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"You turn the tap on, the water's there, and you just think everything's fine": a mixed methods approach to understanding public perceptions of groundwater management in Baton Rouge, Louisiana, USA

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In Louisiana's Capital Area Groundwater Conservation District (CAGWCD), extensive groundwater withdrawals from the Southern Hills Aquifer System have begun to accelerate the infiltration of saltwater into the aquifer's freshwater sands. This accelerated saltwater intrusion has the potential to reduce the amount of groundwater available for public consumption and other industrial and agricultural uses throughout the region. In response to this threat, the Capital Area Ground Water Conservation Commission has begun development of a long-term strategic plan to achieve and maintain sustainable and resilient groundwater withdrawals from the aquifer system. The development of the strategic plan includes an assessment of public attitudes regarding groundwater and groundwater management in the CAGWCD. This paper presents the results of mixed methods public participatory research to evaluate current and historical views and attitudes around groundwater quality, quantity, and cost in the CAGWCD. The mixed methods approach used in this research employed a sequential explanatory design model consisting of two phases. The first phase involved the implementation of an internet-based survey, followed by a qualitative phase aimed at explaining and enhancing the quantitative results. The qualitative phase employed a combination of one-on-one interviews and focus groups. The research found that the primary governance obstacle that decision-makers may face in managing groundwater is a broad lack of public awareness of groundwater and groundwater issues in the CAGWCD. Despite the criticality of over-pumping and saltwater intrusion into the aquifer system, survey research and subsequent interviews and focus groups have shown that the public is largely unaware of these issues. This research also found a general lack of trust in both industry and government to manage groundwater issues and highlighted the need for groundwater management efforts to be led by unbiased, trusted institutions.

KEYWORDS

participatory groundwater governance, risk perception, saltwater intrusion, Southern Hills Aquifer, survey research, mixed methods research

Introduction

Confined and unconfined groundwater aquifers contain approximately 98% of all readily available freshwater on Earth (Aderemi et al., 2021; Elshall et al., 2022; McCartney et al., 2022) and are the source of approximately one-third of all global water withdrawals (Kundzewicz and Doell, 2009). These withdrawals provide more than two billion people globally with fresh drinking water while also supplying approximately 40% of the world's irrigation needs (Cuthbert et al., 2019; Gleeson et al., 2020). Recent research found that an estimated 80% of the world's population currently faces increasing water scarcity and high levels of water insecurity (Scanlon et al., 2023). Given the limited availability of groundwater and the increasing levels of withdrawal, the measuring, monitoring, and management of groundwater resources is critical to ensuring the sustainability of the world's aquifers, many of which are already subject to quantity shortages, overexploitation, land subsidence, saltwater intrusion, and contamination (Elshall et al., 2020; Aderemi et al., 2021). All of these challenges are becoming more common, making it increasingly difficult to ensure reliable water and food supplies across the planet (Aderemi et al., 2021; Scanlon et al., 2023).

These issues are intensified in coastal areas, which are the most densely populated locations in the world. Potable water security is one of the principal concerns for the health and wellbeing of residents living in coastal areas (Shammi et al., 2019). Nearly half of the world's population resides in coastal areas, and aquifers in these areas provide water to over one billion people (Fienen and Arshad, 2016). Coastal aquifers are particularly vulnerable to saltwater intrusion in locations with a combination of rapid population growth and excessive groundwater withdrawals. The over-pumping of these aquifers incurs the risk of decreasing groundwater levels and simultaneously inducing an upward movement of saltwater from the deep saline zones toward the freshwater interface (Basack et al., 2022). Once saltwater intrudes into an aquifer, it is almost impossible to remediate (Greene et al., 2016). Even when groundwater pumping is discontinued, recharge and freshening of the aquifer can be a relatively long process, ranging from 15 to 10,000 years depending on the local conditions and flow regimes (Green, 2016). Such long periods of groundwater recharge highlight the importance of managing groundwater withdrawals and minimizing the risk of saltwater intrusion.

Groundwater management deals primarily with developing a suite of practical interventions based upon knowledge of biophysical processes and their interactions. A fundamental component of groundwater management, however, as well as one of the primary stumbling blocks to its effectiveness, is groundwater governance (Jakeman et al., 2016). While the terms management and governance are often used interchangeably, there are subtle but important differences between them. Whereas groundwater management deals with practical interventions, groundwater governance deals with an interlinked system of laws, regulations, and customs that often constrain management options. Groundwater governance consists of four key elements: effective institutions that integrate stakeholders; policies that support local, regional, and global resource goals; legal systems with the capacity to create and implement laws effectively; and local knowledge, customary or cultural context, and scientific understandings of groundwater systems (Megdal et al., 2015; Gleeson et al., 2020). As evidenced by these key elements, engaging the public sector, the private sector, and civil society in shaping how groundwater resources are managed and how aquifers are used is vital to effective governance (Megdal et al., 2015).

Regulatory agencies have traditionally operated in an environment in which they monopolize governance. Engaging the public in collaborative environmental governance is often seen as presenting significant challenges due to a perception that engagement processes will lead to inefficiencies in both time and resources (Holley and Sinclair, 2013). However, evidence suggests that the opposite is true and that the inclusion of participatory processes is critical to effective groundwater governance as it ensures that a broad range of interests, knowledge, and perspectives are considered, shared, and understood (Holley and Sinclair, 2013; Jakeman et al., 2016). Participatory processes that combine scientific knowledge of biophysical processes with stakeholder perspectives, preferences, and concerns are well suited to address many of the challenges inherent in groundwater governance (Pierce et al., 2016).

One of the primary governance challenges for groundwater managers centers on the fact that groundwater is a hidden resource that is not visible to the public (Healy et al., 2020). The impacts of over-pumping and groundwater contamination are likewise hidden from view and often overshadowed by the more visible surface waters present in rivers, lakes and reservoirs (Neal et al., 2016; Ross, 2016). This problem is exacerbated when there is a lack of scientific knowledge around groundwater systems. Healy et al. (2020) found that where scientific knowledge is limited and policy is lacking, residents often rely on local knowledge developed through neighborhood and kinship networks to guide their resource usage and decision making, increasing the risk of depletion of groundwater resources. Participatory engagement processes that integrate social sciences into the assessment and management of groundwater resources have been shown to make deep, confined aquifers more "visible" to societal actors and contribute to creating a shared understanding of the need to adopt more integrated management (Rouillard et al., 2022).

Participatory engagement processes can also serve to reduce conflict and build trust among stakeholders, researchers, and decision makers (Jakeman et al., 2016). Competition for water resources is a cause of conflict at many different intensities and scales, with regulatory agencies often forced to simultaneously address threats to water security, human wellbeing and environmental protection (Medrano-Pérez et al., 2022). Groundwater extraction is particularly contentious as aquifers are not constrained by political boundaries. Groundwater extraction on one side of a boundary affects hydraulic heads throughout the aquifer and pumping can draw contaminated water across boundaries (Gorelick and Zheng, 2015). Formal and transparent processes of stakeholder engagement have proven effective in preventing disputes and conflicts surrounding the appropriation, use, and control of water resources (Medrano-Pérez et al., 2022). For these process to gain legitimacy, they must emerge from an iterative, collaborative, and bidirectional exchange of information between stakeholders (Elshall et al., 2020). Such engagement

processes generate opportunities to address misconceptions about the science content, establish a shared learning environment, and increase the likelihood of adoption of effective groundwater management solutions (Pierce et al., 2016).

This study focuses on the role that public understanding and perceptions of risk play in effective groundwater governance. When residents are not fully informed on how or why management decisions that directly impact them are made, they may lose trust in decision-makers. Such distrust, when unaddressed, can often lead to the development of knowledge controversies, wherein the policy practices of government agencies become subject to public interrogation and dispute (Whatmore, 2009). Using a mixed methods approach combining internet-based public survey research, interviews, and focus groups, this study provides insights into the linkages between public perceptions and public trust, and seeks to answer the following questions:

(1) Can understanding how residents directly and indirectly relate to groundwater systems aid decision makers in building public support and developing more effective and sustainable groundwater management strategies?
(2) To what extent does the gap in knowledge between residents and decision makers undermine public trust in management actions aimed at promoting groundwater sustainability?
(3) Does a lack of transparency in environmental planning impede the implementation of groundwater sustainability measures?

Survey research was utilized to gauge aggregate measures of public awareness and perceptions of water quality as well as public support for various water-related regulations. Qualitative research methods, including one-on-one interviews and focus groups, were used to review the survey results with residents and local stakeholders in a structured way and identify potential explanatory factors behind many of the survey results. This combination of quantitative and qualitative research methods allows researchers to gain not only a broad overview of the current state of public perceptions of water quality but also an in-depth insight of the reasons for such a state. These three methods can complement each other, providing researchers with breadth and depth of information.

Groundwater governance in Louisiana's Capital Area Ground Water Conservation District

Louisiana's Capital Area Ground Water Conservation District (CAGWCD) is located roughly 80 miles northwest of New Orleans on the lower Mississippi River. The district includes Ascension, East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge, and West Feliciana parishes (counties) and is home to Baton Rouge, the capital of Louisiana and the second largest city in the state (Figure 1). The region is socioeconomically diverse, with residents residing across the full rural–urban continuum (Wang et al., 2020). Despite the CAGWCD containing the Mississippi River, the 15th largest river in the world by volume, it is heavily dependent on groundwater supplies drawn from the Southern Hills Aquifer System (SHAS) for both public drinking water and to support the petrochemical facilities and energy plants in Baton Rouge's industrial corridor.

The SHAS consists of ten separate water bearing units, each named for their depth beneath the ground surface in the area of historically high intensity pumping, which includes both downtown Baton Rouge and the city's Industrial District, which is home to the fifth largest oil refinery in the United States (Figure 2). These water bearing units include the Mississippi River alluvial aquifer, the shallow sands of the Baton Rouge area, the upland terrace aquifer, the "400-foot" sand, "600-foot" sand, "800-foot" sand, "1,000-foot" sand, "1,200-foot" sand, "1,500-foot" sand, "1,700-foot" sand, "2,000-foot" sand, "2,400-foot" sand, and "2,800-foot" sand of the Baton Rouge area and the Catahoula Aquifer (Heywood et al., 2014). The different sands of the aquifer system are nominally permitted for different uses. Groundwater for public supply is withdrawn largely from the 1,500-foot sand while industrial groundwater usage is primarily drawn from the 2,000-foot sand.

