

Strengthening Boil Water Notice Preparedness Through Expert and Community Perspectives in Virginia

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Research Problem Statement

Natural disasters pose persistent and growing risks to critical infrastructure, with infrastructure failures directly affecting community health, safety, and well-being. In the United States, drinking water systems are increasingly stressed by the combined effects of climate change, aging infrastructure, and expanding service demands. Extreme weather events like hurricanes, flooding, and extended power outages have exposed vulnerabilities in centralized water systems. Boil water notices have become a visible and recurring manifestation of these vulnerabilities, signaling both immediate public health risks and deeper systemic fragilities. Boil water notices are public health advisories issued when drinking water systems may be contaminated or experience pressure loss, requiring residents to boil tap water before consumption. Boil water notices have emerged as a critical point of intersection between infrastructure performance, public health protection, and emergency governance.

Existing scholarship has examined boil water notices primarily through the lens of post-disaster response, with particular attention to risk communication, public awareness, and compliance behaviors (Day et al., 2024; Patterson & Adams, 2011; Ram et al., 2007; Rundblad et al., 2010, 2014; Vedachalam et al., 2016). Studies consistently document confusion surrounding advisories, uneven compliance, and disparities across demographic groups (Day et al., 2024; Ram et al., 2007; Rundblad et al., 2010, 2014; Vedachalam et al., 2016). For example, Rundblad et al. identified widespread misunderstanding regarding the type and duration of notices in place, as well as significantly higher non-compliance during disaster-related advisories compared to routine incidents (Rundblad et al., 2010, 2014). Similarly, Vedachalam et al. demonstrated that while reported compliance rates appear high, effective compliance is substantially lower when awareness gaps and partial non-compliance are considered (Vedachalam et al., 2016). More recent work by Day et al. further highlights how income and race influence compliance, emphasizing the importance of perceived efficacy and pre-disaster communication in shaping behavioral responses during complex, cascading disasters (Day et al., 2024). Another body of literature focuses on emergency response planning and disaster management, emphasizing coordination among utilities, aid organizations, and government agencies following major events (Patterson & Adams, 2011; Pinera & Reed, 2007). While these studies underscore the importance of partnerships and formal response plans, they primarily focus on actions taken after a disaster occurs and give less attention to how pre-disaster infrastructure conditions, preparedness decisions, and institutional knowledge contribute to the occurrence and scope of boil water notices.

A critical gap in this literature is the limited attention given to the perspectives of water utility officials, emergency managers, and policymakers responsible for anticipating and managing these risks pre-disaster. The American Water Works Association Research Foundation conducted foundational interviews with water officials in the early 2000s, recommending all-hazards approaches, improved tools, and stronger workforce integration (N. Grigg, 2003), with an updated assessment published in 2006 (N. S. Grigg, 2006). However, this expert-focused work has not been systematically revisited despite a substantial increase in the frequency and intensity of climatological disasters over the past two decades. These gaps suggest that boil water notices are often treated as communication failures or response challenges rather than as indicators of preparedness limitations within water infrastructure systems and hazard mitigation planning. This study advances sociotechnical disaster-preparedness research by examining boil water notices not only as communication failures or emergency response outcomes, but also as indicators of institutional preparedness capacity, interagency coordination, and infrastructure governance.

In 2024, a hurricane-related disruption to the regional water system in Virginia's New River Valley resulted in a large-scale boil water notice affecting multiple jurisdictions and institutions. The advisory impacted residents, businesses, schools, healthcare facilities, and a major university community, requiring rapid adjustments to daily operations and emergency protocols. Although no long-term contamination was detected, the event necessitated extended system flushing, retesting, and coordinated communication efforts that continued for several weeks. The scale and duration of the advisory, combined with the region's reliance on a centralized water system, highlighted the interconnected technical, organizational, institutional, and social challenges associated with managing water service disruptions during extreme weather events.

This event provides a valuable case study for examining boil water notices as indicators of preparedness and system resilience rather than solely as emergency response outcomes. The New River Valley's mix of urban, rural, and institutional water users, along with established emergency management and utility governance structures, offers an opportunity to explore how infrastructure design, interagency coordination, and public communication interact during a water emergency. By situating this study within the context of a real-world disruption, the research seeks to generate insights that are both locally relevant and transferable to other communities facing similar climate-driven risks. The study is organized around several research questions.

