www.water-alternatives.org Volume 19 | Issue 1

Salsabila, S.; MacAfee, E.; Sutadian, A.D. and Nastiti, A. 2026.
Assemblage insights into groundwater governance and
narratives of groundwater 'crisis' in Bandung Basin, Indonesia.
Water Alternatives 19(1): 112-136

Assemblage Insights into Groundwater Governance and Narratives of Groundwater 'Crisis' in Bandung Basin, Indonesia

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ABSTRACT: Dwindling groundwater levels and compromised water quality have led to concerns about the potential for near- and longer-term groundwater crises in the Bandung Metropolitan Area (BMA), located in the Bandung Groundwater Basin of Indonesia. The BMA is a rapidly urbanising region where much of the population relies on groundwater to meet its household needs and and where challenges are being encountered in accessing a reliable groundwater supply. There are multiple perspectives on what aspects of the crisis are most critical and many ideas as to what can and should be done, and with what urgency. Assemblage thinking can help to understand this complex field by highlighting the sociomaterial construction of environmental problems in ways that are always contingent, heterogeneous and influenced by the agency of multiple actors. In this case study, we use media analysis, semi-structured qualitative interviews, document analysis, and participant observation to examine how problematisations of groundwater emerge and coexist. Findings reveal that media narratives, the behaviour of local institutions, and the everyday practices of groundwater users influence water-crisis–related interactions with government and even shape the crisis itself. These dynamics contribute to fragmented groundwater governance where community-led practices coexist with formal institutional arrangements. The study highlights the potential of hybrid governance models to support adaptive and context-sensitive management, particularly in the BMA and in similar urbanising regions.

KEYWORDS: Groundwater, assemblage thinking, urban water management, hybrid governance, Bandung Metropolitan Area, Indonesia

INTRODUCTION

Although groundwater has been used for millenia, its use globally has accelerated since the invention of the electric pump. In many cities of the Global South, groundwater now meets, on average, 79% of domestic water demands (Carrard et al., 2019). The high reliance on groundwater has long been a factor in urban water provision in growing cities. Groundwater has been supplying homes, industries and urban services despite rising urbanisation and uneven access to piped water (La Vigna, 2022; Foster, 2022). Groundwater is not just a technical resource, it also serves as the city's sociomaterial backbone; it fills

infrastructure gaps in water services, supports economic activity, and facilitates everyday urban life. As a result, most major aquifers in arid and semi-arid areas are depleting at rates significantly higher than natural replenishment (Famiglietti, 2014). Globally, groundwater availability and quality are also significantly influenced not only by expanding demand, but also climate change, land-use change and urbanisation (Gupta and Chinnasamy, 2022). The resulting situation is often referred to as a 'groundwater crisis', where groundwater depletion causes overlapping negative impacts on natural ecosystems, social systems, and even on human health (Gupta and Chinnasamy, 2022; Muenratch et al., 2022).

Recent studies of the groundwater crisis, particularly in metropolitan areas of the Global South, focus predominantly on technical and rigid methodologies that primarily address spatial and environmental impacts (Mautner et al., 2020; Baker et al., 2022; Kamdee et al., 2023); they tend to neglect complex social and political dynamics. Conventional and technical solutions are often proposed despite evidence from numerous studies that demonstrates the ineffectiveness of such solutions in mitigating problems and sometimes even indicates that they exacerbate them (Ahmadi et al., 2020; Mautner et al., 2020; Muenratch et al., 2022). The simplified technical approach is particularly inadequate in rapidly developing contexts such as Indonesia, where groundwater issues are constantly evolving in response to rapid urban development (Carrard et al., 2019; Whincup et al., 2024). With a focus on the Bandung Metropolitan Area (BMA) of Indonesia, we thus identify an alternative approach that recognises the complexities of groundwater crises and governance in addressing the challenges of groundwater management.

Groundwater issues in the BMA have received extensive attention in both academic studies and media coverage. Among the concerns documented are excessive abstraction, diminishing groundwater tables, land subsidence, deterioration of water quality, and contamination from home, industrial and agricultural sources. These challenges are frequently portrayed as indicators of a "groundwater crisis", and the prevalence of such narratives indicates that Bandung's groundwater problems have gained ongoing scientific and public attention. In this sense, the BMA is not an example of a neglected environmental hazard, but rather one in which problems are consistently assessed and reported. Despite this sustained focus, the groundwater situation in the BMA continues. Studies continually report findings such as ongoing depletion, contamination, and governance challenges (see, for example, Wangsaatmaja et al., 2006; Tirtomihardjo, 2016; Taufiq et al., 2019; Hasanawi et al., 2022). This then raises an important question: if the Bandung groundwater crisis is well known and thoroughly documented, how are groundwater issues being addressed in the various arenas? In other words, what kind of challenges are being expressed, who is doing so, and how are they being framed? This inquiry shifts the focus from whether groundwater problems exist, to how they are manufactured, prioritised and addressed in media, institutional and everyday contexts.

This highlights a research gap. While much of the existing literature focuses on hydrogeological conditions, regulatory frameworks, or policy instruments (see, for example, Kataoka and Kuyama, 2008; Taufiq et al., 2018, Zaidi and Handayani, 2025), far fewer studies investigate how groundwater problems circulate across multiple sites (such as news media, government institutions, and everyday water practices) or how these problems are translated into concrete governance arrangements. As a result, we have little understanding of how dominant framings of groundwater problems are articulated across multiple knowledge domains, or of how these coexisting problematisations relate to the configuration of groundwater governance responses. Understanding these processes is critical because fragmented problem framings can lead to inconsistent governance responses (Vogler, 2016; Breen et al., 2018). When groundwater is presented as *either* a technological resource, a resource that is at risk due to environmental factors, an object to be regulated or a private household concern, governance responses may occur concurrently rather than in tandem; this strengthens institutional silos and leads to uneven accountability. Fragmentation may impede the long-term sustainability of environmental governance (Isailovic et al., 2013), especially in complex urban systems with various actors and scales.

We propose to address this research gap using assemblage thinking, a conceptual framework that was originated by Deleuze and Guattari (1987) and further developed by DeLanda (2016). Using assemblage

thinking to highlight the role of water management practices can reveal how their social, political and financial aspects influence the construction of problems. Such an approach has been applied in previous research, for instance in Han and Webber (2020)'s study highlighting the historical and contemporary trajectories of Ghana's dams. While some water studies have utilised assemblage thinking (for example, Beilin, 2018; MacAfee, 2021; Rusca et al., 2025), little research specifically addresses groundwater crises and their management through an assemblage lens. This gap is significant because assemblage thinking offers a valuable alternative framework for studying and conceptualising governance beyond static or one-dimensional models, thereby enabling context-sensitive and dynamic analyses (Briassoulis, 2019). This approach is particularly relevant for understanding complex contexts like the BMA, an urbanising region in Southeast Asia where groundwater extraction is increasing rapidly.

This study investigates how groundwater crises are problematised across various assemblages, as well as what these problematisations suggest about groundwater governance in the BMA. This study does not presume a single groundwater crisis; rather, it investigates how several definitions of 'crises' develop across media, institutions and everyday actions. This study asks: How are groundwater crises problematised across different assemblages and what does this reveal about groundwater governance in the Bandung Metropolitan Area? More specifically, the study is directed by the following research questions (RQs):

- RQ 1: How do media assemblages discursively produce multiple problematisations of the groundwater crisis?
- RQ 2: How do the sociomaterial aspects of institutional assemblages selectively stabilise and operationalise certain groundwater crisis problematisations?
- RQ 3: How do everyday assemblages produce provisional groundwater problematisations through practices?

The theoretical contribution of this study consists in using an assemblage perspective to examine groundwater governance as a collection of various overlapping and contingent arrangements, rather than as a cohesive or unified system. An assemblage lens focuses attention on the diverse actors, knowledge, infrastructures, policies and practices that manage groundwater, as well as on the frictions and alignments that arise between them. In doing so, we explain groundwater governance in the BMA as a complex of coexisting and partially related arrangements formed by diverse problematisations.

ANALYTICAL FRAMEWORK

Groundwater crisis governance in the Global South

Groundwater governance in the Global South is increasingly recognised as a complex challenge that is shaped by interactions among state authorities, local communities and a range of informal actors. A growing body of literature emphasises the importance of hybrid governance mechanisms that integrate formal state institutions with local practices, enabling adaptive responses to socio-environmental variability (Nelson, 2022; Hoogesteger, 2022; Cuadrado-Quesada, 2022). Such adaptive governance requires flexibility and iterative self-correction to navigate the inherently ever-changing nature of socio-ecological systems (Nelson, 2022).