In a region that is surrounded by multiple bodies of water, inundated by seasonal rains, and continually threatened by floods, water is not a resource that residents of the CAGWCD often think of as scarce (Woolverton, 2022). Yet, the district's reliance on groundwater has increasingly led to declines in both groundwater quantity and quality within the SHAS. The current rate of groundwater withdrawal exceeds the natural recharge rate of the SHAS, leading to development of large cones of depression in most of the sands (Hemmerling et al., 2016). These cones of depression have grown significantly over the last several decades and have started to induce saltwater movement across the Baton Rouge fault, which was previously thought to be "an important hydrologic barrier that restricts or limits the volume of saltwater moving northward" (Tomaszewski, 1996). The Baton Rouge fault is one of two important fault zones within the CAGWCD. The northernmost fault zone, known as the Denham Springs-Scotlandville fault zone, is permeable and has minimal impact on groundwater flow in the SHAS. The Baton Rouge fault zone has historically been the southern limit of fresh water in the SHAS. South of the Baton Rouge Fault, the water in the aquifer system is generally saline and not usable for potable water. The specific geological source of the saltwater is debated, though it is most likely drawn from either deep halite layers underlying the SHAS or from salt domes located to the south in Louisiana's coastal zone (Anderson, 2012; Anderson et al., 2013; Hanor and Wendeborn, 2023).

Regardless of the source of saltwater, sustained pumping over the last several decades has created a pressure differential from south to north across the Baton Rouge fault zone, promoting the northward movement of saltwater into areas of lowered head pressure (Runge et al., 2020). Multiple studies have documented the presence of increasing chloride levels, an indicator of saltwater intrusion, on the northern side of the Baton Rouge Fault in the water units supporting public drinking water supply and industry (Meyer and Turcan, 1955; Rollo, 1969; Bray and Hanor, 1990; Tomaszewski et al., 2002; Lovelace, 2007; Anderson, 2012; McInnis et al., 2020).

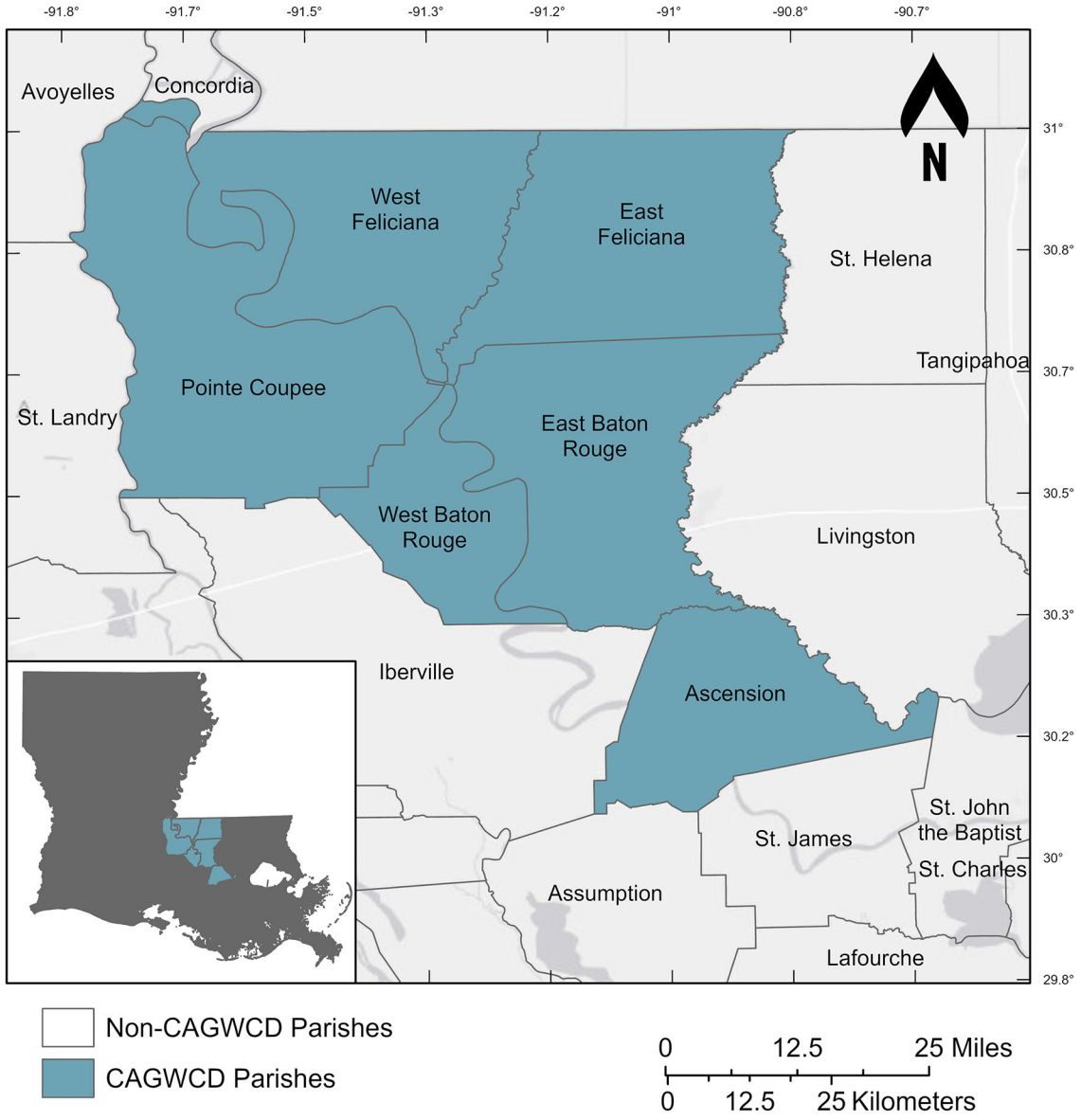

FIGURE 1
The CAGWCD spatial domain. The Baton Rouge Fault is semi permeable to the saltwater south of the fault. Decreases in groundwater pressure north of the fault, enables saltwater intrusion into the SHAS.

Due to concerns in the Baton Rouge region regarding water level declines, saltwater encroachment in several local aquifers, and land subsidence caused by over-pumping of groundwater, the CAGWCD was established and granted legislative authority by Act 678 of the 1974 Regular Legislative Session, which became Louisiana Revised Statutes 38:3071–3084. Section 3071 explains that the creation of the District is "to provide for the efficient administration, conservation, orderly development and supplementation of groundwater resources" of the SHAS.[1] The grants of authority the legislation provided to the Commission includes taking "all necessary steps to prevent intrusion of salt water or any other form of pollutant into any aquifer;" and limiting the production of water from any aquifer "after detailed research, considering both recharge and withdrawal data, when the quality or quantity of the supply of water…is in danger for any reason."[2]

In 2019, a Louisiana Legislative Auditor Report found that the Capital Area Ground Water Conservation Commission (CAGWCC), a group appointed by the Governor of Louisiana to implement groundwater management strategies in the CAGWCD that includes representatives of industry, public supply, and agriculture as well as parish and state government, "does not effectively regulate water withdrawals from the aquifer to reduce and manage saltwater encroachment and ensure the sustainability of fresh groundwater for the future" (Louisiana Legislative Auditor, 2019). Shortly before to the release of this report, the CAGWCC began development of a long-term strategic plan to achieve and

1 Louisiana Revised Statutes 38:3071, 2019.

2 Louisiana Revised Statutes 38:3076, 2003.

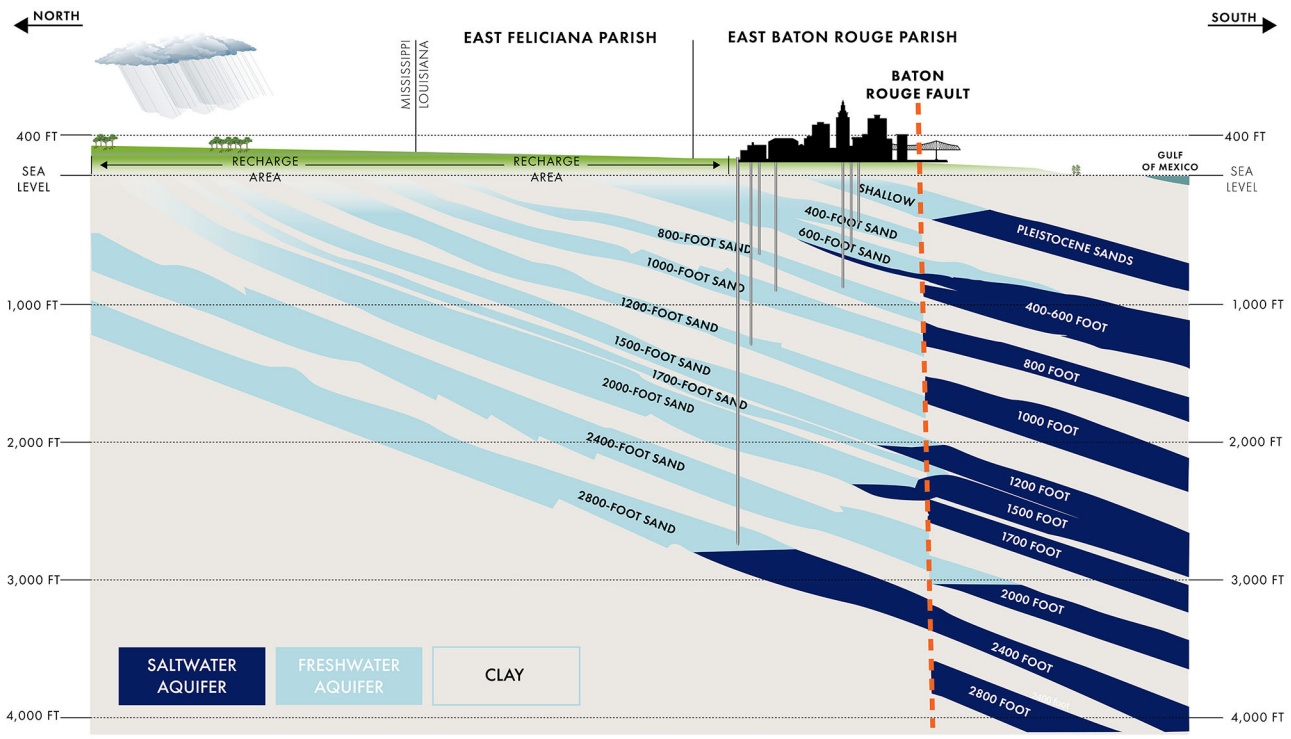

FIGURE 2
Sands of the Southern Hills Aquifer System. The Baton Rouge Fault is semi permeable to the saltwater south of the fault. Decreases in groundwater pressure north of the fault, enables saltwater intrusion into the SHAS.

maintain sustainable and resilient groundwater withdrawal rates within the CAGWCD.

