Assessing Policy Drivers and Barriers for Sustainable Groundwater Management in Michigan

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Introduction

Michigan residents and businesses rely on groundwater for drinking water, irrigation, energy generation, manufacturing and many other uses. Around 44% of Michigan residents use groundwater for drinking water (MI DHHS). Ensuring the quality and availability of groundwater resources is thus central to the health and economic wellbeing of Michigan residents and businesses. While Michigan policymakers have long recognized the need to address water quality challenges affecting groundwater resources, uneven growth and climate change may be placing additional stress on groundwater availability for some users in the state. Even in areas that have not experienced water scarcity to date, changing precipitation and temperature regimes from climate change, and the potential for Michigan to receive "climate migrants" from other parts of the U.S., contribute uncertainty to the sustainable use of groundwater resources (Costa, Zhang, and Levison 2021; Taylor et al. 2013; ASAP 2021).

In this report we describe and analyze the groundwater policy and management framework in the state of Michigan, particularly as it applies to emerging challenges such as population growth, and provide recommendations for policymakers and researchers. Throughout the report we use Ottawa County as an example of how Michigan's groundwater policy framework can make it difficult for communities to ensure the long-term sustainability of their groundwater resources.

Ottawa County is the fastest growing county in Michigan. While agriculture remains a significant part of Ottawa County's economy, the county is also rapidly urbanizing (Ottawa County Planning and Performance Improvement Department 2021a). The county's population increased by nearly 58% from 1990 to 2020 (Ottawa County Planning and Performance Improvement Department 2021b). Groundwater withdrawals in the county from 'major water users' (those that withdraw more than 100,000 gallons per day over a 90-day period) have increased roughly 40% from 2011 and 2020 and over 3,000 new residential wells have been drilled in Ottawa County in the same time period; 40% of those new wells were drilled in the central four townships (EGLE 2020). These increased water demands have placed pressure on the county's groundwater resources and residents have begun reporting issues with well water supply (Personal Interview, local government representative, 2022a). Addressing the growing demand from residential groundwater users has generated renewed interest in the suitability of current groundwater policies in Michigan for the challenges the state will face in the future in Ottawa County and beyond.

Hydrogeological studies commissioned by Ottawa County have shown evidence of aquifer drawdown, with the potential for detrimental impacts on human health and crops, and recharge rates. Static water levels have declined in both the shallow and deep aquifers since 1999, with the issue particularly pronounced for the deep "bedrock" aquifer beneath the four central townships in the county: Allendale, Blendon, Robinson and Olive. As the bedrock aquifer is depleted, naturally occurring brines become increasingly concentrated resulting in elevated levels of chloride in groundwater. At the same time, a thick clay layer separating the shallow and bedrock aquifers slows recharge rates in the area and low transmissivity in the bedrock aquifer

means that the county cannot count on recharge from outside the area to balance withdrawals (MSU IWR 2013; Curtis, Liao, and Li 2018).

While Ottawa County has its own unique hydrogeologic conditions and a rapid pace of growth, the challenges the county is facing raise broader questions about how prepared Michigan is to manage groundwater in a truly sustainable way in the face of changing climate conditions and demographics. There may be other counties across the state where groundwater availability is changing but the change has either not been detected by current groundwater monitoring efforts or not publicly acknowledged. In conjunction with the Ottawa County Water Resource studies, the same team from Michigan State University identified up 17 other counties that may face similar declines in static water levels and related increases in chloride levels due to brine upwelling. However, these other vulnerable counties have not been studied extensively enough to determine their true risk of aquifer drawdown (Lusch et al. 2018; Curtis, Liao, and Li 2018; Personal Interview, academic. 2022a). While higher resolution data could accurately identify those locations most likely to experience drawdown, Ottawa County's experience illustrates the difficulty of addressing aquifer drawdown under the current regulatory framework.

The complexity of Michigan's policies and institutions that govern decisions affecting groundwater make it difficult to evaluate where vulnerabilities are and who might be best positioned to address them. Changes to Michigan water law in the last two decades have sought to regulate groundwater withdrawals by 'major water users' (Lautenberger and Norris 2016). Studies of groundwater withdrawals in Michigan have given relatively less attention to how the policy framework addresses cumulative effects of residential wells on potential water quantity concerns or the links between changing groundwater quantity and quality. Ottawa County's groundwater management challenges may provide lessons for other areas of the state facing rapid growth and whose groundwater resources may be limited by slow aquifer recharge rates, low transmissivity, or confining layers.

Michigan is not alone in grappling with the complexity of sustainable groundwater management. While water scarcity challenges are more commonly associated with Western states, states east of the Mississippi are also grappling with sustainable groundwater management practices due to population growth and climate change (Schattman, Niles, and Aitken 2021). In 2021, the Supreme Court weighed in on a groundwater dispute between Mississippi and Tennessee concerning use and apportionment of the Middle Claiborne Aquifer underlying both states and serving major metropolitan cities, including Memphis (State of Mississippi, Plaintiff v. Tennessee 2021). Counties in northeastern Illinois are also facing aquifer depletion at a rate that may render the aquifer unusable in high-risk areas by as early as 2040 (Mannix et al. 2017).

Without federal guidance on groundwater management, each state has forged its own policy framework resulting in a mosaic of approaches. These approaches range from comprehensive groundwater management legislation defining sustainable or safe yields to piecemeal legislative approaches indirectly related to groundwater (Megdal et al. 2017) . While states and advocacy organizations define groundwater management in different ways, for the purposes of this report, we consider holistic and sustainable groundwater management to consist of policies and

practices that match the water use requirements of multiple sectors and ecosystems, including contamination tolerance and public health dimensions, with the natural constraints of specific and local hydrogeologic features such as recharge and transmissivity rates and surface-groundwater connections. In many states, including Michigan, multiple government jurisdictions and even multiple bodies at the same level of government have purview over the decisions influencing these conditions (Gage and Milman 2021).

This report analyzes the institutions and instruments comprising Michigan's current groundwater management framework. As part of our research, we interviewed fifteen people with deep understanding of Michigan's groundwater policy framework or Ottawa County's groundwater management challenges in particular. The interviewees work on groundwater, groundwater management or land use within state, county or township government, private businesses or associations, and as part of state organized councils. Interviewees were asked to identify state, county or township laws, rules and ordinances that most affected their work on groundwater management, water supply and land use.

We complemented these interviews with additional background and policy research to compile a list of relevant policy documents for analysis including sections of the Safe Drinking Water Act of 1976 and related Michigan Administrative Code, sections of the Natural Resources and Environmental Protection Act of 1994 and related rules, sections of Michigan's Zoning Enabling Act of 2006, sections of Michigan's Planning Enabling Act of 2008, sections of Michigan's Regional Planning Act 281 of 1945, and sections of Michigan's Land Division Act 288 of 1967, webpages and documents from various state agencies, divisions, offices, units and programs. We draw on these interviews and our own analysis to provide recommendations and ideas for policy makers and areas of future research for scholars that could support progress on sustainable groundwater management in Michigan.

