A Groundwater Strategy for Michigan:

Protecting the “Sixth Great Lake”

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Flow Water Advocates

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Cover image credit: NOAA Great Lakes CoastWatch 2014.

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Executive Summary

The Great Lakes Basin holds approximately one-fifth of the world's surface freshwater supply, positioning Michigan, which is bordered by 4 of the 5 of the Great Lakes, as one of the most freshwater-rich regions in the world. In Michigan, groundwater stock is estimated to be roughly equal to the volume of Lake Huron, at 1,000 cubic miles. Yet, because of the state's abundant surface waters, Michigan's groundwater resources are often overlooked. However, groundwater protection is crucial to securing Michigan's future. Nearly 80% of agricultural irrigation and nearly 75% of commercial water use come from groundwater, with 45% of residents relying on groundwater for their drinking water. Irrigation and household well withdrawals are projected to increase with changes in precipitation patterns and population growth, adding additional pressure to this precious resource.

A Groundwater Strategy for Michigan: Protecting the "Sixth Great Lake" assesses Michigan's current groundwater management landscape, identifies areas for improvement, and proposes recommendations for the state legislature, regulatory agencies, and advocacy organizations to advance groundwater protection. To achieve these objectives, researchers conducted a comprehensive review of existing data on Michigan's groundwater resources and management scheme, policy analysis of Michigan and comparative states, and qualitative interviews with local officials, residents, and experts, focused on 3 case study counties.

The research identifies key gaps in Michigan's groundwater management. Policy analysis reveals that Michigan lacks a dedicated groundwater protection statute, and its management of the resource is a layered application of federal, regional, state, and local policies that each apply narrowly. Despite its crucial role in supporting Michigan's natural resources, residents' quality of life, and the economy, groundwater is not comprehensively managed at the state level. Instead, a patchwork of policies and programs that address aspects of groundwater to varying degrees govern its protection. Interviews and document analysis indicate that this arrangement leads to siloed responsibility, inefficient communication about management decisions, and state-level policies that fail to account for region-specific hydrogeological conditions. Compared to regulatory structures in water-scarce regions and neighboring states, Michigan's current management landscape is limited by inadequate groundwater mapping and data management, and adheres to a limited scale of regulatory evaluation.

Case studies of Antrim, Ottawa, and Washtenaw Counties examine how management of industrial contamination, groundwater scarcity, and large water-user permitting functions occur at the local level, identifying successful practices and opportunities for improvement. These case studies reveal the importance of consistent funding for remediation, the crucial role of community advocacy in promoting regulatory accountability, the need for more robust geologic and hydrogeologic data collection to inform decision-making at all levels, and weaknesses in current regulatory statutes that put groundwater and public health at risk.

The report culminates in proposing a 3-part strategy to advance Michigan's groundwater protection.

1. Pass the Michigan Groundwater Protection Act: This proposed bill package is based on best practices in other states and gaps in Michigan policy, would amend three parts of the Natural Resources and Environmental Protection enhancing to cleanup standards and incorporate groundwater into existing local management, establish a user fee for institutional controls, institute a statewide septic code, create a Groundwater Coordinating Council, support expansion of the state's monitoring well network, and authorize a ballot initiative for a $1 billion bond to directly fund groundwater mapping and a new local grant program.

2. Improve Regulatory Oversight, Data Management, and Transparency: Recommendations to the Department of Environment, Great Lakes, and Energy (EGLE) include continuing to revise the Water Withdrawal Assessment Tool, which governs large withdrawals, augmenting data sharing systems, and creating a targeted groundwater education program.
3. Advocate for Groundwater Policy Improvements: Advocacy organizations should work with coalitions to support the passage of the Groundwater Policy Improvements, create complementary education initiatives to the state-level program, conduct fiscal research, and lead campaigns for additional, dedicated funding for groundwater programs.

The Great Lakes State can and should be a champion in protecting the "sixth Great Lake." This report provides a roadmap for groundwater protection that would put Michigan in this leading role.

1 Introduction

The State of Michigan depends on a vital, yet hidden resource – groundwater. Often referred to as the "sixth Great Lake," groundwater in the Great Lakes basin comprises a volume roughly equivalent to that of Lake Huron.[1] Michigan's aquifer systems directly supply drinking water to residents, irrigate agriculture, and provide inputs for other water-intensive industries. Most groundwater is hydrologically connected to Michigan's vast network of streams, lakes, and wetlands, which sustain aquatic life and support recreational and commercial fisheries. Because of Michigan's wealth of surface waters, its groundwater resources are often overlooked. However, groundwater protection is crucial to the state's water security and the region's long-term future.

Globally, groundwater represents the vast majority of usable freshwater (**Figure 1**). 96% of available freshwater, referring to the water not frozen in glaciers and icecaps, is groundwater.[2] Groundwater supplies roughly half of the world's drinking water, and 38% of irrigated lands rely on it.[3] While the scale of global groundwater resources may seem immense, this critical resource is vulnerable and has historically received less systematic assessment than surface water, largely because characterizing subsurface systems is technically complex and groundwater is not visible.

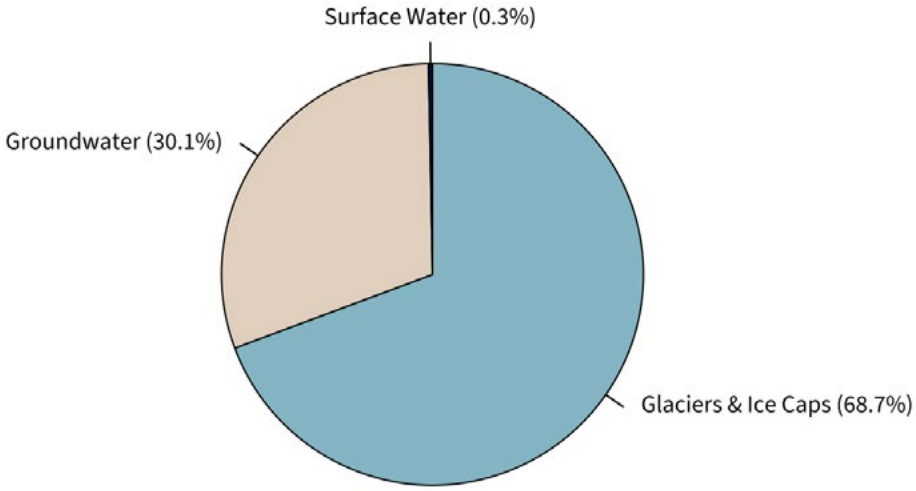

Figure 1. Global distribution of freshwater stores in glaciers and ice caps, surface water, and groundwater. Data from the U.S. Geological Survey (USGS).[4]

The Great Lakes Basin holds around one-fifth of the world's surface freshwater supply, and Michigan is bordered by more freshwater than any other political or geographic region in the world. Because the Great Lakes hold 84% of the nation's freshwater supply, the region is likely to experience increasing resource pressures as temperatures rise, droughts persist in other states, and Michigan's population grows.[5] Within the state, these weather events and precipitation patterns are expected to prompt increased reliance on Michigan's groundwater resources, with agricultural irrigation and household wells already experiencing dramatic increases in withdrawals. As these changes occur, groundwater governance in the United States remains largely decentralized, leaving states and, often, local units of

government responsible for creating, implementing, and enforcing laws, policies, and regulations.[6] This fragmented approach creates inconsistencies in groundwater management, making it even more challenging to address emerging issues and leaving Michigan vulnerable to threats from contamination, overwithdrawal, privatization, and commodification. To effectively manage this key resource in the future, it is essential to establish a comprehensive groundwater protection strategy that integrates surface water management, addresses water security concerns, and invests in the protection groundwater deserves. This report represents a key step toward developing that strategy for Michigan and addressing growing resource concerns.

Research Context

This report builds on a landscape of existing work: research on Michigan's groundwater resources and management recommendations has been conducted by the state government, academic institutions, and non-governmental organizations. At the state level, the Michigan Water Strategy, a 2016 report authored collaboratively by several Michigan state departments, is a 30-year roadmap to manage state water resources.[7] The document outlines nine goals for Michigan's groundwater resources and proposes recommendations, implementation metrics, and lead actors necessary to achieve comprehensive resource protection. It also calls for the creation of a groundwater strategy. Michigan's Water Use Advisory Council (WUAC) reports biennially to the Michigan Department of Environment, Great Lakes, and Energy (EGLE), the Michigan Department of Natural Resources (DNR), and the Michigan Department of Agriculture and Rural Development (MDARD). The WUAC's most recent 2024 report offers recommendations to improve the Water Use Program and highlights accomplishments from previous years' recommendations.[8] The council is established under Part 328 of the Natural Resources and Environmental Protection Act (NREPA) and composed of appointees representing water-using sectors, environmental interests, tribal governments, and hydrogeologists.

Research institutions have also produced reports on Michigan's groundwater management. In 2018, Grand Valley State University's Annis Water Resources Institute released *Integrated watershed management in Michigan: Challenges and proposed solutions*, proposing two novel regional water management structures that would improve planning at an ecologically meaningful scale, leverage coordinated financial strategies, and expand public education.[9] The Cooperative Institute for Great Lakes Research (CIGLR) published a 2022 report titled *Groundwater in Crisis? Addressing Groundwater Challenges in Michigan (USA) as a Template for the Great Lakes*.[10] The report discussed the findings of a virtual summit on Michigan groundwater management with participants from both technical and political backgrounds. The authors developed conceptual models of management responses to various groundwater challenges in Michigan across agricultural, urban, and coastal wetland areas. In 2020, the University of Michigan School for Environment and Sustainability (SEAS) published a report analyzing the risk-based management of groundwater contamination across Michigan.[11] The authors analyzed Part 201 of Michigan's Natural Resources and Environmental Protection Act, which outlines remediation processes for groundwater contamination. The report explains that Michigan's groundwater remediation policy is centered on institutional controls (ICs), a form of land-use control designed to mitigate human exposure while advancing cleanup objectives. In 2023, the Institute of Water Research at Michigan State University (MSU) released a report titled *Michigan Groundwater: Opportunities for Improved Management.*[12] The report evaluates the benefits and threats facing Michigan's groundwater and proposes new initiatives to strengthen data management, data collection, decision-making systems, education, and funding for aquifer recharge. MSU and Flow Water Advocates also furthered research into Michigan's use of ICs in groundwater management, co-authoring a 2024 report titled *Institutional Controls for Groundwater Management: Long-term Costs and Policy Impacts.*[13] This report used seven case study sites of groundwater contamination to examine the long-term economic costs of implementing ICs. In 2025, MSU published an evaluation of Michigan's

water user committee program, finding that none of these state-sanctioned advisory groups have been formed because water users do not trust the state to manage water use, the role and function of the committees is not well communicated, and large-water-users do not perceive water conservation as relevant mission.[14]

Flow Water Advocates, a partner on this report, has published several reports on Michigan groundwater (see more detailed background on their work is just below). The Freshwater Society, a non-governmental organization based in Minnesota, has authored two reports on groundwater management in the Environmental Protection Agency (EPA) Region 5. These reports provide information on how Michigan's groundwater policy compares with those of neighboring states, highlighting Michigan's shortcomings in groundwater education, data availability, and information sharing relative to nearby states.[15, 16]

Across these reports, there are consistent themes that reflect both the areas of greatest consensus and the most urgent concerns. First, existing work stresses that technical tools and processes should be optimized. Within this theme, recommendations include updating the Water Withdrawal Assessment Tool (WWAT), coordinating data management across agencies, and expanding mapping and monitoring efforts. Second, reports recommend investing in comprehensive initiatives to transform groundwater management. Associated recommendations include prioritizing public education, formally recognizing the interconnection of groundwater and surface water, emphasizing groundwater conservation, prioritizing the cleanup of contaminated sites, and dedicating funding to groundwater management. This report adds to existing analyses and recommendations by combining specific local cases in Michigan with the experiences of other states, presenting ambitious goals for which there is both a demonstrated need in Michigan and an existing example elsewhere. It is with appreciation for the analyses and recommendations in these other works that this report continues to examine the challenges and opportunities of Michigan's groundwater management system.

Client Background

Flow Water Advocates (hereafter Flow) is a 501(c)(3) nonprofit organization dedicated to protecting the waters of the Great Lakes Basin for the public's rights and use. Their efforts center around applications of the public trust doctrine regarding threats to water interests and uses. As a nonprofit organization operating within the policy and legal space, Flow has close relationships with Great Lakes groups, legislators, state agencies, higher education institutions, communities, and tribal governments. The organization has particular legal expertise in addition to science-based public policy and ecological knowledge, and its work to date has aligned with these strengths.[17]

Since 2017, Flow has advocated for advancing groundwater protection through reports, model legislation, and public education. Today, Flow's strategic plan advances water protection by focusing on four key areas: the Great Lakes, drinking water, industrial farming, and groundwater. Expanding public education is woven throughout this work. With respect to protecting groundwater, Flow's efforts focus on addressing septic contamination, factory farming and nitrate pollution, algal blooms, legacy contamination, and advancing the "polluter pay" framework for funding the cleanup of contaminated sites.

Key products from Flow upon which this project build include *Public Water, Public Justice* (2018); *The Sixth Great Lake: The Emergency Threatening Michigan's Overlooked Groundwater Resource* (2018); *Deep Threats: Spotlighting and Solving Michigan's Groundwater Emergency* (2021); *Building Consensus: Securing Protections of Michigan's Groundwater* (2023); *Making Polluters Pay: How to Fix State Law and Policy to Protect Groundwater and Michigan Taxpayers* (2023); and *A Watershed Moment: The Great Lakes Compact After Fifteen Years* (2024).[18, 19, 20, 21, 22, 23]

Project Motivations and Approach

This report is motivated by growing concerns surrounding the protection of Michigan's groundwater resources. Despite its history of abundant water, Michigan's water resources are facing rising quantity pressures due to increased agricultural irrigation, greater consumptive use, population growth, and new trends regarding water-intensive industries.[24, 25, 26] Moreover, contamination identified over the last several decades continues to motivate concerns about groundwater quality and pollutant transport. Finally, this research is motivated by Flow's work, which suggests that current groundwater protection in Michigan is fragmented and demands a cohesive, sustainable management approach.[27]

The findings and recommendations in this report do not aim to replicate existing research but rather to expand upon existing analyses of Michigan's groundwater management. To establish a foundational understanding of groundwater, **Section Two** presents an overview of Michigan's groundwater resources and key databases and organizations responsible for collecting and housing groundwater data. Additionally, it explores groundwater withdrawal and contamination, addressing key threats to both quantity and quality. **Section Three** provides an in-depth description of the methods used to conduct the research, highlighting approaches for case study analysis, interviews, and comparative statutory policy analyses. **Section Four** highlights policies that directly and indirectly impact groundwater in Michigan. It also presents a policy analysis of statutory groundwater management by evaluating mechanisms established in five other states, evaluating protections for both groundwater quantity and quality. **Section Five** explores three county-level case studies, their ongoing water resource issues, and the management applications in each case. **Section Six** outlines a 3-part strategy to advance groundwater management, with recommendations for the Michigan legislature, EGLE, and advocacy organizations, based on the report's findings. Finally, **Section Seven** reflects on key findings and proposes next steps for implementation.

2 Overview of Michigan's Groundwater

Michigan's Groundwater

Michigan's groundwater resources are extensive. In the entire Great Lakes Basin, approximately 1,000 cubic miles of fresh groundwater are stored.[28] The storage and flow of groundwater is characterized by the state's glacial history, which has shaped its landscape.[29] While Michigan is surrounded by the Great Lakes and has an overall abundance of freshwater, its unique geological history means the amount of accessible groundwater varies by location. Groundwater is stored in two primary aquifer systems: glacial and bedrock. Michigan is largely covered with glacial deposits, which are especially thick in the northern Lower Peninsula (**Figure A3**). Over 70% of the state's wells draw from glacial deposits.[30, 31] Beneath the glacial deposits lie bedrock aquifers, which tend to be drawn upon in areas where glacial sediment is thin. The Marshall and Saginaw formations are two of Michigan's most productive bedrock aquifers, serving communities throughout the central region of the lower peninsula (**Figure 2**).[32] Geogenic groundwater contaminants–naturally occurring substances from geologic sources–may limit the distributed availability of groundwater for human consumption and usage.

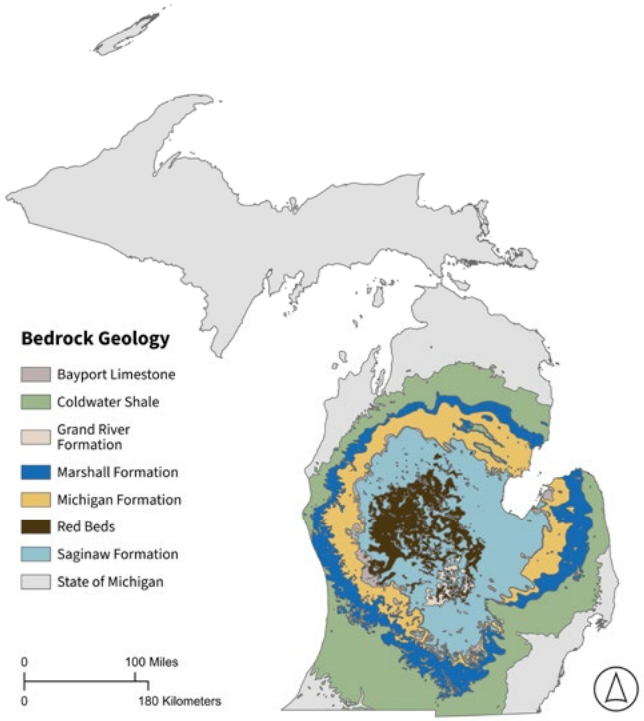

Figure 2. Major Bedrock Geology of the Central Lower Peninsula.[i]
Data source: EGLE GeoWebFace, State of Michigan Open GIS Data.
Projected Coordinate System: NAD 1983 Michigan GeoRef.

Groundwater is a sustained resource only when withdrawals remain in balance with natural recharge. When pumping exceeds recharge over time, aquifers lose storage. Aquifers recharge very slowly, and the residence time of groundwater–the amount of time water spends underground–can range widely.Aquifers recharge when water infiltrates the soil and percolates through the unsaturated zone to the water table. Recharge is spatially variable and often concentrated in specific areas where conditions are favorable. The rate at which aquifers can recharge is complex and depends on many factors, such as aquifer type, climate, soils and geology, vegetation and land use, topography, and depth to groundwater. Confined aquifers, which are bounded by confining layers that prevent flow, recharge less easily than unconfined aquifers. In Michigan, rising temperatures and precipitation, along with a higher frequency of heavy rainfall and extreme weather events interspersed with dry periods, are expected to accelerate in the future, adding

i Bedrock formations were selected based on their inclusion in the USGS 1998 report "Hydrogeologic framework of the Michigan Basin regional aquifer system," written as a part of the Regional Aquifer-System Analysis Program (RASA).

uncertainty to the long-term balance of groundwater supply and demand.[33]

Importantly, Michigan's complex groundwater system is hydrologically connected to its vast surface water resources, including the Great Lakes.[34] It is estimated that direct and indirect groundwater discharges contribute 2.7% and 42% of the inflow to the Great Lakes, respectively.[35] Water moves between surface water and groundwater systems, with surface water infiltrating into the subsurface and groundwater discharging to streams, lakes, and wetlands. This hydrologic connection means that water and the chemicals it contains are continually exchanged between surface water and groundwater, and that groundwater withdrawals can impact surface water flows.[36] Wetlands play an important role in this system by retaining water that would otherwise flow into rivers and lakes, often promoting infiltration to underlying aquifers and improving water quality through natural filtration.[37,38]

Michigan's Groundwater Data

The collection and management of data are crucial to informed groundwater management. In Michigan, four publicly available databases managed by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) provide information on groundwater quantity and quality. These databases are:

- **Wellogic/Water Well Viewer** is Michigan's statewide water well database, which includes comprehensive water well records for after the year 2000 and some historical records.[39, 40]
- **MiEnviro** contains water and air permitting and compliance data, including groundwater discharge permits.[41]
- **Remediation Information Data Exchange (RIDE Mapper)** contains environmental contamination data.[42] RIDE Mapper includes sites regulated under NREPA Parts 201 (environmental contamination sites), 211 (underground storage tanks), and 213 (leaking underground storage tanks). However, Part 201 sites cannot be filtered for sites of groundwater contamination. RIDE Mapper also contains data on land- or resource-use restriction areas and wellhead protection areas (see **Section 4: Policy Analysis**).
- **GeoWebFace** contains geological data. GeoWebFace stores data on the locations of mineral, oil, and gas wells.[43]

In addition to these state databases, various organizations maintain other systems that store important information. These include:

- **U.S. Geological Survey (USGS) Water Data for the Nation** houses a national groundwater database that provides data on Michigan's groundwater resources.[44] Currently, the National Groundwater Monitoring Network (NGWMN) maintains 32 water level network wells and 68 water quality network wells in Michigan.[45]
- The **Great Lakes Regional Water Use Database**, managed by the Great Lakes Commission, contains water use data for the Great Lakes Basin. The database supports queries by jurisdiction, basin, year, water source, and water-use sector.[46]

Geologic and hydrogeologic data collection in Michigan has largely been conducted by EGLE, USGS, and Western Michigan University's Michigan Geological Survey (MGS). Currently, many projects (of which the timelines are variable or unknown, with many in early stages) are underway to collect, organize, and analyze information regarding Michigan's groundwater.[ii]

- The EGLE **Groundwater Monitoring Well Network** is the development of a statewide groundwater monitoring network that will be used to observe trends in groundwater elevations across Michigan. Through this project, EGLE will become a new data provider to

ii L. Pappas, personal communication, February 16, 2026.

NGWMN. EGLE is also developing a statewide stream gauge network to monitor surface waters.

- The EGLE **Groundwater Data Management system (GWDMS)** will centralize Michigan's existing groundwater, surface water, geologic, and chemical data, accept new data entries, support queries, and be linked to GIS; it will consolidate data previously dispersed across different EGLE divisions as paper records.[47]
- The EGLE/USGS **Hydrologic Enhancement for Michigan (HEMI)** project will provide an analysis and enhancement of Michigan's streamgage network, an analysis and enhancement of Michigan's groundwater monitoring network, ground-based and airborne electromagnetic surveys in southwest Michigan, and the development of a regional groundwater flow model in southwest Michigan.[48]
- **MGS STATEMAP** is an eventual goal of establishing a geologic framework for Michigan in areas of importance; currently, surficial geology maps for 6 counties (Allegan, Muskegon, Cass, Kalamazoo, St. Joseph, and Ottawa) are publicly available.[49]
- **MGS Data Gap Analysis** is a project to categorize available Michigan hydrogeologic data and identify areas with data gaps; work includes a statewide correction and validation of water well records.
- **MGS/EGLE Western Michigan Water Resources** is a comprehensive regional water study in Muskegon, Kent, Barry, Kalamazoo, VanBuren, Ottawa, and Allegan Counties in western Michigan, resulting in a public dataset.
- The **Michigan Hydrologic Framework (MHF)** will be a publicly available online model sharing and generation environment with a GIS-enabled interface, facilitating submittal, visualization, validation, and download of shared MODFLOW-based groundwater flow models.[50]

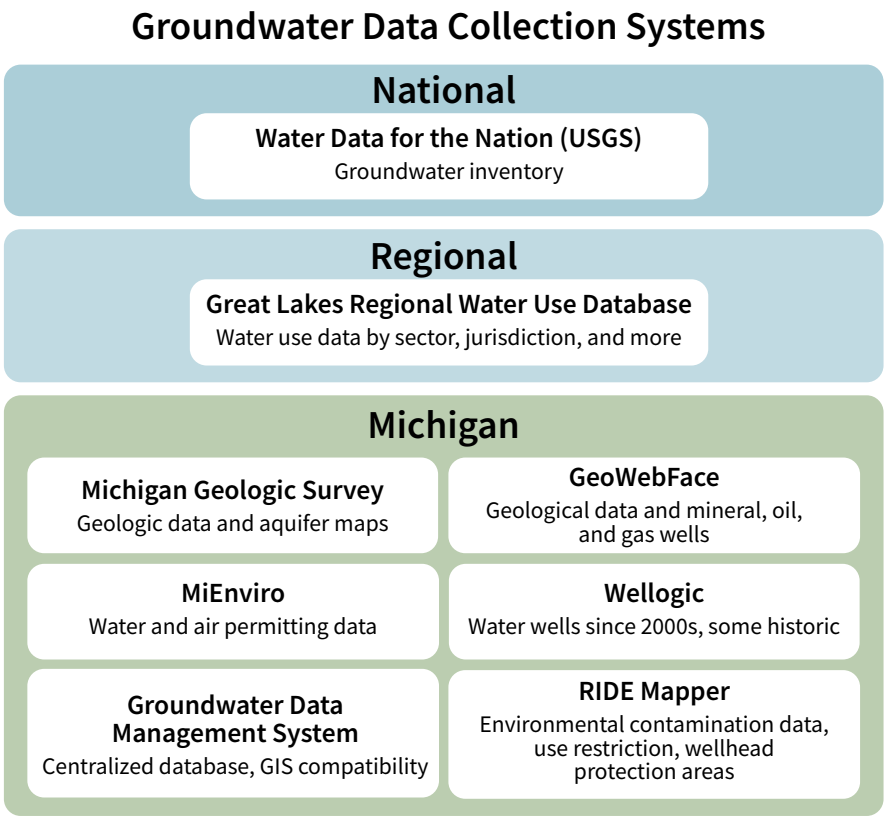

Figure 3. National, regional, and state-level groundwater data collection systems.

Groundwater Withdrawals and Use Patterns

According to a report from 2023, nearly half of all wells have experienced water declines due to pumping outpacing recharge over the last four decades.[51] Overwithdrawal can lead to adverse environmental impacts, including lowered stream and lake levels, fluctuations in stream temperatures, land subsidence (sinking), and saltwater intrusion. In Michigan, saltwater intrusion can occur when deep, brackish water is drawn up into freshwater aquifers from pumping, raising concerns about water quality.[52] Throughout the state, many streams rely on consistent groundwater inputs. Most of Michigan's streams get at least 60% of their baseflow from groundwater, making the state one of the highest baseflow-dominant states in the country.[53] Especially common in the northern Lower Peninsula and the Upper Peninsula, coldwater streams that support culturally and economically important fish species (such as trout) are often gaining streams sustained by groundwater baseflow. Michigan has an estimated 29,538 miles of streams that have been legally classified as "Designated Trout Streams."[54] Overpumping can divert groundwater contributing baseflow to streams throughout the state, potentially affecting water levels, temperatures, and native fish populations.[55] Saltwater intrusion occurs when deep, brackish water is drawn up from the aquifer, raising concerns about water quality.[56]

Figure 4. Brook Trout: the Michigan State Fish. Brook trout are reliant on groundwater-fed streams.[57]

In Michigan, the Water Withdrawal Assessment Process (WWAP) is largely based on the connection between groundwater and surface water. Groundwater withdrawals are evaluated using the Water Withdrawal Assessment Tool (WWAT), a screening tool developed as a part of Michigan's implementation of the Great Lakes - St. Lawrence River Basin Water Resources Compact.[58] The WWAT assesses the impacts of large quantity withdrawals (LQW), defined as withdrawals averaging more than 100,000 gallons per day over a 30-day period. The tool evaluates whether a withdrawal would cause an adverse resource impact (ARI) on nearby streams. Assessments are ecologically based and model fish community responses to streamflow depletion caused by withdrawals. Michigan has defined Water Management Areas (WMA) as drainage areas that group ecologically similar streams in the WWAP process. If a withdrawal is found to cause an ARI, it undergoes a site-specific review (SSR). SSRs are required by law to be completed within 10 business days; however, the 2024 WUAC report recommends an extension of this window to 30 days, which is currently allowed if the SSR is technically complex.[59, iii] A 2024 performance audit identified several limitations of the WWAT, including the use of outdated or limited data for model parameters, SSR delays, discrepancies in streamflow depletion calculations, and concerns about user access and data security.[60, 61]

Recently, the WWAT has been modernized. A redevelopment of the WWAT to integrate PyCap-dss USGS code, released in two stages in 2025 and 2026, allows site-specific parameter inputs and introduces additional streamflow-depletion solutions for different aquifer conditions.[iv] Various other projects are underway to improve Michigan's WWAP: the Aquifer Data Assessment Tool Project to improve aquifer property estimates; catchment-scale accounting, an effort to determine the appropriate area over

iii L. Pappas, personal communication, February 16, 2026.
iv L. Pappas, personal communication, February 16, 2026.

which to track the combined effects of withdrawals on streamflow; downstream accounting, an effort to understand how reductions in streamflow move and change as they travel downstream; and efforts to assess inland lake sensitivity to withdrawals.[62, v]

Not all groundwater withdrawals are created equal. Groundwater use can be categorized as either consumptive, in which case water is withdrawn and not returned to the hydrological system, or non-consumptive, in which case water returns to the same basin from which it was withdrawn or to another water basin. Consumptive use can be calculated either by applying a water-balance equation, where return flows are subtracted from withdrawals, or by multiplying withdrawal amounts by a consumptive-use coefficient.[63] Consumptive use coefficients vary widely by sector and region and equal the amount of water withdrawn that is not returned, divided by the total amount of water withdrawn.[64] Consumptive water uses include evaporation, transpiration, incorporation into products or crops, and consumption by humans or livestock. Consistently, irrigation is by far the most consumptive sector in Michigan. From 2014 to 2023, the reported consumptive use for irrigation was 1,962 million gallons per day (MGD), compared to 245 MGD for the second-largest sector (public supply).[65]

Groundwater withdrawals support many sectors in Michigan, including public water supply, irrigation, and various industries. Between 2014 and 2023, the state's median annual groundwater use was 219 billion gallons, with the irrigation and public water supply sectors accounting for the majority at 93.8 and 77 billion gallons, respectively (**Figure 5**).[66] Across Michigan, the largest water use sector varies by county, and counties see disparate levels of withdrawal (**Figure A4-A10, Figure 6**). Below, the three largest-use groundwater sectors in Michigan (irrigation, public supply, and industrial-manufacturing) are explored in further detail, along with groundwater use from household wells and potential future sources of major withdrawals.

