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The Future of Minnesota Drinking Water: A Framework for Managing Risk

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A project report prepared by staff and faculty of the
University of Minnesota Humphrey School of Public Affairs and the
University of Minnesota Water Resources Center, with funding from the
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Executive Summary

The charge for this report was to identify opportunities for the Minnesota Department of Health (MDH) to better manage risks to Minnesota's drinking water. In addition to examining literature and experience in other jurisdictions, our recommendations are informed by ten discussions with a panel of research and policy experts, and a panel of stakeholders including representatives of large and small community utilities, the water technology industry, state agencies, and well owners.

We have sought to build on the strengths of a state widely recognized for good drinking water management. However, as with all states, the future for drinking water is likely to be challenging due to an ever-increasing number and diversity of drinking water contaminants arising from industrial, agricultural and domestic sources, exacerbated by population pressure, climate change and aging infrastructure for both water and sewage systems. Population shifts from rural to urban areas also create financial challenges for small communities purchasing sophisticated and costly water treatment equipment.

Because of these intensifying pressures, we support the development of a state drinking water plan, built on the ethic of providing safe and sufficient drinking water for all, while protecting the environment. This report informs that plan.

Effective, efficient and trusted governance is key, especially when the system to be managed is such an interconnected and complex one. We suggest using a Governance Assessment Framework (GAF) as the basis for assessing drinking water management as it is now and setting timeline goals for future action. This provides an important foundation for the state drinking water plan. We shared the GAF with the project stakeholder panel and selected MDH personnel and present their preliminary responses to the current level of implementation of GAF criteria in the state. These samples are small, but from well-informed audiences. We have used their feedback as guidance for our recommendations.

Good governance of water and drinking water systems depends on an integrated and coordinated approach from all institutional players. With as many as eight agencies involved in drinking water management in Minnesota, there is a perception of balkanization. Despite that perception, we are told that there is much interagency water management cooperation stimulated by the Clean Water Land and Legacy Act. We found little argument to recommend consolidating drinking water authority, but rather suggest making existing inter-agency cooperation more transparent by creating a statutory framework that not only makes clear the connections between agencies and focuses on the cross-agency ethic of protecting public health and the environment. It may well be necessary to involve a coordinating body to facilitate this cooperation, but how this is done and the extent to which it leads to consolidation of institutional arrangements should be judged pragmatically in terms of the likely cost-effectiveness of delivery.

The recent increase in water service connection fees has improved MDH capacity for oversight of drinking water management. However, small rural communities still face financial challenges, as well as difficulty recruiting qualified water professionals. Here the state might consider consolidation of utilities in the areas of concern. Careful planning and analysis of the cost-effectiveness of alternative arrangements coupled with consideration of drinking water affordability in the affected communities are a priority.

Effective delivery of safe and sufficient drinking water depends on professional capacity at all levels. MDH is well supported but, as noted above, small suppliers in rural areas struggle to recruit and retain

staff. Public confidence could be enhanced with measures to professionalize the vocation such as implementing transparent, and independently mediated, professional accreditation.

Citizen engagement needs more attention. It should be in the spirit of empowerment, not just education. At one level, this could translate into more public participation in defining and measuring the governance criteria, as well as setting goals. At another level, this could translate into more involvement by consumers in monitoring tap water in their homes as technology develops to facilitate this. In addition, citizen concerns need to be more explicitly taken into account by both suppliers and MDH when making risk management decisions. Public confidence in state agencies is important to water management success. Worry reduction, specifically reconciling public and technical risk assessments, is an important part of public health delivery. Equity consequences of decisions also need to be identified, routinely considered, and made explicit. Existing avenues for risk communication should be revisited by MDH with all these features in mind. MDH should seek to extend risk management communications by leveraging partnerships with trusted organizations (such as healthcare professionals and teachers), receptive audiences (such as expectant parents), trusted leaders and by targeting the media.

Localized source-to-tap risk assessments and management plans—water safety plans (WSPs)—can provide a transparent and flexible approach to locally tailored drinking water management. While the Safe Drinking Water Act (SDWA) requirements limit the possible extent of implementation, the opportunity that WSPs provide for consolidating a variety of planning requirements could offset professional capacity challenges faced by smaller municipalities. We suggest that MDH work in partnership with suppliers to explore if the advantages of plan streamlining could outweigh the technical challenges of implementing WSPs.

Comparative risk assessment should be an important part of providing a rational and transparent basis for addressing the ever-increasing contaminants of emerging concern (CECs) associated with drinking water, particularly as agencies face increasing pressure from both the Legislature and the public to regulate CECs more formally and more rapidly. We develop comparative risk assessment guidelines for prioritizing chemicals for more attention and then for action. These guidelines can be applied to CECs as well as to currently regulated compounds. The process already deployed by MDH for prioritizing CECs, with minor exceptions, is well developed. Beyond that, we did not address the development of health-based guidance values in any detail. We believe that the process should be reviewed for consistency with our guidelines and whether it can be accelerated without losing scientific credibility. We provide some broad recommendations about how comparative risk assessment, and associated cost-benefit analysis, can be used to inform the debate on the merits of excluding contaminants from drinking water at source rather than extracting them at a water utility or in the home.

We have not paid much attention to drinking water policy for private wells because, with the exception of construction and testing of new wells, they fall outside the statutory scope of MDH. We have heard concerns that because of costs and “head in the sand” syndrome, water quality monitoring is patchy in this sector. Repeatedly we have heard suggestions that a statutory requirement for well testing at property transfer would not only protect the health of buyers, but also send a powerful signal that the quality of water from private wells needs to be taken more seriously. Providing more readily available and accessible resources for owners to identify hazards associated with local aquifers and wells of particular design and age could also encourage them to develop their own cost-effective approach to water safety planning.

Taken together, the guidance summarized by the Governance Assessment Framework provides a path for structuring a state water plan accounting for interacting risks from source water to drinking water delivery at the tap.

1. Introduction

The approach to drinking water management in Minnesota has been recognized internationally as an example of good practice (e.g. Hartmann et al., 2018). The record on violations of standards under the Safe Drinking Water Act is much better for this state than for most others in the USA (Allaire et al., 2018). However, challenges from the complexity and interconnectedness of the water system mean that all jurisdictions are likely to face uncertainties in the delivery of safe drinking water over both the short and long term. These uncertainties are exacerbated by population pressures, climate change and aging infrastructures in both drinking water and sewage systems. We therefore sought to develop recommendations that build on the considerable strengths of Minnesota in drinking water management while recognizing the need for approaches that avoid surprises (Calow et al., 2019).

This report provides the final output from the two-year project conducted by the University of Minnesota for the Minnesota Department of Health starting in June 2018. The Minnesota Department of Health (MDH) contacted the University of Minnesota (UMN) requesting assistance with research and development of an action plan to address threats to safe drinking water. This work includes the identification of the regulatory, technological, behavioral, and cost barriers that need to be addressed to develop public health policies and actions to address emerging threats to Minnesota drinking water supplied by municipal systems and private wells. Additionally, the UMN team collaborated with MDH staff on the preparation of a report related to risks from lead in Minnesota drinking water. That report was published in 2019 (Minnesota Department of Health, 2019c) and has been presented to the Clean Water Council and other organizations.

The Approach

The project team identified risks and potential responses by examining approaches used in other jurisdictions, exploring national and international risk management literature, interviewing MDH staff, and convening two panels for consultation. The first panel consisted of seven research and policy experts in drinking water treatment technology, hydrology, communication, community engagement, policy, and finance. The second panel consisted of stakeholders from a variety of sectors including agriculture, local government, private well owners, water supply utilities for large and small communities, water technology, and environmental and consumer advocacy organizations. See Appendix for a list of panel members. We met with each panel five times to learn their concerns and recommendations. Their perspectives were important to framing this report, but we did not strive to reach consensus, and they are not responsible for the content or conclusions of the report.

We submitted an interim project report in February of 2019 (Calow et al., 2019) that laid out a draft framework for risk management and outlined possible actions for consideration. In subsequent months, we gathered reactions to these recommendations from MDH staff, the stakeholder panel, and the panel of water resource research and policy experts to understand their priorities and interpretations of the issues. These discussions underlined the need for an emphasis on governance systems as a basis for ensuring an effective, efficient and integrated management system. In response, we developed a Governance Assessment Framework to structure discussions of actions for improving risk management.

We conducted further review of relevant natural science and social science research, interviews with key individuals in the MDH and other jurisdictions, and further discussions with stakeholder and expert panels. In October 2019, we presented to MDH staff on Comparative Risk Assessment and Water Safety Plans and led discussions to gather their feedback on those approaches. Separately, MDH leadership internally reviewed our initial proposal for a Governance Assessment Framework.

We have based the resulting recommendations on three principles: (1) that they should make scientific and technical sense; (2) that, given the limited resources available for deploying public health policy, they should make economic sense; (3) that they should aim to confront and address public concerns about drinking water safety. Our focus has been on public water supplies with lesser attention to private wells.

In developing the report our aim has been to produce a framework of principles that can be used by MDH for informing their strategic planning and, more generally, for developing a drinking water plan for Minnesota. To translate these principles into prioritized actions will be influenced by preferences that relate to resource constraints and political and public pressures. Judgements about these can more appropriately be brought into the process of strategic planning by the MDH than by outside consultants. So intentionally in the report, we have emphasized policy options rather than detailed actions and, except in the broadest of terms, avoided making recommendations on priorities and time scales.

2. A Drinking Water Governance Assessment Framework

The recognition that the water system is complex and multilayered is fundamental to our recommendations for Minnesota. As such, it requires an integrated approach for effective management. As we listened to people's priorities, we came to understand the importance of the governance systems as a basis for ensuring an effective, efficient and integrated management system.

Water governance is gaining global interest. Healthy economies depend on sound public health that is directly connected to the delivery of safe drinking water. The investment of public finances in infrastructure and maintenance of safe water systems is considerable. With that in mind, the Organization of Economic Co-operation and Development (OECD) has taken a lead role in establishing a water governance initiative. OECD uses a bottom-up approach from practitioners and policymakers to flesh out a framework for describing best practice, assessing if it is being achieved through a transparent scoring system and providing a basis for managing improvements over defined timescales (OECD, 2015, 2018). The framework covers three major elements – efficiency, effectiveness and public trust – each divided into four sub-elements that are intended to cover all the major features of good governance. Following detailed consultation with MDH and our panels, we have adapted this Governance Assessment Framework for use on the drinking water system in Minnesota. It can be deployed at any level of drinking water management, but in the first instance, we have focused on the state agencies, in particular MDH, as they have regulatory authority. Using the framework, we have sought to provide a systematic and transparent basis for assessing governance delivery and to highlight areas in need of attention. We asked our panels and MDH personnel, separately, to score the governance criteria in terms of levels of implementation. These were small samples but the participants are well-informed and useful in guiding our views on priorities. The Governance Assessment Framework might be used routinely at intervals to determine which areas need attention.

We used the modified Governance Assessment Framework (GAF) as a core organizing principle in the rest of this report and in developing our recommendations. The GAF incorporates important recommendations that are expanded on in other parts of this report, including comparative risk assessment (the use of sound science to compare and rank contaminants for attention and action) and water safety plans (the development of more flexible, source-to-tap approaches to risk management based on local circumstances, and expanded engagement and attention to equity issues).

2.1. GAF Criteria

The GAF uses twelve criteria of good water governance (Table 1). The criteria are put into three groups: effectiveness of drinking water governance and management, the efficiency of implementation and delivery of drinking water, and trust in the drinking water system and inclusiveness of diverse interests. Along with the explanations of each criterion, we provide preliminary scorings of levels of implementation and reactions of the Stakeholder Panel and a group of MDH staff who each met separately in September of 2019.

Stakeholder reactions and interpretations were collected during a discussion on September 9, 2019. They are summarized graphically for each criterion below, with detailed information in the Appendix. They are based on sample sizes ranging from 14 to 16. The general tone of responses was that, compared to other states, Minnesota is doing well in terms of drinking water governance; however there are many areas for improvement.

Reactions from MDH personnel, collected in late September, 2019, are also summarized graphically for each criterion below. They are based on sample sizes ranging from 5 to 7. The MDH reactions are captured as verbatim quotes from the written feedback that we received.

To repeat, all analyses are based on small but well-informed groups.

Table 1: The Governance Assessment Framework for Minnesota Drinking Water

Effectiveness of drinking water governance and management

1. State-level policy **clearly defines the roles and responsibilities** of each agency with regard to drinking water management, programming, and policy making, for both private wells and public systems.
2. Drinking water is managed at the **appropriate scale emphasizing an integrated major watershed approach.**
3. Drinking water **policy is coherent** horizontally and vertically across administrative and economic sectors including health, environment, energy, agriculture, and industry.
4. State and local drinking water management entities have adequate **professional capacity**

Efficiency of implementation and delivery of drinking water

5. **Processes and institutions are in place generating timely and relevant data** about the water supply and risk management in a way that is suitable to guide policy, prioritize contaminants for attention and action, create transparency for customers, and provide opportunities for dialogue.
6. **Financial revenues** are adequate, appropriately structured, and transparently, efficiently, and equitably allocated.
7. Sound **regulatory frameworks are effectively implemented.**
8. State and local processes incentivize and **foster innovation and flexibility** in finance, sharing information, assessment, and engagement.