The primary purposes of the strategic plan are to promote long-term sustainability of groundwater extraction, long-term planning by water users, and clear communication with the public, requiring a deep understanding of both the scientific processes that shape and form the aquifers and the stakeholder perspectives, preferences, and concerns that govern their usage (Runge et al., 2020). The development of this strategic plan is legislatively limited, such that any actions taken by the CAGWCC cannot "have the effect of in any way denying to any owner of the land or any other person holding rights to water derivative from any landowner a reasonable opportunity to produce and beneficially use his just and equitable share of the groundwater supply" (Louisiana Revised Statutes 38:3076, 2003). In recognition of the CAGWCC's authority to take groundwater management actions as well as the legislative limitations on these actions, development of the strategic plan includes an assessment of public awareness and attitudes around groundwater and groundwater management in the CAGWCD.

Materials and methods

The mixed methods approach in this research employed a sequential explanatory design model consisting of two phases. The first phase involved the implementation of an internet-based survey, followed by a qualitative phase aimed at explaining and enhancing the quantitative results. The qualitative phase employed a combination of one-on-one interviews and focus groups. The sequential explanatory mixed methods approach is valuable for identifying specific quantitative findings, such as unexpected results, outliers, or differences between groups, which require further exploration using qualitative methodology (Doyle et al., 2009). Although the sequential explanatory design model served as the principal mixed methods framework for this research, the one-on-one interviews and focus group research followed a concurrent triangulation design. In this design, the interview and focus group phases occurred simultaneously, with both methods given equal weight in the analysis (Doyle et al., 2009).

Finally, the results of each research phase were presented to the CAGWCC through a series of facilitated forums. The purpose of the facilitated forums was to provide the CAGWCC with the necessary background data needed to make informed decisions about the management of the SHAS. In each facilitated forum, CAGWCC members were provided with the results of the analysis. The research team gave in-depth, technical presentations on the primary topic, which was followed by a discussion between the research team and CAGWCC members led by a third-party facilitator. The presentations were provided to the CAGWCC for further review after each session.

Survey methods

In the fall of 2021, the research team conducted a public internet-based survey among individuals residing within the

CAGWCD. This survey focused on public awareness of water resources, as well as perceptions of water cost, quality, and quantity. The survey was designed by the lead authors and consisted of 11 sociodemographic questions and 33 water-related questions and was administered by Qualtrics, a commercial survey sampling and administration company, from October 19, 2021 to November 1, 2021. A necessary survey sample size was calculated using the formula by Smith (2020), determined by the population size, confidence level corresponding to a Z-score, margin of error, and standard deviation. With a total population of approximately 640,000 within the study area, an ideal survey sample size would be 382 in order to fall within a 5% margin of error. Given the relatively small area represented by the CAGWCD, it was difficult to obtain this ideal number of complete responses through online survey while at the same time ensuring representation from all major demographic groups. In the end, 305 complete responses were obtained, falling between a 5% and 6% margin of error.

Survey respondents were drawn from the Qualtrics sample pool, which consists of both traditional and actively managed market research panels. These panels are composed of individuals who decide to participate in the online survey through a double opt-in registration process, first through random selection via a web-based advertisement or email link and then through the panel member agreeing to take the designated survey. As a result of this double opt-in registration process, online surveys are considered non-probability surveys (Shao and Kam, 2020). A non-probability survey is based on non-random sampling to select a group of participants for the survey. As a result, not every member of the population has an equal probability of being selected into the survey. With consistent low response rates found in traditional probability surveys, non-probability surveys have grown in popularity in recent years due to their cost-effective and timely features. Additional benefits associated with online surveys include eliciting honest and accurate responses to sensitive questions that traditional phone surveys cannot due to individuals' willingness to respond more openly to online surveys (Chang and Krosnick, 2009).

The survey research utilized parish of residence, age, race, ethnicity, and gender as screening questions to address the need for quota sampling of the study area and to determine how representative the sample is in comparison with the underlying population. Further, these sociodemographic characteristics as control variables in inferential analyses. There were some noticeable discrepancies of compositions in gender, age group, and ethnicity between the survey sample and the population of the CACWCD. Often, the sociodemographic composition of a non-probability sample, due to its non-random selection process, is different than that of the population and cannot be considered representative of the population without some adjustment. For this research, raking adjustment, matching, and propensity were used to account for the discrepancy between the sample and the population of the CAGWCD (Kennedy et al., 2016). Despite being the most basic weighting method, raking—which is the process of adjusting the sampling weights of the survey sample so that the marginal totals of the adjusted weights on specified control variables agree with the corresponding totals for the population—has been found to perform as well as more sophisticated methods when weighting online opt-in samples (Battaglia et al., 2009; Mercer et al., 2018). A stepwise adjustment known as iterative proportional raking was thus utilized to obtain probability weights for point estimates in this study (Bergmann, 2011).

Qualitative research methods

In August 2022, the research team presented the results of the public survey to the executive director of a community-based environmental organization based in Baton Rouge and solicited recommendations for individuals to take part in interviews or focus groups to provide deeper insights on the survey results. In September 2022, they virtually presented the same survey results to a larger coalition of civic and community leaders from the Baton Rouge area that addresses the issues facing low-income residents, again inviting members to provide feedback through either interviews or focus groups. In designing the interview and focus group methodology, the research team did not aim to achieve thematic or data saturation (Hennink et al., 2019). Each individual or community-based organization that reached out to the research team was provided with an opportunity to participate in the research. Between November 2022 and January 2023, the research team conducted five one-on-one interviews with individual residents of the CAGWCD and facilitated three focus groups with members of local non-profit and community-based organizations, religious congregations, and young professionals groups. Each focus group consisted of four to seven residents representing a range of concerns and interests, including environmental stewardship and education, social justice, community service, and support for small businesses. One interview was conducted virtually via Microsoft Teams video call (Microsoft Corporation, 2023), while the remainder of the interviews and all of the focus groups were conducted in-person.

The goal of the interview and focus group sessions was to identify explanatory factors behind the public survey results. In each session, the research team provided background on the CAGWCC, the strategic planning process, and how the qualitative research would inform the planning process. Participants were also provided with details regarding the public survey, including sample size and demographics of survey respondents. The research team then presented the results of each of the individual survey questions and facilitated discussions with participants to gauge their reactions and collect data as to why participants believed that survey respondents may have answered as they did. Through this process, the research team also collected qualitative data from interview and focus group participants on their own awareness, attitudes, and preferences for water management strategies as well as their willingness to take steps to conserve water resources. In the focus group sessions, the research team also conducted an anonymous, informal survey on specific water conservation measures to gauge support for potential solutions and policy options in the CAGWCD.

Data derived through the interviews and focus group conversations were audio recorded with the permission of participants. Participants were informed that that their responses would be kept confidential by the research team and that neither they nor their organizations would be identified. Following

each engagement activity, the research team transcribed, coded, and transformed the audio recordings into qualitative data that was then analyzed to detect underlying themes in the dialogue (Hemmerling et al., 2022). Otter.ai software (Otter.ai, 2021) created the initial transcriptions of the audio outputs from the in-person engagement activities. The single interview conducted via video call utilized the built-in recording and transcription functions of Microsoft Teams, which provides more sophisticated capacities for clarity in recording and transcribing than technology-assisted transcription tools (Keen et al., 2022). Technology-assisted transcription tools such as Otter.ai have particular advantages for transcribing audio from focus groups. However, effective transcription requires verbatim transcription and determining which participant is speaking from group recordings containing overlapping voices is difficult for many technology-assisted transcription tools (Keen et al., 2022). To ensure verbatim transcription, one author listened and re-read the transcripts to ensure accuracy with a selection verified by another author (Williams et al., 2023).

Following transcription and review of the qualitative data outputs, the transcripts were imported into MaxQDA qualitative data analysis software (VERBI Software, 2021) to identify and code key themes and takeaways from the interviews and focus groups. The process of assigning codes to raw data is an integral part of the qualitative data analysis process. This research utilized a set of structural codes based upon the results of the public survey, focusing on several themes and sub-themes related to groundwater quantity, quality, and cost. Structural codes are drawn from a project's research goals and questions, unlike data-driven codes that emerge from the raw data or theory-driven codes arising from existing theory or concepts (DeCuir-Gunby et al., 2011). During the coding process, the research team also identified additional data-driven codes that emerged from the raw data. This process sought to make connections between the quantitative outputs of the public survey and the ideas and concepts expressed by interview and focus group participants and identify any causative factors that might underlie the survey responses.

Public meetings and facilitated forums

Following the completion of both the survey research and the participatory engagement activities, the research team presented the results from each research phase to the CAGWCC through a series of meetings and facilitated forums. In the facilitated forums, the research team gave in-depth, technical presentations on the primary topic, which was followed by a discussion between the research team and CAGWCC members, led by a third-party facilitator. These forums were structured to provide the CAGWCC with the necessary background data needed to make informed decisions about the management of the SHAS. Following the facilitated forums, CAGWCC members were provided with the results of the analysis as well as all presentation materials for further review.

The results of the public survey were presented to the CAGWCC on February 24, 2022. This was the fourth in a series of facilitated forums, following presentations on the legal aspects of groundwater management, economics and potential economic impacts of groundwater management decisions, and aquifer dynamics and the environmental modeling of groundwater availability. These initial forums were designed to provide the CAGWCC with the necessary technical background information needed to make informed decisions about the management of the SHAS. Building from these management-related facilitated forums, the fourth forum shifted the focus to issues of groundwater governance and the societal and community impacts of water management decisions made by the CAGWCC. Through the facilitated discussions, the research team and CAGWCC members sought to identify areas of interest and concern arising from the results of the public survey as well as aspects of the data that warranted further analysis through interviews and focus group meetings with stakeholders. In addition to the facilitated forums, the research team presented the results of the survey to the CAGWCC during a public meeting held on September 15, 2022. This meeting coincided with presentations made to civic and community leaders from the Baton Rouge area and provided additional feedback on the public survey and were used to inform the interview and focus group research.

Results

Public awareness of groundwater

Survey results show that an overall lack of awareness of groundwater and groundwater issues exists within the CAGWCD. While the majority of survey respondents were able to correctly identify the supplier of their household water, few were able to identify the source of that water. Over two-thirds of survey respondents identified their water supplier as a private water company (Figure 3). The Baton Rouge Water Company, which operates 66 deep wells in the SHAS ranging in depth from 600 to 2,800 feet to provide water throughout the CAGWCD, is a private company. Several interview and focus participants thought that the Baton Rouge Water Company was a municipal water supplier and expressed surprise that, given Baton Rouge's population of over 222,000, water provision is not municipally run. One participant remarked that "you would think that a city the size of Baton Rouge would own its own water" while another stated that "it's just amazing to me that a city that's not—because I've never lived where the water company was private."

