Recommendations for Better Collaborative Groundwater Monitoring for the US High Plains Aquifer

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Executive Summary: Groundwater is a critical resource for the Great Plains region of the United States, providing drinking water for over 2 million people. However, the High Plains Aquifer (HPA) is under significant threat from over-extraction—defined as the excessive withdrawal of groundwater beyond its natural replenishment rate. This overuse jeopardizes not only water availability but also equitable access and allocation. Effective groundwater monitoring is essential to track trends in water availability, assess the impacts of extraction, and develop strategies to ensure long-term sustainability. Without comprehensive monitoring, it is difficult to address key issues like contamination, depletion, and groundwater quality degradation. While several state-level frameworks exist to enhance groundwater monitoring, they operate independently, leading to gaps in data sharing and collaboration, especially for a transboundary resource like the HPA.

The Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS) are well-positioned to play a more central role in this process. The EPA, with its mandate to protect water quality, and the USGS, with its expertise in nationwide data collection, are critical to supporting a collaborative and comprehensive groundwater monitoring system. By facilitating the integration of state-level efforts, these federal agencies can help ensure that groundwater monitoring is both consistent and accurate, enabling effective decision-making at regional and national levels. This policy memo provides a detailed analysis of current state-level efforts, highlights the role of the EPA and USGS in addressing governance challenges, and proposes a transboundary governance mechanism to enhance collaborative groundwater monitoring. The intended audience includes policymakers at the EPA and USGS, as well as water resource managers who are key to implementing these changes.

I. Groundwater monitoring and its impacts on groundwater quality, quantity, access and allocation

Access to clean water is essential for human health, economic stability, and ecological sustainability (Kılıç, 2020). Groundwater, a primary source of potable water, is a limited natural resource crucial for the Great Plains region of the United States. The United States is the second-largest groundwater user globally (Gumidyala et al., 2020), largely due to its substantial natural reserves, particularly the Great Plains High Plains Aquifer (HPA), the country's largest unconfined aquifer. The HPA directly provides water for drinking, cooking, and sanitation for over 2 million people living in the Great Plains (Gleeson et al., 2010).

States within this region, such as Kansas and Nebraska, report groundwater from the HPA as providing over 70-80% of their daily freshwater use (Buchanan et al., 2015). Such is notable as both lead in nationwide agricultural production and lack adequate surface water supplies as an alternative for supporting this vital industry. This dependence on groundwater sourced from the HPA aquifer underscores its regional primacy and the questions it poses regarding long-term water security. Notably, even states such as Texas, with significant freshwater alternatives (e.g., the Colorado River, The Edwards-Trinity, and Trinity Aquifers), still rely on the HPA to meet over 90% of their irrigation needs (Modala et al., 2015). These data highlight the central issue of groundwater quantity and quality management of the HPA as a principal water resource in the US.

Groundwater monitoring is vital for managing overexploitation, which poses risks to both groundwater quality and quantity. Consistent monitoring would have the potential to reveal declining groundwater levels in semi-arid regions with low precipitation-to-evaporation ratios and are, therefore, heavily dependent on irrigation for agriculture and in need of targeted conservation efforts). In the context of the HPA, over-extraction remains a key threat (Robinson, 2019; Cotterman et al., 2018), leading to reduced water quality from contaminant intrusion and increased salinity (Chang et al., 2017). Additionally, groundwater depletion can cause land subsidence, or the lowering of the Earth's surface caused by intergranular pressure from changing pore volumes of sedimentary rocks, further compromising water availability and infrastructure integrity (Li et al., 2022; Herrera-García, 2021).

Groundwater monitoring allows for the early detection of these, and many other, challenges, enabling timely interventions to mitigate adverse effects on vital groundwater resources. By providing accurate and up-to-date data, groundwater monitoring ensures extraction remains within sustainable limits, protecting the resource and the communities and industries dependent on it by setting the empirical foundations of an effective, equitable water budget. Thus, groundwater monitoring supports a data-driven approach that balances competing demands, facilitating fair distribution of water resources (Condon et al, 2020; Alley, 2007)

American water decision-makers throughout the country, such as those working within both local state water quantity and quality-focused and federal agencies have identified groundwater allocation and quality as primary concerns for groundwater policy in the US (Megdal et al., 2015). This is significant as protecting groundwater resources seems to be politically agnostic, highlighting wider observances within public policy research that the American electorate is overwhelmingly in support of effective and comprehensive water governance interventions from the government.