Trust in the drinking water system **and inclusiveness** of diverse interests

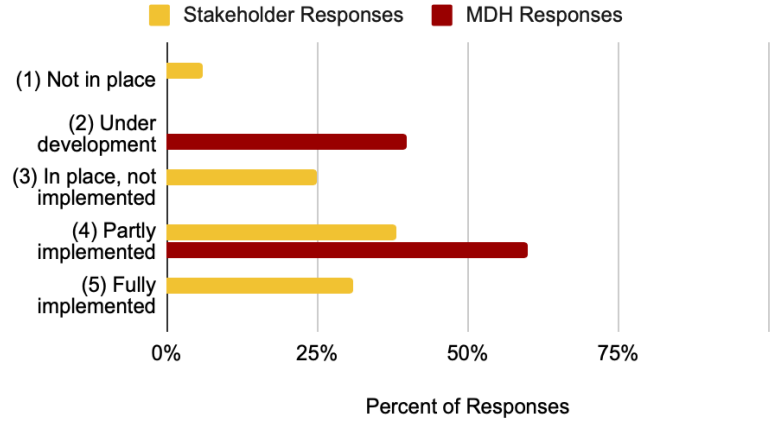
9. State and local drinking water agencies maintain **integrity and transparency** for greater accountability and trust,
10. Drinking water stakeholders, and the nature of their stake, have been clearly identified. **Stakeholders are systematically engaged** in interpreting needs and designing solutions to drinking water concerns.
11. Frameworks exist to identify **trade-offs** and prioritize choices across water treatment alternatives, sectors of water users, different types of communities, and generations of water users.
12. Drinking water **programs and institutions are regularly monitored and evaluated** for their effectiveness and fairness in delivering safe drinking water and managing risks.

2.1.1. Effectiveness Criteria

Criterion 1: *State-level policy clearly defines the roles and responsibilities of each agency with regard to drinking water management, programming, and policy making for both private wells and public systems.*

This criterion considers if the authority and roles of agencies are clearly established for water protection from source to consumer, and if these policies are consistent and aligned across agencies. Water managers, policy makers, and consumers understand who has roles, responsibilities, and authority for components of drinking water management, programming, and policy making.

Figure 1: Stakeholder and MDH Criterion 1 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 1 of the GAF. There were 16 total stakeholder responses and 5 total MDH staff responses to this criterion.

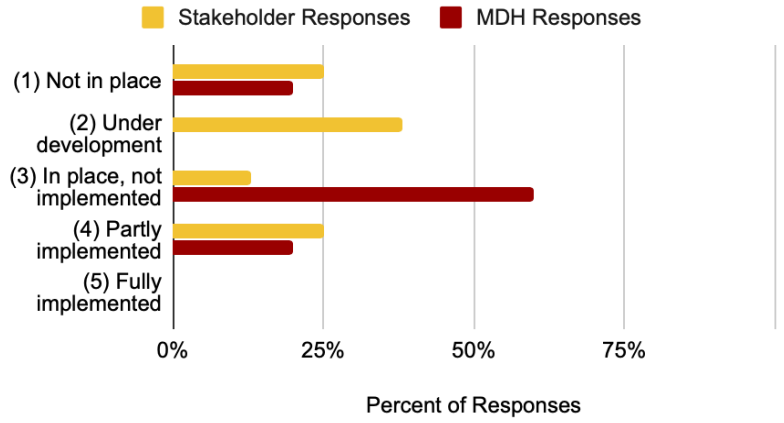
Most stakeholders we surveyed believed that this criterion was either partially or fully implemented. The authorities of the SDWA and the CWA are clearly established. But it was also mentioned that roles and responsibilities are artificially separated based on narrow interpretations of authority.

The MDH staff assessment was "[t]his is a task that was begun with the Executive Branch coordination project in the last days of the Dayton Administration, but there is still work to be done. This is a high priority for the Interagency Groundwater Drinking Water team for this year."

Criterion 2: *Drinking water is managed at the appropriate scale emphasizing an integrated major watershed approach. Management is integrated across scales.*

This criterion considers whether water utilities have adequate autonomy but also coordination with other municipal functions, other watershed authorities, neighboring utilities, and with state and federal agencies.

Figure 2: Stakeholder and MDH Criterion 2 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 2 of the GAF. There were 16 total stakeholder responses and 5 total MDH staff responses to this criterion.

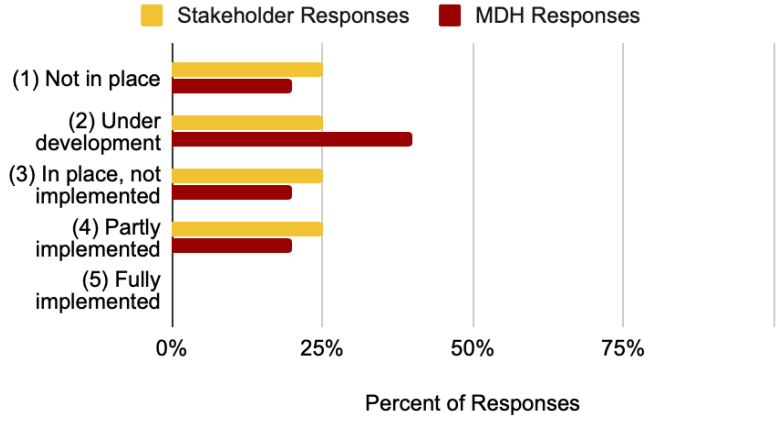
Nearly two-thirds of stakeholder respondents rated this criterion as either not in place or under development. Stakeholder comments mentioned the lack of explicit inclusion of drinking water in Minnesota's One Watershed One Plan program (1W1P). The collaborative, interagency work done under the Groundwater Restoration and Protection Strategies (GRAPS) program was given as an example of current activities demonstrating areas of integration of management. Additionally, the Department of Natural Resources (DNR) is monitoring cumulative withdrawals of groundwater. It was also suggested that the United States Geological Service's (USGS) Hydrologic Unit Codes- 8 digit represented approximately the correct scale for water management.

The MDH staff assessment was that "[s]ome watersheds still have to develop the 1W1P. Meaningful inclusion of drinking water was not consistent across the plans that have been developed to date. The Legislature made a landmark change in the last session and moved drinking water from an optional element to a mandated one in Minnesota Statute 114D. Therefore drinking water may not be fully integrated until the second round of plan development."

Criterion 3: *Drinking water policy is coherent horizontally and vertically across administrative and economic sectors including health, environment, energy, agriculture, and industry.*

This criterion considers whether drinking water policy across agencies allows for effective communication and coordination between agencies, has the ability to account for environmental, agricultural, and industrial impacts as well as health impacts, and links drinking water monitoring with health impact monitoring.

Figure 3: Stakeholder and MDH Criterion 3 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 3 of the GAF. There were 16 total stakeholder responses and 5 total MDH staff responses to this criterion.

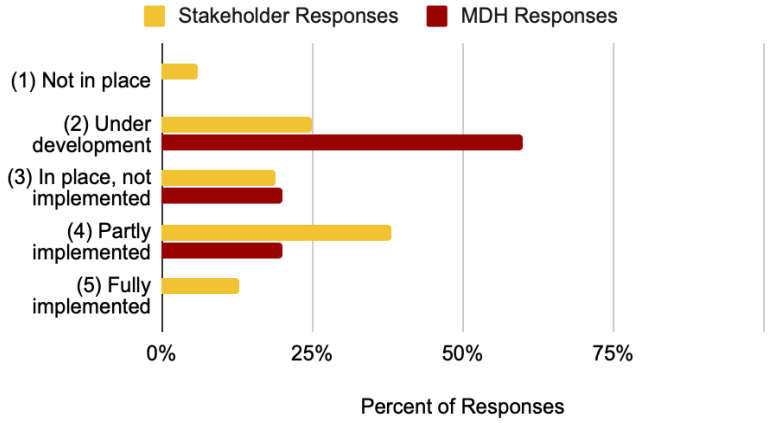
No respondents believed that this criterion was fully implemented in Minnesota, but were generally evenly split across the other levels of implementation. There was a view that though there is coordination among agencies to an extent, for instance the Metro Area Water Supply Advisory Committee (MAWSAC). In general coordination was superficial.

The MDH staff commented "[d]o all sectors value water equally, and have protecting drinking water as their highest priority? No, this is advancing in health and environment, but no clear intentional engagement in other sectors."

Criterion 4: *State and local drinking water management entities have adequate professional capacity.*

This criterion considers whether sufficient expert knowledge, training opportunities, and numbers of employees exist at all levels, as evidenced by professional standards, career incentives, and support networks.

Figure 4: Stakeholder and MDH Criterion 4 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 4 of the GAF. There were 16 total stakeholder responses and 5 total MDH staff responses to this criterion.

Half of stakeholder respondents rated this criterion as either partly or fully implemented; few responded that this criterion was not in place. Stakeholders were under the impression that this criterion was met at the state level, but that locally many utilities or cities did not have adequate professional capacity, especially in rural or smaller systems. They identified examples of existing activities, such as Continuing Education Unit (CEU) training for engineers and earth scientists, and professional organization accreditation programs such as through the MWWA, Minnesota Water Quality Association (MWQA), and Minnesota Groundwater Association (MGWA), among others.

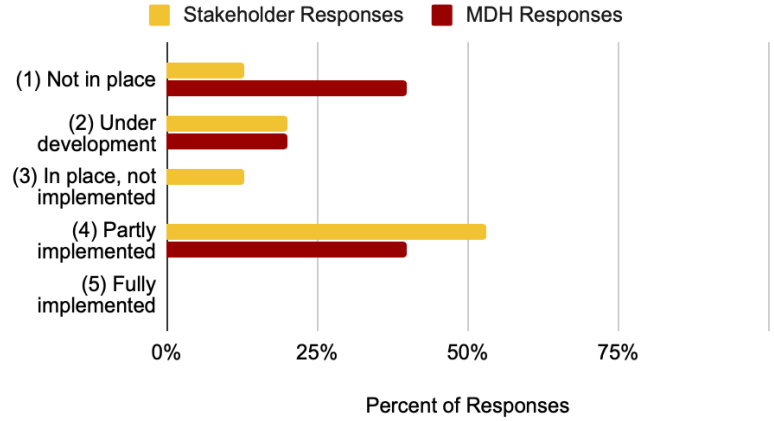
The MDH staff assessment was that this criterion is under development, and also commented that "[c]learly there are disparities in capacity due to income, size of system, threats faced, workforce constraints, etc. The Legislature's increase in our fee and Clean Water Fund for strategic planning around the future of drinking water is a game-changer and allows MDH to take meaningful steps in this direction. MDH work with the Environmental Health Continuous Improvement Board could help define minimal resources needed. Minnesota is facing a growing shortage of water operators. There is room for improvement in the ongoing training and testing of water operators."

2.1.2. Efficiency Criteria

Criterion 5: *Processes and institutions are in place generating timely and relevant data about the water supply and risk management in a way that is suitable to guide policy, prioritize contaminants for attention and action, create transparency for customers, and provide opportunities for dialogue.*

This criterion considers if information is available in forms that are useful for decision-making. .

Figure 5: Stakeholder and MDH Criterion 5 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 5 of the GAF. There were 15 total stakeholder responses and 5 total MDH staff responses to this criterion.

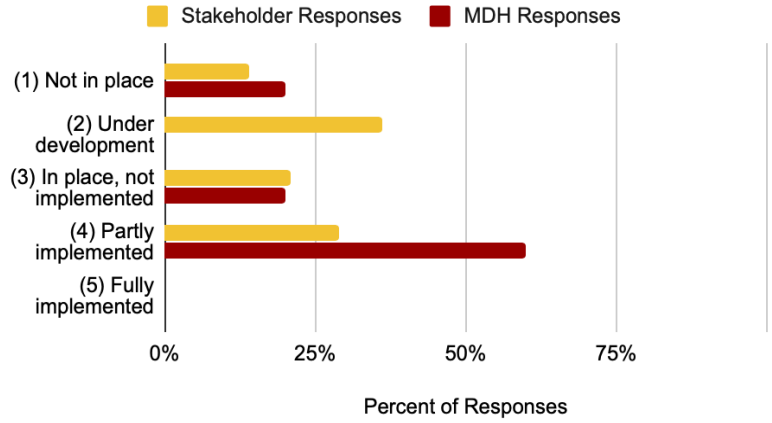
No respondents believed this criterion is fully implemented; most believed it to be partly implemented. Existing programs include MDH monitoring of contaminants under the Safe Drinking Water Act (SDWA), as well as programs evaluating and prioritizing Contaminants of Emerging Concern (CECs). As mentioned previously, MDH has guidance for private well testing, though this is not enforceable. The Clean Water Fund (CWF) has also provided opportunities for increased data collection.