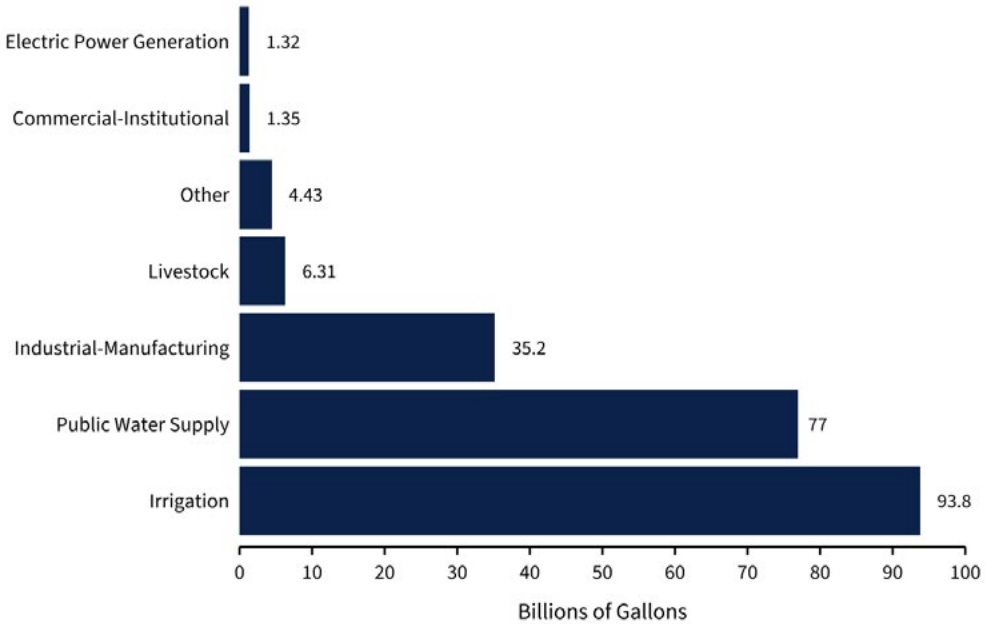

Figure 5. Median Annual Groundwater Usage in Michigan from 2014 to 2023 by Sector.[67] Data obtained from EGLE's webpage for Michigan water use data and filtered for groundwater use.

v L. Pappas, personal communication, February 16, 2026.

Irrigation

Michigan's irrigation sector accounts for the largest share of groundwater use in the state, driven in part by statewide crop diversity (second only to California's).[68] From 2014 to 2023, irrigation used a median annual volume of 93.8 billion gallons of groundwater.[69] Most of these withdrawals occur in the southwest region of Michigan, where agricultural lands are abundant (**Figure A7**).[70] Between 2014 and 2023, the irrigation sector sourced a median of 76.7% of its water from groundwater per year.[71] Importantly, irrigation demand is increasing dramatically: Michigan's total irrigated cropland area expanded by roughly 65% from 1997 to 2017.[72] The number of agricultural irrigation wells more than doubled from 2008 to 2020, suggesting that groundwater is absorbing much of this increased freshwater demand.[73] Michigan's proportion of irrigation sourced from groundwater is higher than that of other states; nationally, 48.5% of irrigation water comes from groundwater.[74]

Public Water Supply

Approximately one-third of Michigan residents who rely on groundwater for their drinking water–1.7 million people–get it from their public water supplies.[75] Between 2014 and 2023, a median of 22.9% of public water came from groundwater, with water utilities using a median of 77 billion gallons annually.[76] Counties with high rates of groundwater use for public supply are concentrated in the southern portion of the Lower Peninsula (**Figure A9**).[77] Nationally, public water supplies receive 39.0% of their water from groundwater.[78] Interestingly, Michigan has 9% of the country's groundwater-supplied public water supply systems, the largest share of any state.[79]

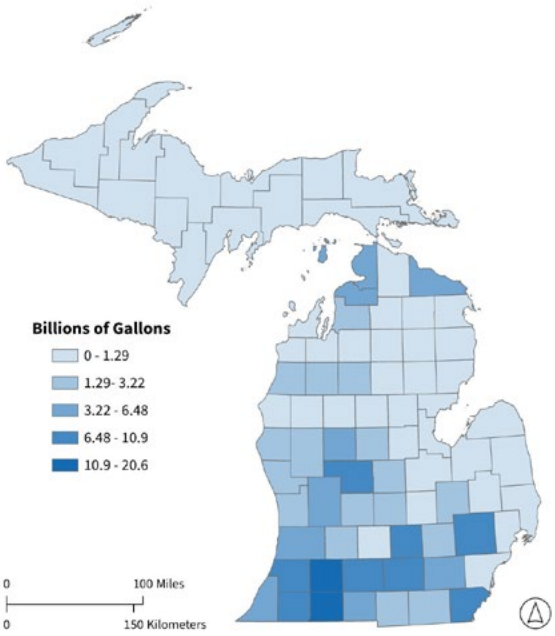

Figure 6. Median Annual Groundwater Use by County in Michigan from 2014-2023.[80. iv]

Industrial Use

Among the most groundwater-intensive industries are pharmaceuticals, cement plants, potash (potassium fertilizer) mining, the pulp/paper sector, and water bottling. The counties with the highest withdrawals for industrial use in 2023 were Monroe (9.8 billion gallons), Presque Isle (7.5 billion gallons), Kalamazoo (6.8 billion gallons), and Charlevoix (3.7 billion gallons).[81] From 2014 to 2023, 15.2% of Michigan's industrial use was supplied by groundwater, compared to 19.1% nationally.[82, 83]

Household Wells

Although they are not counted among major water users due to their dispersed nature, household wells significantly contribute to groundwater withdrawals throughout Michigan. There are over 1 million household wells in the state, which are collectively estimated to withdraw groundwater at a rate of 231 million gallons per day (84.3 billion gallons per year).[85, 86] The northern portion of the

vi EGLE's water use data for 2014-2023 were filtered *for groundwater as the water source. Median annual billions of gallons used per county from 2014 to 2023 were joined with county polygons. Five natural breaks classes were used to classify data in each map frame.*

lower peninsula and the eastern portion of the upper peninsula have the highest household well density (**Figure 7**). 2.6 million citizens, representing 25.6% of Michigan's total population, are served by household wells.[87] Michigan also has the most household wells drilled each year in the United States, and the counties with the highest well dependence are experiencing some of the state's highest population growth (**Figure 7**).[88] These trends suggest that reliance on wells in the state is increasing and will likely continue to do so.[89]

Water Use Sector	Median Annual Total Water Use (billion gallons)	Median Annual Groundwater Use (billion gallons)	Median % of Water Use Supplied by Groundwater
Irrigation	119	93.8	76.7%
Public Water Supply	328	77.0	22.9%
Industrial-Manufacturing	254	35.2	15.2%
Livestock	14.9	6.31	45.4%
Other	6.33	4.43	73.2%
Commercial-Institutional	1.66	1.35	74.3%
Electric Power Generation	2,360	1.32	0.0493%

Table 1. Sector Annual Water Use and Water Supplied by Groundwater in Michigan from 2014-2023.[84] Values were calculated from EGLE's water use data for Michigan for the years 2014-2023.

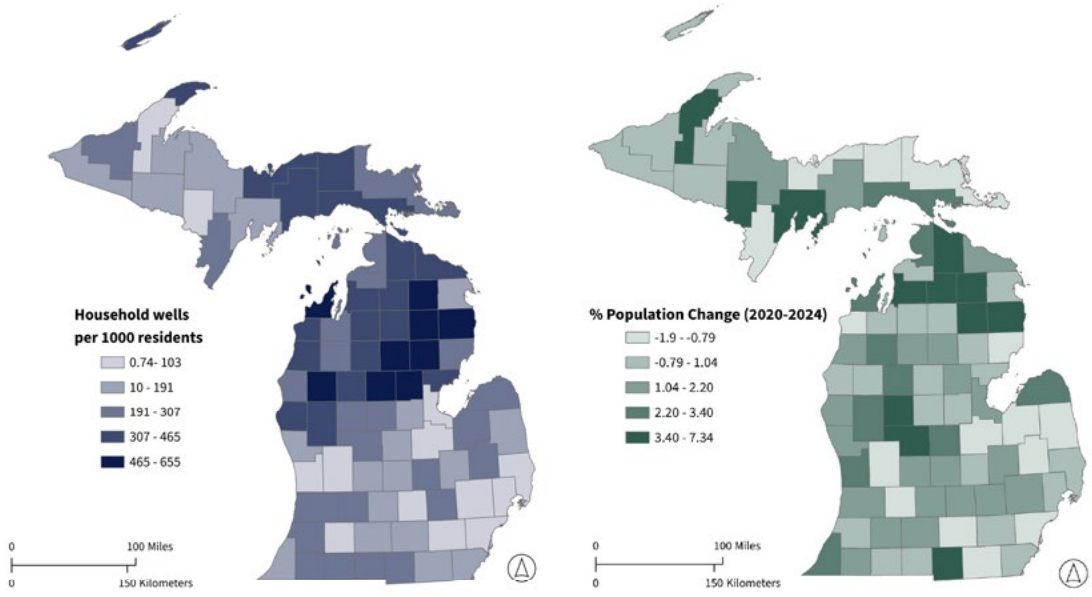

Figure 7. Household wells per 1000 residents and county population change from 2020-2024.[90, 91]

Potential for Future Withdrawals

In addition to the water use of these major sectors, Michigan's industrial future may pose particular challenges for groundwater protection. While still an emerging water-use sector, data center expansion, driven by the rapid adoption of artificial intelligence, will significantly increase related water withdrawals nationwide.

Due in part to these facilities' reliance on water, the Great Lakes region already hosts and is projected to host large clusters of data centers.[92] As of April 2026, Michigan has 74 operating data centers and 16 proposed projects across the state.[93, 94]

Since 2014, national water use by data centers has drastically increased, rising from 5.6 billion gallons to 17.4 billion gallons per year in 2023.[95] The direct water use of data centers depends on several factors, particularly facility size, cooling systems, and water efficiency. Today, hyperscale (very large facilities operated by one technology company) and large colocation (large facilities within which multiple parties operate their own distinct data systems) data centers account for 84% of facilities' national direct water use.[96]

In addition to direct water use for on-site systems, indirect water withdrawals for power generation are projected to increase as the cumulative footprint of data centers and their operational applications expands. In 2024, the indirect water footprint of data centers across the U.S. was 211 billion gallons. Water use is projected to expand as the data center industry grows, but increases in direct and indirect water use depend on system efficiency, technology, and the nature of power generation. Generally, coal, natural gas, and nuclear electricity generation are significant water consumers, while renewable systems like wind and solar are not. In Michigan, electric power generation used 1.32 billion gallons of groundwater annually between 2014 and 2023.[97, 98]

Data center water use presents unique challenges for public water supplies. Compared to other industrial water users, data centers are more consumptive and have more extreme peak withdrawals.[99] Assuming current operations as a baseline, data centers across the country could account for 1% of total public water use and up to 7% of consumptive public water use by 2030.[100]

In Michigan, aging public water systems are already stressed, with a 2025 assessment rating their safety below the national average.[101] Because of poor infrastructure quality and the specific withdrawal patterns of data centers, these new facilities pose physical and hydrologic challenges to the local water supplies that host them, 22.9% of which rely on groundwater (**Table 1**).

Since 2015, Michigan has offered tax exemptions for "qualified" data centers, defined as those that receive a majority of their revenue from colocated businesses distinct from the owner/operator. In 2024, the incentive program was extended to include "enterprise" data centers, which require a minimum investment of $250 million.[102, 103] Facilities that register as one or both of these types are subject to certain employment, energy, and water requirements. Enterprise centers are required to connect to a public water supply, whereas qualified data centers have no water source requirement. When connected to a public water supply, enterprise centers do not have to disclose their water usage, creating a significant transparency and information gap.

Groundwater Quality in Michigan

Groundwater quantity and quality issues are interconnected, as contamination can directly affect the volume of safe, usable groundwater. Moreover, contaminants can become more concentrated as water levels decline, hindering the withdrawal and use of groundwater for drinking, industrial, and agricultural purposes. Groundwater contamination can have profound effects on human health,

the environment, and socioeconomic development.[104] In humans, contaminants have been linked to cancer, liver and kidney damage, and reproductive and nervous system issues, with an increased risk to infants and children (**Table 2**).[105] Notably, USGS data show that 1 in 5 wells nationwide contain at least 1 water contaminant at levels above what is considered safe for human health.[106] These contaminants can come from both anthropogenic and geogenic sources, with key anthropogenic sources including agricultural, industrial, domestic, and urban activities, such as surface application of contaminants (e.g., fertilizers and road salts), contaminant spills, and runoff.

Agriculture

Agricultural contamination is primarily considered nonpoint-source pollution under the Clean Water Act because it originates from diffuse sources, such as pesticide and fertilizer runoff, as well as agricultural byproducts like manure.[107] In 2024, Michigan had 44,000 farms, totaling 9.4 million acres, including crop and livestock acreage, among other uses.[108] Of these farms, 290 are concentrated animal feeding operations (CAFOs), which are classified as point-source pollutants under the Clean Water Act and require a National Pollutant Discharge Elimination System (NPDES) permit.[109, 110] These facilities are reported to generate 62.7 million pounds of manure and other waste per day, which is 17 million pounds more than Michigan's human population of 10 million.[111] This waste is typically stored in liquid form in lagoons and applied to crop fields as fertilizer.[112] The sheer volume of waste, combined with contaminants such as nitrates, phosphorus, antibiotics, pharmaceuticals, and microbial pathogens like E. coli, poses a significant threat to groundwater.[113]

Glyphosate, the most widely used herbicide in Michigan and across the United States, raises further concerns about groundwater quality. Despite its suspected hazards and its classification as "probably carcinogenic to humans" by the World Health Organization, 280 million pounds are applied across the U.S. every year.[114] Glyphosate is highly soluble in water and can persist in groundwater for extended periods. The risk of glyphosate contamination is further exacerbated by a 2026 executive order titled Promoting the National Defense by Ensuring an Adequate Supply of Elemental Phosphorus and Glyphosate-Based Herbicides, which prioritizes chemical production over human health.[115] Improper waste management at CAFOS and the extensive use of chemicals in farming practices increase the risk of contaminants leaching into Michigan's groundwater.

Industry

Industrial contamination can come from chemical spills, leaking underground storage tanks, improper waste disposal, industrial runoff, and mining activities. In Michigan, there are 26,000 known contamination sites that affect soil, surface water, and groundwater to varying degrees.[116] About half of these are "orphaned" sites of known or suspected contamination where the party responsible cannot be identified or held liable, leaving taxpayers to pay an estimated $13 billion in cleanup costs.[117] Of these, over 8,000 are leaking underground storage tanks under Part 213 of Michigan's Natural Resources and Environmental Protection Act (NREPA) (**Figure A1**).[118] More than 300 of these orphaned sites are known to contain Per- and polyfluoroalkyl substances (PFAS). These "forever chemicals" are an emerging water concern throughout Michigan. The state undertakes extensive sampling through the 2017 Michigan PFAS Action Response Team (MPART) program, which publishes data on PFAS sites and areas of interest (AOIs). MPART defines a PFAS site as a property where a groundwater monitoring well sample result exceeds Michigan PFAS cleanup criteria, and the property is determined to be the location of the PFAS source. A PFAS AOI is a location where PFAS is considered to be potentially contaminating groundwater and nearby wells (**Figure A2**). Currently, there are 340 groundwater PFAS sites and 39 PFAS areas of interest in Michigan, with state regulators identifying over 11,000 potential PFAS contamination sites.[119, 120] Kent County contains the most PFAS sites and AOIs, accounting for about 10% of all state sites and AOIs.

Some of the best-known legacy contamination sites impacting groundwater occur in Washtenaw County, Filer City, Hubbell, Muskegon County, Mancelona, and Oscoda.[121, 122, 123]

- In Washtenaw, 1,4-dioxane from a former medical filter manufacturer, Gelman Sciences, created a toxic plume in Ann Arbor and Scio Township.
- Filer City's Packaging Corporation of America dumped billions of gallons of wastewater from black pulping liquor, contaminating groundwater with hazardous chemicals, including arsenic, near Manistee Lake.[124]
- Hubbell's historic copper mining left 200 million tons of toxic stamp sands, high in copper, mercury, and PCBs, along Torch Lake.
- Muskegon County's Ott/Story/Cordova site remains a taxpayer-funded Superfund cleanup site, following mid-1900s waste-disposal and chemical-manufacturing practices that contaminated its groundwater.
- In Mancelona, 13 trillion gallons of groundwater are polluted with trichloroethylene (TCE), forcing costly municipal water connections.
- In Oscoda, Worksmith Air Force Base used a firefighting foam containing PFAS from 1970 to 1973. This contamination was discovered in 2010, becoming one of the first known PFAS contamination sites in the state.

Domestic and Urban Contamination

Common domestic and urban sources of groundwater contamination include failing septic systems, lawn-care chemicals, and urban runoff from road salts and automobile-related contaminants.[125] Of the nearly 1.3 million homes in Michigan that rely on septic systems, an estimated 25% (330,000) are failing, meaning that effluent is not adequately treated before it reaches groundwater. This results in approximately 31 million gallons of partially treated wastewater being discharged into Michigan's groundwater every day, putting private wells and surface waters at risk.[126] Studies have documented that 100% of tested streams in the Lower Peninsula have human fecal contamination.[127] Septic effluent can contain a mix of contaminants, including chloride from water softening, detergents, oils, and other household products, introducing pathogens, viruses, and parasites to groundwater, along with pharmaceuticals, heavy metals, and excess nutrients.[128] Furthermore, excessive, poorly timed, and misapplied lawn care chemicals can also leach into groundwater, run off into surface water, and cause algal blooms that harm aquatic ecosystems.[129]

Urban runoff is a growing contributor to groundwater and surface water pollution, with the increase in impervious surfaces, such as roads and parking lots, accompanying increased development across the state. These surfaces create barriers to water seeping into the ground, preventing natural filtration, and contribute to the collection of contaminants such as oils, heavy metals, fertilizers, and other chemicals. In Michigan, road salts are the main driver of freshwater salinization, with an average of 670 million pounds used each year, all of which eventually enters lakes, streams, and groundwater, contaminating private wells.[130]

Natural Sources

Common geogenic contaminants in Michigan include arsenic, uranium, manganese, radium, and brine, with some parts of the state having naturally higher concentrations than others.[131] Arsenic is one of the most significant geogenic contaminants in Michigan groundwater, especially in the southeast region of Michigan. In some regions, naturally occurring saline water (brine) is also present in deep groundwater; Michigan was once covered in seawater, leaving behind salt deposits. Brine upwelling

occurs when highly saline water from deep subsurface aquifers infiltrates freshwater aquifers, leading to contamination with significant health and environmental consequences. While brine is natural, brine contamination results from human activities that disrupt confining beds, such as pumping and improper well abandonment.

Michigan Groundwater Conclusions

Michigan's groundwater is stored in complex, unique geology. The state relies heavily on its groundwater stocks for domestic, agricultural, and industrial use. Despite this reliance, understanding of the extent of Michigan's groundwater resources remains limited, with aquifer mapping and monitoring of groundwater elevations incomplete. The lack of comprehensive data is particularly concerning given Michigan's reliance on glacial aquifers, which are especially sensitive to shifts in climate and recharge.

Michigan groundwater quantity and quality face growing pressures. Irrigation and public water supply dominate withdrawals, and expanding well drilling in the state suggests that groundwater withdrawals will continue to increase. Michigan also has an unusually high number of private household wells, increasing reliance on largely unmonitored sources. Contamination from various sources is likely widespread, yet testing–especially for private wells–is inconsistent. The full extent of exposure is not well-tracked, and data is largely unavailable.

Beyond its direct use by people, groundwater also quietly sustains much of what makes Michigan's landscape distinctive, feeding the streams and lakes that support native fishes and the broader web of life that defines the state's natural character. Recently, Michigan has increased attention to groundwater management through several ongoing projects. These improvements reflect recognition that current management may not fully capture the complexity and scale of the state's groundwater challenges. Continued advancements will be important, particularly as demand grows and hydrologic conditions become more variable.

Contaminant	Common Sources	Affected Areas	U.S. EPA MCL*	Potential Health Risks
Arsenic[133]	Natural deposits	Primarily southest Michigan[134]	0.010 mg/L	Cancer; thickening and discoloration of skin; issues with blood vessels; high blood pressure; stroke; heart disease; nerve effects; cell function
Nitrate and Nitrite[135]	Failing septic systems, manure, and fertilizers	Spread widely; high concentrations in southwest Michigan	1 mg/L	Methemoglobinemia (elevated levels of methemoglobin in the blood)
Coliform Bacteria[136]	Failing septic systems, animal waste	No data. Based on its sources, likely rural regions	0 mg/L	Vomiting; fever; diarrhea; gastrointestinal issues
Fluoride[137]	Natural deposits, industrial discharge	No data	4 mg/L	Increased likelihood of bone fractures; pits in tooth enamel for young children
PFAS[138]	Airport and military bases (firefighting foam), manufacturing facilities, unlined landfills, farm field application of biosolids, septic systems	See Appendix.	Range from 4 ng/L - 10 ng/L	High blood pressure or pre-eclampsia in pregnant women; thyroid disease; decreased immune system response to vaccines; reduced fertility; liver damage; higher cholesterol; small decreases in infant birth weight; kidney and testicular cancer
Uranium[139]	Natural deposits	Baraga, Houghton, Keweenaw, Gogebic, and Ontonagon Counties. Naturally occurring in Western Upper Peninsula bedrock	30 µg/L	Kidney damage; cancer risk
Manganese[140]	Natural deposits, industrial discharge	No data	0.05 mg/L (SMCL)**	Behavioral changes and other nervous system effects
Volatile organic compounds (VOCs)	Gasoline, dry cleaning solvents, industrial discharge, landfill leachate	Primarily in the southern Lower Peninsula[141]	Varies	Eye, nose, and throat irritation; headaches; loss of coordination; nausea; damage to the liver, kidney, and central nervous system; some cause cancer in animals or humans
Sodium, Chloride[142]	Brine upwelling, brine injection wells, road salts	Brine upwelling: Ottawa County, Southwest Michigan, Thumb region Road Salts: Statewide Injection Wells: 50 Class III, 17 Class V	N/A	Hypertension

** *Maximum contaminant level. **Secondary maximum contaminant level.*

Table 2. Common Groundwater Contaminants in Michigan.[132] Affected areas are listed as "no data" if groundwater contamination data is not publicly available through EGLE.

3 Methods

This report employs interviews, policy analysis, and geospatial mapping to understand Michigan's current groundwater management landscape and that of other states, with the purpose of developing policy recommendations to advance statewide groundwater management. The following section explains the motivation for and process of these three methods. All research was conducted with approval or exemption from the University of Michigan Institutional Review Boards.

Mapping and Contamination Analysis

To provide an overview of Michigan's groundwater systems, several public geospatial datasets were mapped. These include geologic characteristics, patterns of use, residential well density, and some known contamination sites. Major bedrock and Quaternary geology were mapped to provide a visual of the state's complex hydrogeologic setting. Total groundwater use and groundwater use by sector were mapped to assess the scale and spatial distribution of groundwater use. Residential well density was included to visualize reliance on household wells, which are less regulated and monitored than public water systems. Population growth was mapped along with residential well density to demonstrate an overlap of regions with high well dependence and regions of high population growth. The number of PFAS sites and areas of interest (AOIs) and leaking underground storage tank (LUST) sites were analyzed by county to illustrate the spatial distribution of known contamination sources. Geospatial data for additional groundwater contaminants were not consistently available at the statewide level and, therefore, were not included in this analysis.

Groundwater use, residential well density, and known contamination sites were mapped at the county level. Although groundwater systems do not conform to county boundaries, counties represent a practical scale for management and align with the county or multi-county structure of local health departments.

All maps were constructed in ArcGIS Pro. Data were classified using the natural breaks (Jenks) method. A total of 13 maps were made and are presented as Figure 2 and Figure 6 in the body of the report and in Figures A1-A13 in the report appendix. The following maps were developed:

- Michigan bedrock geology
- Michigan Quaternary geology
- Median total groundwater use from 2014 to 2023
- Median groundwater use by sector from 2014 to 2023, for the following seven sectors:
    - Irrigation
    - Public Supply
    - Industrial-Manufacturing
    - Livestock
    - Other
    - Commercial-Institutional
    - Electric Power Generation

- Household well count per 1000 residents in 2020 and population growth from 2020 to 2024
- Quantity of underground leaking storage tanks (LUST) (regulated under Michigan's Natural Resources and Environmental Protection Act (NREPA) Part 213)
- Quantity of PFAS sites and areas of interest

Sources vary for each map. For geology maps, data were obtained from the Michigan Department of Environment, Great Lakes, and Energy (EGLE)'s GeoWebFace. To prioritize bedrock formations, they were chosen based on their inclusion in the USGS 1998 report titled "Hydrogeologic framework of the Michigan Basin regional aquifer system," written as a part of the Regional Aquifer-System Analysis (RASA) Program. Data for PFAS sites and areas of interest come from the Michigan PFAS Action Response Team (MPART) GIS. For LUST, data came from RIDE Mapper. Although data on underground storage tanks (regulated under NREPA Part 211) were also available through RIDE Mapper, only data on leaking underground storage tanks (regulated under NREPA Parts 213) were considered, given their implications for groundwater contamination. For groundwater use maps, data for 2014-2023 were obtained from EGLE's Water Use Data page, combined, and reorganized by sector. Data for county polygons were obtained from Michigan GIS Open Data. The household well density map depends on data from Wellogic and the U.S. Census Bureau.

Interviews and Qualitative Analysis

Interviews were determined to be the most effective research strategy for understanding how groundwater management operates at the individual and various governance levels. For residents who are directly affected by management decisions but not involved in decision-making (referred to as impacted individuals), only direct conversations can convey their experience. Similarly, discussions with local officials and experts directly involved in the creation, transformation, and application of groundwater policies and programs are critical to understanding current practices. Interviews also allowed data collection to be tailored to individual respondents' experiences and local contexts, enabling lessons to be further applied at the state level.

Interviews followed a semi-structured approach, providing consistency while allowing for flexibility in data collection and organic information gathering. The interviews were divided into two groups: "case study" and "expert." Data from case study interviews were used to examine groundwater management experiences in three Michigan counties: Antrim, Ottawa, and Washtenaw. Case study interviews were conducted alongside expert interviews to inform the recommendations presented here. (For rationale regarding the case study framework and choice of counties, see **Section 5: Case Studies**).

Between 5 and 10 community interviews were conducted in each of the three case-study counties. For each county, the interview respondents included local officials, such as township supervisors and municipal water professionals, as well as state officials overseeing local groundwater management, and impacted individuals. All case study respondents had specific personal experience related to local groundwater issues, including resource management, community organizing, or a position in local government or at a local water utility. Fourteen Michigan experts and thirteen out-of-state experts were interviewed, including state-level regulators, consultants, geologists, legislative experts, academics, legal experts, and organizers. Respondents for both interview groups were located through professional networks, preliminary research, and snowball sampling. **Table 4** below shows the respondent count and distribution for each interview group. Of the 36 interviews including 52 people, all interviews except two were recorded, enabling the production of de-identified transcripts and associated analyses. Interview guides for case studies and external state policy analysis are available in the **Appendix**.

Interview Group	Number of Respondents
Antrim County case study	10 total; 7 local officials, 3 impacted individuals
Ottawa County case study	5 total; 4 local officials, 1 impacted individual
Washtenaw County case study	10 total; 5 local officials, 5 impacted individuals
Michigan expert	14
Out-of-state policy expert	13
Total	**52**

Table 3. Respondent count and distribution in case study and expert interview groups.

For case study interviews, two distinct interview guides were developed (for impacted individuals and local officials). For both groups, case study interviews followed a four-part structure:

1. Respondent's role and experience related to groundwater,
2. Relevant mechanisms include information sharing, coordination across groups and offices, and decision-making,
3. Relevant policies, successes, and barriers,
4. Changes respondents would like to make to the management process, and
5. any recommendations specific to their experience.