Michigan's Legal Framework for Groundwater Management

The doctrines governing Michigan's water law provide the basis for any endeavors to manage groundwater and the boundaries within which state and local governments implement groundwater-related legislation. Below we describe how these doctrines and relevant groundwater-related legislation interact. This gives context for the challenges state and local governments face in attempting to manage the state's groundwater resources sustainably.

Michigan's water law relies on the doctrines of riparian rights and reasonable use where case law and the court system determine when water use by one user impedes the rights of other users to 'reasonably use' the water resources associated with their property (Lautenberger and Norris 2016). This applies to any water user, person or entity whose activities impact water users. For example, one of the first cases regarding reasonable use in Michigan occurred between a cemetery operator and a nearby well owner who was concerned about contamination (Lautenberger and Norris 2016).

Prior to 2005, Michigan's framework of riparian rights and reasonable use had distinguished between surface water and groundwater users. However, the Michigan Court of Appeals decision in *Michigan Citizens for Water Conservation v. Nestle Waters North America Inc.* acknowledged the hydrological connection between surface and groundwater thereby eliminating the distinction. Under current Michigan water law , riparians and groundwater users are now treated simply as 'water users' (Michigan Citizens for Water Conservation v. Nestle Waters North America Inc. 2005; Lautenberger and Norris 2016).

This change precipitated the passage of Part 327 of the Natural Resources and Environmental Protection Act (NREPA) which provides regulations regarding the amount of water that can be withdrawn from a watershed either through surface water or groundwater withdrawals. **Critically, these regulations apply only to 'large quantity withdrawal' water users, which the statue defines as water users withdrawing more than 100,000 gallons per day over a 90-day period which is roughly equal to a 70 gallons per minute pumping rate.** The Water Use Program within Michigan's Department of Environment, Great Lakes and Energy (EGLE) regulates these withdrawals (MCL § 324.327). While Part 327 is only one piece of many statutes and regulations related to groundwater management more broadly, it represents the first coordinated effort by the state to limit water withdrawals based on water quantity. Therefore, the statute plays a significant role in reshaping the groundwater management policy landscape and determining state-level decisionmakers in the groundwater management sphere.

Part 327 seeks to balance large quantity water user rights with concerns of over allocating water within a watershed. In contrast to groundwater management legislation in other states, Part 327 sets withdrawal thresholds based on potential damages to stream fisheries, which the statute describes as 'adverse resource impacts' (ARIs). This is an important distinction because the legislation describes no other reason to limit the quantity of a large quantity withdrawal beyond impacts to surface waters. The legislation provides no reason to limit non-commercial withdrawals from residential properties with four units or fewer, as long as those withdrawals are not used for lake augmentation. As we discuss in the next section, **residential water users are exempt from registration and withdrawal regulations under Part 327** (MCL § 324.32705).

In contrast, large quantity withdrawal water users must register their withdrawals with the state through the Water Withdrawal Assessment Tool (WWAT). The tool uses groundwater modeling techniques to determine if a large quantity withdrawal will exceed the threshold for the watershed in which the withdrawal is located thereby causing an 'adverse resource impact'. As we will discuss in the next section, this does not fully address the range of potential impacts that can result from overallocation. The statute explicitly maintains existing Michigan common law regarding 'reasonable-use' riparian rights (MCL § 324.32728). Water Use Program materials and staff are careful to emphasize that the limits imposed through Part 327 do not supersede property owner rights (LaBaron and Blazic 2022).

In additional to the exemption of residential well water users, this approach raises several concerns for implementing agencies and county and local governments. First, it creates the possibility for circumstances where Part 327 would prevent the registration of an additional large

quantity withdrawal in a watershed, yet the water user is able to exercise their rights through the judicial system (LaBaron and Blazic 2022). Second, it does little to address potential water conflicts between water users, whether large or small quantity users, in watersheds that have reached the threshold of allowed withdrawals. Historically, water conflicts in Michigan have been relatively rare (Lautenberger and Norris 2016). These conflicts may arise between two parties for whom the state's Groundwater Dispute Resolution Program applies, or, as in the case of Ottawa County, as conflicts among multiple parties without the same avenues of recourse. We discuss these circumstances more in depth later. The statute does provide for Water User Committees (WUC) that could act as venues for negotiating 'reasonable use' water allocation among large quantity withdrawal users. Under the statute, large quantity withdrawal water users within a watershed could form a WUC and come to an agreement on water allocation in the case that withdrawals are nearing the threshold of allowed withdrawals under Part 327 (MCL § 324.32725). Later, we will discuss the benefits and drawbacks of the Water Use Committee approach.

While Part 327 deals primarily with groundwater water quantity, other statutes and rules regulating groundwater focus largely on water quality. These include Part 22 and 31 of NREPA regarding groundwater quality and discharge to groundwaters, the Michigan Well Code propagated under Public Health Code Act 368 of 1978 (MCL § 333.127) and the Safe Drinking Water Act of 1976 (Part 399) and their subsequent amendments, as well as other Michigan legislation prescribing how land use decisions can be made at which level of government. Many of the above statutes regulate activities that would impair other users 'reasonable use' by damaging groundwater quality, or supersede Michigan common law by virtue of being federal legislation.

Distribution of Authority Over Groundwater Resources in Michigan

In the absence of comprehensive groundwater management legislation at the state level, advocates and officials from any level of government who seek to ensure sustainable groundwater use must navigate the patchwork of legislation governing the state's groundwater quality and quantity. These disparate pieces of legislation grant authority to make groundwater-related decisions to different levels of government.

In Table 1, we outline and summarize these authorities. This table does not represent an exhaustive list of authorities related to surface water quality though these are also intimately connected to groundwater quality. Authorities and responsibilities related to surface water quality can be found in sections of the Safe Drinking Water Act 399 of 1976 and related MI Administrative Code rules as well as the Natural Resources and Environmental Protection Act 451 of 1994 and related rules, Inland Lakes and Streams Act 346 of 1972 and related rules, Soil Erosion and Sedimentation Control Act 347 of 1972 and related rules, Goemaere-Anderson Wetlands Protection Act 203 of 1979 and related rules, and The Drain Code of 1956 Act 40 of 1956 and related rules.

We identified six categories of groundwater management decision-making present in the legislation we reviewed: 1) well drilling and permitting, 2) groundwater quality standards, 3) groundwater withdrawals, 4) managed recharge / discharge to groundwater, 5) land use (including zoning, planning, and land division), and 6) hydrological data management. Rather than shared authorities within categories, authorities tended to be split between levels of government by category. For example, local units of government have almost exclusive purview over land use decisions while state agencies have almost exclusive purview over data management and withdrawals. Notably, there are few categories where county authorities take precedent over state or other local unit decisions. This places counties in a position where they must ‘lead from behind’ when seeking to influence groundwater-related decisions at either the state or the local level.