Despite this, empirical studies reveal that hybrid governance often fails to achieve its intended objectives. In many contexts, informal or local actors become dominant, either due to limited state capacity, undefined or poorly integrated policies, or active resistance to centralised regulations (Cuadrado-Quesada, 2022; Wojnarowski, 2025; Altaf et al., 2025). In other cases, institutional systems are designed to be rigid, which can result in the neglect of emerging challenges and marginalised voices (Nelson, 2022; Samani, 2021). These dynamics produce disjointed strategies that ultimately fail to support long-term sustainability, manifesting instead in fragmented and reactive forms. Groundwater

crises thus persist, and their socio-ecological consequences are extended by exacerbating socio-economic vulnerabilities, particularly among low-income urban communities that are most exposed to shortages and quality risks (Hoogesteger, 2022; Izah et al., 2024).

Recognising these challenges, recent scholarship calls for a systemic understanding of groundwater governance. Rather than framing governance simply as a matter of centralisation versus decentralisation, studies highlight the importance of analysing groundwater governance as an interlinked system despite its fragmented and uneven governance (Cooperman et al., 2025; Atkins and Taylor, 2025; Wojnarowski, 2025). Network analyses and related systems-based approaches allow scholars to trace the flow of elements such as water, knowledge and sociopolitical influence, revealing how governance configurations and decisions shape interlinked and complex socio-ecological systems. These studies highlight that effective groundwater governance requires approaches that are relational across scales and actors while at the same time remaining attentive to the heterogeneous nature of governance arrangements.

Research on governance processes demonstrates that the framing of groundwater issues fundamentally shapes how crises are perceived and addressed. Building on Bilalova et al. (2025), such framings can be understood as normative ideas held collectively by policy actors. These framings then shape how groundwater challenges are defined, which interventions are prioritised, and whose knowledge is legitimised. They structure governance by stabilising particular problematisations of groundwater crises. The articulation of technical data, regulatory priorities and socio-environmental concerns influences which problematisations gain traction (Soltanian et al., 2024). While such framings facilitate coordination and policy intervention, they also risk narrowing groundwater governance debates by privileging technocratic and expert-driven solutions. Empirical studies further demonstrate that local communities can experience both supply-side and demand-management interventions as forms of dispossession; governance paradigms render them objects of regulation rather than political actors, thereby reproducing socio-ecological vulnerability rather than addressing its structural drivers (Wojnarowski, 2025). These strands of literature emphasise that groundwater governance in the Global South is multifaceted and relational, particularly in contexts characterised by socio-ecological vulnerability and institutional complexity.

Assemblage thinking as an analytical lens

Building on insights from the literature on groundwater governance in the Global South, this study develops an analytical framework that conceptualises groundwater crises as relational and emergent assemblages. This framework guides the empirical analysis by tracing how problematisations are produced, circulated and contested across media, institutional and everyday practices, and how these interactions shape governance outcomes. To operationalise this approach, assemblage thinking is used to examine groundwater governance as emergent from heterogeneous and interconnected sociomaterial relations. Following DeLanda, an assemblage is understood as a dynamic and contingent whole that is composed of interacting material elements such as wells, pumping technologies and urban water infrastructures, and immaterial elements such as regulatory categories, policy priorities, expert knowledge, public narratives, social norms and everyday perceptions of water risk. These elements do not combine in linear or hierarchical ways; instead, they emerge through multiple and overlapping assemblages that interact without necessarily forming a unified or stable whole.

Groundwater governance is thus particularly well suited to analysis through assemblage thinking because it is inherently dynamic and contingent. Governance arrangements are rarely fixed or stable; instead, they are continuously reconfigured through environmental variability, infrastructural transformations, political negotiations and frictions, and ongoing sociomaterial interactions (Whaley, 2022; Chatterjee and Kundu, 2022; Salgado-Vargas et al., 2025). As a result, multiple assemblages may

coexist in parallel within the broader domain of groundwater governance; this may encompass media and discursive tools, institutional arrangements, and everyday practices of water access and use.

Assemblage thinking complements systems approaches by foregrounding how governance arrangements emerge, stabilise and reconfigure through heterogeneous sociomaterial relations, with particular attention to contingency, nonlinearity, and the ongoing reworking of relations (Liu and Lo, 2025; Panagiotopoulos et al., 2025). From this perspective, an assemblage is not treated as an entity such as "the state" or "the community"; rather, it is seen as a set of relations that are continuously made and remade through practice. Conceptualising groundwater crises as assemblages thus helps to explain why governance outcomes frequently appear fragmented, contradictory or unstable, while it also opens up analytical space to explore alternative trajectories and configurations of governance. Accordingly, this study treats media narratives, institutional actors and individual, household and community practices not as discrete or bounded units of analysis, but as relational elements whose interactions contribute to the formation of diverse, heterogeneous and contingent groundwater governance assemblages that may be partially connected (rather than fully integrated) systems.

To operationalise assemblage thinking, this study uses problematisation as an analytical anchor. Rather than assuming groundwater problems to be objective conditions, problematisation refers to the processes through which certain conditions come to be recognised, framed and acted upon as "problems", as they are conceptualised and operationalised in critical governance studies (Riemann, 2023; Tiwale and Wagle, 2025). Focusing on problematisation allows this study to trace how particular understandings of groundwater crises are stabilised, how others remain marginal, and how these configurations enable or constrain specific governance responses. This approach makes it possible to examine how groundwater governance is enacted across media, institutional and everyday assemblages as relational configurations that partially overlap and interact, without presuming coherence, effectiveness or linear translation between domains.

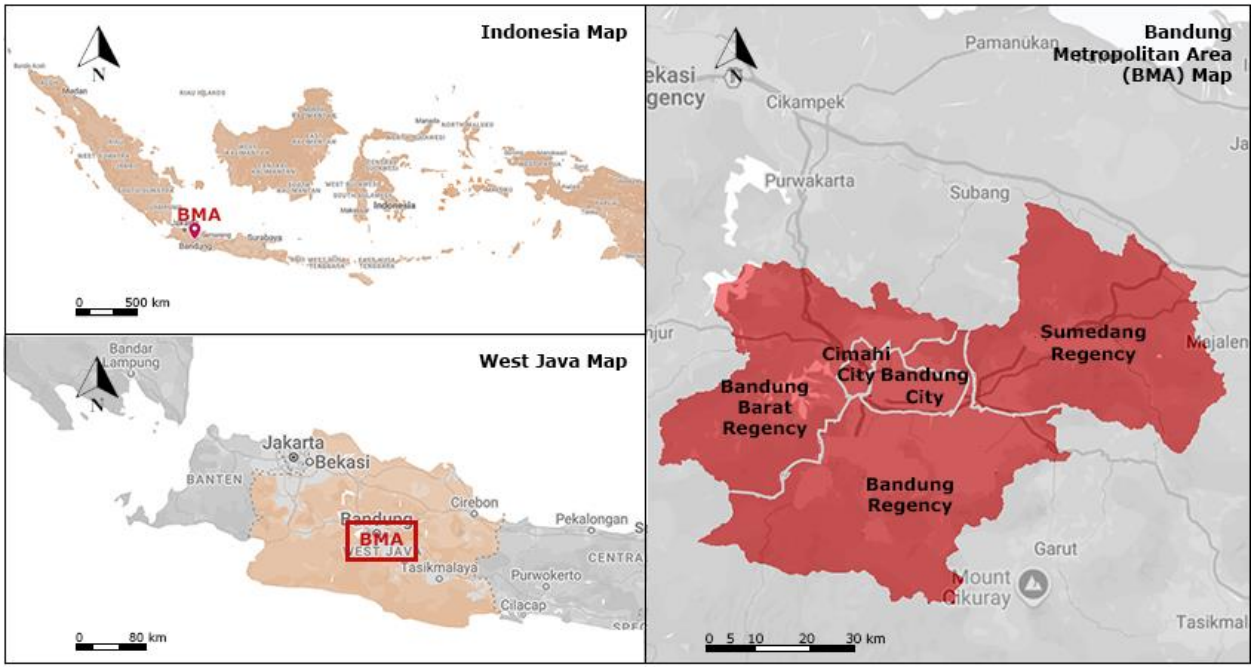
METHODOLOGY

This study employs a qualitative-dominant case study design to examine groundwater governance in the Bandung Basin, Indonesia. Multiple methods are used in an analytically differentiated manner whereby each method is aligned with a specific research question.