The MDH staff assessment was that "[w]e are in the process of developing a risk management approach that covers unregulated contaminants. We are not able to prioritize contaminants for risk management other than SDWA and high visibility non-MCLs. At this time we lack comparative risk assessment capability. We need increased data analysis capability. Transitioning from a legacy database to a state of the art database is fraught with the potential for failure due to IT challenges at both the state and federal levels."

Criterion 6: *Financial revenues are adequate, appropriately structured, and transparently, efficiently, and equitably allocated.*

This criterion considers if revenue sources cover costs, provide equitable access to safe and sufficient drinking water, and incentivize efficient and effective water management, and decision making and that data are documented and accessible.

Figure 6: Stakeholder and MDH Criterion 6 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 6 of the GAF. There were 14 total stakeholder responses and 5 total MDH staff responses to this criterion.

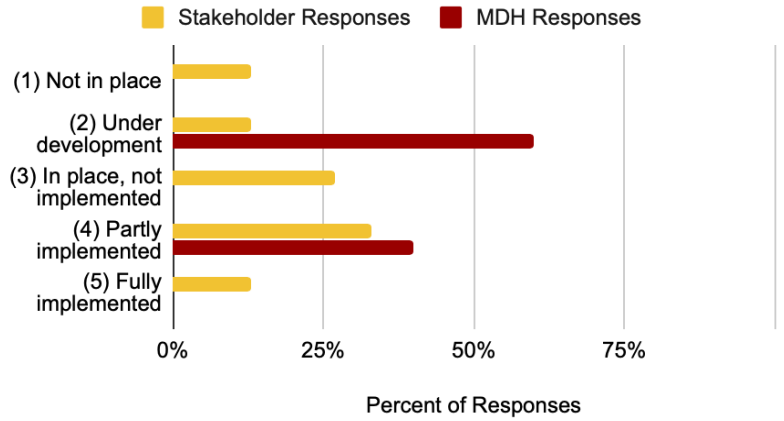
Most stakeholder respondents thought that some of the financial arrangements for efficient drinking water management were in place, but none thought they were fully implemented.

The MDH staff assessment was that "[w]e are in a better financial position now with the fee increase, but it would be better to have the fee paired with inflation increases. If our budget projections hold, we will need to begin to draw on the set-aside from the State Revolving Fund in the next several years. Smaller PWSs in greater Minnesota face financial challenges due to smaller customer bases."

Criterion 7: *Sound regulatory frameworks are effectively implemented.*

This criterion considers if clear standards, processes, and overseers are employed and defined in regulations that promote equitable access to safe drinking water.

Figure 7: Stakeholder and MDH Criterion 7 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 7 of the GAF. There were 15 total stakeholder responses and 5 total MDH staff responses to this criterion.

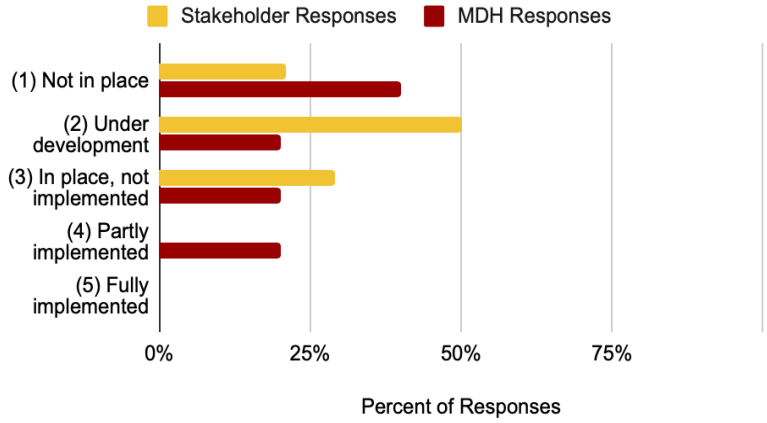
Stakeholder views were that in general, efficient regulations were in place to manage drinking water; in particular the SDWA is well regulated in Minnesota, and MDH has good regulatory frameworks for drinking water systems.

The MDH staff assessment was that "[i]mplementation of the Safe Drinking Water Act for public water systems is effectively managed through a proactive system of robust technical support carried out by district engineers, sanitarians, and specialized engineering support. Compliance is largely achieved through these activities, although enforcement actions are taken when needed."

Criterion 8: *State and local processes incentivize and foster innovation and flexibility in finance, sharing information, assessment, and engagement.*

This criterion considers if mechanisms for ongoing self-evaluation exist and are employed in a way that transparently and iteratively foster innovation [for/and] adaptation.

Figure 8: Stakeholder and MDH Criterion 8 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 8 of the GAF. There were 14 total stakeholder responses and 5 total MDH staff responses to this criterion.

On average, this criterion received the lowest scores from stakeholders. Most thought features were either not in place or under early development for sharing data in a way that fosters innovation. The City of Minneapolis's interest in shared governance and managing peak usage was mentioned as an example of current activities under this criterion.

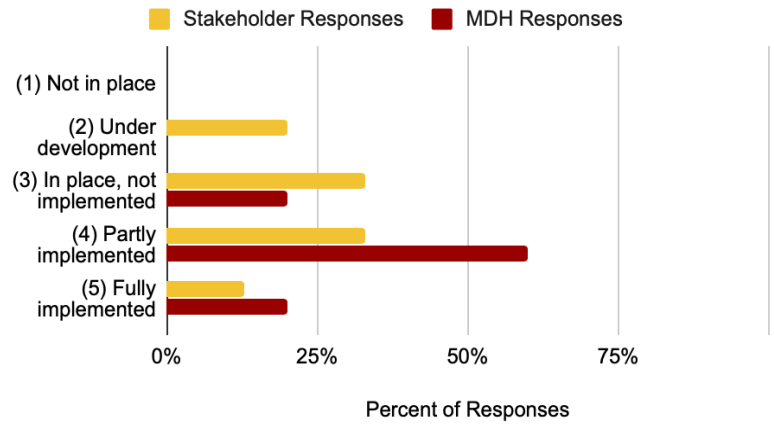
The MDH staff assessment was that "[s]ystems do not always share data with MDH; through MRWA and AWWA we do some of this."

2.1.3. Trust and Inclusiveness Criteria

Criterion 9: *State and local drinking water agencies maintain integrity and transparency for greater accountability and trust.*

This criterion refers to what extent drinking water decision making processes, trade-offs, and relevant data are understandable and accessible to stakeholders, and whether feedback from stakeholders is received and responded to appropriately.

Figure 9: Stakeholder and MDH Criterion 9 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 9 of the GAF. There were 15 total stakeholder responses and 5 total MDH staff responses to this criterion.

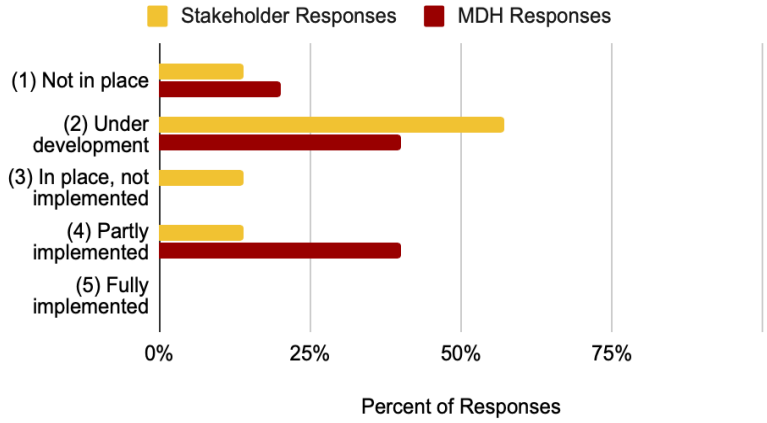
A majority of stakeholder responses suggested actions for furthering this criterion were under development. Stakeholders referenced Consumer Confidence Reports and utility communication with customers as potential examples of ways this criterion is currently being addressed in Minnesota.

The MDH Staff Evaluation was that "Improvements have been made here; because drinking water (both MDH and systems) preferred to 'fly under the radar' for decades, there was lack of support and recognition of drinking water needs until recently. Communications at MDH and systems markedly improved over the last decade, both in quantity and quality. An example is our Drinking Water Risk Communication Toolkit that is rooted in sound social science and available on our website. MDH prepares the data and provides the template for the annual Consumer Compliance [Confidence] Report; the template was recently revised to meet plain language guidelines and CCRs are now available on the MDH website."

Criterion 10: *Drinking water stakeholders, and the nature of their stake, have been clearly identified. Stakeholders are systematically engaged in interpreting needs and designing solutions to drinking water concerns.*

This criterion considers whether communication and engagement between stakeholders and drinking water managers and policy makers is responsive and interactive.

Figure 10: Stakeholder and MDH Criterion 10 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 10 of the GAF. There were 14 total stakeholder responses and 5 total MDH staff responses to this criterion.

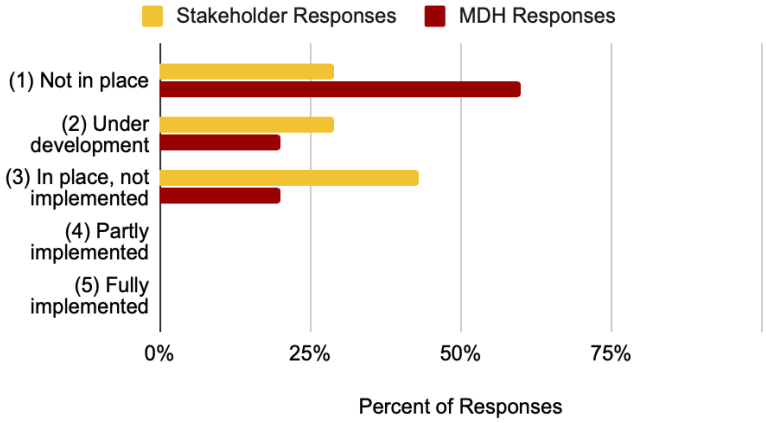
Over half of stakeholder respondents indicated that this criterion is under development. Stakeholders thought that while cities are currently engaged, in general, customers are not. Stakeholders mentioned current activities that attempt to meet this criterion, such as efforts to revise forms for the CCR to meet plain language guidelines.

The MDH staff assessment was "[i]s everyone at the table? Not at this time. This is part of what the UM's work will help us with. If we are to pursue MN MCLs we will need a robust plan for stakeholder engagement."

Criterion 11: *Frameworks exist to identify trade-offs and prioritize choices across water treatment alternatives, sectors of water users, different types of communities, and generations of water users.*

This criterion considers if there are standardized, comparable processes in place that allow decisions about drinking water to be made in a way that incorporates equity into the analyzed trade-offs.

Figure 11: Stakeholder and MDH Criterion 11 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 11 of the GAF. There were 14 total stakeholder responses and 5 total MDH staff responses to this criterion

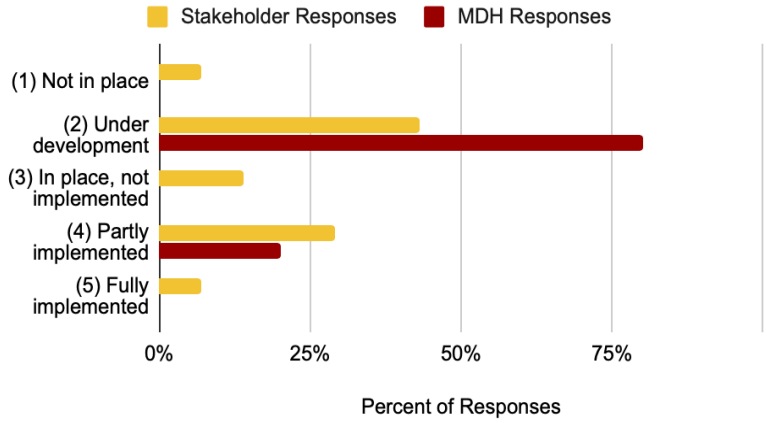
A majority of stakeholder respondents indicated that in Minnesota, this criterion was not implemented. Stakeholders believed that the state is just beginning to address this, mostly through the use of cost trade-offs.

The MDH staff evaluation indicated that this criterion was "Not [in place] at this time for all of these areas. Water treatment alternatives are evaluated by our engineers who review plans, but we allow systems to make choices within the treatment alternatives that we identify as effective."

Criterion 12: *Drinking water programs and institutions are regularly monitored and evaluated for their effectiveness and fairness in delivering safe drinking water and managing risks.*

This criterion considers if measurable indicators for effectiveness and fairness in drinking water are established, and to what extent they contribute to delivery of drinking water.

Figure 12: Stakeholder and MDH Criterion 12 Survey Responses



This figure shows stakeholder and MDH staff responses to Criterion 12 of the GAF. There were 14 total stakeholder responses and 5 total MDH staff responses to this criterion

Most rated this criterion as either in development or in place.