Table 1. Distribution of Groundwater Management Authorities

Decision Making Category	**State Level Authorities**	**County Level Authorities**	**Local Government Authorities** *(i.e., Townships, Municipalities, Villages)*
Well drilling and permitting	- Manages well driller and pump installer registration - Convenes the Director's Well Water Advisory Board - Provides rules and construction code	- Contracted by the state to issue well construction permits, inspect drilled wells	- No explicit authorities reserved in state legislation reviewed
Groundwater Quality	- Provides rules for carrying out the Safe Drinking Water Act 399 of 1976 - Provides groundwater quality rules and minimum standards for protection of public water supplies	- Can review public water supply plans or construction or alteration of waterworks systems - Help identify local sources of potential contamination sources	- No explicit authorities reserved in state legislation reviewed
Groundwater Withdrawals	- Registers large quantity withdrawals (greater than 70 gallons per minute) using an online Water Withdrawal Assessment Tool (WWAT) and completes site-specific reviews when requested - Permits withdrawals greater than 2,000,000 gallons of water per day; (certain withdrawals greater than 1,000,000 gallons of water per day also require permits from EGLE's Water Use Program) - Permits interbasin transfers of 100,000 gallons per day in a 90-day period - Reviews water conservation plans submitted by registered large quantity withdrawal water users - Creates and/or reviews sectoral water conservation measures submitted by water users within a sector	- Local units of government explicitly forbidden from regulating large quantity water withdrawals - May participate in Water User Committees of registrants and permit-holders; may also create a subcommittee of residents to provide advice and information	- Local units of government explicitly forbidden from regulating large quantity water withdrawals - May participate in Water User Committees of registrants and permit-holders; may also create a subcommittee of residents to provide advice and information

	- Initiates civil action against water users knowingly violating large quantity withdrawal regulations - Can convene a meeting of all registrants and permit holders within the watershed to facilitate voluntary reductions in withdrawals - Investigates petitions submitted by registrants or permit holders regarding potential adverse resource impacts - Convenes the Water Use Advisory Council		
Discharge to Groundwater / Recharge	- Manages Michigan Groundwater Discharge Program which permits groundwater discharges	- County Drain/Water Resource Commissioners execute the drain code - Contracted by the state to manage groundwater discharge permits	- Local government unit authorities related to recharge come from land use decisions under section on Land Subdivisions, zoning and planning - Work with the County Drain/Water Resource Commissioners to ensure proper stormwater management
Land Subdivisions, Zoning and Planning	- No explicit authorities reserved in state legislation reviewed	- May review proposed zoning ordinance changes and make recommendations to township zoning commissions, provided there is a county zoning commission, county planning commission or coordinating [county-level] zoning committee made up of members of county-level legislature. - May adopt a master plan and create a planning commission which can: 1. coordinate related plans of local government agencies within the county, 2. review and approve public construction in areas covered by master plans 3. review local unit zoning and ordinance changes and recommend that	- Makes zoning ordinances affecting land use within township, municipal, village limits - May require a site plan before authorization of land use or activity; regulate land use relating to Planned Unit Developments, which can include residential developments, including lot sites, density, required facilities, buffers, open space areas, etc.; -permits buildings and construction - May create a planning commission and adopt a master plan which 'shall' include subjects pertinent to future development including water supply systems and public utilities - Planning commissions have the authority

		townships adopt specific ordinances or rules governing subdivisions of land - May form regional planning commissions with other 'local government units' which include counties, villages, cities, townships and other districts - May be contracted by EGLE to carry out rules promulgated under Land Divisions Act related to suitability of groundwater for subdivisions including percolation, boring and soil suitability tests	to review and approve public construction in areas covered by master plans -Non-exempt planning commissions prepare annual capital improvements programs for public structures including water supply or sewage disposal systems. - May form regional planning commissions with other 'local government units' which include counties, villages, cities, townships and other districts - Approve preliminary or final plats (subdivisions of land) following conditions laid out in MCL Section 560.105 which includes compliance with EGLE rules relating to suitability of groundwater for on-site water supply and in compliance with county drain commissioner, county plat board and county road commission rules.
Hydrogeological Data Management	- Coordinates with other states and provinces to maintain and exchange information; collect and maintain information on water use; assess current and project future water needs in the Great Lakes region - Maintains information on groundwater quality from laboratory tests - Maintains database of well logs - Uses available data to model groundwater flows, contaminant plumes and conduct site-specific reviews	- No explicit authorities reserved in state legislation reviewed except in their role as contractors for well and groundwater discharge permitting	- No explicit authorities reserved in state legislation reviewed

Policy Challenges to Sustainable Groundwater Management in Michigan

In the context of Michigan's complex and multi-layered set of groundwater-related policies and the distribution of authorities that disfavors county-level decision-making, we use the groundwater management challenges facing Ottawa County to understand how and why this policy context contributes to unsustainable outcomes and potential user conflicts at the county level. The analysis reveals three key features of Michigan's groundwater policy framework that create challenges for long-term sustainability under population growth and climate change. They are: 1) the absence of institutions or policies that ensure sustainable use of groundwater resources, 2) the exemption for residential water user withdrawals from existing withdrawal regulations, and 3) land use decisions that do not account for impacts to water balances.

1. Dedicated Institutions for Ensuring Groundwater Sustainability

In Michigan, there is no single state office or program charged with ensuring sustainable use of all types of groundwater resources found in Michigan.

The Department of Environment, Great Lakes and Energy's (EGLE's) Water Use program regulates how large quantity withdrawals of groundwater impact protected surface water stream base flows with the Water Withdrawal Assessment Tool (WWAT), **but it does not consider drawdown in aquifers that would not impact surface water**. As mentioned in the preceding section, under Part 327 there is no mechanism, authorization, or funding for the Water Use program to address aquifer drawdown that is unrelated to surface water depletion, regardless of whether the drawdown is due to large or small quantity withdrawals. Other offices and units charged with groundwater management-related rulemaking and programs are concerned exclusively with water quality concerns.

Ottawa County's circumstances demonstrate that drawdown can occur without being flagged by the WWAT nor mitigated by procedures enumerated in Part 327. There are conditions under which depletion of certain groundwater resources can be divorced from depletion of the kind of surface water resources Part 327 protects. These would largely be withdrawals from aquifers with low transmissivity or from semi or completely confined aquifers, like the bedrock aquifer in Ottawa County. The WWAT could use improved data to flag confined aquifer drawdown. However, because the regulations are concerned only with impacts to surface water, there is no policy mechanism to prevent large quantity withdrawal or residential water users from completely depleting the water source regardless of the impacts on other users.

Local health departments do not have the authority to deny residential or large quantity withdrawal well permits based on concerns of long-term viability of the water supply (Personal Interview, local government representative. 2022b). While there are stipulations for testing aquifer performance using test wells prior to installing a residential well, there is no minimum threshold below which a permit can be denied (Michigan Administrative Code R 560.411). Interviewees noted that in Ottawa County, there have been circumstances where sanitarians

have approved well permits for subdivisions while also warning the developers that the wells were likely to fail in the short to medium-term due to aquifer drawdown even as the wells contribute to further drawdown in the meantime (Personal Interview, local government representative. 2022a; Personal Interview, local government representative. 2022b).