The Bandung Basin was selected as a single case due to its intensive groundwater extraction, rapid urbanisation, and complex multi-level governance context. Empirically, the Bandung Metropolitan Area (BMA) constitutes the primary socio-ecological setting of the study (Figure 1), where media narratives, institutional arrangements and everyday groundwater practices intersect. Within this case study, we analytically distinguish between three domains that correspond to respective assemblage configurations: media, institutional and everyday. These domains are not treated as bounded scales, but rather as overlapping and relational configurations which reflect an assemblage perspective that conceptualises groundwater governance as constituted through heterogeneous relations.

To analyse discursive representations of groundwater issues (RQ1), the study conducted a quantitative content analysis of 33 media articles, with the unit of analysis being the individual article. We systematically searched 10 of the most-consumed online media outlets in Indonesia (including two regional outlets) using key terms such as 'groundwater quantity', 'groundwater quality', 'groundwater crisis', 'Bandung City', and 'Bandung Metropolitan Area (Bandung Raya)'; we also used related terms such as 'groundwater pollution', 'groundwater overuse' and 'land subsidence'. This process yielded 33 documents for analysis, published between 2019 and 2024.

Figure 1. Study area map.



An inductive thematic coding process was applied through multiple reading cycles. Coding was conducted at the sentence and paragraph level, allowing multiple codes to be assigned to a single text segment. Co-occurrence measures were used descriptively to map how different problematisations are assembled within texts, with a focus on identifying patterns of co-presence and relational clustering between discursive elements without aiming to establish causal generalisation.

To study institutional groundwater governance (RQ2), we conducted semi-structured interviews with institutional actors and analysed relevant documents (Table 1 provides an overview of interviewees and their institutional positioning). Interviews followed a flexible guideline that covered regulatory frameworks, permitting procedures, monitoring and enforcement practices, and interagency coordination; they explored how groundwater management is shaped by science and technology, institutional politics and interagency challenges. Interviews were audio-recorded, transcribed verbatim, and anonymised. Each institution was interviewed through a single interview session, with some sessions involving multiple representatives from the same institution. Documentary materials included water resource laws, gubernatorial regulations, permitting guidelines, planning documents and technical standards.

Both interview transcripts and documents were analysed using a combination of in-vivo and descriptive coding. In-vivo coding captured actors' own terms and expressions, particularly for describing practices, priorities and institutional perspectives, while descriptive coding categorised key governance processes, regulatory arrangements and institutional roles, with attention to how heterogeneous elements are assembled to stabilise particular governance arrangements. Analysis proceeded iteratively, moving between interviews and documents to trace relational configurations. Consistent with this analytical approach, the study does not seek to infer or categorise individual political motives or self-interests; rather, it examines how interests and priorities emerge through institutional roles, material arrangements and governance practices.

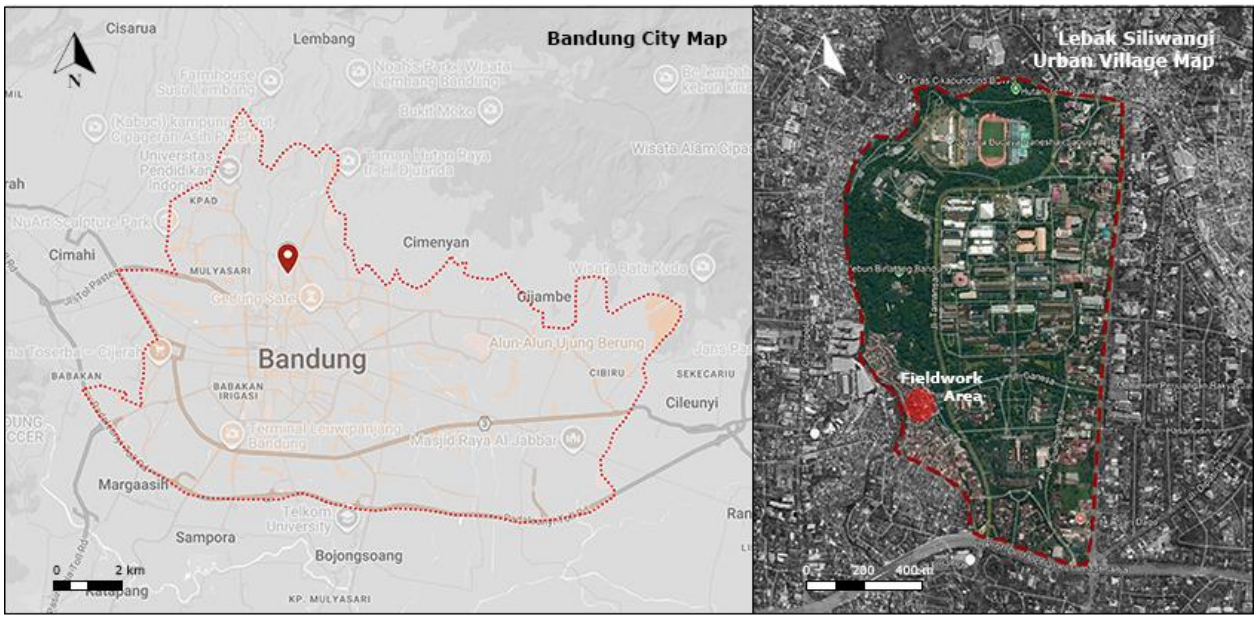
Table 1. Overview of the interviewees from institutions

No.	Institution	Level	Institutional responsibility	Focus of interview
1.	Center for Groundwater and Environmental Geology (PATGTL)	National	Groundwater monitoring, assessment, modelling, and technical recommendations for sustainable management	Groundwater monitoring and assessment, zonation and risk classification, data production, and the role of science and technology in groundwater governance
2.	Energy and Mineral Resources Office (DESDM)	Provincial	Administration and regulation of energy, mineral resources, and groundwater use	Groundwater regulation and permitting criteria, technical oversight, compliance mechanisms, and coordination with other agencies
3.	Investment and One-Stop Integrated Service Office (DPMPTSP)	Provincial	Processing and issuance of investment permits, including permits related to groundwater abstraction	Groundwater-related permitting procedures, administrative processes, interagency coordination, and regulatory constraints
4.	Environmental Agency (DLH)	Provincial	Environmental monitoring, pollution control, and regulatory enforcement	Groundwater quality monitoring, pollution risks, enforcement challenges, and links between groundwater and environmental degradation
5.	Public Housing and Settlements Office (Disperkim)	Provincial	Provision of housing, settlement, and water-related infrastructure	Public water supply provision, infrastructure constraints, and interactions between groundwater use and piped water services
6.	Development Planning Agency (BAPPEDA)	Provincial	Regional development planning and intersectoral coordination	Spatial planning, infrastructure prioritisation, integration of groundwater into development plans, and intersectoral coordination
7.	Regional Research and Development Agency (BP2D)	Provincial	Policy-oriented research and knowledge support for regional governance	Knowledge production, evidence use in policy-making, research – policy interfaces in groundwater, and water infrastructure planning

Data on everyday and communal groundwater practices (RQ3) was collected through in-depth interviews and field observations with residents, including both users and non-users of wells and neighbourhood leaders. Fieldwork was conducted in five neighbourhood blocks (*rukun tetangga*) within one community block (*rukun warga*) in the Lebak Siliwangi Urban Village, Bandung City, selected through purposive sampling (Figure 2). Selection criteria included a dense inner-city location, reliance on a combination of groundwater and piped water, and active local administrative structures; these were exemplified by Lebak Siliwangi, where groundwater use coexists with formal water supply systems. The selected community blocks are analytically, rather than statistically, representative of governance sites where everyday groundwater practices intersect with formal administrative structures; this allowed the study to identify the governance leverage points that were relevant for groundwater management beyond the immediate case. Community and neighbourhood blocks constitute the lowest formalised units of local governance; they link households to urban village (*kelurahan*) authorities through coordination and

mediation functions.[1] In groundwater contexts, neighbourhood leaders facilitate the upward translation of everyday water practices and concerns through routine coordination and reporting into urban village, district and metropolitan (BMA) administrative and planning processes.

Figure 2. Fieldwork area in Lebak Siliwangi, Bandung City, Indonesia.