The MDH is monitored by the EPA for compliance with the SDWA, but not for fairness. PWSs are similarly monitored by the MDH via the SDWA, and through CCRs by consumers. The MDH staff evaluation noted that "[w]e have a work plan for a health equity analysis nearly done. We report out to EPA on a series of federally required performance measures. In addition, we have our own set of internal performance measures that is growing."

2.2. New actions as they relate to criteria

The need for an integrated response to drinking water management makes it difficult to parse the individual criteria of the GAF in making recommendations for future improvements. On the one hand, we see the effectiveness criteria that focus on appropriate integration of the authorities and a sound statutory framework as driving good governance; on the other hand, we recognize that public engagement, and the trust that goes with it, is a firm foundation for any good governance system. Yet having a systematic approach for reviewing the GAF criteria provides a pragmatic basis for assessing the current state of governance in Minnesota and for making suggestions about improvements. We have taken the systematic approach in what follows.

2.2.1. Effectiveness Criteria Actions

The effectiveness criteria of the GAF relate to the need for integrated management at appropriate scales (#2) and more coherence across sectors (#3). At the state level much of this might be facilitated by rationalization of responsibilities across the many (up to eight) agencies involved with drinking water. The roles and responsibilities of agencies are clearly defined (#2) but the split in responsibilities between them for the quality of source water (including groundwater) and that delivered by suppliers to the public can give the impression of incoherence. We shall return to this in Section 3.2. Communities will also be key in furthering an approach to water management that integrates solutions across sectors and jurisdictions. Continued implementation of the One Watershed, One Plan approach by appropriate economic incentives from state funds and/or bonding should be considered as part of the drive for better integration. It will also be important to ensure that development and implementation of these plans supports integration of surface and groundwater management, and integration across jurisdictions and water resource concerns, including drinking water source water, water quality, and cumulative withdrawals. Water Safety Plans (see Section 3.5) are another potential tool for facilitating integration of watershed activities from source to tap.

Effective delivery at all levels depends on adequate professional capacity (#4). There is much to applaud in this state about the professionalism of staff from agencies to suppliers. Yet our stakeholder panel identified weaknesses in professional capacity caused by workers being spread too thinly over diverse tasks, poor retention of staff, and resulting brain drain from small suppliers. These might be addressed by sharing professional staff across multiple communities or expanded accreditation of administration in all parts of the water supply, similar to that of the Public Health Accreditation Board (https://www.phaboard.org), but involving independent local organizations. There was also the suggestion that the state should consider a water system rating that would allow communities to benchmark the outcomes of their processes against each other and provide a roadmap for change. The GreenStep Cities Program (https://greenstep.pca.state.mn.us) has been mentioned as a possible model. Ensuring adequate staffing, with appropriate scientific backgrounds to handle the complexities of drinking water, will also be important.

2.2.2. Efficiency Criteria Actions

The efficiency criteria of the GAF relate to good practice in monitoring and delivery of safe and sufficient tap water in a financially adequate and appropriate way. This state is better than most (Allaire et al, 2018) in terms of maintaining routine monitoring programs (#5) and delivering on federal requirements (#7). Monitoring at tap remains a challenge. Possibly developments in smart monitoring will be helpful in making this more feasible. Monitoring at works also raises challenges as utilities have more and more regulated contaminants to address. Here the flexibility afforded by water safety plans should be given

some attention. We shall consider these further in Section 3.5. Monitoring water quality in private wells remains patchy with many owners ignoring the need. Apart from more encouragement from state agencies for more testing, the development of a statutory requirement for well testing at property transfer appears to be a straightforward step that would not only provide a better basis for protecting the health of house buyers, but also an important signal that the quality of drinking water in private wells needs to be taken more seriously. Better guidance and financial support for private well owners would also help encourage testing and appropriate responses to test results.

Stakeholders expressed concerns and interest in improving data collection and sharing, suggesting: expanding scientific capacity to study health and ecological impacts, and to interpret monitoring data; measuring water withdrawals instead of relying on reported or projected withdrawals; and improving sharing of monitoring data including sharing observation well data from communities. Financial arrangements (#6) seem to be adequately developed at state level where the recent increase in water service connection fee (by the State Legislature in 2019) provided a better basis for supporting services. The availability of funds through the Clean Water, Land and Legacy Amendment also provides useful resources for earmarked programs such as the Contaminants of Emerging Concern program, although general fund spending is declining. Where there are the most challenges is at the level of water suppliers, especially in rural areas where small communities find difficulties and hardship in supporting drinking water delivery. Here the state might consider the consolidation of utilities in the areas of concern. This would require careful planning, with prior research on how consolidation might be achieved and a consideration of the cost effectiveness of any new arrangements. Charting the landscape of drinking water affordability by collecting and connecting data on community demographics (size, economic basis and trends) with data on water budgets (income, expenses, debt status) in terms of both community and household capacity will be a key part of this analysis.

The close association between state agencies and the university research institutions is an important aspect of the innovative approach to water policy (#8). In the context of innovation, there were also a number of suggestions that MDH should work more in partnership with utilities and water industry to explore possible new ways of delivering safe and sufficient drinking water. One area of immediate attention could be in deploying aspects of the drinking water safety plans mentioned above. Stakeholders suggested that local decision makers may need better knowledge of water systems to be able to support innovative thinking, and allowing design-build contracts would promote more collaborative and creative problem solving.

2.2.3. Trust and Inclusiveness Criteria Actions

Finally, turning to the criteria of trust and inclusiveness, we agree with our panel surveys that there is a need for more focus on the stakeholders and their concerns (#10) and on their involvement in making decisions about the inevitable trade-offs and priority choices that occur in drinking water management (#11).

Engagement needs to go beyond education, communication, and gathering input to empower individuals and communities. Examples of actions that are empowering include (a) giving consumers access to information, especially in acute situations, so they can act appropriately and trust that suppliers and MDH are protecting their interests; (b) allowing consumers and suppliers to influence definitions of risks, priorities, and goals; or (c) giving community leaders power to influence messaging and the channels of communication around drinking water issues.

An important step in improving trust and inclusion is for MDH and suppliers to expand their partnerships. This begins with defining key communities, identifying their leadership structure and communication

preferences, and working with the leaders to learn their priority concerns, and identify the key messages that MDH and suppliers want to share with each community. Examples of distinct communities identified by the panels include (a) Some communities of color in urban areas who have distinctive perceptions of risks of tap water and prefer bottled water; (b) Well owners who may have a more independent attitude toward government than other populations; (c) Renters who may never see water quality and utility information; and (d) indigenous communities who identify as water protectors. Health professionals were identified as one of the highest priority groups. Establishing two-way communication with this community could be especially fruitful for distributing information and identifying concerns and barriers. Parents are receptive to the messages for protecting children's health. Pediatricians and other health providers may be able to provide information or facilitate water sampling.

Broader engagement of consumers and suppliers opens the door to involve them in key steps of comparative risk assessment (CRA), i.e., prioritizing which concerns to analyze and setting values for alternatives. Broad engagement addresses the challenge of explicitly integrating public concerns assessment with technical risk assessment in a way that recognizes the benefits and costs, and makes explicit the equity issues of interventions.

Another opportunity for engagement is involving consumers in monitoring – both the collection of data, such as at the tap, and decisions about what is important to monitor. This would raise new challenges for quality control and data privacy.

A final opportunity for broader engagement is to involve suppliers and consumers in the GAF-based auditing of the trust and inclusion criteria. Diverse communities can help scrutinize the achievement of GAF criteria as they relate to public engagement, and also participate in defining criteria and setting goals.

Drinking water communication – from both MDH and suppliers – is a balance of raising understanding of issues without prompting over reaction, and addressing parallel tasks of managing acute events alongside long-term engagement and water protection. While MDH and suppliers have done extensive work in these areas, there is room for expanding and further leveraging media, social media, phone apps, or other novel approaches.

Table 2 is an auditing tool that summarizes the trust and inclusiveness actions. For all of these potential engagement and communication actions, the first step is a discussion between MDH and water suppliers to determine priority actions, how to customize them across the state, and what are the roles of MDH vs. the suppliers.

Table 2: Audit of public and partner engagement

- Are suppliers key partners in auditing engagement activities and identifying unique needs across the state?
- Are critical communities (e.g. health care professionals, elders, teachers and parents) involved?
- Do diverse groups of consumers and suppliers have authentic opportunities to share concerns and learn about costs and benefits?
- Are consumers' and suppliers' concerns integrated with technical assessments of risk to prioritize alternatives and design solutions?
- Are diverse consumers and suppliers involved in the GAF-based auditing of the trust and inclusion criteria?
- Have alternative channels of communication been explored?

3. Elaboration on actions

3.1. Using the GAF

Applications of the GAF

The charge for this project was to help MDH identify opportunities to better manage risks to Minnesota's drinking water supply. This is a multilayered task that should be addressed from multiple interacting perspectives (e.g. infrastructure, social structures, economics, authorities, landscape/geology, and all at various scales). The Governance Assessment Framework (GAF) provides a systematic approach to examining these various issues. It can be the basis for reporting on the state of Minnesota's drinking water supply, to guide regular and inclusive discussions, and to trigger actions to address gaps. The GAF can help facilitate building of shared understanding of risks and awareness of each other's priorities – especially among MDH staff, other agencies, and water suppliers.

Challenges from the complexity and interconnectedness of the drinking water system together with opportunities arising from a new Governor and an active legislature make the time ripe for the development of a state drinking water plan. The GAF will be important in establishing and then routinely driving the delivery of this plan. This should involve all of the GAF criteria.

Additionally, the Drinking Water Section of the MDH is developing a strategic plan that addresses implementation of the Safe Drinking Water Act, managing newly identified risks, and enhancing partnerships. We expect the GAF efficiency criteria to provide a broad framework for developing and delivering the public health aspects of the strategy, and the public trust criteria to be important for the partnerships. As this is an agency-specific document, it is less likely to involve GAF effectiveness criteria, which relate to cross-institutional arrangements.

Method for using the GAF

We recommend the following process for integrating the GAF into MDH activities. Start with the premise that the purpose is to harvest understanding from various perspectives and increase shared understanding. With that in mind, identify who should be part of the GAF discussions. We suggest beginning with MDH staff, staff from affiliated agencies, and drinking water suppliers. Then expand to other groups, depending on preliminary outcomes. Each group takes the following steps over one or more meetings.

1. Participants independently rate how well Minnesota meets the governance criteria with regard to drinking water. Share the results with the group, highlighting the degree of agreement or disagreement.
2. Generate a list of current actors, authority, and activities related to each criterion. Note how policies are implemented and evaluated. This produces a static view of who does what and how.
3. Generate a list of gaps to fulfilling the criteria. Highlight who is impacted by the gaps. Characterize the associated risks.
4. Identify potential actions for addressing the gaps.
5. Prioritize actions based on who is impacted, potential consequences, and feasibility.
6. Develop an action plan that specifies what is the action, who will implement the action, when, and how.

As users delve deeper into the criteria, they will find overlap and interactions among them, reflecting the complexity of drinking water issues. While it may be helpful to tighten up the definitions and scope of each criterion, more important is to use the various questions to examine similar issues from a different frame of reference. For example, one significant interaction is between the first eight criteria and the last

four addressing Trust and Inclusiveness. The fairness (and perceptions of fairness) of the drinking water supply are partially built into the design of the institutions and processes addressed in the first eight criteria. Separating out the Trust and Inclusiveness criteria serves to highlight them, but also risks detaching them from the very structures where trust and inclusiveness are built. Similarly, users may be troubled as they try to assess drinking water governance in isolation from water management more broadly. Indeed, these interactions should be identified during discussions.

The process can be repeated periodically to assess change, perceptions of change, and expectations.