Michigan experts were asked about their experiences, management gaps, and opportunities for advancement. Some Michigan experts were also asked to reflect on the findings of this report, given their specific expertise; for example, in policy, law, hydrology, or environmental advocacy. Out-of-state experts were asked about their experience with various statutory groundwater management methods, the conditions under which their respective states' groundwater management policies and programs were developed, and how their states' management schemes may inspire advances in Michigan's management.

For case study interviews, the qualitative data analysis focused on extracting lessons, opinions, and recommendations from a local context for application at the state level. Similar topics were the focus of expert interview analysis, along with recognizing that experts' experiences are often more removed from on-the-ground management application. Throughout the analyses, researchers focused on distilling individual dialogue into generalizable takeaways for application to Michigan's state-level regulations and legislation.

Policy Analysis

Policy analysis in Michigan examined relevant federal, state, and local policies, both directly and indirectly, as they apply to groundwater. Relevant policies were identified through background research and interviews with groundwater experts, local officials, and residents affected by groundwater challenges. State-level policies relevant to groundwater were separated into three key categories: general, agricultural-based, and zoning. Additional regional and local policies were identified, along with several key legal frameworks and policy conflicts.

In addition to policy analysis for Michigan, a thorough evaluation of groundwater legislation in other states supported the corresponding policy recommendations. This analysis examined existing research on best practices for groundwater management, effective policy mechanisms, and recommendations from scholars, regulatory agencies, legislative bodies, and non-governmental organizations. Identifying key states and policies enabled this analysis to identify successful aspects of policy and implementation as examples for Michigan's future groundwater management, particularly in areas of concern relevant to the state. Based on a scan of statutory groundwater policies across the United States, five primary states of interest were identified: Arizona, California, Minnesota, Virginia, and Wisconsin. These states were selected based on three key factors that make them applicable to groundwater management in Michigan.

First, of these five states, two have policies that apply to Great Lakes water management and hydrogeology more broadly. Portions of both Minnesota and Wisconsin are located within the Great Lakes basin, share hydrologic similarities with Michigan, and, like Michigan, have historically rarely been concerned about groundwater quantity because of the extensive surface water and groundwater. Additionally, Minnesota, Wisconsin, and Michigan are members of the Great Lakes Compact, a key intergovernmental agreement that regulates water management in the Great Lakes region.

Second, key groundwater management policies from western states offer critical guidance on future threats to water quantity in Michigan. Arizona and California were selected due to water quantity concerns. Because of their arid climates, Arizona and California have been developing and implementing policies to address concerns about groundwater availability for several decades. As a result, these policies are much further developed in the context of groundwater scarcity than those of states located in the Great Lakes region. Importantly, unlike Michigan, Arizona is a prior appropriation state, and California is a hybrid state with both riparian and prior appropriation governing water rights.[i, 143, ii, 144] Arizona was selected because of the role of management areas in the state's groundwater protection, and because the policy's practice for many decades enabled extensive analysis of its implementation. California was selected for its 2014 landmark policy, which specifically and effectively incorporates both groundwater quantity and quality.

Third, the last comparative state, Virginia, focuses on threat management and remediation of groundwater contamination. Like Michigan, Virginia follows the legal doctrine of riparian rights, making the statutory framework more applicable to recommendations that would be feasible for Michigan. The state's extensive surface water and groundwater resources, along with its experience managing groundwater quality issues, make Virginia a valuable resource for the collective policy analysis presented here. Finally, despite being situated in a historically water-rich area, Virginia's policy framework acutely addresses emerging water-quantity issues from a riparian rights perspective.

In **Section 4: Policy Analysis**, a qualitative comparative analysis of policy mechanisms and program efficacy identifies specific aspects of external state policies relevant to Michigan and corresponding groundwater policy recommendations (**Table 5**). An ordinal coding process was employed to assess the extent to which a state's policy framework adequately addresses the policy mechanism of interest. Answers were coded using ordinal coding from 0 to 2, where 0 represents insufficient fulfillment of

i The prior appropriation legal framework applies to states primarily located in the Western half of the U.S. founded on the basic principle of beneficial use, meaning a user retains rights to water as long as that water resource continues to be utilized for a beneficial use. Temporal priority, "first in time , first in right," determines which users have superior rights where more recent users may receive little to no allocation in tims of scarcity.

ii The riparian rights legal framework applies to states located in the Eastern half of the U.S. founded on the basic principle of reasonable water use by adjacent land owners. Riparian users have a right to utilize the resources of adjacent water bodies under the primary premise of ownership of the land abutting a water resource. These rights can be enjoyed by a landowner to the extent that such usage does not reach a point of interference with the reasonable use of other riparian landowners and public rights.

policy mechanism, 1 represents partial fulfillment of policy mechanism, and 2 represents sufficient fulfillment of policy mechanism. These values were determined through materials and information provided from a number of expert interviews, legislative texts, corresponding statutory documents, and auxiliary summary documents. Initial matrix scoring results were submitted to state experts for review and editing to ensure they were not only consistent with legislative text and research materials but also aligned with the on-the-ground experience of regulatory officials. All comparative state interviewees across all five states provided review and feedback. To ensure consistency throughout the matrix, Michigan's scores were also reviewed and edited by state-specific regulators and policy experts from Michigan.

Advisory Committee

An advisory committee was formed to help strengthen the report. Seven policy experts, scientists, individuals involved in case study sites, and state officials were convened to review a late draft of the report and provide informed input. Participation in the advisory committee did not require endorsement of the report. All but one committee member attended one virtual meeting during which they provided feedback specific to their area of expertise. Additional feedback was collected during supplementary meetings with some committee members and over email. Input from the advisory committee focused on the accuracy of case studies, state policies, and information about Michigan's groundwater resource. Much of the feedback also refined the recommendations with special consideration of the extensive experience of committee members.

Limitations

Barriers to data accessibility limit the scale and range of geospatial and quantitative analysis presented in this report. Specifically, the contaminated sites available via the RIDE Mapper database of NREPA Part 201 cannot be filtered for groundwater-specific contamination. Moreover, generating maps of specific contaminants is not feasible due to the lack of organized, accessible state-level data.

Several factors limit our qualitative methods. While every effort was made to reach informational saturation for each county case study, the number of respondents limited the type of data that could be collected. While effective at maximizing reach, snowball sampling yields a biased sample because it relies on the professional and personal networks of existing respondents. More broadly, reliance on experiential interviews limits our data to only those features of groundwater management that individuals both experienced and can recall. Data were also affected by respondents' own biases. Despite these limitations, interviewing and qualitative data analysis provide a grounded and robust understanding of the operation, including successes and failures, of groundwater management in Michigan and beyond.

Selecting only five states for policy analysis limits the scope. As a result, there is a body of existing groundwater management literature and legislative action not captured in the report that may be of additional interest when reviewing the context of recommendations for Michigan. Future research could address this limitation and build upon the existing comparative policy analysis by including additional states. The policy analysis matrix relies on results from qualitative research processes and interviews. Despite consistent review methodology across all states, subjectivity remains a limitation of the matrix scores. Further analysis of the comparative states, using both qualitative and quantitative matrices to derive coding, could be utilized in future analysis.

4 Policy Analysis

Groundwater Management in Michigan

Federal Policies

Before examining the policies that protect groundwater in Michigan, it is essential to establish the impact that existing federal policies have on groundwater. Although there are no specific federal groundwater regulations in the United States, each of the laws outlined below offers some level of protection of groundwater. Policy descriptions are presented chronologically, and not necessarily in order of importance. In April 2026, federal environmental rules are undergoing a transformation, shifting towards deregulation and increasing the importance of state-level action.

The **Great Lakes Water Quality Agreement (GLWQA)** was first signed in 1972 by the U.S. President and the Canadian Prime Minister to address surface water contamination in the Great Lakes Basin.[145,146] A 1978 revision recognized the interaction between groundwater and surface water, which had previously been viewed as two separate systems, and added Annex 16 to address groundwater pollution.[147] Annex 16 was further modified in 1987 to require progress reports to begin in 1988 and to create Areas of Concern (AOCs) to address the most contaminated sites within the basin, with Michigan having 14 sites.[148, 149] To date, only 4 of these sites have been successfully restored, while the remaining 11 remain in various stages of restoration.[150] An amendment in 2012 added Annex 8 to address groundwater more holistically, including the preparation of groundwater status reports.[151] More broadly, they must identify groundwater impacts on the Great Lakes, analyze contaminants from point and non-point sources, assess information gaps and science related to groundwater, and analyze other factors, including climate change, that affect groundwater quality of the Waters of the Great Lakes.[152]

The **Clean Water Act (CWA, 1972)** establishes water quality standards and prohibits the discharge of any pollutant from a point source into navigable waters without a permit obtained from the National Pollutant Discharge Elimination System (NPDES).[153] The Act does not directly regulate groundwater; however, it can indirectly affect groundwater in certain circumstances. Because groundwater is directly connected to surface waters, the Act provides limited protection for groundwater connected to regulated surface waters. Additional provisions include funding wastewater treatment facilities, encouraging and funding states to implement nonpoint source pollution plans, and protecting wetlands and other small streams from being filled, measures that all indirectly protect groundwater.[154]

The **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, 1972)** is a federal statute that governs the registration, distribution, sale, and use of pesticides in the United States.[155] The Act authorizes the U.S. Environmental Protection Agency to regulate the availability of pesticides that have the potential to leach into groundwater.[156]

The **Safe Drinking Water Act (SDWA, 1974)** was initially enacted to protect public health in the United States by regulating drinking water supplies.[157] The Act authorizes the EPA to set enforceable standards for contamination in drinking water, protecting against both naturally occurring and man-made contamination.[158, 159] The SDWA was amended in 1986 to authorize the Wellhead Protection Program (WHPP), under which states identify Wellhead Protection Areas (WHPA) and develop programs to

prevent contamination near wells. WHPAs are surface and subsurface areas surrounding a well or well field, through which contaminants can readily migrate into groundwater and the public water supply.[160, 161] In 1996, the Act was further amended to emphasize pollution prevention in order to protect drinking water supplies, requiring states to create a Source Water Protection Program (SWAP) for all public drinking water systems, including surface water and groundwater.[162] While this Act protects public drinking water supplies, it offers no protection to private well users or groundwater-dependent ecosystems.[163]

The **Toxic Substances Control Act (TSCA, 1976)** grants the EPA authority to regulate the manufacture, use, and disposal of chemical substances that may pose risks to human health or the environment.[164] While the Act does not explicitly target groundwater, it can indirectly reduce chemical contamination. In 2016, the Frank R. Lautenberg Chemical Safety for the 21st Century Act amended the TSCA, requiring the identification and completion of risk evaluations for chemicals that may present an unreasonable risk of injury to health or the environment, and restricting or mitigating their use as necessary.[165] The Act requires the EPA to conduct ongoing chemical risk assessments and implement regulations as needed.[166] Several key contaminants regulated by this act include 1,4-dioxane, asbestos, and TCE.[167]

The **Resource Conservation and Recovery Act (RCRA, 1976)** gives the EPA the authority to control all solid and hazardous waste from generation, transportation, treatment, storage, and disposal.[168] Regulating these waste streams prevents leaching into groundwater.[169]

The **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 1980)**, also known as Superfund, authorizes the EPA to respond to chemical releases from uncontrolled or abandoned hazardous waste sites, as well as from accidents and spills into the environment.[170] The Act gives the EPA the authority to seek out responsible parties, compel them to perform cleanup, or recover cleanup costs when the federal government completes the work, thereby cleaning up orphaned sites when responsible parties cannot be identified.[171] Identification of sites, monitoring, and response activities are carried out collaboratively at the state and local levels.[172] In Michigan, Superfund Site Assessments are conducted by Michigan Department of Environmentl, Great Lakes, and Energy, which is responsible for discovering, evaluating, and nominating contaminated sites to the National Priorities List (NPL).[173] Groundwater contamination is common at Superfund sites, with an estimated 85% of NPL remedies addressing it to some extent.[174] The EPA aims to restore groundwater to beneficial use and, when not possible, enacts measures to prevent the migration of contamination, reduce exposure, and evaluate additional risk reductions.[175]

Regional Policies

The Great Lakes—St. Lawrence River Basin Water Resources Compact was enacted in 2008 after the eight Great Lakes states enacted identical Compact legislation. The Canadian provinces of Ontario and Quebec joined the states in addressing the same issues through a nonbinding agreement, building on the 1985 Great Lakes Charter and the subsequent 2001 Great Lakes Charter Annex. The Compact was created to protect the Great Lakes amid growing concerns about water diversions outside the basin. The Compact bans most diversions with a clear process for exceptions; provides consistent review standards for proposed uses of Basin water, allowing flexibility in management; requires each state within the compact to achieve water-conservation and efficiency goals, reporting and registration of significant water users; and establishes the Great Lakes Water Resources Council.[176] Under the Compact, a significant water user is defined as withdrawing over an average of 100,000 gallons per day over a 30-day period.[177] In Minnesota, they have enacted a lower threshold than the compact requires, requiring permits for water users exceeding 10,000 gallons per day or 1 million gallons per year.[178]

The goals of the compact have both direct and indirect impacts on groundwater.[179] Goals that directly impact groundwater include retaining the quantity of surface water and groundwater in the basin and ensuring the sustainable use of the "Waters of the Basin", which includes the Great Lakes, all streams, rivers, lakes, and connecting channels, along with groundwater.[180, 181] Goals that indirectly affect groundwater include protecting and restoring the basin's hydrological and ecosystem integrity, promoting efficient water use, and reducing water losses and waste.[182] While the Compact generally protects water from being diverted outside of the basin, groundwater remains vulnerable to large-scale users located within the basin. Additionally, under this policy, groundwater contamination is not addressed, and the boundaries of the basin's groundwater are ill-defined.[183]

State Policies

Prior to analyzing the existing policy framework in Michigan, it is important to acknowledge that government officials have taken an oath to support and faithfully discharge the state constitution to the best of their ability.[184] Section IV of the Michigan Constitution of 1963 charges the government with duties to protect public health and natural resources. These are:

> **Article 51**
>
> "The public health and general welfare of the people of the state are hereby declared to be matters of primary public concern. The legislature shall pass suitable laws for the protection and promotion of the public health."
>
> **Article 52**
>
> "The conservation and development of the natural resources of the state are hereby declared to be of paramount public concern in the interest of the health, safety, and general welfare of the people. The legislature shall provide for the protection of the air, water, and other natural resources of the state from pollution, impairment, and destruction."

As with federal policies, Michigan lacks specific and comprehensive groundwater policies. Instead, there is a patchwork of policies that primarily focus on surface waters and protecting public health through a risk-based approach. This patchwork approach can lead to confusion and gaps in resource management.[185]

General

The **Michigan Safe Drinking Water Act (MSDWA) (Act 399)** was enacted in 1976, following the passage of the federal SDWA, to protect public health and to grant EGLE direct control over Michigan's public drinking water program.[186] The act was amended in 1986 to include wellhead protection.[187] The statewide Wellhead Protection Program (WHPP) is a voluntary program that maps protection areas, identifies potential contaminants within those areas, and develops methods to manage and minimize threats to the public water supply.[188, 189] These programs manage surface activities, which in turn help protect groundwater by implementing additional land-use restrictions.[190]

The **Michigan Natural Resources and Environmental Protection Act (NREPA-Act 451)** was passed in 1994 to regulate and manage Michigan's lands, waters, and natural resources. Originally, the Department of Natural Resources (DNR) was the only agency responsible for implementing NREPA. Today, responsibility is shared among the DNR, EGLE, and the Michigan Department of Agriculture and Rural Development (MDARD), with EGLE's role focused on regulatory compliance for land and water quality, and MDARD's on agriculture and associated pollution prevention programs. NREPA is a large and complex law divided into four articles, each containing different parts.

- Article I General Provisions (Parts 1 to 27) contains general provisions.
- Article II Pollution Control (Parts 31 to 215) contains provisions on pollution and prevention, waste management, recycling, remediation activities, underground storage tanks, and environmental funding. Of these, **Part 31** (Water Resources Protection), **Part 83** (Michigan Pesticide Control Act), **Part 87** (Groundwater and Freshwater Protection - includes MAEAP (see below)), **Part 91** (Soil Erosion and Sedimentation Control), **Part 201** (Environmental Remediation), **Part 211** (Underground Storage Tank Regulations), and **Part 213** (Leaking Underground Storage Tanks) were found to be of importance for groundwater management.
- Article III Natural Resources Management (Parts 301 to 831) contains provisions relating to habitat management, outdoor recreation, and the management of renewable and nonrenewable resources. Of these, **Part 301** (Inland Lakes and Streams), **Part 303** (Wetland Protection), **Part 327** (Great Lakes Preservation), **Part 328** (Aquifer Protection), **Part 615** (Supervisor of Wells), and **Part 625** (Mineral Wells) are especially important for groundwater management.
- Article VII (Part 901) repealed former acts consolidated into NREPA.[191, 192]

Land-use or resource-use restrictions, as outlined in **Part 201** and **Part 213**, authorize EGLE to set cleanup standards by limiting how contaminated land will be used in the future. These standards are risk-based and examine the potential human-health and ecological risks from exposure to regulated substances at contaminated sites.[193] Exposure pathways include drinking water and vapor intrusion, where vapors from volatile contaminants in soil and groundwater migrate through subsurface pathways and affect indoor air quality in the above buildings.[194]

- **Institutional controls** (ICs) are put in place through the form of deed restrictions or municipal ordinances, preventing groundwater from being used as drinking or irrigation water, preventing the installation of new wells, and abandoning existing wells, requiring connection to municipal water.[195]
- A **restricted covenant** is a legal document that imposes limitations on activity or use at a property. With respect to contaminated sites, restricted covenants are used to reduce exposure to contamination that is left in place.[196]

As of February 2018, there were 3,394 restricted convenants in Michigan under Part 201 and Part 213 (this includes additional restricted convenants under Part 111, Hazardous Waste Management, Part 115, Solid Waste Management, and "other"), with 2,355 being restrictions on groundwater use.[197]

The **Geomare-Anderson Wetlands Protection Act (PA 203**) was passed in 1979 and became effective in 1980, which is now Part 303, Wetlands Protection under NREPA. This established permitting and protection of Michigan's wetlands, allowing Michigan to implement Section 404 under the CWA to establish a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands.[198, 199]Michigan remains one of only three states authorized to implement this federal program, giving EGLE the power to issue permits for wetlands, lakes, and streams under state law while also providing federal approval.[200] This applies to wetlands connected to or located within 1,000 feet of one of the Great Lakes and Lake St. Clair, within 500 feet of an inland lake, pond, river, or stream, or larger than 5 acres in size.[201] This policy has resulted in a dramatic reduction of wetland loss.[202] In 2003, the Sackett vs. EPA ruling restricted what is considered "waters of the United States" under the CWA. However, Michigan's Wetlands Protection Act has insulated the state from the loss of wetlands protection experienced elsewhere.[203] Given the recognized connection between groundwater and surface water, as highlighted in **Section 2: Overview of Michigan's Groundwater**, this law has a significant impact on groundwater.

Part 327 codifies the state's obligation under the Public Trust Doctrine (below), recognizing that water in the Great Lakes Basin is held in public trust for the benefit of citizens, ensuring the state manages its water resources as a common resource.[204]

In 2003, two key acts served as stepping stones for the 2008 Water Use Law. **Public Act 148** of 2003 amended **Part 327**, and added **Part 328**, creating the Groundwater Conservation Advisory Council, to study groundwater resources and make recommendations to the legislature, requiring the DEQ to collaborate with U.S. Geological Survey (USGS) and Michigan State University to develop Groundwater Inventory and Mapping (GWIM).[205] **Public Act 171** of 2003 included an appropriation bill for the DEQ that included $1 million from the Clean Michigan Initiative to support creating a statewide groundwater inventory.[206]

In 2008, Michigan's **Water Use Law** further amended **Part 327** and established the WWAT to screen LQW and comply with the Great Lakes Compact to ensure withdrawals will not cause an Adverse Resource Impact (ARI).[207] The WWAT model uses Water Management Areas, defined by ecologically similar stream segments, to evaluate groundwater withdrawal amounts. While these Management Areas are the scale at which technical assessments of large-scale groundwater use occur, they are not a level of governance. As part of the Water Use Law, **Public Act 179** of 2008 quantifies LQW as withdrawals averaging 100,000 gallons/day or more in a 30-day period.[208] Additionally, under **Part 327**, Water User Committees were formed to address potential ARIs when conflicts arise. **Public Act 508** of 2018 amended **Part 328** to establish a Water Use Advisory Council to study and advise the Water Use Program and make recommendations to the Quality of Life (QOL) agencies, including EGLE and MDARD.[209]

Agricultural-Based Policies

The **Michigan Right to Farm Act, P.A. 93**, was enacted in 1981 to protect farmers from nuisance complaints and litigation. The law gave MDARD the authority to develop and adopt Generally Accepted Agricultural and Management Practices (GAAMPS) for farms and farming operations in Michigan.[210] Key GAAMPS that relate to groundwater include Irrigation Water Use, Manure Management/Utilization, Nutrient Utilization, Pesticide Utilization-Pest Control, and Site Protection.[211] These voluntary programs are designed to minimize the risk of surface water and groundwater contamination from agricultural practices by following science-based standards.

- The **Michigan Agriculture Environmental Assurance Program (MAEAP)** is a complementary, voluntary, verified certification program that helps farmers prevent or minimize agricultural pollution risks under part 87 of NREPA.[212] Through the Cropping, Farmstead, and Livestock systems, producers develop and implement economically feasible pollution prevention practices.[213]

Zoning Laws

There are two primary statutes that govern planning and zoning in Michigan, including the **Michigan Planning Enabling Act (MPEA) (PA 33 of 2008)** and the **Michigan Zoning Enabling Act (MZEA) (PA 110 of 2006)**. These laws give communities the option to zone; those that choose to zone must regularly update a community master plan, which may include zoning ordinances regulating land use and the location of structures. By regulating land use, communities can create designated groundwater recharge areas or prevent heavy industrial development, thereby indirectly affecting groundwater quality and quantity.

- In 2011, the MZEA was amended (MCL 125.3205) to limit zoning authority over the extraction of natural resources from property unless "very serious consequences" would result.[214] These

acts indirectly affect groundwater by giving communities tools to create and enforce master plans and zoning ordinances through land-use decisions.[215] However, they have less control over zoning for mining operations, as demonstrated in Washtenaw County (see **Section 5: Case Studies**) regarding the Vella Pit.

The **Open Space Preservation Provision (PA 177 of 2001**) aims to protect and preserve land resources by concentrating development on a portion of a land parcel, with the remainder permanently preserved.[216] While this provision helps support groundwater recharge by reducing impervious surfaces, in some cases, such as in Ottawa County (see **Section 5: Case Studies**), well clustering can stress the aquifer.

The **Michigan Water Well Construction and Pump Installation Code (Part 127 of Act 368)** establishes minimum specifications and standards for the location, construction, and pumping of wells, and sets strict quality and safety guidelines to protect groundwater. This is implemented through local health departments, which are responsible for well permitting.[217]

Local Policies

The **Well First Policy** was implemented by the Health Department of Northwest Michigan (which oversees Antrim, Charlevoix, Emmet, and Otsego Counties) in 2005 to ensure that any well installed was safe for use in accordance with Part 127 of Act 369, P.A. 1978, and Act 399, P.A. 1976, to protect public health and prevent the consumption of contaminated water. The policy prevents new wells from being installed where municipal water is available. When municipal water is not available, specific construction and sampling methods are required.[218]

Michigan is the only state without a uniform, mandatory statewide septic code, leaving septic systems to be regulated at the local level with county and district health departments acting as the primary regulatory authorities. **Local Septic Ordinances** that rely on point-of-sale inspection rather than regular interval inspections have been implemented by 12 of Michigan's 83 counties.[219] In January of 2026, Senator Sam Singh (District 28) introduced Senate Bill 771, to establish a uniform, statewide septic code granting authority to inspect onsite wastewater treatment systems, setting timelines for establishing a Statewide Sewage code, creating a technical advisory committee, setting registration and review requirements, along with evaluation requirements, and the prescription of fines for failing to comply.[220]

Legal Frameworks and Regulatory Conflicts

In addition to these laws, three important legal topics are integral to understanding Michigan's groundwater management landscape. First, Michigan adheres to the legal framework of **riparian rights** governing water use, which establishes reasonable use rights for landowners adjacent to a water resource. These rights are enjoyed as long as they do not interfere with the reasonable use rights of other riparian landowners. Legally, reasonable use is measured against the established economic or social value of water, harm from the use, the suitability of the use, and the purpose of the use.[221]

Second, two court cases have defined the applicability of the **public trust doctrine** in Michigan. In 1892, in a ruling favoring the state of Illinois, the Supreme Court held that the Great Lakes are a resource held in public trust by the surrounding states.[222] In 1982, the Michigan Supreme Court defined the application of the public trust doctrine to only the state's "navigable waters."[223] Legislators and advocates continue to push for an expanded application of public trust principles to include groundwater. While there is no formal protection of groundwater under Michigan law, the definition

of "Waters of the Basin" in the legally binding Great Lakes Compact (above) suggests opportunities for more inclusive water protection.[224]

Lastly, a regulatory battle over the **commodification** of Michigan's groundwater continues to shape public and official attitudes about water rights. In 2009, Nestlé Water North America settled a nine-year lawsuit with Michigan Citizens for Water Conservation, which raised concerns over impacts to neighboring lakes, streams, and wetlands. This allowed the company to continue withdrawing 576,000 gallons per day (400 gallons per minute) from an Osceola County bottling plant under the Ice Mountain brand, highlighting tensions between private profit and the protection of public trust resources.[225] In 2020, EGLE approved a new withdrawal permit for Nestlé (now BlueTriton Brands), although the withdrawal estimates were adjusted to remain below the level requiring oversight. The combination of Michigan's robust groundwater resources and its groundwater management scheme made West-Central Michigan an attractive landscape for Nestlé's ongoing endeavors.[226] Riparian rights, public trust, and conflict over the rights of various water users continue to shape the state's position on, authority over, and interest in groundwater protection.

State Groundwater Management Beyond Michigan

While the federal level lacks specific groundwater regulations, individual states have taken independent action to manage resources, creating a patchwork of policies across the country.[227] Mechanisms for management vary significantly in their efficacy in protecting groundwater quantity, quality, and related ecological and socioeconomic factors. A complex mixture of factors, including the overall quantity of groundwater, intensive extractive industries, precipitation variability, and population, contributes to the degree of groundwater resource stress.[228] Given the noninterventionist approach to groundwater legislation at the federal level, and 2026 federal rollbacks in national water resource protections, the burden of managing an increasingly imperiled and notoriously complex resource will likely continue to fall on states.[229, 230]

The heightened responsibility of states managing groundwater coincides with falling groundwater levels across the country.[231] Additionally, aquifers' vulnerability to contamination has increased due to increased groundwater pumping, corresponding impacts to hydrologic flows, expanded irrigation practices, increased use of anthropogenic chemical applications, most notably in agriculture, and more.[232] Specific contaminants and areas of resource scarcity are widespread but variable across the country. Given uneven groundwater challenges and inconsistent state policies, some states have pursued increased groundwater resource protection measures.

Five key states and their corresponding groundwater protection policies are evaluated here to identify mechanisms for successful resource management that could be applied in Michigan. For a comprehensive explanation of the process and factors by which the states were selected, refer to **Section 3: Methods**.

Arizona

In 1980, Arizona passed the first iteration of the Groundwater Management Act (GMA), with the primary purpose of achieving safe groundwater extraction yields within state-legislatively designated Active Management Areas (AMAs). The policy intended to balance annual withdrawals with annual recharge. The development and management of the AMAs set Arizona apart from other states at the time by prioritizing areas of greatest concern and by developing standards and regulations in accordance with those priorities.[233] In total, eight AMAs have been designated across Arizona, with the first four developed at the policy's initial enactment and the remaining added in 1994, 2022, 2025, and 2026. Despite accounting for a small percentage of total land, roughly 85% of Arizona's population as of 2025 lives within the boundaries of the first five AMAs.[234]

Within the confines of an AMA, a variety of specific regulations are in place to meet existing groundwater needs and protect aquifers from overdraft. The expansion of agricultural acreage has and continues to be prohibited since the act's conception in what is legislatively designated as Irrigation Non-Expansion Areas (INAs). In addition, regulatory measures are in place to ensure that water-conservation actions are implemented within AMAs, and water-use reporting is required. As in California, each AMA is tasked with developing an individual management plan to ensure that the quantity of water currently used does not limit future use over a 100-year period.[235]

Arizona and the GMA face ongoing challenges due to declining rainfall and political scrutiny of the efficacy of groundwater management statewide.[236] The state has found a way to effectively manage groundwater within AMAs. Beyond that, the 1980 policy remains weak in terms of integrating quality and quantity across agency departmental jurisdictions, since the state's DEQ handles water quality, and the Department of Water Resources (DWR) is tasked with addressing all other aspects of resource management. While practical challenges remain and Arizona continues to experience declining precipitation and increasing water scarcity, the Groundwater Management Act remains a groundbreaking piece of legislation for its time and serves as the baseline for all statutory groundwater management frameworks across the country.[237] Despite its flaws amid unprecedented resource pressures and scarcity, the GMA's designation of vulnerable areas and prohibition on increased agricultural acreage are highly relevant to Michigan's current needs.