- How do water utility officials, emergency managers, and hazard mitigation planners perceive the causes and contributing factors of the New River Valley boil water notice?
- How did community members experience the advisory in terms of access to information, trust in public messaging, and ability to comply with guidance?

Together, these questions aim to identify actionable lessons that can strengthen boil water notice preparedness at both the regional and state levels, spanning perspectives from practitioners to community members.

Research Methodology and Approach

This project will use a mixed-methods, stakeholder-centered approach designed to inform entities to better prepare for water-related disasters. The research consists of three interconnected components, illustrated in Figure 1.

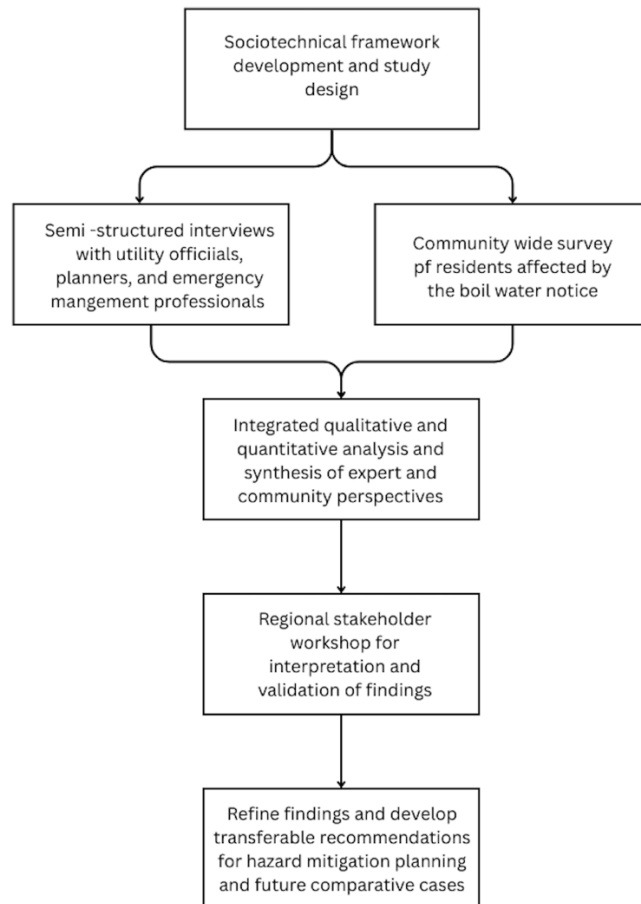


Figure 1. Study design approach for examining boil water notice preparedness

The data for the first part of this study will use approximately 15 semi-structured interviews with water utility officials, emergency management professionals, and hazard mitigation planners who were directly involved in managing or responding to the New River Valley boil water notice in 2024. Interviewees will be chosen through convenience and snowball sampling and continued until theoretical saturation of the information is met (Glaser & Strauss, 2017). Using NVivo Software, we will perform a qualitative thematic analysis on the interview data to understand

perceived causes of system failure, decision-making during the event, communication practices, and opportunities for improving preparedness and interagency coordination.

For the second part of this study, we will implement a community wide survey in the New River Valley. The survey will target approximately 250–300 completed responses from residents affected by the advisory. The survey will assess residents' experiences during the boil water advisory. Survey topics will include access to and trust in public information, household-level preparedness, financial and operational impacts, and perceived clarity of guidance. This component centers community perspectives that are often absent from technical planning documents while providing insight into how preparedness and messaging translate at the household level. Survey data will be analyzed descriptively to identify trends in experience, preparedness, and communication effectiveness.

To translate findings into actionable planning guidance, results from the interviews and community survey will be synthesized and presented during a regional stakeholder workshop. This workshop will convene water utility officials, emergency managers, hazard mitigation planners, and community stakeholders to collaboratively interpret findings and identify priority actions for future Hazard Mitigation Plan updates in the area. Structured facilitation techniques, including guided discussion prompts, breakout groups, and prioritization exercises, will be used to elicit feedback on proposed recommendations and to assess their feasibility within existing planning and regulatory frameworks. This participatory approach ensures that technical findings are refined through practitioner expertise and aligned with local planning capacities and needs.