3.2. Rationalizing responsibilities across agencies for drinking water

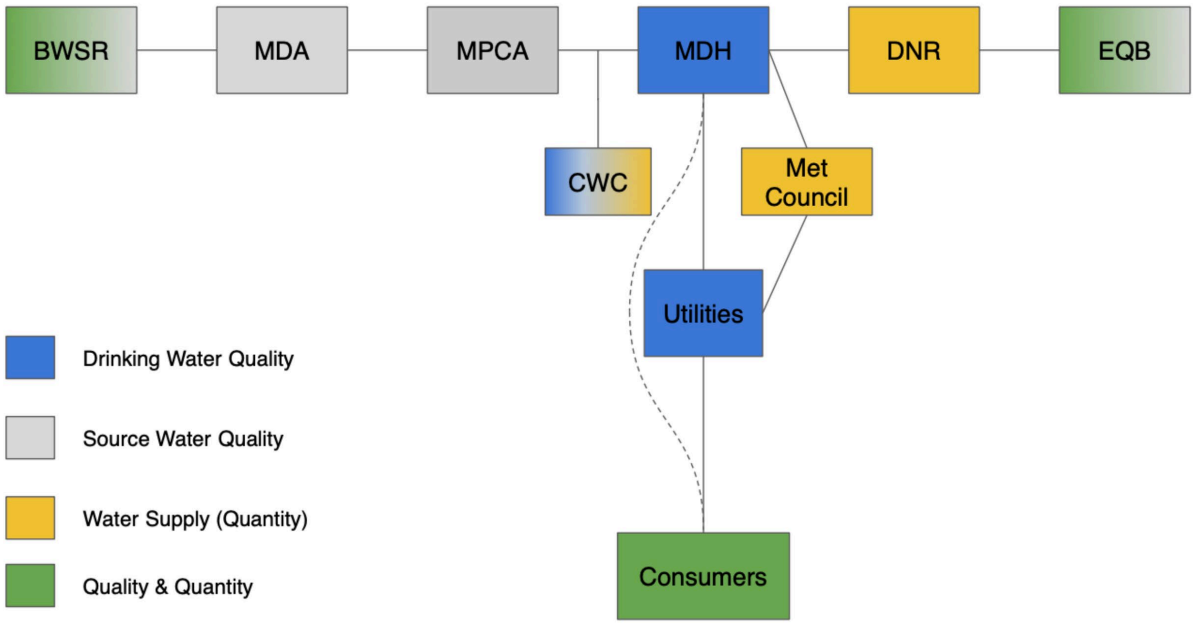
Minnesota draws drinking water from a complex interconnected system that often includes groundwater as a source. An optimized approach to drinking water management will need to compare costs and benefits across the system, source to sink, and on that basis be able to implement appropriate controls (see Section 3.5). Yet responsibilities for water management in Minnesota are sectionalized and distributed across several state-level agencies, in addition to local municipalities and utilities (see Figure 13). There is a perception that this separation of responsibilities is at least unhelpful in best governance practices (Section 2.1). Here we examine this proposition further and develop some recommendations on how to respond.

The MDH is responsible for public water system drinking water quality, ensuring that public water systems meet the federal standards set by the Safe Drinking Water Act. Additionally, under the authority of the 1989 Groundwater Act, MDH establishes informative Health Risk Limits for contaminants in drinking water based on conservative estimates of exposures and effects. MDH also has authority over wellhead protection (Minnesota Rules Chapter 4720) and the construction of new private wells (Minnesota Rules Chapter 4725). The Minnesota Pollution Control Agency (MPCA) manages Clean Water Act water standards for environmental water quality, in addition to point source pollution, total maximum daily load levels, and Superfund sites. Agricultural non-point source pollutants, such as fertilizers and pesticides, are the responsibility of the Minnesota Department of Agriculture (MDA). The multi-agency Public Facilities Authority (PFA) finances municipal water infrastructure, and oversees the Drinking Water Revolving Fund, which allows entities providing public drinking water to apply for low-interest loans for drinking water infrastructure improvements. Water quantity, sustainability, and appropriation authority is managed by the Department of Natural Resources. The Board of Water and Soil Resources (BWSR) manages wetlands and local planning and management of watersheds. BWSR additionally houses the One Watershed, One Plan initiative that strives to substitute county level planning for water management with watershed-wide plans that are more compatible with current ten-year wellhead protection areas by expanding the temporal and spatial scope of plans.

The obvious separation of responsibilities for the quality of water at tap (MDH) and at its various sources (MPCA & MDA) is linked only by an advisory role for MDH; that is, MDH specifies how clean the source must be to protect health but leaves it to other agencies to decide what needs to be done to achieve this. This has been seen as a barrier in developing an integrated approach to drinking water management, compounded by a frustration that older statutes (Minnesota Statutes Chapter 14, sections 144.12 and 144.35) appear to have given MDH broad regulatory authority over both surface and ground waters used as sources of drinking water. Though these statutes have never been repealed, in practice, the statutory framework has defined a more circumscribed role for MDH in source water management.

Figure 13: Horizontal and Vertical Relationships of Water Governance in Minnesota

This figure shows relationships between the main actors in drinking water governance, indicating primary responsibilities of each actor. It is not intended to comprehensively describe every responsibility of each actor. From left to right: Board of Water and Soil Resources (BWSR), Minnesota Department of Agriculture (MDA), Minnesota Pollution Control Agency (MPCA), Minnesota Department of Health (MDH), Minnesota Department of Natural Resources (DNR), Environmental Quality Board (EQB), Clean Water Council (CWC), and Metropolitan Council (Met Council).



Two previous major reviews of Minnesota water governance (MPCA, 2013; Swackhamer, 2011; and the associated report from Helland, 2011) have recognized these challenges for integration in the water system of the state as a whole, and both suggested strengthening local watershed authority and formalizing horizontal, state-level coordination across agencies. From time to time, there have been calls for radical overhaul of the state water system with calls for the formation of a single water department. Our discussions with stakeholders and agency personnel, however, have not suggested much current enthusiasm for this approach. Concerns have been expressed about any amalgamation of agencies undermining their broader responsibilities; for example, MDH's responsibility for all aspects of public health not just drinking water, MPCA's responsibility for ecology across all compartments, not just the aquatic, and MDA's responsibility to diverse aspects of the farm economy. Some also believe that delivering federal requirements of the Safe Drinking Water and Clean Water Acts could be compromised by a superagency if not in the long-term, certainly in the short-term by the disruption of agencies and possible loss of expertise.

In any case, there is a view that because of already existing interagency activity, possibly catalyzed by the collaboration engendered in the Clean Water Land and Legacy Act, the system is delivering anyway. It is hard to point to specific examples of failure as a result of any disconnections between agencies and their responsibilities; apart from the now partially corrected lack of inclusion of drinking water as an explicit issue in the development of the One Watershed, One Plan initiatives.

Perceptions, though, are key. The perception of inadequate integration at the heart of drinking water governance (Section 2.1) may undermine public confidence in drinking water and those who deliver it.

In response to these misgivings, we propose that the interagency activity that apparently already exists on drinking water should be made more transparent. It should be underpinned, formally, by the development of an appropriate statutory framework that not only makes the connections but also bases them on a common ethic across agencies for delivering safe and sufficient drinking water to all in a way that respects the environment. Deliberations from the interagency discussions on drinking water should be open to the public and be part of the public record. It may well be necessary to develop a coordinating body. This could be through a gubernatorial, cabinet-level task force or by enlarging the responsibilities of existing bodies such as the Clean Water Council or the Environmental Quality Board. All options need careful appraisal, in terms of costs, benefits, equity balance and likely success, before taking further action. This should be part of developments under the Governance Assessment Framework described in Section 2 with defined timescales for action and milestones that can be monitored (see especially criteria 2, 3, 9, 10, 12). Whether it leads in the direction of ever more consolidation of institutional arrangements should be judged pragmatically in terms of the cost-effectiveness of delivery. The scope of the changes to Minnesota statutes that we are proposing should reflect the outcome of this analysis of needs. As a minimum, they should be clearer on the roles and responsibilities of participatory agencies and require them to work together more transparently for the common good of safe drinking water. On the other hand, depending on the analysis they could require a more unified institutional organization, not excluding the possibility of a single water agency, although we did not hear strong arguments for this possibility.

3.3. Charting the landscape of affordability

Local governments and their water suppliers are responsible for maintaining and updating water supply infrastructure. Yet, fully addressing water infrastructure requires cooperation across sectors of the government, levels of government, and neighboring jurisdictions. To meet this responsibility, suppliers need funding and financing, but they also need autonomy and local control. Consolidation of utilities is one approach to improving the financial position of water suppliers, but any pooling of resources, sharing expertise, or cooperative finance must be done in ways that account for community identity and the practical needs for local control.

Before designing programs to provide technical support, funding, or finance for local suppliers, it is important to understand the economic position and identity of individual communities. Thus, one potential step to advance drinking water finance is to “chart the landscape of affordability”, i.e. undertake a study to understand the variation in the demographics and economic position of communities across the state so support can be tailored and realistic. The study, as proposed by our expert panel, would examine both demographics and budget data for a representative sample of communities of various sizes, types of water sources, and other significant characteristics. The demographic component would examine the size and economic basis of the community, the utility’s structure and governance, and trends in population and economic drivers. The budget component would examine utility fees, other sources of support, expenses, debt structure and service costs, and future infrastructure budgets. The budget and demographic information would be analyzed together to characterize both community capacity and household capacity, to understand funding needs, and to define disparities across the state.

3.4. Comparative risk assessment

Increasingly, the MDH is being encouraged by the Legislature and others to pay more attention to non-regulated drinking water contaminants. However, financial constraints force choices about which contaminants to monitor and study, which ones to prioritize to reduce exposure, and which actions (or inactions) to implement to reduce exposure of a priority contaminant. Decision-making is complicated by high uncertainty of risks and the need to coordinate among authorities, including the EPA and the Safe Drinking Water Act (SDWA), the MDH and other state agencies, and local water treatment and suppliers. Decisions are further complicated by the need to allocate resources among disparate types of contaminants (e.g. natural vs. anthropogenic, or acute vs. chronic impacts), and by the mismatched time scales of health impacts, detection technology, and infrastructure upgrades.

Comparative risk assessment (CRA) provides a rigorous and transparent process to inform these resource allocation decisions (McBride et al., 2012; Ijiasz & Tlaiye, 1999; USEPA, 1998). Before options can be compared, the impacts of various contaminants or the impacts of potential actions must be expressed in common units. These common units, or comparison criteria, will always be imperfect. The goal is to make better decisions with broader support by making the criteria explicit and transparent, and engaging key players to define the criteria.

Five types of criteria are summarized in Table 3, which can be applied to the three types of decisions – prioritizing contaminants for study, prioritizing contaminants for action, and prioritizing actions for a particular contaminant – but with different amounts of data and levels of uncertainty. The approach is not a new one but it can be tricky to apply (PCAST, 2016). This framework is intended to provide a transparent basis for going beyond federal requirements in managing contaminants in drinking water in Minnesota.

Several of the criteria can employ a variety of health metrics that include lives lost, lifespans shortened and impaired quality of life, sometimes captured in the Quality Adjusted Life Years (e.g. USEPA,1998; PCAST, 2016). The choice of metrics will impact the conclusion of the analysis and may impact the perceived legitimacy of the results.

Table 3: Guidelines for comparing contaminants or actions

These guidelines for carrying out CRAs show how different criteria might be deployed in decision-making with considerations on the advantages and drawbacks.

Criteria	Decision	Considerations
Presence: At what level is the contaminant present?	Which contaminant is present at a higher level?	● Detection depends on analytical technology, and does not reflect impact. ● Methodology to define "presence" must be agreed on
Threshold: Is the contaminant present above a threshold determined to cause an effect?	Which contaminant is present at a higher level relative to its threshold?	● Presence relative to a threshold is the "hazard quotient" ● Using a HQ accounts for different effects of various contaminants ● Assumes we have adequate information to create a threshold ● Misleading in that it ignores dose-response relationships, i.e., it implies linear and identical relationships between dose and effect ● Might be meaningful when differences are orders of magnitude
Severity: What is the severity of the effect of the contaminant?	Which contaminant has a greater impact on life/health at the estimated level of exposure?	● Accounts for entire dose-response relationships, instead of single threshold level ● Enough data rarely available
Cost/benefit: What is the dollar value benefit of reduced exposure compared to the cost of reducing exposure?	Which intervention has a higher benefit relative to the cost of the intervention?	● Must be adjusted to account for differences in the time scales of health impacts and costs incurred ● Difficult because of lack of data ● Concerns about setting dollar valuations for lives and quality of lives ● Important to attempt if economic considerations are important to decision-making
Public concern: How concerned is the public?	Which contaminant is the public more concerned about?	● When public concern varies across communities or diverges from technical assessments, public education and engagement is key

3.4.1. Presence, threshold, and severity criteria

Contaminants should be likely to be present in drinking water to be considered for attention, but presence does not necessarily cause effects and presence alone is not enough for prioritizing contaminants. They must be present at levels likely to cause effect. This is expressed through a hazard (or risk) quotient: the level of exposure compared to a threshold of effects when they occur, or action level when they do not. Hazard quotients are used widely in prioritization; the bigger the quotient, the bigger the supposed risk. Still, thresholds ignore much of the information in dose-response relationships and this can lead to misleading prioritization (Calow, 2014; NRC, 2009). For example, contaminants with the same threshold might differ in effects at higher concentrations leading to a divergence that would be missed by the quotient approach. Better, then, to compare severity in terms of likelihood of effects at likely exposure – but this requires sophisticated probabilistic risk assessment based on full dose-response information (USEPA, 2014). Comparing severity also requires explicitly defining the boundaries of the effects under consideration. For example, will the comparison be limited to human health effects or include broader environmental effects?

3.4.2. Cost/benefit criterion

Given the limited resources for managing contaminants in drinking water, prioritization is needed to assess the benefits of reducing contaminants' impacts and the costs of achieving that reduction (Sunstein, 2018). This could be done with full blown cost-benefit analysis, but that requires appropriate dose-response curves and economic valuation, which are not available for many of the contaminants of emerging concern. Therefore, judgements about fixes and their costs may need to be factored in.