The quantity of water in the bedrock aquifer under Ottawa County central townships is related to quality concerns because of increasing chloride concentrations. However, chloride is considered a secondary contaminant under Michigan Administrative Code R 560.415. This does not allow for a local health department to deny well permits based on chloride levels (Personal Interview, local government representative. 2022b). In the case of primary contaminants, local health departments are authorized to reject certain proposed development sites with stipulated levels of contamination (Michigan Administrative Code R 560.414). In addition, there are stipulations for testing water quality at the time that a new well is drilled. Yet, there are no requirements for periodic water quality testing of single-family residential wells which means a well in Ottawa County could exceed the secondary or even primary contamination levels, without the knowledge of users within the residence. Interviewees speculated that the riparian rights and reasonable use framework forming the backbone of Michigan water law and threat of litigation under that framework may lead state officials to err on the side of requiring local health departments to permit residential wells even where groundwater quality rules might prohibit withdrawals by public water supply (Personal Interview, local government representative. 2022c; Personal Interview, academic. 2022a; Personal Interview, state agency representative. 2022b). This means that both water quality regulations and the water quantity regulations under Part 327 fail to curtail withdrawals that can lead to aquifer drawdown and drawdown-related water quality reductions, nor do they monitor or address potential public health impacts from aquifer drawdown.

2. <u>The Residential Well Exemption</u>

Cumulative impacts from and impacts to residentials well withdrawals are absent from Michigan water quantity regulations.

Water withdrawal regulations under Part 327 exempt both single-family residential users and multifamily residential users not exceeding four residential units and not more than three acres in size (MCL § 324.32727). Withdrawals from wells serving these users are not accounted for in calculations of cumulative impacts on surface waters. While this ‘de minimus’ approach may be more appropriate in certain areas where withdrawals from agricultural irrigation vastly outpace residential use, the growth and density of well-dependent residential developments in areas like Ottawa County shows that the cumulative impact of these withdrawals should not be overlooked (Mechlem 2016).

Under Michigan Administrative Code R 560.411 wells for drinking water and household purposes must yield 10 gallons per minute; if they yield less, additional water storage capacity is required. Thus, a subdivision with densely placed residences can quickly exceed the large quantity withdrawal threshold of 70 gallons per minute pumping rate (which is equal to the 100,000 gallons per day threshold). However, because these withdrawals are made by

individual property owners for residential purposes, the WWAT does not incorporate the cumulative impact on protected surface waters (Personal Interview, state agency representative. 2022a; Personal Interview, academic. 2022a). Their cumulative impact on potential aquifer drawdown is similarly unregulated by the state.

Michigan groundwater quantity regulations do not consider the potential negative impacts new large quantity withdrawals may have on the long-term water quality of and availability to nearby residential wells (MCL § 324.32706e). One interviewee noted there may also be circumstances where large quantity withdrawals can impact subsurface flow of contamination plumes which could contaminate wells intended for drinking water (Personal Interview, local government representative. 2022a).

Because the WWAT is only concerned with stream depletion, it may register large quantity withdrawals in locations that could cause water supply issues for nearby residential wells. Even in areas with abundant groundwater and rapid recharge rates, large quantity withdrawals from high-capacity wells (greater than 70 gallons per minute) can cause a cone of depression which draws down the water table and can impact nearby wells (MI DEQ 2019).

The Groundwater Dispute Resolution program authorized by Part 317 of NREPA seeks to address these kinds of water conflicts (MCL § 324.317). The program applies in circumstances where a small-quantity well experiences issues with water supply that is directly attributable to a nearby high-capacity well. Interviewees noted that instances of this kind of dispute are relatively uncommon (Personal Interview, state agency representative. 2022a). This may be because of the difficulty in attributing the small-quantity well's issues to a specific high-capacity well. In other circumstances, a local health department may anticipate the threat to nearby residential wells upon reviewing a large quantity withdrawal well permit application and could work with the Water Use Program and the large quantity withdrawal water user to adjust the withdrawal registration. However, the Groundwater Dispute Resolution program does not address instances of general drawdown like that facing Ottawa County where dry or lower-than-needed residential well pumping rates cannot be directly attributed to a single user.

3. <u>The Disconnect Between Groundwater Availability and Land Use</u>

Groundwater rules referenced in Michigan's land use legislation do not protect against land use changes that threaten long-term groundwater availability.

State law regarding land division and splits contains stipulations around groundwater supply that may not be appropriate for all counties and have led to challenges in Ottawa County in particular. Michigan Zoning Enabling Act and the Land Division Act do include 'suitability of groundwater' in the criteria for permitting landowners to exercise the option of rezoning land for more dense housing under MCL § 125.3506. However, because other state rules pertaining to groundwater 'suitability' do not consider potential drawdown from residential sources, this provision would not prohibit well-dependent dense housing developments in areas with groundwater depletion. MCL § 560.109, in the Land Division Act, requires, among other stipulations, subdivisions of parcels to be at least 1 acre in size. In areas of Ottawa County this

may be an inappropriate size for well-dependent residential developments because of the number of new wells and quantity of groundwater these homes would withdraw.

For example, a 20-acre parcel could be split into 20, 1-acre residential lots each withdrawing at 10 gallons per minute. A single non-residential user seeking to withdraw an equivalent cumulative amount for the same 20 acre lot would be required to register through the WWAT and may not have received authorization for the full withdrawal amount (Personal Interview, local government representative. 2022a)

Rural townships like those in the central portion of Ottawa County must plan ahead to ensure water demands are covered by other regional public water systems. A township's growth must be built into the required 5-year, 20-year demand projections for those regional public water supplies (Michigan Administrative Code R 325.11203; (Personal Interview, local government representative. 2022c). Negotiating contracts with those public water supplies may take valuable time if townships find themselves responding to a crisis similar to that in the central portion of Ottawa County. At the same time, residents dependent on individual residential wells do not have 5-year and 20-year projections ensuring consistent water supply.

In combination with township ordinances, required ordinances from the state can create circumstances that exacerbate potential water supply issues. An example of this occurred in Jamestown Township in Ottawa County between 2020 and 2021. The township intended to prevent high density development in a certain part of the county by placing an ordinance against infrastructure development including water lines. However, a residential developer was able to leverage the state's required Open Space Development ordinance, which was designed to encourage density through density bonuses, to put more houses on a parcel than the zoning ordinances would otherwise allow. Because the original township zoning ordinance prevents municipal infrastructure in that area, the developer planned to install residential wells for the units (Personal Interview, local government representative. 2022c; Personal Interview, local government representative. 2022a). This kind of situation exemplifies how local control and state requirements can converge to incentivize additional well-dependent residential developments that can exacerbate burdens on groundwater resources.

Working Toward Policy Solutions in Michigan

There are a range of policy solutions available to address the gaps identified above. Some solutions can be implemented by state, county and local decisionmakers within the current regulatory framework whereas others might require changes to administrative code or legislation. Below, we raise three policy and procedural changes that state, county and local governments can employ to support sustainable groundwater management in the face of population growth and climate change. These are: groundwater management planning; coordinated land use planning among county and local governments; and education and outreach. There are ways for these changes to be implemented within the current policy landscape. However, we also point out where each solution may fall short without legislative

support and intervention. In the following section we identify improvements the state will need to make to hydrogeologic data collection and use to support statewide implementation of the suggested policy solutions. Both the policy changes and data improvements presented here surfaced frequently during interviews.