California

In 2014, California passed the Sustainable Groundwater Management Act (SGMA) as its primary mechanism for managing groundwater quantity and quality, identifying the hydrologic connection between surface water and groundwater.[238] Passed largely in response to ongoing drought conditions across the state and substantial depletion of critical basins, SGMA requires the formation and operation of Groundwater Sustainability Agencies (GSAs) by local government, organizations, and stakeholders in cases where basins have been determined by the state to be of medium, high, and critical priority due to prolonged adverse environmental, social, or economic impacts on groundwater resources.[239] These GSAs are tasked with developing regional Groundwater Sustainability Plans (GSPs) that aim to avoid and mitigate basin overdraft within 20 years. SGMA emphasizes the relationship between groundwater and surface water, as each GSP must outline a management pathway that ensures no depletion of, or adverse impacts on, interconnected surface water resources resulting from basin regulation.[240]

Management success is guided by six key "undesirable results": (1) significant and unreasonable groundwater decline, (2) reduction in groundwater storage, (3) seawater intrusion, (4) water quality degradation, (5) land subsidence, and (6) interconnected surface water depletion.[241] When GSAs fail to manage their local basins sufficiently and in a manner consistent with the 20-year sustainability timeline, SGMA calls for state intervention as a legislative backstop to ensure proper resource management. California's State Water Resources Control Board (SWRCB) has the authority to intervene in the management process, designate probationary periods for failing basins, and assume management responsibility.[242]

In conjunction with California's existing water resource policy framework, SGMA has been highly successful in supporting continued groundwater data collection. The breadth of the state's groundwater data collection largely comes from extensive well-monitoring records in the California Statewide Groundwater Elevation Monitoring (CASGEM) database. In effect, since 2009, this publicly accessible data collection and distribution platform tracks seasonal and long-term groundwater elevation trends across basins and monitoring wells throughout the state. The database contains records of approximately 2 million water-level measurements from 1849 to the present.[243] California's

DWR administers and maintains the database, while water-level measurements and data submissions are conducted by local entities throughout the state. When no local entity conducts groundwater-level measurements, the DWR steps in to collect the necessary data and update CASGEM records accordingly.[244] CASGEM's public accessibility increases transparency and opportunities for public or stakeholder involvement and engagement.

Interviews with state agency experts largely supported SGMA's success and pointed to potential areas of applicability for Michigan. Experts highlighted the periodic review process for GSPs and the understanding that GSPs are living, not static, documents as important strengths. Periodic GSP evaluation allows the state to more accurately assess a basin's status and track whether it is meeting sustainability goals and preventing undesirable outcomes. This evaluation process allows GSPs to be dynamic and responsive to potentially changing groundwater conditions, with one expert stating that "the GSP is not meant to sit on the shelf." In terms of regulatory compliance, the SWRCB's role as the legislative enforcer is critical to the successful implementation of sustainable basin management practices. The threat of state intervention and strict withdrawal restriction mandates, which rescind local control, has sufficiently curbed GSAs' defictions to date. Across the state, 86 basins' GSPs have been approved, while only six have been designated to be inadequate, thus requiring intervention and ultimately management by the SWRCB.[245]

Interview respondents highlighted empirical conditions and data transparency under SGMA. All groundwater data collected by GSAs is made publicly available by the state, and communication is important to California's groundwater management framework more broadly. Most notably, communication between GSAs and the state is consistent and grounded in a shared understanding of how information should be shared. Beyond GSAs, communication with and education of the public are key to SGMA's success. Stakeholder engagement in groundwater management decisions is also emphasized, and opportunities for involvement are readily available through publicly accessible GSA meetings and hearings. Additionally, public education programs highlight not only the importance of protecting groundwater resources but also provide baseline information about groundwater, since the natural resource is difficult to visualize and understand. SGMA has effectively triggered widespread increases in groundwater data collection, development, and rollout of more than 80 successful GSPs, reductions in land subsidence, and increased water supply reliability and recharge projects.[246]

Overall, California's Sustainable Groundwater Management Act underscores the importance of a comprehensive, publicly available groundwater data system and serves as a key model for Michigan. Although Michigan's governance system is complex, the severity of the current groundwater challenges the state faces necessitates local government, organizational collaboration, and stakeholder engagement similar to that created and implemented by California's GSAs under SGMA, to serve as an additional layer of protection to address distinct regional challenges to groundwater resources in Michigan.

Minnesota

In 1989, Minnesota passed the Groundwater Protection Act (GWPA) with the dual purposes of protecting state groundwater quality and quantity.[247] Enacted as a result of significant statewide drought conditions in the 1980s and inflated levels of consumptive use, the act's passage led to the development of many subsequent groundwater protections. The policy was revised in 1990 and has served as a successful mechanism for coordinating and protecting groundwater across five key state regulatory agencies. This system assigns groundwater protection area designations to specific government agencies and facilitates cross-agency collaboration and information sharing.

The policy's "sensitive areas" are identified based on their vulnerability to water quality threats.

The GWPA outlines a number of measures aimed at preventing contamination of groundwater, including (1) establishment of sensitive areas, (2) prohibition of contaminants near drinking water wells, (3) conservation easements for protection of sensitive areas, (4) statewide nitrate and pesticide management plans, and (5) promotion of sustainable agricultural and pest management practices that prevent agricultural contamination. Additionally, exposure to contaminants is regulated by adopting Health Risk Limits (HRLs) to prevent human exposure.[248] The GWPA effectively advances efforts to prevent groundwater resource degradation, particularly that resulting from anthropogenic sources.[249]

A key aspect of Minnesota's groundwater management framework under the GWPA is its dual regulatory system. The state uses both voluntary and involuntary controls to manage nonpoint groundwater contamination. Voluntary controls are essentially best management practices (BMPs). When BMPs fail to adequately protect groundwater quality, water resource protection requirements (WRPRs) are enforced by the Minnesota Department of Agriculture.[250] Reexamination of this enforcement rule is underway to improve contamination prevention, particularly regarding increased nitrate pollution from agricultural activities. The multi-level management framework allows flexibility in policy adherence and opportunities to reverse course individually before consequences are imposed. In the years following the initial implementation, the GPA has evolved to include additional environmental and public health protections, resulting in reduced contamination and decreased per capita water use.[251]

Regarding groundwater quantity, the act increases groundwater research initiatives to enhance statewide data collection.[252] Examples of these initiatives include the state's requirement to complete a statewide nitrogen study, the implementation of education programs, and the establishment of monitoring networks. Groundwater quantity is protected through water-use fees and stringent restrictions on highly water-intensive once-through cooling systems.[253] Groundwater quality and quantity are further protected through the act's biennial funding for the implementation of the regulations outlined by the policy.

Interviews with state officials and experts from nonprofit organizations illustrate how the act has successfully documented and reported on the status of state water quality and quantity. Resource status is communicated across agencies and to the public through consistent reporting, newsletters, and direct outreach to industries. Minnesota's development of an extensive monitoring well network is a continued success for effective management, providing robust aquifer-layer information and continuous data collection. Additionally, the state uses groundwater modeling programs to better understand hydrologic resources and identify areas of sensitivity or concern.

Minnesota's groundwater protection framework is an example of successful top-down regulatory management and multi-agency coordination; therefore, it is highly applicable to Michigan's system of divided agency authority. Since its initial implementation, the GPA has successfully led to improvements in groundwater monitoring and pollutant testing, pesticide cleanup in agricultural regions, funding for and implementation of water planning under local government, heightened cooperation and coordination of responsibilities across agencies, and an overall enhancement of groundwater policy salience within the state legislature.[254] Since Michigan and Minnesota have similar climates and water-use needs, the success of Minnesota's GWPA and the corresponding improvements in groundwater quality and quantity serve as a key proxy for how well resource protection could be achieved in Michigan.

Wisconsin

Wisconsin passed the Comprehensive Groundwater Protection Act (CGPA) in 1983, expanding organizational capacity and legal authority to control groundwater contamination. The primary

purpose of the original Comprehensive Groundwater Protection Act is to prevent groundwater pollution through a two-tiered, multi-agency regulatory approach.[255] This policy serves as the blueprint for state water quality standards by establishing prescriptive statutes to prevent groundwater contamination. Groundwater contamination violations are based on threshold concentrations, with two violation levels: enforcement standards and prevention action limits. Per expert knowledge, state regulatory agencies are required to review their rules and promulgate amendments as necessary. This ensures that the activities, practices, and facilities regulated by the state agency comply with the applicable standards. Enforcement standards define limits for each identified groundwater contaminant; attaining or exceeding these standards indicates a violation. In such cases, response actions are required to minimize groundwater contamination and restore compliance with standards. Prevention action limits are set percentage thresholds of the enforcement standards that, when reached, trigger source control and contaminant remediation efforts and initiate protective action measures. Importantly, Wisconsin's groundwater management framework does not rank or classify state aquifers by concern or importance. Instead, the policy explicitly assumes that all groundwater aquifers in Wisconsin are entitled to equal protection under the law, meaning that no one aquifer in the state is awarded greater attention than another. To encourage compliance and agency cooperation, the act created the Groundwater Coordinating Council (GCC), primarily composed of state officials, to advise state agencies, promote information exchange, and coordinate regulatory efforts.[256]

To address water quantity impacts not covered by the 1983 policy, the state passed the 2003 Wisconsin Act 310. Act 310 expanded the state authority over groundwater protection efforts by considering the environmental impacts of high-capacity wells. The act directly recognizes the connection between surface water and groundwater resources and the effects of high-capacity wells. To implement the water quantity regulatory requirements, high-capacity well owners must pay an application fee for a new high-capacity well. Additionally, users must track their monthly water use and report this information to the state. The purpose of this management mechanism, per Act 310, is to provide an initial framework for regulating high-capacity well withdrawals when data indicate that harm may occur in specific instances. Additionally, the act extends environmental protections for state water resources by strengthening protections for trout streams and surface water bodies.[257]

Interviews with groundwater experts from state agencies highlight the importance of Wisconsin's extensive data collection, primarily through the Groundwater Retrieval Network (GRN) database, which provides comprehensive groundwater quality data statewide. GRN publicly reports well depth, statuses, construction reports, and groundwater quality data, among additional identifying variables.[258] Expert input further explains that Wisconsin also maintains a water-use data system that tracks all high-capacity wells and their monthly water use. Respondents shared that the primary impetus for enacting the Comprehensive Groundwater Protection Act was a consensus that protecting drinking water resources statewide was necessary. In addition to regulatory measures, Wisconsin's groundwater quantity protections were further clarified by landmark findings of the state Supreme Court. First, the unanimous 2011 ruling in Lake Beulah Management District v. DNR affirmed the Wisconsin DNR's role as a trustee for navigable surface waters, specifically the department's duty to ensure that surface waters are protected from impacts caused by groundwater withdrawals.[259] Second, Clean Wisconsin v. DNR (2021) held that the DNR has legal authority to consider potential harm to waters of the state from the cumulative impacts of high-capacity well groundwater withdrawals and must impose protection measures when deemed necessary (i.e., in cases of potential harm to the environment and water resources).[260] State experts explained that the combination of legislation and enforcement has enabled site-specific consideration of groundwater withdrawals.

Interviews and legislative language suggest that Wisconsin's policy framework for addressing

groundwater quality is particularly applicable to Michigan, because the states are geographically comparable and face similar contaminant threats, particularly PFAS contamination of private wells. Additionally, groundwater conditions in Wisconsin are highly variable across the state, similar to Michigan. This hydrologic diversity necessitates flexible policies that address unique regional challenges, making Wisconsin's management system particularly applicable to Michigan. Overall, Wisconsin's regulatory framework consistently emphasizes fact-based, site-specific management that addresses both quantity and quality in the water-rich Great Lakes state.

Virginia

To safeguard Virginia's water resources from contamination and overuse, the state passed the Ground Water Management Act in 1992, an amendment to its 1973 Groundwater Act. The updated standards set forth in the Ground Water Management Act of 1992 increase protections for groundwater against pollution and water shortages, primarily by establishing a groundwater permitting system that considers conjunctive use.[261] Like other state groundwater policies, the Ground Water Management Act was passed in response to declining groundwater levels in the state. Groundwater quality is legislatively protected because the act grants Virginia's DEQ the authority to revoke permits that result in inadequate water quality.[262] Critical to its success, the policy divides the eastern portion of the state into two specified groundwater management areas managed by the state DEQ. In addition to these management areas, groundwater management citizen advisory committees were created to incorporate citizen input into decision-making. These committees can propose budgetary actions, conduct statutory oversight, and make regulatory recommendations to the DEQ, which have been successfully implemented, thereby bridging the gap between state agencies and the public. Expert input further specified that advisory committees are limited to making proposals and recommendations, while oversight committees are authorized by statute to perform specific oversight functions such as groundwater recharge.

Interview respondents suggested that the backbone of Virginia's groundwater management success lies in its well permitting system. Within both designated groundwater management areas, permits are required for groundwater withdrawals of 300,000 gallons or more per month, with occasional exceptions. Even beyond groundwater management areas, Virginia has a statewide requirement to report groundwater withdrawals to the state department if they exceed an average daily value of 10,000 gallons/day in any single month. To safeguard drinking water resources, groundwater withdrawals designated for human consumption are legislatively prioritized over other withdrawal uses.[263] Findings from interviews conducted with four state groundwater experts from Virginia's DEQ substantiated the success of the state's permit requirements. These conversations explained that permits are granted based on determinations made using a comprehensive groundwater flow model. This model incorporates location, withdrawal quantity, and groundwater depth to determine whether a permit can be provided. The model further evaluates groundwater resources by assessing the area of impact (i.e., the areal extent of each aquifer where more than one foot of drawdown is predicted to occur due to a proposed withdrawal).[264] The permitting program also provides a framework for DEQ to collaborate with commercial well drillers to collect geological samples, borehole geophysical logs, and other site-specific data.

Interviews importantly noted that Virginia's groundwater management system has been uniquely bolstered for decades by the state's strong relationship with the USGS. Through this state-federal relationship, they have successfully developed a comprehensive network of groundwater monitoring wells across the state, tracking groundwater levels, trends, and quality. The state DEQ frequently contracts with the USGS to conduct special studies and develop interpretive publications on groundwater resource status. The development and ongoing maintenance of this statewide

monitoring well network have significantly improved the DEQ's ability to respond quickly to emerging threats to groundwater resources and to predict future trends of concern.

The success of Virginia's groundwater permitting system is highly applicable to Michigan and could help guide the expansion of Michigan's existing permitting framework. Michigan's current permitting system focuses primarily on the interaction between surface water and groundwater, whereas Virginia's system ensures that groundwater is also protected as a distinct resource. This distinction in permitting frameworks would be a beneficial avenue for Michigan to develop. Additionally, Virginia's groundwater regulation system underscores the need to improve groundwater data collection through thorough monitoring, ideally via a statewide network of monitoring wells. More broadly, the Ground Water Management Act recognizes and stresses the need for groundwater to be reasonably controlled under the presumption that groundwater is a public resource and, as something belonging to the commonwealth, it has to be sustainably managed. This framework of collective management and policy rhetoric could be applied to Michigan as a strategy for implementation or legislative support.[265]

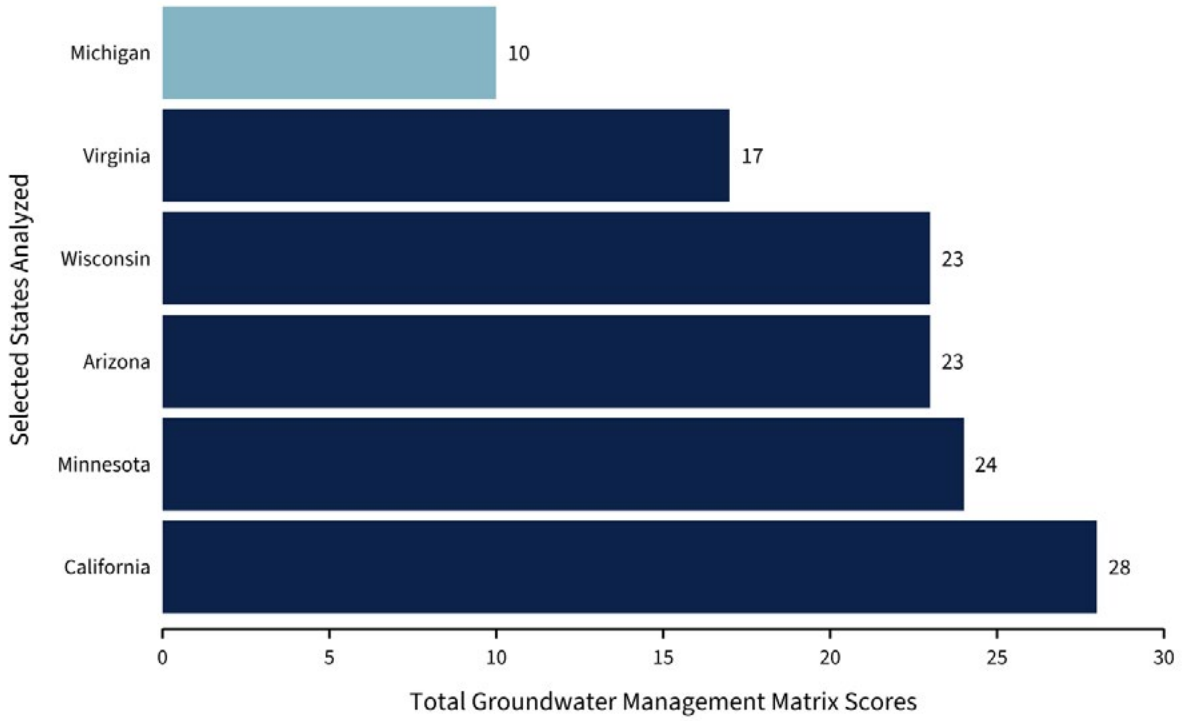

Figure 8. Summarized results of the Comparative Groundwater Management Policy Matrix. Data source: Table 5.

Qualitative analysis

Figure 8 and **Table 5** compare the strengths and weaknesses of selected state policies. An ordinal coding system ranging from 0 to 2 quantifies the success, breadth, and efficacy of statutory groundwater management (see **Section 3: Methods** for further explanation of the qualitative coding process).

Policy Conclusions

Taken together, groundwater governance in Michigan is characterized by a fragmented, multi-level governance framework, with federal policies providing a baseline but offering only limited, indirect protections. These federal protections operate by regulating various chemicals, offering limited protections for wetlands and drinking water, and providing mechanisms for cleanup in extreme circumstances through the EPA Superfund. Notably, through federal regulation, wetlands that have a continuous surface connection are protected, leaving wetlands that are connected to underlying aquifers, without a surface connection, vulnerable. Additionally, drinking water protections are only extended to municipal systems, leaving private wells exposed. The limited protection leaves state and local regulations to fill in the gaps.

Similar to federal-based policies, Michigan primarily offers indirect groundwater protection through a patchwork of regulations that primarily focus on surface water and public health. This is accomplished by providing additional drinking water and wetlands protection, land-use restrictions, regulation of waste discharges, monitoring of large-scale withdrawals, and mitigation of indirect impacts from agricultural and zoning policies. Key areas in which Michigan's groundwater management excels include the use of the Water Withdrawal Assessment Tool. While it has limitations, the tool is novel in its approach of linking groundwater withdrawals, streamflow depletion, and fish response in a statewide screening tool to assess LQW. Additionally, Michigan is one of only three states to implement a wetlands protection program that offers enhanced wetlands protection compared to federal provisions. Together with an analysis of policies from other states, these findings suggest areas for policy improvement in Michigan.

The above analysis of groundwater management beyond Michigan evaluates successful groundwater policies and identifies patterns and strengths from states with strong groundwater management systems. Across these five states, legislative documents and interviews emphasize the importance of extensive statewide data collection. Specifically, the adoption and use of groundwater modeling and mapping of hydrologic resources and groundwater flows are effective for identifying areas of concern and recognizing the interaction between hydrogeology and regulatory decisions. Each state evaluated here has defined management areas, enabling greater regional adaptability in agency oversight and regulatory efforts. Consistently, the presence of a statewide monitoring well network was a prominent factor in the success of groundwater protection measures. The production and public accessibility of groundwater status reports are critical for providing the public and regulatory agencies with updated resource information that supports efficient management.

Beyond the shared strengths of identifying specific management areas, data collection, and information sharing, each comparative state offers a unique strength applicable to recommendations for Michigan. California's ongoing review of management plans and revisions to management decisions are primary strengths. The flexibility afforded to management structures by this feature is increasingly important as issues of groundwater overwithdrawal and emerging contaminants become more prevalent across the country, including in Michigan.[266] Minnesota's framework for designating sensitive areas based on vulnerability to water quality threats enables the explicit identification of existing groundwater quality concerns and provides an avenue for regulatory efforts that are both preventive and proactive. Wisconsin's dual enforcement levels offer an innovative way to increase policy acceptability by allowing flexible initial regulation, while ensuring that required standards are met through the backstop of prevention action limits. In Virginia, the groundwater monitoring well framework and coordination with external agencies illustrate the importance of tracking resource status and the need to address hydrological variability when collecting groundwater data and developing regulatory standards from that data. Arizona's creation of AMAs and Irrigation

Non-Expansion Areas provides defined regions for groundwater management and spatially defines regulatory areas of priority and heightened concern, with a strong emphasis on protecting groundwater for agriculture and drinking water. The culmination of these legislative strengths in other states underscores how far behind Michigan remains in groundwater protection and regulation, in both quantity and quality.

Comparative Groundwater Management Policy Matrix

Policy Mechanism	Michigan	Arizona	California	Minnesota	Wisconsin	Virginia
Statutory groundwater management policy	0	2	2	2	2	2
Groundwater resource status reports or documents are consistenly developed and publicaly available	0	2	2	2	2	1
Geological mapping of current groundwater resources and hydrologic flows	1	1	2	2	2	2
Groundwater well data is publicly available through a database	1	2	2	2	2	1
Multi-tiered enforcement of groundwater management with voluntary and involuntary mechanisms	1	1	1	2	2	0
Management decisions are made by legislatively mandated management areas within the state	1	2	2	2	1	2
Quantity and quality of groundwater resources are jointly managed	0	1	2	1	2	0
Regulatory agencies coordinate groundwater management	1	1	1	1	2	1
Stakeholders are incorporated in groundwater decision-making processes	1	2	2	1	1	1
Comprehensive groundwater data are collected through the presence of a montioring well network	1	2	2	2	2	2
Models track groundwater resources and inform management decisions	2	1	2	2	1	2
Consistent and accessible communication between the public and regulatory agencies	1	1	2	1	2	1
Local-level groundwater management plans	0	2	2	1	1	1
Comprehensive funding for groundwater managemnet	0	1	1	1	1	1
Groundwater pumping fees disincentivize overwithdrawal of resources	0	1	1	1	0	0
Aquifers or basins ranked by importance or level of concern	0	1	2	1	0	0
Total	**10**	**23**	**38**	**24**	**23**	**17**

Table 4. Matrix of selected statutory groundwater legislation and policy frameworks. States of interest are compared to Michigan's existing groundwater governance framework. Scores are determined by combining direct policy language, supporting legislative documents, and expert interviews: 0=insufficient fulfillment of policy mechanism, 1=partial fulfillment of policy mechanism, and 2=sufficient fulfillment of policy mechanism.

5 Case Studies

Motivation and County Selection

The case studies explored in this section serve three key purposes. First, each case illustrates different aspects of Michigan's current groundwater management framework, including successes and challenges. Second, these cases further our policy evaluation by grounding the high-level policy analysis conducted for this report in real-world applications. Third, they facilitate the translation of lived experiences, understood through interviews with affected individuals, local officials, and experts, into policy recommendations for Michigan.

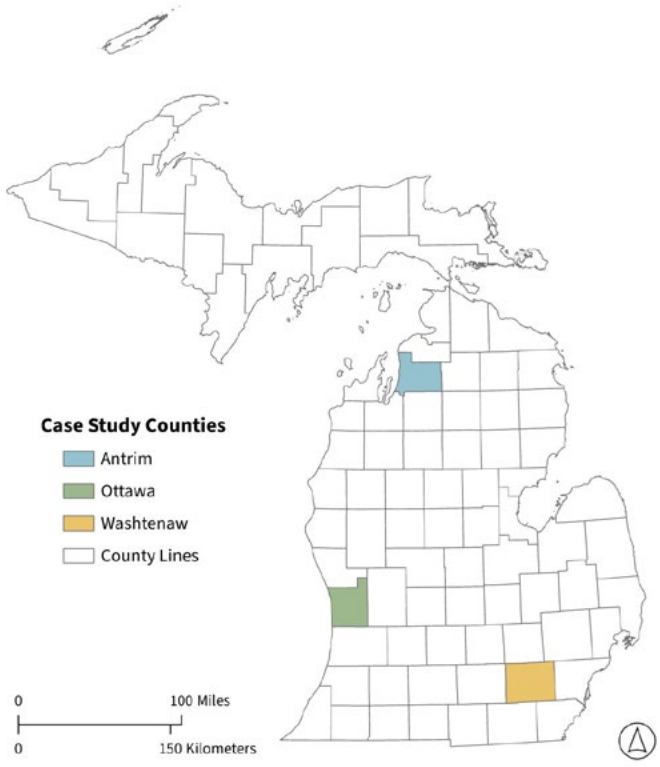

Figure 9. Map of the three case study counties: Antrim (blue), Ottawa (green), and Washtenaw (yellow). Data source: State of Michigan Open GIS Data.

To serve these three functions, Antrim County, Ottawa County, and Washtenaw County were selected as case studies of groundwater management in Michigan (**Figure 9**). Michigan's groundwater system is complex, and the problems it continues to face cannot be captured entirely by the experiences of individuals in these three counties. Instead, these cases provide a diverse set of examples to inform and illustrate the analysis and recommendations in the rest of this report. Focusing on these three counties provides insight into the complexity of groundwater management decisions involving a wide range of social, demographic, economic, political, and hydrogeological conditions. In addition to representing a range of external conditions, these counties also reflect different kinds of groundwater challenges, including industrial contamination, mining, and aquifer depletion, as well as differences in groundwater management practices over the last forty years. Lastly, these cases illustrate the role of various management decisions in safeguarding citizens and groundwater.

Antrim County

Background

Our case study in Antrim County investigates the management of two sites: the Tar Lake Plume and the Wickes Manufacturing TCE Plume. Both are orphaned sites resulting from industrial pollution, though the timelines, contaminants, and management practices differ. These sites were chosen to examine groundwater management in the context of industrial pollution, to compare key differences between state and federal approaches, and to identify additional challenges associated with

groundwater management in areas with seasonal residents. The Tar Lake Plume focuses on complete remediation, while the TCE Plume illustrates the use of institutional controls (ICs) as the primary management mechanism.

Antrim County Background Information	
Well distribution	94% of the wells in Antrim County draw from glacial deposits; less than 1% from the bedrock aquifer.[266]
Wells by type	9,107 household; 303 public; 175 irrigation; 44 unknown; 39 other; 34 test; 14 heat; 13 industrial.[267]
Watersheds	Elk River Chain of Lakes Watershed; Jordan River Watershed; Manistee River Watershed; Direct to Lake Michigan; Boyne River; South Arm of Lake Charlevoix.[268]
Population characteristics	Population - 24,697 (2025 estimate; more than doubles in the summer[269]); Population by race - white 93.9%, two+ races 4%, Native American 0.7%, Asian 0.4%, African American 0.4%, other 0.6%; Economic and Income - average income $42,161, median household income $71,421, poverty rate 9.45%; Population by age - median age 51.8.[270]
Key sites	Tar Lake Plume; TCE Plume

Table 5. Background information for Antrim County.