Ultimately, effective groundwater monitoring is critical to address these concerns, as it involves collecting and analyzing data related to groundwater levels, flow, and quality. This process includes measuring water table levels, tracking changes in groundwater storage, and testing for contaminants. Effective monitoring provides the necessary data for informed water decision-making, offering a comprehensive understanding of groundwater conditions past, present, and future. This understanding is crucial for developing strategies that ensure long-term sustainability. However, current efforts are insufficient. The lack of a coordinated transboundary approach to groundwater monitoring exacerbates these issues, leading to data gaps and inconsistent management practices across state lines. This fragmented approach hinders the ability to develop comprehensive strategies that address the biophysical realities of the HPA, highlighting the need for enhanced collaborative monitoring mechanisms.

II. Status of collaborative groundwater monitoring of the High Plains Aquifer

Groundwater monitoring programs in the Great Plains states—including South Dakota, Kansas, Nebraska, Oklahoma, Texas, New Mexico, Colorado, and Wyoming—play a critical role in managing the High Plains Aquifer (HPA). Each state has developed individual strategies for groundwater monitoring, but the primary issues with state-level monitoring of transboundary aquifers like the HPA are data inconsistencies and a lack of comprehensive coverage, which results in insufficient data to fully assess the aquifer's long-term condition and sustainability (Dennehy et al., 2015). In this context, each HPA state employs different methodologies and standards for data collection, complicating efforts to create a unified understanding of the aquifer's health and resilience.

For example, Kansas relies on the Kansas Geological Survey (KGS) to measure groundwater levels and quality regularly, particularly in the HPA region. Nebraska's Natural Resources Districts (NRDs) oversee groundwater management and monitoring, utilizing a network of observation wells to track water levels and quality (Sophocleous, 2012). In Texas, with its diverse water resources, the Texas Water Development Board (TWDB) plays a central role in groundwater data collection and management, including the HPA (Closas and Molle, 2018). However, these state-centric systems differ in how they collect, process, and use groundwater data. While some states use similar metrics such as water levels, flow rates, and contaminant levels, the frequency, accuracy, and analytical methods can vary significantly (Kang et al., 2019). This variation presents a barrier to harmonizing the data, hindering a clear and consistent understanding of the HPA's overall status. Despite the clear limitations of state-based efforts, groundwater monitoring of the HPA remains primarily within the jurisdiction of individual states, with limited federal intervention.

Federal agencies like the United States Geological Survey (USGS) do contribute significantly to groundwater monitoring, particularly through programs like the National Water-Quality Assessment (NAWQA) and the Groundwater and Streamflow Information Program (GWSIP). However, these programs remain limited in comparison to state-level efforts due to their broad scope, constrained funding, and supportive rather than regulatory role. The USGS's focus on nationwide assessments often lacks the specificity required for detailed regional management, such as that needed for the HPA. While the USGS provides valuable high-level data and context-setting reports, these efforts cannot substitute for the more granular, frequent, and localized monitoring conducted by state agencies. Furthermore, the Environmental Protection Agency (EPA), with its mandate to ensure safe drinking water under the Safe Drinking Water Act, has a critical yet indirect role in overseeing groundwater monitoring, ensuring that drinking water quality standards are met. However, the EPA's oversight is largely regulatory and focused on compliance, rather than coordination of monitoring efforts.

A major challenge is the absence of mandatory collaboration between states and federal agencies such as the USGS and the EPA. This lack of coordination results in data gaps and inconsistent monitoring approaches, preventing the comprehensive, regional groundwater management strategies required for a resource as expansive and ecologically vital as the HPA (Petersen-Perlman et al., 2018; Megdal et al., 2015). While federal programs like NAWQA provide essential context, the states' lack of alignment creates inefficiencies, leading to fragmented data that undermine effective long-term groundwater management. Within states, agencies often collaborate effectively on data collection and management. For instance, Nebraska's NRDs and Texas' Groundwater Conservation Districts (GCDs) have established coordinated efforts to manage groundwater resources at a state level. However, this trend of intra-state collaboration does not extend across state borders. For example, while Kansas and Nebraska both monitor the HPA, there is no formal mechanism for these states to share data or coordinate their monitoring activities. This fragmented approach does not reflect the biophysical realities of the HPA, whose boundaries extend beyond individual state lines. Without a comprehensive, transboundary groundwater monitoring policy, inefficiencies and data gaps will persist, hampering the sustainable management of the aquifer. The HPA's hydrological continuity necessitates a collaborative, cross-state approach to monitoring in order to ensure that policies are based on complete data, minimizing risks to water access and allocation for all stakeholders.

