conditions rather than lake proximity, beach location, or drilling depth alone. Notably, arsenic was not detected in sand point wells, which likely reflects their shallower depth and reliance on different aquifer materials than drilled bedrock wells. However, sand point wells represented a smaller proportion of the sample and may be more vulnerable to other contaminants, emphasizing that no single well type is universally protective.

Given the chronic health risks associated with long-term arsenic exposure, including increased risk of cancer, cardiovascular disease, and adverse developmental outcomes, these results have important public health implications. Because arsenic is colorless, odorless, and tasteless, the high rate of reported satisfaction with well water (79%) underscores that sensory perception is not a reliable indicator of safety and that testing is essential.

For property owners with arsenic, an arsenic reduction unit can be installed in areas where water is consumed and used for cooking, usually the kitchen. Contact a local water conditioning company to learn about treatment options. To read more about arsenic, visit the Minnesota Department of Health (MDH) website here.

Nitrate Patterns and Land Use Considerations

Unlike arsenic, nitrate in groundwater is usually human caused. Nitrate concentrations were generally low across PGOLID, with 94% of wells testing below 3 mg/L and only 1% exceeding the EPA MCL of 10 mg/L. This suggests that, at a district-wide scale, groundwater is not heavily impacted by widespread nitrate contamination. However, the identification of nitrate "hotspots" in specific beaches including Liberty, Clearview, Senns, Linden Park, Lakeview, and Broadwater I, indicates that localized land use factors, such as septic system density, well placement, soil characteristics, or historical land management practices, may influence nitrate occurrence. To read more about nitrates in well water, visit the MDH website here.

While the majority of nitrate detections were below regulatory thresholds, the presence of detectable nitrate in these areas may warrant targeted follow-up, particularly for households with infants or vulnerable populations.

Bacterial Contamination and Well Integrity

Coliform bacteria were detected in 11% of sampled wells, indicating potential vulnerabilities in well construction, maintenance, or surface water intrusion. Because samples were collected from raw water prior to treatment, these detections reflect aquifer or well integrity conditions rather than household plumbing issues. While coliform presence does not necessarily indicate fecal contamination, it signals pathways through which pathogens could enter the well and suggests that periodic disinfection, inspection, or structural improvements may be necessary for affected wells.

Property owners with positive bacteria results should first re-sample to confirm the results. If they are still positive, then the well should be chlorinated. To read more about coliform bacteria, visit the MDH website here.

The occurrence of bacteria across multiple beaches further reinforces the importance of well-specific management rather than assumptions based on location alone.

Hardness, Manganese, and Iron

Hardness values were uniformly high across PGOLID, with a median of 325 mg/L (as $CaCO_3$), consistent with groundwater derived from carbonate-rich geologic formations. The identification of softened samples, even though raw-water sampling was requested, indicates that some properties may not know the details of their household water system. While hardness itself is not a health concern, it strongly influences water taste, scaling, and treatment decisions, which likely contributes to the high prevalence of water softeners and resident dissatisfaction in some cases.

Manganese occurs naturally in rocks and soil and can be found in water, food, and air. The human body needs some manganese to stay healthy. The recommended daily intake for manganese depends on a person's age and sex. For humans over one year old, a safe level of manganese in drinking water is 300 µg/L or less. A range of 0 to 930 µg of manganese was found in PGOLID wells, with a median of 210 µg/L. Treatment is recommended for wells over 300 µg/L (64 wells). To read more visit the MDH website here.

Iron in water does not usually present a health risk. The human body needs iron to transport oxygen in the blood. Most iron comes from food, since the body cannot easily absorb iron from water. Iron may give water a metallic taste and affect how food and beverages, such as coffee, taste. Iron can also cause yellow, red, or brown stains on dishes, laundry, and plumbing fixtures. Water treatment, such as softeners, can help reduce iron. To read more visit the MDH website here.

Study Limitations

This study relied on voluntary participation, which may introduce selection bias if property owners with known or suspected water quality issues were more likely to participate. However, the randomized recruitment process, high participation rate, and broad geographic coverage reduce the likelihood that results substantially overestimate contamination prevalence. Additionally, some well information (depth, age, type) was unavailable for a portion of participants, limiting the ability to fully assess relationships between well characteristics and contaminant occurrence.

Sampling was conducted during a single summer season, and temporal variability, particularly for bacteria and nitrate, was not assessed. Future studies could incorporate repeat or seasonal sampling to better characterize short-term variability.

Management Implications and Future Directions

The findings of this study have direct implications for PGOLID decision-making. The widespread occurrence of arsenic supports the need for continued education, routine testing, and household-level treatment rather than reliance on voluntary or complaint-driven testing alone. The lack of a predictable spatial pattern suggests that district-wide solutions such as centralized water supply, point-of-entry treatment programs, or financial assistance for arsenic treatment, may warrant consideration alongside individual well management. Importantly, treatment systems such as softeners and reverse osmosis do not fully remove arsenic, which reinforces the need for targeted treatment where arsenic is present.

Additionally, the beach-based sampling framework developed for this study provides a replicable model for future monitoring, targeted follow-up in identified nitrate or bacteria hotspots, and evaluation of trends over time.

Overall, this assessment demonstrates that while PGOLID groundwater is generally low in nitrate and bacterial contamination, arsenic represents a pervasive and significant risk. Addressing this issue will require a combination of continued monitoring, public education, and infrastructure or treatment strategies to ensure safe drinking water for both seasonal and year-round residents.