Tar Lake Plume

Antrim Iron Company operated in Mancelona from 1886 to 1945, producing hard and soft lumber, wood chemicals, and charcoal pig iron.[272] It was one of the most significant iron ore operations in the country, employing 500 men at its peak.[273] During operations, all unusable chemicals and waste from leftover wood products used in iron production were disposed of in a natural depression measuring 4.5 to 5.5 acres, now known as Tar Lake.[274, 275] When the company went out of business in 1945, it left behind extensive soil and groundwater contamination, including the volatile organic compounds Trichloroethylene (TCE), tetrachloroethene (PCE), and benzene (for more information, see contaminant details in **Section 2: Overview of Michigan's Groundwater**).[276] The U.S Environmental Protection Agency (EPA) began investigating Tar Lake in 1982 after identifying potential contamination linked to the former industrial site. The following year, Tar Lake was added to the National Priorities List (NPL) under the Superfund Program.[277] The EPA then conducted a remedial investigation/ feasibility study in 1985 to collect site data, determine the nature of the waste, assess human and environmental health risks, conduct treatability testing, and evaluate cleanup alternatives.[278, 279] Tar Lake's priority ranking was approximately 200 out of 1,000 sites needing cleanup across the United States.[280, 281]

In the early 1990s, resident Gary Knapp learned of the site's superfund designation when the EPA and Michigan Department of Environmental Quality (MDEQ) were delivering records to the Mancelona Library.[282] Knapp began working with both entities to advocate for the site's cleanup, as it became clear to him that the EPA likely hadn't taken action due to the community's perceived apathy.[283] In the mid-1990s, at the EPA's suggestion, Knapp created the Brownfield Action Committee, a community-based group that brought together stakeholders at the local, state, and federal levels to coordinate their cleanup efforts. The group secured a Technical Assistance Grant from the EPA, which enabled

them to hire a technical advisor to help establish the Brownfield Redevelopment Authority, a formal administrative board that supports future land use.[284, 285]

Knapp led lobbying efforts to spur further action at the state level, eventually gaining Superfund funding from the EPA.[286] Cleanup efforts began in the late 1990s, during which 47,000 tons of tar waste were removed and recycled for energy.[287] Following the removal of tar and contaminated soils, the ongoing treatment included groundwater extraction and treatment, as well as the implementation of ICs.[288] In 2013, the EPA determined that additional remediation was necessary, including soil excavation and expanded groundwater treatment. The cleanup design was completed in 2018.[289] Due to changing site conditions, including increased groundwater elevations, the design required revision in 2024.[290]

As of 2025, the Tar Lake Site remains under active remediation and long-term monitoring. While much of the 234-acre site has been cleaned up, including the removal of two large parcels of land from the Superfund list–the 45-acre Eastern Tailings area in 2005 and a 75-acre area in 2011–groundwater and soil contamination persist.[291] In 2021, the Bipartisan Infrastructure Law allocated $1 billion to clean up 49 backlogged contaminated sites, including providing an unspecified amount to Tar Lake. This supports cleanup recommendations under the 2024 site design, which are anticipated to begin in the spring of 2026. The EPA continues to conduct site reviews every 5 years to ensure that previously implemented measures continue to protect public health and environmental functions.[292] The Michigan Department of Environment, Great Lakes, and Energy (EGLE) conducts ongoing groundwater monitoring and treatment operations.

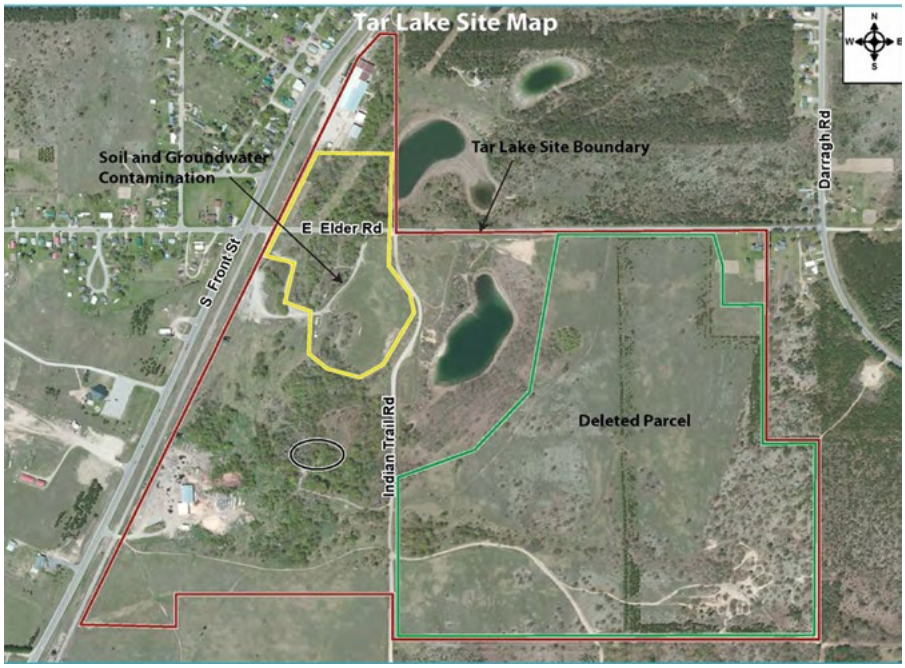

Figure 10. Map of Tar Lake Plume in Antrim County showing the site boundary, remediated portion (in green) and soil & groundwater contamination (in yellow).[293]

Wickes Manufacturing TCE Plume

Wickes Manufacturing (formerly known as Mount Clemens Industries, Inc.) operated in Mancelona from 1947 to 1967, using TCE to manufacture auto parts.[294] During that time, waste containing TCE was routinely disposed of on the ground and in shallow, sandy pits, allowing the chemical to leach into

the soil and dissolve in the groundwater.[295, 296] Over time, this improper disposal has led to significant subsurface contamination.

The Plume was discovered accidentally in 1986 while the EPA was removing unrelated metal contamination from nearby groundwater.[297] By the time the contamination was discovered, Wickes Manufacturing had long since ceased operations, and the TCE had migrated far beyond the original facility. It was soon recognized as one of the largest TCE plumes in the United States.[298, 299]

Following the discovery of the plume, the state of Michigan launched an investigation into the area to determine the extent of the contamination. Residential wells were tested, and more than 142 monitoring wells have been installed to track flow rates and directions, TCE occurrence, and changes in TCE levels over time.[300] This information is used to determine the extent of the Plume and to predict future migration.[301]

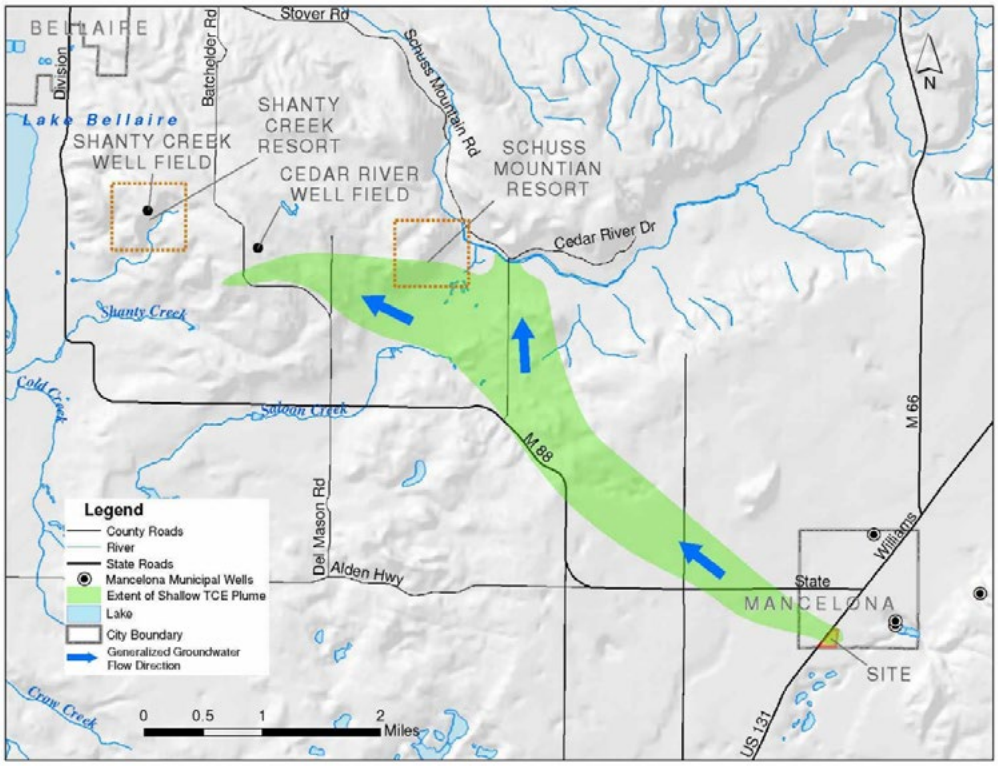

Figure 11. Map of the Wickes TCE Plume in Antrim County spreading northwest from the Village of Mancelona.[302]

The Mancelona Area Water and Sewer Authority (MAWSA) was established in 2001 at the recommendation of the DEQ (now EGLE). The MAWSA combines several local water systems, including Mancelona Village, Mancelona Township, Schuss Mountain Water, and the Sewage Authority, to provide safe municipal water to replace wells impacted by the Wickes TCE Plume and the nearby Tar Lake Plume.[303] The following year, residents formed the Antrim County United Through Ecology (ACUTE) Coalition. The group's goal was to raise awareness, facilitate discussions between residents and state agencies, and coordinate cleanup efforts for the site.[304]

In 2003, the state of Michigan assumed responsibility for managing the orphaned site. EGLE determined that the cleanup cost would range from $22 to $99 million, that no remediation method could guarantee a full cleanup, and that 20+ years of operating and maintenance costs would be required.[305] Given these estimates, the state determined the best course of action was to provide

residents with an alternative source of clean drinking water.[306] The Health Department of Northwest Michigan implemented the Well First Policy in 2005, which prioritizes connecting new residents to municipal water, requiring specific construction and sampling methods where municipal water is not available.[307] This policy was later expanded in 2012 and again in 2018 to account for the Plume's expansion. In conjunction with the Well First expansion, MAWSA has continued to extend municipal water service to areas with existing wells that are being impacted as the Plume migrates.[308]

By 2024, the state of Michigan had invested approximately $27 million to address the TCE Plume. This includes allocating nearly $15 million to fund the MAWSA, and an additional $12 million has been invested in extending and connecting homes to water mains, providing funding for sampling, providing bottled water to residents with TCE detected in their well until they are able to connect to the municipal system, and various monitoring and sampling initiatives.[309, 310] Between 2004 and 2024, 1,920 monitoring well samples have been collected and analyzed.[311]

Today, the TCE Plume contaminates an estimated 13 trillion gallons of groundwater, extending approximately 6.5 miles in length, 1.5 miles in width, and percolating down 450 feet.[312] Over 500 private wells and several community drinking-water wells have been affected. The Plume is moving at a rate of 330-525 feet per year from Mancelona, northwest, where it branches into two lobes, the west lobe and the north lobe (**Figure 11**).[313] The west lobe is moving below Schuss Mountain Resort toward Shanty Creek and Lake Bellaire, although it is not expected to reach the lake for many years. The north lobe intersects with the Cedar River, where the TCE volatilizes and evaporates. The area downstream of the surface water-groundwater interface has not been shown to contain TCE, nor has the area north of the river.[314]

The primary mechanisms for reducing harmful impacts on community members are the implementation of ICs, including the Well First Policy and expanded access to municipal water. Residents with existing wells impacted by TCE are connected to municipal water from the MAWSA. Where municipal water is not yet available, EGLE will provide bottled water to residents until they can be connected to the municipal system. The Well First Policy requires that, when building a new dwelling in an area with municipal water available, the builder must connect to the public water system. Where public water is unavailable, groundwater must be tested. If the test shows that volatile organic compounds (VOCs) exceed the EPA's maximum contaminent level (MCL), building permits will not be issued until an approved water source is located. This policy exists to ensure residents have access to clean drinking water and that contamination is not discovered after significant investment in a project.[315]

Community Perspectives and Takeaways

The experiences of local officials and residents in Antrim County indicate overall confidence in the state's management of the two contaminated sites. Eight out of ten community members considered the state's management, particularly of the Wickes site, a success. Interviews suggest that funding and local community collaboration are critical pieces of effective management. However, the Wickes Plume continues to expand as management focuses on minimizing human exposure, creating both greater ecological risk and a greater burden of contamination for future generations. Key groups that currently participate in groundwater management in Antrim County include EGLE, the Village of Mancelona, MAWSA, the EPA, and the Health Department of Northwest Michigan. While it has since disbanded, the ACUTE Coalition played an important role in mobilizing action in the early 2000s.

Management of the contaminated Tar Lake and Wickes plume sites has been consistently supported by extensive state funding. In addition to this financial support, EGLE also played a role in creating the MAWSA, which combines local resources to serve the ever-expanding group of residents who have lost

safe access to their wells. EGLE's role in creating MAWSA was praised by local officials for increasing community confidence in the management process and, in turn, catalyzing collaboration among affected communities. When asked about how their case could contribute to better groundwater management in other communities, a long-time resident and current local official said, "I think we were real lucky, when they formed MAWSA at the time, when they came to them to form the authority, that… all the communities, like the townships and the village all collaborated. That doesn't happen a lot in a lot of other communities, and I think we were real lucky that way, that that happened." According to local officials and regional agents, this logistical and financial support from the state is critical to protecting residents from harm.

An equally important factor in managing both sites is community engagement. Specifically, two elements of working with local communities were repeatedly mentioned as crucial. First, EGLE's project manager for both the Tar Lake site and the TCE plume continues to collaborate with local libraries and administrative offices to distribute information about contamination in general and residents' exposure in particular, using methods such as fact sheets and presentations. They also maintain strong relationships with local officials regarding the status of the sites. One community member told us, "So, of course, immediately you're wanting to make sure that your family is safe, and that you understand what's going on. And there is some of that that happens. But a little bit of education goes a long ways. And helping people understand … the extent of the municipal system at this point. Thanks to [EGLE site manager], … what's already in place is just tremendous."

Second, parties involved with managing the contamination and limiting human exposure act around the schedules of seasonal residents. Antrim County is home to several large resorts, including Shanty Creek and Schuss Mountain, and many residents affected by the TCE plume live there only for a few months each year. To accommodate this fluctuating occupancy, the Health Department of Northwest Michigan and MAWSA reach out to residents and strategically sample wells during peak vacation times. According to interviewees, these two outreach methods have created a trustworthy system of information sharing between the state, local agencies, and residents that promotes public health.

The key challenge of groundwater management in Antrim County, specifically for the TCE plume, is that it relies solely on a risk-based public health approach. Since Mount Clemens Metal Products dumped TCE in the mid-20th century, and the state was unaware of it until 1986, the plume has grown into the largest TCE plume in the country. The state has deemed remediation infeasible (financially and logistically) due to its scale. And as a result, the plume is migrating towards Torch Lake and the Cedar River, as well as the Cedar River well field that contributes to MAWSA's water supply. Although the expansion of municipal water has, as far as current evidence indicates, successfully protected human health from the chemical, the plume's expansion remains an exposure threat to residents through vapor intrusion and connected ecological systems.[316] This contamination will persist in the soil for future generations, and the costs of any eventual remediation will only increase as the plume expands. Moreover, because TCE is extremely difficult to remove and the plume is so large that remediation is infeasible, the community has likely lost access to the aquifer's drinking water forever.

The contamination cases in Antrim County illustrate the importance of state funding, public engagement, and community connection in long-term groundwater management. One local official credited much of the sites' abundant funding to "luck." But organized community advocacy played an undeniable role in drawing attention to the sites and in challenging the state to create effective communication systems to keep local governments and residents informed.

While these factors have built a sense of success among community members, the limitations of Michigan's cleanup standards and the exceptionalism of funding availability indicate shortfalls in the state's groundwater management. Although the decades of ignorance that allowed the Wickes plume

to fester may not have been preventable, the case demonstrates the exponential and irrevocable cost of contamination when it is allowed to continue and expand. Lastly, the community sentiment that financial and technical support from the state was "lucky" and exceptional indicates that more funding and staff capacity are necessary to fully support thorough, community-approved resource management.

Ottawa County

Background

This case study of Ottawa County examines overwithdrawal from the glacial drift and Marshall aquifers and resulting brine upwelling. This county was selected because of the compounding quantity (aquifer depletion) and quality (brine upwelling) issues raised in its case, its rapidly increasing population, and its conservation and education management strategies, rather than ICs or remediation.

Ottawa County Background Information	
Well distribution	62% of wells in Ottawa County draw from glacial deposits; 31% from the bedrock aquifer (primarily Marshall Formation (confined).[315]
Wells by type	21,011 household; 1,506 irrigation; 791 public; 621 test; 198 unknown; 175 other; 98 industrial; 53 heat.[316]
Watersheds	Black-Macatawa, Lower Grand River, Kalamazoo River, Pere Marquette-White, and Lake Michigan.[317]
Population characteristics	Population - 308,280 (2025 estimated); Population by race - white 85.5%, two+ races 6.3%, other 3.5%, Asian 2.8%, African American 1.6%, Native American 0.5%. Economic and Income - average income $52,620, median household income $87,144, poverty rate 8.16%; Population by age - median age 36.3.[318]
Key sites	Groundwater shortages throughout the county, most severe in the central area.[319]

Table 6. Background information for Ottawa County.

Overwithdrawal and Brine Intrusion

Groundwater issues in Ottawa County are driven by the area's geology, land use, population growth, and periodic droughts. The area is underlain by two extensive aquifers, including a shallow, unconfined glacial drift aquifer and the Marshall Formation, a confined bedrock aquifer (see **Section 2: Overview of Michigan's Groundwater**).[322] Due to depletion of the glacial aquifer, there is increased reliance on the bedrock aquifer, which is overlain by a thin layer of clay that prevents vertical recharge. When the aquifer is pumped faster than it can be replenished, water availability becomes an issue, as does saltwater intrusion from natural deposits deep within the aquifer. Ottawa County is the fastest-growing of Michigan's 10 largest counties, with 3.14% population growth between 2020 and 2024.[323] As the population continues to rise, competition for groundwater from the Marshall aquifer has intensified.

Groundwater shortages were first reported in 2007 when residents' wells ran dry, and farmers saw their crops die. Residents in the newly constructed Highland Trail subdivision of Allendale Township were the first to experience their water shortages through their wells. This was followed by farmers noting that their soybean crop was being "burned" because it was irrigated with water from deep wells drawing up salty brine.[324]

Following the reported shortages, the Ottawa County Board of Commissioners partnered with the Institute of Water Research at Michigan State University (MSU) to investigate the issue. They launched a two-phase study.[325]

- In Phase 1, which concluded in 2013, they analyzed existing groundwater data to map aquifers, evaluate recharge areas, and characterize groundwater quality, with particular focus on salinity and nitrate concentrations.[326] A key output of this study was the Interactive Web-based Water Resources Decision Support System, an online tool integrating the MSU study results with county and state data to visualize aquifer characteristics, groundwater flow, and water quality in Ottawa County. The county began using the work completed in this stage for planning and management.
- Phase 2 of the study concluded in 2018. It aimed to address questions raised in Phase 1, including why Ottawa County water is becoming increasingly salty, what factors control the occurrence of dry wells, whether the issues reflect a larger systemic problem, and how groundwater conditions might change over time. Key takeaways from this study indicated that the aquifer would continue to decline and that sodium chloride concentrations would continue to rise if proactive measures were not taken.[327]

Local officials, local governments, and residents took various actions based on the findings from the MSU reports. In 2019, Ottawa County's Department of Strategic Impact launched the Groundwater Sustainability Initiative to ensure that all residents and stakeholders in the county have permanent, sustainable access to clean water for reasonable use.[328] They created a comprehensive plan outlining education, integration, mitigation, and coordination strategies. For each identified strategy, the county outlined the approach, its components, essential partners, and next steps for implementation.[329]

- **Education strategies**: launching an outreach campaign, providing online resources with local groundwater information, forming partnerships for college, youth, and community education, and building a community presence.
- **Integration strategies**: engaging stakeholders and promoting household conservation, including landscape and irrigation practices.
- **Mitigation strategies**: establishing regulatory and policy frameworks, such as creating model zoning ordinances and health code revisions, land-use planning, water recycling strategies, and groundwater monitoring and mapping.
- **Coordination strategies**: developing county support personnel, a Groundwater Technical Advisory Board, a Groundwater Commission, and collaboration.

Other measures include converting turfgrass to native, low-maintenance landscapes on county campuses, an action that not only saves water and money but also acts as a model for future water-efficiency projects across other public facilities and for the public.[330] Also in 2019, Allendale Township implemented a temporary development moratorium, which led to a policy requiring new residential developments to connect to municipal water sourced from Lake Michigan.[331]

In 2021, the County Board of Commissioners established the aforementioned 15-member Groundwater Technical Advisory Board to provide policy recommendations and help develop regulatory standards to protect groundwater in Ottawa County.[332] Groundwater Board members are

appointed by the Ottawa County Board of Commissioners. Today, the Groundwater Board includes 17 individuals from the county government, local governments, public utilities, agriculture, education, real estate, members of the scientific community, well drillers, and one community member at large.[333] The Board meets regularly to discuss opportunities in groundwater management, monitor relevant ongoing initiatives, and make policy recommendations to the county.[334] Since the summer of 2025, representatives from EGLE's Water Use Program and Groundwater Data Unit have attended each of their meetings.[i]

Ottawa County continues to face challenges with groundwater quantity and, as a result, quality. These issues are exacerbated by changing weather conditions. In 2025, Ottawa County was under a severe drought, receiving less than two-thirds of its normal precipitation.[335] The reduction in rainfall significantly affects the Marshall Aquifer's recharge capacity, a process already constrained by its confinement. Residents in Ottawa County receive water from municipal sources, such as Lake Michigan, or from private wells; however, much of the county is rural and lacks access to municipal water, and extending lines to these areas is often cost-prohibitive, limiting municipal access to cities. This leads county officials to prioritize educating residents on water conservation as their primary management strategy.

Community Perspectives and Takeaways

Aquifer depletion in Ottawa County is an emerging threat long in the making. While the direct causes of aquifer depletion are restrictive hydrology and overuse, local officials suggest that the two main drivers of the problem are a lack of public awareness about groundwater and insufficient hydrogeological mapping to understand the challenge. In their view, greater public awareness and mapping would allow the region to conserve groundwater in general and plan resource management based on robust, up-to-date information, eventually turning the water crisis into a manageable problem. One county-level official emphasized the importance of education eight times during their interview, largely chastising residents for excessive lawn irrigation and domestic use. Interestingly, they praised agricultural producers for decreasing consumptive groundwater use.

In addition to education and mapping, municipalities have taken steps to concentrate new residential development along existing municipal water systems, which overwhelmingly draw from Lake Michigan, to decrease pressure on the aquifer. Explaining that their community passed such an ordinance, one local official recalled: "Usually [developers] go, 'Well, that doesn't make any sense, I can't afford to do that.' It's like, well, neither can we. So why don't you build closer to where the source is today." As outlined above, the county has taken strong initiative by creating a Groundwater Technical Advisory Board to allocate resources, guide long-term planning, and bring attention to the depletion. The county has also created productive partnerships with institutions such as MSU, Michigan Geological Survey, and Hope College to advance planning and research.

According to interviewees, three successes in Ottawa County's management of aquifer depletion highlight the importance of cross-agency relationships in groundwater management. Primary groups involved in management and advocacy include the Ottawa County Office of Strategic Impact, the Office of County Water Resources Commissioner, the Ottawa County Health Department, and the Groundwater Board. First, designating the Office of Strategic Impact as a leader in addressing the problem appears to have clarified responsibility for certain initiatives, such as community education and outreach, thereby making them more effective. Throughout interviews, specific individuals were referenced as leaders on particular topics. Second, the establishment of the Groundwater Technical Advisory Board, often cited in interviews as a productive step toward comprehensive long-term planning, is another example of explicit leadership and collaboration between agencies. Groundwater

i L. Pappas, personal communication, February 16, 2026.

Technical Advisory Board members are appointed by the County Board of Commissioners and serve an advisory role to groundwater management at the County level. Lastly, communication across levels of government was identified as critical to maintaining information and implementing short-term solutions in Ottawa County. One example of this collaboration is the partnership between Allendale Township and the Health Department to educate residents about local water quantity concerns through the well-permitting process.

In addition to these important successes, our interviews with local officials in Ottawa County identified six key challenges of groundwater management that make conserving groundwater more difficult.

1. State regulations restrict large-scale water reuse, such as graywater for feed-grade agricultural irrigation or residential irrigation. This limitation results in more net consumptive groundwater use than necessary, and officials across Ottawa County's agencies are interested in taking advantage of expanded water reuse opportunities should they become available.
2. While the Water Withdrawal Assessment Tool (WWAT) considers compounding water use in water management areas, the tool accounts only for large, registered withdrawals and does not account for compounding small-scale water use in concentrated areas, such as well-dependent subdivision housing developments. Residential water use is posited to be the driving force behind overwithdrawal in Ottawa County, and the county is among the fastest-growing in Michigan.[336, 337] Because of residential groundwater use and the county's growth, the importance of assessing the risks of compounded residential withdrawals and of diverting some of that use to graywater was emphasized in interviews.
3. A general lack of public awareness of groundwater was identified as a barrier to greater water conservation across all our interviews. Respondents in the county called for greater school and community engagement to expand Michigan residents' understanding of where their water comes from. Importantly, education alone cannot protect groundwater. As one local well-driller told us, "Education is such a key component of all this going forward. …But education won't do it alone. You still got [to do] your part."
4. Given the county's unique experience as the first (but, importantly, not only) Michigan county to face such vast quantity concerns, officials involved with the issue shared that they've received little support from the state. While county officials were largely resistant to relinquishing decision-making power, they wished they had more funding and greater access to state technical expertise to tackle the challenges of groundwater mapping and monitoring.
5. The first round of external research done on the topic in 2013 was limited by the lack of complete hydrologic data. Instead, it relied in part on well-driller records, which, while robust, may not meet scientific standards and are not intended for quantitative analysis. The study's reliance on alternative data underscores the state's need for comprehensive, accurate hydrogeological data for groundwater management.
6. Increasingly frequent drought conditions on Michigan's west side exacerbate aquifer depletion.[338] While the Marshall Aquifer is confined and recharges slowly, drought conditions hinder recharge to both the Marshall and bedrock aquifers due to limited filtering of rainfall. Drought also magnifies residential water-use habits, such as lawn irrigation for especially dry grass.

Ottawa County's case over the last roughly 15 years demonstrates valuable lessons on groundwater management mechanisms. First, the specific roles of certain agencies—in this case, the Office of Strategic Impact and the Groundwater Technical Advisory Board—and collaboration across groups and levels of government can facilitate more efficient and effective management. In contrast, regulatory limits on water reuse, the disregard of compounding, small-scale water use in Michigan's Water

Withdrawal Assessment Program, weak public awareness, lack of technical and financial support from the state, shortage of accurate and appropriate groundwater data, and increasing drought conditions make management more difficult in this case. These successes and challenges highlight areas for appreciation and advancement in groundwater protection. In fact, some are already being addressed to improve the County's management. In 2025, Ottawa County joined EGLE's Hydrologic Enhancement for Michigan (HEMI) mapping project in collaboration with the U.S. Geological Survey. While it is forecasted to take many years, this data collection and analysis will provide the most detailed hydrologic models for the region to date.

Washtenaw County

Background

This Washtenaw County case examines the Gelman plume and dewatering and contamination associated with the Vella Pit. Both issues stem from industrial operations; however, the Gelman plume is historic 1,4-dioxane pollution, and the Vella Pit is an ongoing gravel mining operation. Selecting this county allowed us to examine industrial pollution involving a liable party, the intersection of contamination and municipal water, and quantity and quality issues arising from dewatering, damage to wetlands, and the creation and dredging of a lake. These cases highlight the intersection of work and management across local, state, and federal agencies.

Washtenaw County Background Information	
Well distribution	86% of the wells in Washtenaw County draw from glacial deposits; 11% in the bedrock aquifer (primarily Marshall Formation.[337]
Wells by type	30,270 household; 727 public; 695 other; 612 irrigation; 438 test; 264 unknown; 85 industrial; 55 heat.[338]
Watersheds	Huron River Watershed, Rouge River Watershed, River Raisin Watershed, North Branch Swan Creek Watershed, Stony Creek Watershed, and Grand River Watershed.[339]
Population characteristics	Population - 363,600 (2025 estimate; 6th largest population in Michigan); Population by race - white 70%, African American 11.6%, Asian 8.9%, two+ races 7.7%, other 1.6%, Native American 0.3%. Economic and Income - average income $57,977, median household income $87,156, poverty rate 13.84%. Population by age - median age 34.8.[340]
Key sites	Gelman 1-4, dioxane plume, Vella Pit

Table 7. Background information on Washtenaw County.

Gelman plume (1,4-Dioxane)

From 1966 to 1986, Gelman Sciences (later Pall Corporation and now Danaher) used 1,4-dioxane, a synthetic industrial solvent, in its manufacturing process for various filters and pollution-testing products.[343] During Gelman's production, it disposed of wastewater onsite, where it seeped into

the groundwater, creating a large, migrating plume that has impacted surrounding communities by removing their access to wells, forcing municipal connections, and reducing property values.[344]

The plume was discovered in 1984 by a University of Michigan public health student, Dan Bicknell, while completing water testing at Third Sister Lake in the Saginaw Forest.[345] Subsequent investigations and sampling by the Washtenaw County Health Board found 1,4-dioxane in 30 residential wells north of the Gelman property.[346, 347]

In the decades since, the state of Michigan, the City of Ann Arbor, Washtenaw County, Scio Township, and various environmental organizations have been involved in addressing and advocating for the cleanup of the contamination. In 1988, the state of Michigan filed its first lawsuit against Gelman, resulting in the 1992 consent judgment requiring the company to pay over $1 million in damages and $4 million to initiate cleanup and monitoring.[348] Initial remediation included pumping contaminated groundwater, treating it, and discharging it into a tributary of the nearby Huron River.[349] EGLE (then the Department of Environmental Quality) was responsible for managing and overseeing the consent judgment activities and the necessary National Pollutant Discharge Elimination System (NPDES) permit.[350] Despite these efforts, the plume continued to spread.