III. Policy options and consequences of inaction

Expanding groundwater monitoring, a form of groundwater governance, in the Great Plains region already has indications of support from both local stakeholders and the federal government. The recent passage of Proposition 6 in Texas in 2023, which expanded state water funding and institutional oversight (Fowler, 2023), and the popularity of the "Texas Runs on Water Campaign" (Texas Water Foundation, 2022), exemplify this trend. Additionally, the US Geological Survey (USGS) has regularly provided grants to local states to expand groundwater monitoring efforts, such as Kansas' grant to enhance monitoring from 2021 to 2023 (Kansas Geological Survey, 2023).

These examples indicate a growing recognition of the importance of groundwater management and an increasing willingness among stakeholders to invest in such initiatives. The success of these programs, and others like them, suggests a strong foundation and public backing for more comprehensive and collaborative groundwater monitoring policies. This section explores two policy options to enhance groundwater monitoring in the High Plains Aquifer (HPA) and the potential consequences of inaction.

i. Policy option 1: Establish a federal-state collaborative groundwater monitoring program

The creation of a federally coordinated program facilitated by the US Geological Survey (USGS) and the Environmental Protection Agency (EPA) would mandate collaboration between states for groundwater monitoring of the HPA. The USGS would be responsible for developing standardized data collection protocols and maintaining a centralized data repository, while the EPA, under its Safe Drinking Water Act (SDWA) authority, would ensure regulatory compliance with groundwater quality standards.

Advantages

This program would standardize data collection methods across state lines, creating consistency in monitoring groundwater levels, contamination, and other key metrics. Real-time data sharing would be ensured through a centralized platform managed by the USGS, enhancing transparency and facilitating cross-state collaboration. Joint research projects between federal and state agencies would enable innovative solutions and knowledge sharing. Moreover, federal funding could be channeled through existing mechanisms such as the EPA's Water Infrastructure Finance and Innovation Act (WIFIA) and the Bureau of Reclamation's WaterSMART initiative to support state-level monitoring efforts.

Disadvantages & challenges

Securing adequate federal funding may be difficult, particularly in a political environment where budgetary constraints and competing national priorities are significant concerns. Allocating these funds equitably across the Great Plains states could also present challenges, particularly given each state's varying dependence on the HPA. Furthermore, some states may resist federal oversight, preferring to maintain control over their groundwater monitoring programs due to the diversity of legal doctrines governing groundwater use, such as prior appropriation in the West and the rule of capture in Texas (Sophocleous, 2012).

Historically, US groundwater governance has been fragmented, with each state employing different methodologies and legal frameworks for managing and monitoring groundwater. This diversity reflects regional priorities and poses significant challenges to data standardization and collaborative efforts. For example, different states may use varied methods for data collection, which complicates standardization. Overcoming this will require significant political will to harmonize data collection techniques and ensure states' willingness to upload data to a federal repository. Additionally, congressional action may be required to expand the mandate of the EPA and USGS, secure funding, and establish long-term sustainability for the program.

ii. Policy option 2: Interstate compact for groundwater monitoring and management

Forming a legally binding interstate compact among the Great Plains states would enable collaborative management and monitoring of the HPA. The compact would establish a governance structure for cooperative groundwater management, including joint funding mechanisms, shared data collection protocols, and coordinated policy development. A governing body, composed of representatives from each state and federal agencies like the USGS and EPA, would oversee the implementation of the agreement and ensure compliance with established protocols.

Advantages

One of the key benefits of this policy option is that it promotes harmonization between state policies and regulations related to groundwater monitoring. By aligning these policies, the compact would ensure that monitoring efforts are both comprehensive and reflective of the biophysical realities of the HPA, which spans multiple state boundaries. The compact would also develop a joint funding mechanism, wherein member states contribute to a shared pool supplemented by federal grants (e.g., through the EPA's Clean Water State Revolving Fund (CWSRF) or WaterSMART), to support collaborative monitoring efforts. This approach can increase the financial sustainability of monitoring programs and help bridge funding disparities among states. Additionally, the data generated would be more accessible and shared more efficiently, improving transparency for broader stakeholders and the general public (Huber et al., 2019).

Moreover, this policy option ensures that all participating states have an equal voice in decision-making, fostering a sense of equity and inclusivity. Furthermore, public participation and stakeholder engagement mechanisms could address potential issues of water justice, ensuring that marginalized communities' needs are considered in groundwater management.