3.4.3. Public concerns criterion

Public concerns are an important but complicating feature in prioritizing contaminants for management. Public assessments of risks, determined by various kinds of concern assessments (from surveys and interviews to stakeholder forums), generally diverge from technical assessment (Slovic, 2000). Public concerns may vary considerably from community to community. For public water supplies, the public will often overestimate risks of contaminants relative to the technical assessments. Local and state water supply managers may choose to respond by (1) communicating that management decisions based on uninformed public perceptions will have costs without commensurate benefits, and/or (2) attaching value to public peace-of-mind, and including this in the calculation of benefits of an action.

3.4.4. The MDH Contaminants of Emerging Concern program

The MDH effectively uses severity criteria for prioritizing contaminants of emerging concern for development of guidance values (Lewandowski et al., 2016). The approach is based on relative severity and approximates the dose-response method. Toxicity potential is scored in terms of non-cancer and cancer potency, severity, and other considerations. Exposure potential is scored in terms of fate, persistence, disposal, and release and occurrence in water. Contaminants with highest scores in both are prioritized for more data collection and might ultimately be subject to the development of guidance values. The approach is sound, although there is room to improve the transparency of the scoring and expert judgment processes.

The MDH also applies the principles of comparative risk assessment by using quantitative and probabilistic approaches to set health-based guidance values (HBVs) and Health Risk Limits (HRLs). We have not looked in detail at this process in the current work. MDH developed an extensive list of guidance

values in “Human Health-Based Water Guidance Table” (Minnesota Department of Health, 2019a,b) that involves a considerable amount of data and analyses. The assessments use endpoints from the literature based, where possible, on available dose-response assessments. Extrapolation from acute to chronic responses and from lab animals to people involve the use of uncertainty factors. As with any comparative risk assessment, data selection from the literature and choice of uncertainty factors can sometimes lead to biases and therefore should be made explicit.

Developing guidance values is time consuming, exacerbated by pressures to address ever more contaminants, and do so more rapidly. Possible short cuts could be helpful, such as using read-across techniques (Pawar et al., 2019) to fill data gaps, but they need to be carefully assessed in terms of scientific credibility.

The CEC prioritization process as currently applied by MDH does not involve cost-benefit analysis. This is not the case with the development of standards under SDWA, which incorporates costs of treatment in addition to health impacts. The increasing pressures to develop a regulatory approach in this state and the limited resources upon which to do it may provide grounds for revisiting the need to bring in cost-benefit analysis in the state program.

The University report on CECs (Lewandowski et al, 2016) stopped short of an assessment of the development of HBVs and HRLs. In the light of all the concerns given above, possibly the time is right to extend the review initiated by the University to the entire CEC program.

3.4.5. Deciding between management options

Local water suppliers are generally the decision-makers regarding trade-offs among treatment technologies and other aspects of drinking water management, while MDH serves an advisory role. Additionally, the state may have to make some overarching decisions in terms of managing contaminants either by excluding from the water source or by removing them from the water works or in the home.

Generally, preventing contamination is more cost effective than water treatment, but this ignores the individual and societal benefits resulting from contaminating a drinking water source, for example from food production or industrial activities. The costs versus benefits of all prevention and treatment options can be compared, but this raises important questions about defining who enjoys the benefits (e.g. of food production), and who bears the cost of remediation or health impacts. Similarly, there is a separation between the statutory authority of those responsible for source water protection and those responsible for water supply as discussed in earlier sections on governance (see Section 3.2). The cost-benefit comparisons are further complicated by the different time scales of costs, benefits, prevention actions, and infrastructure actions.

There are no easy answers in making decisions about management options, but this should not be a recipe for inaction. At the state level there is a case for considering if the source/sink options for the management of drinking water quality are being delivered optimally. Comparative risk assessment should be used to develop a coherent and transparent framework for the assessment. However, deciding on whose values should drive the cost-benefit consideration will need to be based on a dialogue that engages a broad range of consumers, suppliers, and agencies (as discussed in Section 2.2.3).

3.4.6. Example applications

Even with limited data and substantial assumptions, comparative risk assessment and cost benefit analysis often reveal large valuation differences, and can clarify the trade-offs that need to be discussed. This information is invaluable for policy discussions locally and at the state level.

The framework outlined in Table 3 is intended to provide guidelines on comparative risk assessment criteria and their consequences. There is no single optimal criterion, the choice depending on the science of the contaminants and the social-political context of the specific issue.

With any set of contaminants and management options included in the comparative risk assessment or cost benefit analysis, care should be taken to establish system boundaries and sectors of impairment. With some contaminants, such as nitrate, management could occur at multiple levels--at the source, at the utility, or in the home. Chemical properties and processes such as residence time and species formation may also need to be considered. Comparing point source pollutants (such as some bacterial contaminations) may be a simpler process than comparing nonpoint source pollutants (such as chloride). The process for estimating benefits of pollutants would be different for chemicals that are products of industry as opposed to naturally occurring contaminants.

Establishing system boundaries has several components: defining the contaminants to compare (single chemicals, combinations, break-down products, sources other than water); defining the scope of impacts (human health or ecological health, local or regional, time scale of impacts); specifying units for quantifying impacts and defining who/what is impacted; defining actions to examine (no action, source protection, move the source, treatment at works, treatment at tap); and finally quantifying the feasibility and cost of actions, specifying who will pay costs, and when; and identifying ancillary benefits of action or inaction. Some comparisons, such as chlorine by-products vs. bacterial contamination, are complicated by different time-scales and scopes of impacts. This does not mean that comparisons shouldn't be attempted. Even a qualitative discussion of these components can increase understanding of trade-offs, facilitate decision-making, and inform ongoing communication strategies.

These numerous potential considerations are not meant to make cost-benefit analysis and comparative risk assessment seem daunting, rather to emphasize that the framework we have provided is just that -- a framework, not a step by step procedure.

3.5. Water Safety Plans

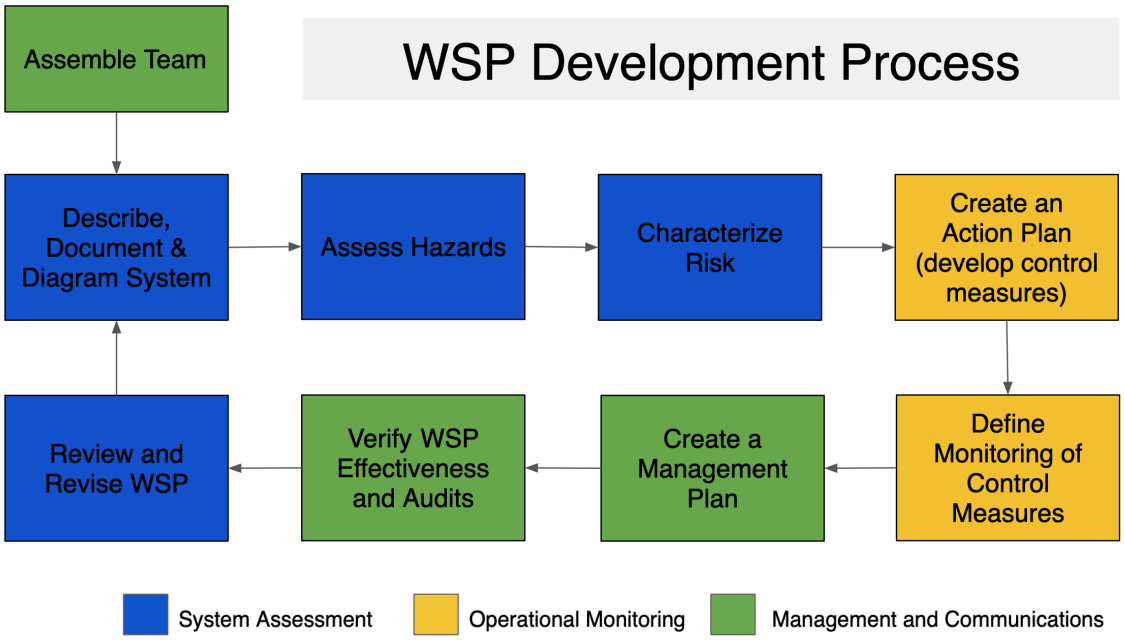
Water Safety Plans (WSPs) are an important part of the GAF. They provide potential flexibility in tailoring drinking water management to local circumstances, through hazard assessment and plan consolidation, in a way that could potentially help water suppliers come to terms with an increasing array of contaminants. That said, federal regulatory requirements through the SDWA mean that there are some limitations on realizing this potential. Here we explore these tensions and make some suggestions on how WSPs might be useful in a more limited way in developing future approaches for drinking water management in Minnesota.

WSPs have been developed by the World Health Organization (WHO) as recommended frameworks for risk assessment and management for drinking water. The frameworks are employed in some form in over 40 countries and are under development in several others (WHO, 2017). The plans address risk management using site- and system-specific analysis, and in their most complete form are scoped to include the entire water system, from catchment to consumer. Though WSPs can be used as the sole or primary framework for drinking water risk management, they are flexible in that simpler, smaller scope versions can also be used to supplement current best practices in drinking water management (Gunnarsdóttir and Gissurarson, 2008; Baum et al., 2015). WSPs are 'living documents' that are reviewed annually or after an incident occurs, such as the exceedance of a compliance standard for a contaminant.

While they may be used as the main framework for drinking water management, particularly in countries developing drinking water legislation and management programs for the first time, countries with existing drinking water legislation can use WSPs to consolidate and expand upon the best practices and laws already in place. For instance, in the USA, states and utilities would be unable to disregard maximum contaminant levels set through the Safe Drinking Water Act, but flexibility allows for creation of WSPs for only one part of the system, or expanding instead of replacing compliance monitoring. Rather than developing risk management plans at each of the four stages described by WHO, (source water, treatment plant, distribution network, and consumer) a supplier may decide to develop a WSP for just source water. There is potential for WSPs to combine several state level water plans that are already required into a single document; in Minnesota this could combine water supply plans, wellhead management plans, emergency response plans, existing treatment and distribution network diagrams and best operating procedures, and others. This consolidation may provide the potential to reduce redundancy and burden on suppliers.

WSPs expand on the Hazard Analysis and Critical Control Points system implemented for food safety, which evaluates the potential of food contaminants to cause problems for human health. Food safety is monitored through batch testing, while water distribution is a more continuous mechanism with different monitoring challenges (Gunnarsdóttir and Gissurarson, 2008). However, WSPs do establish critical thresholds for contaminants likely to be in drinking water, and employ control measures to ensure those thresholds are not reached. Literature around the implementation of WSPs emphasizes a boots-on-the-ground, know-your-system approach to this hazards assessment and risk analysis. Guidelines on the creation of WSPs state that at each stage of the drinking water system, source, treatment, distribution network, and consumer, to the extent possible, in-person visual assessment and photo documentation of hazards may identify and provide information on hazards that may not come up in tabletop exercises for hazard assessment. The documentation will additionally allow for comparison of conditions before and after the safety plan is implemented. The general steps for development of WSPs are presented in Figure 14.

Figure 14: Water Safety Plan Development Process
This figure presents a general overview of the development process of water safety plans, adapted from WHO (2017).



A management team with high technical capacity is assembled, including WSP coordinators, watershed scientists, water supply managers, and government agency staff. Once a management team is created, the water system is described, documented, and diagrammed in a flowchart format. The flowcharts indicate and document all steps of the water system, including all equipment, treatment processes, storage tanks, etc., from source to consumer. Hazard assessment is then conducted at each of these nodes, using both table-top exercises for hazard identification and physical site visits. For each hazard identified, risk characterization is conducted through the use of a semi-quantitative matrix multiplying the likelihood of exposure to a hazard by the severity of consequence or impact of that exposure. This process may involve referencing already-existing scientific literature regarding dose-response relationships for identified hazards. Expert judgement and public opinion can be used to adjust the ranking and prioritization of each hazard. Then, the management team develops an action plan to address the highest priority risks as identified by the risk characterization process. This plan is reviewed annually or post incident in order to assess whether goals are being met. WSPs do not explicitly incorporate cost-benefit analysis in the risk prioritization process, but may be included in the creation of the action plan step using external frameworks, as water systems work with finite resources. Once the action plan is in place, monitoring of control measures is defined. This monitoring expands beyond reactive compliance monitoring for contaminant levels at the post treatment stage, and can range from near constant online monitoring of chlorine levels or at tap monitoring, to biomonitoring or annual inspections of the integrity of the infrastructure surrounding wells. Methods and frameworks to evaluate the effectiveness of the WSPs are developed and form the basis for audits of the water system. On an annual or post-incident basis, the entire WSP is reviewed and revised in order to adjust to the plan to address any changes, such as improvement or degradation of source water quality.

Where implemented internationally, WSPs have demonstrated positive outcomes for individual water systems, ranging from increased compliance with existing drinking water standards, increased

transparency and communication with stakeholders as identified by governing bodies, and increased quality of drinking water (Viera J, 2011). They provide opportunities for continual engagement with consumers, suppliers, and critical communities through inclusion of these parties in the development and execution of the framework, while providing the opportunity to address the water system holistically through a source to tap scope of risk management (WHO, 2017). The framework allows for risk prioritization based on local needs, and can be flexible in total scope of implementation. It additionally compiles or develops a referenceable framework for standardized operating procedures that is system specific, potentially increasing the legibility of the system for future operators or responders in the case of emergency.