Key Findings

This study adopts a sociotechnical systems perspective to examine boil water notices as organizational and infrastructural failures emerging from interactions among physical infrastructure systems, governance structures, interagency coordination processes, and public communication. Sociotechnical theory emphasizes that infrastructure performance is shaped not only by engineered components, but also by human decision-making, organizational practices, regulatory frameworks, and public behavior (Trist & Bamforth, 1951; Walker et al., 2008). From this perspective, boil water notices function as signals of system-level stress within interconnected technical and social domains.

Preliminary findings from conversations with hazard mitigation planners suggest that vulnerabilities leading to boil water notices emerge at the intersection of multiple system components. Technical factors such as infrastructure age, system redundancy, and power dependence interact with institutional factors including emergency protocols and interagency coordination. These interactions are further shaped by social dimensions like public trust, risk perception, and the clarity and timing of communication. Rather than a single point of failure, boil water notices appear to result from cascading interactions across these domains, consistent with theories of tightly coupled and complex systems (Perrow, 2011).

Building on these preliminary observations, the ongoing interview and survey phases of this study are expected to further examine how organizational coordination, governance structures, and household experiences shape preparedness and response during boil water advisories. From

an institutional perspective, interviews with water utility officials and emergency managers are expected to reveal how knowledge-sharing practices, prior experience, and organizational roles influence preparedness and response. Decisions regarding when to issue advisories, how to communicate uncertainty, and how to coordinate across agencies are embedded within broader governance structures and resource constraints. The findings are expected to build on earlier work that emphasizes all-hazards approaches and workforce integration (N. Grigg, 2003; N. S. Grigg, 2006).

Community survey results are anticipated to highlight how sociotechnical interactions shape household-level experiences during boil water advisories. Access to information, trust in water utilities and local government, and the perceived feasibility of compliance are expected to vary across households and institutions. We expect these findings to align with prior research demonstrating uneven compliance and persistent confusion during advisories (Day et al., 2024; Rundblad et al., 2010; Vedachalam et al., 2016), while situating these behaviors within a broader system of infrastructural and institutional constraints.

Implications

This project contributes to the development of more targeted and effective strategies for managing and mitigating boil water notices by reframing them as sociotechnical preparedness challenges rather than solely emergency response events. By integrating expert knowledge from water utility officials and emergency managers with community experiences, the study supports a more holistic approach to water infrastructure resilience and hazard mitigation planning.

Although this research is grounded in a case study of the New River Valley, the sociotechnical framework employed is generalizable to other regions with urban, rural, and institutional water users that rely on centralized water systems and face increasing climate-related risks. Many communities across the United States share similar conditions, including aging infrastructure, interdependent utility systems, and diverse populations with varying capacities to comply with emergency advisories. As such, the findings and methodological approach developed in this study can inform hazard mitigation planning beyond the immediate study area.

The project's recommendations will be aligned with FEMA hazard mitigation guidance, best practices in infrastructure resilience, and community-based planning methods, enabling integration into current and future state and regional Hazard Mitigation Plans. While the project does not involve physical infrastructure investments, it enhances technical feasibility for future mitigation efforts by identifying system-level vulnerabilities, institutional coordination gaps, and communication challenges that can be addressed through planning, training, and targeted infrastructure improvements.

Future research will extend this work by applying the sociotechnical framework to additional communities that have experienced boil water notices under different hazard conditions. Comparative case studies will allow for cross-case analysis of how governance structures, infrastructure configurations, and community characteristics influence preparedness and outcomes. By examining similarities and differences across cases, future work will seek to identify

transferable best practices and context-specific strategies for reducing water system vulnerability and enhancing resilience in the face of increasingly frequent and complex disasters.