Following the initial court proceeding, several other cases have arisen, including four amendments to the original consent judgment to reflect changes in state laws and new information.[351] In a 2005 lawsuit between the state of Michigan and Gelman Industries, the court established a Prohibition Zone (PZ) as an IC for managing the plume. While the company is required to continue to pump and treat contaminated groundwater to lower concentrations, the PZ allows groundwater within its boundaries to remain and migrate at concentrations above those acceptable for residential drinking water. All properties within the PZ are required to connect to municipal water, as the installation, maintenance, and operation of wells for drinking or irrigation are prohibited within the PZ boundaries.[352] The PZ was expanded in 2011 with the third amendment to the consent judgment.[353]

Between 1995 and 2000, Michigan relaxed its cleanup standards, raising allowable levels of 1,4-dioxane in groundwater from 3 parts per billion (ppb) to 85 ppb.[354] In 2016, EGLE updated the state's cleanup criteria, lowering the maximum acceptable level before action is required to 7.2 ppb. The reduction in cleanup criteria prompted the fourth amended consent judgment in 2023, which adopted the lower maximum acceptable level, reduced the groundwater-to-surface water interface (GSI) level from 2,800 to 280 ppb, and expanded the PZ.[355] As of 2026, there is no federal MCL for 1,4-dioxane, leaving states to decide whether and where to set their own standards.[356] Out of the 12 states that have done so, Michigan has the highest (most lenient) MCL.[357]

Throughout this activity, local advocacy has been central to maintaining public awareness of the plume and advocating for increased cleanup. In 1995, residents formed Scio Residents for Safe Water to promote groundwater protection and preserve groundwater.[358] In 2017, the Coalition for Action on Remediation of Dioxane (CARD) formed a partnership of local governments and citizens to improve transparency, coordination, and cleanup outcomes.[359] These groups have been integral to raising public awareness of the plume and to maintaining contact with relevant actors, such as the State and the Health Department.

In 2021, EGLE issued a letter to the EPA formally requesting that the Gelman plume be added to the Superfund NPL, which would allow federal oversight and potentially more aggressive cleanup measures, as well as federal funding.[360] This move echoed decades of similar efforts by residents and local governments, who cited limited state progress in addressing the plume as a major concern. In 2024, the EPA proposed the site for superfund listing with the endorsement of Governor Gretchen Whitmer and U.S. Representative Debbie Dingell.[361] While awaiting the EPA's decision on Superfund

designation, the fourth consent judgment remained in effect.[362] In March of 2026, EGLE announced that the EPA had officially added the Gelman plume to the NPL, marking the start of a coordinated federal-state cleanup effort. The EPA will take the lead on developing a comprehensive analysis of the plume, developing remediation plans, and determining enforcement actions.[363] Following its initial discovery, the plume has expanded to be 3 miles long and 1 mile wide.[364] As of April 2026, the plume has primarily impacted private wells. However, it is trending toward Barton Pond on the Huron River, which is where Ann Arbor Water sources 85% of its municipal water.[365]

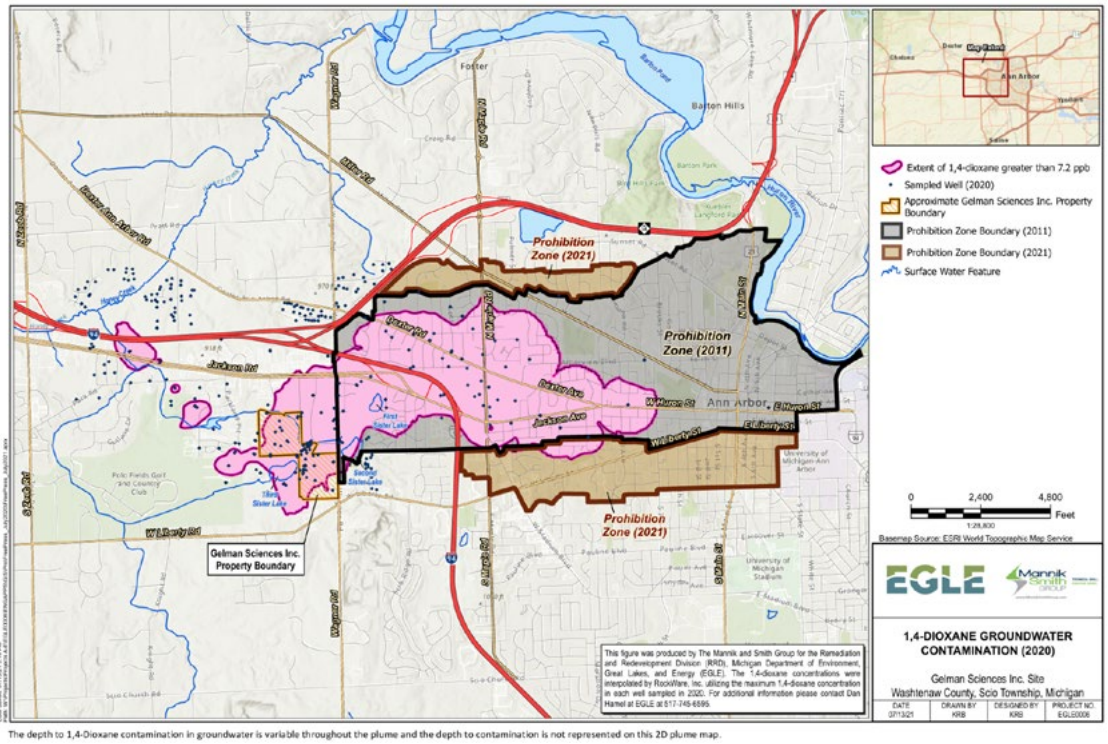

Figure 12. Map of the Gelman 1-4, Dioxane Plume in Ann Arbor showing the extent of the plume and the 2011 and 2021 prohibition zones.[366] Image credit: EPA.

Vella Pit Dewatering

In 2020, Mid Michigan Materials (MMM) purchased the Vella Pit, a former family-run sand-and-gravel mining operation in Ann Arbor Charter Township. They applied for a Conditional Use Permit (CUP), which is required by the township's zoning ordinance. The permitting process includes a hydrogeological study and work plan, baseline water quality measures, an environmental impact statement, public notification, and a public hearing to receive community input.[367] Residents assert that they learned about the CUP application from signs posted at the site stating that the process was pending. Several residents, fearful of the impact of increased operations, began to participate in the Planning Commission proceedings. Despite their concerns, the township granted the mine a CUP, and operations began soon after.

Beginning in 2022, residents near the mine noticed their wells losing pressure and running dry.[368] Residents independently contacted local drilling companies about their well issues, and the companies informed them that what they were experiencing was not unique: they had serviced other calls in the area involving well owners with similar problems. Residents began meeting to discuss how to address the problem and attending township meetings, which, in some cases, were hosted at Washtenaw Community College to accommodate the large turnout.

In May of 2023, MMM submitted a permit through EGLE to increase its withdrawals from 2.0 million gallons per day to 4.8 million gallons per day. It was later revealed that their permit application was retroactive as they had already been pumping up to 4 million gallons per day.[369] Shortly after, MMM withdrew the permit following significant community pushback and anticipating EGLE's denial. Around this time, local residents created a webpage to inform the public of ongoing issues and provide updates.

Later that year, Ann Arbor Township found that the mining operation had violated its Conditional Use Permit, Development Agreement, and Township Ordinances, citing 13 violations, including impacts to drinking water and nearby wetlands. They filed a motion for a temporary injunction, seeking to prohibit MMM from mining. Pumping at the Vella Pit was temporarily halted following a court order in October of 2023, which prohibited them from discharging wastewater or groundwater, or causing a net loss of groundwater from the site.[370, 371] Simultaneously, EGLE cited MMM for additional violations, including Parts 31 (Water Resources Protection), 91 (Soil Erosion and Sedimentation Control), 301 (Inland Lakes and Streams), 303 (Wetland Protection), and 327 (Great Lakes Preservation).

After this permit attempt, the mine changed tactics: instead of dewatering, it created and enlarged a lake and began dredging its bottomlands. Michigan law requires a permit for dredging and enlarging lakes, which MMM failed to receive (MCL 324.30102).[372] Soon, the dewatering issues shifted to water quality issues, with residents up to three miles from the Pit experiencing brown tap water, black water filters within days of replacement, and irreparable damage to their filtration and water softening systems.[373] The new lake is just east of Massey Lake, which the EGLE Violation Notice identified as contaminated due to MMM's activities.[374]

Figure 13. Aerial image of Contaminated Massey Lake (bottom) and the newly created lake (top) April 2025 Image credit: Michael Watts.

In May of 2025, several significant events took place. By this time, the lake they had created had been enlarged to approximately 15 acres, and the mine submitted a Part 301 (Inland Lakes and Streams) permit in May with plans to continue to enlarge it to 59 acres.[375] As part of the permit application, MMM was required to submit a hydrologic study, which found that the lake in question is connected to and fed by groundwater, and that enlargement of the lake would be a source of pollution to the aquifer and nearby surface water.[376] Despite making this connection, the hydrologic study failed to discuss the

impact of mining bottomlands on connected groundwater. In this application, MMM shared its plans to mine the lake over the next 20 years.[377, 378] EGLE reclassified the now 15-acre lake on site as an A-1d impoundment—an industrial/commercial wastewater treatment facility—because it was filled with mine slurry and sludge.[379] Despite this waste pit being directly hydraulically connected to the aquifer that supplies drinking water to the nearby residents and its close proximity to residential wells (120 yards), the mine continued to dredge through 2025.[380]

In July of that year, the mine's CUP expired, and they received an administrative stay from the township in order to continue operating.[381] The township and EGLE hosted public hearings regarding their Part 301 permit application, at which the township claimed the Vella Pit had no violations, and MMM admitted they were already enlarging and dredging the lake—their application was, in fact, retrospective.[382]

In September, the township settled with the mine over the violation of the CUP, granting them 6 more years of mining with no fines.[383] The next day, EGLE found the hydrological model MMM had submitted was "unreliable," citing that it failed to accurately predict the impacts their plan would have on groundwater. EGLE denied the permit application for the second time. [384, 385]

On December 15, 2025, three families that live near the Pit filed a lawsuit against MMM, arguing that the operator has violated the Michigan Natural Resources and Environmental Protection Act, violated their riparian rights to Massey Lake, and operated as a public and private nuisance.[386] Mining activities have and are continuing to create vibrations, noise, and dust. Residents argue that the mine's activities have caused immediate and irreparable harm, and are requesting that the mine remediate and restore the site to its original condition.[387]

In January of 2026, the same families that filed a lawsuit against Mid Michigan Materials, filed a contested case against EGLE regarding a Part 31, Groundwater Discharge General Permit granted November 24, 2025. Under this contested case, it is alleged that the mine's discharge violates Part 31 by discharging wastewater to surface water that is injurious to waters of the state and private property; causes erosion, runoff, and flooding to adjacent properties; creates unsafe conditions and the facility's treatment and that control is not in good working order.[388]

Community Perspectives and Takeaways

The contamination caused by Gelman Sciences and the aquifer depletion associated with the Vella Pit are sensitive, sometimes visceral, environmental issues for both residents and officials who manage the sites. Several interviewees highlighted the tension among Ann Arbor's reputation as a leader in environmental protection, the University of Michigan's status as an elite research institution, and the ongoing threats posed by both contamination and overwithdrawal to residents' health and quality of life. The groundwater issues in Washtenaw County both illustrate the power of local advocacy and expose key weaknesses in Michigan's current regulatory structure.

In both cases, community advocacy pushed for better management and oversight of agencies. CARD has worked with EGLE and local groups for decades to monitor site progress and hold those involved in groundwater management accountable. Regular meetings between officials and advocacy groups involved in the 1,4-dioxane plume, including EGLE, CARD, and the County Health Department, were cited as a productive forum for information sharing. Save Our Wells worked with Ann Arbor Township to demand a state investigation into the Vella Pit mine, and impacted residents continue to pursue additional avenues for accountability. Like in Antrim County, advocacy groups can uphold the responsibilities of official actors and raise public awareness, thereby increasing pressure on those involved in management. However, while valuable, grassroots advocacy should not be necessary for effective groundwater management that protects people and natural resources.

The Gelman plume and Vella Pit demonstrate the inadequacy of Michigan's regulatory framework and enforcement approach in two ways. First, at the Vella site, withdrawal and discharge permits were repeatedly violated. Moreover, EGLE was aware of these violations and their connection to nearby residential wells that had run dry, and had issued warnings. Despite this state-level awareness, the mine has continued to operate and violate its permits without disruption. Permitting systems mean little for groundwater protection without effective enforcement mechanisms to ensure compliance. A 2024 Auditor General's report evaluating Michigan's water withdrawal program similarly concluded that EGLE does not adequately track whether large-scale water users withdraw within the limits of their water use permits.[389] The failure of the state's permitting process to prevent groundwater misuse suggests that EGLE needs both stronger enforcement power and greater internal capacity to monitor permitted water users.

Second, with respect to the Gelman plume, application of Part 201 of NREPA allows the responsible party to remediate only to the extent necessary to keep dioxane levels below the public health threshold. Private consultants hired by liable parties to develop site plans have also exerted considerable sway over the extent to which dioxane is removed from the ground. One EGLE official told us, "...they have the ability to what's called 'self-implement.' They can do something, and … maybe it's not what we think is the best, but … we have somewhat limited input on what we can tell others to do in that scenario." As a result, the plume continues to expand and is now approaching the Huron River, which supplies the majority of Ann Arbor Water's municipal supply.[390] An analyst from the Washtenaw County Health Department explained, "Instead of [putting] the energy in while it was concentrated in a little area, now it's diluting a big area, and it's exponentially more difficult to try to clean up." In response to the EPA's consideration to designate the plume a Superfund site, a lawyer from Danaher, which now owns Gelman, insisted that the company has satisfied Michigan's remediation standards.[391] However, the state law that Gelman satisfies allows contamination to migrate and persist. One EGLE analyst told us, "It would be great to see more effective cleanup. But, right now, people aren't being exposed, the Michigan law is more about risk management than clean up, and, based on the criteria that we have for managing that risk, we think that the Gelman site people are protected right now." The requests for federal intervention by EGLE, Representative Debbie Dingell, and Governor Gretchen Whitmer emphasize the failure of state regulation to sufficiently protect groundwater and residents. In March of 2026, the EPA announced that the Gelman plume had been added to its NPL and, as of April 2026, CARD, EGLE, and the EPA are in communication about transitioning management and public engagement from the state to federal staff.[ii]

Groundwater contamination and depletion in Washtenaw County demonstrate the power of community organizing to increase accountability and identify critical weaknesses in state-level protections and enforcement. Specifically, EGLE's failure to enforce against permit violations and the limitations of Part 201, which focuses on minimum public health thresholds while allowing contamination to fester, are areas that require improvement in Michigan's groundwater management.

Case Study Conclusions

These case studies facilitate ground-level evaluation of Michigan's current groundwater management practices. In Antrim County, two industrially contaminated sites have been robustly funded by the EPA and EGLE. Through intergovernmental collaboration and thoughtful engagement with residents, the State has fostered trust and a sense of success. However, groundwater contamination persists with no plan for remediation, infinitely limiting the human and ecological value of groundwater. In Ottawa County, the combination of unique geology and excessive groundwater withdrawal, exacerbated by population growth and drought, continues to cause groundwater scarcity. While the county is

ii R. Rayle, personal communication, March 24, 2026.

investing in public education on water conservation and has created the Groundwater Board to advise on projects and planning, gaps in groundwater mapping, withdrawal assessment, and water reuse opportunities continue to pose barriers to better management. In Washtenaw County, the ongoing expansion of the Gelman plume and permit violations at the Vella Pit expose weaknesses in Michigan's regulatory provisions.

The gaps revealed by these examples of current management suggest several opportunities for better groundwater protection:

- The state should provide more funding and technical support to local entities facing groundwater challenges. In Antrim County, MAWSA depends on state funds and logistical support to protect residents by expanding their public water supply while the contamination spreads unabated. In Ottawa County, officials await state-funded groundwater mapping, without which they cannot properly assess the problem or plan to solve it. While regulation and appropriation occur at the state level, the generous allocation of both financial and technical resources must be shared with local actors to effectively protect groundwater and public health.
- Intentional and proactive public education must be pursued to fortify effective management across groundwater issues. The actions of state officials who maintain regular, fact-based communication with residents in Antrim County were commended by community members. In Ottawa County, the County aims to change the course of its groundwater challenge by encouraging water conservation through public outreach. While the impact education will have in Ottawa County is not yet known, the approach in both cases suggests that local officials rely on information sharing as a key part of groundwater management.
- Michigan remediation standards must be strengthened to prevent the persistence or expansion of contamination that would limit future groundwater use. In Antrim and Washtenaw Counties, industrial contaminants were deliberately introduced into soil and groundwater, and the plumes migrated until they were discovered. In both cases, the contamination has since been allowed to continue to expand, spreading towards surface water bodies and public water supplies. Michigan's current risk-based approach to cleanup maintains contaminant levels low enough to technically protect human health and connected ecosystems, but it does not prioritize actually removing contamination. In the case of the Wickes plume, since TCE is extremely difficult and expensive to remove, and the plume is so large, it will likely persist indefinitely. Such an allowance practically relinquishes the value of groundwater—both financial and environmental—to legacy polluters.
- Future aspects of Michigan's Water Use Program must account for the compounding effects of small-scale withdrawals. In Ottawa County, officials are concerned about the impact of well-dependent population growth on the depleted Marshall aquifer. Michigan's Water Withdrawal Assessment Tool is a comprehensive model for evaluating large-scale withdrawals and is currently being updated as additional, more specific data become available. As the WWAT is improved over time, additional complementary research should investigate novel ways to account for the impact of small-scale wells in a given area, which may use just as much or more water as a single large user.
- Michigan must eliminate zoning privileges for natural resource mining. In Michigan's Zoning Enabling Act, natural resource mining is especially protected from local land use regulation.[392] In practice, this provision means that municipalities may not "zone out" mining operations or exclude such land use from their ordinances. Even Ann Arbor Township's extensive permitting process for mines could not prevent abuse by MMM, which flagrantly violated its permit conditions.[393]

The stories of local groundwater challenges demonstrate both where Michigan's current management system is significantly involved and where it falls short. In the next section, these findings are combined with an analysis of Michigan's groundwater use and contamination, as well as policy research, to propose strategic recommendations.

6 Recommendations

Given that there is no national groundwater management governance system, states are largely on their own to manage groundwater resources. This is both a liability and an opportunity for Michigan, as the previous sections show that Michigan has significant legislative and administrative gaps in groundwater management. To leverage the lack of federal governance and leadership as an opportunity, we propose a 3-part strategy that includes making recommendations to the legislature, the Michigan Department of Environment, Great Lakes, and Energy (EGLE), and advocacy organizations.

This 3-part strategy would establish the "Great Lakes State" as a leader in the protection of the Sixth Great Lake, our groundwater. In addition to the research presented in this report, the proposals for the legislature, EGLE, and advocacy organizations below build off of existing studies and recommendations. Moreover, they are based in Article IV, Sections 51 and 52 of Michigan's Constitution, which charges the state with protecting public health and natural resources, respectively (see **Section 4: Policy Analysis**).[394, 395] The recommendations presented below are related but not necessarily interdependent; each should be approached with its own timelines, actors, and mechanisms for change. They are numbered for clarity, not to indicate prioritization. Following an outline of the 3-part strategy, the reasoning for each recommendation is explained, and example legislative language is provided.

Three-Part Strategy

Part 1 - Recommendations to the Michigan Legislature

1. Pass the Michigan Groundwater Protection Act, a bill package that:
    - Amends the Natural Resources and Environmental Protection Act (NREPA) to increase cleanup standards and establish an implementation fee.
    - Creates a Michigan Septic Code.
    - Amends the Michigan Zoning Enabling Act to enhance local control.
    - Establishes a Groundwater Coordinating Council to enable integrated management and communication.
    - Empowers Watershed Councils and Watershed Alliances to include groundwater in their jurisdictions.

2. Establish the Groundwater Protection Initiative to issue a bond and create a Groundwater Trust Fund.

3. Appropriate funds from the Groundwater Trust Fund for groundwater mapping and a new grant program for local authorities.

4. Appropriate funds for groundwater monitoring and modeling.

Part 2 - Recommendations to the Department of Environment, Great Lakes, and Energy (EGLE)

1. Strengthen the Water Withdrawal Assessment Process.
2. Add a data-sharing platform to the new data management systems.
3. Create a targeted groundwater education program with MSU Extension.

Part 3 - Recommendations to Advocacy Organizations

1. Support the passage of the Michigan Groundwater Protection Act.
2. Create and support educational initiatives about groundwater.
3. Identify future funding sources for groundwater protection.
4. Lead campaigns to support state-level groundwater protection funding.

Rationale

Rationale — Recommendations to the Michigan Legislature

Pass the comprehensive Michigan Groundwater Protection Act to:

Amend NREPA to increase cleanup standards and establish an implementation fee.

Part 201 of NREPA establishes the Environmental Remediation Program, authorizing EGLE's Remediation and Redevelopment Division to set cleanup standards by considering future land use. These cleanup standards are primarily risk-based and examine potential public health, safety, and welfare, as well as environmental impacts, from exposure to hazardous substances at contaminated sites.[396] Feasibility Studies are conducted to assess the nature, extent, and impact of a release by developing, evaluating, and selecting appropriate response activities, considering environmental, legal, and cost criteria.[397] Amending the definition of "technically feasible" would strengthen cleanup standards by removing flexibility in cleanup actions, shifting away from a cost-driven, risk-based approach toward one that prioritizes the use of the most effective available cleanup technology, unless the responsible party can demonstrate that such technology is environmentally or legally impractical. Cost should not be weighted equally with environmental and legal constraints.

This amendment is supported by our case study of Washtenaw County, which examined the management of the 1,4-dioxane plume from Gelman Sciences, known as the Gelman Plume. The company has an agreement to pump and treat contaminated water to lower concentrations, but is not required to restore the groundwater to beneficial use. In the years following the discovery of the pollution, the plume has expanded drastically and is encroaching on the Huron River, a major municipal drinking water source for the City of Ann Arbor. Under the current law, the company has satisfied Michigan's remediation standards. The issue is that these standards are weak, and the risk-based approach fails to account for the long-term costs of removing access to the aquifer, allowing the liable party to avoid responsibility and pass these costs on to community members.

As identified in **Section 2: Overview of Michigan's Groundwater**, there are over 26,000 known contamination sites in the state, with an estimated 18,000 sites covered by Part 201.[398] While over half of the state's contaminated sites are orphaned, the remaining have liable parties, which means the State of Michigan can and should hold them accountable.

While the provisions in Part 201 must be stricter, there are some cases in which it is truly impossible to

clean up contamination due to the nature of the substance or some physical property of the site. For this reason, in combination with implementing stricter remediation standards, EGLE should establish a user fee for institutional controls (ICs) to disincentivize their application and directly fund groundwater protection. Michigan's risk-based approach to contaminant cleanup employs a combination of land- and resource-use restrictions and remediation to limit human exposure to harmful substances. In part due to provisions in Part 201 of NREPA, which requires remediation only to the extent "technically feasible," Michigan applies more than 4,000 of these ICs to more than 3,500 sites.[399] While limiting groundwater access through ICs may prevent direct human exposure for some time, it exacerbates contamination by allowing substances to spread. Such migration also increases the cost of eventual remediation, as large sites are more expensive and difficult to clean up. In some cases, such as the TCE plume in Antrim County, human access to groundwater may be permanently restricted, infinitely magnifying the social, economic, and ecological costs.

In 2024, MSU and Flow published *Institutional Controls for Groundwater Water Management: Long-Term Costs and Policy Impacts*, a comprehensive report evaluating the real-world consequences of land-use restrictions in Michigan.[400] The study also developed a cost-calculation tool that EGLE could employ or adapt to determine accurate fees for IC applications. The current risk-based approach to remediation requires only the minimum protection for human and ecological health, with minimal consequences for polluters. Implementing a user fee would prioritize remediation, with fee revenue contributing to groundwater protection, better protecting Michigan residents and resources.

Create a Michigan Septic Code.

Establishing a statewide septic code is essential for protecting groundwater, the environment, and human health. Despite its very high well density, Michigan is the only state without a statewide septic code. Only 12 of Michigan's 83 counties have enacted Local Septic Ordinances to standardize maintenance and inspection, leaving 71 counties without a septic policy.[401] Of the counties that have implemented Local Septic Ordinances, they typically rely on point-of-sale inspections rather than regular interval inspections.[402] This framework is ineffective, as documented by the number of failing septic systems and the presence of fecal contamination in surface waters throughout the state. While the specifics of this policy are outside of the scope of this project, it is essential that this threat to groundwater be addressed by establishing a statewide code that adequately protects both ground and surface water throughout the state.

Amend the Michigan Zoning Enabling Act to enhance local control.

The Michigan Zoning Enabling Act is the primary statute governing zoning in Michigan. This Act authorizes local governments to zone, allowing land-use controls such as designating groundwater recharge areas or segregating heavy industrial development. This local control was limited by a 2011 amendment, which mandates that zoning ordinances cannot prohibit the mining of valuable natural resources through zoning unless "very serious consequences" would result from that extraction (see **Section 4: Policy Analysis**). These consequences may include impacts on surrounding land uses, nearby property values, traffic and pedestrian safety, public health, and overall pubic interest in extracting the resources.[403]

Removing or revising this provision would restore local communities' ability to restrict or deny permits for actions that would degrade water resources before damage occurs, even if the impacts don't qualify as "very serious consequences." This is especially important because some damage is irreparable, such as lowered water tables and wetland sedimentation. This recommendation was inspired by the Vella Pit and ongoing sand and gravel mining issues, which have affected residents

in the surrounding area by causing their wells to go dry, introducing contamination, necessitating expensive water-softening and filtration replacements, and reducing their property values. As it stands, the 2011 provision limits local discretion, favors industry over residents' rights, and fails to protect local water resources.

Establish a Groundwater Coordinating Council to facilitate the exchange of groundwater information.

In Michigan, groundwater falls within the jurisdiction of multiple state agencies, including EGLE, the Department of Agriculture and Rural Development (MDARD), and the Department of Health and Human Services (MDHHS). To bridge management gaps and ensure collaboration and communication, Michigan should establish an interagency Groundwater Coordinating Council (GCC) to track groundwater management efforts and ensure consistent dissemination of progress and data through publicly available annual reports. The groundwork for this interagency action has already been laid by the Michigan PFAS Action Response Team (MPART), a successful interagency group established to address the ongoing public health challenges posed by PFAS contamination.[404] With regular, organized communication and coordinated efforts, MPART exemplifies that Michigan has the political will to implement a GCC. Such an example should be used as guidance for a council focused on groundwater protection.[405]

While Michigan's current groundwater management framework includes the Water Use Advisory Council (WUAC), the WUAC lacks the capacity to track management activities and provide comprehensive annual reporting. The WUAC's research capacity is limited because membership is essentially voluntary. Additionally, given the council's diverse and representative membership, many members lack the broad expertise in groundwater resource management needed to write exhaustive studies on the resource. And, importantly, the WUAC's mission is use-based; GCC products should take a holistic approach to the role and value of groundwater, accounting for use, contamination, and ecological function. The WUAC should serve in an advisory position to GCC work, reviewing drafts of annual reports and providing feedback. The WUAC's biennial recommendations could be incorporated into the annual GCC report to enhance expertise and enable more targeted outreach to both regulators and members of the public.

Analysis of Wisconsin's Comprehensive Groundwater Protection Act and the corresponding establishment of the state's own Groundwater Coordinating Council illustrates a tangible and effective model for Michigan. Wisconsin's council of state officials, among other experts, serves as a mechanism to bridge the gap between state regulatory agencies and to emphasize data and information exchange within coordinated regulation.[406] Wisconsin's council is tasked with increasing agency efficiency, advising regulators, and developing publicly accessible annual reports to the legislature.[407] The most recent report for 2025 provides updates directly from the council and includes primary recommendations based on current conditions, takeaways, and trends in ongoing challenges (e.g., nitrates, PFAS), as well as an evaluation of groundwater monitoring and management tools.[408] Both MPART and Wisconsin's Groundwater Coordinating Council are useful examples for Michigan's own GCC.

Empower Watershed Councils and Watershed Alliances to include groundwater in their jurisdictions.

Part 311 of NREPA (Local River Management) authorizes the creation of Watershed Councils and River Management Areas by 3 or more local units of government that are located wholly or partially within a watershed. Watershed Councils study water resources, including water use, water quality,

and reliability; prepare reports regarding water trends, emerging water problems, and policy needs; recommend the creation of river management districts; advise the government of watershed needs; collaborate on data collection; and organize staff and funding to carry out its functions.[409] The Michigan legislature should expand the jurisdiction of Watershed Councils to include groundwater, acknowledging the hydrological connection between groundwater and surface water. Interviews indicate that strengthening water management below the state level was of interest to both local actors and state policy experts, who appreciate Michigan's unique regional geologic conditions. Groundwater Sustainability Agencies in California and Active Management Areas in Arizona also provide similar, strong examples of regional management schemes.