While the majority of survey respondents could identify their household water supplier, 72% of them could not correctly identify the source of their household water as groundwater (Figure 3). This result stands in contrast with the data obtained from interview and focus group participants, for which the majority of whom knew that groundwater was the source of their household water. Many participants said that they were not surprised by the survey results, however, and offered several possible explanations as to why such an apparent knowledge gap might exist. First, several participants claimed that the terminology surrounding the topic of groundwater could be a source of confusion to the general public. One participant noted that "when you say groundwater to the average person, they think immediately you're talking about the water that's the runoff rainwater. That's groundwater to regular

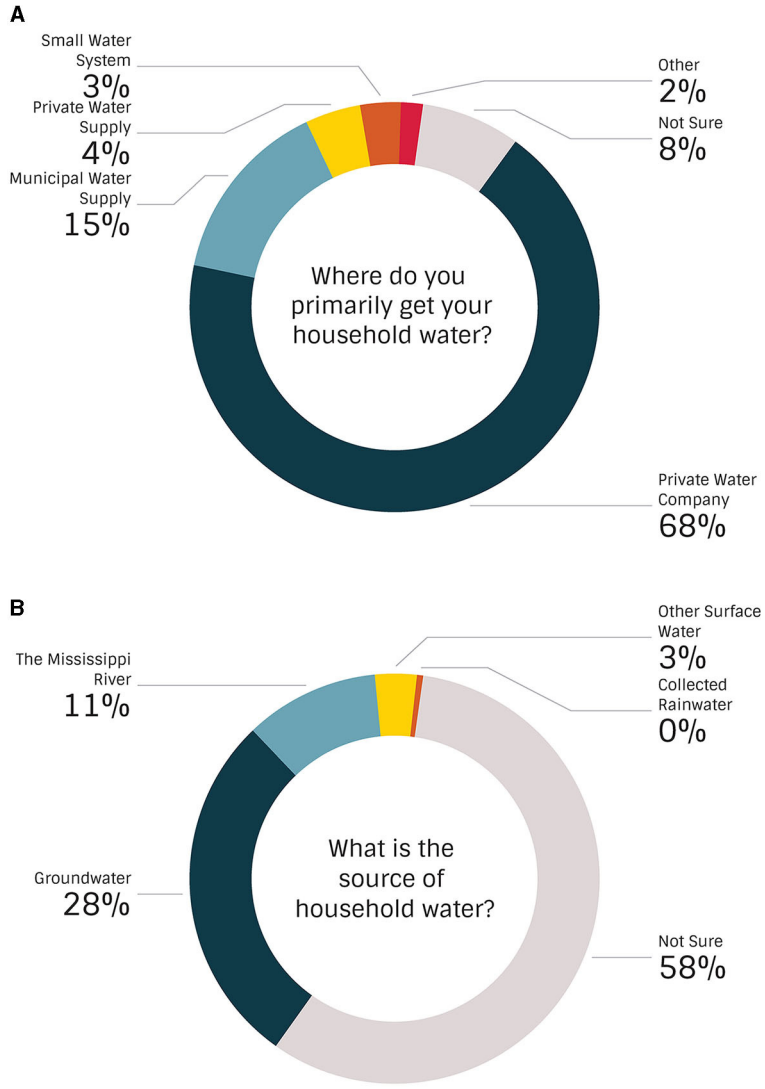

FIGURE 3
Public awareness of household water supplier **(A)** and source **(B)** in the CAGWCD.

people…I don't know what the survey says, but that could be very confusing."

Interview and focus group participants also noted the use of several interchangeable or alternative terms for the word "groundwater" as another possible reason for why some survey respondents might have said that they were "not sure" about the source of their household water. One participant stated that "I would have guessed groundwater because I don't know what an aquifer would be." When asked to suggest alternative terms that could be used in place of "groundwater," participants stated a preference for "well water," as the term "aquifer" might "make it even more complicated because then you'd have to […] explain what the aquifer is."

Of the interview and focus group participants who correctly identified their source of household water as groundwater, some were unsure if groundwater was their *only* source of water. As one participant stated, "I knew it was groundwater, but I thought we were already pumping river water in some ways, through Baton Rouge." Therefore, despite awareness that groundwater is their primary source of household water, some participants believed that river water is supplemental and utilized for certain household purposes.

Public perceptions of household water

While survey respondents were largely unable to identify the source of their household water, their perceptions of this water is overwhelmingly positive, with a large majority of respondents indicating that taste (72%), appearance (88%), odor (77%), and feel (85%) are good or excellent overall (Figure 4). When asked how the quality of their household drinking water had changed over the past 5 years, 68% of respondents believed that it was "the same," with another 15% stating that it was "better" now than it was 5 years ago. The positive perceptions of groundwater expressed by

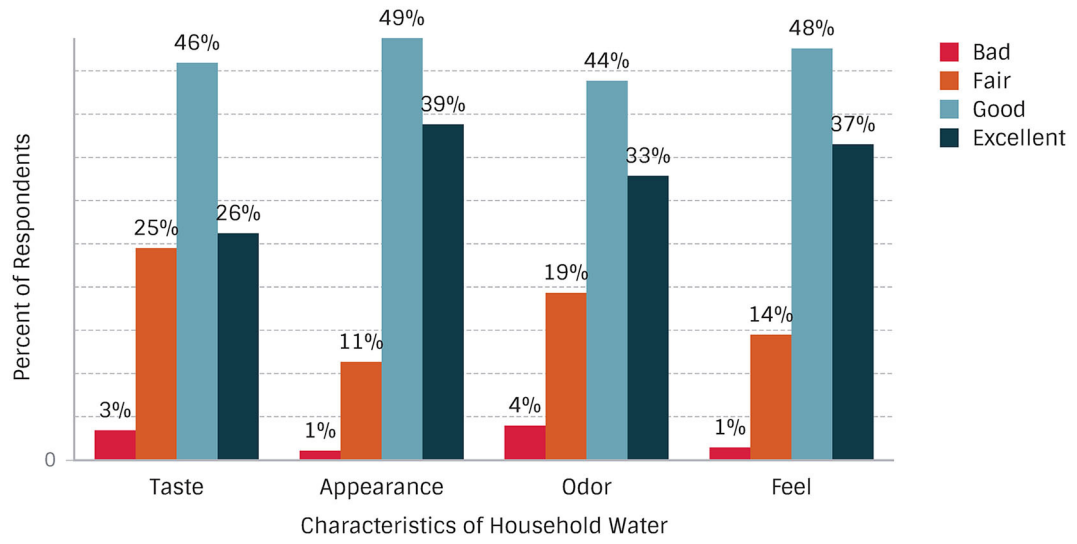

FIGURE 4
Public perceptions of household water characteristics in the CAGWCD.

survey respondents were closely aligned with those expressed by interview and focus group participants. Likewise, most interview and focus group participants indicated that they have not noticed any changes in the quality of their drinking water over the last 5 years. Mirroring the survey results, some interview and focus group participants noted that they have experienced positive and negative changes in the perceived quality of their drinking water over time. When questioned, interview and focus group participants provided more nuanced responses, with several participants noting that changes in drinking water quality are tied to several factors external to the actual quality of the water in the SHAS. Specifically, participants noted that the quality of one's household drinking water is directly related to the quality of the water delivery system. Several noted that the replacing of water pipes and infrastructure following a major flood event that impacted Baton Rouge and the surrounding parishes in 2016 resulted in notable improvements in the quality of their household water. Others highlighted that moving into a different home with aging pipes could likely change one's perception of their drinking water. Conversely, moving into a newer house or renovating the plumbing in one's current house can directly impact perceived water quality. Overall, interview and focus group participants noted that these and other external factors can directly contribute to the perception of household water characteristics and quality, making it difficult to measure and attribute variations in perception over time.

Public perceptions of household water quality and characteristics were more clearly revealed through survey questions and focus group discussions centered on the perceived quality of groundwater compared to surface water (Figure 5). Overall, survey respondents indicated that their perceptions of groundwater were more favorable than their perceptions of surface water, with 62% believing that the quality of groundwater was either "good" or "very good" compared to 45% who rated surface water equally. To avoid survey bias, the distributed survey instrument did not ask respondents to compare their household water to that of other specific cities. However, during the interviews and focus groups, participants were asked how household water in the CAGWCD compares to that of New Orleans or other nearby cities and their responses were revealing.

Despite some interview and focus group participants reporting issues with their household water, all strongly preferred Baton Rouge water to that of any other city. The preference for Baton Rouge water was particularly notable when compared to the perceived quality of water in New Orleans, which is comprised of treated Mississippi River water. Many participants admitted that they will not drink tap water when visiting New Orleans. As one participant stated,

> My husband doesn't even want us to brush our teeth in the water in New Orleans. And he has family [living] there. And when his mother was alive, he put giant filters on all of her faucets because she cooked rice and she brushed her teeth, and she made tea. And it was all nasty.

Multiple participants suggested that the threat of switching from groundwater to treated Mississippi River water as the CAGWCD's primary source of household water would be a strong motivator for enacting change and increasing public awareness.

> Another thing you can tell people about the water, kind of get them more interested in like our water quality here, a lot of people in Baton Rouge travel to New Orleans, I guarantee about 95% of the population here has been to New Orleans more than one time. And they definitely know about the water. So, if we all bring up this in regular conversation, an "if you didn't know, but this is the reason is because New Orleans drinks out of the river and we don't, but the river's there, we'll be drinking out of it soon." Then they change their mind…

Interview and focus group participants suggested that the aversion to drinking "New Orleans water," (i.e., river, or surface water) has also persisted in populations that have moved to Baton

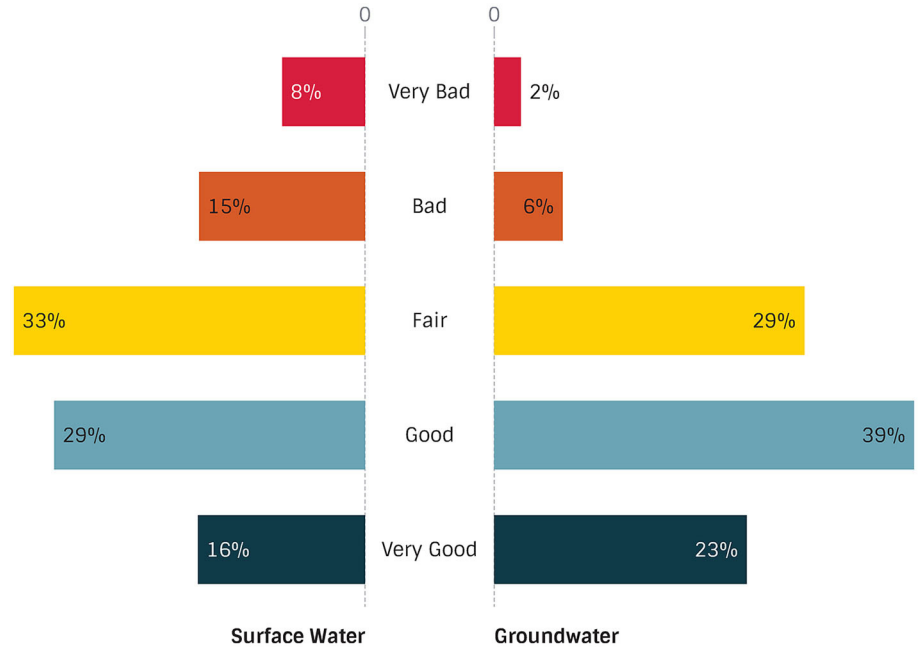

FIGURE 5
Public perceptions of surface water vs. groundwater quality in the CAGWCD.