Interviews focused on water-use practices, infrastructure, decision-making processes and informal governance arrangements. Observations documented material characteristics of wells, pumps, storage systems and spatial relations between users. Data was coded inductively using descriptive and in-vivo coding to capture practices and material-social relations; this was supported by analytical memos that traced emergent linkages across actors, infrastructures and spatial conditions.

Table 2. Summary of research design and methodological approach.

Research question	Type of assemblage	Mode of assemblage	Methods
RQ1	Media assemblage	Discursive and narrative practices	Content analysis of 33 articles
RQ2	Institutional assemblage	Sociomaterial practices	Semi-structured interviews and document analysis
RQ3	Everyday assemblage	Everyday individual and community practices	In-depth interviews and field observations

As summarised in Table 2, the study examines three analytically distinct but interconnected assemblages, each addressed through a specific combination of methods. Across all domains, analysis followed an iterative and reflexive process that was consistent with assemblage thinking. Coding schemes were refined through repeated engagement with the data, and analytical memos were used to document how

[1] This is according to the Regulation of the Mayor of Bandung Number 11 of 2024 concerning Urban Village Community Institutions in Bandung City.

relations between discursive, institutional and material elements were interpreted. The analysis prioritised coherence in relational patterns within each domain rather than seeking saturation in isolated categories.[2]

RESULTS

Media assemblages (RQ 1: How do media assemblages discursively produce multiple problematisations of the groundwater crisis?)

Media content analysis was used to answer the first research question. Across 33 media articles, several types of elements appeared repeatedly and functioned as the building blocks of the groundwater crisis narratives. We initially found 11 codes through open coding and constant comparison (see Appendix 1 for details). The result is an in-depth picture of the groundwater crisis as it is discussed in the local media of Bandung, which shows how groundwater is problematised in multiple overlapping ways as codes intertwine with each other to build a particular problematisation (Table 3). Key problematisations include biophysical risk, compliance failure, infrastructural incapacity and everyday survival and inequality. A wide range of actors are referenced in the media coverage, with governmental institutions playing a central role. Executive agencies such as the Center for Groundwater and Environmental Geology (PATGTL), the West Java Provincial Energy and Mineral Resources Office (DESDM), the Bandung City Environmental and Sanitation Agency (DLHK), the West Bandung Regency Regional Disaster Management Agency (BPBD), and the Bandung City Regional Drinking Water Company (PDAM Tirtawening) are frequently cited as operational actors who actively implement monitoring, regulation and technical interventions; they also frequently appear as key information sources, providing data and technical information. These actors typically justify their claims using quantitative data, expert statements and technical indicators, which are often derived from PATGTL, DLHK or DESDM and supported by academics who contribute studies and expert judgment. Meanwhile, other actors, particularly industrial users, are mostly discussed rather than acting as information sources, and local communities are less represented as subjects of discussion and as contributors of information.

In the problematisation of biophysical risk, groundwater is constituted discursively as a measurable object. It is represented as a quantifiable biophysical stock whose depletion becomes identifiable and verifiable, thereby framing the crisis as a measurable biophysical risk. To illustrate, in segments coded as groundwater level decline (GLD), statements from PATGTL document water tables at depths of 60 to 100 metres (far below the designated safe range of 20 to 40 metres) and Environmental Agency (DLH) warnings of annual declines of 60 to 80 percent; these stated figures embed the crisis within hydrogeological measurement infrastructures. This risk is extended from the present into the future through water crisis warnings (WCWs) that continued extraction and insufficient recharge could exhaust Bandung's groundwater within the next 50 to 100 years; specifically, a clean water crisis is projected for around 2050. These projections, together with cascading effects such as land subsidence and water quality deterioration (coded as GCI, for groundwater cascading impacts), justify expert calls for technical and regulatory interventions (action advisories, or AA) by linking quantifiable depletion to broader socio-environmental risks. Anchored in technical calculations and solutions and in expert authority, groundwater depletion is problematised as a risk that is both present and anticipatory, with cascading environmental and societal consequences.

[2] The protocol of this research was approved by the Humanities and Social Research Ethical Committee of the National Research and Innovation Agency or BRIN (Number 529/KE.01/SK/08/2023) following the Declaration of Helsinki principles.

Table 3. Key groundwater problematisations and associated actors in Bandung media.

Key problematisation	Analytical code	Operational framing	Main operational actors	Key information source
Biophysical risk	groundwater level decline (GLD), water crisis warnings (WCW), groundwater cascading impacts (GCI), action advisories (AA)	The groundwater crisis is operationalised through routine monitoring of groundwater levels, risk classification, and long-term projections, linking measured decline to land subsidence, flooding, and future water scarcity that requires technical interventions	Bandung City Government, DLHK, PATGTL, Ministry of Energy & Mineral Resources	Official monitoring data (PATGTL, DLHK), climate monitoring data, expert assessments, academic studies
Compliance failure	action advisories (AA), government measures (GM), groundwater abstraction permission (GAP)	The groundwater crisis is operationalised as a problem of rule violation and excessive abstraction, addressed through permits, administrative measures, and public advisories aimed at controlling large-scale abstraction and promoting conservation practices	Bandung City Government, PDAM Tirtawening, PATGTL, Ministry of Energy & Mineral Resources, BUMN, industries, communities	Government statements (local and national), official monitoring data, academic studies
Infrastructural incapacity	clean water supply-demand (CWSD), water crisis warnings (WCW), urbanisation (U)	The groundwater crisis is operationalised as an infrastructural challenge, reflecting urban water supply – demand mismatches, insufficient sanitation, and limited recharge capacity	PDAM Tirtawening, Bandung City Government, West Java Government, local communities, urban developers, industrial and tourism users	PDAM official data, government reports, planning documents, academic studies
Everyday survival and inequality	groundwater experience (GE), clean water supply-demand (CWSD), drought (D), polluted groundwater (GP), groundwater cascading impacts (GCI)	The groundwater crisis is operationalised in everyday life as declining access, deteriorating quality, and rising coping costs, shaped by drought, pollution, and cascading environmental impacts that unevenly affect households and communities	Urban residents, households, PDAM, private water vendors, public/private hospitals, bottled water producers	Residents' testimonies, community forums, academic studies, government datasets, environmental NGO announcements

Note: DLHK = Environment and Forestry Service; PATGTL = Center for Groundwater and Environmental Geology; PDAM = Regional Drinking Water Company; BUMN = state-owned enterprises.

Through segments reflecting groundwater abstraction permission (GAP), government measures (GM), and action advisories (AA), groundwater is understood as both a measurable biophysical stock and a governable resource whose depletion is attributed to failures of compliance. Segments discussing which types of actors have permission to abstract groundwater (GAP) identify industries, particularly hotels and factories, as primary contributors to groundwater decline due to high-volume abstraction and the spread of unlicensed deep wells. The crisis is thus problematised not only as an environmental risk but also as a non-compliance problem in which excessive extraction reflects weak enforcement and regulatory breaches. This framing is reinforced in articles that describe particular measures (government measures, or GM), which list state responses such as issuance of warning letters, tightening of abstraction permits, and monitoring of industrial groundwater use. Through these interventions, groundwater is enacted as a regulatory object whose sustainability depends on institutional discipline and administrative control. Compliance measures aimed at addressing groundwater depletion also include mandatory rainwater

harvesting systems and standardised conservation infrastructures directed at both industries and urban users (AA).

Within segments that emphasise GAP and GM, groundwater is no longer positioned merely as an environmental resource to be taken for granted; it is considered as an input to production whose extraction is closely tied to economic activity and urban development. This material framing is reinforced in passages about urbanisation (U), where groundwater is framed as an enabling resource for urban expansion and industrial operations. Passages reflecting clean water supply-demand (CWSD) further highlight the consequences of rapid urbanisation, which has taken the form of large-scale land-use conversion from agriculture to residential, industrial and tourism, and the rapid population growth in the Bandung Basin that is further intensifying water demand.

According to most CWSD-coded passages in spatial planning and environmental assessment documents, Bandung Regency faces a documented water deficit of approximately 9.56 million litres per year, while PDAM Tirtawening produces significantly less clean water than required; this has prompted the National Ombudsman to frame the issue as a matter of public accountability. Residents and industries thus increasingly rely on groundwater extraction to meet local demand. Some water crisis warning (WCW) segments, often coded alongside CWSD in the same articles, reinforce this connection by framing groundwater depletion as a clean-water-supply crisis. This interlinkage between groundwater and inadequate public water infrastructure is thus portrayed as a set of urban infrastructure inputs that are working together to meet water demand.