Relatedly, Part 312 of NREPA (Watershed Alliances) allows 2 or more municipalities to create Watershed Alliances to study problems and plan and implement activities to address surface water quality and flow issues of mutual concern in watersheds within their boundaries. Watershed alliances can prepare watershed management plans, monitor and analyze water and ecosystem data, engage and educate the public, and design and implement projects and other actions to protect water quality, manage flows, restore beneficial uses, and protect public health. Watershed alliances are distinct from watershed councils in that they are legal entities with the authority to sue or be sued, to carry out their responsibilities under law, to raise funds, and to administer programs.[410, i] This amendment would expand the jurisdiction of Watershed Alliances, which currently focus on surface water and flow, to include groundwater. Similar to the amendment proposed to Part 311, incorporating groundwater into the Watershed Alliances is motivated by input from Michigan policy experts and by the regional management success of Groundwater Sustainability Agencies in California and Active Management Areas in Arizona. This bill would require Watershed Alliances to include groundwater in their water management plans, creating a more holistic approach to addressing water quality and quantity concerns within the watershed, and empowering local communities to protect their groundwater resources.

In Michigan, there are 86 watersheds and approximately 28 watershed groups that work across municipal boundaries to address water challenges within their watersheds.[411] These entities work with local governments to increase capacity by conducting public education, water quality monitoring, and other State responsibilities.[412] Watershed groups also serve as representatives and mediators with state-level agencies, making management and community engagement more effective through delegation. The benefit of incorporating groundwater into these existing watershed groups is the ability to draw on their local expertise and relationships with residents and local and state officials in order to holistically address water quantity and quality concerns. Coordinated regional groundwater planning may also yield economic and ecological benefits by enabling more efficient, informed implementation.[413] Importantly, groundwater does not follow watershed boundaries. Nonetheless, expanding the jurisdiction of Watershed Councils and Watershed Alliances, which already collaborate and implement water management plans, leverages Michigan's existing infrastructure to empower regional decision-making.

Establish the Groundwater Protection Initiative to issue a bond and create a Groundwater Trust Fund.

To address funding needs in Michigan's groundwater management scheme, we propose the "Groundwater Protection Initiative" (GPI), a $1 billion environmental general obligation bond to invest in urgent initiatives. Various avenues for funding exist, including, but not limited to, a legislative appropriation, a tax or fee on groundwater-related activities, such as mining or industrial withdrawals, or an environmental bond. Michigan's successful legacy of employing bonds for environmental

i B. Wilson, personal communication, March 30, 2026.

protection, examples from other states, with demonstrated success attributed to significant upfront investment, and the reliability of bonds for up-front investments, support the recommendation for a new GPI.

In 1988, Michigan voters approved the Quality of Life Bond Proposal, which included both the Environmental Protection Bond Proposal and the Recreation Bond Proposal, to finance environmental protection (82.5% of funding) and public recreation (17.5% of funding) programs. In 1998, the Clean Michigan Initiative (CMI) proposed a similar ballot measure, which passed, authorizing a $675 million bond to finance environmental protection programs, state park improvements, and local recreation projects.[414] Since then, CMI funds have contributed to supplying public water to residents whose groundwater access has been restricted by contamination and supported the cleanup of contaminated sites for which no responsible party exists ("orphan sites"), among many other applications.[415]

Nearly thirty years later, groundwater protection is finally a priority of state environmental regulation, and CMI funds have been fully allocated.[416] The research presented here identifies opportunities for Michigan to advance groundwater protection to secure public health, preserve water resources in public trust, and safeguard the state's residential and economic future. While some of these priorities have been identified numerous times through transdisciplinary studies, significant and dedicated funding to advance groundwater protection in Michigan, and therefore protect the Great Lakes, remains elusive.

Michigan has a credit rating of at least AA as of 2026 and a legacy of popular general obligation bonds with meaningful environmental protection impact. The 1988 Environmental Protection Bond Proposal and the Recreation Bond Proposal received 77% and 63% of the vote, respectively.[417] In 1998, the CMI received 63% of the vote. Regardless of policy, the Great Lakes are a powerful unifying interest for residents of the region, including Michigan residents.[418]

Other states have also established successful environmental bonds that contributed to groundwater protection. California passed a $11.14 billion bond in 2014, $900 million of which was dedicated to preventing pollution, managing cleanup, and prioritizing groundwater recharge and storage.[419] In 2024, California passed a $10 billion bond, which allocated $3.8 billion to drinking water protection, water recycling, groundwater storage, and flood control.[420] New York dedicated $650 million of a $2.2 billion bond to water quality protection and drinking water infrastructure in 2022.[421] Both of these states provide examples of how the legislature's water protection priorities can be directly funded through the voter-approved commitment of state credit.

In 2024, Michigan Representative Alabas Farhat proposed the Clean Michigan Initiative Reauthorization Act, which would authorize a $10 billion bond to replace the depleted funds of the original CMI. The Act would have committed $1 billion to grants for local water initiatives. Of this, $500 million was directed to well protection and $500 million to pollution prevention. As of April 2026, the Act remains referred to the Committee on Natural Resources, Environment, Tourism, and Outdoor Recreation.[422] For natural resource protection, bonds are a significant, direct, and upfront political and financial investment.

The recommendation to create the GPI is motivated by the success of previous environmental bond initiatives and the documented electoral popularity of water protection in Michigan, examples from other states, and qualitative data collected through interviews with a range of groundwater actors, which conclude that funding opportunities for better groundwater protection are inadequate and that no existing funding source may serve to support groundwater initiatives. The $1 billion figure is an estimate of the necessary investment in Michigan's groundwater initiatives, based on Michigan's past environmental bonds, a review of funding currently allocated to Michigan's water protection, examples from other states, and expert input. In conjunction with the GPI, a Groundwater Trust Fund

should be created to preserve bond (and any future) funds specifically for groundwater management.

Appropriate funds from the Groundwater Trust Fund for groundwater mapping and a new grant program for local authorities.

The legislature should appropriate $500 million from the Groundwater Trust Fund to Michigan Geological Survey (MGS) and EGLE for groundwater mapping efforts. Although initiatives have been undertaken to inventory Michigan's groundwater resources, most notably by MSU in 2003 in accordance with Public Act 148, mapping is still inadequate to support project design and resource planning, such as in Ottawa County.[423] Continued support for the MGS is essential to advancing statewide geologic data collection and aquifer mapping. MGS is pursuing several efforts to improve understanding of Michigan hydrogeology, including a comprehensive regional water resources study in western Michigan that will result in a public, web-based dataset (see **Section 2** for more). MGS's work is directly relevant to Michigan's Water Withdrawal Assessment Process (WWAP) and Water Withdrawal Assessment Tool (WWAT). Where geologic data are sparse, the WWAT defaults to generalized parameters that may not reflect true conditions, risking both under- and over-protective permitting decisions. The ongoing work of MGS should be bolstered and expanded beyond the currently planned 13-county area to fully assess Michigan's groundwater resources at a scale applicable for assessment, design, and planning.

$500 million of the Groundwater Protection Initiative bond should be appropriated from the Groundwater Trust Fund to a new state-administered groundwater grant program for local governments. Funds should be available for projects that advance water conservation, public education, and pollution prevention. Given the state's diverse hydrogeology and the multilateral governance structures of counties, townships, cities, villages, and authorities, much groundwater management happens at the local level. And the consequences of inadequate management—depletion, salinity, and contamination—directly impact communities. While regulatory structures must be administered at the state level for generalized application, local programs can consider local hydrogeological context, target community-specific concerns, and delegate small-scale projects. EGLE currently offers Water Infrastructure Grants to local governments, funded through the Bipartisan Infrastructure Law, the American Rescue Plan, and state budget allocations.[424] To empower local governments to take on capital investments that further groundwater protection, the legislature should establish a similar local grant program for groundwater-specific initiatives.

Case study interviews revealed several groundwater management mechanisms that would benefit from state-level funding opportunities. For example, Ottawa County is seeking to establish a re-landscaping rebate program for residents interested in transitioning from turfgrass to native, drought-resistent plants, but has yet to secure funding.[425] In Washtenaw County, a health department analyst explained that the department was hesitant to pursue robust community education about the 1,4-dioxane plume due to financial limitations, which made public engagement a costly time commitment compared to mandated duties for which funding was directly allocated. And in addition to the passage of a statewide septic code, local grants could support well and surface water testing to identify and prevent residential groundwater pollution.

Appropriate funds for groundwater monitoring and modeling.

Effective groundwater management in Michigan requires coordinated, recurring investment in monitoring infrastructure. Establishing a statewide monitoring well network is critical to accurately assess groundwater levels. Groundwater levels cannot be observed directly without dedicated measurement infrastructure – without it, managers cannot distinguish natural variability from

long-term decline or verify whether withdrawal regulations are protective. Currently, the U.S. Gelogical Survey (USGS)'s National Groundwater Monitoring Network (NGWMN) maintains only 32 water level network wells in Michigan. EGLE has received funding to serve as a data provider to NGWMN and is developing plans for a broader groundwater monitoring network.[426, ii] Given the state's diverse geologic and hydrogeologic makeup, a more extensive monitoring network is necessary. Continued funding would allow EGLE to expand the well network or reactivate dormant wells, thereby strengthening long-term data collection. Virginia provides a strong example of effective statewide groundwater monitoring: the state Department of Environmental Quality has a dedicated Groundwater Characterization and Monitoring Program (GCMP) that collects, analyzes, and interprets hydrologic data from monitoring wells. These results help inform Virginia's overall groundwater supply planning and response to emerging threats.[427] Appropriating funding to expand Michigan's groundwater monitoring program is a necessary recurring cost, whose benefits will substantially reduce future costs from preventable resource challenges and pressures.

Dedicated funding for groundwater modeling is also necessary to support sound resource management. Virginia's robust groundwater flow models illustrate how modeling can directly support regulatory management efforts. Groundwater resources are modeled by location, withdrawal quantities, water-level depth, etc., and evaluated by impact area. In this way, Virginia can use modeling tools to map resources and identify impacts of withdrawals and contamination.[428] Monitoring and mapping (above) may describe a system as it exists, but models simulate how groundwater might behave under different scenarios, translating those results into decision-relevant predictions. Specifically, continued support should be provided for the development of the Michigan Hydrologic Framework (MHF), which is building a platform that offers centralized access to surface water and groundwater models. The MHF, a project with the Institute of Water Research at Michigna State University (MSU), USGS, and EGLE, will be a publicly available online model-sharing and generation environment with a GIS-enabled interface, facilitating the submittal, visualization, validation, and download of shared MODFLOW-based groundwater flow models. The legislature should annually appropriate sufficient funds (see the WUAC 2024 recommendations) for EGLE to maintain an expanded monitoring well network and to refine models.[429]

Rationale — Recommendations to EGLE

Strengthen the Water Withdrawal Assessment Process.

Michigan should continue to revise and strengthen its WWAP. EGLE is actively improving the WWAT through several efforts, including a modernization project that incorporates updated USGS streamflow-depletion modeling code, PyCap-dss, to assess large-scale withdrawals, allows site-specific parameter inputs, and introduces additional streamflow-depletion solutions for different aquifer conditions. Additional initiatives, such as the Aquifer Data Assessment Tool Project, catchment-scale and downstream accounting projects, and a project to assess inland lake sensitivity, further expand Michigan's capabilities for withdrawal assessment.

Currently, Michigan assesses groundwater withdrawals primarily in terms of their effects on streamflow, rather than on the potential depletion of the bedrock aquifer supply. While the majority of Michigan wells draw from shallow glacial aquifers, communities that rely heavily on bedrock aquifers (such as Ottawa County, where many wells draw from the Marshall Aquifer) would benefit from expanded assessment considerations. In these settings, the slow recharge of bedrock aquifers means that long-term sustainability depends on maintaining a balance between withdrawals and

ii L. Pappas, personal communication, February 16, 2026.

replenishment. A more comprehensive understanding of bedrock aquifer recharge and supply would provide the knowledge necessary to develop a framework that incorporates aquifer capacity into withdrawal evaluations. With improved characterization of these aquifers, it may also be possible to better estimate the combined effects of many small-scale wells tapping a shared groundwater source. This assessment is difficult to represent within the existing streamflow-based framework, in which impacts are evaluated based on well proximity to streams rather than on cumulative withdrawals from a finite aquifer. Analyzing this aspect would be useful in regions like Ottawa County, where the cumulative effects of small-scale withdrawals appear to be a primary driver of overwithdrawal. EGLE should expand Michigan's water withdrawal assessment framework to incorporate the realities of bedrock aquifer recharge and storage.

Add a data-sharing platform to the new data management systems.

As of April 2026, EGLE is developing the Groundwater Data Management System (GWDMS) to serve as a single location for statewide hydrogeological data from all EGLE divisions, including groundwater, geology, and laboratory analysis. The GWDMS remains in the early stages of development, and existing data is currently disjointly recorded in paper documents across multiple inter-agency divisions and documented in legacy systems. In one interview, a Washtenaw County health department analyst described how the current system of data and information sharing between local government and state agencies is highly time-inefficient, leading to delayed site cleanups and drawn-out management processes. By the time data, such as the baseline environmental assessments that identify existing contamination at a site, is made available, enforcement entities don't necessarily communicate with permitting officials or project managers. This delay leads to additional issues with data sharing across levels of groundwater management. The disconnect between data management and storage limits the ability of EGLE staff and local management entities to access, share, and use this critical state resource data. The GWDMS under development should be augmented to manage all statewide data in a single system, thereby improving the agency's ability to understand hydrogeology and groundwater resources. A data-sharing platform would substantially increase the state's ability to ensure that decisions about groundwater resources management are well-informed. Michigan has experienced first-hand the need for data transparency and multi-level data accessibility. To reach its full potential, the GWDMS should provide publicly accessible groundwater contamination data, as this would improve transparency and support local- and state-scale management through better-informed decision-making.

Create a targeted groundwater education program with MSU Extension.

EGLE should establish and lead the creation of a groundwater-specific series of education modules in collaboration with MSU Extension's Water School for application by public schools and to the general public. Groundwater is "out of sight, out of mind"—often forgotten, or perhaps never known in the first place, by water users, officials, and legislators alike. Nonetheless, groundwater should be as well understood as the Great Lakes, which are well known and intricately linked to groundwater.[430] Greater public awareness of the importance of this resource and the threats to it can lead to more effective protective measures, such as water conservation in areas experiencing shortages, like Ottawa County, and measures to prevent contamination. Other studies of Michigan groundwater management, particularly the Institute of Water Research at MSU's 2023 *Michigan Groundwater: Opportunities for Improved Management* and the State's 2016 *Sustaining Michigan's Water Heritage*, emphasize the need for dedicated education programs to bolster stewardship.[431][432] Education is widely recommended as a management tool to prevent contamination from septic systems and to increase public investment in water protection programs.

Regardless of the specific issue or level of analysis, public education about groundwater was listed by a third of Michigan interviewees as a valuable part of more effective resource management in our research. Nowhere is this more evident than in Ottawa County, where every respondent listed education as a barrier to better groundwater management, and public education about groundwater is a preeminent tool of county- and municipality-level efforts to curb excessive residential water use.

EGLE's "Know it Before You Throw It" recycling campaign is an example of a successful public education initiative catalyzed at the state level.[433] The campaign focuses on improving recycling accuracy by reaching residents with fun graphics and simple language. It was designed with consideration of community data, which indicated that most residents were already interested in recycling but were not recycling properly, leading to contamination and diverting recyclables to the landfill. Through general awareness education focused on the most basic best practices, "Know it Before you Throw It" has led to noticeable improvements in community recycling.[434]

In 2020, Michigan Sea Grant partnered with MSU Extension to host Water School, a series of webinars aimed at increasing local and state officials' knowledge of water management.[435] Given the example of the "Know It Before You Throw It" campaign and the existing public education work of Sea Grant and MSU Extension, EGLE should collaborate with MSU Extension and Michigan Sea Grant to design and launch a public groundwater education campaign. This groundwater education initiative should focus on changing specific behaviors that impact Michigan's groundwater resources today, such as conserving water, testing and maintaining wells, and inspecting and maintaining septic systems.

To expand its reach and use dedicated resources efficiently, educational materials should be accessible and simple. Online videos, fact sheets, educational modules, printable posters, and social media campaigns can work together to reach diverse audiences across platforms, including schools, community centers, continuing education training, and professional workshops. Finally, EGLE and MSU Extension should partner with advocacy organizations (below) and empowered Watershed Councils (above) to achieve impact through community engagement.

Rationale - Recommendations to Advocacy Organizations

The environmental advocacy community has always been a champion for the Great Lakes, driving policy, securing funding, educating the public, and leading restoration initiatives. However, compared to surface water, groundwater has received less support. Leveraging strong support for the Great Lakes, advocacy organizations have an opportunity to achieve important gains in groundwater protection. Work to advance these recommendations will involve advocacy organizations working within coalitions of other groups, including but not limited to the Michigan Farm Bureau, the Michigan League of Conservation Voters, Michigan Municipal League, and the Michigan Environmental Council, as well as professional groups such as the Michigan Association of County Drain Commissioners. The report highlights recommendations for groundwater protection for the Legislature and EGLE; without strong support and attention from the advocacy community, these recommendations are unlikely to be fully implemented (or even partially). To support these groundwater protection initiatives, advocacy organizations should:

Support the passage of the Michigan Groundwater Protection Act.

The Groundwater Protection Act requires advocacy organizations to promote change and mobilize support to influence legislators and regulators. Educating policymakers, other decision-makers, and key segments of the public about groundwater's value and threats is critical. While designing a full campaign plan is beyond the scope of this project, advocates will need to build a powerful, diverse coalition–based around support for water protections generally–in order to prioritize and pass the

multiple components of the Groundwater Protection Act. California and the passage of Sustainable Groundwater Management Act (SGMA) exemplify this dual need for education and coalition-building through the development of baseline groundwater research and the analysis of statewide challenges by key advocacy organizations. Moreover, philanthropic organizations will need to play a key role. In California, the Water Foundation, a highly respected 501(c)(3) with an extensive network of partner organizations, developed interest groups of groundwater stakeholders to identify challenges, differing perspectives, and areas of common ground. These efforts aided in overall public understanding of statewide groundwater issues and were a major impetus for California's SGMA.[436]

The role of ACUTE in Antrim County illustrates the ability of community-based advocacy to motivate groundwater management. Here, organized community support played a significant role in drawing state policymakers' attention to groundwater contamination. This advocacy simultaneously engaged residents and educated the public, in turn, garnering further support for state-based remediation measures. Challenges faced by Antrim County, as well as Ottawa and Washtenaw Counties, can serve as cautionary cases for advocacy organizations to promote the Groundwater Protection Initiative and prevent further challenges. As an invisible public resource, groundwater management requires advocacy organizations to support and uphold legislative protections through educational campaigns, public empowerment, and coalition-building to effectively influence the decisions of legislators and regulators.[437]

Create and support educational initiatives about groundwater.

Engaging with Michigan residents about groundwater is a foundational role of advocacy organizations. As mentioned above, education was identified as a key challenge for better groundwater management. Interviews with Michigan residents and local and state officials suggest a knowledge gap in the public's understanding of surface water and groundwater. While the qualitative research presented in this report did not specifically investigate the consequences of low public understanding of groundwater, public education is widely recognized to foster greater appreciation for water and, in turn, stewardship that promotes best practices in conservation and pollution prevention.[438, 439, 440]

Advocacy organizations are uniquely positioned to connect with community members about groundwater topics, issues, and opportunities. To advance the goals of stewardship, conservation, and pollution prevention with respect to groundwater, advocacy organizations should work in conjunction with the new education initiative led by EGLE and MSU Extension described above. This collaborative effort may also include empowered Watershed Councils (see above), which bring together the water interests of multiple communities.

Identify future funding sources for groundwater protection.

Advocacy organizations should conduct a fiscal analysis of funding sources for groundwater management protection legislation and identify avenues to apply financial resources. Experts and local and state officials in Michigan identified inadequate funding as a key obstacle to more informed, faster, and more thorough groundwater management. Although there is an unmet need to address challenges such as remediation, data availability, and water conservation, Michigan has limited dedicated funding for groundwater. Through the Groundwater Protection Initiative, Michigan voters will make a sizable commitment to advancing groundwater protection. Given Michigan's successful history employing bonds for environmental protection and examples from other states, this GO bond is the best avenue for direct, significant investment in groundwater protection for an immediate but finite term.

To bolster the financial resources for Michigan's groundwater management programs, advocacy organizations, philanthropic groups, and academic institutions should conduct a fiscal study to identify additional, durable funding opportunities to pursue in future legislative campaigns. This research should be made publicly available and promoted at the state level.

Lead campaigns to support state-level groundwater protection funding.

Advocacy campaigns to the Michigan legislature to promote the Groundwater Protection Initiative should be conducted. The above outline and reasoning for a bond-funded Groundwater Protection Initiative are among multiple pathways to provide sufficient financial backing for groundwater management in Michigan. The critical role of advocacy organizations is to identify which funding mechanisms would garner the greatest support and thereby have the highest likelihood of success both at the ballot box and within the state legislature. Regardless of which funding source proves most salient and successful, advocacy organizations must assume a strong leadership role in campaigning for a state-level ballot measure to protect groundwater and ensure consistent funding.

California's 2014 Sustainable Groundwater Management Act (SGMA) exemplifies successful funding via a ballot measure that Michigan advocacy organizations can utilize as both guidance and political leverage. While SGMA itself was passed by the legislature, significant funding for managing groundwater resources under the act was approved by voters. The successful ballot measure allocated $900 million to groundwater sustainability managed by the State Water Resources Control Board, with grants distributed across the state's groundwater basins. At present, this initiative has paid off, and remediation of groundwater contamination, scarcity, and ecosystem services is successfully underway.[441] Michigan advocacy organizations should analyze advocacy campaigns leading up to SGMA's ballot measure success to identify mechanisms that swayed public opinion, leveraged ongoing groundwater resource challenges, and promoted the benefits of financial investments in state groundwater protection.[442]

Legislative Language

Example legislative language for the enactment of a comprehensive groundwater management policy in Michigan could read as follows:

The Michigan Groundwater Protection Act

The Michigan legislature declares that, in recognition that Michigan's groundwater is invaluable, interconnected with the State's surface waters, and precious, and that there is increasing demand upon the resource from present and new uses, and in further recognition that an adequate and high-quality supply of groundwater is crucial to the welfare, health, and safety of Michigan residents, industrial uses, and farmers, the withdrawal and protection of groundwater of the State should be regulated in a manner than benefits the people of Michigan, is compatible with the long-range planning of water resources, and is consistent with the responsibility of the State to protect public health and natural resources as stated in Michigan Constitution, Article IV, § 51, 52.

Groundwater Protection Bills

- A bill to amend Part 201 of NREPA to narrowly define the term "technically feasible" according to expert scientific advice from the Department of Environment, Great Lakes, and Energy (EGLE).
- A bill to authorize EGLE to establish a user fee for responsible parties establishing an institutional control that inhibits groundwater access, with the fee amount set by the Department of Environment, Great Lakes, and Energy (EGLE).
- A bill to create a statewide septic code.
- A bill to amend the MZEA to remove the "very serious consequences" provision.
- A bill to establish an interagency Groundwater Coordinating Council (GCC) directed by law to assist state agencies in the coordination and exchange of information related to groundwater programs.
- A bill to authorize the Groundwater Coordinating Council to develop annual groundwater reports that summarize the state of the resource and its management, provide updates on activities and projects related to groundwater management, and present recommendations, to be advised by the Water Use Advisory Council and presented to the legislature upon publication.
- A bill to amend Part 311 of NREPA to expand the jurisdiction of Watershed Councils to include groundwater, so that research and policy recommendations from Watershed Councils include all regional waters.
- A bill to amend Part 312 of NREPA to expand the jurisdiction of Watershed Alliances to include groundwater, so that research and planning from Watershed Alliances include all regional waters.

The Michigan Groundwater Protection Initiative

- A bill to establish the Groundwater Protection Initiative, which would authorize the state, with voter approval, to borrow $1 billion and issue general obligation bonds to finance environmental protection programs.
- Associated ballot question: "Shall the state of Michigan finance environmental and natural

resources protection programs that would protect and improve groundwater quality and drinking water protection, strengthen local groundwater management, prevent pollution and groundwater depletion, protect cold water streams, and enhance public education by borrowing a sum not to exceed $1 billion and issuing general obligation bonds of the state, pledging the full faith and credit of the state for the payment of principal and interest on the bonds, the method of repayment of the bonds to be from the general fund of this state?"

- A complementary bill to create the Groundwater Trust Fund.
- A complementary bill to provide for the distribution of the $1 billion in general obligation bonds to the Groundwater Trust Fund under the proposed Groundwater Protection Initiative.
- A bill to authorize the Department of Environment, Great Lakes, and Energy to establish a Groundwater Protection Grant Program.

7 Conclusions

Groundwater is vital to Michigan's economy, natural resources, and residents, yet compared to surface water, it remains underappreciated. Recent state-level efforts, such as new investments in the water withdrawal program and the allocation of resources to groundwater initiatives, indicate growing recognition of its importance.[443, 444] This report builds on a collection of similarly motivated initiatives by community organizers, environmental groups, and academics to advance recognition of groundwater in Michigan's natural resource management landscape. As such, the recommendations presented here work together with reports from institutions, including Michigan State University, University of Michigan, Flow Water Advocates, the State of Michigan, and Michigan's Water Use Advisory Council, to emphasize the need for further investment in groundwater protection.[445, 446, 447, 448, 449, 450]

The analyses presented in this report make it clear that, under the current regulatory framework, Michigan is not equipped to address the intersection of challenges posed by withdrawals, contamination, and long-term aquifer sustainability. Given the increased water demand from agriculture and household wells across the state, in conjunction with increased pressures from contamination, both new and existing, Michigan needs to take a stronger stance in protecting its water resources. Compared to water-scarce regions and neighboring states, Michigan is falling behind. It is critical that Michigan undergo policy reform to protect its water resources, the environment, and public health by implementing stricter remediation standards, increasing accountability for polluters, closing regulatory gaps, such as those created by the absence of a statewide septic code, and addressing zoning protections that prioritize profits over environmental and public health.

Empowered by constitutional and moral mandates for the protection of public health and natural resources, we urge you to join this mission. The path forward requires coordination across state agencies, local governments, advocacy organizations, and communities. Protection of the sixth great lake is possible, and it is time for the State of Michigan to support progress and invest in the betterment of groundwater resources for current and future generations.