Barriers to implementation of WSPs exist in the US. The SDWA prevents full implementation of prioritization-based risk management due to required monitoring and compliance standards for over 90 contaminants. More generally, the development of WSPs requires high levels of technical capacity as well as increased labor costs. These can be barriers to implementation specifically for smaller systems with few operators and limited financial resources (WHO, 2017; Amjad et al., 2016). Moreover, learning by doing at one site is unlikely to be transferable to others because of the uniqueness of hazards at particular sites. (Baum et al., 2015; Setty et al., 2019). Finally, within WSPs, there is no established method of cost-benefit analysis for risk prioritization. As systems realistically have access to limited resources to address risks, this cost comparison step will need to be addressed through risk literature or elements of other external drinking water risk management frameworks (Setty et al., 2019).

Despite these barriers we see the possibility of using WSPs to advantage at various levels in the development of more efficient and effective drinking water management. First, all entities, including the state, might use the management cycle summarized in Figure 14 as a basis for driving the GAF process. Second, water suppliers could save time by using even attenuated versions of WSPs as a basis for rationalization and consolidation of management plans. Third, they may also be integrated with or mirror elements of 1W1P in that WSPs develop a local, watershed specific plan for drinking water that attempts to lower the planning burden on suppliers. Last, but not least, it will be worth exploring the extent to which the legal requirements of the SDWA do indeed limit the flexibility intended by the WSPs.

4. Summary of Actions for Consideration

Building on its strengths, Minnesota needs to plan for a challenging future in managing the risks to drinking water supplies. There will be an ever-increasing number and diversity of drinking water contaminants, arising from industrial, agricultural and domestic sources. Extreme weather events associated with climate change may compromise wastewater treatment and lead to contamination. Aging infrastructure for both water and sewage systems means that cross contamination is a problem. The widespread occurrence of lead in plumbing throughout the state has been identified as a continuing challenge (Minnesota Department of Health, 2019c). Declining population in rural communities raises problems of finance for technology and technicians. Even with the promise of increasing investment (such as the Governor's recent bonding proposal) in infrastructure and clean-up technology the state will need to remain vigilant to all these pressures. We have made these recommendations in that spirit. They focus on developing a good governance system that can respond in an integrated and flexible fashion to emerging challenges and do so in a way that commands public confidence. Our report intentionally emphasizes a framework of principles and policy options. Except in the broadest terms below, we have avoided making statements about priorities and time scales. Developing the principles into prioritized actions will depend on political and public preferences modulated by resource constraints that should be guided by MDH. That said, there is a place for external facilitators to work with MDH and stakeholders to develop more detailed action planning based on these recommendations.

The time is right for a state drinking water plan. We agree with the view that given these challenges, together with a new Governor and a dynamic Legislature, the time is opportune for the development of a state drinking water plan. These recommendations are intended to inform that Plan. The Plan should be built on the ethic of delivering safe and sufficient drinking water to all in a way that respects the environment.

This is a linchpin to all the other recommendations and so deserves immediate consideration.

More effective governance is key. This is a multilayered task that should be addressed from multiple perspectives (e.g. infrastructure, social structures, economics, authorities, landscape/geology, and all at various scales). The Governance Assessment Framework (GAF) provides a systematic approach to examining these perspectives. MDH should consider using the GAF both as an important foundation for the state drinking water plan and then as a guide to a routine review process that defines actions, milestones and timelines.

The review process for the GAF could be based on the action planning that we have outlined in the Water Safety Plan (WSP) development (see below). The Action Plan would be driven by a management team and have clear goals over defined time intervals.

The deployment of the GAF in conjunction with the state water plan deserves immediate attention but there should also be subsequent on-going and routine reviews. The GAF process and criteria can also provide a framework for informing the MDH Drinking Water Protection Section strategic plan, although this is likely to be more limited and focus on the efficiency and trust criteria.

Pay attention to integration and base it on a statutory requirement. An important part of effective drinking water governance is an integrated approach to managing the system across many agencies, and ensuring integration of responsibilities across the whole system from source (surface and groundwater) to tap. The interagency drinking water activity that already exists should be strengthened. In addition to informal interactions among agency staff, integration would be improved by being underpinned, formally, by the development of an appropriate statutory framework that not only connects the agencies but also bases them on a common ethic in protecting health and the environment as described above. Some

interagency discussions on drinking water should be open to the public and part of the public record. It may well be necessary to develop a coordinating body. We envisage this being through a gubernatorial, cabinet-level task force or by revising the responsibilities of existing bodies such as the Clean Water Council or the Environmental Quality Board, (e.g. as suggested in the Water Sustainability Framework, Swackhamer 2011). All options need careful appraisal, in terms of costs, benefits, equity and likely success. If the chosen option leads to consolidation of state institutions, cost effectiveness of delivery should be a determining factor. The scope of the statutory change that goes along with these developments should reflect the outcome of this analysis of needs. On the one hand, and as a minimum, it should be clearer on the roles and responsibilities of participatory agencies and require them to work together more transparently for the common good of safe drinking water. On the other hand, it could require a more unified institutional organization, not excluding the possibility of one water agency, and make resources available accordingly.

This integrated approach requires urgent consideration given the importance of maintaining public trust in delivery of clean water.

Consider consolidation of utilities in rural areas as a way of addressing their financial problems. Financial support for drinking water management within the state is generally sound. However, small rural communities are experiencing difficulties and hardship in supporting drinking water delivery. Here the state might consider the consolidation of utilities in the areas of concern. This would require careful planning, with prior research on how consolidation might be achieved and a consideration of the cost effectiveness of any new arrangements. Charting the landscape of drinking water affordability by collecting and connecting data on community demographics (size, economic basis and trends) with data on water budgets (income, expenses, debt status) in terms of both community and household capacity will be a key part of this analysis.

How rapidly this should be developed will depend on the urgency of financial challenges in small rural communities.

Consider accreditation as a way of recognizing and driving professional development. Effective delivery of safe drinking water depends on adequate professional capacity. Currently, this is patchy in Minnesota. MDH is well supported but suppliers, especially in rural areas, face challenges attracting and maintaining sufficiently trained staff. Addressing staff deficiencies should be part of the consolidation of water suppliers (see previous recommendation). At all levels, consideration should be given to an accreditation process that is independently mediated. The development of a water rating system that allows communities to benchmark against each other could also provide incentives for better delivery and enhanced professional involvement.

These recommendations should be considered when possible.

Define and engage a broader audience in decision-making and communication. To better account for suppliers' and consumers' diverse concerns and values, MDH should explore opportunities to engage more audiences in decision-making regarding the inevitable trade-offs and priority choices that occur in drinking water management. This involves defining the critical communities and their leaders, and then giving them a voice in designing communication with their communities, prioritizing monitoring and treatment options, scrutinizing the achievement of GAF criteria as they relate to public engagement and equity in delivering safe water, and even participating in defining assessment criteria and goals. A particular challenge is integrating public concerns assessments with technical risk assessments. For revising engagement and communication actions, a first step is a discussion between MDH and water suppliers to determine priority actions, how they will vary across the state, and what are the roles of MDH

vs. the suppliers. MDH may consider an equity study across all aspects of the drinking water system, and mechanisms to monitor the fairness of responses to drinking water concerns.

One possible approach to increasing engagement of consumers is to involve them in monitoring, such as by taking advantage of the future possibility of smart monitoring of water at the tap. Implementation of home monitoring will require strong public engagement to gain support and protect homeowner privacy.

The audit of engagement opportunities described in Table 2 (Section 2.2.3) should be carried out on existing activities as soon as possible, with further deployment as new communication channels are contemplated.

Consider encouraging deployment of water safety plans by water suppliers as a way of streamlining planning. WSPs could potentially provide an efficient basis for water management by suppliers given the more flexible approach based upon the particular needs as identified by hazard analysis and a tailored management response. However, the somewhat rigid requirements of the federal Safe Drinking Water Act together with high levels of technical requirements and labor costs of WSPs has meant that there has been little or no uptake across states. WSPs do have the potential to combine already required state level water plans into a single document. In Minnesota this would combine water supply plans, wellhead management plans, emergency response plans, existing treatment and distribution network diagrams, and best operating procedures. MDH should work with suppliers and the Metropolitan Council to explore if there could be advantages from plan streamlining using the WSP as a driver.

These recommendations should be considered for development when possible.

Comparative risk assessment should drive prioritization of contaminants of emerging concern and the development of health-based guidance values. MDH is being encouraged to pay more attention to non-regulated chemicals. Given the sheer volume of potential contaminants, this has to be based on a rational scientific approach of prioritization. This involves two stages: prioritizing chemicals likely to be present in drinking water for more attention and prioritizing action against chemicals already identified as threats to public health. We have provided a basis for doing this and recommend that MDH take stock of its staffing, expertise, and data availability to evaluate its ability to complete comparative risk assessments, and determine future needs. The CEC program is identifying chemicals for more attention. The program has been reviewed by UMN. It is based on sound principles but the judgments and scoring systems that it uses need to be more available. Health-based guidance values are based on prioritization for action. These take effort and time and involve the application of uncertainty factors that can be obscure. We have not addressed the guidance value process in detail. The process should be reviewed to consider if it is consistent with the principles of CRA and if it can be accelerated without losing scientific credibility.

How urgently these recommendations are considered will depend on the extent of the external pressures for developing a more formalized and rapid approach to non-regulated chemicals.

Comparative risk assessments should also be considered as a basis for making decisions about options for the management of contaminants at sources or water works. There can be heated debate about these options. A prevailing argument is that prevention of contamination is better than cleanup. However, this ignores the individual and societal benefits associated with food production and industrial activity that are associated with the contamination of waters. There are broad issues of values and equity here that may need revisiting. Comparative risk assessment and associated cost-benefit analysis will not resolve the issues but they can provide a rational basis for discussion. This should be coupled with an inclusive debate, with wide-ranging representation, on how citizens value safe drinking water in the broader context of economic development.

How urgently this is considered will depend on pressure for a more integrated approach for management across the supply chain.

Consider proposing to the Legislature that testing of private wells at transfer of property should be mandatory. Monitoring water quality in private wells remains patchy with many owners unaware of or ignoring the need. Apart from more encouragement from state agencies for more testing, the development of a statutory requirement for well testing at property transfer appears to be a straightforward step that would provide a better basis for protecting the health of house buyers. It also signals that the quality of drinking water in private wells needs to be taken more seriously. An added benefit could be development of a WSP approach providing user-friendly hazard analyses for private well owners, which would inform well owners about potential contaminants and other hazards in their wells depending on age and type.

The proposal for legislation on testing private wells at property transfer should be considered as soon as opportune.

5. Conclusions

Minnesota is a leader in the provision of safe drinking water. But it needs to develop drinking water policy that recognizes important future challenges. One of these, aging infrastructure as a source of contamination, is increasingly being acknowledged as a problem here and throughout the US. Additionally, an ever-increasing number and diversity of drinking water contaminants, arising from industrial, agricultural, and domestic sources will contaminate source waters. Anticipated extreme weather events associated with climate change may compromise wastewater treatment and lead to further contamination. Our recommendations, therefore, focus on developing a good governance system that can respond in an integrated and flexible fashion to these emerging challenges and do so in a way that commands public confidence. Key to this will be coordination between all the agencies involved with water governance to provide a holistic response to drinking water. We recommend that this should be underpinned by statutes in a way that clarifies and makes transparent the responsibilities of all involved and that they are responsive to a common ethic of providing safe and sufficient drinking water for all in a way that respects the environment. Public preferences should be a prominent part of this governance approach and we make recommendations on how that might be better achieved. Because of the potential diversity and complexity of emerging contaminants not yet addressed in federal statutes it will be important to be able to prioritize them for attention and ultimately action, and to make decisions about optimizing treatment between source and tap. This prioritization process should be consistent and transparent. We suggest a methodology based on the science of comparative risk assessment and management. Throughout the report, our recommendations emphasize a framework of principles and policy options. MDH should guide the development of these principles into prioritized actions based on political and public preferences modulated by resource constraints.

6. Acronyms

1W1P	One Watershed One Plan
CCR	Consumer Confidence Report
CEC	Contaminants of Emerging Concern
CWA	Clean Water Act
CWF	Clean Water Fund
DNR	Department of Natural Resources
DWSMA	Drinking Water Supply Management Area
EPA	Environmental Protection Agency
GAF	Governance Assessment Framework
GRAPS	Groundwater Restoration and Protection Strategies
HACCP	Hazard Analysis and Critical Control Points
MAWSAC	Metropolitan Area Water Supply and Advisory Committee
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MPCA	Minnesota Pollution Control Agency
MWWA	Minnesota Well Water Association
MWQA	Minnesota Water Quality Association
PHAB	Public Health Accreditation Board
SDWA	Safe Drinking Water Act
USGS	United States Geological Survey
WHO	World Health Organization
WSP	Water Safety Plan

7. Bibliography

Allaire, M., Wu, H., & Lall, U. (2018). National trends in drinking water violations. *Proceedings of the National Academy of Sciences,* 115, 2078-2083. DOI: https://doi.org/10.1073/pnas.1719805115

Amjad, U., Luh, J., Baum,R., Bartram, J. (2016). Water Safety Plans: bridges and barriers to implementation in North Carolina. *J Water Health 14*(5), 816-826.