Beyond its linkages with public water systems, groundwater problematisation is demonstrated as a multidimensional phenomenon, even when appearing in minor codes; drought (D), for instance, links groundwater availability to seasonal variability and scarcity, while passages about groundwater cascading impacts (GCI) show how groundwater depletion and contamination worsen subsidence, flooding and urban hydrology, lowering water tables and increasing flood and pollution risks. When considered alongside urbanisation (U) and clean water supply-demand (CWSD) segments, these processes position groundwater as a sociomaterial relational entity, inseparable from urban infrastructures, environmental dynamics and demographic pressures.

The relational meaning of groundwater is further reflected in segments coded as groundwater experience (GE), which capture households and urban residents struggling with drying wells due to drought (D) or polluted groundwater (GP), while also facing limited public supply (CWSD). Residents are thus forced to drill deeper wells, purchase bottled or tanker water, and invest in pumps and storage. Cases in Rancasari and Bandung Timur show households spending significant time and money on securing water for drinking, cooking and sanitation. These passages illustrate groundwater as being central to everyday survival and they show how access becomes a financially mediated struggle that widens socio-economic inequalities.

The analysis thus shows a variety of interlinked and emergent groundwater problematisations. Groundwater can be problematised as a measurable risk that is stabilised through measurement, projection and expert classification. As governance and economic dimensions enter the discussion, the crisis is opened up to being rearticulated as a problem of compliance failure, which foregrounds industrial extraction, regulatory enforcement and engineered interventions. Embedded in processes of urbanisation and public water provision, groundwater problematisations also reflect infrastructural incapacity, which reveals tensions between public water capacity and growing demographic, economic and environmental pressures. At the level of everyday users, meanwhile, groundwater becomes entangled with daily life; there, multiple facets produce financial burdens and differentiated access, highlighting socio-economic struggles. While these framings make the groundwater crisis meaningful in different ways, they do not automatically translate into governance. The following section thus examines how certain problematisations are selectively taken up, stabilised and operationalised through

institutional assemblages, while others remain marginal or fail to consolidate into binding governance responses.

Institutional assemblages (RQ 2: How do the sociomaterial aspects of institutional assemblages selectively stabilise and operationalise certain groundwater crisis problematisations?)

Within institutional governance arrangements, groundwater is enacted as a measurable object that takes its shape through formal laws, institutional mandates and standardised technical procedures. For instance, according to *Law No. 17 of 2019 on Water Resources* and *West Java Gubernatorial Regulation Number 97 of 2020 concerning the Implementation of Regional Regulation Number 1 of 2017 on Groundwater Management*, institutions assigned to manage groundwater, particularly PATGTL and DESDM, are responsible for constructing and maintaining monitoring wells and conducting standardised monitoring procedures that generate data on groundwater levels. This data is subsequently analysed and translated into zoning maps that depict groundwater availability across different areas, which is classified as safe, vulnerable, critical or damaged (PATGTL, Pos. 24). The groundwater-level data is also translated into other outputs such as technical policy reviews produced by research-oriented institutions. In this configuration, the problematisation of depletion risk emerges from multiple elements including wells, maps and institutional actors, and is operationalised through decision-making processes such as evaluating permissible extraction volumes, prioritising conservation interventions, and informing regional and local development planning (PATGTL, Pos. 62; BAPPEDA, Pos. 44). The result is multiple overlapping sub-assemblages within the institutional assemblage; these are made up of different sociomaterial elements, namely the permitting process assemblage, the administrative and fiscal assemblage, the enforcement assemblage, and the planning assemblage. Together these assemblages make up the institutional governance context of groundwater.

Within the permitting process assemblage, the problematisation of groundwater depletion translates not only into decisions regarding permissible extraction volumes; rather, it becomes dynamic and layered. Permit applicants are required to submit detailed hydrogeological information such as borehole depth, extraction volume and duration of groundwater use; these are assessed in conjunction with institutional monitoring data and zonation maps. This integration of applicant data into existing institutional databases enriches the knowledge base, allowing the problematisation to be iteratively reinforced or recalibrated and adaptively operationalised. On this basis, applications in critical or damaged zones may be denied, while zoning classifications are further operationalised into differentiated taxation regimes, with higher levies imposed on extraction in more critical areas (DLH, Pos. 19 & 30).

Through these mechanisms, hydrogeological knowledge is converted into an administrative and fiscal assemblage where the problematisation of groundwater risk becomes rearticulated as a compliance-oriented mode of governance, with boundaries layered across laws, digital systems, technical standards and institutional actors. These boundaries delineate who may extract groundwater, under what conditions, and according to which technical criteria; this shapes how applicants must conduct extraction practices to remain compliant. This boundary-making does not apply uniformly across all users, however; for non-industrial actors, for example, the governance assemblage explicitly incorporates legal exemptions. As articulated by a representative of the Geological Agency, *Law No. 17/2019* recognises the *hak rakyat atas air*, whereby groundwater use for basic daily needs does not require permits, as it constitutes a fundamental right (PATGTL, Pos. 86); thus only non-business users with groundwater needs exceeding 100m³ per month for social purposes are required to renew usage approval every seven years, while users below this threshold are exempt from permits and taxation. These exemptions, at the same time, draw attention away from cumulative non-industrial abstraction, reinforcing a governance focus on industrial compliance. In doing so, the governance arrangements effectively detach industry-focused regulatory mechanisms from the broader sociomaterial realities of groundwater use, particularly the everyday practices and lived experiences of households and communities.

The enforcement assemblage exists to protect and secure this arrangement. Groundwater management officers, supported by local law enforcement, verify submitted documentation, inspect required monitoring and recharge infrastructures, investigate violations, and impose sanctions where necessary (DPMPTSP, Pos. 88). These enforcement practices also reveal the persistence of illegal groundwater extraction by industrial actors despite the involvement of multiple boundary actors, including PATGTL, DESDM, DLH, Investment and One-Stop Integrated Service Office or DPMPTSP, the Regional Revenue Agency or BAPENDA, and the police. Since 2022, in response to this inherent instability of compliance, the governance assemblage has been further stabilised through the centralisation of authority and the introduction of the Online Single Submission (OSS) system. The OSS functions as a boundary technology that rigidifies governance by standardising application procedures and embedding technocratic criteria directly into digital workflows. By automating decision pathways and constraining discretionary interaction, the OSS reinforces a compliance-oriented configuration of groundwater governance.

Finally, within the planning assemblage, groundwater is institutionally framed as a sociomaterially interconnected resource, with the growing risk of depletion acknowledged as a central challenge. Correspondingly, water resource planning under *Law No. 17/2019*, alongside the *Balai Besar Wilayah Sungai* (BBWS) Citarum Strategic Plan (2020-2024), West Java's Regional Spatial Plan or RTRW (2022-2042), and Bandung's Regional Spatial Plan or RTRW (2022-2042), calls for river-basin-scale management that integrates groundwater and surface water in line with the principles of Integrated Water Resources Management (IWRM). Planning arrangements, however, have thus far failed to translate into public service and infrastructure governance. This is shown in governance interactions over centralised public water infrastructure that are dominated by disputes over tariff-setting. Such disputes have delayed its development in several municipalities, for instance in the management of the Kertasari regional drinking water supply system or SPAM water supply project whereby the West Java Provincial Government sells treated water to the Bandung Municipal Government (Disperkim, Pos. 21 & 25; BAPPEDA, Pos. 108). Within this assemblage, groundwater is primarily enacted as an economic commodity embedded in intergovernmental transactions, rather than as a scarce resource requiring urgent intervention.

The planning assemblage diverges from the permitting and enforcement assemblages where economic logics, although mediated through investment-oriented institutions such as DPMPTSP and BAPENDA, operate in tandem with anticipatory risk-based compliance mechanisms. At certain institutional levels within the planning assemblage, economic rationalities are decoupled from depletion risk and long-term resource security concerns. These governance interactions do not merely delay infrastructure expansion while reinforcing a persistent problematisation of infrastructural mismatch in practice; they also demonstrate the coexistence of multiple and competing prioritisations across institutional assemblages. These dynamics reveal the selective operationalisation of groundwater risk across institutional assemblages, where compliance mechanisms succeed in industrial contexts, but planning domains prioritise economic and transactional logics over urgent threat, resulting in a detachment from public service and infrastructure assemblages.