1. Groundwater Management Planning

The state could explore the use of Groundwater Management Plans (GWMPs) for areas at risk of groundwater drawdown and overallocation. GWMPs organize various stakeholders to achieve a certain set of goals for a specific groundwater resource. These plans can include activities such as water conservation efforts and managed aquifer recharge programs. They may also define the concept of yield, either safe yield or sustainable yield, which relates to the amount of water that can be removed from an aquifer safely or sustainably. Gage and Milman (2021) analyzed the use of GWMPs in 12 of the 13 states whose regulatory structures include GWMPs. Their study suggests that the process of developing the GWMPs requires collaboration among disparate parties that may build the political and social support necessary for management success. The process of writing a GWMP, and its implementation, can open lines of communication and provide a venue for facilitating agreements (Escobedo Garcia and Ulibarri 2022; Gage and Milman 2021). The GWMP approach has the benefit of focusing on a particular groundwater resource whether a glacial aquifer within a watershed or a single confined aquifer. This allows the plan to be tailored to the specific hydrogeologic conditions of and water user demands on the groundwater resource. Interviewees discussed how the wide range of geologic features and water user demands across the state can make statewide regulations unresponsive to the needs and concerns of individual regions (Personal Interview, academic. 2022b; Personal Interview, local government representative. 2022d). GWMPs could allow for greater flexibility and increased local stakeholder involvement in management decisions.

There may be potential to develop GWMPs for vulnerable groundwater resources in Michigan through existing governing entities. Options include county governments, regional planning commissions and related working groups, watershed councils, or Water User Committees under Part 327. Each of these venues has benefits and drawbacks and may be more appropriate for some areas of the state than others.

In the case of Ottawa County, the county serves as a convenient venue for coordinating sustainable use of bedrock aquifer water in that area. The combination of groundwater discharge into the Grand and Macatawa Rivers running through the northern and southern portion of the county and the aquifers' low transmissivity indicate that land use changes to bedrock aquifer recharge areas outside the county are less likely to impact water quantity within the county (MSU IWR 2013). Ottawa County's Groundwater Sustainability Initiative is developing a GWMP (Ottawa County Planning and Performance Improvement Department 2019). The county has already identified a number of solutions currently available to county governments across the state in its Groundwater Sustainability Initiative Proactive Strategies Index (2019). These solutions range from providing training for landscape professionals and homebuilders to instituting rebate programs for water efficient appliances and fixtures. Though

tailored particularly to Ottawa County's stakeholders and strengths, this strategy index does provide a blueprint for actions counties can take under the current distribution of authorities. However, as we discuss more later, the county continues to encounter limitations on its authority to regulate and is limited in its capacity to incentivize behavior change among those with jurisdictional authority.

In other parts of Michigan, there may be more circumstances where at-risk aquifers or recharge areas straddle jurisdictional boundaries (Lusch et al. 2018). This would require greater collaboration between two or more counties and the relevant local units of government. Having a dedicated body beyond the county to organize this collaborative effort could be beneficial to planning efforts. There is both precedent and a legal framework for these kinds of cross-jurisdictional planning efforts in the Regional Planning Act and examples of this kind of collaboration relating to surface water in legislation authorizing watershed councils and alliances (MCL 324 § 324.312; "Final Report of the Water Use Advisory Council" 2014). These bodies have experience in facilitating joint decision-making among multiple government units and stakeholder groups. Watershed councils also have experience working on water-related concerns and could provide expertise on surface-groundwater connections. However, there are parts of the state that do not have active regional planning commissions nor watershed councils. It remains unclear whether areas at-risk of drawdown or overallocation have active regional planning commissions or watershed councils.

Water User Committees authorized under Part 327 have the potential to serve as venues for groundwater planning as well. There is some evidence that these kinds of self-regulating collectives can partially succeed in reducing groundwater drawdown (Smith et al. 2017). However, WUCs may be limited in their ability to do so for several reasons. First, their membership consists only of large quantity withdrawal users and local government officials, though a participating local government official may create an ad hoc subcommittee of residents to provide advice and information (MCL § 324.32725). There may be relatively few large quantity withdrawal users withdrawing from a particular semi or completely confined aquifer; at the same time, there may be many more residential users which could make organizing and facilitating coherent negotiations challenging. Nor would the Water Use program have authority to limit residential withdrawals under the statute as it theoretically can for large quantity withdrawals. This creates a set of circumstances less than conducive to productive negotiation regarding limiting aquifer drawdown.

Second, this role would extend beyond the legislatively defined goals for Water User Committees. The Water Use Advisory Council's 2014 report explores the incentives and dynamics at play for WUCs at length, casting doubt on the capacity of WUCs to even meet legislatively goal (Water Use Advisory Council 2014). It therefore seems unlikely that this kind of body would voluntarily take on an extra-legislative role in self-managing aquifer drawdown not related to an adverse resource impact.

Third, Water User Committees remain an untested experiment, even as watersheds within the state have surpassed the threshold of allowable water use. In the fourteen years since its

passage, no water users have taken advantage of this section. The Water User Advisory Council has a working group on Water Users Committees that is developing a Water User Committee Manual and seeks to pilot a Water Users Committee to inform the manual's developments (Water Use Advisory Council 2020; Personal Interview, local government representative. 2022d). There is opportunity for including language and guidance around confined aquifer drawdown, but at present there is not enough evidence to discuss the utility of WUCs in addressing water conflicts, especially those not explicitly defined in the legislation.

Regardless, under the current framework, none of these entities is empowered to manage groundwater withdrawals from both large and small quantity users which greatly limits the potential impact of planning. As the Ottawa County case has shown, multi-stakeholder engagement efforts without authority to manage, and limit, both large-quantity and residential withdrawals are likely to run into barriers in enforcing sustainable groundwater use. In this respect, there may be lessons for Michigan from other states like California, which recently passed a Sustainable Groundwater Management Act. Under this California law, local Groundwater Sustainability Agencies are established in 'special permitting areas' which are recognized as particularly vulnerable. These agencies have the flexibility to tailor their permitting regimes to local conditions. Notably, the provisions in this act appear to supersede California common law regarding water allocation (Nelson and Perrone 2016). For any existing entity in Michigan to manage large and small quantity withdrawals, there would need to be legislative changes which could raise the kinds of water law conflicts Part 327 seeks to avoid.

There is potential to layer groundwater management planning legislation on top of current regulations. In this situation, some parts of the state could employ GWMPs and other parts could retain the current approach depending on the vulnerability of the groundwater resources in question. Groundwater management planning has the potential for incorporating the needs and concerns of both large and small quantity users as well as the attributes unique to a region in a way that statewide regulations cannot. For example, water lines drawing from Lake Michigan pass through Allendale Township (Personal Interview, state agency representative. 2022a). These water lines can more easily serve new residential developments in Allendale than they could agriculture producers in other parts of the county. Groundwater management planning could surface regional assets like water lines and create governance structures and agreements that direct different groups of water users to the most appropriate water source. Overall, a more thorough study of how groundwater management planning legislation could be adapted for a Michigan context could explore this approach and related concerns.