Rouge from the New Orleans area. For example, two participants moved from New Orleans to Baton Rouge as adults and credited New Orleans' "constant boil water advisories" for "definitely turn[ing] all of us off toward ever drinking out of a tap." Although one of these participants now drinks filtered tap water (in Baton Rouge), the other participant will not despite years of residency in the CAGWCD. A participant in a separate focus group echoed this sentiment and suggested that this issue exists on a larger scale:

> [A]ll the people [that] moved to the greater Baton Rouge, or to the District area, the nine parish area, after Katrina [were] drinking bottled water before they came and continue to drink [it] and that's a large number of people you know, because I mean it's not only City of New Orleans, it's St. Bernard, you know, North Shore. Everybody who was affected by Katrina, probably all drink bottled water. A large percentage of them.

The perception that tap water is not safe to drink could help explain why, while the vast majority of survey respondents held positive views of their household water quality, 37% still filtered their tap water and 66% primarily used bottled water for drinking (Figure 6) within the CAGWCD. These results were largely mirrored in discussion with interview and focus group participants. Many respondents noted that they filter their tap water before drinking it. Most participants also stated that they also primarily use bottled water themselves.

Whether due to actual risk or the perception of risk, most participants expressed that, while the convenience of bottled water is certainly a consideration, safety was the primary factor in choosing to drink bottled water over tap water, which some participants based on distrust of the distribution and delivery infrastructure (pipes both leading to and inside their homes). Participants without direct, personal experience with household water issues cited Flint (Michigan), Jackson (Mississippi), and St. Joseph (Louisiana) as examples of cities with infrastructure and management failures that led to unsafe, contaminated drinking water. Participants expressed concern that similar failures could occur locally, particularly in a landscape as heavily dotted with industry as the CAGWCD. One participant added, "you never know what's going on overnight, or what problems may exist around here with industry. So to be safe, the best thing to do is drink, use bottled water for drinking."

Public awareness of threats to groundwater

Although the preference for bottled water can be attributed to a variety of factors and not exclusively to safety concerns, fear of the distribution infrastructure or other water quality issues described by interview and focus group participants may partially illustrate why survey respondents perceived aging water and wastewater infrastructure as the greatest risk to their household water, with 64% viewing it as a problem to some degree (Figure 7). Survey respondents perceived contamination of water sources as the second highest threat at 57%, and 58% expressed at least some degree of concern about the quality of drinking water in their area.

Despite the ongoing issues faced by the CAGWCC related to saltwater intrusion into the SHAS, only 47% of survey respondents considered saltwater intrusion to be a problem, the lowest combined total of all other possible threats listed. One interview and focus group participant speculated that the general public likely thinks saltwater intrusion is "something from when you go in the ocean." Another participant speculated that the lack of knowledge

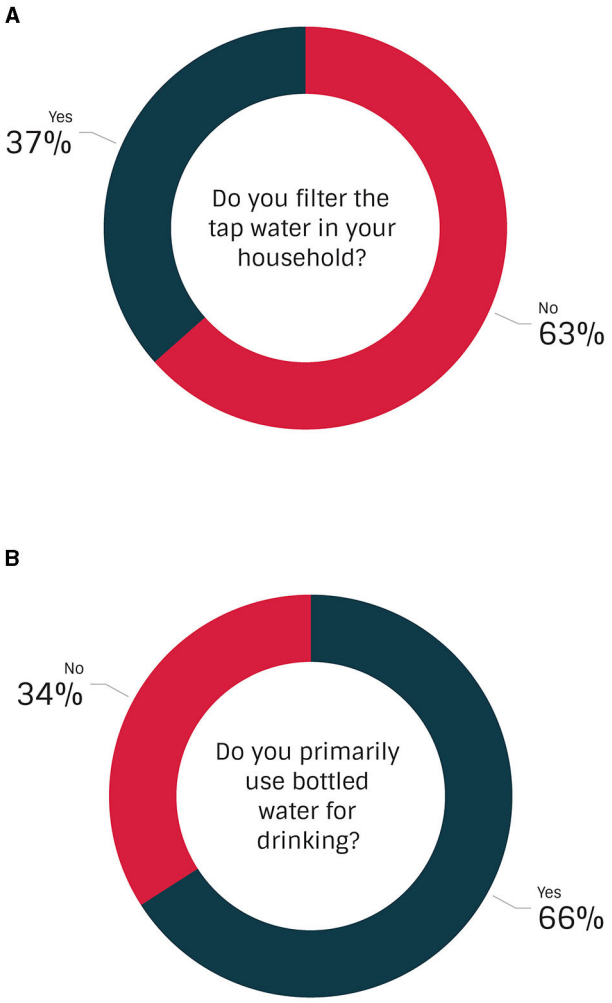

FIGURE 6
Public use of filtered **(A)** and bottled **(B)** water for drinking in the CAGWCD.

surrounding saltwater intrusion is to be expected when so many respondents could not correctly identify groundwater as the source of their household water, particularly since other public issues (e.g., crime, traffic) are prioritized over water. When asked where water management issues might rank among public issues of priority, this participant, a regional planner, stated,

> Crime, traffic, some other stuff, water…it's definitely not saltwater intrusion. That's not what was the problem in Flint. So why would we think there's a problem here? You don't even know that we had groundwater. We think it's coming from the Mississippi.

Similarly, despite the risk of over-pumping of the SHAS, the availability of drinking water does not appear to be a concern among a substantial proportion (57%) of survey respondents (Figure 8). When asked specifically about whether they perceived depletion of their household water source as a problem (Figure 7), 49% of survey respondents either indicated that it was not a problem at all (29%), or they were unsure (20%) whether it was a problem. When questioned on this knowledge gap between groundwater managers and residents of the CAGWCD, interview and focus group participants pointed to the visibility and apparent abundance of water, the constant threat of flooding, and the devastating floods of 2016 as explanations for why many respondents did not perceive water availability as a concern. However, interview and focus group participants estimated that results may change if the survey was conducted during one of the numerous heat waves and droughts that southeast Louisiana experienced in recent years. As one participant noted in January 2022, more than a year after the public survey was distributed,

> Right now, I think we're on the cusp of something serious happening. Because if you look at the water table just across, you know, the Mississippi River and drought…I've lived here since '62. I've never seen water that low in my lifetime.

Interview and focus group participants suggested that prior to the drought, water scarcity was difficult to fathom, but recent dry conditions have raised awareness of water management issues and many expressed concerns over the possibility of having to drink river water if groundwater is depleted. One participant pointed to drought as a possible motivator to shift public attitudes from "not concerned" to at least some degree of concern regarding availability.

> You [turn the] tap on, the water's there and you just think everything is fine. And there's not this sense that there could be a problem. And I think in starting to have droughts or whatever, then you start to worry about it.

Participants also voiced concern around over-pumping of the aquifer by industry. While roughly half (47%) of the survey respondents believed that public supply was the biggest consumer in the area, followed by industry at 26% (Figure 9), nearly all interview and focus group participants assumed that industry is the largest user of water. Many participants expressed frustration over a perceived lack of monitoring and oversight of industry's water usage; several suggested that industry should be required to use river water for certain purposes to avoid depletion of groundwater.

> Participant 1: Another aspect about the industry is their usage of like ExxonMobil cooling towers, they don't need clean water. They don't need tap water. They can use river water to do that.
> Participant 2: It costs more money.
> Participant 1: Well, it's gonna cost all of us more money. And them too, in the end.

In addition to concerns over future costs, many interviews and focus group participants are fearful of the long-term implications of groundwater depletion, namely that their descendants would one day be required to drink river water.

> I was in a meeting…and they were talking about industry, you know, using Mississippi water to cool their industry instruments and other things that they were doing that you know some believe was causing fish kills…they said that it was much, much less expensive to use city water than to use the Mississippi water because they'd have to purify it before it could be used on their instruments…they are thinking that for iron

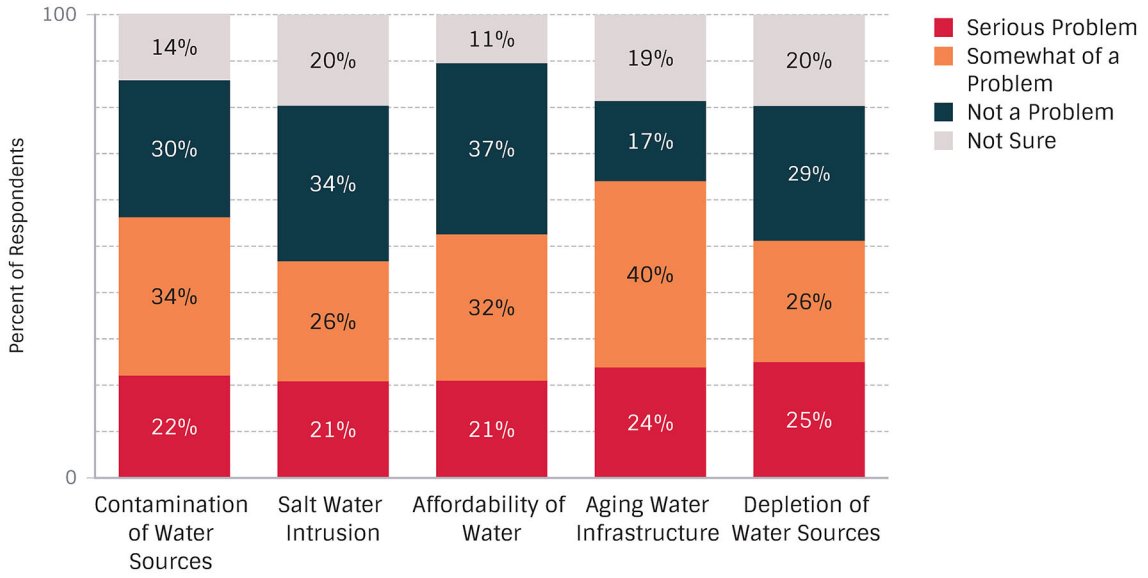

FIGURE 7
Public perceptions of risk to household water in the CAGWCD.