Meanwhile, groundwater use by non-industrial actors also remains outside the institutional assemblage, while industrial and large-scale extractive users are entangled within institutional assemblages through permitting, monitoring and compliance mechanisms. In the final section, we present a focused analysis of the ways groundwater crises are assembled by non-industrial users through their everyday practices, which have been thus far under-represented in the media and institutional perspectives.

Everyday assemblages (RQ 3: How do everyday assemblages produce provisional groundwater problematisations through practices?)

The individual, household and communal practices of non-industrial water users produce everyday assemblages and grounded problematisations of groundwater crises. These problematisations emerge from the entanglement of individual interests, perceptions, social relations, negotiations and environmental conditions, rather than merely from standardised metrics. Drawing on lived and material experiences, community actors develop situated understandings of groundwater that shape both patterns of access and forms of local water management, including informal and communal governance arrangements. Everyday assemblages thus vary according to local material and spatial conditions, as well as social contexts and household-level circumstances.

Unlike institutional assemblages, which frame groundwater problems as quantifiable risk, in social or everyday life such a framing rarely emerges. Most interviewees described only qualitative experiences, reporting temporary reductions in water levels that they typically attributed to seasonal variability or technical disruptions. Such interpretations of scarcity obscure markers of urgency and indicators of escalation, thereby weakening the sense of abnormality through which groundwater decline is recognised as a risk. As expressed by one respondent,

> Whether in the dry season or the rainy season, these wells perform well. Even during the dry season, the water continues to flow. The only issue with bore wells like this is the machinery. If the pump breaks down, the water cannot be lifted. Aside from that, this type of well performs well even in the dry season (Interviewee 3, Pos. 277).

Even when some wells went permanently dry, social recognition of the crisis was not triggered; instead, the wells were simply abandoned, sealed or left unused. Depletion thus remains a contingent condition rather than a dominant organising axis of the everyday groundwater assemblage. Groundwater is generally assumed to be abundant and fluctuations in supply are taken to be characteristic of self-correcting processes. Situated material practices accommodate the fluctuations and displace risk concerns.

Community actors tend to problematise groundwater primarily in terms of its day-to-day dependability; they focus on whether water is available and usable when needed, rather than considering long-term resource security. Concerns over water quality also emerged from our interviews, as many respondents referred to groundwater clarity, odour and potential contamination from PDAM sediment releases or leaking drainage systems. Rather than using standardised indicators of water usability, however, residents often relied on preference-based contingencies; their concerns were thus interpreted through individual and context-specific lenses. During the rainy season, for example, murky or cloudy water is frequently perceived as harmless since it typically clears after a few hours through sedimentation. Similarly, artesian wells that were originally expected to reach safe drinking water at 80 metres were sometimes stopped at 40 metres once abundant water appeared (Interviewee 4, Pos. 88). Such practices illustrate how technical indicators are pragmatically reinterpreted within this assemblage.

The social nature of problematisations was particularly evident from our interviews; drilling of artesian wells, for example, is normally expected to involve neighbour consent, embedding social negotiation at the very core of local governance. A neighbourhood leader, for example, described an arrangement whereby borehole owners are free to extract water and in return he is welcome to take water from them whenever public services or electricity fail (Interviewee 3, Pos. 145). Another leader justified unpermitted drilling by stating that, "the house was bought, so drilling and the well become part of their private territory" (Interviewee 1, Pos. 26). These interactions demonstrate how local norms interact with interpretations of administrative authority to co-produce informal boundaries. As a result, many property owners, particularly those managing boarding houses, have normalised the constructing of artesian wells without notifying local leaders, only engaging authorities once a problem arises (Interviewee 2, Pos. 20-

21). This indicates that the compliance-oriented problem governance for industrial actors is often bypassed in everyday practices, with residents actively shaping local enforcement and governance dynamics.

As material invisibility prevents depletion risk from fully taking shape as a socially recognisable problem, it further amplifies governance gaps between institutions and everyday actors. Deep within closed private compounds, wells that are sometimes decades old remain practically undetectable to institutional actors, limiting institutional awareness of groundwater conditions and thereby structuring which concerns become problematised and which remain unknown and unaddressed. Concerns about water quantity and access, meanwhile, are selectively recognised and relational; they are not seen as properties of the well itself, but rather as the effects of neighbouring extraction. As one interviewee living adjacent to jet pump users explained, "If a jet pump is installed next door, my water supply will decrease. What used to be a plentiful source will become reduced. My well draws water directly from the natural source, so it does not interfere with anyone else's supply" (Interviewee 1, Pos. 24).

At the same time, the perceived incapacity of public water infrastructure (which is the responsibility of PDAM, the Regional Drinking Water Company) shapes the practices of individual and household groundwater users. Residents report water that turns yellow, carries a strong chlorine odour or flows unpredictably. These characteristics generate a range of coping practices, including storing water in elevated 1000- or 2000-litre 'toren tanks', sedimenting water in buckets, discarding cloudy water, or relying on refillable gallon containers and bottled water; meanwhile, subscription fees, minimal charges and limited bathroom space lead to inequalities within and between neighbourhoods (Interviewee 1, Pos. 90-102; Interviewee 2, Pos. 10; Interviewee 5, Pos. 89-98). Collectively, these everyday experiences and adaptive practices produce a problematisation of water inequality, reflecting how differential levels of access, reliability and quality of water shape the lived realities of households, as observed in media narratives.

These sociomaterial frictions shape a range of residents' decisions that can increase pressure on groundwater resources; these include whether to return to using groundwater from private wells, whether to source household water from a combination of sources, and whether to participate in communal management of shared wells. Emergent local governance structures are anchored in the use of communal groundwater wells; these are often situated within shared plots, structured by geological conditions, and constrained by localised infrastructures. Spatial relations play a critical role in this arrangement as proximity and accessibility determine who can use shared infrastructure and under what circumstances. As one neighbourhood leader noted, "Residents from Neighbourhood Unit 3 rarely use the facilities at Neighbourhood Unit 4 because it is farther away. Mostly, only those who live nearby will come (Interviewee 2, Pos. 16)".

Beyond such material and spatial configurations, governance is further shaped by non-material elements including prevailing social norms, moral expectations, individual interests and willingness to contribute, as well as the competencies of neighbourhood leaders with regard to mediating extraction-related conflicts and evaluating residents' moral use of water. These norms are enacted through flexible and situational contribution arrangements, as explained by one neighbourhood leader during an interview:

> Interviewer: Do people pay a contribution, sir?
>
> Interviewee: Yes, they do. Until now, some are charged IDR 15,000, others IDR 20,000, depending on the household situation. Each household may consist of several people, including a spouse.
>
> Interviewer: And what if someone suddenly uses the water?
>
> Interviewee: That's fine. They are not formally registered anyway. It's not a problem, as long as someone pays the monthly contribution every month (Interviewee 2, Pos. 185-190).

When these heterogeneous elements converge, they produce emergent boundaries such as informal rules, spatial limits, and expectations regarding fees and labour contributions, alongside oversight mechanisms that stabilise usage patterns in ways that partially mirror formal governance structures.

Significant fragility is introduced, however, by the absence of binding instruments including formal regulations, reliable permitting and enforcement procedures, and systematic data on groundwater extraction or conservation; this is accentuated by being coupled with reliance on voluntary participation and self-governance. As has been observed in past instances, leadership authority may weaken, informal or illicit extraction can occur, and shared infrastructure may be neglected (Interviewee 1, Pos. 84; Interviewee 2, Pos. 149-151). These dynamics become particularly evident in the variation across communal wells, especially in their material arrangements such as sanitation infrastructure, electric pumps, and distribution pipes. Control over groundwater use is thus contingent rather than absolute.

This analysis shows that groundwater problematisation at the everyday level does not align with institutional framings of depletion as a quantifiable risk. Problematisation emerges instead through lived and material practices, relational effects and pragmatic judgments that are centred on dependability, usability and social negotiation. These provisional problematisations give rise to fluid and informal governance arrangements that are contingent, fragmented and unevenly stabilised; they are shaped by material visibility, spatial relations, social norms and infrastructural performance. Everyday groundwater governance thus neither simply mirrors nor directly translates institutional problematisations; rather, it selectively engages, bypasses or reworks them as parallel modes of stabilisation. These findings set the stage for the Discussion section of this paper, which examines how these multiple assemblages interact, why certain problematisations travel into governance while others remain marginal, and what this reveals about the coexistence of multiple forms of groundwater governance across scales.