Disadvantages & challenges

Negotiating and ratifying an interstate compact will require substantial legal and political effort. Given the diverse water needs and legal frameworks of different states, negotiations could be contentious and time-consuming. Coordinating policies and monitoring efforts across states could lead to conflicts, particularly in states where water use priorities differ sharply. Ensuring that states make fair contributions to the joint funding pool may also pose challenges, especially if certain states feel they are overpaying relative to their needs or usage.

Moreover, managing the data produced through the compact will be complex. States would need to ensure that the data is ingested properly and maintained in a way that promotes seamless integration and oversight. Without robust systems in place, this could lead to delays and inconsistencies in groundwater management, particularly if technical capabilities vary across states. Additionally, extensive public involvement could complicate decision-making, though it is crucial for building transparency and trust.

iii. Consequences of inaction

Failing to implement enhanced collaborative groundwater monitoring for the HPA will likely exacerbate existing challenges. Without a coordinated approach, data gaps and inconsistencies will persist, making it increasingly difficult to manage the aquifer effectively. Over-extraction and contamination risks will escalate, compromising water quality and availability, and leading to increased conflicts over water resources. These conflicts will likely exacerbate socio-economic disparities, undermining efforts to achieve water justice.

Moreover, the absence of a unified strategy will hinder the ability to respond to and mitigate the impacts of climate change on groundwater resources. The HPA, a shared resource, requires coordinated efforts to protect it from overuse and degradation. Without collaboration, policies will be based on incomplete data, leading to suboptimal decisions that fail to address the aquifer's biophysical realities or protect it for future generations. Proactive measures are therefore essential to ensure the sustainable and equitable management of groundwater in the Great Plains region.

IV. Policy recommendation

It is recommended to adopt Policy option 2. This approach is the most feasible and effective in addressing the critical issues of achieving fair and equitable groundwater access and allocation in the High Plains Aquifer (HPA) region. Policy Option 2 establishes a legally binding interstate compact among the Great Plains states, fostering a unified and collaborative approach to groundwater monitoring and management. By creating a governing body composed of representatives from each state, this compact ensures that all states have a voice in the decision-making process. This inclusive structure promotes fairness and equity, facilitating the development of policies that address the specific needs and priorities of each state and its stakeholders.

One of the primary advantages of this policy option is its ability to harmonize state policies and regulations related to groundwater monitoring and management. The current fragmented approach, where states operate independently, leads to inconsistencies in data collection and gaps in groundwater management. By aligning policies, the interstate compact ensures that monitoring efforts are comprehensive and reflective of the biophysical realities of the HPA, whose boundaries extend beyond individual state lines. This harmonization is crucial for developing effective, data-driven strategies that can sustainably manage the aquifer.

Moreover, the joint funding mechanism established by the compact ensures that all states contribute to and benefit from pooled resources. States would leverage federal resources from agencies such as the EPA's Clean Water State Revolving Fund (CWSRF) and the US Geological Survey's Groundwater and Streamflow Information Program (GWSIP), ensuring that the financial sustainability of monitoring programs is enhanced. This approach also guarantees that less affluent states are not disadvantaged in groundwater monitoring efforts, promoting equity in resource allocation. The flexibility of joint funding mechanisms, supplemented by federal grants, provides additional support for expansive and technologically advanced monitoring efforts, without imposing a top-down federal approach.

The compact also emphasizes stakeholder engagement and public participation in decision-making processes. This inclusion is vital for addressing groundwater justice issues, ensuring that the voices of marginalized communities are heard and their needs considered. Transparent and participatory decision-making builds public trust and support for groundwater management policies, increasing the likelihood of successful implementation and compliance. Compared to Policy Option 1—a federally coordinated program—Policy Option 2 is more feasible because it directly involves the states that are most affected by the HPA. States are more likely to buy into a solution that they help craft, compared to a federally mandated program, which may be seen as top-down and less responsive to local conditions. Additionally, a regional compact can be more agile and responsive to changes in the aquifer's conditions, adapting policies more quickly than federal systems. This flexibility is crucial for addressing the dynamic nature of groundwater resources in the HPA.

Furthermore, harmonizing data collection through a regional compact would significantly improve the accessibility and usability of data. A centralized data repository would provide a valuable resource for researchers, policymakers, and other stakeholders, facilitating broader community engagement and informed decision-making. This is a substantial benefit over a federal-state approach, where data might remain siloed within different agencies and states. While Policy Option 1 offers valuable federal-state collaboration, it falls short in addressing the need for a cohesive and legally binding framework that ensures sustained and equitable cooperation among states. The interstate compact provides a more robust solution by legally formalizing cooperation, reducing the risk of non-compliance, and ensuring long-term commitment from all parties involved.

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