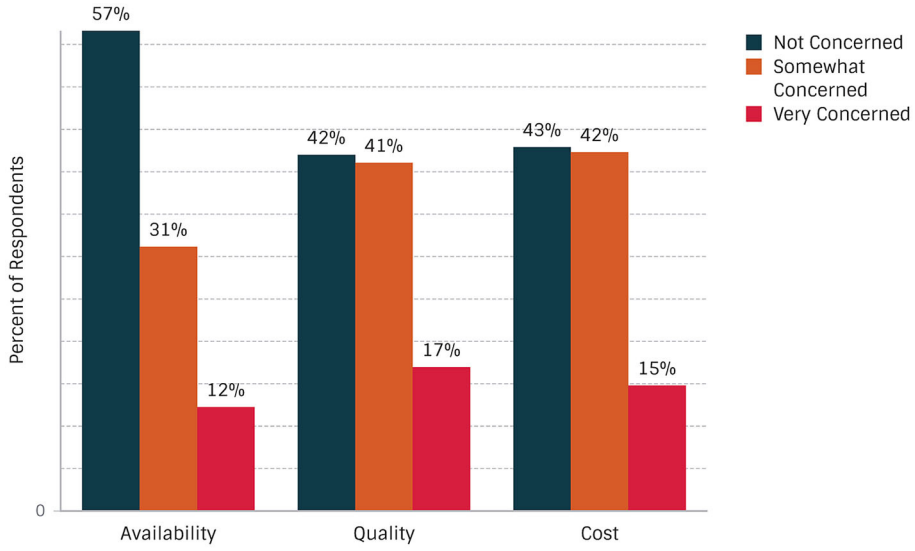

FIGURE 8
Level of concern on water availability, quality, and cost in the CAGWCD.

> and metal it's not good…so I hate to think of a future [where] my grandchildren, great- grandchildren will be forced to drink the water that today industry is rejecting.

Seventy-eight percent of survey respondents reported that they had not read or heard anything about groundwater management in the CAGWCD Of those respondents who had heard about groundwater management issues, nearly half received their information from newspapers while almost a quarter of respondents heard about groundwater issues on television. Interviews and focus groups revealed potential differences in news sources based upon age group. While participants of all ages claimed to consume news from both local and national media outlets, older participants found local newspaper and television reporting to be "more reliable" than other news sources. Several participants mentioned reading groundwater articles in the local Baton Rouge news outlet, *The Advocate,* "every few years," but did not recall seeing any recently, which some participants pointed to as a greater challenge, namely that without being in a crisis, people are not aware there is an issue. As one participant summed,

> If you open the paper or watch TV news […] you probably have 50 articles on crime, and in the average week, none on water. And there's this critical mass of when you put out enough information that the public actually wants to know more, then the news spreads or the amount of news spreads. People want

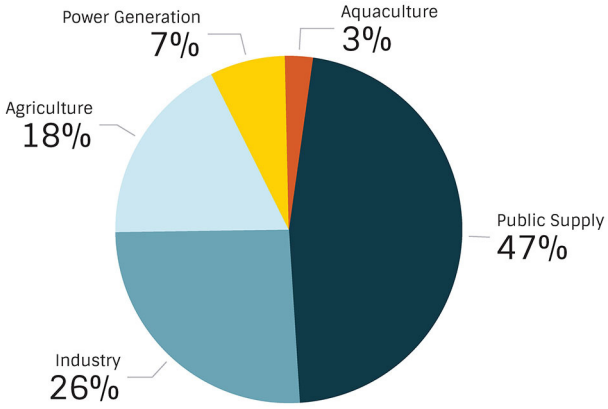

FIGURE 9
Public perception of the largest consumer of water in the CAGWCD.

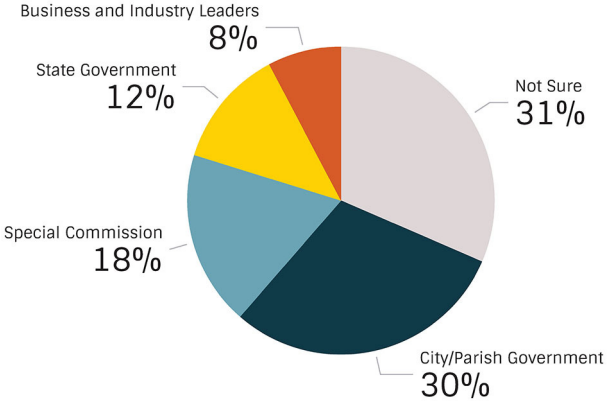

FIGURE 10
Most trusted entity to manage groundwater in the CAGWCD.

> to know about crime, traffic, education, and [...] you know that repeats itself. Water, we aren't there, yet. And there's no information coming out and therefore nobody cares.

Younger participants conversely reported receiving their news from national media outlets. These news sources were often consumed digitally and are presented in consolidated formats. One participant cited as an example *The Daily*, a 20-min daily news podcast provided by the *New York Times*. This news format is not well suited to report on local and regional issues and typically does not report on local news stories, including any discussions on regional groundwater management.

Despite differences in how they received news, several participants cited an overall lack of trust in news media and questioned the ability of the news media to effectively relay unbiased groundwater management information on a broader scale. One participant noted that "there's so much conflicting information out there and misleading information that it's hard for anybody to really know what's going on." Several participants therefore expressed a need for messaging from an unbiased, trusted group to circumvent this perceived lack of trust in media outlets. Many indicated that while news outlets are still relevant and important for disseminating information about groundwater, a targeted campaign might be more effective in achieving desired results and reaching a broader audience.

A targeted, coalition-building campaign that "[leans] into invested institutions" that includes an advertising component with educational pieces through direct mail was recommended for its potential to "elicit a little bit more weight." Interview and focus group participants offered examples of groups that could be trusted to deliver an unbiased, independent message on groundwater management issues that might be acceptable to all members of the community. Groups mentioned by participants include the Recreation and Park Commission for the Parish of East Baton Rouge, Louisiana State University AgCenter, and the Brighten Up Baton Rouge Task Force (aka "The Litter TaskForce" and/or "The TaskForce"). Churches and schools were also identified by some as trusted organizations that could be relied upon to communicate this information more broadly. Participants suggested that these trusted groups should coordinate with other similarly minded groups and cross populate on social media to further spread messaging on groundwater issues in the CAGWCD.

Public support for groundwater management

When asked who should manage a serious risk to groundwater, the survey results showed that city and parish government garnered the highest amount of trust among respondents, at 30%, while an almost equal number of respondents (31%) were unsure as to who should be trusted to handle these issues (Figure 10). Industry leaders and state government garnered the least support among survey respondents, with only 8% and 12% of respondents, respectively, selecting them as the most trusted entities to manage a serious threat to groundwater resources.

Eighteen percent of survey respondents felt that a special commission would be the most trusted entity to manage a threat to groundwater resources. When questioned on this issue, many interview and focus group participants stated that a special commission or task force filled with experts who have enforcement authority would garner the most trust and support, although most recognized that implementing this option would be challenging. One participant explained the complexity of water governance as a possibility for why nearly one third of respondents were unsure.

> Normally, I would say city-parish government, but because it's a multi-parish issue, like that isn't really feasible. State government is not very functional and then special commission. The issue there is like you would have to be structured in a way where it actually has the ability to do something, which is usually an issue because commissions are formed and the people are gathered at the table and they have all these ideas, but then they don't have jurisdiction to do anything about it... it's a generally tough question because I also wouldn't trust business and industry leaders because industry is primarily causing the problem.

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Another participant reasoned that the 31% of respondents selecting "not sure" was really a referendum on the city-parish government.

> In theory, I think what the public is saying, they haven't really seen the city-parish demonstrate that they can handle anything. Or any kind of crisis like that. I think that's what the people are saying. And I think most people would want it to be a local role to hopefully manage. I agree that it'd be better to keep it local.

Interview and focus group participants also noted that several survey respondents likely did not realize that the Baton Rouge Water Company was a private company and not a public utility; nor did many of the participants realize this themselves prior to discussions with the research team. These participants pointed to this as a possible reason for why nearly one third of all survey respondents selected city-parish as the entity that would be most trusted to manage a serious threat to groundwater resources. As one participant stated, "most people probably already think, with the Baton Rouge Water [Company], with the name and everything, they probably already think that it's city-parish" and that the city-parish would therefore be the most trusted entity to manage a threat to groundwater in the CAGWCD.

When asked about the cost of their water bills, 61% of survey respondents noted that they thought they were "about right" while 35% thought that they were "high." Despite the fact that only 5% of survey respondents felt that their water bills were low, just over 50% of respondents reported that they would be willing to pay more to guarantee safe drinking water (Figure 11). Of these, nearly half (49%) stated a willingness to pay $5 more per month, with 19% claiming they would pay $5 to $10 more per month to guarantee safe drinking water, indicating that guaranteeing drinking water safety is a priority among residents of the CAGWCD.

The distributed survey instrument did not include current monthly water rates in the CAGWCD so as to avoid survey bias, nor were they asked to compare their monthly rates with those of other cities. However, during interviews and focus groups, participants were provided with the current Baton Rouge Water Company rate structure to serve as a conversation prompt with participants. In 2022, the monthly rate structure was $2.933 per hundred cubic feet for the first three hundred cubic feet of water used, $1.253 for the next 197 hundred cubic feet, and $0.761 for each additional hundred cubic feet used (Baton Rouge Water Company, 2022). Many participants pointed to lower rates at higher tiers of usage as incentivizing increased use:

> Participant 1: I think you're incentivizing volume sales to volume users because it's a known line item. You know how many gallons ExxonMobil and Honeywell are gonna use every single year with relatively accurate ability. [. . .]
>
> Participant 2: Yeah, this is, the way they incentivize it, it's not helping. It's not helping the problem.