DISCUSSION

The findings indicate that groundwater problematisations are not simply transmitted from discursive arenas into governance; rather, they emerge from sociomaterial configurations within media, institutional and everyday assemblages. Only some problematisations become stabilised and even fewer consolidate into a shared governing object within particular institutions or practices. As a result, these processes produce multiple and provisional forms of groundwater governance rather than a coherent response to the groundwater crisis.

Media discourses around groundwater crises in the Bandung Metropolitan Area are dominated by problematisations of environmental risk, citizen non-compliance, infrastructural incapacity and water struggles. Alternative narratives appear with only minor frequency, but nonetheless act as building blocks in the shaping of broader problematisations of groundwater; these include narratives around causal environmental impacts, seasonal variability, river pollution and struggles over water access. They interact with more frequently mentioned elements such as industrial abstraction practices, government interventions and official warnings, to influence how groundwater issues are interpreted and contested. When tracing problematisations into institutional arrangements, however, only certain problematisations become a stable part of governance arrangements, specifically environmental risk and compliance issues. As previous studies suggest, such dominant technocratic framings tend to perpetuate simplified problem definitions and obscure the complexity of sociomaterial relations by marginalising certain actors and forms of knowledge (Jamali et al., 2023). This explains why compliance-oriented permitting systems emerge as the most stabilised governance configuration, while other problematisations remain marginal and do not consolidate into formal governance practices.

In contrast to the institutional assemblage of groundwater crisis, which is largely reflected and reported in the media assemblage, many everyday actors perceive the groundwater crisis as a public issue or discourse, not necessarily as an immediate problem requiring their attention or action. This pattern is supported by environmental communication studies showing that discursive problematisations

can reshape public narratives, expert authority and coalitional alignments, without necessarily translating into governance transformation unless they align with compatible institutional arrangements and material infrastructures (Song and Alivi, 2025; Rinaldi, 2023). Importantly, this apparent disconnect does not indicate resistance to dominant crisis narratives; rather, it points to a different ontological understanding of groundwater conditions, one that is tangibly anchored in pumps, storage tanks, spatial proximity and everyday water infrastructures. As presented in the findings, evidence from peri-urban Cimahi suggests that this apparent disconnect between crisis discourse and everyday action is shaped not by resistance but by a practical ontology of water in which reliability, affordability and sensory experience guide everyday water choices (Prayoga et al., 2021).

The gap between everyday and institutional assemblages thus reveals a paradox at the core of compliance-oriented regulation. We conceptualise this gap as a form of selective governability in which groundwater becomes manageable precisely through processes of simplification, abstraction and boundary-making. This resonates with Whaley's (2022) argument that mainstream water governance renders complex and messy water relations governable by standardising indicators, delimiting responsible actors, and bracketing everyday practices and power relations. In the Bandung case, the institutional assemblage stabilises only a narrow and abstracted version of groundwater as a governable object, while diffused pollution, cumulative degradation and informal water practices remain outside regulatory concern. From an ontological perspective, this abstraction aligns with MacAfee's (2022) critique of water quality governance, where universalising categories obscure the situated material relations and ethical dimensions through which groundwater is actually experienced. The apparent success of compliance-oriented groundwater governance should thus be understood not as resolving the groundwater crisis; rather, it should be seen as the temporary stabilisation of a bounded governance object in which industrial actors are primarily constituted as administratively legible units of compliance, while remaining misaligned with everyday sociomaterial water practices.

This logic of selective governability also explains why groundwater problematisations stabilise unevenly across institutional domains. Groundwater sectoral institutions such as PATGTL and DESDM produce groundwater problematisations through monitoring wells, zonation maps and permitting systems, resulting in extraction regulations and aquifer protection; groundwater governance at the planning level, on the other hand, is shaped by different pressures and policy prioritisations. In local planning practices, groundwater rarely appears as a governing object in its own right; instead, policy attention is primarily oriented towards flooding, infrastructure vulnerability, public health risks and disaster preparedness (Abdillah et al., 2025). Implementation efforts thus tend to focus on surface-oriented interventions such as green open spaces, infiltration capacity and watershed management through technical fixes, including retention ponds and drainage systems (Setiadi et al., 2023).

Although at the national level groundwater governance is formally integrated into broader water management frameworks through Integrated Water Resources Management (IWRM), our analytical results show that this integration does not resolve governance fragmentation. Rather, integration operates primarily at the level of policy discourse and strategic frameworks, while governance continues to be enacted through sectoral institutional mandates, standardised technical procedures, and distinct data infrastructures that generate their own problematisations of groundwater (Valette, 2024; Sunarwibowo et al., 2025). Integration, in practice, thus remains weakly operationalised as planning and public service assemblages prioritise economic, infrastructural and transactional logics, while groundwater risk is stabilised mainly within sectoral, compliance-oriented regulatory institutions. This contributes to persistent policy implementation gaps, particularly in translating integrative planning objectives into effective groundwater interventions (Sunarwibowo et al., 2025).

More recently, national policy orientation has shifted towards the food-energy-water (FEW) nexus, which reframes groundwater as a strategic reserve that supports national resilience and economic development. This reframing is shaped in part by external pressures such as World-Bank-driven reforms and the Sustainable Development Goals. This reorientation is reflected in the National Medium-Term

Development Plan (RPJMN) 2025-2029, which highlights uneven water distribution, rising demand, declining water quality, limited storage capacity and weak local utility performance, and prioritises water self-sufficiency through a source-to-sea implementation strategy. While this requalification elevates groundwater's strategic importance within national development narratives, it simultaneously risks reinforcing transactional infrastructure governance. As Valette (2024) argues, contemporary water governance remains dominated by industrial and market-oriented valuation regimes, where critiques from civic and domestic worlds are selectively incorporated without fundamentally challenging commodification. Consistent with this, our analysis of institutional assemblages shows that public water services increasingly enact water through economic rationalities, marginalising environmental sustainability and limiting policy attention to supply expansion rather than to groundwater extraction control or broader regime reconfiguration.

At the same time, communal infrastructure governance is emerging as a pragmatic response to the gaps and limitations of both sectoral regulation and planning regimes. Our empirical findings show that communal groundwater infrastructures are assembled through everyday sociomaterial frictions in public water provision, including infrastructural unreliability, spatial proximity and shared dependency. Rather than being designed through formal policy, these arrangements stabilise access through informal rules, flexible contribution mechanisms and locally embedded authority structures. This resonates with empirical studies in Bandung that demonstrate that the sustainability of decentralised water supply systems (DWSS) depends on structured local organisations, active community participation and stable financial arrangements, with informal practices playing a crucial role in maintaining functionality (Maryati et al., 2022).

As also illustrated by broader basin-scale governance experiences such as the Citarum programme, however, the effectiveness of community-based governance remains inherently place-bound and functionally limited. Community initiatives are most effective in managing everyday infrastructure, behaviour change and local environmental stewardship, but they are ill-equipped to address cross-boundary extraction control, industrial compliance or cumulative resource depletion. These limitations are reinforced by fragmented authority, entrenched subnational elites, and informal veto players embedded in local political-economic networks (Novalia et al., 2025). Communal infrastructure governance should thus not be understood as a substitute for basin-level groundwater regulation, but rather as a complementary mode of governance that anchors everyday water security while simultaneously exposing the limits of top-down integration frameworks such as IWRM.

In terms of monitoring, our findings suggest that citizen-based monitoring is feasible primarily for assessing perceived groundwater quality and reporting service disruptions, as communities are able to identify changes such as increased turbidity, colour variation or well sedimentation through low-cost observational practices and limited technical training. This finding is consistent with empirical studies in Bandung Regency that document widespread turbidity and contamination risks in shallow groundwater and emphasise the role of community awareness and water quality monitoring in mitigating health impacts (Fahimah et al., 2023; Salami et al., 2025). Our analysis further shows, however, that citizens still face significant limitations in assessing groundwater quantity, abstraction dynamics and cumulative impacts, as well as in distinguishing between subjective perceptions and objectively verifiable indicators. Citizen-based monitoring thus needs to be positioned as a complementary mechanism that enhances early detection and public visibility of groundwater risks, while remaining dependent on state-provided technical support to reduce subjectivity and ensure data comparability across sites.