Dissemination of findings through practitioner-oriented materials, professional conferences, and community forums will further support knowledge-sharing and capacity-building across the water and emergency management sectors. Collectively, this work aims to advance both scholarly understanding and practical planning approaches for improving boil water notice preparedness in a changing climate.

REFERENCES

Day, A. M., O'Shay, S., Islam, K., Seeger, M. W., Sperone, F. G., & McElmurry, S. P. (2024).

Boil water notices as health-risk communication: Risk perceptions, efficacy, and compliance during winter storm Uri. *Scientific Reports*, *14*(1), 850.

<https://doi.org/10.1038/s41598-023-50286-y>

Glaser, B., & Strauss, A. (2017). *Discovery of Grounded Theory: Strategies for Qualitative Research*. Routledge. <https://doi.org/10.4324/9780203793206>

Grigg, N. (2003). *Water Utility Security: Multiple Hazards and Multiple Barriers*.

[https://ascelibrary.org/doi/epdf/10.1061/%28ASCE%291076-](https://ascelibrary.org/doi/epdf/10.1061/%28ASCE%291076-0342%282003%299%3A2%2881%29)

[0342%282003%299%3A2%2881%29](https://ascelibrary.org/doi/epdf/10.1061/%28ASCE%291076-0342%282003%299%3A2%2881%29)

Grigg, N. S. (2006). Ready or not? Disaster preparedness and emergency response in the Water industry. *Journal AWWA*, *98*(3), 242–255. [https://doi.org/10.1002/j.1551-](https://doi.org/10.1002/j.1551-8833.2006.tb07619.x)

[8833.2006.tb07619.x](https://doi.org/10.1002/j.1551-8833.2006.tb07619.x)

Patterson, C. L., & Adams, J. Q. (2011). Emergency response planning to reduce the impact of contaminated drinking water during natural disasters. *Frontiers of Earth Science*, *5*(4),

341–349. <https://doi.org/10.1007/s11707-011-0196-8>

Perrow, C. (2011). *Normal Accidents: Living with High Risk Technologies*.

<https://www.torrossa.com/en/resources/an/5576535>

- Pinera, J., & Reed, R. A. (2007). Maximizing aid benefits after urban disasters through partnerships with local water sector utilities. *Disaster Prevention and Management: An International Journal*, 16(3), 401–411. <https://doi.org/10.1108/09653560710758350>
- Ram, P. K., Blanton, E., Klinghoffer, D., Platek, M., Piper, J., Straif-Bourgeois, S., Bonner, M. R., & Mintz, E. D. (2007). Household Water Disinfection in Hurricane-Affected Communities of Louisiana: Implications for Disaster Preparedness for the General Public. *American Journal of Public Health*, 97(Supplement_1), S130–S135. <https://doi.org/10.2105/AJPH.2006.094441>
- Rundblad, G., Knapton, O., & Hunter, P. R. (2010). Communication, perception and behaviour during a natural disaster involving a “Do Not Drink” and a subsequent “Boil Water” notice: A postal questionnaire study. *BMC Public Health*, 10(1), 641. <https://doi.org/10.1186/1471-2458-10-641>
- Rundblad, G., Knapton, O., & Hunter, P. R. (2014). The Causes and Circumstances of Drinking Water Incidents Impact Consumer Behaviour: Comparison of a Routine versus a Natural Disaster Incident. *International Journal of Environmental Research and Public Health*, 11(11), Article 11. <https://doi.org/10.3390/ijerph111111915>
- Trist, E. L., & Bamforth, K. W. (1951). *Some Social and Psychological Consequences of the Longwall Method of Coal-Getting*. <https://journals.sagepub.com/doi/10.1177/001872675100400101>
- Vedachalam, S., Spotte-Smith, K. T., & Riha, S. J. (2016). A meta-analysis of public compliance to boil water advisories. *Water Research*, 94, 136–145. <https://doi.org/10.1016/j.watres.2016.02.014>

Walker, G. H., Stanton, N. A., Salmon, P. M., & Jenkins, D. P. (2008). A review of sociotechnical systems theory: A classic concept for new command and control paradigms. *Theoretical Issues in Ergonomics Science*, 9(6), 479–499.

<https://doi.org/10.1080/14639220701635470>