Some interview and focus group participants also took issue with the phrase "to guarantee safe drinking water" (Figure 11), with many believing that their current payments should already

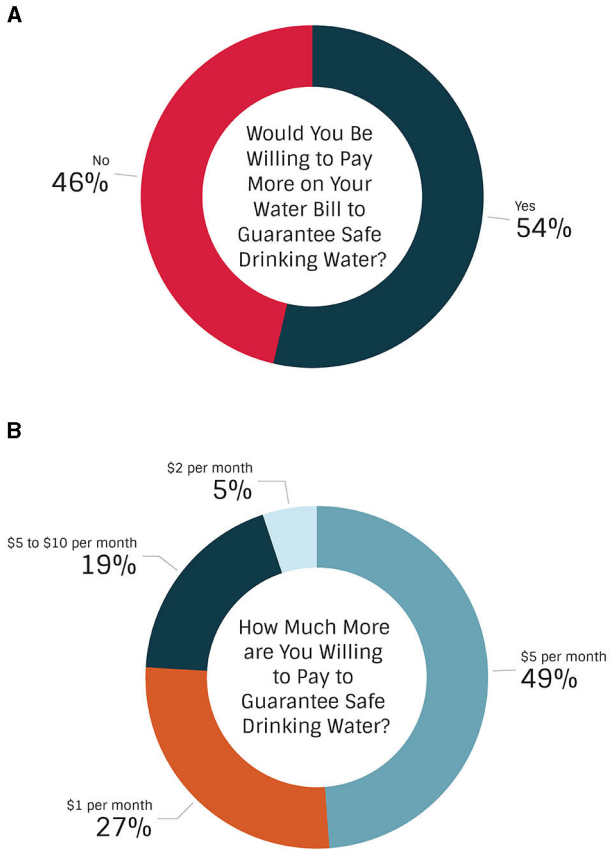

FIGURE 11
Willingness to pay **(A)** and amount willing to pay **(B)** to guarantee safe drinking water in the CAGWCD.

be guaranteeing safe water. As one participant expressed, "I mean, you're already paying for your water, so why should you have to pay extra for clean water, since you're supposed to be paying for clean water right now?"

Participants in one focus group stated that they were willing to pay more, but wanted more security in what their additional payments would guarantee.

> Participant 1: I already have safe drinking water so. . .
>
> Participant 2: What can you guarantee me? In Baton Rouge, if they want to guarantee something. [Laughter]
>
> Participant 3: Like, update all the 50 year-old to 70 year-old piping? Like if that's gonna be this whole initiative, then yes, yeah.
>
> Participant 1: If they're gonna pay for ExxonMobil to have new water-cooling infrastructure installed that draws off the river on my dime, then no.
>
> Participant 3: The executives get like a pay raise, then no.
>
> Participant 1: No, I would not mind paying a little more to invest in Baton Rouge's own water infrastructure. . .
>
> Participant 2: I'm not paying for Exxon to just retool themselves.

Others believed that willingness to pay more to guarantee safe drinking water does not fully articulate the consequences of

aquifer depletion and the potential of losing groundwater as the primary source of drinking water. One exchange between focus group participants highlights this issue.

> Participant 1: Those were the individual homeowners that were willing to pay more? You know, to me, it's a little deeper question. Another question, I would say to preserve and maintain drinking water…how much would it cost for water if it wasn't safe to drink? To be treated and all, are you willing to pay five dollars a month to preserve the [current] drinking water, or are you willing to pay $50 per month for water that's polluted that has to be treated and whatever else?
>
> Participant 2: […] I just think that just ensuring safe drinking water isn't what we're after. It's more than that.
>
> Participant 1: [The question hasn't] articulated the consequences. If you don't have safe drinking water, what is that gonna look like? How much is it going to cost? That's the, to me, the missing link.
>
> Participant 2: For me it's that you can get safe drinking water from the Mississippi River, [but] I don't want that.

Therefore, some interview and focus group participants stated that they were potentially willing to pay more but indicated that their willingness is dependent upon preserving the aquifer. As one participant stated, "I'm willing to pay more if it means the aquifer is protected. I don't want to pay more to ensure safe drinking water and then we still run out of aquifer." Others in the focus group echoed this participant's statement and pointed to the need for reliable monitoring and an awareness of how much water is being used before requiring the public to pay more, particularly when industry reporting is currently on a voluntary basis.

> It has been our understanding that [reporting is] almost like the honor system. And an honor system might work in some things but when you might be charged [fines] for excessive use of the water. I don't trust [the] system […] and there's no indication that all the wells have meters on them, or if the meters are accurate. That's another thing. We got money last year or year before, to at least go out and put meters on a well because that was, nobody knew what the use was. Or nobody was even checking the usage because they didn't have meters; they didn't even know where all the wells were…

The lack of monitoring and mistrust in the current system was also reflected in discussions surrounding public support of possible water policy options. Investment in groundwater monitoring garnered the highest amount of support (56%) among survey respondents (Figure 12), which many interview and focus group participants attributed to the gap in understanding on how much groundwater is being withdrawn from the SHAS. One participant explained the survey respondents' support for metering and accountability, stating,

> It's so much to fix when you trust people, that we trust corporations to tell the truth about things they're making money on. The first step is holding them accountable […] if the numbers aren't right, then the first step is actually getting the numbers.

Even with enhanced, accurate monitoring of groundwater withdrawals in the SHAS, interview and focus group participants acknowledged that enforcement would be difficult, noting that most CAGWCD residents would generally be opposed to new regulations. This perception was reinforced by the survey results, which found that regulatory options to manage groundwater received the least amount of support among respondents (Figure 12). Slightly over a quarter of survey respondents supported increasing rates for large volume users, for example, with roughly the same number of respondents outright opposing this option. Similarly, 28% of survey respondents supported imposing caps on non-essential uses, while 21% expressed opposition to this option. Many interview and workshop participants agreed that public opposition toward regulation would be a challenge, but it would be necessary to implement regulatory change to preserve the SHAS.

> No one likes regulation, so if you come across something that's going to bring about regulation, people are going to close their ears, but you're going to have to start, somebody's gonna have to control what's wandering in and out of the study and to observe the water supply and everything.

Some participants alternatively suggested that opposition to rate increases for large volume users could be due to a misconception over what constitutes a "large volume user." As one participant explained,

> That's probably just a misunderstanding of what a large volume user is…more probably like, "I have five kids that all shower every day. I'm a large volume user," not "I'm an industrial plant using thousands of gallons every day."

It was therefore not difficult for interview and focus group participants to imagine why conducting educational campaigns to increase public awareness of water management-related issues received the third highest amount of support among survey respondents (42%). Participants in one focus group captured respondents' support for educational campaigns and opposition toward regulatory options by summarizing,

> Participant 1: "If we go back to 78%, or whatever the percentage of people are not aware of, they've heard nothing about groundwater. They don't see it as a problem. So instead of changing our rates or imposing caps, we don't know anything about it. So let's do an educational campaign and let's invest in monitoring, and
>
> Participant 2: That make sense. Start with the stuff that isn't going to cause waves…

To gauge support among focus group participants for educational campaigns and other water management policy options, the research team also conducted an anonymous, informal poll on specific water conservation measures and potential solutions to reduce groundwater demand in the CAGWCD. After hearing about groundwater management issues related to over-pumping of the SHAS and discussing the results of the public survey, all 15 focus group participants supported conducting educational campaigns for voluntary water conservation, while

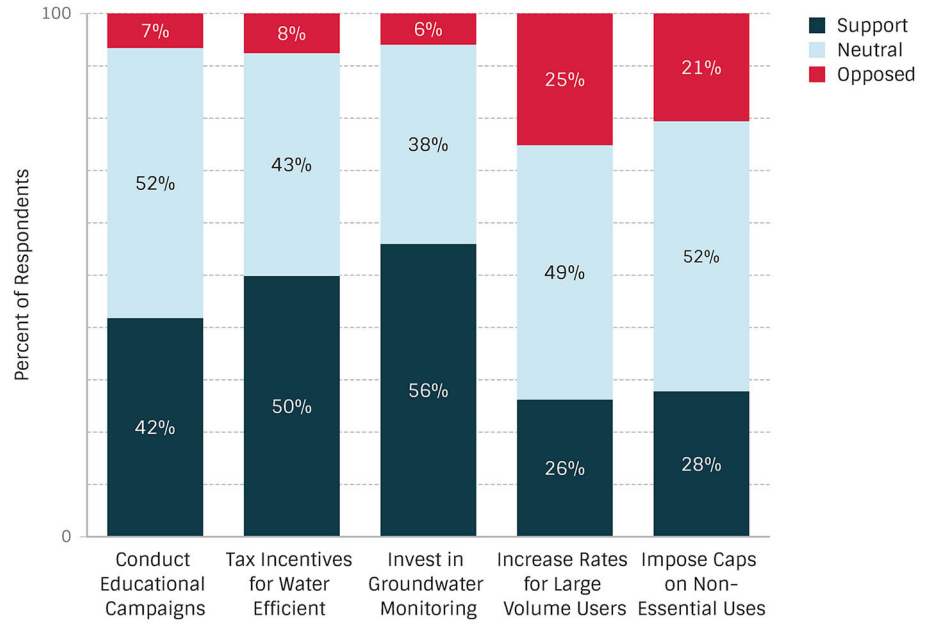

FIGURE 12
Level of public support for water management policy options in the CAGWCD.

nearly all (13 out of 15) supported offering tax incentives for the installation of water-saving equipment and investing more in monitoring groundwater.

Two-thirds of focus group participants (10 out of 15) supported increasing rates for large volume users. Three participants were neutral, and two participants were opposed to rate increases. One theme that emerged during interview and focus group discussions around increasing rates for higher usage alludes to potential reasons for participants' neutrality and opposition. Most participants believed that rate increases to large volume residential users would not be as effective as first addressing industry usage. Many participants claimed to already be taking action to reduce their usage of household water and expressed an attitude of, "Why should I lower my use when industry is the largest user?" As one participant noted,

> That bothers me a little bit. I mean, I think we are conserving water, you know, I don't let the water run when I brush my teeth. I put a little bit of water in the sink when I shave and instead of letting it run and so on and so forth. Load the dishwasher up until there's no more room before I turn it on. You know that I should conserve now whereby industry just pumps as much as they want to without control, without the oversight. I'm not, we don't even know how much they pump out. That irks me.

This feeling could also help explain why there was less consensus on imposing caps for non-essential water usage (e.g., swimming pool, landscaping, and lawn watering). Although slightly over half of focus group participants (8) supported imposing caps for non-essential water usage, three participants were opposed, and four were neutral.