Finally, funding may also preclude the kind of collaboration a Groundwater Management Plan both requires and fosters. The activities completed by Ottawa County were funded by a grant from the state (Personal Interview, local government representative. 2022c). Without this influx of funding or some other funding mechanism, other counties, regional planning committees, watersheds councils, or theoretical WUCs may not have the resources to undertake similar projects tailored to their own needs. This, again, is a situation where legislative action or existing state funding sources, like the Clean Water State Revolving Fund or Source Water Protection grants, could allocate funding to support groundwater planning activities.

2. Coordinated planning among local units of government

Under the current regulatory framework, local units can still make progress on groundwater sustainability through enhanced coordination and collaboration. Coordinated land use decisions can impact both water demand and water supply. Counties and the state can facilitate this kind of coordination through providing information, staff time, or other resources.

The role local units of government play in land use planning and zoning under current regulatory framework means that a coordinated approach among local units can slow the growth in well-dependent residences and alleviate pressures on aquifers. The central townships in Ottawa County have taken various approaches and leveraged different tools depending on their circumstances. Allendale Township is the most urban of the four and the closest to water pipes providing drinking water from Lake Michigan to nearby cities of Wyoming and Grand Rapids. Michigan Common Law Section 324.32726 curtails local government units from enacting or enforcing ordinances regulating large quantity withdrawals. Yet, it also explicitly states that the section is not "intended to diminish or create any existing authority of municipalities to require persons to connect to municipal water supply systems." Therefore, in 2019, the township opted to require all new subdivisions to be hooked up to municipal water (Personal Interview, local government representative. 2022e; Allendale Township Board of Trustees 2020). Olive Township now requires that if a property is split more than 5 times, residents built on those splits must be hooked up to public water (Personal Correspondence, local government representative. 2022). In both cases, the townships first placed a moratorium on new development prior to making ordinance changes (Personal Interview, local government representative. 2022e; Olive Township Board of Trustees 2019). As of July 2022, Robinson Township is in the middle of updating its master plan drafts, which contain references to Ottawa County's Groundwater Sustainability Initiative with the intention of aligning activities (Ransford 2022). Allendale and Blendon Township supervisors have served on the Initiative's task force (Ottawa County Planning and Performance Improvement Department 2019). While the initiative has lost some momentum as a result of the COVID-19 pandemic, continued dialogue can build trust between township and county officials and facilitate further coordination around limiting pressures on an aquifer and promoting recharge (Personal Interview, local government representative. 2022a; Personal Interview, private sector representative. 2022a; Personal Interview, local government representative. 2022f).

Counties are also permitted under Michigan Administrative Code R 560.426 to require that an on-site water supply well must be complete prior to construction on any parcel less than an acre. This requires collaboration and communication between townships that permit buildings and counties that permit wells. Washtenaw County, for example, has an ordinance and program EGLE's Source Water Unit's 'Water Well Manual' refers to as a 'well-first' program (MI DEQ 2019). Well-first programs can get out ahead of conflicts where homebuilders and developers complete work on a parcel or set of parcels prior to determining if the groundwater is suitable for drinking water wells. Well-first programs can save significant expense and in some cases prevent additional well-dependent subdivisions in areas vulnerable to drawdown (Personal Interview, state agency representative. 2022b). They also create formal avenues of

communication about development that can avoid confusion that might lead to breakdowns in trust (Personal Interview, local government representative. 2022b). Yet, the size stipulated in rule 560.426 may not be large enough for all counties in the state. It may be appropriate for some counties experiencing groundwater availability concerns to have well-first programs for parcels larger than one acre. This is an example where a small change to administrative code could support better groundwater management through existing mechanisms.

Curtailing new well-dependent subdivisions either through requiring municipal hookups or limiting land splits may not be sufficient to prevent continued drawdown given the slow rate of recharge into the bedrock aquifer and therefore additional well failures. Nor does this provide a solution for those residences whose wells have already run dry or will fail in the short to medium-term. There are residential users for whom municipal water is not an option either due to distance from the residence to the nearest water main, a paucity of neighbors that could share the expense of a water line extension. Extending a water line to an area of a township requires enough demand from that area to prevent water quality concerns related to water age (Personal Interview, local government representative. 2022d; Personal Interview, local government representative. 2022g). Municipal water hookups may not be a viable option for irrigation water use either due to location or cost (Personal Interview, local government representative. 2022f). These circumstances highlight the need to consider both sides of the water balance equation.

Local government land use decisions can impact the supply side of the water balance through influencing aquifer recharge rates. Some of these mechanisms include reducing impervious surfaces like parking lots and rooftops and improving stormwater systems to promote infiltration (Howard and Gerber 2018). In Ottawa County, stormwater management has traditionally focused on expediting drainage to prevent flooding from heavy rains which can have a negative impact on recharge, but the county has made recent efforts to improve infiltration through land cover management (Personal Interview, local government representative. 2022a). This may be another avenue for greater collaboration between county and township planners. Township officials already work closely with county drain commissioners on ensuring residential developments comply with the Drain Code (Personal Interview, local government representative. 2022c; Personal Interview, local government representative. 2022h). Incorporating discussion on groundwater recharge areas and rates into these conversations may be a natural way to cultivate a focus on sustainable groundwater management among local units of government. Future research could explore systems of projecting recharge rate changes resulting from land use changes and governance mechanisms for compensating for related recharge loss.

In those circumstances where recharge to an aquifer primarily occurs outside of the jurisdiction that most heavily uses the aquifer, there may be opportunities for partnerships between local units of government focused on recharge and land use. This could follow a model of payments for ecosystem services where townships with high groundwater demand pay townships with recharge areas to leave those areas undeveloped. There is precedent for this kind of activity in the Purchase of Development Rights programs authorized under the Michigan Zoning Enabling

Act (MCL § 125.3507-09). This program requires a local unit to have adopted a Purchase of Development Rights ordinance. The local unit is then able to purchase the rights to develop a property from a local property owner with the intention of preserving the property as either solely for agricultural use or a natural area. The statute also allows the local units of government's legislative body to enter into agreements with other local units for cross-jurisdictional purchases which would allow a township to purchase development rights to its aquifer's recharge areas in cooperation with the other local unit and the property owner.

Urban development does not inherently lead to reductions in aquifer recharge. Research suggests that recharge losses from urban growth can be compensated with new sources of recharge resulting from urban runoff to drywells and catch basins and subsequent infiltration, excess watering of lawns among and reduced evapotranspiration among others (Howard and Gerber 2018). These losses and new sources will vary with the specific land use and geology of an area. In some places, increased infiltration from green infrastructure can overwhelm a glacial aquifer system and lead to additional flooding (Howard and Gerber 2018). In the case of Ottawa County, however, the geology largely prevents new sources of urban growth-related recharge, like lawn watering, from replenishing the bedrock aquifer even as new urban growth-related demands place stresses on that aquifer. This, once again, demonstrates the need for detailed hydrogeologic data and local level groundwater models in order to understand water balances in a region. These data can then be used to guide land use planning across jurisdictions overlaying the relevant aquifer as it has begun to do in Ottawa County.