Baum, R. Amjad, U., Luh, J., Bartram, J. (2015). An examination of the potential added value of water safety plans to the United States national drinking water legislation. *International Journal of Hygiene and Environmental Health* 218, 677–685.

Calow P. (2014) Environmental risk assessors as honest brokers or stealth advocates. *Risk Analysis,* 34, 1972 - 1977. DOI: 10.1111/risa.12225

Calow, P., Kelley, S., Kirby, E., Levers, L., Lewandowski, A. & Siewe, M.L.N. (2018). *Interim Report on the Future of Drinking Water: A framework for Managing Risk.*

Governor's Office. Budget for One Minnesota. Website accessed 22Jan2020. https://mn.gov/mdhr/news-community/government-relations/budget-2019.jsp
Direct link to One Minnesota Fact Sheet pdf:
https://mn.gov/mdhr/assets/Bonding%20Bill%20Fact%20Sheet_tcm1061-376785.pdf

Gunnarsdóttir, M.J. and Gissurarson,L.R. (2008). HACCP and water safety plans in Icelandic water supply: preliminary evaluation of experience. *J Water Health 6*(3), 377-82.

Hartmann, J., van der Aa, M., Wuijts, S., de Roda Husman, A.M. & van der Hoek, J.P. (2018) Risk governance of potential emerging risks to drinking water quality: analyzing current practices. *Environmental Science and Policy*, 84, 97 – 104. DOI: https://doi.org/10.1016/j.envsci.2018.02.015

Helland, John; Enzler, Sherry Anne. (2011). Policy Technical Work Team Report: Minnesota Water Sustainability Framework, January 2011. University of Minnesota. Water Resources Center. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/182393.

Ijiasz, E. & Tlaiye, L. (1999). Comparative Risk Assessment. *Pollution Management*, 2. The World Bank.

Lewandowski, A., Kelley, S., Meinert, J., & Williams, C. (2016) Review of the Minnesota Department of Health Contaminants of Emerging Concern Program Process for Selecting Chemicals. University of Minnesota Water Resources Center and Humphrey School of Public Affairs. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/208839

Minnesota Department of Health. Retrieved (2019a) Guidance values and standards for contaminants in drinking water. Retrieved from https://www.health.state.mn.us/communities/environment/risk/guidance/gw/index.html

Minnesota Department of Health. Retrieved (2019b). Human Health-based Guidance Table. Retrieved from https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html

Minnesota Department of Health (2019c). *Lead in Minnesota Water*. Minnesota. MDH.

MN Session Laws 2009, c 37, § 4

MPCA. (2013). Water Governance Evaluation Report. Retrieved from https://www.pca.state.mn.us/water/water-governance-evaluation-report

McBride, G. Ross, T., & A. Dufour. (2012). Comparative Risk Analysis. In Dufour, A., Jamie Bartram, J., Bos, R., & Gannon, V. (Eds). *Animal waste, Water Quality, and Human Health.* World Health Organization. London, UK.

National Research Council (NRC) of the National Academies (2009). Science and decisions. Advancing risk assessment. Washington DC, The National Academies Press.

OECD (2015). *OECD Principles on Water Governance*. Paris, OECD. Retrieved from www.oecd.org/gov/regional-policy/OECD-Principles-on-Water-Governancebrochure.pdf.

OECD (2018). Implementing the OECD Principles on Water Governance: Indicator Framework and Evolving Practices. Paris, OECD. DOI: https://doi.org/10.1787/9789264292659-en

Pawar G, Madden JC, Ebbrell D, Firman JW and Cronin MTD (2019). In Silico Toxicology Data Resources to Support Read-Across and (Q)SAR. *Frontiers in. Pharmacol*. 10:561. doi: 10.3389/fphar.2019.00561

President's Council of Advisors on Science and Technology (PCAST) (2016). *Science and Technology to Ensure the Safety of the Nation's Drinking Water.* Executive Office of the President.

US. Environmental Protection Agency (USEPA) (1998). *Comparative Risk Framework Methodology and Case Study.* National Center for Environmental Assessment.

US Environmental Protection Agency (USEPA) (2014). Risk assessment forum white paper. Probabilistic risk assessment methods and case studies. Retrieved from https://www.epa.gov/sites/production/files/2014-12/documents/raf-pra-white-paper-final.pdf

Setty, K., McConnell, R., Raucher, R., Bartram, J. (2019). Comparative evaluation of risk management frameworks for U.S. source waters. *AWWA Wat Sci.* 2019;e1125.

Slovic, P (2000). *The perception of risk.* London, Earthscan.

Sunstein, C.R. (2018) The cost-benft revolution. Cambridge, Massachusetts, The MIT Press.

Swackhamer, Deborah. (2011). Minnesota Water Sustainability Framework. Water Resources Center, University of Minnesota. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/98976.

Viera, J. (2011). A strategic approach for water safety plan implementation in Portugal. *J Water Health*. *9*(1):107-16.

8. Appendices

8.1. Project Advisory Panels

The perspectives of panel members were important to framing this report, but we did not strive to reach consensus, and they are not responsible for the content or conclusions of the report.

8.1.1. Expert Panel

- Mae Davenport, UMN Department of Forest Resources
- Ray Hozalski, UMN Civil and Environmental Engineering
- Bonnie Keeler, UMN Humphrey School of Public Affairs
- John Linc Stine, UMN Institute on the Environment Fellow; Executive Director, Freshwater
- Rebecca Swenson, UMN Department of Agricultural Education, Communication & Marketing
- Jared Trost, US Geological Survey
- Jerry (Zhirong) Zhao, UMN Humphrey School of Public Affairs

8.1.2. Stakeholder Panel

Members of the stakeholder panel represented the following.

- St. Paul Regional Water Services
- Metropolitan Council Water Supply Planning Unit
- Moorhead Public Service
- Fairmont Public Utilities
- Currie City Council
- St. Louis County elected official
- Dakota County Environmental Resources Department
- Minnesota Association of Watershed Districts
- Upper Minnesota Watershed Management Organization
- East Ottertail SWCD
- Farmer and local elected official
- Minnesota Well Owners Organization (MNWOO)
- Minnesota Water Well Association
- Dow Chemical Water Solutions
- Tonka Water
- Environmental Consultant
- Freshwater
- CURE (Clean Up the River Environment)
- League of Women Voters
- WaterBar
- Homeland Security and Emergency Management
- The Legislative Subcommittee on Water Policy
- Minnesota Department of Agriculture

8.2. Governance Assessment Framework

The notes in this table provide examples of comments received from the stakeholder panel during discussions of the GAF. These examples are not meant as a conclusive review of the criteria, but to demonstrate how the framework can be used to systematically evaluate the state of water governance and facilitate discussion on areas of strength and gaps.

Effectiveness Criteria				
GAF Principals	1. State-level policy **clearly defines the roles and responsibilities** of each agency with regard to drinking water management, programming, and policy making, for both private wells and public systems.	2. Drinking water is managed at the **appropriate scale emphasizing an integrated major watershed approach**	3. Drinking water **policy is coherent** horizontally and vertically across administrative and economic sectors including health, environment, energy, agriculture, and industry.	4. State and local drinking water management entities have adequate **professional capacity**
What we do now	Roles are artificially siloed based on narrow interpretation of authority	DNR to some extent looks at cumulative withdrawals HUC 8 is approximately the right scale	Agencies sit in the same room and divvy up areas rather than integrate and create solutions	"Yes" at state level "No" at local level because it's not their only job
Needed Actions / Gaps and Actions for consideration	Prevent contamination; agree on an aspirational goal Implementation of private well responsibilities may be perceived as ineffective based on numbers of homeowners willing or able to test and treat their wells Roles and responsibilities of water authorities are perceived by some stakeholders as artificially siloed based on narrow interpretations of authority Water could be consolidated under one singular "Water Agency" that addressed quantity and quality, rather than spreading the roles across agencies.	Improved integration of surface and groundwater Research into cumulative impact of quantity withdrawal is needed Need for continued and increased integration of ground and surface water management, as well as integration across county, city, and state scales for more accurate cumulative quantity withdrawals. Consolidation of utilities could be considered in some regions of the state. More immediately, MDH could consider a study of the potential cost and effectiveness impacts of consolidation	Development of goals and water ethics that include county, city, and state level Modify current regulatory framework to address conflicting goals in water management Evaluate cumulative impact of MPCAs withdrawal permits beyond temporary withdrawal quantity estimates Shift towards collaboration between agencies, rather than siloing responsibilities	Need to share responsibility Require accreditation of administration at all stages of the water supply system, for example through the Public Health Accreditation Board Develop quantitative framework and rating system for water quality that allows benchmarking between communities Create a roadmap with steps for communities to achieve better water quality Build capacity for private well owners

Efficiency Criteria				
GAF Principals	**5. Processes and institutions are in place generating timely and relevant data** about the water supply and risk management in a way that is suitable to guide policy, prioritize contaminants for attention and action, create transparency for customers, and provide opportunities for dialogue.	**6. Financial revenues** are adequate, appropriately structured, and transparently, efficiently, and equitably allocated.	7. Sound **regulatory frameworks are effectively implemented.**	8. State and local processes incentivize and **foster innovation and flexibility** in finance, sharing information, assessment, and engagement.
What we do now	Clean Water Fund has led to more data collection Agencies are not science organizations. They do not present unbiased data	Fund could be generated from known pollution sources via tax on nitrogen, tile, pesticides	MDH has good regulatory frameworks for water systems Groundwater Protection Rule isn't effectively implemented	City of Minneapolis is looking at shared governance and how to manage peak usage Reuse projects
Needed Actions / Gaps and Actions for consideration	Increase ability to actually measure water use for permits rather than estimate Go beyond just collecting data for regulatory purposes--provide interpretations/actions along with data Agencies are not purely science organizations; they do not necessarily provide unbiased data Increase frequency and expediency of data publication in a way that is accessible to general consumers, especially regarding observation wells Increase data sharing across agencies and resources for data analysis Address lack of epidemiological studies related to drinking water Explore possibility of at tap monitoring and smart monitoring of water quality	Increase financial resources for treatment of contaminated water, specifically private wells General Fund spending is declining MDA could provide funding for treatment of agricultural chemicals Fund could be generated from known pollution source, such taxes on nitrogen or pesticides Rural and small PWS need greater financial capacity	Need to assess whether frameworks are appropriate and fair (e.g. for urban vs. rural systems) Take local input into consideration Measure and document effects of best management practices Gap exists in enforcement of private well testing-could require well testing at property transfer	Increase financial resources Regulation for water reuse and related projects Allow design-build contracts to promote collaborative problem solving Increase alignment between decision makers and utility staff willing to innovate, including improving decision makers' water knowledge to allow effective partnership with water industry WSPs provide an example of situational flexibility in water management

Trust and Inclusiveness Criteria				
GAF Principals	9. State and local drinking water agencies maintain **integrity and transparency** for greater accountability and trust,	10. Drinking water stakeholders, and the nature of their stake, have been clearly identified. **Stakeholders are systematically engaged** in interpreting needs and designing solutions to drinking water concerns.	11. Frameworks exist to identify **trade-offs** and prioritize choices across water treatment alternatives, sectors of water users, different types of communities, and generations of water users.	12. Drinking water **programs and institutions are regularly monitored and evaluated** for their effectiveness and fairness in delivering safe drinking water and managing risks.
What we do now	Annual water quality report (consumer confidence reports) Utilities communicate with customers and respond to complaints	Customers are not engaged Cities are engaged Currently trying to educate and engage public (e.g. MDH pamphlets)	Just beginning to address this, mostly by cost trade offs	MDH is monitored by EPA for SDWA compliance but not fairness Public water systems monitored by MDH via the SDWA, and via CCR by consumers Met Council monitored by water supply plans, wellhead protection plans, MAWSAC and legislature
Needed Actions / Gaps and Actions for consideration	Get people's attention Not take it for granted Need for agencies to share information and data with increased frequency and transparency Need for agencies to disclose purpose and intent of data collection--Reassure that information and data won't be used against people, PWSs Assess barriers to communication and trust (between agencies themselves and with stakeholders)	Agencies should be working more closely together Need continued efforts to increase engagement and knowledge, particularly of end of line users Increase agency collaboration rather than siloing responsibilities	Need to include more than cost Integrated, holistic decision making that includes cost, ecosystem concerns, social values, etc. Increase coherence between wastewater and drinking water regulation and management	Produce a white paper on health equity and drinking water Respond proportionally to disparate risks across communities, specifically with regards to lead Develop and employ mechanisms or frameworks to monitor fairness