The poll of policy options presented to focus group participants also included an open-ended question that allowed participants to suggest additional policy options not included in the initial survey. Of the six focus group participants who opted to answer this question, three stated that industry use of groundwater should be limited, either through regulation/enforcement or requiring industrial users to use river water and reuse when possible. One of these three participants also suggested requiring reduced lawn watering during droughts. Other suggestions included buying out Baton Rouge Water Company so that the public owns it, increasing rates as volume increases, and involving the community in water management solutions.

Recognizing that survey respondents express broad support for tax incentive and rebate programs, the research team expanded this question and polled focus group participants on specific rebate programs that have been used in other cities to help conserve water. When polled on whether they would take advantage of rebate programs that incentivize customers to purchase or install more efficient appliances to reduce water use, nearly all (12 out of 15) indicated their support, and the remaining three participants noted that they were possibly supportive depending on the details of the program. Focus group participants were also polled on their support for specific indoor and outdoor rebate options that they might take advantage of. Of the indoor rebate options presented to participants, showerheads garnered the most support, followed by high efficiency washing machines, low flow toilets, and hot water recirculation systems. Of the outdoor rebate options presented, native plant installation garnered the most support, followed by bulk organic mulch, smart irrigation controllers, and professional landscaping driplines. One participant also suggested the need to gauge support for larger, community-scale green infrastructure projects such as bioswales and rain gardens that would provide

co-benefits that not only reduce flooding, but that could also temporarily store stormwater for irrigation and/or aquifer recharge.

When focus group participants were presented with educational programming options, a pilot program that offers a $20 credit on their water bill to low-income residents who participate in conservation efforts received the most support. Other options that received substantial support included development of a "WaterSmart Academy" for local landscaping contractors to learn about outdoor water conservation practices and programs for government agencies to learn about reducing their water usage. Slightly under half of participants supported a garden website and newsletter, as well as WaterSmart workshops and events for the public, respectively.

Finally, when asked how likely they were to use less water after conversations on groundwater issues, most participants were either somewhat or very likely to conserve water. However, three out of 15 participants were neutral on the issue and of the remaining two participants, one was somewhat unlikely and the other was not at all likely to conserve water. Participants were not offered a textbox to explain their position on the issue of personal water conservation efforts, so it is therefore impossible to be certain as to why participants responded as they did. However, suggestions offered to the previous question on policies that participants would favor in addition to those provided by the survey may offer an explanation. The two major themes in those responses were public ownership (i.e., "buying out Baton Rouge Water Company so the public owns it") and requiring industries to use river water and/or reuse instead of groundwater. Therefore, it is possible that the participant(s) who selected "none of the above," found that policies, rebates, and programs aimed at reducing public consumption may have little impact if industry is allowed to continue business-as-usual (i.e., pumping groundwater with little oversight or monitoring).

Discussion

Previous research on participatory groundwater governance found that increasing public access to legal and scientific information enables groundwater regulators to achieve considerable participatory success, which in turn can result in successful adoption and implementation of groundwater management actions (Cuadrado-Quesada and Gupta, 2019). When such information is lacking, regulators may face several governance obstacles in managing groundwater and addressing issues such as saltwater intrusion into freshwater sands. As the survey, interview, and focus group results presented in this current research show, one of the primary governance obstacles that that the CAGWCC face is a lack of public awareness of groundwater and groundwater issues in the CAGWCD. Despite the criticality of over-pumping and saltwater intrusion into the SHAS, survey research and subsequent interviews and focus groups with residents of the CAGWCD have shown that the public is largely unaware of these issues. In fact, not only were most survey respondents unaware of over-pumping of the aquifer and subsequent saltwater intrusion, but many were also not even aware that there is an aquifer system underlying the city of Baton Rouge that supplies their drinking water.

The literature identifies several potential explanatory factors for why such a gap in public understandings might exist. First, groundwater is a resource that is largely hidden from public view and the impacts of over-pumping and contamination are similarly invisible to the public (Healy et al., 2020). This perceived invisibility of groundwater is often magnified in locations with highly visible surface waters present in rivers, lakes and reservoirs (Neal et al., 2016; Ross, 2016). This finding was borne out by this current research, which found that the unseen aspect of groundwater relative to other local risks and hazards in Louisiana was a primary contributing factor in the lack of public awareness of groundwater issues in the Baton Rouge area. As noted by interview and focus group participants, it floods and rains a lot in the CAGWCD and as a result, water scarcity will be "hard to sell" for groundwater regulators. Recognizing the need to raise the visibility of groundwater and groundwater issues in the CAGWCD, the survey respondents as well as the interview and focus group participants expressed broad support for an educational campaign.

Research has shown, however, that simply increasing scientific knowledge and raising awareness of groundwater issues is not in and of itself sufficient to address existing knowledge gaps between the public and other users of public water supplies, regulators, and groundwater scientists (Healy et al., 2020). This leads to the second potential explanatory factor explaining why there is a notable gap in public understandings of groundwater in the CAGWCD; a lack of meaningful public involvement in groundwater decision-making. Previous research has shown that public awareness of groundwater issues improves when robust public participation in decision-making processes is combined with improved access to information (Varady et al., 2016). Focus group participants specifically recommended involving the community in water management solutions as a viable policy approach that the CAGWCD could utilize to manage groundwater more effectively. From a governance perspective, implementing participatory engagement processes into the assessment and management of groundwater resources can help community members better understand the science and policy options associated with groundwater management and make deep, confined aquifers more "visible" to the public (Simpson and De Loë, 2020; Rouillard et al., 2022). This in turn can contribute to creating a shared understanding among groundwater users and regulators of the need to adopt more integrated groundwater management solutions.

Robust public participation in the decision-making process combined with improved access to information also serves to increase levels of public trust in that process, another key contributing factor to reduced public understanding of groundwater issues. Research has shown that the public often perceives scientific research as biased, particularly when that research is funded by government agencies, regulators, or industry (Varady et al., 2016). In the CAGWCD, a general lack of trust in both industry and government can create a critical governance obstacle that the CAGWCC may face in managing the SHAS. Several interview and focus group participants noted that profit is the primary goal of industry and private companies, including Baton Rouge Water Company. Many expressed concerns that there may be little incentive for industry to voluntarily limit groundwater pumping given this profit motive.

Many interview and focus group participants view a lack of monitoring and oversight of industry's water usage as evidence of an unwillingness for regulators and industry to do their part

in protecting the aquifer. Even though increased monitoring of groundwater was broadly supported by participants, several concerns were raised. Participants expressed a need for meaningful action to be taken beyond the mere collection of data. They recognize that monitoring of groundwater alone will not result in sustainable outcomes and that monitoring needs to be tied to policy and enforcement actions. Increased monitoring carries its own perceived risks, however. Participants expressed concern that increased monitoring might result in rate increases, which could directly impact the financial wellbeing of some residents, particularly those on fixed incomes. There was stated concern that the cost of "fixing the problem" might be expected to fall on residents rather than industry and other large water users. This broad distrust also extends to government and government regulators. Several interview and focus group participants noted that the conservative political beliefs and ideologies of many Southeast Louisiana residents, including those in the CAGWCD, have led to an overall desire for less government surveillance and regulation in all aspects of life, including groundwater management. This simultaneous recognition of the need to regulate groundwater usage and an expressed desire for less government control can present a significant challenge for the CAGWCD in developing and implementing a long term strategic plan to manage the SHAS. Research has found that water users often disdain or resist restrictions, which can complicate efforts to protect groundwater resources (Varady et al., 2016).

Overall, this research has shown how participatory groundwater governance can help regulators and decision-makers overcome inherent biases in traditional groundwater management processes by increasing public awareness of groundwater issues, improving the quality of public engagement, and fostering trust among groundwater users and regulators. As the CAGWCC moves forward in developing a strategic plan to manage groundwater resources in the CAGWCD, the survey, interview, and focus group data collected through this research identify several potential pitfalls the commission will face, while also providing several paths forward to assure public buy-in of the plan. Perhaps the most important finding is that residents of the CAGWCD are happy with the quality of their water. Despite a broad lack of understanding around groundwater and the source of household water in the CAGWCD, most residents recognize that their household water is of very high quality relative to that of other cities. They also recognize the importance of healthy, high-quality drinking water to them and their families and the value of protecting it. Additionally, most participants are also broadly aware of the threat that contaminated water can pose to communities, primarily from news coverage of places like Flint (Michigan), Jackson (Mississippi), and St. Joseph (Louisiana). While the issues faced by these communities are different from those of the CAGWCD, these examples can provide important common ground for stakeholders and decision-makers and prompt discussions on groundwater management and sustainability.

Further, while survey respondents and focus group participants expressed a broad distrust in industry leaders and government to manage groundwater issues in the CAGWCD, many did express support for a special commission or task force. Overall, the interviews and focus groups highlighted the need for groundwater management efforts to be led by unbiased, trusted institutions. While participants noted that this commission or task force needs to include experts and decision-makers who have enforcement authority, it should also include members from local organizations that can be trusted to deliver an unbiased message on groundwater management issues to residents, including churches, schools, neighborhood and community organizations, and local recreation departments. Ultimately, the key to effective groundwater governance according to residents of the CAGWCD is to build trust among researchers, decision makers, and users of groundwater resources. When researchers, regulators, and industry operate apart from residents, public trust and buy-in for any subsequent management actions will be difficult to obtain, particularly when the need to take action is not broadly understood.

In summary, groundwater governance involves a complex interplay among government agencies, non-governmental organizations, the industrial sector, and residential users of groundwater. Due to its often contentious and political nature, groundwater governance is a "trying and usually unappreciated task" that necessitates popular support to successfully implement management actions (Varady et al., 2016). Understanding how the public's awareness and perceptions of groundwater issues influence their support for management actions is a vitally important component of groundwater governance. This knowledge provides groundwater regulators and policymakers with opportunities to cultivate broader awareness and interest in groundwater and sustainability issues. This research employs a mixed methods approach to understanding complex groundwater management issues. Through this approach, several pathways for increasing public support for groundwater management actions are identified. Future research could adopt a similar approach to understanding the intricacies of balancing stakeholders' interests with policy making goals in the management of other environmental issues.

Data availability statement

The raw qualitative data (including audio files and full transcripts) presented in this article are not readily available in order to preserve the confidentiality and anonymity of participants. Requests to access the datasets should be directed to shemmerling@thewaterinstitute.org.

Ethics statement

The studies involving humans were approved by the University of Alabama Institutional Review Board (IRB # 21-05-4628) and the University of New Orleans Institutional Review Board (IRB # 01Aug22). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SH: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft. AH: Formal analysis,

Investigation, Writing – review & editing. WS: Formal analysis, Investigation, Writing – review & editing. DL: Writing – review & editing. AG: Formal analysis, Writing – review & editing. AD: Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2024.1289400/full#supplementary-material

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