3. Education and Outreach

In order for counties local units to effectively collaborate and use hydrogeologic data for decision-making, staff and elected officials must possess appropriate hydrogeologic knowledge and expertise. This may require outreach and education from the state, or in some cases from counties to townships. Sanitarians at local health departments, township supervisors and planning commissions at all levels need to be equipped with the proper skills for incorporating hydrogeologic data use into their workflows. This will allow local decisionmakers to model water supply challenges and deploy preventative strategies like those discussed above before residents' experience well failures or farmers lose crops.

Previous programs by the MSU Sea Grant Extension and state programs, like MSU's Water School and related resources, have begun this work (Personal Interview, academic. 2022a). Prior to the COVID-19 pandemic, the state held regular training workshops for local health department staff on wells and hydrogeology (Personal Interview, state agency representative. 2022b).

The Water Use Advisory Council 2020 Biennial Report also recommends providing additional training for well drillers and county health departments which will both improve the accuracy of the data well drillers collect and log as stipulated in MCL § 333.127 and also help build relationships between well drillers and sanitarians which may enable expedited problem solving and clarity as groundwater and well water issues arise (Water Use Advisory Council 2020; Personal Interview, private sector representative. 2022c; Personal Interview, academic. 2022b).

Another area, less thoroughly described in the Water Use Advisory Council 2020 Biennial Report, is the potential need for mediation services. These services could be useful in the event of the formation of a Water Users Committee that must agree on water withdrawal reductions or in convening residents to negotiate payment structures for municipal water extension (Personal Interview, state agency representative. 2022b). As the Water Use Advisory Council Report in 2014 noted, the Water Use Program has less experience with this kind of service provision, there may be opportunities for collaboration across entities that do have more experience in convening and facilitation such as Michigan Sea Grant Extension (Water Use Advisory Council 2014; Personal Interview, academic. 2022a).

Ottawa County's Groundwater Sustainability Initiative also identified and is pursuing outreach opportunities to the broader public through traditional media outlets, school programs, signage on county lands and parks, webpages and through convening relevant stakeholders such as realtors serving potential homebuyers in the area (Personal Interview, local government representative. 2022a; Personal Interview, private sector representative. 2022a; Ottawa County Planning and Performance Improvement Department 2019). While this outreach has precipitated communication and collaboration with townships and community organizations in the case of Ottawa County, broader evidence is mixed on the impacts of public raising awareness as a mechanism for addressing water conservation challenges (E. Mansur and Olmstead 2012; 2011). Public education is only one of several tools governments at all levels might employ.

Improving Hydrogeologic Data Statewide

The policy solutions suggested above require that state, county and local units of government have an advanced understanding of the hydrogeologic conditions and groundwater resources within their jurisdictions. This will not be possible without improving the quality and quantity of hydrogeologic data statewide. As advocates and researchers have discussed, Michigan lacks organized and detailed hydrologic data at the resolution needed to make decisions regarding sustainable groundwater use (Steinman et al. 2022). Acquiring these data will enable the state and county governments to develop more sophisticated, local level hydrogeologic models.

Local-level groundwater models would improve Michigan's groundwater management in several ways. Determining sustainable use of a groundwater resource goes beyond establishing static thresholds of safe or sustainable yield (Groundwater Conservation Advisory Council 2006). Rather, granular groundwater models allow decisionmakers to incorporate changing hydrogeologic and land use data. This, in turn, allows the model to more accurately project both future water levels and water availability in semi- or completely confined aquifers, as well as adverse resource impacts to streams. Use of local models could also contribute to enhanced county-state data sharing and collaboration. This could have spillover effects on addressing water quality concerns and impacts to residential wells that the model used in the current Water Withdrawal Assessment Tool cannot. Developing these local models would enable counties and

townships to create dynamic water budgets that respond to changing hydrological conditions. For example, they could model water use scenarios like construction of new well-dependent residential developments to predict long-term impacts on groundwater resources. This in turn could enable greater collaboration with developers and well drillers regarding where well-dependent residences are viable (Personal Interview, private sector representative. 2022b; Personal Interview, private sector representative. 2022c). These models could develop 5-year and 20-year groundwater supply projections that complement the required 5-year and 20-year public water supply plans. Finally, as discussed above, local level models can provide detailed information on recharge areas which will allow local units of government to make targeted and efficient zoning decisions that promote recharge.

To date, Michigan has not prioritized collecting the data needed to develop these kinds of models. When the Michigan legislature passed Part 327 in 2008, it recognized the need for improved hydrogeologic data to populate the Water Use Program's key decision-making tool, the Water Withdrawal Assessment Tool, and permitted technical modifications to the tool under certain circumstances (MCL § 324.32706a(6)). The legislature had previously authorized and appropriated funds for the Groundwater Inventory Mapping program (GWIM) under an amendment to Part 328 in 2003. These data became the key inputs still used in the WWAT as of 2022. However, even at the time of data collection, there were some concerns about the resolution and accuracy of the GWIM inventory. The funds allocated were insufficient to complete detailed mapping of the entire state which means that the WWAT lacks granularity. Without higher resolution data, the tool is hampered in its ability to achieve its intended purpose (Water Use Advisory Council 2014; Personal Interview, academic. 2022a; Personal Interview, academic. 2022b).

Changing hydrological conditions perpetuated by climate change and uneven growth make more regular updates to data inputs even more critical (Luetkemeier, Söller, and Frick-Trzebitzky 2022; Costa, Zhang, and Levison 2021; Taylor et al. 2013). Collecting comprehensive and regular data inputs necessary for accurate calculations of both streamflow depletion and aquifer drawdown requires significant funding. Ongoing funding structures authorized under Part 327 and Part 317 do not provide the kind of ongoing resources needed to undertake hydrogeologic studies at the scale necessary for informing sustainable groundwater management across the state.

In March 2022, the Michigan Legislature passed PA 53 which provided 10 million dollars in funding to the Water Use Advisory Council to complete activities recommended in the Water Use Advisory Council 2020 Report including creation of a Michigan Integrated Water Management Database, creation of the Michigan Hydrologic Framework, and increased hydrogeologic mapping in 25 targeted areas of Michigan. These initiatives are intended to enable the creation of local-scale groundwater models that are both unique to county concerns and compatible with state-level tools. However, the influx of funding provided by PA 53 is not a sustained funding mechanism for regular data collection, nor is it sufficient for supporting counties in creating the local level models under the Michigan Hydrologic Framework. Part 327 prohibits EGLE from levying additional water withdrawal related fees beyond the water

withdrawal permit fees enumerated in the legislation which means that on-going collection and maintenance of these data would require either a new legislatively defined revenue source, or internal adjustments to EGLE's budget. Other studies may be needed to explore the feasibility of either approach.

Meanwhile, incorporating existing data into decision making tools provides an interim solution. Under the 2020 recommendations by the Water Use Advisory Council, EGLE has formed a working group with representatives from various offices to compile the different sources of hydrogeologic data housed across the department into the Michigan Integrated Water Management Database (Water Use Advisory Council 2020). A one-stop-shop approach to hydrogeologic data across the state may facilitate additional use of those data beyond the narrow statutory requirements and flag potential problems for proactive discussion across levels of government. For example, referencing residential well log data or lab results from water quality tests in site-specific reviews for large quantity withdrawals may start to account for potential cumulative impacts of residential wells and flag areas where large quantity withdrawals might divert subsurface contaminant flow toward residential users.