At the same time, monitoring functions should be analytically distinguished from the enforcement of regulatory compliance. Extending community enforcement to industrial actors would expose communities to substantial political and personal risks, particularly in contexts such as Bandung where groundwater governance is shaped by contested and unstable sociopolitical boundary arrangements (Novalia et al., 2025). In such settings, community involvement in enforcement may generate social sanctions, local conflicts or informal pressures that blur institutional boundaries and weaken

accountability mechanisms (Jaffrey et al., 2024). This underscores the need for hybrid governance arrangements in which citizens focus on peer-based and community-to-community monitoring; they can function as reporting agents for visible service disruptions and suspected illegal extraction, as they have already demonstrated the capacity to observe and identify changes in water performance and in the socio-behavioural patterns of users (Pratama et al., 2025). In the meantime, verification, sanctioning and enforcement of industrial groundwater use should remain firmly within formal regulatory mechanisms; this reduces the risks of displacing regulatory responsibility away from the state and shifting enforcement burdens onto actors who lack formal authority or protection (Dudi et al., 2025).

CONCLUSION

This study shows that groundwater problematisations in the BMA emerge unevenly across media, institutions and everyday practices, rather than flowing linearly from discourse to policy. It demonstrates a qualitative-dominant approach that uses multiple methods to trace how sociomaterial configurations stabilise, reconfigure or marginalise different problematisations across discursive, institutional and everyday domains. The study highlights how multiple governance arrangements operate in parallel, with community-led practices coexisting with formal institutional mechanisms. These parallel arrangements reveal gaps and complementarities, as well as opportunities for hybrid governance that combines institutional authority with local knowledge and everyday practices. By doing so, the findings provide conceptual insights and practical reflections for more adaptive and context-sensitive groundwater governance.

This study has several analytical limitations that are important to acknowledge. First, while the paper discusses governance recommendations such as citizen monitoring, integrative urban water planning and greater community involvement, it does not seek to specify their technical feasibility, cost-effectiveness or enforcement mechanisms. This reflects the study's positioning as an assemblage-based analysis that offers a way of thinking about groundwater problematisation and governance formation, rather than a policy design or implementation blueprint. From this perspective, commonly proposed interventions should be understood as conditional, rather than as universally applicable solutions whose feasibility depends on their alignment with existing institutional mandates, technical infrastructures and local political-economic contexts.

Second, while industrial abstraction and pollution are central to groundwater conditions and narratives in the Bandung region, this study approaches industrial activities as embedded within compliance-oriented institutional assemblages rather than as standalone empirical objects. This analytical choice allows the study to focus on domains where groundwater problematisations remain weakly connected to institutional assemblages, revealing the coexistence of governance arrangements that operate in parallel with formal institutions. In doing so, the analysis highlights the potential for hybrid governance.

Finally, while the analytical insights offered here are intended to be theoretically and analytically transferable, the findings are empirically grounded in the Bandung Metropolitan Area. Our findings should thus not be read as universally generalisable, although they highlight governance dynamics that are likely to resonate across other urbanising regions. Future research could extend this assemblage-based approach to other spatial contexts in order to examine how similar problematisations are reassembled under different institutional and hydrogeological conditions.

ACKNOWLEDGEMENTS

This research is funded by RIIM BRIN (Riset dan Inovasi untuk Indonesia Maju) Gelombang 3 from the National Research and Innovation Agency (BRIN), Indonesia and Lembaga Pengelola Dana Pendidikan (LPDP) – Indonesia Endowment Fund for Education Agency (contract number 5/IV/KS/05/2023 and 333/ITI.B07/KS.00/2023). We are grateful for the media article collection by Afiz Ahzariyusa and the supports provided by Sholihah Rahmatunnisa Utami, Nur Novilina Arifianingsih, Kaela Laksmana, Almira Ramadhanti, and Ade Supriatin.

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APPENDIX 1. MEDIA CONTENT ANALYSIS RESULTS

No.	Segment code	Operational framing	Operational actor	Key information source	Groundwater enactment framing
1	Groundwater level decline (GLD) (17 articles)	Monitoring groundwater levels via boreholes and observation wells, classification into safe/critical zones, calculation of annual decline (60 – 80%), linking groundwater decline to land subsidence, flooding and water availability	Bandung City Government, DLHK, PATGTL Badan Geologi, Ministry of Energy & Mineral Resources	Official monitoring data (PATGTL, DLHK), expert observations	Measurable object, governable resource
2	Government measures (GM) (14 articles)	Regulatory and administrative actions to manage groundwater and urban clean water availability, including water supply expansion, SPAM, pipelines, rainwater harvesting (RWH), infiltration wells and circulars for businesses	Bandung City Government, PDAM Tirtawening, state-owned enterprises (BUMN), DLHK, BPBD, TNI, community, private sector and academics	Bandung local government agencies' statements (DLHK, BPBD, PDAM), academic experts	Measurable object, governable resource
3	Action advisories (AA) (13 articles)	Public and industrial advisories to conserve water and protect groundwater resources including water-saving practices, RWH, infiltration wells, wastewater reuse, green spaces, responsible land use and public awareness campaigns	Bandung City Government, PDAM Tirtawening, Representative Council Bandung, environmental NGOs, universities, industries, developers, community, general public	PDAM press releases, academic research, environmental NGOs announcements	Measurable object
4	Clean water supply–demand (CWSD) (11 articles)	Urban water supply–demand mismatches addressed through PDAM expansion, SPAM and surface water development, and emergency water provision to reduce groundwater dependence	PDAM Tirtawening, Bandung City Government, West Java, Ombudsman RI, local communities, private sector (industry and tourism)	PDAM official data, Ombudsman RI reports, academic studies, media reports	Urban infrastructure input, sociomaterial relational entity
5	Groundwater abstraction permit (GAP) (7 articles)	Groundwater decline is framed as a consequence of excessive large-scale abstraction, positioning permits and moratoria as regulatory tools to curb over-extraction in degraded aquifers	PATGTL Badan Geologi, Ministry of Energy & Mineral Resources, provincial and municipal/regency governments, industrial and commercial groundwater users (licensed and unlicensed), and academic researchers	Official monitoring data, government officials' statements, academic studies, media reports	Governable resource, urban infrastructure input

6	Water crisis warning (WCW) (6 articles)	Scientific risk forecasting of an impending water crisis, based on long-term projections of groundwater depletion, declining recharge capacity, water pollution and environmental degradation in urbanising regions	Academic experts, UNESCO and environmental NGOs	Academic studies and expert assessments, government datasets, environmental NGOs' announcements	Measurable object, urban infrastructure input
7	Groundwater pollution (GP) (6 articles)	Systematic observation of urban groundwater contamination and its interaction with sanitation systems, surface-groundwater mixing and intensive pumping, resulting in declining water quality and public health risks	Academics and research institutions, urban households using self-supply groundwater, industrial and informal economic actors, government planning agencies	Academic research and expert statements, laboratory water quality measurements, official research reports, policy forums	Sociomaterial relational entity
8	Urbanisation (U) (5 articles)	Urbanisation and settlement expansion without adequate sanitation and recharge protection directly contaminate groundwater and undermine urban water security	Local governments, spatial planning agencies, housing developers, PDAM, industrial users, urban residents, and environmental NGOs	Government datasets, planning documents, local government reports, academic studies	Urban infrastructure input, sociomaterial relational entity
9	Groundwater experience (GE) (4 articles)	Everyday manifestation of groundwater crisis as declining access, deteriorating quality and increasing household and institutional coping costs, driven by groundwater depletion, infrastructure failure and unequal service provision	Urban residents and households, PDAM, private water vendors, public and private hospitals, academic experts, local government units, political donors	Urban residents' testimonies, community forums, academic studies	Sociomaterial relational entity
10	Drought (D) (4 articles)	Climate-induced drought risk and seasonal water scarcity driven by El Niño and a positive Indian Ocean Dipole (IOD), producing uneven impacts on urban and peri-urban water security	State climate authority, state research institutions, local governments, PDAM, affected communities	Climate monitoring data, climate research analyses, urban residents' testimonies	Sociomaterial relational entity
11	Groundwater cascading impacts (GCI) (4 articles)	Linking groundwater over-extraction and contamination to sequential environmental impacts, including declining water tables, land subsidence, increased flooding and deteriorating water quality	Bottled water producers, PDAM, groundwater users (industrial and domestic), local and national government agencies, academic researchers	Scientific expert research, government datasets, government agency statements	Sociomaterial relational entity, measurable object