Acronyms

ACUTE	Antrim County United Through Ecology
AMA	Active Management Area
AOI	Area of interest
ARI	adverse resource impact
CAFO	concentrated animal feeding operation
CARD	Coalition for Action on Remediation of Dioxane
CIGLR	Cooperative Institute for Great Lakes Research
CUP	conditional use permit
DNR	Department of Naturla Resources
DWR	Department of Water Resources
EGLE	Michigan Department of Environment, Great Lakes, and Energy
EPA	U.S. Environmental Protection Agency
GCC	Groundwater Coordinating Council
GSI	groundwater-to-surface water interface
GWDMS	Groundwater Data Management System
HEMI	Hydrologic Enhancement for Michigan
IC	institutional control
LQW	large quantity withdrawal
LUST	leaking underground storage tank
MAWSA	Mancelona Area Water and Sewer Authority
MCL	maximum contaminant level
MDARD	Michigan Department of Agriculture and Rural Development
MDEQ	Michigan Department of Environmental Quality
MGS	Michigan Geological Survey
MHF	Michigan Hydrologic Framework
MMM	Mid Michigan Materials
MPART	Michigan PFAS Action Response Team
MPEA	Michigan Planning Enabling Act
MSU	Michigan State University
MZEA	Michigan Zoning Enabling Act
NGWMN	National Groundwater Monitoring Network
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NREPA	Michigan Natural Resources and Environmental Protection Act
PFAS	per- and polyfluoroalkyl substances
RASA	Regional Aquifer-System Analysis
RIDE (Mapper)	Remediation Information Data Exchange (Mapper)
SEAS	University of Michigan School for Environment and Sustainability
SGMA	(California) Sustainable Groundwater Management Act
SMCL	secondary maximum contaminant level
TCE	trichloroethylene
USGS	U.S. Geological Survey
VOC	volatile organic compound
WMA	water management area
WUAC	Water Use Advisory Council
WWAP	Water Withdrawal Assessment Process
WWAT	Water Withdrawal Assessment Tool

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Appendix

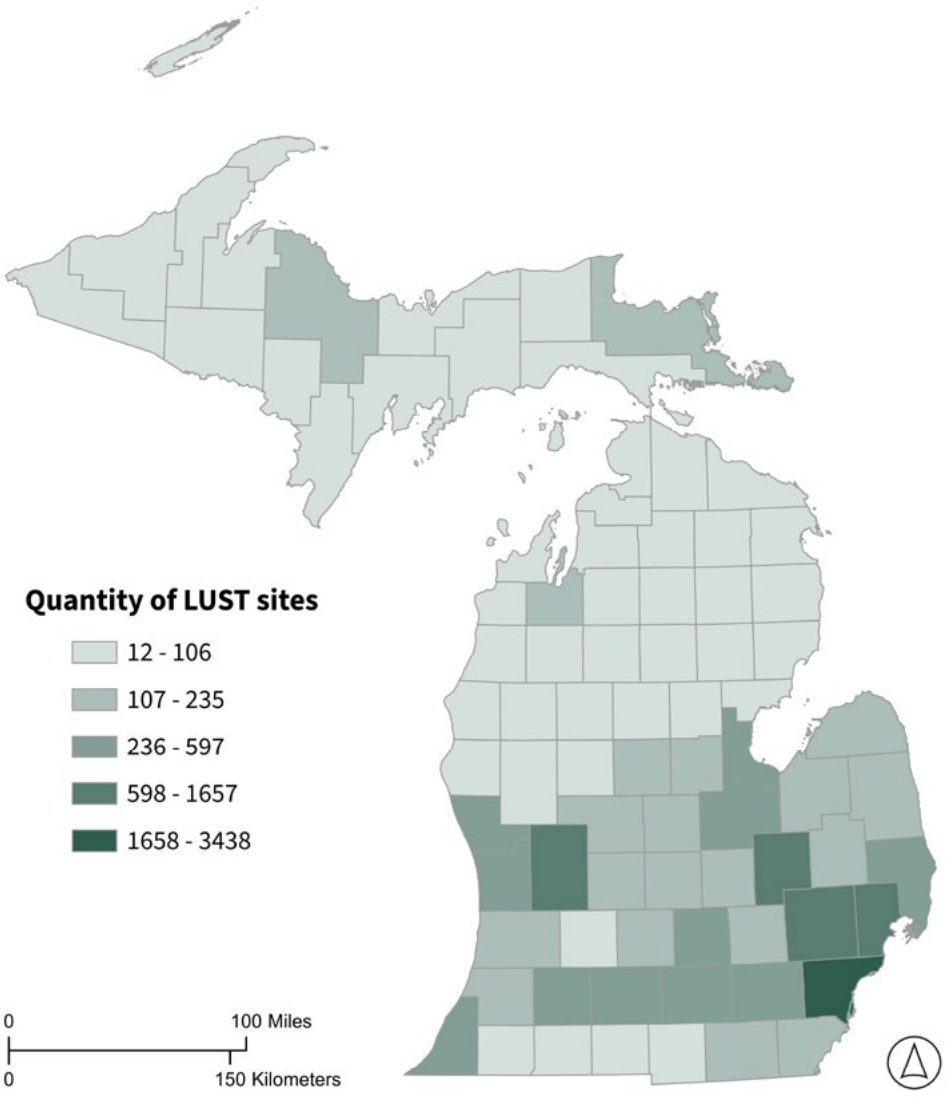

Figure A1. Leaking Underground Storage Tanks by County in Michigan by County. Darker counties indicate a higher number of leaking underground storage tanks. Five natural breaks classes were used to classify data in each map frame. These wells are regulated under Part 213 of NREPA. Data sources: Michigan Department of Energy, Great Lakes, and Environment (EGLE) Ride Mapper, State of Michigan Open GIS Data. Projected Coordinate System: NAD 1983 Michigan GeoRef.

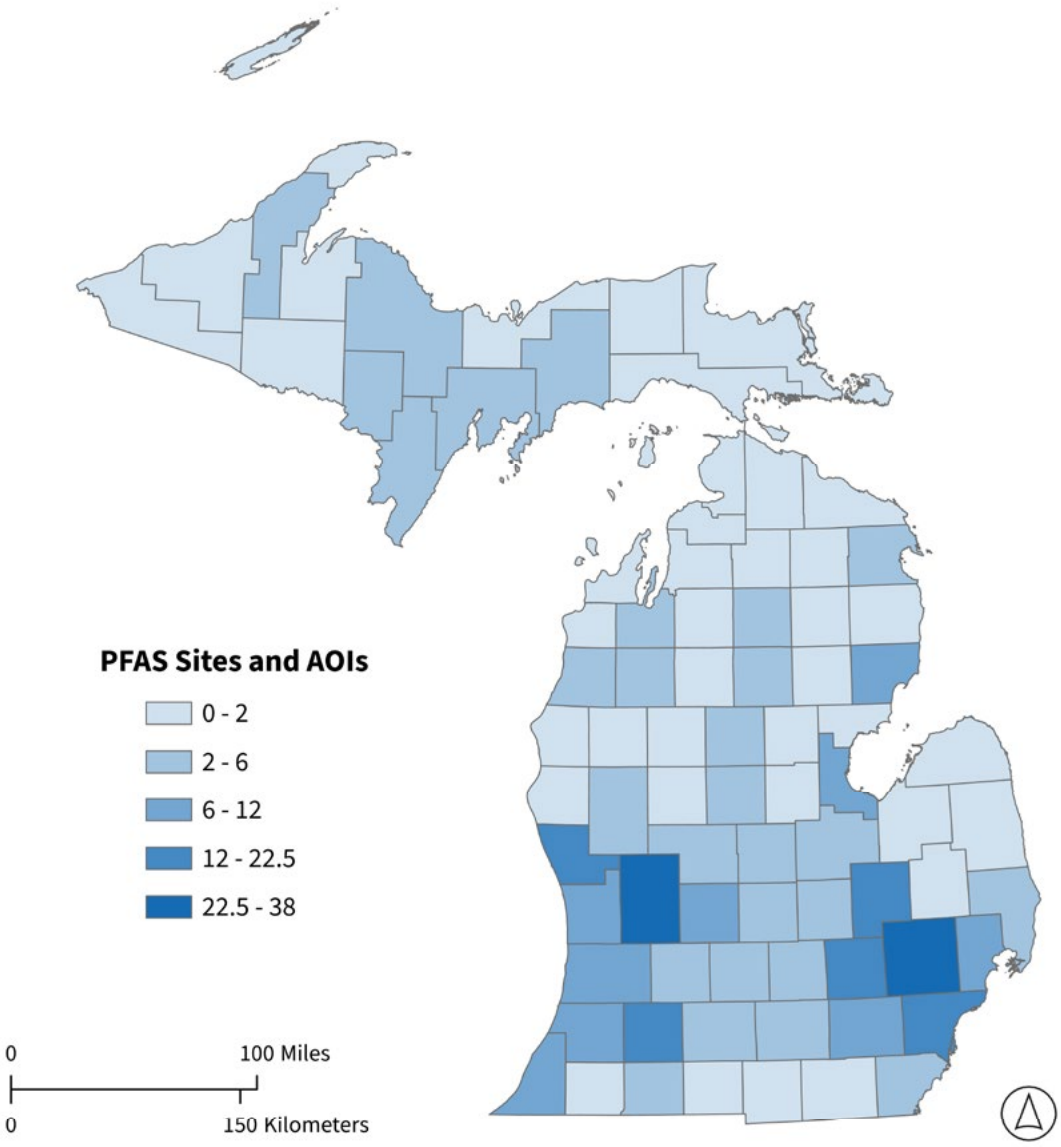

Figure A2. PFAS Sites and Areas of Interest (AOIs). AOIs are areas under investigation for potential PFAS contamination with an undetermined source. Data sources: Michigan Department of Energy, Great Lakes, and Environment (EGLE) MPART GIS System, State of Michigan Open GIS Data. Projected Coordinate System: NAD 1983 Michigan GeoRef.

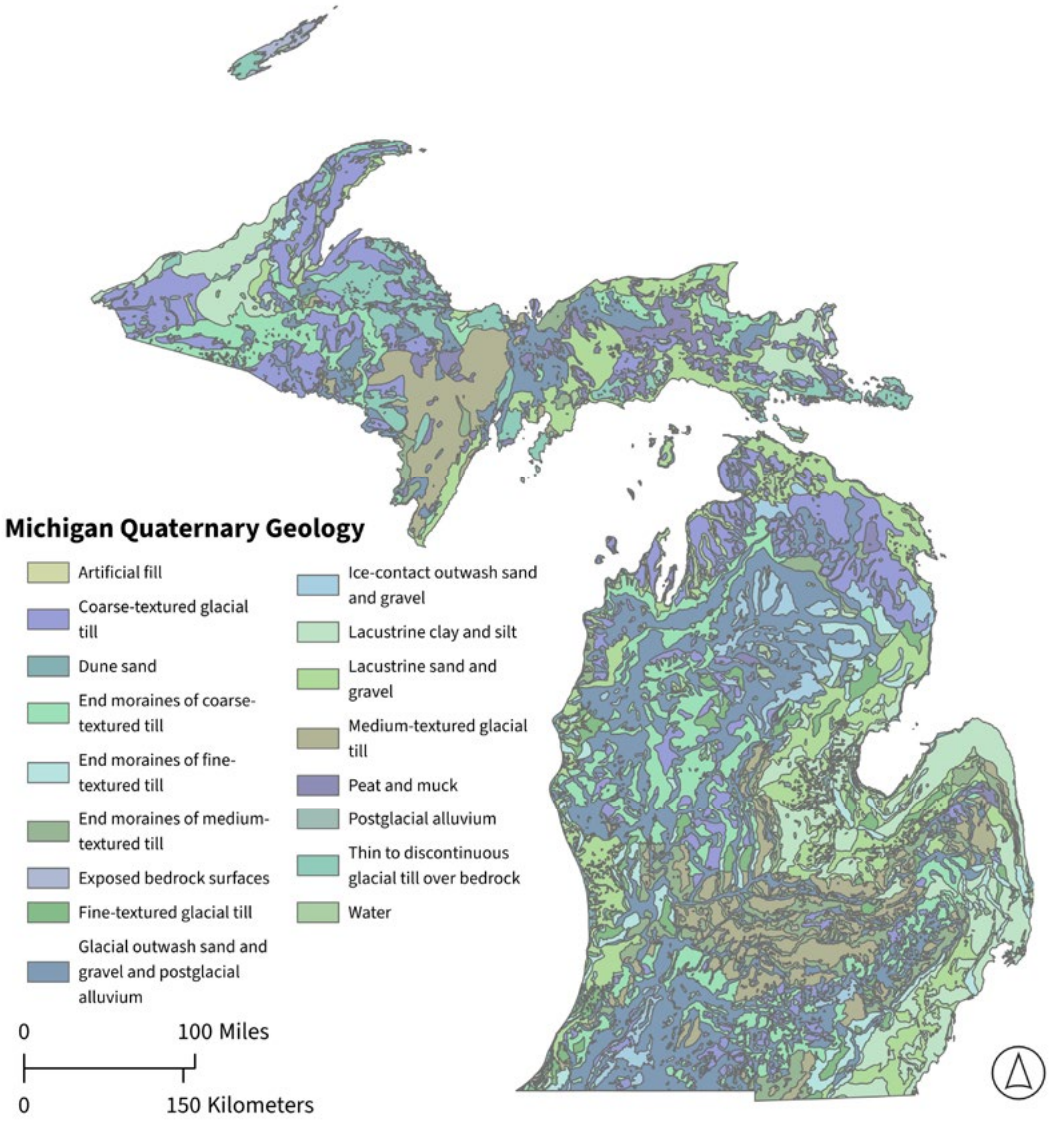

Figure A3. Quaternary Geology of Michigan. Quaternary geology refers to geology from the most recent geological period, the Quaternary Period, which is unconsolidated sediments lying above bedrock formations. Data source: Michigan Department of Energy, Great Lakes, and Environment (EGLE) GeoWebFace, State of Michigan Open GIS Data. Projected Coordinate System: NAD 1983 Michigan GeoRef.

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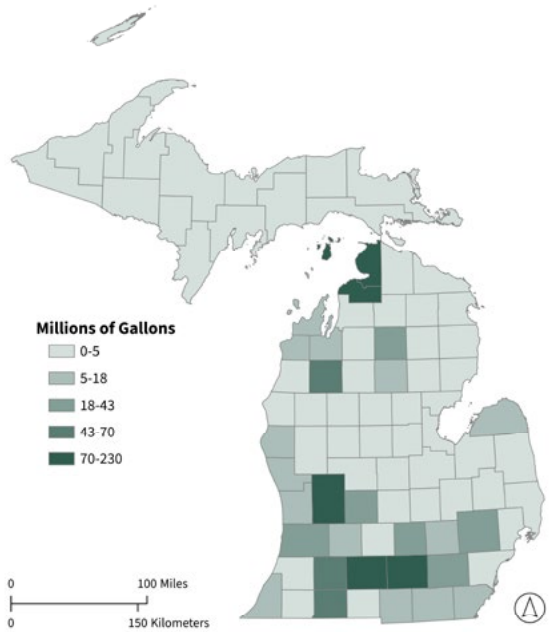

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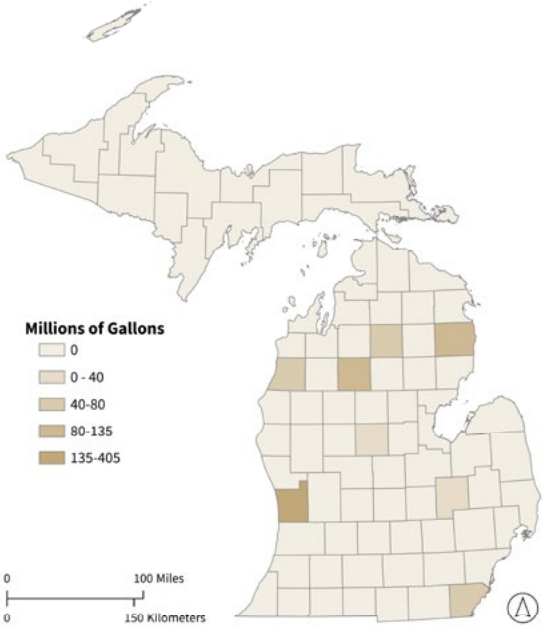

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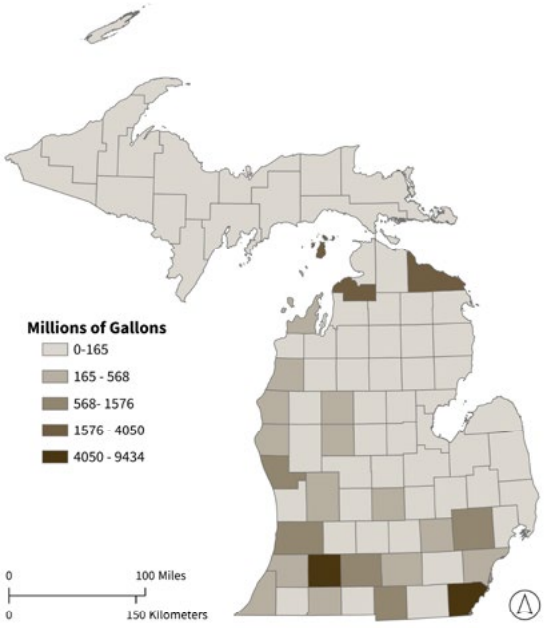

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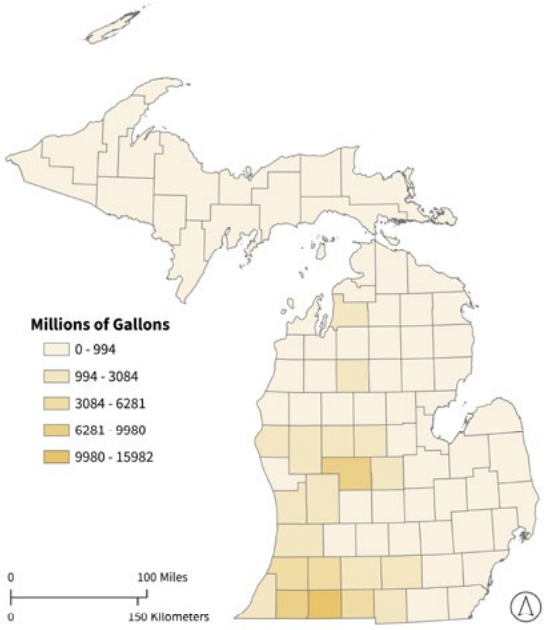

Figure A4-A7. Median Annual Groundwater Use by Sector and by County in Michigan from 2014-2023. EGLE's water use data for 2014-2023 were filtered for groundwater as the water source and organized by sector [23]. "Other" water use includes any water used for purposes outside of the other six sectors. Median annual millions of gallons used per county from 2014 to 2023 were joined with county polygons. Five natural breaks classes were used to classify data in each map frame. Data source: Michigan Department of Energy, Great Lakes, and Environment (EGLE) Water Use Data, State of Michigan Open GIS Data. Projected Coordinate System: NAD 1983 Michigan GeoRef.

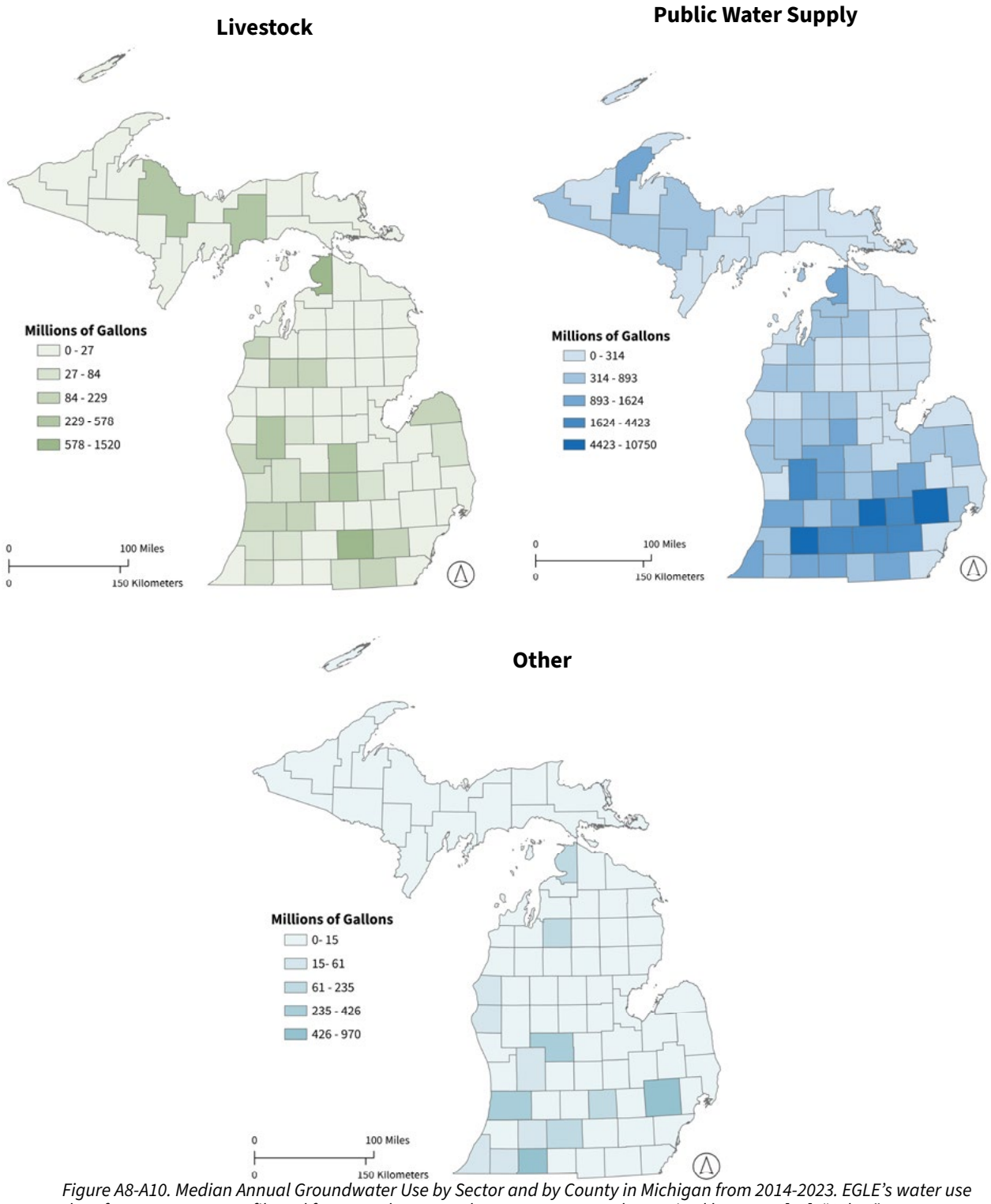

Figure A8-A10. Median Annual Groundwater Use by Sector and by County in Michigan from 2014-2023. EGLE's water use data for 2014-2023 were filtered for groundwater as the water source and organized by sector [23]. "Other" water use includes any water used for purposes outside of the other six sectors. Median annual millions of gallons used per county from 2014 to 2023 were joined with county polygons. Five natural breaks classes were used to classify data in each map frame. Data source: Michigan Department of Energy, Great Lakes, and Environment (EGLE) Water Use Data, State of Michigan Open GIS Data. Projected Coordinate System: NAD 1983 Michigan GeoRef.

Interview Materials

General Case Study Resident Interview Guide

Thank you for taking the time to speak with us. As you know, this interview is part of a project aimed at developing a comprehensive groundwater management strategy for Michigan. As part of this effort, we're interested in learning about community experiences related to groundwater problems, including the groundwater issues here in X County. Telling your story is crucial to our understanding and analysis. This conversation should take no more than an hour; we'll spend the first segment getting to know you, your community and your experience, then move on to questions about resources, and conclude by asking about what you would change if you could.

Introductory Questions

First, can we record this conversation? The recording will be used to create a transcript for our research purposes, and we will not publish your name.

How long have you lived here?

What do you do for work?

Do you have family here?

If you could use three words to describe your community, what would they be?

Personal Water Use and Perceptions

What can you tell us about where your water comes from?

Have you ever had to restrict your water usage around your home? If so, Why?

Do you know of others who have experienced restrictions around their water use?

Tell me about the quality of your water.

How confident are you in the safety of your water? Why?

Have you had your water tested? How often? For what contaminants?

Have you experienced other issues with your groundwater?

Community Water Use and Perceptions

Beyond your experience with groundwater issues at home, what problems are you aware of with groundwater in the area?

How did you first learn about this/these problem(s)? When was that?

Thinking about when you first learned about these issues, what did you do?

Understandably, some people might be curious about or scared of this kind of issue. How did you feel about your exposure/proximity to the problem?

Who did you talk to about the issue? (neighbors, family, etc.)

What information did you receive about the issue(s)? From whom?

Where did you look for more information?

Reflective Water Use and Perceptions

Thinking back: What do you wish you had heard from local officials or the state?

What kinds of resources do you wish you had had in the beginning?

How has this experience impacted the way you interact with water?

Do you only drink bottled water? Do you use a water filter in your home?

What, if anything, has changed in your community since the issues have been identified?

Future-facing Questions

Who is responsible for protecting groundwater in your area?

Do you think they are doing a good job? Why or why not?

What policies are you familiar with that protect your groundwater?

Do you think the policies in place have been adequate for protecting your groundwater?

Do you feel like you know enough about how your groundwater is managed?

What do you wish you knew?

What kinds of policies do you think should be in place to protect groundwater in your area?

How can local and state governments assist your community in protecting groundwater in the future?

What concerns do you still have about groundwater issues in your area?

Is there anything else you would like to share with us that we did not ask about during the interview?

That concludes our interview. Thank you so much for taking the time to meet with us to share your experience. In the coming months, we are going to compile our research, form an advisory committee, and create recommendations for groundwater management at the state level. We would be happy to share our conclusions with you.

General Case Study Local Official Interview Guide

Thank you for taking the time to speak with us. As you know, this interview is part of a project aimed at developing a comprehensive groundwater management strategy for Michigan. As part of this effort, we're interested in learning about experiences related to groundwater problems, including the groundwater issues here in X County. Your experience as a local official (commissioner, consultant, etc.) is crucial to our understanding. This conversation should take no more than an hour; we'll spend the first segment getting to know you, your community, and your experience, then move on to questions about resources and policies, and conclude by asking about what you would change if you could.

Introductory Questions

Can we record this conversation? The recording will be used to create a transcript for our research purposes. Information will only be shared anonymously or in aggregate.

Tell me about your position in (city, county, etc.).

How long have you worked in this position?

What does your day-to-day work entail?

Who do you report to?

If you could use three words to describe your community/county, what would they be?

Experience and examples

Tell us about the top groundwater quantity or quality issues you've dealt with.

Please choose one most critical issue and keep that in mind for the next few questions.

How did you first learn about that problem?

When was that?

Who was involved?

When you first discovered the issue, what did you do?

How did the county/your office/your business gather information, and from whom?

Who else did you reach out to for additional information or resources?

How did your department/office/business respond?

What changes did you ask/are you asking residents or industries to make in response to the issue?

Do you find that residents are shifting behaviors (using less water, filters, etc.)?

What about agriculture or industry? (ask if relevant for the location/issue)

What kinds of resources do you wish you had had when you first encountered the issue?

What do you wish you had heard from the state?

Broad experience questions

What are the primary mechanisms you use to communicate about groundwater with the public?

How effective are they?

Why/How do you know?

Thinking about those critical examples you shared with us, how do you think some of those processes of information gathering, collaboration, and reaction could be improved?

Policy Questions

What groups, offices, or agencies do you coordinate with on groundwater issues?

From that list, who would you say plays the most important role in your work?

Across Michigan communities, actions such as updating local ordinances, public outreach, and establishing monitoring systems are taken in response to groundwater problems. What, if anything, has changed in your community since the issues have been identified?

We've heard from others that some policies can facilitate groundwater management at the local level, while other policies can be limiting. What state or local policies are most impactful to your work on groundwater, whether positively or negatively?

What gaps in groundwater management have you encountered? (Or, Where do existing policies fall short?)

What about any barriers to your management efforts? This could include resources like funding, staffing, data, or technical expertise.

Who do you see as most responsible for protecting groundwater in your area?

What have they done well?

What additional actions do you hope they will take to address challenges?

Reflective and Future-facing Questions

Do you believe the laws, ordinances, or other forms of formal protection have been adequate to protect your water's safety?

What actions or policies should be taken to further protect groundwater quality and quantity in your area?

How can the state government assist your community in protecting groundwater in the future?

What concerns do you still have about groundwater issues in your area?

Is there anything else you would like to share with us that we did not ask about during the interview?

That concludes our interview. Thank you so much for taking the time to meet with us to share your experience. In the coming months, we are going to compile our research, form an advisory committee, and create recommendations for groundwater management at the state level. We would be happy to share our conclusions with you.

General External State Policy Interview Guide

Thank you for taking the time to speak with us. As you know, this interview is part of a project aimed at developing a comprehensive groundwater management strategy for Michigan. As part of this effort, we're interested in learning about successful groundwater management policies and regulations that other states have implemented in order to develop recommendations for what could be successful for the state of Michigan. From our research on statutory groundwater legislation we found that the [groundwater policy] in [state of interest] has been successful in many ways, and we want to learn more about the specifics of the policy as well as its efficacy on the ground. This conversation should take no more than an hour; we'll spend the first segment with introductions and your experience working with the policy, and then we will move on to questions about the policy mechanisms and efficacy more specifically, and conclude by asking about what you would adjust to the current management of groundwater if you could.

Introductory Questions

Can we record this conversation? The recording will be used to create a transcript for our research purposes. Information will only be shared anonymously or in aggregate.

Tell me about your position for the state of [state of interest].

What does your day-to-day work entail?

How does the [groundwater policy] interact with your work?

Policy Content Questions

In your words, can you describe the [groundwater policy].

What groups, offices, or agencies coordinate together on implementation of the policy?

How does groundwater data collection factor into implementation and efficacy of the policy?

We've read from other states that the incorporation of local level groundwater management can be both productive and limiting. To what extent has local management been effective under the [groundwater policy] and to what extent has it been potentially limiting?

What aspects of local level policy integration are the most impactful to overall groundwater protection?

How does the policy incorporate stakeholder engagement into groundwater management?

For our research on Michigan it is important that we develop recommendations that incorporate mechanisms for managing quality and quantity simultaneously. How are these two aspects of groundwater resource management addressed by the [groundwater policy]?

What political conditions allowed for the passage of the [groundwater policy]?

Policy Communication Questions

What are the primary mechanisms you use to communicate about groundwater with the public?

How effective are they? Why/how do you know?

Thinking about those critical examples you shared with us, how do you think some of those

processes of information gathering, collaboration, and reaction could be improved?

Reflective and Future-facing Questions

What gaps in groundwater management remain? Are there aspects of the existing policies framework that fall short or need additional work?

What about any barriers to your management efforts? This could include resources like funding, staffing, data, or technical expertise.

Can you identify any aspects of existing regulations or policies that should be extended or developed to further protect groundwater quality and quantity in [state of interest]?

What role can the state government play in protecting groundwater in the future?

Do you still have any concerns about groundwater issues?

Is there anything else you would like to share with us about [groundwater policy] in [state of interest] that we did not ask about during the interview?

That concludes our interview. Thank you so much for taking the time to meet with us, share your experience, and provide insight into [groundwater policy], it sounds like this policy has been really beneficial for [state of interest] and we hope to incorporate many aspects of this positive management example into our recommendations for the state of Michigan. In the coming months, we are planning to continue compiling our research and developing recommendations for groundwater management at the state level, and we would be happy to share our conclusions with you later this year.