As the challenges in Ottawa County have elucidated, additional data is not a panacea, especially where the distribution of authorities precludes the use of those data for decision-making. Nearly a decade after the initial water resource study was completed in the county, officials continue to encounter limits on their capacity to address drawdown, drying wells, and contaminant concerns and ensure safe and sustainable groundwater use.

Local groundwater models created under the new Michigan Hydrologic Framework could provide justification for the state to adjust its interpretation of current rules or develop additional water quantity criteria that would allow these models to determine what EGLE's current rules describe as an "adequate quantity and quality" of "potable, adequate, reliable and protected on-site water supply" (Michigan Administrative Code R 560.401, R 560.404, R 560.405).

Areas for Additional Research

The policy gaps and potential solutions identified above generate the need for additional research on several fronts. First, as mentioned above, the policies reviewed as part of this report do not represent all relevant policy or case law related to groundwater management in Michigan or beyond. A more in-depth legal review by legal scholars could identify creative avenues for leveraging existing legal structures to provide state, county, and local decisionmakers with the kind of legal backing they may need to enforce changes that could lead to more sustainable groundwater use. This could include a more in-depth analysis of tools available under wellhead protection programs such as nonpoint source pollution prevention and control grants for the purchase of land or rights in land to protect aquifer recharge areas (MCL § 324.8802). Alternatively, a review of groundwater management structures in other Great Lakes basin states, including funding mechanisms for hydrogeologic data collection, could inform and support a basin-wide approach for groundwater management. This would be especially useful in

light of recent efforts to compile a surface-groundwater model for the Great Lakes Basin (Great Lakes Science Advisory Board and Research Coordination Committee 2018; Great Lakes Science Advisory Board Research Coordination Committee, 2022). It could also be useful to explore how groundwater governance, water conservation, water recycling, and managed aquifer recharge policies and programs from as far afield as California or Arizona, states known for both water scarcity and innovation in water governance, might apply in the Great Lakes context (Eden et al. 2016; Nelson and Perrone 2016).

Second, for the state to best target educational and outreach activities to local government leaders, the state may need additional information on the local capabilities. These capabilities include hydrogeologic knowledge, geographic information systems expertise, current water supply monitoring systems, as well as the sources of funding available to local units for developing these capabilities and the status of local unit cooperation on land use decisions. This information would allow the state to identify regions most at risk of unsustainable groundwater use due to hydrogeologic conditions and growth in well-dependent residential developments, as well as regions least equipped to deal with the kind of water supply concerns facing Ottawa County. This information could also guide revisions to funding criteria and outreach for water-related grant programs, like the Source Water Protection Fund, Freshwater Protection Fund, Safe Drinking Water State Revolving Fund and Clean Water State Revolving Fund, so that they target remedial or preventative measures aimed at groundwater depletion or even support communities in developing groundwater models under the Michigan Hydrogeologic Framework.

Coordinated groundwater management planning and land use planning require cooperation and negotiation from water users, property owners, businesses and other entities. Each of these entities and stakeholder groups will have their own political agenda. The groups are also likely to have varying access political resources for influencing policymakers. Public opinion and conception of groundwater may also impact the feasibility of addressing policy gaps through coordinated planning. A study describing the political landscape could identify and help to address potential political obstacles to coordinated government action like groundwater management planning or collaboration on land use decisions.

Finally, counties and other local government units may seek to address drawdown concerns through managed aquifer recharge (Personal Interview, local government representative. 2022f). As discussed earlier, Ottawa County simultaneously experiences problems of managing surface water runoff from heavy precipitation events alongside groundwater availability concerns. More water scarce regions, like Arizona, have invested heavily in developing managed aquifer recharge and water banking programs (S. Megdal and Dillon 2015). These can range from installing infiltration basins in areas of high recharge for collecting precipitation to aquifer storage and recovery systems that inject freshwater directly into an aquifer (Alam et al. 2021). There is a dearth of both scientific and policy research on managed aquifer recharge applications in Michigan. More scientific studies are needed to determine which managed aquifer recharge options could play a role in Michigan groundwater sustainability concerns. Should the science support use of these programs, a more in-depth exploration of options available to county and local governments current regulatory framework could open up new

policy solutions. This could include greater exploration of the Groundwater Discharge Permitting program at the state level and authorities afforded under the Michigan Drain Code and federal Clean Water Act.

Conclusion

Through our analysis of legislation, administrative code, and relevant documents, as well as through interviews with stakeholders, we identified three policy gaps in Michigan's current groundwater regulatory framework that make it challenging to manage growing residential groundwater withdrawals. First, the current framework does not ensure sustainable management of groundwater resources that lack significant hydrological connection to protected surface water streams. Second, it operates with a 'de minimus' approach thereby exempting residential well users from withdrawal regulations. This poses a threat to sustainable groundwater use in areas with high residential or urban growth, like Ottawa County. Finally, Michigan's land use regulations do little to protect against threats to long-term groundwater sustainability. Land use changes promoting sustainable groundwater management require proactive action and collaboration from local units of government who often have the fewest resources and least access to hydrogeologic data. While county-level governments may be better equipped to address local groundwater challenges, these units of government also lack authorities provided to the state and townships or municipalities.

We identified several solutions that are feasible within the current legislative context and could improve groundwater management in Michigan. First, state and local governments could collaboratively explore the use of Groundwater Management Plans for particularly vulnerable areas like Ottawa County. Second and related, state and county governments could collaborate to engage local units of government in coordinating land use planning that considers water supply through recharge rates and demand through zoning, planning and land division decisions. Third, all levels of government can invest in education and outreach to improve communication channels between relevant stakeholders and across jurisdictions. **In order to implement these solutions, the state must invest in collecting and maintaining high resolution hydrogeologic data and support the development of sophisticated local-level groundwater models.** Without these data and models, decisionmakers lack accurate predictions of impacts from water withdrawals and planning decisions.

Michigan's reliance on its groundwater resources makes management of those resources pivotal for its future, especially as the impacts of climate change become increasingly severe. Given changes to hydrological cycles that impact groundwater availability, and use and population growth in at-risk areas, Michigan can no longer afford to rely on perceived water abundance to provide water for the many well-dependent residences across the state. The state's groundwater policy landscape has created a policy gap for residential groundwater withdrawals. In places with challenging hydrogeologic conditions, like those in Ottawa County, this gap is already being felt. This report adds to the growing body of literature on the importance of groundwater in Michigan and addresses concerns regarding groundwater

sustainability in the state by identifying key policy gaps and suggesting ways state, county and local decisionmakers can coordinate to overcome policy gaps. As the state faces further changes from population growth and climate change it will become increasingly important that decision-making tools and information resources keep pace. The complexity in Michigan's groundwater institutions and the distribution of groundwater-related authorities assigned to state, county, and local governments necessitate creative collaboration across levels of government. Further investment in data will be necessary to support sound decision making.

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